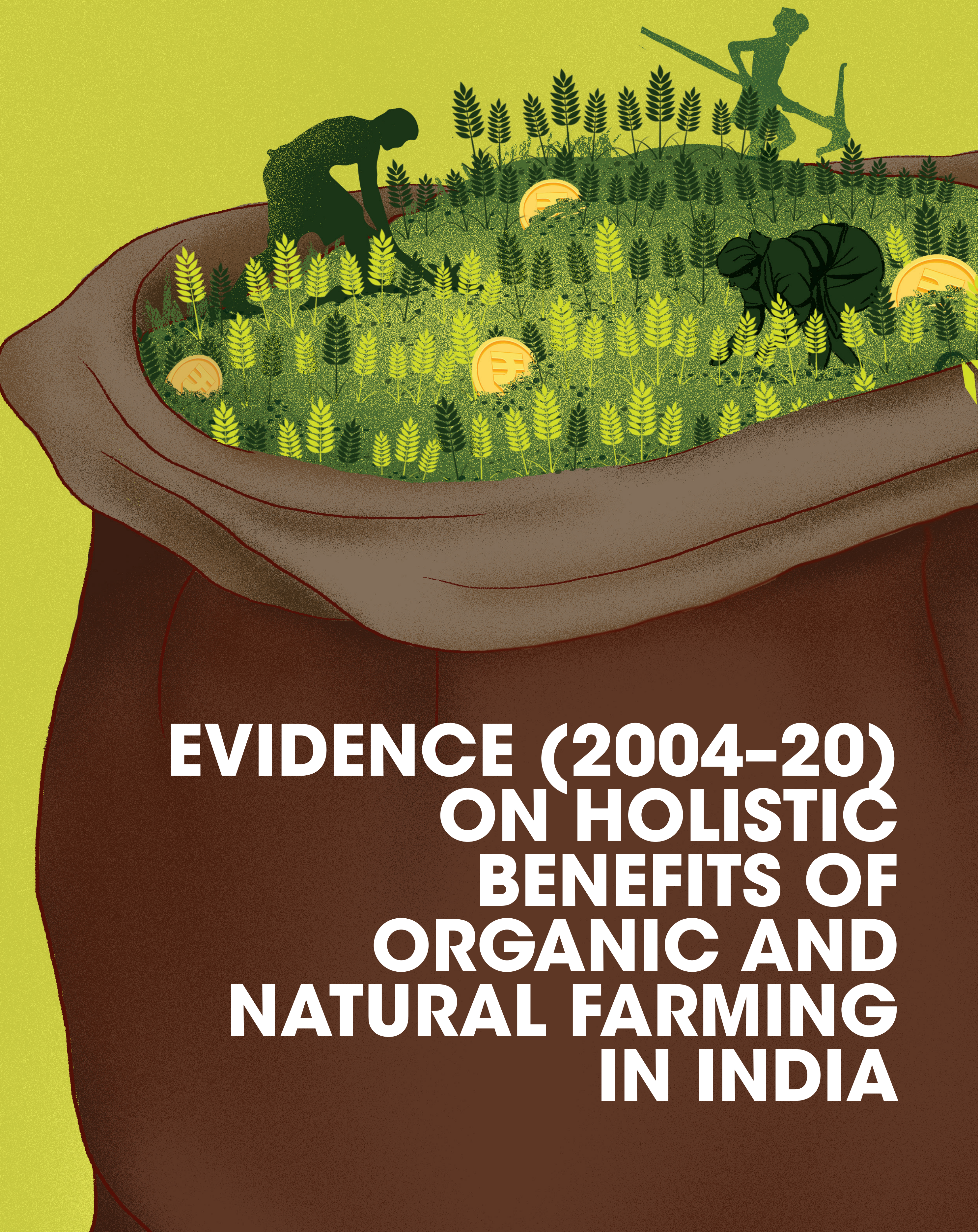

EVIDENCE (2004–20) ON HOLISTIC BENEFITS OF ORGANIC AND NATURAL FARMING IN INDIA

EVIDENCE (2004–20) ON HOLISTIC BENEFITS OF ORGANIC AND NATURAL FARMING IN INDIA

Authors: Amit Khurana, Mohammad Abdul Halim and Abhay Kumar Singh

Editor: Akshat Jain

Cover and design: Ajit Bajaj

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41, Tughlakabad Institutional Area
New Delhi 110 062
Phones: 91-11-40616000
Fax: 91-11-29955879
E-mail: sales@cseinida.org
Website: www.cseindia.org

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Introduction

India has one of the highest arable land areas in the world[1] with a net sown area of 140.1 million hectares (ha).[2] Agriculture and allied sectors employ 54.6 per cent of the total workforce in India (2019–20).[3] The country successfully adopted the Green Revolution in the 1960s—an input and chemical-intensive agriculture model—to overcome food scarcity by use of high yield varieties, pesticides, fertilizers, and agriculture machinery and irrigation systems. However, over the years, this resulted in several negative impacts related to ecological, economic and existential aspects of agriculture. This includes declining soil fertility and food diversity, increase in farmers' debt, dependence on agro-chemicals, and pest resistance. In addition, chemical-intensive agriculture adversely affects the health of humans and animals.

These negative impacts have been deliberated upon extensively in the last few decades and even more so in the last few years. As a result, the agro-ecological movement has started gaining momentum. This includes efforts by champion farmers and civil societies. While the government passed its first policy on organic farming in 2005, subsequent action was minimal. In 2015–16, it came up with a flagship programme, called Paramparagat Krishi Vikas Yojana (PKVY), which apart from being limited in scale, continues to face implementation challenges. All this while, barring a few exceptions, action at the state level has been suboptimal. This explains why only 2.7 per cent (3.8 million ha) of net sown area (140.1 million ha) in India is covered under organic and natural farming as part of different policies. This includes 0.41 million ha of natural farming.[4] In a recent shift, the government has started talking publicly in favour of organic and natural farming. The Prime Minister, highlighting the ill-effects of chemical-based farming, recently appealed to make natural farming a mass movement in the country.

Nonetheless, over the last two decades, the government's action to upscale agro-ecological practices has been half-hearted and severely limited. One main reason is the lack of conviction among policy makers, which has prevented them from taking ambitious action to mainstream organic and natural farming. This has largely been due to the limited consensus among the scientific community in favour of organic and natural farming and the singular view of yield to assess these non-chemical agricultural practices. This has been attributed to limited evidence, which was building up over the last two decades but failed to catch the attention of policymakers.

This report consolidates and presents the evidence on holistic benefits of organic and natural farming such as on yield, livelihood, soil health and environment. This is done by analysing the results of the government's own long-term research project from 2004 and other scientific studies over the last decade. This first of its kind report aims to help inform the policy making process, create awareness among the larger scientific community and build capacity in agriculture extension systems. The report can be of help to farmers and civil society members who want to take the message and learnings forward.

Approach to collection, analysis and presentation of holistic evidence

Collection of evidence

Collection of evidence involved two broad sets of sources. The first was results of the ongoing All India Network Project on Organic Farming (AI-NPOF) from 2004 to 2019. The annual reports were taken from the ICAR website. The second set of sources was 89 unique scientific studies conducted in India on different aspects of organic and natural farming published or presented during 2010–20.

The AI-NPOF is a pan-India research project conducted by Indian Council of Agricultural Research (ICAR) through the Indian Institute of Farming System Research (IIFSR), Modipuram. It started as a pilot project in 2004–05 with an objective to develop a scientific package of practices for organic farming from a systems perspective at 13 centres in 12 states. In 2014–15, more centres were included. Currently, it is being implemented across 20 centres in 16 states with Project Directorate for Farming Systems Research (PDFSR) as the nodal institute (see *Annexure 2—Table 1: Details of centres under the AI-NPOF [2004–19]*).

Analysis of evidence

The results of AI-NPOF documented in their annual reports were analysed. These results were of experiments conducted in 74 cropping systems at 19 centres in 16 states across five ecosystems between 2004 and 2019. The project involved assessment of productivity, profitability and sustainability across three management practices (approaches) i.e., organic, integrated (towards organic) and inorganic, which were further divided into six management practices (methods). These approaches and methods are:

1. **Organic approach (ORG)**
    a. Organic method (OF), with 100 per cent of the nutrients from organic sources and complete organic management
    b. Organic innovative method (OIN), with 75 per cent of the nutrients from organic sources + innovative inputs [any two of cow urine (10 per cent), panchagavya, plant growth-promoting rhizobacteria and vermiwash (10 per cent)]

2. **Integrated approach (towards organic) (INT)**
   a. Integrated method (IN75), with 75 per cent organic + 25 per cent inorganic nutrients and management
   b. Integrated method (IN50), with 50 per cent organic + 50 per cent inorganic nutrients and management

3. **Inorganic approach (INO)**
   a. Inorganic method (IOF), with 100 per cent inorganic nutrients and management
   b. State recommended (SR) method or farmers' package (choice given to centres)

The results of AI-NPOF are analysed in two ways across different sections of the report:

1. **Based on mean values:** Mean values (2014–19) are calculated for all three approaches and six methods. The values for organic approach and integrated approach are compared with the values for inorganic approach. Analysis is also done to know the significantly higher (>20 per cent) mean values. Approach with highest mean value is also ascertained. Similarly, mean values of all methods are compared.

2. **Based on actual values**: Analysis of highest of actual values (such as of yield) across six methods over the five-year period (2014–19) has been done for crops. The same has also been done for the year 2018–19 in some cases for cropping systems as well as crops. For long-term trends, actual values during 2004–19 have been analysed for crops in some cases and centres in others.

The analysis of other scientific studies reflects evidence from different geographies, settings and stakeholders on issues which are not limited to those captured in the AI-NPOF project and add more diversity to the overall evidence as well as complement it.

Presentation of holistic evidence

The report comprises four evidence sections and a section on conclusion and way ahead. Within each of the four sections, analysis of AI-NPOF project and scientific studies are presented as separate chapters:

1. **Crop yield:** The comparison among three approaches and six methods based on mean yield values and highest actual yield values has been presented for select 31 crops, which belong to five food groups, namely vegetables, oilseeds, pulses, spices and cereals. Crops with significantly higher yield (>20 per cent) than inorganic approach are also presented. These crops were grown as part of 74 cropping systems at 19 centres. In addition, evidence from 32 scientific studies has been reviewed and collated.

Long-term trends of crop yield across multiple centres are presented as graphs in Annexure 1.

2. **Cost of cultivation, income and livelihood:** The comparison among three approaches and six methods based on mean values and highest values has been presented for cost of cultivation, gross returns, net returns and benefit-cost ratio for 63 cropping systems at 17 centres. Cropping systems with significantly higher values than inorganic approach have also been presented. In addition, evidence from 43 scientific studies has been reviewed and collated.

   Long-term trends of net returns at respective centres are presented as graphs in Annexure 1. For this, recorded mean net return values, which reflected all cropping systems at a centre, were analysed for the years 2004–19. Detailed comparison among methods has been presented in Annexure 2. In order to maintain consistency in recorded AI-NPOF results for correct interpretation, values of net returns and benefit-cost ratio have been re-calculated based on a standard formula in some centres/cases, where they were calculated in a different way than the rest.

3. **Soil health and environment**: The comparison among three approaches and six methods based on mean values and highest values for available nitrogen, potassium, phosphorus, organic carbon, bulk density and rhizosphere microbial population has been presented for up to 62 cropping systems across 16 centres. Cropping systems with significantly higher values than inorganic approach have also been presented. In the case of soil micronutrients, instead of mean values, actual values for the year 2018–19 have been analysed and presented for up to 19 cropping systems across five centres. In addition, evidence from 33 scientific studies has also been reviewed and collated.

   Long-term trends of organic carbon, soil macronutrients and bulk density at respective centres have been presented as graphs in Annexure 1. For this, recorded mean values, which reflected all cropping systems in a centre, were analysed for the years 2004–19. Comparison among methods in case of soil macronutrients and rhizosphere microbial population has been presented in Annexure 2.

4. **Food quality and nutrients:** The comparison among three approaches and six methods based on actual values for the year 2018–19 has been presented for select 26 food quality and nutrient parameters in 15 crops grown at six centres. Crops with quality parameters significantly higher than inorganic have also been presented. In addition, evidence from 11 scientific studies has also been reviewed and collated.

Executive summary

The report presents consolidated and holistic evidence on benefits of organic and natural farming on crop yield, income and livelihood, soil health and environment, and food quality. This is in comparison to inorganic approach that is dependent on chemicals and integrated farming approach which is characterised by chemical-based and non-chemical practices. Collectively, the evidence reflects productivity, profitability and sustainability of organic and natural farming.

Overall, results from two sets of sources are collected, collated and analysed to develop consolidated evidence on four key aspects. The two sources are AI-NPOF of the Indian Council of Agriculture Research and scientific studies conducted across India. The four key aspects are crop yield; cost of cultivation, income and livelihood; soil health and environment; and food quality.

1. Evidence on benefits of organic and natural farming on crop yield

AI-NPOF

In the case of AI-NPOF results, analysis is done for select 31 crops grown as part of 74 cropping systems at 19 centres in five ecosystems. These crops are from five food groups i.e., vegetables, oilseeds, pulses, spices and cereals. For in-depth analysis, results from 2014 to 2019 are used, wherein comparison of highest yield values and mean yield values is done for different crops. The comparison is done among three approaches, i.e., organic approach (ORG), integrated approach (INT) and inorganic approach (INO) based on six methods within these i.e., organic method (OF), organic innovative method (OIN), integrated method (IN75), integrated method (IN50), inorganic method (IOF) and state recommended method (SR). The actual yield results of AI-NPOF from 2004 to 2019 are analysed for long-term trends.

The consolidated evidence reflects that, out of the 504 times that yield results were recorded during 2014–19, 41 per cent of the times yields were highest with organic approach, followed by 33 per cent with integrated and 26 per cent with inorganic approach. In the case of vegetables, oilseeds and cereals, yield with organic approach was highest more times than integrated and inorganic approach. In pulses and spices, it was highest more times with integrated approach than with organic and inorganic approach.

Specifically, in the case of vegetables, yield was highest 48 per cent times with organic approach, followed by 36 per cent with integrated and 16 per cent with inorganic approach. In oilseeds, yield was highest 58 per cent times with organic approach, followed by 17 per cent with integrated and 25 per cent with inorganic approach. In pulses, yield was highest 32 per cent times with organic approach, 42 per cent with integrated and 26 per cent with inorganic approach. In spices, yield was highest 32 per cent times with organic approach, 54 per cent with integrated and 14 per cent with inorganic approach. In cereals, yield was highest 35 per cent times with organic approach, followed by 32 per cent with integrated and 33 per cent with inorganic approach.

When five-year mean yields are compared, in 27 out of 31 crops (87 per cent) yields were higher with organic approach than with inorganic approach as part of one or more cropping systems. Out of this, in 14 crops (52 per cent), the mean yield was significantly higher (>20 per cent). These crops are tomato, potato, French bean, ladyfinger, linseed, black gram, pigeon pea, chickpea, ginger, coriander, black pepper, basmati rice, rice and maize. These 14 crops were grown at 12 centres—Bajaura, Bhopal, Calicut, Dharwad, Ludhiana, Pantnagar, Ranchi, Umiam, Gangtok, Modipuram, Narendrapur and Thiruvananthapuram—in five ecosystems. The other 13 crops with higher though not significantly higher mean yields are broccoli, chillies, vegetable pea, onion, capsicum, cowpea, groundnut, mustard, soybean, green gram, cowpea, turmeric and durum wheat. The remaining four crops with lower mean yields in all cropping systems, wherever they are grown, are sunflower, lentil, fennel and wheat.

With integrated approach, mean yields were higher than inorganic approach in 30 out of 31 crops (97 per cent) as part of one or more cropping systems. Out of this, in 19 crops (63 per cent), mean yields were significantly higher. These crops are tomato, potato, French bean, vegetable pea, ladyfinger, cauliflower, linseed, soybean, black gram, pigeon pea, chickpea, lentil, green gram, ginger, turmeric, coriander, basmati rice, rice, and maize. These crops were grown at 10 centres—Bajaura, Calicut, Karjat, Ludhiana, Pantnagar, Ranchi, Gangtok, Modipuram, Udaipur and Thiruvananthapuram Thiruvananthapuram—in four ecosystems. The other 11 crops with higher though not significantly higher mean yields are broccoli, chillies, onion, groundnut, mustard, sunflower, cowpea, fennel, black pepper, wheat and durum wheat. The remaining one crop with lower mean yield is capsicum, grown as part one cropping system at one centre.

Long-term trends of crop yield revealed that organic approach is better than inorganic and is at par with integrated. By and large this was also true in the case of organic methods (OF and OIN).

SCIENTIFIC STUDIES

In addition to results of AI-NPOF, evidence is reviewed and collated from 32 scientific studies in India on organic and natural farming published or presented during 2010–20. These studies were conducted in different locations by a wider scientific community and added to the overall evidence in favour of organic and natural farming.

These studies found that crop yields can be higher with organic and natural farming approaches in comparison to other approaches with chemicals. Examples of such crops include spinach, baby corn, broccoli, potato, ladyfinger, tomato, onion, chilli, pigeon pea, cowpea, black gram, rice, ragi, pearl millet, wheat and banana in the case of organic approach. In the case of natural farming, crops like maize, groundnut, sugarcane, finger millet, soybean, jowar and turmeric also showed higher yields. **These studies also highlighted the importance of bio-inputs and organic inputs as well as organic management and natural farming practices**. These inputs include farmyard manure, vermicompost, poultry manure, foliar spray of banana pseudostem, green manure, liquid bio-fertilizers, Jeevamrutha, Beejamritha, Ghanajeevamritha, Panchagavya, Fish-Protein Hydrolysate (FPH), Phosphate Solubilizing Bacteria (PSB), Azotobactor and Rhizobacteria. Positive role of seed soaking with liquid manure, mulching and intercropping is also captured in some studies. **These studies also include those crops about which it is said that they usually take few years with organic management practices to get comparable or more yield than inorganic approach**, such as in the case of wheat, maize, rice, cluster bean, sesame, cumin and psyllium husk. In some cases, such as potato, the yields are comparable within a year.

2. Evidence on benefits of organic and natural farming on cost of cultivation, income and livelihood

AI-NPOF

In the case of AI-NPOF, for in-depth analysis, comparison of mean values of cost of cultivation, gross returns, net returns and benefit-cost ratio is done for different cropping systems. The results between 2014–19 are used to arrive at mean values and compared for three approaches and six methods. Long-term trends are analysed for net returns in a particular centre. Recorded mean net return values, which reflected all cropping systems at a centre, were analysed for the years 2004–19.

COST OF CULTIVATION

Among three approaches, out of 63 cropping systems, cost of cultivation was highest in 63 per cent cropping systems with organic approach at 15 centres, 8 per cent with integrated approach at three centres and 29 per cent with inorganic approach at eight centres. With organic approach, the cost of cultivation was lowest in five per cent cropping systems. The five-year mean cost of cultivation with organic approach was higher than inorganic in 51 cropping systems (81 per cent). Within these, it was significantly higher in 67 per cent cropping systems. It was higher by up to 72 per cent (from Rs 57,395/ha) in one of the cropping systems. Similarly, mean cost of cultivation with integrated approach was higher than inorganic in 45 cropping systems (71 per cent). Within these, it was significantly higher in 36 per cent cropping systems. It was higher by up to 51 per cent (from Rs 1,23,431/ha) in one of the cropping systems. **With organic approach, the mean cost of cultivation was lower than inorganic in 19 per cent cropping systems.**

It is evident that cost of cultivation is higher with organic approach than integrated approach. This high cost is explained by the fact that organic and bio-inputs used in the AI-NPOF are largely purchased from the

market and not produced on-farm, as the project involves experimental farms. Whereas, organic inputs cost less if produced on-farm by farmers.

GROSS RETURNS

Among three approaches, out of the 61 cropping systems, gross returns are highest in 49 per cent with organic approach at 13 centres, 15 per cent with integrated approach at five centres and 36 per cent with inorganic approach at four centres. The five-year mean gross returns with organic approach are higher than inorganic in 74 per cent cropping systems. Within these, they are significantly higher in 82 per cent cropping systems. They are higher by up to 97 per cent (from Rs 2,76,350/ha) in a particular cropping system. Similarly, mean gross returns with integrated approach are higher than inorganic in 67 per cent cropping systems. Within these, they are significantly higher in 20 per cent cropping systems. They are higher by up to 125 per cent (from Rs 2,76,350/ha) in a particular cropping system. **It is evident that gross returns are much better with organic approach than with integrated and inorganic approach.**

NET RETURNS

Among all three approaches, out of 61 cropping systems, net returns are highest in 64 per cent with organic approach at 12 centres, 11 per cent with integrated approach at four centres, and 25 per cent with inorganic approach at five centres. The five-year mean net returns with organic approach are higher than inorganic in 67 per cent cropping systems. Within these, they are significantly higher in 88 per cent cropping systems. They are higher by up to 370 per cent (from Rs 45,942/ha) in a particular cropping system. Similarly, mean net returns with integrated approach are higher than inorganic in 56 per cent cropping systems. Within these, they are significantly higher in 12 per cent cropping systems. They are higher by up to 395 per cent (from Rs 67,843/ha) in a particular cropping system.

Despite high cost of cultivation in 51 cropping systems as mentioned above, net returns are highest in 63 per cent of these cropping systems with organic approach at 11 centres. Within these, they are significantly higher in 88 per cent cropping systems. Similarly, in the case of integrated approach, despite high cost of cultivation in 45 cropping systems, net returns are highest in 11 per cent cropping systems at three centres. Within these, they are significantly higher in 16 per cent cropping systems. **It is evident that net returns are much better with organic approach than with integrated or inorganic approaches. It is also evident that despite high cost of cultivation with organic approach, net returns are more favourable than integrated approach.**

The long-term trends on net returns revealed that net returns are much better with organic than inorganic approach. They are also better than integrated approach.

BENEFIT-COST RATIO

Among three approaches, out of the 61 cropping systems, benefit-cost ratio is highest in 21 per cent with organic approach at nine centres, 13 per cent with integrated approach at seven centres and 66 per cent with inorganic approach at eight centres. The five-year mean benefit-cost ratio with organic approach is higher than inorganic in 56 per cent cropping systems. Within these, it is significantly higher in 53 per cent cropping systems. It is higher by up to 171 per cent (from 2.5) in a particular cropping system. Similarly, mean benefit-cost ratio with integrated approach is higher than inorganic in 34 per cent cropping systems. Within these, it is significantly higher in 29 per cent cropping systems. It is higher by up to 69 per cent (from 2.4) in a particular cropping system.

Despite high cost of cultivation in 51 cropping systems, benefit-cost ratio is highest in 47 per cent cropping systems with organic approach at nine centres. Within these, it is significantly higher in 44 per cent cropping systems. Similarly, in the case of integrated approach, despite high cost of cultivation, in 45 cropping systems, it is highest in nine per cent cropping systems at three centres. Within these, it is significantly higher in 25 per cent cropping systems. **It is evident that benefit-cost ratio is much better with organic approach than with integrated or inorganic approaches. It is also evident that despite high cost of cultivation with organic approach, benefit-cost ratio is favourable, even more than in the case of integrated approach.**

SCIENTIFIC STUDIES

In addition to the AI-NPOF, evidence is reviewed and collated from 42 scientific studies conducted in India on organic and natural farming, which were published or presented during 2010–20. These studies conducted in different locations by a wider scientific community added to the overall evidence in favour of organic and natural farming.

These studies reveal that the cost of inputs required for organic and natural farming are comparatively less as these are locally and naturally available. Sustained lower cost of cultivation, eco-friendly and cheaper biofertilizers, and less variable costs makes organic farming a low-cost alternative to chemical-based farming. Income and profit are also high under organic farming. The major cost in inputs comes in the form of manual labour and production of vermicompost. Marginal farmers are more likely to achieve sustained livelihood through organic and natural farming due to low cost of cultivation, intercropping, labour requirements and comparatively good market rates for their organic produce.

There are studies which suggest that in the case of natural farming, yields may not always be high for all crops, but the benefit-cost ratio is several times higher than chemical-based farming. Along with minimized cost of production and premium prices for the produce, incomes and profits under natural farming are higher than conventional farming. On an average, even without certification, produce from natural farming fetches twice the income of conventional farming. Organic and natural farming

has the potential to provide year-long sustained food production for consumption and sale. Practices like multi-cropping, crop rotation and crop diversification guarantee increased incomes, sustained livelihood, empowerment of women farmers, along with making small and marginal farmers less dependent on moneylenders.

3. Evidence on benefits of organic and natural farming on soil health and environment

AI-NPOF

In the case of AI-NPOF results, for in-depth analysis, comparison of five-year mean values (2014–19) of organic carbon, soil macronutrients, bulk density and rhizosphere microbial population is done as per different cropping systems. This is done for three approaches and six methods. In the case of soil micronutrients, one-year results of 2018–19 were used for similar analysis. Long-term trends of organic carbon, soil macronutrients, bulk density and rhizosphere microbial population are analysed for a particular centre. For this, recorded mean values which reflected all cropping systems in a centre are analysed for the years 2004–19.

ORGANIC CARBON

Among all three approaches, out of 34 cropping systems at nine centres, mean organic carbon in soil is highest in 91 per cent cropping systems with organic approach at all centres. In the remaining nine per cent cropping systems, it is highest with integrated approach. The five-year mean organic carbon, with organic approach is higher than inorganic in 97 per cent cropping systems. Within these, it is significantly higher in 67 per cent cropping systems. It is higher by up to 242 per cent (from 0.69 per cent) in a particular cropping system. Similarly, mean organic carbon with integrated approach is higher than inorganic in 94 per cent cropping systems. Within these, it is significantly higher in 44 per cent cropping systems. It is higher by up to 195 per cent (from 0.69 per cent) in a particular cropping system.

Long-term trends at 16 centres indicate that by and large, organic carbon is consistently highest with organic approach (mostly OF method) at all centres. These centres are Bajaura, Bhopal, Calicut, Coimbatore, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram, Pantnagar, Raipur, Ranchi, Ajmer, Umiam, Narendrapur and Sardarkrushinagar.

It is evident that organic carbon in soil is much better with organic approach (mostly with OF method) than with integrated and inorganic approaches. It is also evident that organic carbon is more favourable with integrated approach than with inorganic approach.

NITROGEN IN SOIL

Among all three approaches, out of 58 cropping systems at 15 centres, mean available nitrogen is highest in 57 per cent cropping systems with organic approach at 12 centres. It is highest in 21 per cent with integrated approach at eight centres and in 22 per cent with inorganic approach at

four centres. The five-year mean available nitrogen with organic approach is higher than inorganic in 74 per cent cropping systems. Within these, it is significantly higher in 12 per cent cropping systems. It is higher by up to 40 per cent (from 205 kg/ha) in a particular cropping system. Similarly, mean available nitrogen with integrated approach is higher than inorganic in 62 per cent cropping systems. Within these it is significantly higher in 11 per cent cropping systems. It is higher by up to 39 per cent (from 273 kg/ha) in a particular cropping system.

Long-term trends indicate that available nitrogen with organic approach (mostly with OF method) is highest throughout at Bhopal, Dharwad, Jabalpur, Karjat, Ludhiana and Ranchi. At Coimbatore, Pantnagar, Umiam, Calicut, Modipuram and Sardarkrushinagar it is highest either in initial or the last few years. At Raipur, it is highest with inorganic approach and at Bajaura with integrated approach in the later years.

It is evident that available nitrogen in soil is much better with organic approach than with integrated and inorganic approaches. It is also evident that available nitrogen is more favourable with integrated approach than with inorganic approach.

PHOSPHORUS IN SOIL

Out of 62 cropping systems at 16 centres, mean available phosphorus is highest in 58 per cent cropping systems at 13 centres with organic approach. It is highest in 23 per cent with integrated approach at eight centres and in 19 per cent with inorganic approach at five centres. The five-year mean available phosphorus with organic approach is higher than inorganic in 74 per cent cropping systems. Within these, it is significantly higher in 52 per cent cropping systems. It is higher by up to 243 per cent (from 3.3 kg/ha) in a particular cropping system. Similarly, mean available phosphorus with integrated approach is higher than inorganic in 69 per cent cropping systems. Within these, it is significantly higher in 47 per cent cropping systems. It is higher by up to 232 per cent (from 19.7 kg/ha) in a particular cropping system.

Long-term trends with organic approach indicate that available phosphorous is highest throughout at Bhopal, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram and Ajmer. At Pantnagar, it is highest in the last few years. At Bajaura, Calicut and Sardarkrushinagar, it is highest either with organic and integrated approach. At Coimbatore and Ranchi, it is highest with inorganic approach. At Raipur and Narendrapur, it is highest with inorganic approach except for the last few years.

It is evident that available phosphorus in soil is much better with organic approach than with integrated and inorganic approaches. It is also evident that available phosphorus is more favourable with integrated approach than with inorganic approach.

POTASSIUM IN SOIL

Out of 59 cropping systems at 16 centres, mean available potassium is highest in 53 per cent cropping systems at 12 centres with organic approach. It is highest in 28 per cent with integrated approach at eight centres and in 19 per cent with inorganic approach at five centres. The five-year mean available potassium with organic approach is higher than inorganic in 69 per cent cropping systems. Within these, it is significantly higher in 21 per cent cropping systems. It is higher by up to 95.5 per cent (from 126 kg/ha) in a particular cropping system. Similarly, mean available potassium with integrated approach is higher than inorganic in 76 per cent cropping systems. Within these, it is significantly higher in 13 per cent cropping systems. It is higher by up to 101.4 per cent (from 127 kg/ha) in a particular cropping system.

Long-term trends with organic approach indicate that available potassium in soil is highest throughout at Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram, Ranchi, Ajmer and Sardarkrushinagar. At Coimbatore, it is highest with organic approach except in the last few years. At Umiam and Narendrapur, it is mostly highest with integrated approach. At Bajaura, it is highest in later years with integrated approach. At Raipur, it is always highest with inorganic approach. At Pantnagar, Bhopal and Calicut, it is mostly highest with inorganic.

It is evident that available potassium in soil is better with organic approach than with integrated and inorganic approaches. It is also evident that available potassium was more favourable with integrated approach than with inorganic approach.

NITROGEN, PHOSPHORUS AND POTASSIUM IN SOIL

In the case of available nitrogen, phosphorus and potassium collectively, mean values of all three macronutrients with organic approach are higher than with inorganic approach in 26 cropping systems (42 per cent) at 10 centres. These centres are Bajaura, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram, Umiam, Ajmer and Sardarkrushinagar.

SOIL BULK DENSITY

Among three approaches out of 28 cropping systems at seven centres, mean bulk density is lowest in 52 per cent cropping systems with organic approach at four centres. It is lowest in 34 per cent cropping systems with integrated approach at four centres and it is lowest in 14 per cent with inorganic approach at two centres. The five-year mean bulk density with organic approach is lower in 75 per cent cropping systems. It is lower by up to 9.3 per cent (from 1.41 g/cc) in a particular cropping system. Similarly, mean bulk density with integrated approach is lower than inorganic in 79 per cent cropping systems. It is lower by up to 8.6 per cent (from 1.1 g/cc) in a particular cropping system.

Long-term trends with organic approach indicate that soil bulk density is lowest throughout at Dharwad, Jabalpur, Raipur, Umiam, Narendrapur and Sardarkrushinagar. Only at Thiruvananthapuram, it is highest with organic.

Lower bulk density is favourable. It is evident that organic approach is better than integrated and inorganic approach. It is also evident that bulk density is more favourable with integrated approach than with inorganic approach.

BACTERIA IN SOIL

Among all three approaches, out of 32 cropping systems at eight centres, mean bacteria is highest in 84 per cent cropping systems with organic approach at all centres. In 13 per cent, it is highest with integrated at two centres and three per cent with inorganic approach at one centre. The five-year mean bacteria with organic approach is higher than inorganic in 91 per cent cropping systems. Within these, it is significantly higher in 86 per cent cropping systems. It is higher by up to 274 per cent (from 6.8 x10^6 cfu/g) in a particular cropping system. Similarly, mean bacteria with integrated approach is higher than inorganic in 81 per cent cropping systems. Within these, it is significantly higher in 65 per cent cropping systems. It is higher by up to 192 per cent (from 10.9 x10^6 cfu/g) in a particular cropping system.

More bacteria in soil are favourable. It is evident bacteria in soil is better with organic approach than with integrated and inorganic approaches. It is also evident that bacteria in soil is more favourable with integrated approach than with inorganic approach.

FUNGI IN SOIL

Among all three approaches, out of 32 cropping systems at eight centres, mean fungi is highest in 72 per cent cropping systems with organic approach at seven centres. In 12 per cent, it is highest with integrated at two centres and 16 per cent with inorganic approach at two centres. The five-year mean fungi with organic approach is higher in 78 per cent cropping systems. Within these, it is significantly higher in 76 per cent cropping systems. It is higher by up to 173 per cent (from 7.5 x10^6 cfu/g) in a particular cropping system. Similarly, mean fungi with integrated approach is higher than inorganic in 66 per cent cropping systems. Within these, it is significantly higher in 52 per cent cropping systems. It is higher by up to 56 per cent (from 9.0 x10^6 cfu/g) in a particular cropping system.

More fungi in soil are favourable. It is evident that fungi in soil with organic approach is much better than with integrated and inorganic approaches. It is also evident that fungi in soil is more favourable with integrated approach than with inorganic approach.

SOIL ACTINOMYCETES

Among all three approaches, out of 32 cropping systems, mean soil actinomycetes are highest in 69 per cent cropping systems with organic approach at all centres. In 25 per cent, they are highest with integrated approach at three centres and six per cent with inorganic approach at two centres. The five-year mean soil actinomycetes with organic approach are higher than inorganic in 84 per cent cropping systems. Within these, they are significantly higher in 56 per cent cropping systems. They are higher by up to 101 per cent (from 1.7 x10^6 cfu/g) in a particular cropping system. Similarly, mean soil actinomycetes with integrated approach are higher than inorganic in 34 per cent cropping systems. Within these, they are significantly higher in 73 per cent cropping systems. They are higher by up to 238 per cent (from 10.5 x10^6 cfu/g) in a particular cropping system.

More soil actinomycetes are favourable. It is evident that soil actinomycetes in soil with organic approach are much better than with integrated and inorganic approaches. It is also evident that soil actinomycetes in soil are more favourable with integrated approach than with inorganic approach.

PHOSPHATE SOLUBILIZING BACTERIA (PSB)

Out of 21 cropping systems, mean phosphate solubilizing bacteria is highest in 76 per cent cropping systems with organic approach at all centres. In 10 per cent, it is highest with integrated and in 14 per cent with inorganic approach, both at two centres. The five-year mean phosphate solubilizing bacteria with organic approach is higher than inorganic in 81 per cent cropping systems. Within these, it is significantly higher in 47 per cent cropping systems. It is higher by up to 307 per cent (from 1.4 x10^6 cfu/g) in a particular cropping system. Similarly, mean PSB with integrated approach is higher than inorganic in 19 per cent cropping systems. Within these, it is significantly higher in 50 per cent cropping systems. It iss higher by up to 1496 per cent (from 1.4 x10^6 cfu/g) in a particular cropping system.

More phosphate solubilizing bacteria in soil is favourable. It is evident that phosphate solubilizing bacteria in soil with organic approach is much better than with integrated and inorganic approaches. It is also evident that phosphate solubilizing bacteria in soil is more favourable with integrated approach than with inorganic approach.

SOIL BACTERIA, FUNGI, ACTINOMYCETES AND PHOSPHATE SOLUBILIZING BACTERIA

Collectively, mean values of bacteria, fungi and soil actinomycetes with organic approach are higher than with inorganic approach in 21 cropping systems (about 66 per cent) at eight centres. These centres are Bajaura, Bhopal, Coimbatore, Dharwad, Jabalpur, Karjat, Ludhiana and Narendrapur. Phosphate solubilizing bacteria results are available for lesser number of centres. When compared, it is higher with inorganic approach in 12 cropping systems along with bacteria, fungi and soil actinomycetes.

Collectively, mean values of bacteria, fungi and soil actinomycetes with integrated approach are higher than inorganic approach in five cropping systems (about 17 per cent) at two centres. These centres are Dharwad and Ludhiana. Phosphate solubilizing bacteria results are available for lesser number of centres. When compared, it is never higher in even a single cropping system along with bacteria, fungi and soil actinomycetes.

SOIL MICRONUTRIENTS—IRON, MANGANESE, ZINC AND COPPER

The available iron in soil was highest in 74 per cent cropping systems with organic approach at all centres. Available manganese with organic approach was highest in 63 per cent cropping systems at all centres. Available zinc with organic approach was highest in 89 per cent cropping systems at all centres. Available copper was highest in 78 per cent cropping systems at all centres, except one. **Collectively, values of all four micronutrients with organic approach are higher than inorganic approach in 16 cropping systems (76 per cent) at five centres. These centres are Bajaura, Calicut, Dharwad, Pantnagar, and Sardarkrushinagar.**

Similarly, with integrated approach, out of 19 cropping systems at five centres, available iron is highest in 21 per cent cropping systems at all centres. Available manganese with integrated approach is highest in 37 per cent cropping systems at all centres. Available zinc with integrated approach is highest in 11 per cent cropping systems at all centres. Available copper with integrated approach is highest in 22 per cent cropping systems at all centres but one. Collectively, values of all four micronutrients with integrated approach are higher than inorganic approach in 11 cropping systems (23 per cent) at four centres. These centres are Bajaura, Calicut, Dharwad and Sardarkrushinagar.

SCIENTIFIC STUDIES

In addition to the AI-NPOF, evidence is reviewed and collated from 33 Indian scientific studies and results on soil health and environment with organic and natural farming published or presented during 2010–20. These studies which were conducted in different locations by a wider scientific community added to the overall evidence in favour of organic and natural farming.

These studies suggest that organic farming led to the growth of active organic matter and soil organisms in the soil. Organic fertilization increases the total carbon, nitrogen and ammonium concentration, and improves soil fertility. Organic manures such as farmyard manure (FYM) alone or in different combinations with vermicompost and biofertilizers along with organic practices improve the soil structure, enhance soil fertility and improve soil organic carbon. They also show positive impact on bulk density. The findings also indicate that due to the application of organic manure, there was a higher soil moisture content, increase in water holding capacity, enhanced porosity and higher availability of major soil nutrients, i.e., nitrogen, phosphorus and potassium in the soil. It also improves plant and animal biodiversity. **Organic farming also positively impacts the environment and climate, as it improves sustainability index and increases carbon sequestration. Organic farming may address both emissions avoidance and carbon sequestration.**

With natural farming and Zero Budget Natural Farming (ZBNF), studies revealed that soil health and fertility, macro and micro nutrients, soil organic carbon, soil enzymes, earthworms, soil respiration and microbial biomass increase after adoption of natural farming. Natural farming also led to soil porosity, aeration, light texture, moisture retention, etc. Natural farming also improves overall resilience of crops to adverse climatic

conditions. Natural farming improves energy and water efficiency. It also has the potential to reduce carbon emissions as ZBNF fields showed improvement in soil organic carbon. The studies also highlight that ZBNF can help prevent over-extraction of groundwater, enable aquifer recharge, and eventually contribute to increasing water table levels. As ZBNF eliminates the use of inorganic chemical inputs, it is likely to improve the quality of groundwater aquifers.

4. Evidence on benefits of organic and natural farming on food quality and nutrients

AI-NPOF RESULTS

Actual values of 28 different food quality and nutrient parameters in 15 crops cultivated with three approaches and six methods under the AI-NPOF in 2018–19 were compared. These crops were from five food groups i.e., vegetables, oilseeds, pulses, spices and cereals. **Compared with inorganic approach, across 51 sets of test results, in 67 per cent cases, results are higher with organic approach and in 64 per cent cases they are higher with integrated approach.**

In 12 out of 15 crops, parameters tested were found highest with organic approach. In seven out of these, all parameters tested were highest with organic approach. These crops are cauliflower, French bean, soybean, mustard, black gram, rice and wheat (grown in Bhopal). In the remaining five crops, one or more parameters are highest with organic approach or were same with all approaches. These crops are carrot, tomato (grown at Bajaura and Umiam), turmeric, black pepper and fennel. In the case of carrot and tomato (grown at Bajaura), in one or more parameters tested, the results are significantly higher with both organic and integrated approaches. In pea, parameters tested are highest with integrated approach. In ginger, results of one parameter are highest with integrated and the other with inorganic approach. Coriander is the only crop where all parameters tested are highest with inorganic. In the case of wheat grown at Ranchi, results of all parameters tested are highest with inorganic approach. **The food quality and nutrition with organic approach are found to be better than inorganic, and also slightly better than integrated approach.**

SCIENTIFIC STUDIES

In addition to the AI-NPOF, evidence is reviewed and collated from 11 Indian scientific studies and results on food quality and nutrition parameters of crops with organic and natural farming published or presented during 2010–20. These studies which were conducted in different locations by a wider scientific community added to the overall evidence in favour of organic and natural farming.

These studies found that the quality parameters like total carotenoids, total soluble solids, vitamin C, total sugars and lycopene are higher with organic approach in vegetables and fruits. Organically grown corn, strawberries and Marion berries have significantly higher (around 30 per cent) levels of cancer-fighting antioxidants. In case of papaya, the quality parameters were higher with organic as compared to recommended dose of fertilizers. Organically grown taro had higher nutrient content. Organic farming also improved the physical attributes of vegetables such as cabbage, tomato and cowpea. Organically grown rice showed higher nutritive values than that grown with chemicals. Evidence also indicates that organically cultivated leafy greens, tomato and cauliflower were found superior in microbial quality than their conventionally grown counterparts.

SECTION I:
EVIDENCE ON CROP YIELD

Summary: Benefits of organic and natural farming on crop yield

Overall, the results of AI-NPOF from 2004–19 are considered for analysis. The results of 2014 to 2019 are considered for deep-dive analysis, whereas the entire set of results are analysed to understand the long-term trends.

The deep-dive analysis is based on highest yield values and mean yield values for 31 different crops, from five food groups, comprising of vegetables, oilseeds, pulses, spices and cereals across 74 cropping systems at 19 centres. These centres are located in five ecosystems—arid, semi-arid, humid, sub-humid and coastal.

Out of the recorded 504 times across six methods, yield was highest 41 per cent times with the organic approach, followed by 33 per cent with integrated and 26 per cent with inorganic approach.

In the case of vegetables, oilseeds and cereals, yield with organic approach was highest more times than integrated and inorganic both. Out of the recorded 122 times for vegetables, yield was highest 48 per cent times with the organic approach, followed by 36 per cent with integrated and 16 per cent with inorganic approach. Out of the recorded 91 times for oilseeds, yield was highest 58 per cent times with the organic approach, followed by 17 per cent with integrated and 25 per cent with inorganic approach. Out of the recorded 81 times for pulses, yield was highest 32 per cent times with the organic approach, 42 per cent with integrated and 26 per cent with inorganic approach. Out of the recorded 28 times for spices, yield was highest 32 per cent times with the organic approach, 54 per cent with integrated and 14 per cent with inorganic approach. Out of the recorded 182 times for cereals, yield was highest 35 per cent times with the organic approach, followed by 32 per cent with integrated and 33 per cent with inorganic approach.

With reference to mean yields with organic approach, 27 out of 31 crops (87 per cent) recorded higher mean yield than inorganic approach as part of one or more cropping systems. These included ten vegetables, four oilseeds, five pulses, four spices and four cereals. Out of this, in 14 crops (52 per cent) the mean yield was significantly higher (>20 per cent). These crops were:

- **Four vegetables:** Tomato, potato, French bean and ladyfinger
- **One oilseed:** Linseed
- **Three pulses:** Black gram, pigeon pea and chickpea
- **Three spices:** Ginger, coriander and black pepper
- **Three cereals:** Basmati rice, rice and maize

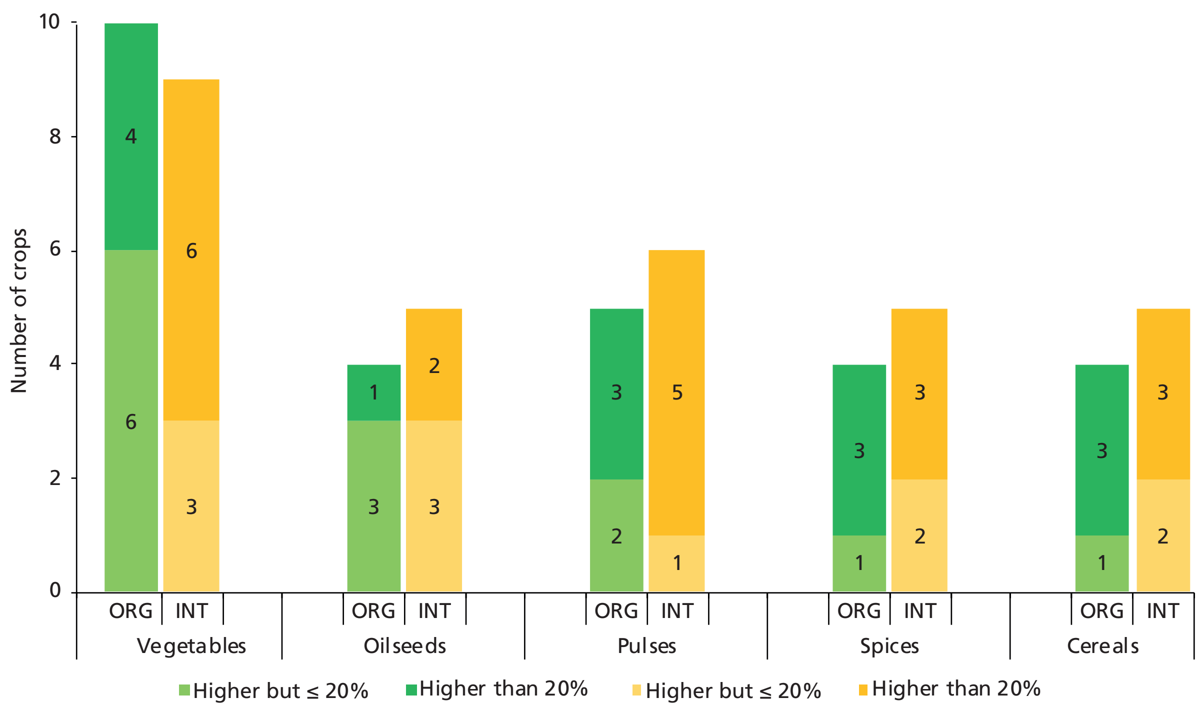
The other 13 crops with higher mean yield but not significantly higher are broccoli, chillies, vegetable pea, onion, capsicum, cowpea, groundnut, mustard, soybean, green gram, cowpea, turmeric and durum wheat. The remaining four crops with lower mean yield in all cropping systems wherever they were grown are sunflower, lentil, fennel and wheat. Out of these, mean yield of wheat was significantly lower in only one of six cropping systems it was part of.

These 14 crops were grown at 12 centres—Bajaura, Bhopal, Calicut, Dharwad, Ludhiana, Pantnagar, Ranchi, Umiam, Gangtok, Modipuram, Narendrapur and Thiruvananthapuram—in five ecosystems.

With reference to mean yields with integrated approach, 30 out of 31 crops (97 per cent) recorded higher mean yields than inorganic approach as part of one or more cropping systems. These included nine vegetables, five oilseeds, six pulses, five spices and five cereals. Out of this, in 19 crops (63 per cent) the mean yield was significantly higher. These crops were:

- **Six vegetables:** Tomato, potato, French bean, vegetable pea, ladyfinger and cauliflower
- **Two oilseeds:** Linseed and soybean
- **Five pulses:** Black gram, pigeon pea, chickpea, lentil and green gram
- **Three spices:** Ginger, turmeric, and coriander
- **Three cereals:** Basmati rice, rice, and maize

Graph 1: Comparison of mean yield of organic and integrated approaches with inorganic approach



The 11 crops with higher mean yield but not significantly higher are broccoli, chillies, onion, groundnut, mustard, sunflower, cowpea, fennel, black pepper, wheat and durum wheat. There were 19 crops with lower mean yields in all cropping systems wherever they were grown. These 19 crops were grown at ten centres—Bajaura, Calicut, Karjat, Ludhiana, Pantnagar, Ranchi, Gangtok, Modipuram, Udaipur and Thiruvananthapuram—in four ecosystems. The remaining one crop is capsicum with lower yield, which was grown only as part of one cropping system at one centre.

Crop yield is higher with organic approach than with inorganic approach across multiple food groups (vegetable, oilseed, pulses, spices and cereal) and different ecosystems in the country. This was also true for integrated approach. Highest yields were recorded on most occasions with organic approach. In some cases, yields with integrated approach were at par with organic approach.

In addition to the AI-NPOF, evidence was reviewed and collated from 32 Indian scientific studies and results on different aspects of organic and natural farming published or presented during 2010–20. These studies which were conducted by different stakeholders in different settings and geographies add to the overall evidence in favour of organic farming and natural farming.

There are studies suggesting that yields are higher with organic and natural farming approaches. In the case of organic with spinach, baby corn, broccoli, potato, ladyfinger, tomato, onion, chilli, pigeon pea, cowpea, black gram, rice, ragi, pearl millet, wheat, and banana. In case of natural farming crops like maize, groundnut, sugarcane, finger millet, soybean, jowar and turmeric showed higher yields.

Studies also highlight the importance of bioinputs and organic inputs as well as organic management and natural farming practices. These inputs include farmyard manure, vermicompost, poultry manure, foliar spray of banana pseudostem, green manure, liquid biofertilizers, Panchagavya, Jeevamrutha, Beejamritha, Ghanajeevamritha, Fish-Protein Hydrolysate (FPH), Phosphate Solubilizing Bacteria (PSB), Azotobactor and Rhizobacteria. The positive role of seed soaking with liquid manure, mulching and intercropping are also captured in some studies.

There are studies suggesting that it usually takes a few years with organic management practices to get comparable or more yield than with inorganic approaches, such as in the case of wheat, maize, rice, cluster bean, sesame, cumin and psyllium husk. In some cases, such as potato, the yield was comparable within a year.

With organic farming, yields were higher in vegetables, oilseeds, pulses, spices and cereals. This was also true in the case of natural farming in most of the cases. The use of multiple, local, low-cost organic and bioinputs led to higher yield in comparison to conventional farming. During the transition time which varies, yield with organic and natural farming may reduce.

Chapter 1: Comparison of different approaches as per AI-NPOF

In this section, recorded results are analysed for 31 crops across 19 centres in all five ecosystems during 2014–19. Comparison of highest yield value and mean yield value was carried out for organic and integrated approaches in relation to inorganic approach. The same comparison was also done for six methods. For long-term trends, the actual yield values recorded during 2004–19 were analysed. These are presented as graphs in Annexure 1.

1.1 Vegetables

Ten types of vegetables were analysed as part of 21 unique cropping systems (overall 30) across 10 centres in four ecosystems (except in arid ecosystem) in kharif, rabi and summer seasons. These were broccoli, potato, French bean, vegetable pea, tomato, cauliflower, chillies, onion, capsicum and ladyfinger. Out of the recorded 122 times for vegetables, yield was highest 48 per cent times with the organic approach, followed by 36 per cent with integrated and 16 per cent with inorganic approach (see *Table 1: Comparison of mean yields of vegetables with different approaches and methods [2014–19]*).

Organic approach

Analysis done for ten crops revealed that mean yields for all crops are higher with organic approach as part of one or more cropping systems. These crops were grown in three different seasons in nine centres and in four ecosystems. In case of tomato, potato, French bean and ladyfinger, the yield was significantly higher (> 20 per cent) in some cropping systems. In the case of broccoli, chillies, vegetable pea and onion, yields were lower than inorganic approach only once.

On comparing mean yields across all cropping systems, it was found that in 70 per cent cases (out of 30 cropping systems), yields with organic approach were higher than with inorganic approach. Out of these, in 29 per cent cases yields were significantly higher. It was higher by up to 62 per cent (from 6,121 kg/ha) in a particular cropping system. Within the organic approach, yields with both methods (OF and OIN) were higher in more cropping systems than inorganic method (IOF).

Integrated approach

In case of integrated approach, nine out of ten crops had higher mean yields than with inorganic approach. These crops were grown in three different seasons, in nine centres and in four ecosystems. Only once each in French bean, chillies, onion and capsicum and twice in vegetable pea, yields were slightly lower than inorganic approach.

With integrated approach, yields were higher than inorganic approach in 63 per cent cases (out of 30 cropping systems). Out of which in 42 per cent cases yield was significantly higher. It was higher by up to 59 per cent (from 6,281 kg/ha) in a particular cropping system. Within integrated approach, yields with both methods (IN75 and IN50) were higher than inorganic method (IOF) in more cropping systems.

Inorganic approach

Within inorganic approach, inorganic (SR) method had yields higher than inorganic method (IOF) in more cropping systems.

CROP-WISE ANALYSIS

Tomato: Tomato was cultivated with cauliflower, French bean and broccoli during all the three seasons in Bajaura and Umiam, located in a humid ecosystem.

Overall, in 10 out of 13 times, yields were highest with organic approach followed by three times in integrated approach.

In all the three seasons and in both the centres, organic approaches showed higher mean yields than inorganic approach. Within the organic approaches, yields were higher with OF method in both the centres and with OIN method in one centre.

Within the integrated approach, yields were higher than with inorganic approach with both the methods (IN75 and IN50).

Long-term trends revealed that the yield of tomato, when grown at Bajaura during kharif season, was by and large highest with organic (OIN) method. When grown in summer, it was highest in the later years with the same method. In Umiam, yields were mostly highest with organic (OF) method during the later years (see *Annexure 1—Figure 1.1: Graphs showing long-term trends for crop yield—Vegetables*).

Broccoli: Broccoli was cultivated with carrot, potato, French bean and tomato in Umiam during the kharif season and with basmati rice in Narendrapur during rabi, both in humid ecosystems.

Overall, in 10 out of 15 times, yields were highest with organic approach followed by four times in integrated approach and once with inorganic.

In Umiam, during kharif, organic approaches showed higher mean yields than inorganic approach. Within the organic approaches, yields were higher with both organic methods (OF and OIN). In Narendrapur, mean yields with organic approaches and methods were slightly lower than with inorganic.

Within the integrated approach, yields were higher with IN50 method.

Long-term trends revealed that the yields of broccoli in Umiam by and large were highest throughout the years with organic approach. In Narendrapur, yields were highest in the later four years through organic (OF) method.

Potato: Potato was cultivated with maize, ladyfinger, basmati rice, rice and broccoli as a rabi crop in Modipuram and Pantnagar under the semi-arid ecosystem, in Ranchi under sub-humid ecosystem and in Umiam under the humid ecosystem.

Overall, in 14 out of 18 times, yields were highest with organic approach followed by three times with integrated approach and once with inorganic.

Under the organic approach, potato showed higher mean yields in all four centres in comparison with the inorganic approach. Within the organic approach, yields were higher with organic (OF) method in all the centres and with organic (OIN) method in three of the four centres except in Umiam where they were slightly lower than inorganic.

Under the integrated approach yields were higher than inorganic in all the four centres. Within the integrated approach, yields were higher with both methods (IN75 and IN50) than inorganic in all the centres.

Long-term trends revealed that by and large yield of potato in Ranchi and Pantnagar were highest throughout with organic approach. In Umiam and Modipuram, yields were by and large highest throughout with integrated approach (both IN75 or IN50 method).

French bean: French bean was cultivated with tomato, cauliflower, broccoli, paddy, sesame, maize and ginger in Bajaura during summer and in Umiam and Narendrapur during rabi season, both in humid ecosystems, and in Gangtok also during rabi season in sub-humid ecosystem. As Sikkim is an organic state, comparison with inorganic method was not carried out for Gangtok.

Overall, in eight out of 15 times, French bean recorded highest yields with the organic approach followed by six times with integrated and once with inorganic.

In both the seasons, mean yields with organic approach were higher than inorganic across all three centres. Within the organic approach, yields were higher with both organic methods (OF and OIN) in all three centres.

With integrated approach yields were higher than inorganic in all centres except Narendrapur. Within the integrated approach, yields were higher than inorganic with both methods in Bajaura (IN75 and IN50) and with one method (IN50) in Umiam. In Narendrapur, yields under both approaches were slightly lower than inorganic.

Long-term trends revealed that by and large French bean yields in Narendrapur and Gangtok were highest throughout the years with organic approach (largely OF method). In Umiam, yields were highest in the last four years. In Bajaura, yields were by and large highest throughout with integrated approach (either IN75 or IN50 method).

Chillies: Chillies were cultivated with soybean during the rabi season in Raipur, located in sub-humid ecosystem and with sunflower during kharif in Coimbatore, located in semi-arid ecosystem.

Overall, three out of nine times, yields were highest with organic approach followed by four times in integrated and two times with inorganic approach.

When mean yields were compared, yield with organic approach was higher than inorganic approach in Raipur by 3 per cent and lower in Coimbatore by 7 per cent. Within the organic approach, yields were higher with both methods (OF and OIN) in Raipur and with one method (OIN) in Coimbatore.

With integrated approach, yields were higher in Coimbatore by 2 per cent and lower in Raipur by 9 per cent. Within the integrated approach, yields were significantly higher with IN75 method and lower with IN50 method at Coimbatore. In Raipur, yields were lower with both methods.

Long-term trends revealed that yield of chillies in Coimbatore was highest in the initial years and in Raipur, yields were highest in the alternate years.

Vegetable pea: Vegetable pea was cultivated with basmati rice, ladyfinger, and soybean during the rabi season in Jabalpur and Raipur under the sub-humid ecosystem and in Pantnagar and Bajaura under humid ecosystem.

Out of the 20 times, highest yields under the organic approach were recorded seven times, which was also at par with inorganic approach followed by six times with integrated approach.

Mean yields under the organic approach were higher in three of the four centres. Among the organic methods also, yields were higher than inorganic in three centres with both the methods (OF and OIN).

With the integrated approach, yields were higher than inorganic in two of the four centres. Within the integrated approach, yields were higher with IN75 method in two centres and with IN50 method in three centres.

Long-term trends revealed that by and large yields of vegetable pea in Pantnagar were highest throughout with organic approach (largely OF method). In Raipur, yields were highest in the later years and in Jabalpur, they were rarely highest with organic methods. In Bajaura, yields were by and large highest mostly with integrated approach (IN50 method).

Onion: Onion was cultivated with rice and soybean as a rabi crop in Karjat under the coastal ecosystem and in Raipur under the sub-humid ecosystem.

Out of the total four times, inorganic approach recorded highest yields on all four occasions.

Under organic approach, mean yields in onion were higher than inorganic at Karjat and lower than inorganic at Raipur. Within the organic approach, yields with OF method were higher and with OIN method were lower in Karjat. They were slightly lower with both methods in Raipur.

With the integrated approach, yields were higher than inorganic in one of the two centres. Within the integrated approach, yields were higher with integrated (IN5O) method in one centre and in the rest, yields were slightly lower than inorganic.

Long-term trends revealed that yields of onion were higher for organic at Karjat and lower in Raipur. Within the integrated approach, the integrated (IN50) method recorded higher yields at Karjat against the inorganic (IOF) method.

Capsicum: Capsicum was cultivated with paddy and green gram in Narendrapur during the rabi season, under the humid ecosystem.

Overall, three out of the three times capsicum recorded highest yields under the organic approach.

Capsicum recorded higher mean yields under the organic approach in comparison to the inorganic approach. Within the organic approach, yields under the OF method were higher and under the OIN method were slightly lower in comparison to the inorganic method (IOF).

Under integrated approach and methods, yields were lower than inorganic.

Long-term trends revealed that by and large yields of capsicum in Narendrapur were highest throughout the years with organic (OF) method.

Ladyfinger: Ladyfinger was cultivated with maize and potato in Modipuram during the summer season in the semi-arid ecosystem and with pea at Bajaura during kharif in the humid ecosystem.

Overall, in three out of the ten times ladyfinger recorded highest yields with organic approach, followed by six times under integrated and once with inorganic approach.

Mean yields with the organic approach were higher than inorganic. Within the organic approach, yields were higher with both the organic methods (OF and OIN).

Under the integrated approach also, yields were higher than the inorganic approach. Within the integrated approach, yields with both the methods (IN75 and IN50) were higher than inorganic (IOF).

Table 1: Comparison of mean yields of vegetables with different approaches and methods (2014–19)

Crops	Cropping systems	Centre (season)	Ecosystem	Mean yield as per IOF method (Kg/ ha)
Tomato	Tomato – cauliflower – French bean	Bajaura (Kha)	Humid	3,872
	Fallow – cauliflower – tomato	Bajaura (Sum)	Humid	5,250
	Broccoli – tomato	Umiam (Rabi)	Humid	14,816
Broccoli	Broccoli – carrot	Umiam (Kha)*	Humid	12,511
	Broccoli – potato			
	Broccoli – French bean			
	Broccoli – tomato			
	Basmati rice – broccoli – sesbania green manure	Narendrapur (Rabi)	Humid	4,229
Potato	Maize – potato – ladyfinger	Modipuram (Rabi)	Semi-arid	20,654
	Basmati rice – potato	Pantnagar (Rabi)	Semi-arid	9,270
	Rice – potato	Ranchi (Rabi)	Sub-humid	12,082
	Broccoli – potato	Umiam (Rabi)	Humid	13,970
French Bean	Tomato – cauliflower – French bean	Bajaura (Sum)	Humid	3,584
	Broccoli – French bean	Umiam (Rabi)	Humid	8,170
	Paddy – French bean – sesame	Narendrapur (Rabi)	Sub-humid	4,820
	Maize + ginger	Gangtok (Rabi)~	Humid	-
Chillies	Soybean – chilli	Raipur (Rabi)	Semi-arid	8,280
	Chillies – sunflower	Coimbatore (Kha)	Sub-humid	5,844
Veg Pea	Basmati rice – vegetable pea – sorghum (F)	Jabalpur (Rabi)	Sub-humid	3,570
	Basmati rice – vegetable pea	Pantnagar (Rabi)	Humid	5,806
	Lady finger – pea	Bajaura (Rabi)	Humid	4,794
	Soybean – pea	Raipur (Rabi)	Sub-humid	6,283
Onion	Rice – onion (White) (till 2017 rice – Dolichos bean)	Karjat (Rabi)	Coastal	14,757
	Soybean – onion	Raipur (Rabi)	Sub-humid	13,986
Capsicum	Paddy – capsicum – green gram	Narendrapur (Rabi)	Humid	9,607
Ladyfinger/Lady finger	Maize – potato – ladyfinger	Modipuram (Sum)	Semi-arid	5,135
	Lady finger – pea	Bajaura (Kha)	Humid	5,738
Cauliflower	Tomato – cauliflower – French bean	Bajaura (Rabi)*	Humid	7,490
	Fallow – cauliflower – tomato			
	Black gram – cauliflower – summer squash			
Total crops - 10	Total unique cropping systems – 21	Centres – 10	Ecosystems – 4	
Number of recorded results				
Crop yields with higher respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent cases)				
Crop yield where values are significantly higher (> 20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher yields (in per cent cases)				
Range of difference in mean with inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)				

Note: (-) represents data not available; * At these centres the mean value of the particular common crop under analysis was taken into account; ~ In Gangtok, inorganic methods are not practised so comparison is not carried out; @ Value of only SR method is given so value of INO is value of SR; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic method or approach, and values in red cells indicate lesser than inorganic method or approach

Mean yield difference compared to IOF method (%)					Mean yield as per INO approach (Kg/ha)	Mean yield difference compared to INO approach (%)		No. of times highest yields were recorded			
OF	OIN	IN75	IN50	SR		ORG	INT	Total	ORG	INT	INO
14	18	23	**39**	14	4,148	8	**22**	13	10	3	0
88	**91**	63	81	33	6,121	**62**	48				
14	-6	-	5	-	14,816	4	**5**				
13	2	-	11	-	12,511	7	**11**	15	10	4	1
-6	-5	-3	-3	-9	4,049	-1	1				
8	3	9	9	8	21,513	1	**5**	18	14	3	1
34	29	17	22	1	9,296	**31**	19				
48	37	22	14	-14	11,214	**54**	27				
11	-3	-	8	-	13,970	4	**8**				
49	61	**78**	68	53	4,530	22	**37**	15	8	6	1
14	**18**	-	8	-	8,170	**16**	8				
11	7	-3	-9	9	5,042	**4**	-10				
-	-	-	-	-	2,810	**49**	29				
3	**8**	-7	-7	4	8,466	**3**	-9	9	3	4	2
-8	0.1	**15**	-4	7	6,060	-7	**2**				
-17	-28	-18	-6	-12	3,363	-18	-6	20	7	6	7
11	7	9	9	2	5,878	**8**	8				
33	41	48	**57**	43	5,818	13	**26**				
5	**19**	-5	0.4	7	6,501	**8**	-6				
11	-23	-11	**18**	-24	13,011	7	**18**	4	0	0	4
-5	-1	-8	-14	10	14,675	-7	-15				
4	-2	-20	-17	-12	9,007	**8**	-14	3	3	0	0
25	15	14	17	16	5,548	**11**	7	10	3	6	1
42	40	66	**82**	19	6,281	29	**59**				
37	37	55	**65**	40	8,989	14	**34**	15	0	12	3
29	29	24	29	25		30	30	122	58	44	20
69	59	50	59	60		70	63				
40	41	58	41	27		29	42				
-17 – 88	-28 – 91	-20 – 78	-17 – 82	-24 – 53		-18 – 62	-15 – 59				

Long-term trends revealed that yield of ladyfinger in Modipuram were highest in the initial years. In Bajaura, yields were by and large highest throughout with integrated approach (either IN75 or IN50 method).

Cauliflower: Cauliflower was cultivated with tomato, French bean, black gram and summer squash during the rabi season in Bajaura under the humid ecosystem.

Out of the total 15 times, integrated approach recorded highest yields on 12 occasions followed by three times under inorganic.

Mean yields under the organic approach were higher than the inorganic approach. Within the organic approach, yields under both the organic (OF) and organic (OIN) methods were higher than the inorganic (IOF) method.

Under the integrated approach, yields were higher in comparison to the inorganic approach. Within the integrated approach, yields under both the integrated (IN75 and IN50) methods were higher than inorganic.

Long-term trends revealed that yields of cauliflower in Bajaura were by and large highest throughout with integrated approach (both IN75 or IN50 methods).

1.2 Oilseeds

Five types of oilseeds were analysed as part of 16 unique cropping systems (overall 22) across 13 centres in five ecosystems in kharif and rabi seasons. These were linseed, groundnut, mustard, sunflower and soybean. Out of the recorded 91 times for oilseeds, yield was highest 58 per cent times with the organic approach, followed by 17 per cent with integrated and 25 per cent with inorganic approach (see *Table 2: Comparison of mean yields of oilseeds with different approaches and methods [2014–19]*).

Organic approach

Analysis done for five crops revealed that mean yields for four of the five crops are higher with organic than inorganic approach as part of one or more cropping systems. These crops were grown in two different seasons in eight centres and in four ecosystems. In case of linseed the yield was significantly higher (> 20 per cent) in some cropping systems. In the case of sunflower, soybean and mustard yields were lower than inorganic approach only once and thrice in case of groundnut.

When mean yields were compared across all cropping systems, it was found that in 45 per cent cases, yields with the organic approach were higher than inorganic approach. Out of these, in 10 per cent cases yields were significantly higher (>20 per cent). It was higher by up to 39 per cent (from 616 kg/ha) in a particular cropping system. Within the organic approach, yields with both methods (OF and OIN) were higher than inorganic method (IOF).

Integrated approach

All crops had higher mean yields with integrated approach than with inorganic approach. These crops were grown in two different seasons, in eight centres and in four ecosystems. Only once in mustard, twice in groundnut and thrice in soybean, yields were lower than inorganic approach. Reductions in yields of all crops in comparison to inorganic were negligible.

Within integrated approach, yields were higher than inorganic approach in 45 per cent cases. Out of which in 20 per cent cases yield was significantly higher. It was higher by up to 25 per cent (from 444 kg/ha) in a particular cropping system. Within integrated approach, yield with both methods (IN75 and IN50) were higher than inorganic (IOF) in about half the cropping systems.

Inorganic approach

Within inorganic approach, SR method had yields higher than IOF method in 38 per cent cropping systems.

CROP-WISE ANALYSIS

Linseed: Linseed was cultivated with soybean and rice in Bhopal under the semi-arid ecosystem and in Ranchi under sub-humid ecosystem during the rabi season.

In nine out of the nine times organic approach recorded the highest yields.

In both the centres, organic approach showed higher mean yields than inorganic. Within the organic approach, yields were higher with both methods (OF and OIN) in both centres.

With integrated approach also yields were higher in both the centres with both methods (IN75 and IN50). In Ranchi, yields were comparatively higher than in Bhopal for all approaches and methods.

Long-term trends revealed that by and large yields of linseed in Bhopal and Ranchi were highest throughout the years with organic approach (largely OF method) (see *Annexure 1—Figure 1.2: Graphs showing long-term trends for crop yield—Oilseeds*).

Groundnut: Groundnut was cultivated with hybrid cotton, rice, wheat, green gram, and cassava as a rabi crop in Karjat and Thiruvananthapuram under the coastal ecosystem, and as a kharif crop in Dharwad and Sardarkrushinagar under the arid ecosystem.

In eight out of the 13 times inorganic approach recorded highest yields in five years, followed by three times with organic and twice with integrated.

In Thiruvananthapuram organic approach showed higher mean yields than inorganic and in Dharwad, Karjat and Sardarkrushinagar yields were slightly lower. Within the organic approach, yields were lower with both methods (OF and OIN) in all four centres.

With integrated approach yields were higher in two centres and slightly lower in the other two. Within the integrated approach, yields were either slightly

Table 2: Comparison of mean yields of oilseeds with different approaches and methods (2014-19)

Crops	Cropping systems	Centre (season)	Ecosystem	Mean yield as per IOF method (Kg/ha)
Linseed	Soybean – linseed	Bhopal (Rabi)	Semi-arid	1,311
	Rice – linseed	Ranchi (Rabi)	Sub-humid	642
Groundnut	Groundnut + hybrid cotton	Dharwad (Kha)	Arid	2,053
	Rice – brinjal (till 2017 rice – groundnut)	Karjat (Rabi)	Coastal	2,490
	Groundnut - wheat – green gram	SK Nagar (Kha)	Arid	1,955
	Cassava – groundnut	Thiruvananthapuram (Rabi)	Coastal	1,474
Mustard	Maize – mustard – sesbania green manure	Modipuram (Rabi)	Semi-arid	2,129
	Soybean – mustard	Bhopal (Rabi)	Semi-arid	1,073
	Rice – field bean (till 2017 rice – mustard)	Karjat (Rabi)	Coastal	747
	Paddy – mustard – green gram	Narendrapur (Rabi)	Humid	1,323
Sunflower	Chillies – sunflower	Coimbatore (Rabi)	Semi-arid	1,989
Soybean	Soybean – durum wheat	Bhopal (Kha)*	Semi-arid	713
	Soybean – mustard			
	Soybean - chickpea			
	Soybean – linseed			
	Soybean – maize	Raipur (Kha)*	Sub-humid	1,822
	Soybean – pea			
	Soybean – chilli			
	Soybean – onion			
	Soybean – wheat	Ludhiana (Kha)	Semi-arid	1,268
	Maize + soybean – buckwheat	Gangtok~ (Kha)	Sub-humid	-
	Soybean – fenugreek	Udaipur (Kha)	Semi-arid	539
Total crops – 5	Total unique cropping systems – 16	Centres – 12	Ecosystems – 5	
Number of recorded results				
Crop yields with higher respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent cases)				
Crop yield where values are significantly higher (> 20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher yields (in per cent cases)				
Range of difference in mean with inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)				

Note: (-) represents data not available; * At these centres the mean value of the particular common crop under analysis was taken into account; ~ In Gangtok, inorganic methods are not practised so comparison is not carried out; @ Value of only SR method is given so value of INO is value of SR; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic method or approach, and values in red cells indicate lesser than inorganic method or approach

higher or slightly lower in three of the four centres with both the integrated (IN75 and IN50) methods. In the case of inorganic (SR) method, yields were higher than inorganic in two of the four centres.

Long-term trends revealed that yields of groundnut in Dharwad were highest in the initial years and in Karjat in the later years through organic (OF) method. In Sardarkrushinagar and Thiruvananthapuram, yields were never highest with organic approach.

Mean yield difference compared to IOF method (%)					Mean yield as per INO approach (Kg/ha)	Mean yield difference compared to INO approach (%)		No. of times highest yields were recorded			
OF	OIN	IN75	IN50	SR		ORG	INT	Total	ORG	INT	INO
15	9	11	5	0.0	1,311	**12**	8	9	9	0	0
36	30	22	15	-8	616	**39**	24				
-2	-1	-0.4	0	**6**	2,119	-5	-3	13	3	2	8
-1	-11	-0.4	-2	-10	2,370	-1	**4**				
-14	-15	-0.4	2	**5**	2,004	-16	-2				
-10	-10	-13	-14	-40	1,179	**13**	8				
8	8	10	7	**19**	2,331	-2	-1	16	9	3	4
17	10	13	5	2	1,082	**13**	8				
0.0	-8	**7**	-1	-8	717	0.1	**8**				
7	1	2	3	-6	1,286	**7**	5				
-4	6	**16**	4	9	2,079	-4	**5**	5	0	5	0
23	16	18	6	3	724	**18**	10	48	32	5	11
5	5	-2	-3	**6**	1,878	**2**	-5				
10	8	3	0	5	1,301	**6**	-1				
-	-	-	-	-	1,335@	**3**	-5				
-18	-37	**6**	-1	-35	444	-12	**25**				
21	21	21	21	21		22	22	91	53	15	23
38	43	48	43	38		45	45				
25	11	10	0	0		10	20				
-18 – 36	-37 – 30	-13.0 – 22	-14 – 15	-40 – 19		-16 – 39	-5 – 25				

Mustard: Mustard was cultivated with maize, soybean, rice and green gram as a rabi crop in Karjat under the coastal ecosystem, in Modipuram and Bhopal under semi-arid ecosystems and in Narendrapur under humid ecosystem.

Overall, in nine out of the 16 times organic approach recorded highest yields in five years, followed by three times with integrated and four times with inorganic.

In three of the four centres, organic approach showed higher mean yields than inorganic and slightly lower in the other. Within the organic approach, yields were higher and at par (once) with organic (OF) when compared with inorganic method. With organic (OIN) method, yields were slightly lower than inorganic at Karjat.

With integrated approach yields were similar to organic approach, higher in three of the four centres and slightly lower in the other. Within the integrated approach, yields were higher with both methods in all centres except in Karjat where it was slightly lower with integrated (IN50) method. In the case of inorganic (SR) method, yields were higher than inorganic in two of the four centres.

The long-term trends revealed that yields of mustard in Modipuram were highest in the initial years and in Bhopal and Narendrapur in the later years with OF method. In Karjat, yields were highest through integrated approach (IN75 method) in the later years.

Sunflower: Sunflower was cultivated with chillies in Coimbatore during the rabi season under the semi-arid ecosystem.

Overall, in five out of the five times integrated approach recorded highest yields in five years.

At Coimbatore, organic approach showed slightly lower mean yields than inorganic. This was similar in the case of yields with OF method as well. With OIN method yields were higher than inorganic across the years.

With the integrated approach yields were higher than inorganic approach by five per cent. Within the integrated approach, yields with both integrated methods (IN75 and IN50) were higher than inorganic. In the case of inorganic, yields with SR method were higher.

Long-term trends revealed that by and large yields of sunflower in Coimbatore were highest throughout with integrated approach (both IN75 or IN50 methods).

Soybean: Soybean was cultivated with durum wheat, mustard, chickpea, linseed, maize, pea, chilli, onion, wheat, maize, buckwheat and fenugreek during the kharif season in Bhopal, Ludhiana and Udaipur under the semi-arid ecosystems and in Raipur and Gangtok under sub-humid ecosystems. As Sikkim is an organic state, comparison with inorganic method was not carried out for Gangtok.

Overall, in 32 out of the 48 times organic approach recorded highest yields in five years, followed by five times under integrated and 11 times under inorganic approach.

In all centres except in Udaipur, organic approach showed higher mean yields than inorganic. Similarly, within the organic approach, yields were higher with both methods (OF and OIN).

With integrated approach yields were higher in two centres and slightly lower in the rest. Within the integrated approach, yields were either higher or slightly lower with both the integrated (IN75 and IN50) methods. In the case of inorganic (SR) method, yields were slightly higher than inorganic in three centres.

Long-term trends revealed that by and large yields of soybean in Bhopal, Gangtok and Ludhiana were highest throughout the years with organic approach (largely OF method). In Raipur, yields were highest with organic approach in the later years. In Udaipur, yields were highest with integrated approach only once (IN75 method).

1.3 Pulses

Six types of pulses were analysed as part of 21 unique cropping systems (overall 21) across 14 centres in five ecosystems, in kharif, rabi and summer seasons. These were black gram, pigeon pea, chickpea, green gram, cowpea and lentils. Out of the recorded 81 times for pulses, yields were highest 32 per cent times with the organic approach, 42 per cent with integrated and 26 per cent with inorganic approach (see *Table 3: Comparison of mean yields of pulses with different approaches and methods [2014–19]*).

Organic approach

Analysis done for six crops revealed that mean yields for five of the six crops are higher with organic than inorganic approach as part of one or more cropping systems. These crops were grown in three different seasons in 10 centres and in all ecosystems. In case of black gram, pigeon pea and chickpea, the yield was significantly higher (> 20 per cent) in some cropping systems. In the case of pigeon pea, green gram and lentils, yields were also lower than inorganic approach only once and twice in case of cowpea and chickpea.

When mean yields were compared across all cropping systems, it was found that in 67 per cent cases, yields with organic approach were higher than with inorganic approach. Out of these, in 21 per cent cases yields were significantly higher (>20 per cent). They were higher by up to 66 per cent (from 590 kg/ha) in a particular cropping system. Within organic approach, yields with both methods (OF and OIN) were higher in more cropping systems than with inorganic (IOF) method.

Integrated approach

All crops had higher mean yields with integrated approach than with inorganic approach. These crops were grown in three different seasons, in 10 centres and in all ecosystems. Only once each in black gram and green gram, and twice in chickpea and cowpea yields were lower than inorganic approach. Except once in the case of chickpea the reductions in yields were negligible.

With integrated approach, yields were higher than inorganic approach in 62 per cent cases. Out of which in 54 per cent cases yields were significantly higher. They were higher by up to 109 per cent (from 2,679 kg/ha) in a particular cropping system. Within integrated approach, yield with both methods (IN75 and IN50) were higher in more cropping systems than inorganic (IOF).

Inorganic approach

Within inorganic approach, the SR method had yields higher than the IOF method in lesser number of cropping systems.

CROP-WISE ANALYSIS

Black gram: Black gram was cultivated with cauliflower, summer squash, maize, durum wheat, wheat, chickpea, and taro during kharif in Bajaura under the humid ecosystem and in Udaipur under the semi-arid ecosystem and during the rabi season in Thiruvananthapuram under the coastal ecosystem.

Overall, in three out of 17 times, yields were recorded highest with organic approach and ten times with integrated approach followed by four times with inorganic.

In all the centres, organic approach showed higher mean yields than inorganic approach. Within the organic approach, yields were higher with organic (OF) method in two centres and slightly lower in the other. With the OIN method, yields were higher than inorganic in all three centres.

With integrated approach yields were higher in two of three centres and slightly lower in the other. Within the integrated approach, yields were identical and higher with both methods in two centres. In the case of inorganic, yields with SR method were higher than with IOF method in only one of the three centres.

Long-term trends revealed that yields of black gram in Udaipur were highest in the initial years. In Bajaura and Thiruvananthapuram, yields were by and large highest throughout with integrated approach (both IN75 or IN50 methods) (see *Annexure 1—Figure 1.3: Graphs showing long-term trends for crop yield—Pulses*).

Pigeon pea: Pigeon pea was cultivated as a sole crop in Dharwad under the arid ecosystem and with maize in Gangtok under sub-humid ecosystem during the kharif season. As Sikkim is an organic state, comparison with inorganic method is not carried out for Gangtok.

Overall, two times each out of seven times, yields were recorded highest with organic approach and integrated approach. Yields were recorded highest with inorganic thrice.

In Dharwad, organic approach showed slightly lower mean yields than inorganic. Within the organic approach, yields were slightly higher or comparatively lower with organic methods (OF and OIN) than with inorganic method.

With integrated approach yields were higher in Dharwad. Within the integrated approach, yields were higher with both the methods. Yields with SR method were higher than yields with IOF method.

Long-term trends revealed that by and large yields of pigeon pea in Gangtok were highest throughout the years with organic approach (largely OF method). In Dharwad, yields were by and large highest throughout with integrated approach (either IN75 or IN50 method).

Chickpea: Chickpea was cultivated with soybean, maize, basmati rice and rice as a rabi crop in Bhopal and Ludhiana under the semi-arid ecosystems, in Dharwad under arid ecosystem, in Jabalpur under sub-humid ecosystem, in Pantnagar under the humid ecosystem, and in Karjat under the coastal ecosystem.

In 12 out of the 23 times, yields were recorded highest with organic approach followed by seven with integrated and four with the inorganic approach.

In four of the six centres, organic approach showed higher mean yields than inorganic approach. Within the organic approach, yields were higher with OF method in five centres and with OIN method in four centres when compared with inorganic method.

With integrated approach also yields were higher in four of the six centres. Within the integrated approach, yields were higher under IN50 method in all the centres and under IN75 method in five centres. In the case of inorganic, yields were exceptionally higher with SR method than with IOF method in Pantnagar.

Long-term trends revealed that by and large yields of chickpea in Bhopal, Dharwad and Pantnagar (except one year) were highest throughout the years with organic (OF) method. In Jabalpur yields with organic approach were never highest. In Ludhiana, yields were highest with organic approach on a couple of occasions and in Karjat yields were by and large highest throughout with integrated approach (either IN75 or IN50 method).

Green gram: Green gram was cultivated with paddy, mustard, capsicum, sorghum, and barley as a summer crop in Narendrapur under the humid ecosystem and in Modipuram under the semi-arid ecosystem; and as a kharif crop in Dharwad under the arid ecosystem.

Overall, six out of the 19 times, yields were recorded highest with the organic approach followed by eight times with the integrated approach and five times with inorganic approach.

In three of the four centres, organic approach showed higher mean yields than inorganic and slightly lower in the remaining one. Within the organic approach, yields were higher with both the organic methods (OF and OIN) in the same three centres, when compared with inorganic method.

With integrated approach also yields were higher in three of the four centres and slightly lower in the remaining one. Within the integrated approach, yields were higher under both the methods (IN75 and IN50) in the same centres and slightly lower in the other. In the case of inorganic (SR) method, yields were higher in almost all the centres compared with the inorganic method.

Table 3: Comparison of mean yields of pulses with different approaches and methods (2014–19)

Crops	Cropping systems	Centre (season)	Ecosystem	Mean yield as per IOF method (Kg/ ha)
Black gram	Black gram – cauliflower – summer squash	Bajaura (Kha)	Humid	674
	Black gram + maize – durum wheat	Udaipur (Kha)*	Semi-arid	223
	Black gram + sweet corn – chickpea			
	Black gram – wheat			
	Taro – black gram	Thiruvananthapuram (Rabi)	Coastal	3,272
Pigeon pea	Pigeon pea (Sole)	Dharwad (Kha)	Arid	1,541
	Maize + pigeon pea	Gangtok~ (Kha)	Sub-humid	-
Chickpea	Soybean – chickpea	Bhopal (Rabi)	Semi-arid	1,391
	Maize – chickpea	Dharwad (Rabi)	Arid	1,357
	Basmati rice – chickpea – maize (f)	Jabalpur (Rabi)	Sub-humid	619
	Rice-chickpea (till 2017 rice – maize)	Karjat (Rabi)	Coastal	1,493
	Basmati rice – chickpea – green manure (GM)	Ludhiana (Rabi)	Semi-arid	763
	Basmati rice – chickpea	Pantnagar (Rabi)	Humid	1,450
Green gram	Paddy – mustard – green gram	Narendrapur (Sum)	Humid	1,121
	Paddy – capsicum – green gram	Narendrapur (Sum)	Humid	1,096
	Green gram – sorghum	Dharwad (Kha)	Arid	908
	Rice – barley – green gram	Modipuram (Sum)	Semi-arid	619
Cowpea	Cowpea – safflower	Dharwad (Kha)	Arid	1,592
	Green gram – cumin – vegetable cowpea	SK Nagar (Sum)	Arid	4,963
	Cassava – vegetable cowpea	Thiruvananthapuram (Rabi)	Coastal	17,064
Lentils	Rice – lentil	Ranchi (Rabi)	Sub-humid	417
Total Crops – 6	Total unique cropping systems – 21	Centres – 14	Ecosystems – 5	
Number of recorded results				
Crop yields with higher respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent cases)				
Crop yield where values are significantly higher (> 20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher yields (in per cent cases)				
Range of difference in mean with inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)				

Note: (-) represents data not available; * At these centres the mean value of the particular common crop under analysis was taken into account; ~ In Gangtok, inorganic methods are not practised so comparison is not carried out; @ Value of only SR method is given so value of INO is value of SR; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic method or approach, and values in red cells indicate lesser than inorganic method or approach

Long-term trends revealed that by and large yields of green gram in Narendrapur were highest throughout the years with organic approach. In Modipuram, yields were highest in the initial years. In Dharwad, yields were never highest with organic approach.

Mean yield difference compared to IOF method (%)					Mean yield as per INO approach (Kg/ha)	Mean yield difference compared to INO approach (%)		No. of times highest yields were recorded			
OF	OIN	IN75	IN50	SR		ORG	INT	Total	ORG	INT	INO
33	29	42	**45**	26	761	16	**27**	17	3	10	4
-5	**3**	-10	-1	-3	220	**1**	-4				
26	23	**71.2**	71	-36	2,679	52	**109**				
0.2	-13	4	5	**8**	1,599	-10	**1**	7	2	2	3
-	-	-	-	-	590	**66**	41				
18	12	13	8	2	1,409	**13**	9	23	12	7	4
27	10	8	15	15	1,460	**10**	3				
-22	-35	-27	**1**	-25	541	-18	-1				
10	-3	16	**17**	-12	1,407	10	**23**				
41	49	**53**	52	-6	741	49	**57**				
12	10	5	5	**115**	2,282	-29	-33				
13	**17**	6	10	-1	1,115	**16**	8	19	6	8	5
16	**18**	10	12	0.3	1,098	**17**	11				
-10	-11	-2	-3	**7**	941	-14	-6				
22	16	36	**37**	17	670	10	**26**				
-5	-5	-3	**6**	3	1,616	-6	**0.04**	10	3	2	5
-14	-16	1	3	**11**	5,234	-19	-3				
-5	-16	-5	-26	-23	15,076	**1**	-4				
-10	-20	8	**19**	-28	358	-1	**32**	5		5	
20	20	20	20	20		21	21	81	26	34	21
55	50	65	75	50		67	62				
45	30	31	27	20		21	54				
-212 – 41	-35 – 49	-27 – 71	-26 – 71	- 36 – 115		-29 – 66	-33 – 109				

Cowpea: Cowpea was cultivated with safflower, green gram, cumin and cassava during kharif in Dharwad under the arid ecosystem, during summer in Sardarkrushinagar under arid ecosystem and during rabi in Thiruvananthapuram under coastal ecosystem.

Overall, three out of the 10 times, yields were recorded highest with the organic approach followed by twice with the integrated approach and five times with inorganic approach.

Only at Thiruvananthapuram, organic approach showed slightly higher mean yields than inorganic approach. Within the organic approach, yields were lower with both the organic methods (OF and OIN) in all the three centres, when compared with inorganic method.

With integrated approach also yields were slightly higher in Dharwad. Within the integrated approach, yields were higher in two of the three centres with IN50 method and slightly higher or slightly lower than inorganic under IN75 method in the three centres. In the case of inorganic yields were higher with SR method than IOF method in two of the three centres.

Long-term trends revealed that yields of cowpea were highest in the later years with organic (OF) method. In Dharwad, yields were never highest with organic and in Sardarkrushinagar, yields were by and large highest in the later years with integrated approach (IN50 method).

Lentils: Lentils were cultivated with rice in Ranchi during the rabi season under the sub-humid ecosystem.

In five out of the five times, integrated approach recorded highest yields across the five years.

Organic approach showed slightly lower mean yields in comparison to inorganic approach. With the organic method, yields with both organic methods were lower than the inorganic method.

Under integrated approach, yields were higher than the inorganic approach. Within the integrated approach, yields were higher with both the methods (IN75 and IN50) as compared to inorganic.

Long-term trends revealed that by and large yields of lentils in Ranchi were highest throughout with integrated approach (both IN75 and IN50 methods).

1.4 Spices

Five types of spices were analysed as part of eight unique cropping systems (overall eight) across four centres in three ecosystems, in kharif and rabi seasons. These were ginger, turmeric, coriander, fennel and black pepper. Out of the recorded 28 times for spices, yield was highest 32 per cent times with the organic approach, 54 per cent with integrated and 14 per cent with inorganic approach (see *Table 4: Comparison of mean yields of spices with different approaches and methods [2014-19]*).

Organic approach

Analysis done for five crops revealed that mean yields for four of the five crops were higher with organic than with inorganic approach as part of one or more cropping systems. These crops were grown in two different seasons in two centres and in two ecosystems. In case of ginger, coriander and black pepper the yield was significantly higher (> 20 per cent) in some cropping systems. In the case of fennel, yields were lower than inorganic approach in both instances.

On comparing mean yields across all cropping systems, it was found that in 63 per cent cases, yields with the organic approach were higher than inorganic approach. Out of these, in 80 per cent cases yields were significantly higher. They were higher by up to 46 per cent (from 15,648 kg/ha) in a particular cropping system. Within organic approach, yields with both methods (OF and OIN) were higher in more cropping systems than inorganic method (IOF).

Integrated approach

In case of integrated approach, all crops had higher mean yields than inorganic approach. These crops were grown in two different seasons, in three centres and in two ecosystems. Only once in the case of fennel, yields were lower than inorganic.

With integrated approach, yields were higher than inorganic approach in 88 per cent cases. Out of which in 43 per cent cases yields were significantly higher. They were higher by up to 48 per cent (from 17,493 kg/ha) in a particular cropping system. Within integrated approach, yield with IN75 method was higher than inorganic (IOF) in similar number of cropping systems.

Inorganic approach

Within inorganic approach, SR method had yields higher than IOF method in more cropping systems.

CROP-WISE ANALYSIS

Ginger: Ginger was cultivated as a sole crop in Calicut during the kharif season under the coastal ecosystem.

Organic and integrated approach each recorded highest yields once out of the two times.

Organic approach showed significantly higher mean yields compared to inorganic approach. Within organic approach, yields were also higher with both the organic methods (OF and OIN).

With integrated approach, yields were higher and at par with organic approach against the inorganic method. Within integrated approach, yields were higher through both the methods (IN75 and IN50) as well.

Long-term trends revealed that by and large yields of ginger in Calicut were highest in the later years with integrated approach (IN75 method) (see *Annexure 1—Figure 1.4: Graphs showing long-term trends for crop yield—Spices*).

Turmeric: Turmeric was cultivated as a sole crop in Calicut during the kharif season under the coastal ecosystem.

Table 4: Comparison of mean yields of spices with different approaches and methods (2014–19)

Crops	Cropping systems	Centre (season)	Ecosystem	Mean yield as per IOF method (Kg/ha)
Ginger	Ginger (Sole)	Calicut (Kha)	Coastal	15,648
Turmeric	Turmeric (Sole)	Calicut (Kha)	Coastal	17,493
Coriander	Basmati rice – chickpea	Pantnagar (Rabi)	Humid	1,033
	Basmati rice – vegetable pea	Pantnagar (Rabi)	Humid	923
	Cluster bean/green gram – coriander	Ajmer (Rabi)	Arid	687
Fennel	Cluster bean/green gram – fennel	Ajmer (Rabi)	Arid	1,512
	Green gram – fennel – fennel	Sardarkrushinagar (Rabi)	Arid	1,636
Black Pepper	Black Pepper (Sole)	Calicut (Kha)	Coastal	1,272
Total Crops – 5	Total unique cropping systems – 8	Centres – 5	Ecosystems – 3	
Number of recorded results				
Crop yields with higher respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent cases)				
Crop yield where values are significantly higher (> 20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher yields (in per cent cases)				
Range of difference in mean with inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)				

Note: (-) represents data not available; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic method or approach, and values in red cells indicate lesser than inorganic method or approach

In two out of the two times, integrated approach recorded highest yields in comparison to inorganic approach.

Organic approach showed higher mean yields than inorganic. Within the organic approach, yields were also higher with both the organic methods (OF and OIN).

With integrated approach yields were significantly higher compared to the inorganic method. Within integrated approach, yields were higher through both the methods (IN75 and IN50) as well.

Long-term trends revealed that by and large yields of turmeric in Calicut were highest throughout with integrated approach (both IN75 and IN50 methods).

Coriander: Coriander was cultivated with basmati rice, chickpea, vegetable pea and cluster bean/green gram as a rabi crop in Pantnagar under the humid ecosystem and in Ajmer under arid ecosystem.

In six out of the 14 times, organic approach recorded highest yields in comparison to the inorganic approach followed by seven times with integrated approach and once with inorganic.

In one of the two centres, organic approach showed higher mean yields than inorganic approach. Within the organic approach, yields were higher with

Mean yield difference compared to IOF method (%)					Mean yield as per INO approach (Kg/ha)	Mean yield difference compared to INO approach (%)		No. of times highest yields were recorded			
OF	OIN	IN75	IN50	SR		ORG	INT	Total	ORG	INT	INO
37	56	**78**	14	-	15,648	46	46	2	1	1	0
12	28	**63**	34	-	17,493	20	**48**	2	0	2	0
-0.1	11	**13**	5	-27	891	22	**26**	14	6	7	1
27	23	4	11	4	942	**22**	5				
-5	-1	**26**	12	19	751	-12	**9**				
-4	-1	**18**	8	13	1,611	-8	**6**	7	0	4	3
-26	-28	-9	1	**11**	1,727	-31	-9				
38	-	-	10	-	1,272	**38**	10	3	2	1	0
8	7	7	8	5		8	8	28	9	15	4
50	57	86	100	80		63	88				
50	75	50	13	0		80	43				
-26 – 38	-28 – 56	-9 – 78	-0.6 – 34	- 27 – 19		-31 – 46	-9 – 48				

organic (OF) method in Pantnagar when cultivated with vegetable pea and slightly lower in the rest. Similarly, with organic (OIN) method, yields were higher in one centre and slightly lower in the other centre.

With integrated approach, yields were higher than the inorganic method in both the centres. Within integrated approach, yields were higher through both the methods (IN75 and IN50) in both the centres. With inorganic approach, yields were also comparatively higher with SR method than with IOF method in two cropping systems.

Long-term trends revealed that by and large yields of coriander in Pantnagar were highest throughout with organic approach. In Ajmer and Pantnagar, yields were by and large highest throughout with integrated approach (largely IN75 method).

Fennel: Fennel was cultivated with cluster bean and green gram as a rabi crop in Ajmer and Sardarkrushinagar under the arid ecosystem.

Out of the total seven times, integrated approach recorded higher yields on four occasions against three with the inorganic approach.

In both the centres, organic approach showed lower mean yields than inorganic approach. Within the organic approach, yields were lower with both the organic methods (OF and OIN) but was slightly lower in Ajmer.

With integrated approach, yields were higher compared to the inorganic method in one centre and slightly lower in the other. Within the integrated approach, yields were higher with both the methods (IN75 and IN50) in Ajmer and with one method (IN50) in Sardarkrushinagar. With inorganic approach, yields were also higher with SR method than with IOF method in both the centres.

Long-term trends revealed that by and large yields of fennel in Ajmer were highest with integrated approach (largely IN75 method). In Sardarkrushinagar, yields with organic approach were never highest.

Black pepper: Black pepper was cultivated as a sole crop in Calicut during the kharif season under the coastal ecosystem.

In two out of the three times organic approach recorded higher yields in comparison to the inorganic approach followed by once with integrated approach.

Organic approach showed higher mean yields than inorganic approach. Within the approach, yields with organic (OF) method were higher than inorganic.

Yields were also higher with integrated approach as compared to the inorganic approach. Within the integrated approach, yields were comparatively higher with IN50 method.

Long-term trends revealed that by and large yields of black pepper in Calicut were highest mostly with organic (OF) method.

1.5 Cereals

Five types of cereals were analysed as part of 42 unique cropping systems (overall 49) across 14 centres in five ecosystems in kharif and rabi seasons. These were basmati rice, rice, wheat, durum wheat and maize. Out of the recorded 182 times for cereals, yield was highest 35 per cent times with the organic approach, followed by 32 per cent with integrated and 33 per cent with inorganic approach (see *Table 5: Comparison of mean yields of cereals with different approaches and methods [2014–19])*.

Organic approach

Analysis done for five crops revealed that mean yields for four of the five crops are higher with organic than inorganic approach as part of one or more cropping systems. These crops were grown in two different seasons in nine centres and in three ecosystems. In case of basmati rice, rice and maize, the yield was significantly higher (> 20 per cent). In the case of wheat, yields were lower than with inorganic approach.

On comparing mean yields across all cropping systems, it was found that in 22 per cent cases, yields with the organic approach were higher than inorganic approach. Out of these, in 27 per cent cases yields were significantly higher (>20 per cent). They were higher by up to 88 per cent (from 1,423 kg/ha) in a particular cropping system.

Integrated approach

With integrated approach all crops had higher mean yields than with inorganic approach. These crops were grown in two different seasons in 11 centres and in four ecosystems. In case of wheat and durum wheat, yields were lower than inorganic approach on two occasions.

Within integrated approach, yields were higher than inorganic approach in 37 per cent cases. Out of which in 17 per cent cases yield was significantly higher (>20 per cent). It was higher by up to 59 per cent (from 1,423 kg/ha) in a particular cropping system.

Inorganic approach

Within inorganic approach, the SR method had yields higher than IOF method in more cropping systems.

CROP-WISE ANALYSIS

Basmati rice: Basmati rice was cultivated with durum wheat, chickpea, berseem, vegetable pea, wheat, potato and broccoli in Jabalpur under the sub-humid ecosystems, in Pantnagar and Narendrapur under humid ecosystems and in Modipuram and Ludhiana under semi-arid ecosystems during the kharif season.

Overall, organic approach recorded highest yields on 22 occasions out of the total 52 times followed by 13 times under integrated and 17 times under inorganic.

In four of the five centres, organic approach showed higher mean yields than inorganic and slightly lower in the fifth centre. Within the organic approach, yields were higher with both methods (OF and OIN) in all centres barring Jabalpur where yields were slightly lower with OF method.

With integrated approach also, yields were higher in three centres and slightly lower in the remaining two. Within the integrated approach, yields were higher with both the integrated (IN75 and IN50) methods in three centres. Similar results were also observed with the inorganic (SR) method.

Long-term trends revealed that by and large yields of basmati rice in Pantnagar were highest mostly with organic approach. In Narendrapur, in Modipuram and in Ludhiana, yields were highest in the later years, when cultivated with wheat. In Ludhiana, when cultivated with chickpea, yields were by and large highest in the later years with integrated approach (either IN75 or IN50 method). In Jabalpur yields were never highest with organic approach (see *Annexure 1—Figure 1.5: Graphs showing long-term trends for crop yield—Cereals*).

Rice: Rice was cultivated with groundnut, maize, mustard, dolichos bean, wheat, lentil, potato, linseed, carrot, French bean, green gram, capsicum and sesame as a kharif crop in Karjat with a coastal ecosystem, at Ranchi under sub-humid ecosystem, and in Umiam and Narendrapur under humid ecosystem.

Table 5: Comparison of mean yields of cereals with different approaches and methods (2014-19)

Crops	Cropping systems	Centre (season)	Ecosystem	Mean yield as per IOF method (Kg/ha)
Basmati rice	Basmati rice – durum wheat	Jabalpur (Kha)*	Sub-humid	3,318
	Basmati rice – chickpea			
	Basmati rice – berseem			
	Basmati rice – veg pea			
	Basmati rice – wheat	Pantnagar (Kha)*	Humid	3,996
	Basmati rice – chickpea			
	Basmati rice – veg pea			
	Basmati rice – potato			
	Basmati rice – durum wheat – sesbania green manure	Modipuram (Kha)	Semi-arid	3,228
	Basmati rice – chickpea – green manure	Ludhiana (Kha)	Semi-arid	4,268
	Basmati rice – wheat – green manure		Semi-arid	4,194
	Basmati rice – broccoli – green manure	Narendrapur (Kha)*	Humid	3,801
Rice	Rice – brinjal (till 2017 rice – groundnut)	Karjat (Kha)*	Coastal	4,211
	Rice – chickpea (till 2017 rice – maize)			
	Rice – field bean (till 2017 rice – mustard)			
	Rice – onion (White) (till 2017 rice – Dolichos bean)			
	Rice – wheat	Ranchi (Kha)*	Sub-humid	3,064
	Rice – lentil			
	Rice – potato			
	Rice – linseed			
	Rice – carrot	Umiam (Kha)*	Humid	4,221
	Rice – potato			
	Rice – French bean			
	Rice – potato			
	Rice – mustard – green gram	Narendrapur (Kha)*	Humid	5,325
	Rice – capsicum – green gram			
	Rice – French bean – sesame			
Wheat	Basmati rice – wheat – green manure	Ludhiana (Rabi)*	Semi-arid	4,730
	Cluster bean – wheat – summer moong		Semi-arid	5,486
	Soybean – wheat (till 2015–16, pigeon pea – wheat)		Semi-arid	5,258
	Basmati rice – wheat	Pantnagar (Rabi)	Humid	4,736
	Rice – wheat	Ranchi (Rabi)	Sub-humid	2,856
	Black gram – wheat	Udaipur (Rabi)	Semi-arid	3,119
Durum Wheat	Soybean – durum wheat	Bhopal (Rabi)	Semi-arid	2,719
	Basmati rice – durum wheat – green manure	Jabalpur (Rabi)	Sub-humid	4,301
	Basmati rice – durum wheat – sesbania green manure	Modipuram (Rabi)	Semi-arid	3,673
	Maize + black gram – Durum wheat – sesbania green manure	Udaipur (Rabi)	Semi-arid	4,056

Mean yield difference compared to IOF method (%)					Mean yield as per INO approach (Kg/ha)	Mean yield difference compared to INO approach (%)		No. of times highest yields were recorded			
OF	OIN	IN75	IN50	SR		ORG	INT	Total	ORG	INT	INO
-4	-19	-10	-7	-14	3,089	-5	-1	52	22	13	17
20	16	14	13	2	4,029	**17**	13				
40	30	35	31	14	3,454	**26**	24				
0.9	0.8	0.1	-0.1	0.8	4,286	**0.4**	-0.4				
0.8	**1**	-1	-3	-0.5	4,184	**1**	-1				
11	6	7	6	0.4	3,808	**8**	6				
-2	-8	-4	**0.5**	-5	4,098	-2	**1**	45	24	14	7
20	**23**	10	12	-15	2,827	**32**	21				
6	-4	-	**9**	-	4,221	1	**9**				
7	3	9	**11**	2	5,382	4	**9**				
-20	-26	-10	-2	-1	4,697	-23	-6	24	0	8	16
-4	-6	2	**3**	1	5,501	-5	**3**				
-12	-13	1	**2**	-1	5,226	-12	**2**				
-0.2	-4	4	**6**	0.2	4,740	-2	**5**				
-12	-16	-5	-5	-27	2,474	-1	**9**				
-16	-17	-11	-8	-4	3,063	-15	-8				
17	11	13	6	1	2,733	**13**	9	18	5	3	10
-13	-23	-11	-4	-10	4,083	-14	-2				
-4	7	10	**18**	7	3,806	-2	**10**				
-25	-18	-10	-12	**1**	4,081	-22	-11				

Crops	Cropping systems	Centre (season)	Ecosystem	Mean yield as per IOF method (Kg/ha)
Maize	Maize – cotton – green manure	Coimbatore (Kha)	Semi-arid	5,628
	Beetroot – maize – green manure	Coimbatore (Rabi)	Semi-arid	4,971
	Maize – chickpea	Dharwad (Kha)	Arid	6,028
	Rice – maize	Karjat (Rabi)	Coastal	15,704
	Maize (popcorn) – potato – ladyfinger – sesbania green manure	Modipuram (Kha)*	Semi-arid	5,542
	Maize (sweet corn) – mustard – sesbania green manure		Semi-arid	8,083
	Soybean – maize	Raipur (Kha)	Sub-humid	12,192
	Maize + black – gram – durum wheat – sesbania green manure	Udaipur (Kha)	Semi-arid	1,728
	Maize + black gram – chickpea		Semi-arid	2,520
	Maize + ginger – French bean	Gangtok~ (Kha)	Sub-humid	-
	Maize + soybean – buckwheat			
	Maize + turmeric – rajma			
	Maize – pigeon pea			
Total Crops – 5	Total unique cropping systems – 42	Centres – 14	Ecosystems – 5	
Number of recorded results				
Crop yields with higher respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent cases)				
Crop yield where values are significantly higher (> 20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher yields (in per cent cases)				
Range of difference in mean with inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)				

Note: (-) represents data not available; * At these centres the mean value of the particular common crop under analysis was taken into account; ~ In Gangtok, inorganic methods are not practised so comparison is not carried out; @ Value of only SR method is given so value of INO is value of SR; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic method or approach, and values in red cells indicate lesser than inorganic method or approach

Overall, in 24 of the 45 times, organic approach recorded highest yields in five years, followed by 14 times with integrated and seven times with inorganic approach.

In three of the four centres, organic approach showed higher mean yields than inorganic and slightly lower in the fourth centre. Within the organic approach, yields were higher or slightly lower with both methods (OF and OIN) in all the centres.

With integrated approach, yields were higher than inorganic in all the centres. Within the integrated approach, yields were higher with both the integrated (IN75 and IN50) methods and slightly lower only once in all the centres. With inorganic (SR) method yields were slightly better only in one centre.

Long-term trends revealed that by and large yields of rice in Ranchi were highest throughout the years with organic approach. In Umiam and Narendrapur, yields were by and large highest throughout with integrated

Mean yield difference compared to IOF method (%)					Mean yield as per INO approach (Kg/ha)	Mean yield difference compared to INO approach (%)		No. of times highest yields were recorded			
OF	OIN	IN75	IN50	SR		ORG	INT	Total	ORG	INT	INO
-9	4	**11**	3	7	5,812	-5	**4**	43	12	20	11
-6	-2	**17**	3	8	5,163	-7	**6**				
-12	-23	-26	-5	**5**	6,170	-19	-18				
-10	-9	-8	-3	-14	14,639	-3	**1**				
-9	-8	-1	0.1	**6**	5,715	-11	-3				
-9	-9	-4	-2	-3	7,946	-7	-1				
7	**10**	-13	-14	6	12,553	**5**	-16				
-18	-11	-6	**9**	-16	1,590	-7	**10**				
-13	-22	-27	-5	-4	2,464	-16	-14				
-	-	-	-	-	1,423	**88**	59				
28	28	27	28	27		49	49	182	63	58	61
36	39	48	57	56		22	37				
10	18	8	6	0		27	17				
-25 – 40	-26 – 30	-27 – 35	-14 – 31	-27 – 14		-22 – 88	-18 – 59				

approach (largely IN50 method). In Karjat yields were highest in integrated (IN50) method in the later years.

Wheat: Wheat was cultivated with basmati rice, cluster bean, summer moong, soybean, basmati rice, rice, and black gram as a rabi crop in Ludhiana and Udaipur under the semi-arid ecosystems, in Ranchi under the sub-humid ecosystem, and in Pantnagar under the humid ecosystem.

In 16 out of the 24 times, inorganic approach recorded highest yields in five years followed by eight times under the integrated approach.

In all four centres, organic approach showed lower mean yields than inorganic, but in three of these centres the yields were slightly lower. Within the organic approach, yields were lower with both methods (OF and OIN) in all the centres.

With integrated approach yields were higher than inorganic in three of the four centres and in the fourth the yields were slightly lower. Within the integrated approach, yields were higher with both the integrated (IN75 and IN50) methods in two centres and slightly lower in the rest. With inorganic (SR) methods yields were mostly lower than inorganic.

Long-term trends revealed that by and large yields of wheat in Pantnagar were highest throughout with integrated approach (IN75 and IN50 method). In Ludhiana, yields were highest with integrated approach on most occasions when cultivated with moong and soybean. In Udaipur and Ranchi, yields were never highest with organic approach.

Durum wheat: Durum wheat was cultivated with soybean, basmati rice, maize and black gram as a rabi crop in Bhopal, Modipuram and Udaipur under the semi-arid ecosystems and in Jabalpur under the sub-humid ecosystem.

Out of the total 18 times, organic approach recorded highest yields on five occasions followed by three times under integrated approach. With inorganic approach yields were highest on 10 occasions.

Only in one centre did organic approach show higher mean yields than inorganic. Within organic approach, yields with OF method were higher in Bhopal and under the OIN method yields were higher in Bhopal and Modipuram.

With the integrated approach, yields were higher in two out of the four centres and slightly lower in one. Within integrated approach, yields under both the integrated methods (IN75 and IN50) were higher in two centres. Within inorganic, yields were only slightly better with SR method than IOF method in three of the four centres.

Long-term trends revealed that by and large yields of durum wheat in Bhopal were highest in the later years. In Modipuram, yields were by and large highest mostly with integrated (IN50) method. In Udaipur and Jabalpur, yields were never highest with organic approach.

Maize: Maize was cultivated with cotton, beetroot, chickpea, rice, potato, ladyfinger, mustard, soybean, black gram, durum wheat, ginger, French bean, buckwheat, turmeric, rajmah, and pigeon pea in both the kharif and rabi seasons in Coimbatore and only during kharif season in Modipuram and Udaipur under the semi-arid ecosystems, in Dharwad under the arid ecosystem, in Raipur and Gangtok under the sub-humid ecosystems, and in Karjat under the coastal ecosystem. As Sikkim is an organic state, comparison with inorganic approach is not carried out for Gangtok.

In 12 of the 43 times, organic approach recorded the highest yields in 5 years, followed by 20 times under integrated and 11 times under inorganic.

In one of the six centres, organic approach showed higher mean yields than inorganic, and in the rest, the yields were lower than inorganic. Within the organic approach, yields with both the methods (OF and OIN) were higher only in one centre.

Under integrated approaches, yields were higher than inorganic in three of the six centres and lower in the rest. Within the integrated approach, yields were higher with both methods (IN75 and IN50) only in one centre. With integrated (IN50) method, yields were also higher on two other occasions. With the inorganic (SR) method, yields were comparatively higher in three centres.

Long-term trends revealed that yields of maize in Gangtok were highest throughout the years with organic approach (OF method). With OIN method, in Dharwad, Udaipur (when cultivated with black gram and chickpea), and in Modipuram (when cultivated with potato and ladyfinger), yields were highest in the initial years, and in Raipur in the later years. In Coimbatore, Modipuram (when cultivated with mustard) and Udaipur (when cultivated with black gram and wheat), yields were by and large highest throughout with integrated approach (either IN75 or IN50 method). In Karjat, yields were never highest with organic approach.

Chapter 2: Review of scientific studies

There are 32 scientific studies and results on organic and natural farming on yields of crops by different stakeholders in different settings and geographies. These studies were published or presented during 2010–20.

2.1 Higher yield with organic farming and natural farming

A field experiment was carried out at Dry Farming Research Station, Targhadia, Gujarat for six years (2001–06) to observe the response of legume crops to enriched compost and vermicompost under rain-fed conditions.The results, published in 2010, highlighted that there is no significant difference in grain yield of legume crops due to application of various nutrients, but the fodder yield of green gram and black gram was significantly influenced by different treatments.[5]

A decade long research on organic farming of tropical tuber crops was taken up at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, during 2004–2015. Six separate field experiments were conducted on Elephant foot yam (EFY), yams and taro, to compare organic management over conventional system. The results indicate that organic farming resulted in 10–20 per cent higher yield in EFY, white yam, greater yam, lesser yam and dwarf white yam, i.e., 20, 9, 11, 7 and 9 per cent, respectively. In taro, a slight reduction in the crop yield was noticed under organic farming (5 per cent), this was because taro leaf blight could not be controlled by organic measures.[6]

A field experiment on onion, conducted at Indian Institute of Horticultural Research farm, Hesaraghatta, Bengaluru during 2005–08 and published in 2012, highlighted that the treatment which received 100 per cent recommended nitrogen (Recommended Dose of Nitrogen-RDN) equivalent through organics, produced highest yield of 21.1 tonnes/hectare.[7]

A different field experiment carried out at the Crop Research Farm Department of Agronomy, Allahabad School of Agriculture, Allahabad, Uttar Pradesh during 2014, and published in 2017, on the performance of pearl millet crops through the use of plant growth promoting rhizobacteria revealed that combinations of diazotrophic bacteria Pseudomonas fluorescens, Azotobacter chroococcum, Azospirillum lipoferum and Acetobacter diazotrophicus along with Trichoderma viride significantly increased crop growth and yield of pearl millet crop.[8]

Another field experiment conducted at Research Institute on Organic Farming, University of Agricultural Sciences, Bengaluru during 2015 on the growth and yield of cowpeas in red sandy loam soil, reveals that a combined application of the liquid formulation of Jeevamrutha and Panchagavya increased grain yield by 59 per cent over control along with improvements in yield attributes like number of pods per plant, length of pods, pod weight, number of seeds per pod, seed weight per plant and 100-seed weight.[9]

In the case of broccoli cultivation, an experiment conducted at Regional Agricultural Research Station, Rajouri and Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu, during 2009–10 and 2010–11, and published in 2017, revealed that a combination of 50 per cent nitrogen with farmyard manure and seedling dip with Azospirillum recorded significantly higher yields.[10]

Another study conducted in Suwana village, near Krishi Vigyan Kendra, Bhilwara and Maharana Pratap University of Agriculture & Technology in Udaipur, published in 2017, on the yield and quality of onion, revealed that a combined use of 100 per cent recycling-derived fertilizers (RDF) through vermicompost, phosphate solubilizing bacteria and Azotobactor significantly increased the bulb yield and quality of the onions.[11]

An experimental study conducted in Tamil Nadu, at Agricultural College and Research Institute, Madurai during 2006–07 and published in 2017 found that the joint application of Albizia lebbeck in the form of green leaf manure and Annona squamosa in the form of seed soaking along with foliar sprays recorded the highest performance of growth parameters, yield and quality characters of ladyfinger.[12]

A study carried out by Department of Organic Agriculture, College of Agriculture, Palampur, Himachal Pradesh and published in 2018, for maize, gram, wheat and mash in different cropping patterns with 12 different treatment combinations revealed that organic farming practices deliver significantly higher yields with maize–wheat cropping systems, which are at par with integrated farming practices and superior to inorganic methods.[13]

Another experiment conducted over a period of 60 days in 2017, and published in 2019 by the Department of Food and Nutrition and Research Centre, Smt. VHD Central Institute of Home Science, Bangalore University, found that the yield of spinach with proper dose of Fish-Protein Hydrolysate (FPH) liquid in soil, can increase by 40 per cent.[14]

With regard to organic seeds production in ladyfinger, in the mid hills of north-western Himalayas, a study conducted at the Research Farm of Regional Agricultural Research Station, Rajouri, in Jammu during 2016 and 2017, published in 2019, revealed that significantly higher seed yield was recorded in treatment combination of half dose farmyard manure along with a quarter dose each of vermicompost and poultry manure. The same study also states that organic manure has performed significantly better in combination treatments as compared to single organic manure treatment (FYM, poultry manure or vermicompost).[15]

An experiment on black gram conducted in the mid hills of Meghalaya during 2018–19 in the experimental farm of College of Agriculture, Kyrdemkulai revealed that organic amendments in a combination of poultry manure along with seed priming with poultry manure liquid wash and application of mulch gave significantly higher yields in comparison to other treatment combinations such as farmyard manure, pig manure, poultry manure, and maize stover mulch.[16]

In the case of onion, an experimental study at Tamil Nadu Agricultural University, Coimbatore during 2018–19 highlighted that application of humic acid and foliar spray of banana pseudostem resulted in the highest yield among other treatments such as Panchagavya, nitrogen, potassium, phosphorus, and farmyard manure.[17]

A review study on banana, presented at the 5th Jammu & Kashmir Agriculture Science Congress in 2019, highlighted that the use of biofertilizer, particularly inoculation with Azotobacter, could substitute 50 per cent nitrogen requirement of banana and produce higher yield over full doses of nitrogen application. The study also mentioned that these bioinoculants not only affect the fruit yield but also improve the fruit quality.[18]

A review study, published in 2020, on organic liquid manures and biofertilizers has revealed that organic liquid manures have the potential to improve yield and growth in crops.[19]

A five-year study (2012–16) conducted at the research complex of ICAR, Sikkim, and published in 2020, on baby corn cultivation revealed that with the joint application of farmyard manure and vermicompost there is an increase in yield and quality of organic baby corn in broad bed and furrow (BBF) land configuration with intense rainfall.[20]

In Karnataka, organic farming practices carried out on potatoes and tomatoes by Avishkar, a civil society organization, revealed that the use of Jeevamrutha doubled the size of potatoes.[21] While in the case of tomatoes, there was 75 per cent reduction in the use of chemical fertilizers and an increase in yield by 20 per cent and improvement in quality and size in potatoes.

A study conducted by Development Research Communication and Services Centre in West Bengal on the effects of intercropping and organic fertilizers highlighted that crop yield increased with intercropping and use of organic fertilizers.[22]

Natural farming

Research was carried out from 2012 to 2015 through questionnaires administered on 97 farmers, four focus groups ranging from 10 to 40 farmers, and 31 in-depth semi-structured interviews with farmers, ZBNF leaders and KRRS leaders in seven districts of Karnataka. It was found that 78.7 per cent farmers reported increase in yield, 12.8 per cent farmers shared there was no reduction in yield and only 8.5 per cent farmers said there was reduction in yield.[23]

A field survey was carried out by the ICAR-National Academy of Agricultural Research Management, Hyderabad in three states of Andhra Pradesh, Karnataka and Maharashtra from February to May 2019. The survey highlighted that almost all farmers who adopted Zero Budget Natural Farming (ZBNF) and natural farming methods use Jeevamritha and Beejamritha. The study concluded that crop yield with natural farming is higher only in case of finger millet in Karnataka and paddy in Andhra Pradesh. However, when supplemented with even a small quantity of farmyard manure and Ghanajeevamritha, yield of all crops (sugarcane, finger millet, soybean, jowar, cotton and turmeric) improved significantly.[24]

Evidence presented by T. Vijaykumar in the National Food Conclave in 2019 highlighted that increase in yields were also recorded for major crops cultivated during the wet season under ZBNF in Andhra Pradesh. Under irrigated conditions, paddy recorded an increase of 14 per cent, while maize and sugarcane recorded an increase of 21 per cent and 51 per cent respectively over non-ZBNF methods. Under rain-fed conditions, crops like groundnut recorded an increase of 34 per cent, while cotton and ragi recorded an increase by 10 per cent and 34 per cent respectively over non-ZBNF methods.[25]

In the case of ZBNF conducted in Andhra Pradesh, a review published in 2020 reported an increase in yields among all crops across all the districts but one, which could be due to the soil becoming anaerobic due to water logging.[26] In a different review paper published in 2020 in Kerala, it was found that farmers who have adopted ZBNF have seen increased yields.[27]

Another study carried out by Centre for Study of Science Technology and Policy (CSTEP) in 2020 mentioned that the difference in yields in chilli and paddy under ZBNF and non-ZBNF was negligible; while in other crops like groundnut, cotton and maize, non-ZBNF appears to exhibit higher yields.[28]

A case study published in 2020 by the Centre for Science and Environment reported that among farmers practising ZBNF in Andhra Pradesh, 57 per cent reported an increase in yield. For another 35 per cent, the yield remained same, while 8 per cent of farmers reported decreased yields as compared to chemical farming. ZBNF yield of many farmers decreased in the first year as compared to chemical-based farming but it either became equal or increased after three to four years. The case study also pointed out that under certain crops like rice, black gram, green gram and pulses, where the multi-cropping system was not followed along with other methods of natural farming, yields did not increase even after many years of practice.[29]

2.2 Transition time to attain comparable or higher yields with organic farming

In the case of basmati rice cultivation, a study was conducted in Haryana during the wet seasons of 2009 and 2010 in farms to see the effects of organic farming on productivity and quality. The study concluded that the mean grain yield of rice was slightly lower in organic fields as compared to conventional fields. However, grain yields were found to be stabilized in organic cultivation, probably due to the cultivation of organic rice in the same fields over the last nine years.[30] Another field experiment with rice conducted over five years from 2005 to 2010 at Directorate of Rice Research, Andhra Pradesh, revealed that during the initial two years inorganic methods yielded better results during the wet seasons; but later yields with organic methods improved. During the dry seasons, inorganic methods performed better than organic methods, but once the soil fertility was built up sufficiently, organic system also produced yields equal to conventional systems.[31]

Experiments were conducted at the Central Arid Zone Research Institute (CAZRI), Jodhpur with leguminous and non-leguminous crop rotation on crops like cluster bean and sesame during rainy seasons and cumin and psyllium during winters from 2008 to 2010. As 2009 was a drought year, the results varied and could not fit into a trend. The study concluded that surface application of manure with applicator and incorporation in soil also improves yield in comparison to traditional methods of application. Moreover, crop rotations also helped increase yields. Legumes contributed 25–30 per cent higher yield in the subsequent crop. Findings also confirmed that yields during the initial 2–3 years might be low, but once the system is developed, the yields were comparable to conventional farming and sometimes even better.[32]

A long-term study with seven organic treatments was conducted in Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University, Palampur from 2006–07 to 2012–13 on maize and soybean in wet seasons and wheat and gram during the dry seasons. After the end of seven years of study, optimum increase in yields for maize were observed with treatment combination of himcompost (HC) + vermicompost (VC) and for wheat with single application of VC. With other treatment combinations (FYM+VC, FYM+HC), there was a decrease in yield for wheat except for control.[33]

A study was carried out at Organic Farming Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar from 2004–14, on the effects of long-term use of organic, inorganic and integrated management practices on carbon sequestration and soil carbon pools in different cropping systems. The study revealed that during 2013–14, the equivalent yield of various cropping systems with organic management was 10.46 per cent higher in comparison to inorganic management practices.[34]

A long-term field experiment was conducted for comparing the soil and crop productivity under organic farming with that of inorganic and integrated farming (INF) practices in Meghalaya from 2005–12. Results from the experiment published in 2016 demonstrated that average rice productivity was highest under organic and INF, followed by inorganic management practices. Potato tuber yield was significantly higher under INF in the first year. During the seventh year, yield recorded under organic and INF were statistically similar. Average tuber yield under INF and organic were 260 per cent and 237 per cent higher than that under control. Average tomato yield under organic was 25.6 per cent higher than inorganic and 82.9 per cent higher than that under control. In the case of French beans, average green pod yield for seven years was significantly higher under INF by 10, 16 and 262 per cent compared to organic, inorganic and control, respectively. The carrot root yield under INF and organic were 46.5 per cent and 42.3 per cent higher than that recorded under inorganic. Therefore, the experiment concluded that the productivity of crops under INF was much better than inorganic but remained statistically similar to organic farming.[35]

A review study published in 2020 on pigeon pea concluded that during the initial years of organic farming, its yield was less, but nearly 20 per cent improvement in yield was observed in organic pigeon pea over inorganically grown pigeon pea in a span of 4–5 years. Hence, pigeon pea being a low input and drought resistant leguminous crop fits well under organic farming.[36]

SECTION II:
EVIDENCE ON COST, INCOME AND LIVELIHOOD

Summary – Benefits of organic and natural farming on cost of cultivation, income and livelihood

Cost of cultivation

Out of the 63 cropping systems, cost of cultivation was highest in 63 per cent with organic approach in 15 centres, 8 per cent with integrated in three centres and 29 per cent with inorganic approach in eight centres.

Compared with inorganic approach, mean cost of cultivation with organic approach was higher in 81 per cent cropping systems. Within these it was significantly higher (>20 per cent) in 67 per cent cropping systems. It was higher by up to 72 per cent (from Rs 57,395/ha) in a particular cropping system. Similarly, mean cost of cultivation with integrated approach was higher than inorganic in 45 cropping systems (71 per cent). Within these it was significantly higher in 36 per cent cropping systems. It was higher by up to 51 per cent (from Rs 1,23,431/ha) in a particular cropping system.

The cost of cultivation was lowest in 5 per cent of the cropping systems with organic approach and 24 per cent with integrated approach. Compared with inorganic approach, mean cost of cultivation with organic approach was lower in 19 per cent cropping systems and was up to -24 per cent (from Rs 1,39,133/ha). With integrated, it was lower in 29 per cent cropping systems and was up to -26 per cent (from Rs 89,296/ha).

Gross returns

Out of the 61 cropping systems, gross returns were highest in 49 per cent with organic approach in 13 centres, 15 per cent with integrated in five centres and 36 per cent with inorganic approach in four centres.

Compared with inorganic approach, mean gross returns with organic approach were higher in 74 per cent cropping systems. Within these, they were significantly higher in 82 per cent cropping systems. They were higher by up to 97 per cent (from Rs 2,76,350/ha) in a particular cropping system. Similarly, mean gross returns with integrated approach were higher than inorganic in 67 per cent cropping systems. Within these, they were significantly higher in 20 per cent cropping system. They were higher by up to 125 per cent (from Rs 2,76,350/ha) in a particular cropping system

Net returns

Out of the 61 cropping systems, net returns were highest in 64 per cent with organic approach in 12 centres, 11 per cent with integrated in four centres, and 25 per cent with inorganic approach in five centres.

Compared with inorganic approach, mean net returns with organic approach were higher in 67 per cent cropping systems. Within these, they were significantly higher in 88 per cent cropping systems. They were higher by up to 370 per cent (from Rs 45,942/ha) in a particular cropping system. Similarly, mean net returns with integrated approach were higher than inorganic in 56 per cent cropping systems. Within these, they were significantly higher in 12 per cent cropping systems. They were higher by up to 395 per cent (from Rs 67,843/ha) in a particular cropping system.

Despite high cost of cultivation in 51 cropping systems, net returns were highest in 63 per cent cropping systems with organic approach in 11 centres. Overall, they were higher than inorganic in 67 per cent cropping systems. Within these, mean net returns were significantly higher in 88 per cent cropping systems.

With integrated, the cost of cultivation was higher than inorganic in 45 cropping systems. It was highest in 11 per cent cropping systems in three centres. Overall, it was higher than inorganic in 56 per cent cropping systems. Within these, mean net returns were significantly higher in 16 per cent cropping systems.

Benefit-cost ratio

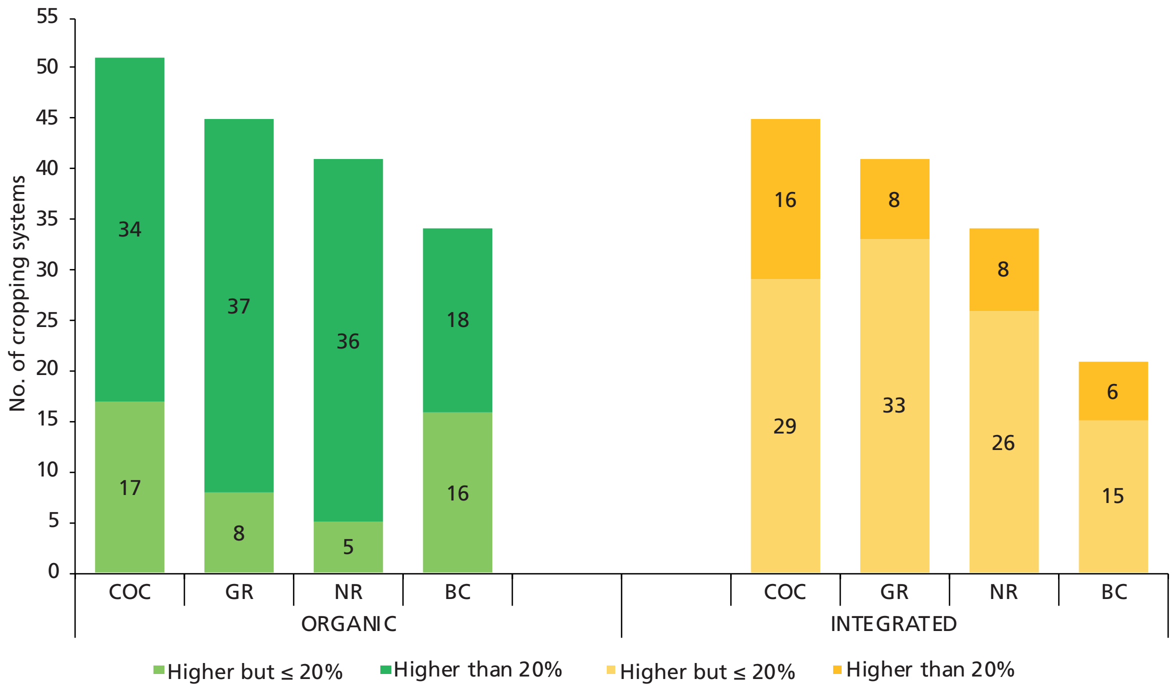
Out of the 61 cropping systems, benefit-cost ratio was highest in 21 per cent with organic approach in nine centres, 13 per cent with integrated in seven centres and 66 per cent with inorganic approach in eight centres.

Compared with inorganic approach, mean benefit-cost ratio with organic approach was higher in 56 per cent cropping systems. Within these it was significantly higher in 53 per cent cropping systems. It was higher by up to 171 per cent (from 2.5) in a particular cropping system. Similarly, mean benefit-cost ratio with integrated approach was higher than inorganic in 34 per cent cropping systems. Within these it was significantly higher in 29 per cent cropping systems. It was higher by up to 69 per cent (from 2.4) in a particular cropping system.

Despite high cost of cultivation in 51 cropping systems, benefit-cost ratio was highest in 47 per cent cropping systems with organic approach in nine centres. Overall, it was higher than inorganic in 53 per cent cropping systems. Within these, mean net returns were significantly higher in 44 per cent cropping systems.

With integrated, when the cost of cultivation was higher than inorganic in 45 cropping systems, it was highest in nine per cent cropping systems in three centres. Overall, it was higher than inorganic in 27 per cent cropping systems. Within these, mean net returns were significantly higher in 25 per cent cropping systems.

Graph 2: Comparison of mean cost of cultivation, gross returns, net returns and benefit-cost ratio of organic and integrated approach with inorganic approach



Evidence from 42 scientific studies and results on organic and natural farming, published during 2010–20, were analysed on cost, profitability and sustained livelihood indicators by different stakeholders in different settings and geographies.

The studies reveal that the cost of inputs required for organic and natural farming is comparatively less as these are locally and naturally available. Sustained lower cost of cultivation, eco-friendly and cheaper biofertilizers, and less variable costs make organic farming a low-cost alternative to chemical-based farming. The major cost in inputs comes in the form of manual labour and production of vermicompost. Marginal farmers are more likely to achieve sustained livelihood through organic and natural farming due to low cost of cultivation and labour requirements, intercropping, and comparatively good market rates for their organic produce.

In the case of natural farming, yields may not always be high for all crops, but the benefit-cost ratio is several times (13.6) higher than chemical-based farming. Along with minimized cost of production and premium prices for the produce, the income and profit under natural farming are higher than conventional farming. On an average, even without certification, produce from natural farming fetches twice the income of conventional produces. Organic and natural farming have the potential to provide year-long sustained food production for consumption and sales.

Practice of multi-cropping, crop rotation and crop diversification guarantee increased income, sustained livelihood, empowerment of women farmers and independence of small and marginal farmers from moneylenders.

Chapter 3: Comparison of different approaches as per AI-NPOF

Recorded results were analysed for 63 cropping systems in cost of cultivation and 61 cropping systems in gross returns, net returns, and benefit-cost ratio across 17 centres in all five ecosystems during 2014–19. Comparison of mean values for cost of cultivation, gross returns, net returns and benefit-cost ratio was carried out for organic and integrated approaches in relation to inorganic approach. The same comparison was also done for six methods in relation to inorganic method (see *Annexure 2—Table 2: Comparison of cost of cultivation, gross returns, net returns and benefit-cost ratio with different methods*). For long-term trends, centre-wise mean of net returns recorded during 2004–19 were analysed (see Ann*exure 1— Figure 2: Graphs showing centre wise long-term trends for net returns [2004– 19]*).

3.1 Cost of cultivation

Organic approach

The cost of cultivation was highest in 63 per cent cropping systems with organic approach in 15 centres. Compared with inorganic approach, mean cost of cultivation with organic approach was higher in 81 per cent cropping systems. Within these, it was significantly higher (>20 per cent) in 67 per cent cropping systems. It was higher by up to 72 per cent (from Rs 57,395/ha) in a particular cropping system (see *Table 6: Comparison of mean values of cost of cultivation, gross returns, net returns and benefit-cost ratio with different approaches [2014–19]*).

The cost of cultivation was lowest in five per cent with organic approach. Compared with inorganic approach, mean cost of cultivation was lower in 19 per cent cropping systems. It was lower by up to -24 per cent (from Rs 1,39,133/ha) in a particular cropping system.

Both organic methods (OF and OIN) had lower mean cost of cultivation in lesser number of cropping systems than other methods. Between the two, OIN method was slightly better.

Cropping systems with lower mean cost of cultivation were part of eight centres. In none of the centres was it lower in all cropping systems. In Bajaura, Calicut, Coimbatore, Dharwad, Jabalpur, Ludhiana, Raipur and Sardarkrushinagar, it was lower in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, chillies and onion among vegetables; sunflower and soybean among oilseeds; pigeon pea, green gram and cowpea among pulses; turmeric and cumin among spices; and basmati rice and wheat among cereals.

It is evident that cost of cultivation is higher with organic approach in more cropping systems. It is also clear that integrated approach is less costly than organic approach. This is because the on-farm organic inputs used in the AI-NPOF project centres are largely purchased. The 2017 organic farming crop production guide as part of AI-NPOF project reports that the cost of cultivation with organic inputs increases by about 13 per cent.[37]

Integrated approach

The cost of cultivation was highest in 8 per cent cropping systems with integrated approach in three centres. Compared with inorganic approach, mean cost of cultivation with integrated approach was higher in 71 per cent cropping systems. Within these, mean cost of cultivation was significantly higher (>20 per cent) in 36 per cent cropping systems. It was higher by up to 51 per cent (from Rs 1,23,431/ha) in a particular cropping system.

The cost of cultivation was lowest in 24 per cent with integrated approach. Compared with inorganic approach, mean cost of cultivation was lower in 29 per cent cropping systems. It was lower by up to -26 per cent (from Rs 89,296/ha) in a particular cropping system.

Both integrated methods (IN75 and IN50) had lower mean cost of cultivation in a higher number of cropping systems than inorganic, but about the same number as organic. Between the two, IN50 method was slightly better.

Cropping systems with lower mean cost of cultivation were part of nine centres. In none of the centres was it lower in all cropping systems. In Bajaura, Calicut, Coimbatore, Dharwad, Jabalpur, Ludhiana, Raipur, Sardarkrushinagar and Udaipur it was lower in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, chillies and onion among vegetables; sunflower, groundnut and soybean among oilseeds; pigeon pea, green gram, cowpea, cluster bean and summer moong among pulses; turmeric, fenugreek and cumin among spices; and basmati rice, durum wheat and wheat among cereals.

3.2 Gross returns

Organic approach

The gross returns were highest in 49 per cent cropping systems with organic approach at 13 centres. Compared with inorganic approach, mean gross returns with organic approach were higher in 74 per cent cropping systems. Within these, mean gross returns were significantly higher in 82 per cent cropping systems. They were higher by up to 97 per cent (from Rs 2,76,350/ha) in a particular cropping system.

Both organic methods (OF and OIN) had higher mean gross returns in a higher number of cropping systems than other methods. Between the two, OF method was slightly better.

Cropping systems with higher mean gross returns were part of 15 centres. In 12 centres it was higher in all cropping systems. These centres are Bajaura, Calicut, Jabalpur, Karjat, Ludhiana, Modipuram, Pantnagar, Raipur, Ranchi, Umiam, Narendrapur and Thiruvananthapuram. In Coimbatore, Dharwad and Sardarkrushinagar, it was higher in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, carrot, broccoli, capsicum, brinjal, potato, chillies, summer squash, cassava, taro, and onion among vegetables; groundnut, linseed, sesame, mustard, sunflower and soybean among oilseeds; lentils, black gram, field bean, cluster bean, pigeon pea, green gram, chickpea and cowpea among pulses; ginger, turmeric and cumin among spices; and maize, barley, sorghum, basmati rice, rice and wheat among cereals.

Integrated approach

The gross returns with integrated approach were highest in 15 per cent cropping systems in five centres. Compared with inorganic approach, mean gross returns with integrated approach were higher in 67 per cent cropping systems. Within these, mean gross returns were significantly higher in 20 per cent cropping systems. They were higher by up to 125 per cent (from Rs 2,76,350/ha) in a particular cropping system.

Both integrated methods (IN75 and IN50) had higher mean gross returns in more number of cropping systems than inorganic but lesser than organic. Between the two, IN50 method was slightly better.

Cropping systems with higher mean gross returns were part of 14 centres. In nine centres they were higher in all cropping systems. These centres were Bajaura, Calicut, Coimbatore, Ludhiana, Modipuram, Pantnagar, Ranchi, Umiam, and Narendrapur. In Dharwad, Jabalpur, Karjat, Ajmer and Thiruvananthapuram they were higher in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, carrot, summer squash, broccoli, taro, ladyfinger, vegetable pea, beetroot, brinjal, chillies, potato and onion among vegetables; sunflower, mustard, linseed, groundnut and soybean among oilseeds; chickpea, lentils, pigeon pea, green gram, black gram, cowpea, cluster bean and summer moong among pulses; ginger, turmeric, fenugreek, coriander and cumin among spices; and maize, barley, rice, basmati rice, durum wheat and wheat among cereals.

3.3 Net returns

Organic approach

The net returns were highest in 64 per cent cropping systems with organic approach in 12 centres. Compared with inorganic approach, mean net returns with organic approach were higher in 67 per cent cropping systems. Within these, mean net returns were significantly higher in 88 per cent cropping systems. They were higher by up to 370 per cent (from Rs 45,942/ha) in a particular cropping system.

Both organic methods (OF and OIN) had higher mean net returns in a higher number of cropping systems than others. Between the two, OF method was slightly better.

Cropping systems with higher mean net returns were part of 12 centres. In 11 centres, they were higher in all cropping systems. These centres are Bajaura, Calicut, Karjat, Ludhiana, Modipuram, Pantnagar, Raipur, Ranchi, Umiam, Narendrapur and Thiruvananthapuram. In Jabalpur they were higher in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, carrot, broccoli, capsicum, brinjal, potato, chillies, summer squash and onion among vegetables; cassava, taro, sesame, mustard, linseed and soybean among oilseeds; lentils, black gram, field bean, cluster bean, green gram, chickpea, summer moong and cowpea among pulses; ginger, turmeric and coriander among spices; and maize, barley, basmati rice, rice, durum wheat and wheat among cereals.

Integrated approach

The net returns with integrated approach were highest in 11 per cent cropping systems in four centres. Compared with inorganic approach, mean net returns with integrated approach were higher in 56 per cent cropping systems. Within these, mean net returns were significantly higher in 12 per cent cropping systems. They were higher by up to 395 per cent (from Rs 67,843/ha) in a particular cropping system.

Both integrated methods (IN75 and IN50) had higher mean net returns in lesser number of cropping systems than organic approach, but more than inorganic approach. Between the two, IN50 method was slightly better.

Cropping systems with higher mean net returns were part of 13 centres. In seven centres they were higher in all cropping systems. These centres were Bajaura, Calicut, Coimbatore, Ludhiana, Modipuram, Pantnagar and Umiam. In Jabalpur, Karjat, Ranchi, Ajmer, Narendrapur and Thiruvananthapuram they were higher in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, broccoli, carrot, summer squash, beetroot, chillies, potato and onion among vegetables; sunflower, sesame, linseed, and soybean among oilseeds; black gram, chickpea, green gram, cowpea, cluster bean and summer moong among pulses; ginger, turmeric, and coriander among spices; and maize, barley, basmati rice, rice, durum wheat and wheat among cereals.

When recorded mean values of net returns for all cropping systems within a centre were analysed through graphs to see the trend for years between 2004 and 2019, it was found that by and large net returns with organic approach (largely OF method) were highest throughout in centres at Bajaura, Modipuram, Ludhiana, Pantnagar, Raipur and Ranchi (see *Annexure 1—Figure 2: Graphs showing centre wise long-term trends for net returns*). In the case of centres at Dharwad, Jabalpur and Sardarkrushinagar, they were highest except in the last few years of recorded data. In the case of centres at Umiam and Karjat they were highest in the last few years. They were never highest at Udaipur and Ajmer.

In a centre at Calicut, net returns were highest with organic (OF) and integrated (either IN50 or IN75) in the earlier years and with integrated (IN50) in the later years. In Coimbatore, they were highest with inorganic, integrated and organic approaches in alternate years and with integrated (either IN50 or IN75) in the later years.

Net returns and high cost of cultivation

Out of the 51 (81 per cent) cropping systems in which cost of cultivation was higher with organic than inorganic, net returns were highest in 32 cropping systems (63 per cent) in 11 centres. Overall, they were higher in 34 cropping systems (67 per cent). Within these, mean net returns were significantly higher (>20 per cent) in 30 cropping systems (88 per cent). They were higher by up to 269 per cent (from Rs 67,843/ha) in a particular cropping system.

In case of integrated, out of the 45 (71 per cent) cropping systems in which the cost of cultivation was higher than inorganic, net returns were highest in five cropping systems (11 per cent) in three centres. Overall, they were higher in 25 cropping systems (56 per cent). Within these, mean net returns were significantly higher in four cropping systems (16 per cent). They were higher by up to 395 per cent (from Rs 67,843/ha) in a particular cropping system.

3.4 Benefit-cost ratio

Organic approach

The benefit-cost ratio with organic approach was highest in 21 per cent cropping systems in nine centres. Compared with inorganic approach, mean benefit-cost ratio with organic approach was higher in 56 per cent cropping systems. Within these, mean benefit-cost ratio was significantly higher in 53 per cent cropping systems. It was higher by up to 171 per cent (from 2.5) in a particular cropping system.

Both organic methods (OF and OIN) had higher mean benefit-cost ratio in more number of cropping systems than others. Between the two, OIN method was slightly better.

Cropping systems with higher benefit-cost ratios were part of 10 centres. In four centres, the ratio was higher in all cropping systems. These centres were Bajaura, Pantnagar, Raipur, and Narendrapur. In Jabalpur, Modipuram and Ranchi it was higher in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, carrot, broccoli, capsicum, potato, chillies, summer squash and onion among vegetables; cassava, taro, sesame, mustard, linseed and soybean among oilseeds; lentils, black gram, field bean, cluster bean, green gram, chickpea, summer moong and cowpea among pulses; ginger, turmeric and coriander among spices; and maize, barley, basmati rice, rice, durum wheat and wheat among cereals.

Integrated approach

The benefit-cost ratio with integrated approach was highest in 13 per cent cropping systems in seven centres. Compared with inorganic approach, mean benefit-cost ratio with integrated approach was higher in 34 per cent cropping systems. Within these, mean benefit-cost ratio was significantly higher in 29 per cent cropping systems. It was higher by up to 69 per cent (from 2.4) in a particular cropping system.

Both integrated methods (IN75 and IN50) had higher mean benefit-cost ratio in lesser number of cropping systems than organic but more than inorganic. Between the two, IN50 method was slightly better.

Cropping systems with higher benefit-cost ratios were part of nine centres. In four centres it was higher in all cropping systems. These centres were Bajaura, Calicut, Ludhiana, and Modipuram. In Jabalpur, Ranchi, Umiam, Sardarkrushinagar and Thiruvananthapuram it was higher in one or more cropping systems. Crops grown as part of these cropping systems were tomato, cauliflower, French bean, ladyfinger, vegetable pea, broccoli, carrot, summer squash, taro, and potato among vegetables; linseed, mustard and soybean among oilseeds; black gram, chickpea, green gram, cowpea, cluster bean and summer moong among pulses; ginger, turmeric, and cumin among spices; and maize, barley, basmati rice, rice, durum wheat and wheat among cereals.

Benefit-cost ratio and high cost of cultivation

Out of the 51 (81 per cent) cropping systems in which cost of cultivation was higher with organic than inorganic, benefit-cost ratio was highest in 23 cropping systems (47 per cent) in nine centres. Overall, it was higher in 27 cropping systems (53 per cent). Within these, mean net returns were significantly higher (>20 per cent) in 12 cropping systems (44 per cent). It was higher by up to 50 per cent (from 2.4) in a particular cropping system.

In case of integrated approach, out of the 45 (71 per cent) cropping systems in which the cost of cultivation was higher than inorganic, benefit-cost ratio was highest in four cropping systems (nine per cent) in four centres. Overall, it was higher in 12 cropping systems (27 per cent). Within these, it was significantly higher in three cropping systems (25 per cent). It was higher by up to 69 per cent (from 2.4) in a particular cropping system.

Table 6: Comparison of mean values of cost of cultivation, gross returns, net returns and benefit-cost rati

Cropping systems	Centre	Ecosystem	CoC - mean INO (Rs/ha)
Tomato – cauliflower – French Bean	Bajaura	Humid	3,03,366
Fallow – cauliflower – tomato			2,05,864
Black gram – cauliflower – summer squash			2,62,573
Lady finger – pea			1,85,477
Ginger	Calicut	Coastal	1,32,254
Turmeric			2,05,864
Maize – cotton – green manure	Coimbatore	Semi-arid	67,507
Chillies – sunflower – green manure			2,05,864
Beetroot – maize – green manure			91,054
Cowpea/green gram – safflower	Dharwad	Arid	33,381
Pigeon pea (Sole)			2,05,864
Green gram – sorghum			31,819
Groundnut + hybrid cotton			40,636
Maize – chickpea			28,395
Basmati rice – durum wheat – green manure	Jabalpur	Sub-humid	77,038
Basmati rice – chickpea – maize fodder			76,137
Basmati rice – berseem (seed and fodder)			89,296*
Basmati rice – vegetable pea – sorghum (fodder)			96,186*
Rice – brinjal	Karjat	Coastal	2,29,212
Rice – chickpea			95,410
Rice – field bean			1,05,508
Rice – onion (White)			1,53,582
Basmati rice – chickpea – green manure	Ludhiana	Semi-arid	75,982
Basmati rice – wheat – green manure			2,05,864
Cluster bean – wheat – summer moong			60,948
Soybean – wheat			52,489
Basmati rice – durum wheat – sesbania green manure	Modipuram	Semi-arid	62,044
Rice – barley (malt) – green gram			80,406
Maize (popcorn) – potato – ladyfinger – sesbania green manure			1,62,058
Maize – mustard – sesbania green manure			56,242
Basmati rice – wheat	Pantnagar	Humid	58,006
Basmati rice – chickpea + coriander			54,055
Basmati rice – vegetable pea + coriander			61,637
Basmati rice – potato			81,581
Soybean – maize	Raipur	Sub-humid	69,074
Soybean – pea			56,034
Soybean – chilli			62,566
Soybean – onion			62,038

io with different approaches (2014–19)

CoC - mean difference from INO		GR - mean INO (Rs/ha)	GR - mean difference from INO		NR - mean INO (Rs/ha)	NR - mean difference from INO		BC ratio - mean INO	BC ratio - mean difference from INO	
ORG (%)	INT (%)		ORG (%)	INT (%)		ORG (%)	INT (%)		ORG (%)	INT (%)
-3	-6	3,49,308	46	32	45,942	370	286	1.1	51	41
-2	-7	2,73,737	69	37	67,873	283	171	1.3	71	47
2	3	4,22,121	34	29	1,59,548	88	72	1.6	32	25
-8	-5	2,50,772	28	28	65,294	131	121	1.3	40	35
26	18	3,20,927	87	97	1,13,204	130	113	2.4	50	69
-2	-7	4,67,897	24	25	3,30,522	25	16	3.4	4	14
35	19	1,56,502	-4	9	88,995	-33	2	2.3	-29	-8
-2	-7	1,15,557	1	11	61,715	-19	14	2.3	-20	-4
20	12	2,93,166	-1	8	2,02,111	-11	7	3.3	-19	-5
42	31	45,459	-7	-3	12,078	-145	-99	1.5	-17	-12
-2	-7	74,471	-4	1	53,456	-21	-11	3.6	-27	-20
47	36	79,346	9	-0.1	47,527	-16	-24	2.6	-18	-19
45	22	1,30,688	-5	-9	90,052	-28	-23	3.2	-30	-23
68	37	92,490	-2	-12	64,095	-33	-33	3.2	-33	-28
17	-2	1,63,566	9	3	86,529	2	6	2.3	-10	1
12	1	1,39,960	2	-2	63,822	-9	-5	1.9	-8	-4
-15	-26	2,05,610	1	-7	1,16,314	13	8	3.0	-5	3
-15	-23	1,98,687	2	-4	1,02,501	19	14	2.5	5	7
34	25	7,77,568	25	6	5,48,356	21	-3	3.4	-7	-15
28	21	1,58,903	28	10	63,493	28	-6	1.7	-0.00001	-9
21	14	1,80,428	17	-4	74,920	13	-29	1.7	-3	-16
41	30	4,79,209	32	15	3,25,627	27	8	3.1	-7	-11
10	2	1,27,214	24	3	51,232	45	4	1.7	14	1
-2	-7	1,64,261	32	15	97,841	55	26	2.5	171	14
14	-5	1,64,295	27	4	1,03,347	34	10	2.8	15	12
19	-3	1,54,947	18	0.3	1,02,457	17	2	3.0	1	4
41	17	1,31,262	54	24	69,218	65	30	2.2	7	2
26	1	1,28,255	35	4	47,849	51	10	1.6	7	4
18	2	3,85,651	41	5	2,23,593	58	7	2.4	19	2
35	4	1,55,830	28	4	99,588	24	4	2.9	-7	2
11	19	1,67,116	33	9	1,09,110	44	4	2.9	20	-8
3	16	2,27,497	38	8	1,73,442	50	6	4.2	37	-7
0.3	11	2,03,846	34	9	1,42,208	49	8	3.3	35	-2
3	16	1,51,618	52	18	70,037	109	20	2.0	44	-3
3	2	2,67,510	21	-12	1,98,436	27	-17	3.9	20	-11
0.01	-0.5	2,00,244	23	-6	1,44,211	31	-8	3.7	27	-1
-1	-2	2,34,112	20	-9	1,71,546	28	-11	3.8	25	-6
-3	-3	2,67,433	11	-12	2,05,395	16	-15	4.5	20	-6

Cropping systems	Centre	Ecosystem	CoC - mean INO (Rs/ha)
Rice – wheat	Ranchi	Sub-humid	49,174
Rice – lentil			45,888
Rice – potato			66,237
Rice – linseed			35,472
Broccoli – carrot	Umiam	Humid	1,65,096
Broccoli – potato			2,01,961
Broccoli – French bean			1,49,895
Broccoli – tomato			1,78,197
Green gram – fennel	Ajmer	Arid	42,249
Green gram – coriander			41,048
Cluster bean – fennel			42,462
Cluster bean – coriander			41,261
Basmati rice – broccoli – sesbania green manure	Narendrapur	Humid	1,68,282
Paddy – mustard – green gram			1,13,734
Paddy – capsicum – green gram			1,45,514
Paddy – French bean – sesame			2,09,262
Groundnut – wheat – green gram	Sardarkrushinagar	Arid	1,19,234
Green gram – cumin – vegetable cowpea			1,39,133
Green gram – fennel			75,826
Cassava – veg. cowpea	Thiruvananthapuram	Coastal	1,23,431
Cassava – groundnut			-
Taro – black gram			2,08,507
Taro – green gram			-
Maize + black gram – durum wheat – sesbania green manure	Udaipur	Semi-arid	57,395
Sweet corn + black gram – chickpea			48,754
Black gram – wheat (Triticum aestivum)			62,420
Soybean – fenugreek			42,736
Number of recorded results			
Cropping systems with higher respective values among approaches (in per cent)			
Cropping systems where value is significantly higher (>20 per cent) than inorganic approach, calculated out of overall higher (in per cent)			
Range of difference in mean with inorganic approach (in per cent)			

Note: (-) represents data not available; Bold numbers reflect highest values among approaches; Values in green cells indicate higher than inorganic approach, and values in red cells indicate lesser than inorganic approach, except in case of COC where it is opposite

CoC - mean difference from INO		GR - mean INO (Rs/ha)	GR - mean difference from INO		NR - mean INO (Rs/ha)	NR - mean difference from INO		BC ratio - mean INO	BC ratio - mean difference from INO	
ORG (%)	INT (%)		ORG (%)	INT (%)		ORG (%)	INT (%)		ORG (%)	INT (%)
35	17	99,618	37	5	40,355	39	-6	2.1	-0.1	-11
23	14	64,624	44	9	14,989	96	-4	1.5	20	-2
22	10	1,55,892	67	11	71,724	100	11	3.3	21	-10
27	13	60,859	58	15	20,310	102	18	1.7	24	2
26	9	4,02,598	26	12	2,37,502	27	14	2.4	1	3
20	10	3,52,374	27	11	1,50,413	35	14	1.7	6	2
27	13	3,92,622	33	9	2,42,728	37	6	2.6	6	-3
22	10	4,18,355	33	11	2,40,158	41	12	2.3	9	1
49	32	2,20,787	-23	-10	1,74,749	-35	-17	1.6	-38	-21
33	21	1,16,106	-22	11	70,068	-53	8	0.8	-37	-4
57	38	2,16,838	-12	-1	1,70,162	-28	-10	1.6	-41	-26
42	27	1,09,721	-22	14	21,015	-74	1	0.8	-47	-14
25	13	4,04,967	22	3	2,36,684	19	-3	2.2	2	-7
31	14	1,98,824	42	9	85,090	56	1	1.8	12	-4
29	15	2,78,401	38	5	1,32,887	47	-7	1.9	7	-9
29	15	4,63,710	37	8	2,54,448	44	2	2.4	4	-9
6	-0.2	2,33,848	2	-6	1,14,614	-2	-11	2.0	-6	-8
-24	-15	2,69,940	-22	-9	78,484	-19	-3	2.2	-6	2
10	2	1,04,389	-2	-9	32,303	-14	-20	1.5	-9	-14
33	51	4,37,022	34	-4	3,13,591	34	-26	3.6	1	-37
-	-	-	-	-	-	-	-	-	-	-
41	38	2,76,350	97	125	67,843	269	395	1.3	39	63
-	-	-	-	-	-	-	-	-	-	-
72	47	2,48,506	-22	-6	1,91,111	-50	-22	4.4	-55	-37
42	25	2,14,168	-24	-22	1,65,414	-43	-35	4.4	-47	-37
38	23	1,83,838	-19	-8	1,21,417	-49	-23	3.1	-44	-27
6	-3	84,179	-19	-10	41,443	-46	-17	2.0	-20	-1
63	63		61	61		61	61		61	61
81	71		74	67		67	56		56	34
67	36		82	20		88	12		53	29
-24 – 72	-26 – 51		-24 – 97	-22 – 125		-145 – 370	-99 – 395		-55 – 171	-37 – 69

Chapter 4: Review of scientific studies

There are 42 scientific studies and results on organic and natural farming which have been analysed for cost of cultivation and input cost; price, income and returns; and sustainable livelihood and rural employment. These have done by different stakeholders in different settings and geographies. These studies were published or presented during 2010–20.

4.1 Cost of cultivation with organic and natural farming

An experiment conducted at the Directorate of Rice Research Farm, Hyderabad for five years (2004–05 to 2009–10) highlighted that natural resources used in organic farming are easily and locally available.[38] Experiments were conducted in the Central Arid Zone Research Institute (CAZRI) on leguminous and non-leguminous crops like cluster bean and sesame during rainy seasons and cumin and psyllium during winters from 2008 to 2010. The experiments highlighted that inputs costs are reduced using local resources once the organic system is fully developed. The major costs borne are the labour costs for seeding, weeding, spraying, harvesting, etc.[39] In experimental studies, comparing organic to inorganic farming such as in the case of wheat cultivation, the variable cost per acre was less in organic farming as mentioned in a study done on primary data from 85 organic growers and 75 inorganic growers spread over 30 villages in the districts of Patiala and Faridkot for the period 2008–09 in Punjab.[40]

A review article published in 2013 revealed that organic farming is a low-cost alternative to conventional chemical-based agriculture or inorganic farming. One of the reasons is that the need for inputs and prerequisites is less in organic farming as compared to chemical farming.[41] Another field experiment during kharif 2014, conducted at the Crop Research Farm Department of Agronomy, Allahabad School of Agriculture, found that bio-fertilizers used in organic farming are cheaper.[42] Another study conducted with 60 farmers from Haridwar, Uttarakhand, published in 2015, found that the cost of cultivation of organic wheat and organic paddy per bigha (1 bigha = 0.63 hectare) was less in comparison to conventional farming.[43]

In a project on comparative cost-benefit analysis of organic and conventional farming, carried out by Directorate of Economics and Statistics, Uttarakhand in two blocks of Haridwar in 2017, it was found that the total variable cost on a per hectare basis for the cultivation of organic paddy, wheat and sugarcane was less as compared to inorganic cultivation.[44] An interview-based study of 50 organic producers from Mysore district, Karnataka, published during 2017, highlighted that the cost of cultivation in organic farming in multiple crops was found to be less compared to the secondary data on modern farming systems which involve use of chemicals like pesticides.[45]

Another experiment carried out on on rice and cotton for comparative analysis between organic and conventional farming in Jangaon district of Telangana in the year 2019–20 highlighted that the cost of cultivation was higher under conventional farming than organic farming. Even though the yields were higher under conventional farming, the gross returns in organic cultivation were higher due to the premium price it fetches from the market.[46]

A publication from 2020 claims that the production cost in organic farming decreases by 25–30 per cent as it enters the third and fourth year of cultivation.[47]

Natural farming

Under natural farming, similar results were observed. A study was undertaken in the Northern Dry Zone of Karnataka during the year 2018–19 to compare the economics between Zero Budget Natural Farming (ZBNF) and conventional farming by the University of Agricultural Sciences, Dharwad. The study revealed that the cost of cultivation under ZBNF was lower compared to the conventional farming system because the cost of external inputs under ZBNF was significantly lower due to recycling of farm resources. The average yield realized under the ZBNF system was slightly lower than the conventional farming system in all the crops except foxtail millet.[48]

A survey by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) conducted in 13 districts of Andhra Pradesh with 97 farmers on ZBNF in 2019 revealed that the cost of cultivation is less in ZBNF and loss incurred due to low yields can be compensated by the low cost and with premium prices the produce fetches in the market.[49]

An impact assessment of ZBNF carried out by the Centre for Economic and Social Studies in 2019 in 13 districts of Andhra Pradesh reported that, due to considerable reduction in the paid cost incurred for the production of crops, the net income per hectare accrued to farmers from different crops is substantially higher under ZBNF than under non-ZBNF.[50]

Report from a dipstick survey of 100 farmers carried out across 13 districts of five states by A.T.E Chandra Foundation and PRAXIS on natural farming during 2019 highlighted that 82 per cent farmers reported reduction in input costs and 40 per cent of all the small and marginal farmers reported savings of up to Rs 10,000 per annum.[51]

A review on ZBNF from 2020 observed that farmers can save on cost of seeds, fertilizers, and plant protection chemicals to reduce the cost of production. It also mentions that every dollar (USD) invested results in direct benefits equalling $13. Some of the other direct benefits of natural farming are—lower costs of borrowing, income gain from intercropping, and a slightly higher selling price.[52]

A study conducted from 2010 to 2020 at Chandra Shekhar Azad University of Agriculture & Technology, Kanpur with 35 farmers in seven districts, on ZBNF, revealed that that the average net returns are significantly higher under natural farming, due to low cost of cultivation and high selling prices of the produce. The study also pointed out that, even without certification, the farmers were able to sell their produce at 1.5 to 2 times the average cost.[53]

4.2 Price, income and livelihood with organic and natural farming

A field experiment was conducted during 2006–08 at Veer Chandra Singh Garhwali College of Horticulture, Govind Ballabh Pant University of Agriculture and Technology, Pauri Garhwal, Uttarakhand, to check the effects of different organic manures in comparison to inorganic inputs on growth, yield and quality attributes of capsicum and garden pea. It's results, which were published in 2011, highlighted that application of organic manures like poultry manure along with biofertilizers can also achieve the yield target and get good returns under better management practices. Organic manures are locally available, eco-friendly and helpful in sustaining soil health.[54]

A review published during 2013 on climate change, which also focused on farmers' income in India, suggested that organic farmers were also able to increase their income due to higher sales prices.[55]

In a project on comparative cost-benefit analysis of organic and conventional farming, carried out by Directorate of Economics and Statistics, Uttarakhand in two blocks of Haridwar in 2017, it was found that the net returns over variable cost were higher for organic than inorganic paddy, wheat and sugarcane. The lower crop yield in basmati paddy, wheat and sugarcane in the initial years which later was at par, was well compensated by the higher price it fetched in the market.[56] The same study found that the average benefit-cost ratio indicates that organic farming is profitable. It showed that the farmers are getting 1.36, 1.58 and 1.67 times over one rupee investment in the case of organic cultivation of rice, wheat and sugarcane respectively.

A comparative cost and profit analysis of organic and non-organic farming practices in the Himalayan region was carried out in 2018 at Palampur, Himachal Pradesh for maize, gram, wheat and mash in different cropping patterns with 12 different treatment combinations. The study found that despite higher cost of cultivation in organic farming due to high labour cost and production of vermicompost, gross returns and net returns were significantly higher under organic farming practice due to higher yields of pulse crops under organic treatment and their higher prices per kilogram over cereal crops. It also mentioned that the benefit-cost ratio of organic and inorganic were at par with each other, but in the long run organic management will be more profitable.[57]

A study on basmati rice cultivation in Haryana, conducted during the wet seasons of 2009 and 2010, concluded that farmers' income increased after adopting organic farming. It found that net returns in this case were 50 per cent more than under inorganic farming.[58] Similar observations were made in the case of onion cultivation in Rajasthan during a study conducted at a farmer's field in 2017 in Suwana village near Krishi Vigyan Kendra, Bhilwara, Maharana Pratap University of Agriculture & Technology, Udaipur.[59] In the case of turmeric and cotton in Tamil Nadu, organic farmers earned 45.4 per cent higher net income than conventional farmers. This was mentioned in an analysis on organic farming conducted in Erode district of Tamil Nadu and published in 2012.[60] A study from Andhra Pradesh published in 2013 concluded that organic farmers earned 37 per cent higher net profits in paddy, 33 per cent in red gram and 59 per cent in groundnut, even without organic certification, due to lower cost of cultivation.[61]

A study conducted in Udupi, Karnataka, published in 2020, on major crops like paddy, areca nut, coconut and vegetables, found that 80 per cent of farmers earned good income through organic farming due to good market rates for their produce.[62] The same study also mentions that 61 per cent of farmers achieved good returns within one year of adopting organic farming. Moreover, organic produce fetches a premium price of 20–30 per cent more than conventional foods.[63] Further a review-based study on pigeon pea published in 2020 also suggested that the market rates offered for organically produced pigeon pea are double those of inorganically produced pigeon pea.[64]

In a comparative study on different farming systems in Gadag, Karnataka, published in 2013, it was found that the net returns realized by farmers were maximum in organic farming system as compared to other farming systems in the study area. The practice of multi-cropping, crop rotation and crop diversification with horticulture crops not only guarantees increased income, but also generates employment.[65]

Another case study conducted to understand the impact of organic farming on sustainable livelihood of marginal farmers in Shimoga district of Karnataka, published in 2014, observed that organic farming can contribute to sustainable livelihoods of marginal farmers. The results of the study indicated that a small farmer owning one to two acres of land could live self-sufficiently.[66]

Another study conducted with 60 farmers from Haridwar, Uttarakhand, published in 2015, showed that with the increased income levels from organic produce, farmers are more likely to achieve sustainable and secure livelihood.[67]

An interview-based study of 50 organic producers from Mysore district, Karnataka, published during 2017, on rural labour involved in organic farming, found that it can make the labour force less dependent on moneylenders.[68]

In 2018, a study conducted on 1632 families associated with the Timbaktu Collective in Andhra Pradesh, found that organic farming not only provided better economic returns and empowerment of the women but also provided enhanced livelihood support to the landless farmers. It also found that 61.1 per cent of the households under the study recorded an increase in income after they shifted to organic farming, with 78.6 per cent farmers actively participating in thrift and savings. Moreover, farmers' dependency on moneylenders decreased by 73.8 per cent.[69]

A 2019 publication, 'An Economic Analysis of Organic Farming in Shivamogga Taluk' highlighted that, after conversion to organic farming, there was an increase in the yield of crops. This, along with reduced cost of cultivation, helped the farmers with increased income and sustainability. Also, due to better input use efficiency and reduced risks of crop failures, the farmers' self-reliance and livelihood are ensured.[70]

A review study 'Organic farming in India: Concept, Applications and Perspectives' published in 2020, observes that, while organic farming might not be profitable and cost-effective in the initial years, it provides opportunities for rural employment because it is labour intensive.[71]

Natural farming

A study published in 2018 by ICAR-Agricultural Technology Application Research Institute, Ludhiana highlighted that cereal crops like rice, wheat and barley are not economically advantageous for the farmer. However, vegetables, pulses (except mung beans), sugarcane, cotton, mustard and linseed crops have economic advantage in natural farming over conventional farming.[72]

A discussion paper by MANAGE-Centre for Agricultural Extension Innovations, Reforms, and Agripreneurship (CAEIRA) published in 2020 also highlighted that the farmers should adopt ZBNF to minimize input cost and enhance productivity.[73]

In a survey conducted under ZBNF Andhra Pradesh on 600 farmers, and published in 2020, significantly lower input costs per acre were found when compared to their non-ZBNF peers. Crop diversification was noticed with 12 per cent farmers opting for vegetable and fruits being grown in kharif in ZBNF leading to a higher and more regular income for the farmers.[74]

A field survey by ICAR-National Academy of Agricultural Research Management, Hyderabad, Telangana in three states of Andhra Pradesh, Karnataka and Maharashtra from February to May 2019 mentions that natural farming may not be yield enhancing for most crops but it surely increases farmers' income through low input costs and premium prices for the produce.[75]

A survey-based study with 97 farmers on ZBNF in Andhra Pradesh published in 2019 shows that 85.7 per cent of surveyed farmers reported increase in income and 90.9 per cent reported lower cost of production.[76]

Similar results were also highlighted in the case of some major crops cultivated under ZBNF in Andhra Pradesh during the wet season of 2018. Data presented in 2019 at a National Food Conclave in Delhi by the AP-ZBNF team highlighted that there was a significant increase in the net incomes of farmers under ZBNF over non-ZBNF cultivation. Moreover, the benefit to cost ratio under ZBNF was also calculated at 13.6 times.[77]

A case study by CSE on Andhra Pradesh's Climate-Resilient Zero-Budget Natural Farming (CRZBNF), published in a 2020 report *State of Organic and Natural Farming in India: Challenges and Possibilities*, conducted in 10 districts of Andhra Pradesh with 182 ZBNF farmers through Focus Group Discussions (FGD) and in-depth interviews, found reduction in farming expenses.[78] The case study stated that farmers growing different crops in different districts attributed the decrease in input costs largely to the non-usage of chemical inputs and usage of local organic inputs. It also cited that due to the reduced input cost in natural farming, farmers were able to grow two crops in a year rather than the one crop that they previously grew with uncertain irrigation in chemical-based farming. Fifty per cent of the farmers' interviewed were able to get 2–200 per cent higher prices. Around 70 per cent of farmers from Guntur district received higher prices for their ZBNF produce while another 16 per cent of the farmers received premium prices in Kadapa. It also highlighted another important benefit of ZBNF which was the continuous flow of income throughout the year. The longer duration of yield of some vegetable crops further contributed to the increase in net incomes.

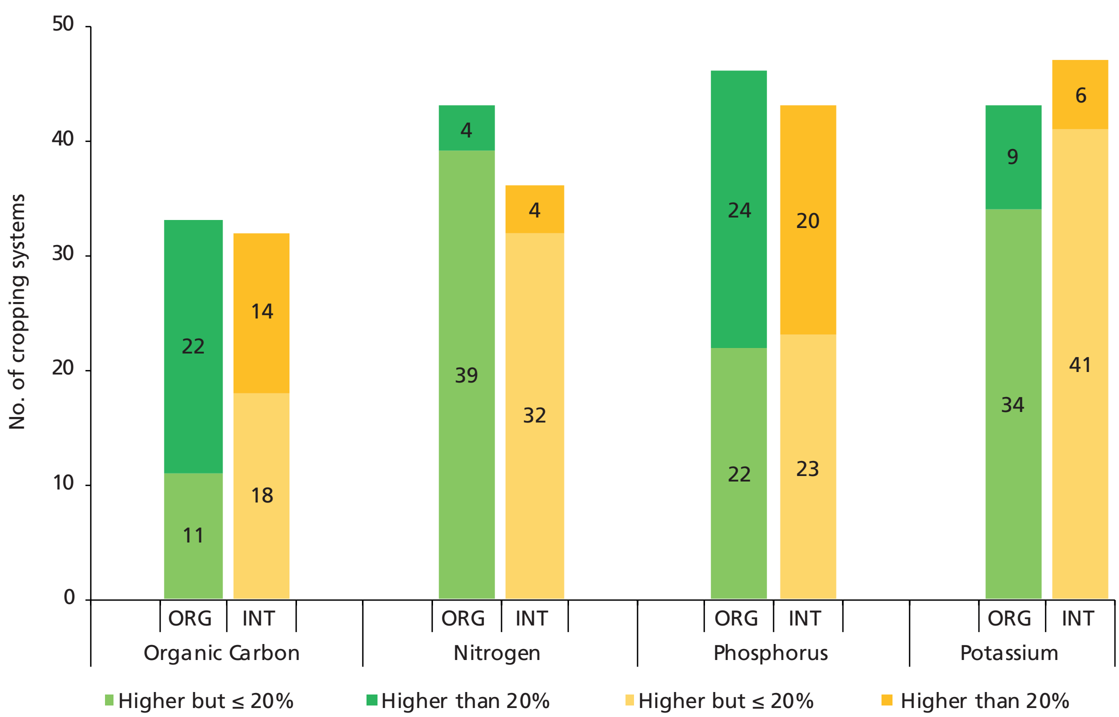
SECTION III: EVIDENCE ON SOIL HEALTH AND ENVIRONMENT

Summary – Benefits of organic and natural farming on soil health and environment

Among all the approaches (organic, integrated and inorganic) in 34 cropping systems at nine centres, mean organic carbon is highest in 91 per cent cropping systems with organic approach at all centres. In the remaining nine per cent, it is highest with integrated approach. Compared with inorganic approach, mean organic carbon with organic approach is higher in 97 per cent cropping systems. Within these, it is significantly higher (>20 per cent) in 67 per cent cropping systems. It is higher by up to 242 per cent (from 0.69 per cent) in a particular cropping system.

Similarly, mean organic carbon with integrated approach is higher than inorganic in 94 per cent cropping systems. Within these, it is significantly higher in 44 per cent cropping systems. It is higher by up to 195 per cent (from 0.69 per cent) in a particular cropping system.

Graph 3: Comparison of mean organic carbon, available nitrogen, phosphorus and potassium of organic and integrated approaches with inorganic approach



Out of 58 cropping systems at 15 centres, mean available nitrogen is highest in 57 per cent cropping systems with organic approach at 12 centres. It is highest in 21 per cent with integrated and in 22 per cent with inorganic approach. Compared with inorganic approach, mean available nitrogen with organic approach is higher in 74 per cent cropping systems. Within these, it is significantly higher in 12 per cent cropping systems. It is higher by up to 40 per cent (from 205 kg/ha) in a particular cropping system. Similarly, mean available nitrogen with integrated approach is higher than inorganic in 62 per cent cropping systems. Within these it is significantly higher in 11 per cent cropping systems. It is higher by up to 39 per cent (from 273 kg/ha) in a particular cropping system.

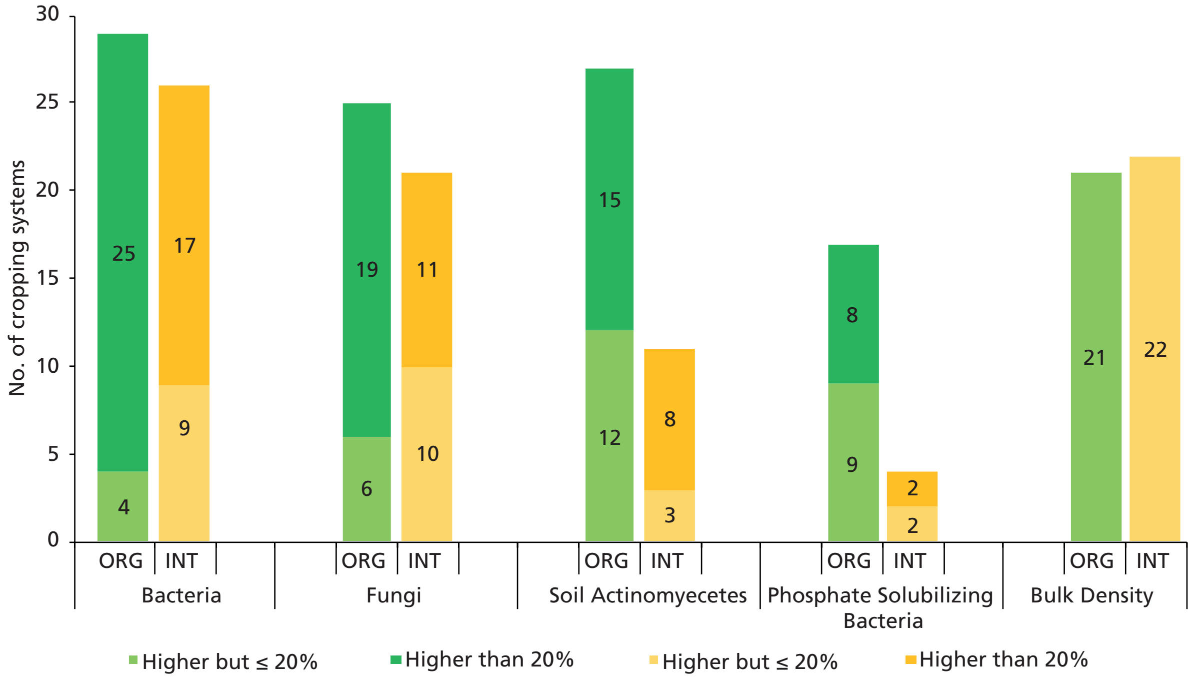
Out of 62 cropping systems at 16 centres, mean available phosphorus is highest in 58 per cent cropping systems at 13 centres with organic approach. It is highest in 23 per cent with integrated and in 19 per cent with inorganic approach. Compared with inorganic approach, mean available phosphorus with organic approach is higher in 74 per cent cropping systems. Within these, it is significantly higher in 52 per cent cropping systems. It is higher by up to 243 per cent (from 3.3 kg/ha) in a particular cropping system. Similarly, mean available phosphorus with integrated approach is higher than inorganic in 69 per cent cropping systems. Within these, it is significantly higher in 47 per cent cropping systems. It is higher by up to 232 per cent (from 19.7 kg/ha) in a particular cropping system.

Out of 59 cropping systems at 16 centres, mean available potassium is highest in 53 per cent cropping systems at 12 centres with organic approach. It is highest in 28 per cent with integrated and in 19 per cent with inorganic approach. Compared with inorganic approach, mean available potassium with organic approach is higher in 69 per cent cropping systems. Within these, it is significantly higher in 21 per cent cropping systems. It is higher by up to 96 per cent (from 125.8 kg/ha) in a particular cropping system. Similarly, mean available potassium with integrated approach is higher than inorganic in 76 per cent cropping systems. Within these, it is significantly higher in 13 per cent cropping systems. It is higher by up to 101 per cent (from 127 kg/ha) in a particular cropping system.

In the case of available nitrogen, phosphorus and potassium collectively, mean values of all three macronutrients with organic approach are higher than inorganic approach in 26 cropping systems (42 per cent) at 10 centres. These centres are Bajaura, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram, Umiam, Ajmer and Sardarkrushinagar.

Out of 28 cropping systems at seven centres, mean bulk density is lowest in 52 per cent cropping systems with organic approach at two centres. In 34 per cent cropping systems, it is lowest with integrated and in 14 per cent with inorganic approach. In remaining one cropping system, the mean available bulk density is same with both organic and integrated approaches. Compared with inorganic approach, mean bulk density with organic approach is lower in 75 per cent cropping systems. It is lower by up to -9.3 per cent (from 1.41 g/cc) in a particular cropping system. Similarly, mean bulk density with

Graph 4: Comparison of mean rhizosphere microbial population and bulk density of organic and integrated approaches with inorganic approach



integrated approach is lower than inorganic in 79 per cent cropping systems. It is lower by up to -8.6 per cent (from 1.16 g/cc) in a particular cropping system.

Out of 32 cropping systems at eight centres, mean bacteria is highest in 84 per cent cropping systems with organic approach at all centres. In 13 per cent, it is highest with integrated and in 3 per cent with inorganic approach. Compared with inorganic approach, mean bacteria with organic approach is higher in 91 per cent cropping systems. Within these it is significantly higher in 86 per cent cropping systems. It is higher by up to 274 per cent (from 6.8 $x10^6$ cfu/g) in a particular cropping system. Similarly, mean bacteria with integrated approach is higher than inorganic in 81 per cent cropping systems. Within these it is significantly higher in 65 per cent cropping systems. It is higher by up to 192 per cent (from 11 $x10^6$ cfu/g) in a particular cropping system.

Out of 32 cropping systems at eight centres, mean fungi in soil are highest in 72 per cent cropping systems with organic approach at seven centres. In 12 per cent, they are highest with integrated and in 16 per cent with inorganic approach. Compared with inorganic approach, mean fungi with organic approach are higher in 78 per cent cropping systems. Within these they are significantly higher in 76 per cent cropping systems. They are higher by up to 173 per cent (from 7.5 $x10^6$ cfu/g) in a particular cropping system. Similarly, mean fungi with integrated approach are higher than inorganic in 66 per cent cropping systems. Within these, they are significantly higher in 52 per cent cropping systems. They are higher by up to 56 per cent (from 9.0 $x10^6$ cfu/g) in a particular cropping system.

Out of 32 cropping systems, mean soil actinomycetes are highest in 69 per cent cropping systems with organic approach at all centres. In 25 per cent, they are highest with integrated and in 6 per cent with inorganic approach. Compared with inorganic approach, mean soil actinomycetes with organic approach are higher in 84 per cent cropping systems. Within these they are significantly higher in 56 per cent cropping systems. They are higher by up to 101 per cent (from 1.7 $x10^6$ cfu/g) in a particular cropping system. Similarly, mean soil actinomycetes with integrated approach are higher than inorganic in 34 per cent cropping systems. Within these they are significantly higher in 73 per cent cropping systems. They are higher by up to 238 per cent (from 10.5 $x10^6$ cfu/g) in a particular cropping system.

Out of 21 cropping systems mean phosphate solubilizing bacteria (PSB) in soil are highest in 76 per cent cropping systems with organic approach at all centres. In 10 per cent, they are highest with integrated and in 14 per cent with inorganic approach. Compared with inorganic approach, mean PSB with organic approach are higher in 81 per cent cropping systems. Within these they are significantly higher in 47 per cent cropping systems. They are higher by up to 307 per cent (from 1.4 $x10^6$ cfu/g) in a particular cropping system. Similarly, mean PSB with integrated approach are higher than inorganic in 19 per cent cropping systems. Within these they are significantly higher in 50 per cent cropping systems. They are higher by up to 1,496 per cent (from 1.4 $x10^6$ cfu/g) in a particular cropping system.

In the case of bacteria, fungi, soil actinomycetes and PSB collectively, mean values of rhizosphere microbial population with organic approach are higher than inorganic approach in 21 cropping systems (about 66 per cent) at eight centres. These centres are Bajaura, Bhopal, Coimbatore, Dharwad, Jabalpur, Karjat, Ludhiana and Narendrapur. Along with PSB, they are higher in 12 cropping systems (data for PSB is not available for the other centres).

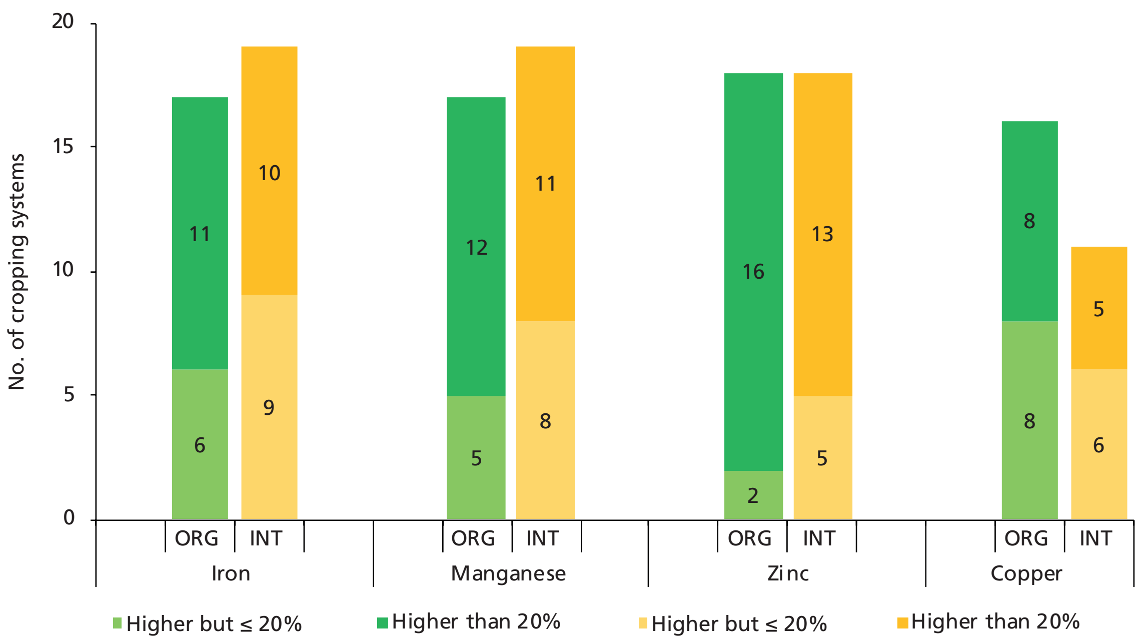
Out of 19 cropping systems at five centres, available iron is highest in 74 per cent cropping systems with organic approach at all centres. It is highest in 21 per cent with integrated approach. In remaining one cropping system (5 per cent) the available iron is same with both organic and integrated approaches. Compared with inorganic approach, available iron with organic approach is higher in 90 per cent cropping systems. Within these, it is significantly higher in 65 per cent cropping systems. It is higher by up to 87 per cent (from 40.7 ppm) in a particular cropping system. Similarly, available iron with integrated approach is higher than inorganic in all cropping systems. Within these, it is significantly higher in 53 per cent cropping systems. It is higher by up to 65 per cent (from 9.5 ppm) in a particular cropping system.

Out of 19 cropping systems at five centres, available manganese is highest in 63 per cent cropping systems with organic approach at all centres. In the remaining 37 per cent, it is highest with integrated approach. Compared with inorganic approach, available manganese with organic approach is higher in 90 per cent cropping systems. Within these, it is significantly higher in 71 per cent cropping systems. It is higher by up to 58 per cent (from 9.9 ppm) in a particular cropping system. Similarly, available manganese with integrated approach is higher than inorganic in all cropping systems. Within these, it is significantly higher in 58 per cent cropping systems. It is higher by up to 58 per cent (from 6.7 ppm) in a particular cropping system.

Out of 18 cropping systems at five centres, available zinc is highest in 89 per cent cropping systems with organic approach at all centres. In the remaining 11 per cent, it is highest with integrated approach. Compared with inorganic approach, available zinc with organic approach is higher in all cropping systems. Within these, it is significantly higher in 89 per cent cropping systems. It is higher by up to 341.2 per cent (from 0.6 ppm) in a particular cropping system. Similarly, available zinc with integrated approach is higher than inorganic in all cropping systems. Within these, it is significantly higher in 72 per cent cropping systems. It is higher by up to 250 per cent (from 0.6 ppm) in a particular cropping system.

Out of 18 cropping systems at five centres, available copper is highest in 78 per cent cropping systems with organic approach at all centres. In the remaining 22 per cent, it is highest with integrated approach. Compared with inorganic approach, available copper with organic approach is higher in 89 per cent cropping systems. Within these, it is significantly higher in 50 per cent cropping systems. It is higher by up to 133 per cent (from 1.2 ppm) in a particular cropping system. Similarly, available copper with integrated approach is higher than inorganic in 61 per cent cropping systems. Within these, it is significantly higher in 46 per cent cropping systems. It is higher by up to 66 per cent (from 1.0 ppm) in a particular cropping system.

Graph 5: Comparison of available iron, manganese, zinc and copper of organic and integrated approaches with inorganic approach



In the case of available iron, manganese, zinc and copper collectively, values of all three macronutrients with organic approach are higher than inorganic approach in 16 cropping systems (84 per cent) at five centres. These centres are Bajaura, Calicut, Dharwad, Pantnagar and Sardarkrushinagar.

In addition to the AI-NPOF, evidence has been reviewed and collated from 33 Indian scientific studies and results on soil health and environment with organic and natural farming published or presented during 2010–20. These studies which are conducted by different stakeholders in different settings and geographies add to the overall evidence in favour of organic farming and natural farming.

The studies revealed that organic and natural farming improves overall soil health, reduces soil degradation and promotes agro-biodiversity, adding sustainability to the agro-ecological approach of farming. Organic inputs and practices result in the growth of active organic matter and organisms in the soil. Organic fertilization increases the total carbon, nitrogen and ammonium concentration, and improves soil fertility. Organic manures such as farmyard manure (FYM) alone or in different combination with vermicompost and biofertilizers along with organic practices improved the soil structure, enhanced soil fertility and improved soil organic carbon. They showed positive impact on soil bulk density over a period of three years. The findings also indicate that due to the application of organic manures, there is a higher soil moisture content, increased water holding capacity, enhanced porosity and higher availability of major soil nutrients—nitrogen, phosphorus and potassium—in the soil. Organic manures also improve plant and animal biodiversity. Organic farming positively impacts the environment and climate, as it improves sustainability index and increases carbon sequestration. It is also found that organic farming may address both emissions avoidance and carbon sequestration through low nitrogen emission and reduced carbon dioxide emission.

In addition to these, it is also found that soil fertility, soil organic carbon (SOC), soil enzymes, earthworms, macro and micro nutrients, soil respiration and microbial biomass increased with adoption of natural farming and Zero Budget Natural Farming (ZBNF). Natural farming leads to better soil health, soil porosity, aeration, light texture, moisture retention, etc. Natural farming improves overall resilience of crops to adverse climatic conditions, and energy and water efficiency. It also has the potential to reduce carbon emissions as ZBNF fields showed improvement in soil organic carbon. The studies also highlight that ZBNF can help prevent over-extraction of groundwater, enable aquifer recharge, and eventually contribute to increasing water table levels. Given that ZBNF eliminates the use of inorganic chemical inputs, it is likely to improve the quality of groundwater aquifers.

Chapter 5: Comparison of different approaches as per AI-NPOF

Overall, the results of AI-NPOF with respect to organic carbon, soil macro and micro nutrients, bulk density and rhizosphere microbial population during 2004–19 across five ecosystems (arid, semi-arid, humid, semi-humid and coastal) were considered for analysis. Total number of cropping systems and centres for which the results were available varied. Except in the case of soil micro nutrients, wherein results of 2018–19 were considered, values of 2014–19 were considered for deep-dive analysis. This analysis included mean highest values of different cropping systems with three approaches and comparison of mean higher values among three approaches and six methods. To understand the long-term trends at centres, mean of all cropping systems during 2004–19 were analysed, except for soil micro nutrients and rhizosphere microbial population (see *Annexure 1—Figures 3.1–3.5: Graphs showing centre wise long-term trends*).

5.1 Organic carbon in soil

In case of organic carbon, results recorded for up to 34 cropping systems at nine centres for 2014–19 were analysed (see *Table 7: Comparison of mean organic carbon (%) with different approaches and methods [2014–19]*).

Organic approach

Out of 34 cropping systems mean organic carbon was highest in 91 per cent with organic approach at nine centres.

Compared with inorganic approach, mean organic carbon with organic approach was higher in 97 per cent cropping systems. Within these, it was significantly higher (>20 per cent) in 67 per cent cropping systems. It was higher by up to 242 per cent (from 0.69 per cent) in a particular cropping system.

Among organic methods, with OF method, organic carbon was higher in all cropping systems than with all the other methods. With OIN method, it was higher in 97 per cent cropping systems than with inorganic (IOF) method.

Cropping systems with higher mean organic carbon were part of all nine centres. In eight centres, organic carbon was higher in all cropping systems. These centres were Bajaura, Bhopal, Calicut, Dharwad, Jabalpur, Karjat, Ludhiana and Modipuram. In Coimbatore, it was at par with inorganic approach.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, chillies, beetroot,

Table 7: Comparison of mean organic carbon (%) with different approaches and methods (2014–19)

Cropping systems	Centre	Ecosystem	Organic carbon-mean as per IOF method (%)
Tomato – cauliflower – French Bean	Bajaura	Humid	0.66
Fallow – cauliflower – tomato			0.72
Black gram – cauliflower – summer squash			0.67
Lady finger – pea			0.73
Soybean – wheat	Bhopal	Semi-arid	0.61
Soybean – mustard			0.58
Soybean – chickpea			0.61
Soybean – linseed			0.62
Ginger – fallow	Calicut	Coastal	1.95
Black pepper			1.39
Cotton – maize	Coimbatore	Semi-arid	1.48
Chilli – sunflower			0.60
Beetroot – maize			0.60
Cowpea – safflower	Dharwad	Arid	0.60
Pigeon pea (sole)			0.57
Green gram – sorghum			0.56
Groundnut + hybrid cotton			0.54
Maize – chickpea			0.70
Basmati rice – durum wheat – green manure	Jabalpur	Sub-humid	0.71
Basmati rice – chickpea – maize fodder			0.68
Basmati rice – berseem fodder			0.67
Vegetable pea – sorghum fodder			0.70
Rice – brinjal	Karjat	Coastal	1.50
Rice – chickpea			0.86
Rice – Field bean			0.96
Rice – onion (white)			1.30
Basmati rice – chickpea – green manure	Ludhiana	Semi-arid	0.45
Basmati rice – wheat – green manure			0.46
Cluster bean – wheat – summer moong			0.42
Soybean – wheat			0.44
Basmati rice – durum wheat – sesbania green manure	Modipuram	Semi-arid	0.62
Coarse rice – barley (malt) – green gram			0.40
Maize (popcorn) – potato – ladyfinger + sesbania green manure			0.35
Maize (sweet corn) – mustard – sesbania green manure			0.40
Number of recorded results			
Cropping systems with higher respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)			
Cropping systems where values are significantly higher (>20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher (in per cent)			
Range of difference in mean from inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)			

Note: (-) represents data not available; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic

Organic carbon-mean difference compared to IOF method (%)					Organic carbon-mean difference as per INO approach (%)	Organic carbon-mean difference compared to INO approach (%)	
OF	OIN	IN75	IN50	SR	INO (IOF+SR)	ORG	INT
101.8	72.2	45.6	34.4	29.0	0.76	**63.3**	22.3
65.4	49.0	33.2	25.2	22.4	0.80	**41.3**	16.2
84.2	69.3	44.3	36.0	29.5	0.77	**54.1**	22.2
50.0	44.8	29.0	29.8	9.8	0.77	**40.5**	23.3
63.7	44.9	37.1	31.0	3.3	0.62	**51.8**	31.9
58.9	48.9	44.2	40.7	1.3	0.58	**52.9**	41.5
37.3	35.2	30.3	18.9	-4.1	0.60	**39.1**	27.2
45.9	41.1	24.4	26.0	-5.3	0.60	**47.4**	28.6
29.7	**35.0**	11.5	21.4	-	0.98	**164.7**	132.9
78.0	63.8	31.4	63.8	-	0.69	**241.8**	195.1
31.2	-	-	7.5	-	0.74	**31.2**	7.5
3.3	0.0	3.3	3.3	3.3	0.61	0.0	**1.6**
5.0	1.7	5.0	3.3	0.0	0.60	3.3	**4.2**
1.7	0.0	0.0	-5.0	0.0	0.60	**0.8**	-2.5
25.0	12.3	15.5	3.9	6.6	0.59	**14.9**	6.2
25.2	8.7	13.8	10.7	0.2	0.56	**16.9**	12.2
35.3	16.3	6.4	16.5	12.0	0.57	**18.7**	5.1
15.1	13.3	7.8	9.2	-1.9	0.69	**15.3**	9.6
15.0	14.0	9.2	11.0	-0.7	0.71	**14.9**	10.5
22.1	20.3	11.5	12.1	-1.5	0.68	**22.1**	12.6
13.7	**14.5**	9.7	11.7	-1.9	0.67	**15.2**	11.8
15.1	13.3	7.8	9.2	-1.9	0.69	**15.3**	9.6
26.7	12.7	-4.0	-4.0	-6.7	1.45	**23.8**	-0.7
57.0	47.7	16.3	17.4	9.3	0.90	**45.6**	11.7
50.0	42.7	5.2	5.2	-2.1	0.95	**47.9**	6.3
43.1	43.1	-2.3	3.1	-9.2	1.24	**50.0**	5.2
22.8	17.6	15.4	12.5	-2.2	0.45	**21.6**	15.2
41.6	36.5	27.7	20.4	-5.8	0.44	**43.2**	27.8
44.9	38.6	34.6	29.1	0.0	0.42	**41.7**	31.9
31.6	28.6	24.8	22.6	0.8	0.45	**29.6**	23.2
24.2	19.4	12.9	17.7	17.7	0.68	**11.9**	5.9
23.3	10.0	3.3	7.5	7.5	0.42	**12.4**	1.6
57.1	42.9	51.4	56.2	25.7	0.40	32.9	**36.3**
55.0	23.3	35.8	41.7	10.0	0.42	**32.5**	32.1
34	33	33	34	31		34	34
100.0	97.0	93.9	94.1	51.6		97.1	94.1
87.1	59.4	45.2	43.8	25.0		67	44
1.7 – 101.8	0 – 72	-2.3 – 51.4	-5 – 63.8	-9.2 – 29.5		0 – 241.8	-2.50 – 195.1

method or approach, and values in red cells indicate lesser than inorganic method or approach maize (sweetcorn), maize (popcorn), dolichos bean potato among vegetables; soybean, mustard, linseed sunflower, safflower and groundnut among oilseeds; black gram, cowpea, chickpea, pigeon pea (sole), cluster bean and green gram among pulses; ginger, black pepper cumin and fennel among spices; and wheat, rice, basmati rice, coarse rice, maize, barley and sorghum among cereals.

Integrated approach

Out of 34 cropping systems, organic carbon was highest in 9 per cent with integrated approach at two centres.

Compared with inorganic approach, mean organic carbon with integrated approach was higher in 94 per cent cropping systems. Within these, it was significantly higher in 44 per cent cropping systems. It was higher by up to 195 per cent (from 0.69 per cent) in a particular cropping system.

In both the integrated (IN75 and IN50) methods, organic carbon was 94 per cent higher than inorganic (IOF) method.

Cropping systems with higher mean organic carbon were part of all nine centres. In seven centres, organic carbon was higher in all cropping systems except for one at Dharwad and Karjat. These centres were Bajaura, Bhopal, Calicut, Coimbatore, Jabalpur, Ludhiana and Modipuram.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, chillies, beetroot, maize (sweetcorn), maize (popcorn), dolichos bean potato among vegetables; soybean, mustard, linseed sunflower and groundnut among oilseeds; black gram, cowpea, chickpea, pigeon pea (sole), cluster bean and green gram among pulses; ginger, black pepper cumin and fennel among spices; and wheat, rice, basmati rice, coarse rice, maize, barley and sorghum among cereals.

Inorganic approach

With SR method, organic carbon in soil was higher than IOF method in 52 per cent cropping systems.

Long-term trends

Long-term trends (2014–19) indicate that by and large organic carbon was highest with organic approach (largely OF method) in all centres—Bajaura, Bhopal, Calicut, Coimbatore, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram, Pantnagar, Raipur, Ranchi, Ajmer, Umiam, Narendrapur and Sardarkrushinagar (see *Annexure 1—Figure 3.1: Graphs showing centre wise long-term trends for organic carbon*).

5.2 Soil macronutrients: Available nitrogen, phosphorus and potassium

In case of available nitrogen, phosphorus and potassium, results recorded for up to 62 cropping systems at 16 centres during 2014–19 are analysed.

AVAILABLE NITROGEN

ORGANIC APPROACH

Out of 58 cropping systems mean available nitrogen was highest in 57 per cent cropping systems at 12 centres.

Compared with inorganic approach, mean available nitrogen with organic approach was higher in 74 per cent cropping systems. Within these, mean available nitrogen was significantly higher (>20 per cent) in 12 per cent cropping systems. It was higher by up to 40 per cent (from 205 kg/ha) in a particular cropping system (see *Table 8: Comparison of mean values of available nitrogen (N), phosphorus (P) and potassium (K) in soil (kg/ha) with different approaches [2014–19]*).

Both organic methods (OF and OIN) had higher mean available nitrogen than the other methods. Between the two, OF method had higher mean available nitrogen in more cropping systems (80 per cent) than OIN method (76 per cent) (see *Annexure 2—Table 3: Comparison of available nitrogen, phosphorus and potassium with different methods [2014–19]*).

Cropping systems with higher mean available nitrogen were part of 13 centres. In 10 centres it was higher in all cropping systems. These centres are Bajaura, Calicut, Coimbatore, Jabalpur, Karjat, Ludhiana, Ranchi, Umiam, Ajmer and Sardarkrushinagar. In Bhopal, Dharwad and Modipuram it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, field bean, vegetable pea, beetroot, chillies, onion, maize popcorn, sweet corn, potato, carrot, broccoli, vegetable cowpea among vegetables; black gram, cowpea, lentil, chickpea, cluster bean, summer moong, green gram among pulses; soybean, linseed, sunflower, safflower, groundnut, mustard among oilseeds; ginger, turmeric, black pepper, chilies, fennel, coriander, cumin among spices; and wheat, durum wheat, maize, rice, coarse rice, basmati rice and barley among cereals.

INTEGRATED APPROACH

Mean available nitrogen was highest in 21 per cent cropping systems at eight centres.

Compared with inorganic approach, mean available nitrogen with integrated approach was higher in 62 per cent cropping systems. Within these, mean available nitrogen was significantly higher (>20 per cent) in 11 per cent cropping systems. It was higher by up to 39 per cent (from 273 kg/ha) in a particular cropping system.

Among integrated methods, IN75 method had higher mean available nitrogen in more cropping systems (70 per cent) than IN50 method (63 per cent).

Cropping systems with higher mean available nitrogen were part of 12 centres. In seven centres it was higher in all cropping systems. These centres are Calicut, Coimbatore, Jabalpur, Karjat, Ludhiana, Ranchi, and Sardarkrushinagar. In five centres, Bhopal, Bajaura, Dharwad, Modipuram and Umiam it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, field bean, vegetable pea, beetroot, chillies, onion, potato, carrot, broccoli, vegetable cowpea among vegetables; black gram, cowpea, lentil, chickpea, cluster bean, summer moong, green gram among pulses; soybean, linseed, sunflower, safflower, groundnut, mustard among oilseeds; ginger, turmeric, black pepper, chilies, fennel, cumin among spices; and wheat, durum wheat, maize, rice, coarse rice, basmati rice and barley among cereals.

INORGANIC APPROACH

Mean available nitrogen with inorganic approach was highest in 22 per cent cropping systems at four centres.

Only at two centres, Pantnagar and Raipur, mean available nitrogen was highest with inorganic approach in all cropping systems. Available nitrogen with SR method was higher than IOF method in 21 (about 48 per cent) cropping systems. However, it was significantly higher only in one cropping system.

LONG-TERM TRENDS

Long-term trends (2004–19) indicate that by and large available nitrogen was highest with organic approach (largely OF method) at Bhopal, Dharwad, Jabalpur, Karjat, Ludhiana and Ranchi. At Coimbatore, Pantnagar and Umiam, it was highest except in the last few years. At Calicut, Modipuram and Sardarkrushinagar, it was highest in the last few years. At Bajaura, it was highest in later years with integrated (IN50), and at Raipur it was highest with inorganic approach (either IOF or SR) throughout (see *Annexure 1—Figure 3.2: Graphs showing centre wise trend of available nitrogen*).

AVAILABLE PHOSPHORUS

ORGANIC APPROACH

Out of 62 cropping systems, mean available phosphorus was highest in 58 per cent cropping systems at 13 centres.

Compared with inorganic approach, mean available phosphorus with organic approach was higher in 74 per cent cropping systems. Within these, mean available phosphorus was significantly higher in 52 per cent cropping systems. It was higher by up to 243 per cent (from 3.3 kg/ha) in a particular cropping system.

Both organic methods (OF and OIN) had higher mean available phosphorus than the other methods. Both the methods had higher mean available nitrogen in 75 per cent cropping systems.

Cropping systems with higher mean available phosphorus were part of 15 centres. In nine centres it was higher in all cropping systems. These centres are Bajaura, Bhopal, Dharwad, Jabalpur, Ludhiana, Modipuram, Pantnagar, Umiam, and Ajmer. In six centres—Calicut, Coimbatore, Karjat Raipur, Narendrapur and Sardarkrushinagar—it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, field bean, beetroot, onion, potato, carrot, broccoli, vegetable cowpea, maize popcorn and sweet corn among vegetables; black gram, chickpea, cowpea, Pigeon pea (sole), cluster bean, summer moong, green gram among pulses; soybean, linseed, safflower, groundnut, mustard among oilseeds; ginger, turmeric, fennel, coriander, among spices; and wheat, durum wheat, maize, rice, coarse rice, basmati rice, sorghum and barley among cereals.

INTEGRATED APPROACH

Out of 62 cropping systems, mean available phosphorus was highest in 23 per cent cropping systems at eight centres.

Compared with inorganic approach, mean available phosphorus with integrated approach, was higher in 69 per cent cropping systems. It was higher by up to 232 per cent (from 19.7 kg/ha) in a particular cropping system. Within these, it was significantly higher in 47 per cent cropping systems.

In case of integrated methods, mean available phosphorus was higher with IN50 in 71 per cent cropping systems and in 53 per cent with IN75 method.

Cropping systems with higher mean available phosphorus were part of 14 centres. In nine centres it was higher in all cropping systems. These centres are Bajaura, Bhopal, Calicut Jabalpur, Karjat, Ludhiana, Modipuram, Pantnagar and Umiam. In five centres, Coimbatore, Dharwad, Ranchi, Narendrapur and Sardarkrushinagar it was higher in one or more cropping system.

Crops grown as part of these cropping systems were - tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, field bean, beetroot, onion, potato, carrot, broccoli, vegetable cowpea, maize-popcorn, maize-sweet corn and capsicum among vegetables; black gram, chickpea, cowpea, , cluster bean, summer moong, green gram, among pulses; soybean, linseed, safflower, groundnut, mustard among oilseeds; ginger, turmeric, black pepper, fennel, coriander, cumin among spices; and wheat, durum wheat, maize, rice, coarse rice, basmati rice, and barley among cereals.

INORGANIC APPROACH

Out of 62 cropping systems, mean available phosphorus with inorganic approach was highest in 19 per cent cropping systems at five centres. It was higher with SR method than IOF method in 72 per cent (41 cropping systems).

LONG-TERM TRENDS

Long-term trends (2004-19) of highest available phosphorus at various centres indicate that it was highest with organic approach (largely OF method) in Bhopal, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram and Ajmer. In Pantnagar, it was highest in the last few years of recorded data. At Bajaura, Calicut and Sardarkrushinagar available phosphorus was highest on most of the occasions either with organic or with integrated. In Raipur, except for the initial years, it was highest with integrated (IN75) methods, so was the case at Narendrapur. At Ranchi except for the initial year, it was always highest with inorganic (both IOF and SR), while at Coimbatore it was always highest with inorganic approach (see *Annexure 1—Figure 3.3: Graphs showing centre wise long-term trends for available phosphorus*).

AVAILABLE POTASSIUM

ORGANIC APPROACH

Out of 62 cropping systems, mean available potassium was highest in 53 per cent cropping systems at 12 centres.

Compared with inorganic approach, mean available potassium with organic approach was higher in 69 per cent cropping systems. It was higher by up to 96 per cent (from 125.8 kg/ha) in a particular cropping system. Within these, it was significantly higher in 21 per cent cropping systems.

With both the organic methods (OF and OIN), mean available potassium was higher than inorganic (IOF) method in about 77 per cent of cropping systems.

Cropping systems with higher mean available potassium were part of 14 centres. In seven centres it was higher in all cropping systems. These centres are Bajaura, Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram and Ranchi. In seven centres—Bhopal, Calicut, Coimbatore, Umiam, Ajmer, Narendrapur and Sardarkrushinagar—it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were - tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, chillies, field bean, onion, potato, carrot, broccoli, maize popcorn and sweet corn among vegetables; black gram, chickpea, cowpea, Pigeon pea (sole), cluster bean, summer moong, green gram and lentil among pulses; soybean, linseed, sunflower, safflower, groundnut, mustard among oilseeds; ginger, black pepper, fennel among spices; and wheat, durum wheat, maize, rice, coarse rice, basmati rice, sorghum and barley among cereals.

INTEGRATED APPROACH

Out of 62 cropping systems, mean available potassium was highest in 28 per cent cropping systems at eight centres.

When comparison was made with inorganic approach, mean available potassium with integrated approach was higher in 76 per cent cropping systems. Within these, it was significantly higher in 13 per cent cropping systems. It was higher by up to 101 per cent (from 127 kg/ha) in a particular cropping system.

With both integrated (IN75 and IN50) methods, mean available potassium was about 80 per cent higher than all other methods.

Cropping systems with higher mean available potassium were part of 13 centres. In nine centres, potassium was higher in all cropping systems. These centres were at Bajaura, Coimbatore, Dharwad, Jabalpur, Karjat, Ludhiana, Ranchi, Umiam and Ajmer. In four centres—Calicut, Pantnagar, Modipuram and Sardarkrushinagar—it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, chillies, beetroot, field bean, onion, potato, carrot, broccoli, maize popcorn and sweet corn among vegetables; black gram, chickpea, cowpea, Pigeon pea (sole), cluster bean, lentil, summer moong, green gram and lentil among pulses; soybean, linseed, sunflower, safflower, groundnut, mustard and sesame among oilseeds; ginger, black pepper, fennel and coriander among spices; and wheat, durum wheat, maize, rice, basmati rice and sorghum among cereals.

INORGANIC APPROACH

Out of 62 cropping systems, mean available potassium with inorganic approach was highest in 19 per cent cropping systems at five centres.

LONG-TERM TRENDS

Long-term trends (2004–19) of highest available potassium at various centres indicate that by and large available potassium with organic approach (largely OF method) was highest at Dharwad, Jabalpur, Karjat, Ludhiana, Modipuram, Ranchi and Sardarkrushinagar. At Ajmer, it was highest with organic (OIN) method. At Coimbatore, it was highest with organic during the initial few years. At Umiam, available potassium was by and large highest with integrated. At Narendrapur it was highest with integrated in later years. At Calicut it was highest about equally with integrated and inorganic approach followed by organic. At Bajaura, it was highest in later years with integrated (IN50). At Raipur it was highest with inorganic approaches throughout. At Pantnagar, it was highest with inorganic in the initial years and at Bhopal, it was highest with inorganic approach on most occasions (see *Annexure 1—Figure 3.4: Graphs showing centre wise long-term trends for available potassium*).

Table 8: Comparison of mean values of available nitrogen (N), phosphorus (P) and potassium (K) in soil (kg

Cropping systems	Centre	Ecosystem	Available N (kg/ha) - mean as per INO (IOF+SR) approach (kg/ha)
Tomato – cauliflower – French Bean	Bajaura	Humid	234.0
Fallow – cauliflower – tomato			244.2
Black gram – cauliflower – summer squash			212.7
Lady finger – pea			228.2
Soybean – wheat	Bhopal	Semi-arid	168.2
Soybean – mustard			172.5
Soybean – chickpea			177.2
Soybean – linseed			175.0
Ginger – fallow	Calicut	Coastal	272.6
Turmeric – fallow			205.0
Black pepper			211.5
Cotton – maize	Coimbatore	Semi-arid	242.8
Chillies – sunflower			249.0
Beetroot – maize			254.0
Cowpea – safflower	Dharwad	Arid	250.7
Pigeon pea (sole)			270.3
Groundnut + hybrid cotton			271.6
Green gram – sorghum			268.4
Maize – chickpea			271.0
Basmati rice – durum wheat – green manure	Jabalpur	Sub-humid	268.5
Basmati rice – chickpea - maize fodder			256.0
Basmati rice – berseem fodder and seed			259.4
Vegetable pea – sorghum fodder			257.9
Rice – brinjal	Karjat	Coastal	278.7
Rice – chickpea			250.1
Rice – field bean			249.4
Rice – white onion			273.8
Basmati rice – chickpea – green manure	Ludhiana	Semi-arid	288.8
Basmati rice – heat – green manure			302.1
Cluster bean – wheat – summer moong			299.7
Soybean – wheat			322.4
Basmati rice – durum wheat – sesbania green manure	Modipuram	Semi-arid	345.0
Coarse rice – barley (malt) – green gram			339.2
Maize (popcorn) – potato – ladyfinger + Sesbania			366.6
Maize (sweet corn) – mustard – sesbania green manure			378.8

g/ha) with different approaches (2014–19)

Available N - mean difference compared to INO approach (%)		Available P - mean as per INO (IOF+SR) approach (kg/ha)	Available P - mean difference compared to INO approach (%)		Available K - mean as per INO (IOF+SR) approach (kg/ha)	Available K - mean difference compared to INO approach (%)	
ORG	INT		ORG	INT		ORG	INT
8.2	6.1	40.4	**73.9**	60.2	125.8	**95.5**	89.4
1.4	-5.1	41.2	**78.1**	63.5	140.2	**77.6**	70.2
12.8	**22.6**	38.6	**81.4**	74.9	149.2	46.3	**59.5**
14.4	**18.3**	39.1	**83.7**	72.8	126.6	91.5	**101.4**
10.9	7.0	31.5	**68.2**	13.6	493.8	-0.7	-2.5
-0.4	**4.9**	32.1	**43.5**	9.1	464.0	**3.4**	-2.6
-2.8	-6.5	27.3	**63.6**	30.8	436.6	**2.0**	-2.4
1.0	-0.1	27.8	**69.9**	25.5	465.2	-0.5	-0.8
35.1	**38.5**	30.9	40.8	**67.3**	308.7	7.0	**11.4**
40.2	32.5	19.7	205.1	**232.3**	285.5	-27.3	-16.3
15.3	**15.7**	28.4	-46.3	**40.4**	166.4	**15.0**	10.5
7.2	**18.2**	12.7	-7.4	-10.0	428.8	2.6	**7.0**
7.5	**33.7**	13.5	-14.8	-26.5	466.1	1.6	**4.0**
8.3	**17.4**	9.8	0.0	**7.8**	469.5	-1.2	**1.6**
7.5	4.9	33.3	**10.2**	9.5	366.1	**12.7**	9.8
-1.5	-4.3	33.3	**0.6**	-3.6	377.6	0.9	**5.5**
-2.5	-4.2	32.2	**13.8**	0.8	359.8	**13.6**	4.6
-0.4	-2.0	35.5	**0.3**	-11.6	383.3	3.8	**4.3**
-1.2	-4.3	33.9	**3.2**	-1.7	368.8	**6.1**	4.2
7.3	4.2	14.6	**10.8**	6.6	265.7	**5.0**	4.0
7.7	6.4	13.5	**17.0**	8.4	260.3	**7.8**	3.5
8.9	7.4	14.4	4.9	**5.4**	261.1	**5.9**	5.1
8.3	5.2	13.7	10.4	**21.6**	245.7	**12.5**	9.8
7.2	5.7	31.0	**4.2**	1.0	353.6	**7.1**	6.0
7.8	**8.6**	28.5	-0.2	**3.0**	361.7	**7.8**	6.4
14.8	13.1	28.7	**7.5**	4.4	345.9	**13.8**	12.2
8.4	6.9	30.0	3.3	**7.5**	367.7	**7.5**	5.4
24.3	19.8	41.0	**29.5**	17.5	139.7	**14.4**	7.5
12.3	**13.5**	41.9	**24.9**	11.7	142.4	**15.3**	8.8
14.5	11.0	44.4	**16.0**	13.3	145.2	**7.4**	6.4
13.8	12.3	41.6	15.6	**16.1**	141.1	**14.9**	4.9
-1.4	**7.1**	27.2	**52.6**	4.0	189.9	**65.2**	33.7
13.8	9.9	30.1	**62.1**	42.4	319.2	**4.2**	-12.1
9.9	-6.2	17.1	**82.7**	48.2	281.1	**9.8**	9.4
3.0	-1.2	12.4	**161.7**	83.5	318.1	**7.9**	5.1

Cropping systems	Centre	Ecosystem	Available N (kg/ha) - mean as per INO (IOF+SR) approach (kg/ha)
Basmati rice – wheat	Pantnagar	Humid	303.5
Basmati rice – chickpea			301.7
Basmati rice – vegetable pea			304.0
Basmati rice – potato			287.1
Soybean – Maize	Raipur	Sub-humid	239.9
Soybean – pea			239.7
Soybean – chilli			239.3
Soybean – onion			238.5
Rice – wheat	Ranchi	Sub-humid	252.6
Rice – lentil			255.0
Rice – potato			271.0
Rice – linseed			246.4
Broccoli – carrot	Umiam*	Arid	232.3
Broccoli – potato			242.4
Broccoli – French bean			243.7
Broccoli – tomato			242.9
Green gram – fennel	Ajmer	Arid	134.2
Green gram – coriander			131.6
Cluster bean – fennel			136.1
Green gram – coriander			131.6
Basmati rice – broccoli – sesbania green manure	Narendrapur	Humid	
Paddy – mustard – green gram			
Paddy – capsicum – green gram			
Paddy – French bean – sesame			
Groundnut – wheat – green gram	Sardarkrushinagar	Arid	147.5
Green gram – cumin – vegetable cowpea			146.7
Green gram – fennel – fennel			141.1
Number of recorded results			
Cropping systems with higher respective values among approaches (in per cent)			
Cropping systems where values are significantly higher (>20 per cent) than inorganic approach, calculated out of overall higher (in per cent)			
Range of difference in mean from inorganic approach (IOF+SR) (in per cent)			

Note: (-) represents data not available; Bold numbers reflect highest values among approaches; Values in green cells indicate higher than inorganic approach, and values in red cells indicate lesser than inorganic approach

Available N - mean difference compared to INO approach (%)		Available P - mean as per INO (IOF+SR) approach (kg/ha)	Available P - mean difference compared to INO approach (%)		Available K - mean as per INO (IOF+SR) approach (kg/ha)	Available K - mean difference compared to INO approach (%)	
ORG	INT		ORG	INT		ORG	INT
-24.7	-22.9	41.6	**42.1**	38.3	228.0	-0.1	**5.3**
-22.7	-22.7	52.2	**13.9**	12.5	252.9	-5.6	-4.6
-22.9	-23.3	48.1	**25.5**	20.5	247.4	-3.9	**8.1**
-19.2	-19.1	56.2	**15.7**	4.0	241.6	-0.1	**0.5**
-4.7	-2.5	18.3	-6.9	-5.4	335.0	-5.8	-3.0
-2.7	-2.7	17.6	**4.3**	-0.1	337.2	-5.1	-5.8
-2.1	-2.5	18.4	-4.5	-3.8	332.1	-4.5	-5.0
-2.7	-2.6	19.2	-9.3	-6.9	333.4	-5.0	-3.8
19.8	10.5	60.1	-4.3	-8.9	150.2	**45.7**	23.2
26.5	12.2	57.4	-9.6	-4.2	149.6	**50.6**	11.8
14.7	9.8	61.6	-4.4	-8.2	151.5	**34.2**	16.4
22.8	9.8	58.2	-1.7	**166.0**	156.3	**43.7**	19.9
8.1	6.6	15.4	**39.6**	32.5	246.8	**15.3**	14.0
2.0	-6.6	16.0	26.3	**30.6**	266.5	**4.0**	2.7
10.0	6.2	16.7	36.2	**40.7**	292.6	-8.0	**4.8**
2.8	**3.6**	17.3	12.1	**42.8**	256.8	5.6	**18.3**
3.4	-0.5	14.8	**17.0**	-2.4	328.0	**5.7**	4.6
5.0	-0.6	14.4	**20.7**	-1.2	362.8	-1.4	**0.7**
2.9	-0.2	3.3	**242.6**	-280.8	330.4	**4.5**	3.6
5.0	-0.6	14.4	**20.7**	-1.2	362.8	-1.4	**0.7**
		62.7	**3.6**	2.4	260.6	4.6	**10.4**
		89.4	-10.2	**10.7**	251.9	-3.4	-1.8
-		82.5	-19.6	-19.2	286.6	-8.1	-1.9
		67.8	-15.6	-9.7	221.7	6.1	**8.8**
2.4	2.3	15.7	9.1	**9.8**	191.4	**1.6**	1.5
2.7	2.2	14.7	-5.1	-1.9	185.7	-0.8	-0.7
2.8	1.5	13.5	**16.3**	2.3	182.9	-0.3	-0.9
58	58		62	62		62	62
74.1	62.1		74.2	69.4		69.4	75.8
11.6	11.1		52.2	46.5		20.9	12.8
-24.7 – 40.2	-23.3 – 38.5		-46.3 – 242.6	-280.8 – 232.2		-8.1 – 95.5	-12.1 – 101.4

5.3 Bulk density of soil

In case of bulk density, results recorded for 28 cropping systems at seven centres for 2014–19 were analysed (see *Table 9: Comparison of bulk density (g/cc) with different approaches and methods [2014–19]*).

Organic approach

Out of 28 cropping systems at seven centres, mean bulk density was lowest in 52 per cent cropping systems at four centres.

Compared with inorganic approach, mean bulk density with organic approach was lower in 75 per cent cropping systems. It was lower by up to -9.3 per cent (from 1.41 g/cc) in a particular cropping system. Bulk density with OF method and OIN method was lower than inorganic (IOF) method in 75 per cent and 71 per cent cropping systems respectively.

In four centres, bulk density was lower in all cropping systems. These centres were Dharwad, Jabalpur, Umiam and Sardarkrushinagar. At Narendrapur and Udaipur it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, French bean, vegetable pea, potato, broccoli, carrot, vegetable cowpea, capsicum among vegetables; mustard, sesame, safflower and groundnut among oilseeds; cowpea, chickpea, pigeon pea (sole) and green gram among pulses; cumin, and fennel among spices; and wheat, durum wheat, rice, basmati rice, maize and sorghum among cereals.

Integrated approach

Out of 28 cropping systems at seven centres, mean bulk density was lowest in 34 per cent cropping systems at four centres.

Compared with inorganic approach, mean bulk density with integrated approach was lower than inorganic in 79 per cent cropping systems. It was lower by up to -8.6 per cent (from 1.16 g/cc) in a particular cropping system.

Bulk density with IN50 method, was lower than all other methods in 89 per cent cropping systems. With IN75 method it was lower than inorganic (IOF) method in 75 per cent cropping systems.

In three centres, bulk density with integrated approach was lower in all cropping systems. These centres were Jabalpur, Umiam and Sardarkrushinagar. At Dharwad, Narendrapur, Thiruvananthapuram and Udaipur it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, French bean, vegetable pea, potato, broccoli, carrot, capsicum, vegetable cowpea, cassava and maize (sweet corn) among vegetables; soybean, mustard, sesame, safflower and groundnut among oilseeds; black gram, cowpea, chickpea, pigeon pea (sole) and green gram among pulses; cumin, fenugreek and fennel among spices; and wheat, durum wheat, rice, basmati rice, maize and sorghum among cereals.

Inorganic approach
Out of 32 cropping systems, mean bulk density was lower in only 14 per cent cropping systems with inorganic approach at two centres.

Long-term trends
Long-term trends (2004–19) of bulk density at various centres indicates that bulk density with organic approach was lowest at all centres except Thiruvananthapuram (see *Annexure 1—Figure 3.5: Graphs showing centre wise long-term trends for bulk density (g/cc), 2014–19*)

5.4 Rhizosphere microbial population: Bacteria, fungi, soil actinomycetes and phosphate solubilizing bacteria
In case of bacteria, fungi, soil actinomycetes and phosphate solubilizing bacteria (PSB), results recorded for up to 32 cropping systems at eight centres for 2018–19 are analysed.

BACTERIA IN SOIL

ORGANIC APPROACH
Out of 32 cropping systems, mean bacteria was highest in 84 per cent cropping systems at all centres.

Compared with inorganic approach, mean bacteria with organic approach was higher in 91 per cent cropping systems. Within these it was significantly higher (>20 per cent) in 86 per cent cropping systems. It was higher by up to 274 per cent (from 6.8 x10^6 cfu/g) in a particular cropping system (see *Table 10: Comparison of bacteria, fungi, soil actinomycetes and phosphate solubilizing bacteria (PSB) in soil with different approaches [2014–19]*).

Both organic methods (OF and OIN) had higher mean bacteria than the other methods. Between the two, OF method had higher mean bacteria in more cropping systems (88 per cent) than OIN method (84 per cent) (see *Annexure 2—Table 4: Comparison of bacteria, fungi, soil actinomycetes and phosphate solubilizing bacteria (cfu/g) with different methods [2014–19]*).

Cropping systems with higher mean available bacteria were part of all eight centres. In six centres, it was higher in all cropping systems. These centres were Bajaura, Bhopal, Coimbatore, Jabalpur, Ludhiana and Narendrapur. In Dharwad and Thiruvananthapuram, it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, beetroot, chillies, broccoli, vegetable cowpea, capsicum, cassava and taro among vegetables; black gram, chickpea, cowpea, pigeon pea (sole), cluster bean, summer moong, green gram among pulses; soybean, linseed, sunflower, safflower, groundnut, mustard and sesame among oilseeds; and wheat, durum wheat, maize, rice and basmati rice among cereals.

Table 9: Comparison of bulk density (g/cc) with different approaches and methods (2014–19)

Cropping systems	Centre	Ecosystem	Bulk density - mean as per IOF method (g/cc)
Cowpea – safflower	Dharwad	Arid	1.28
Pigeon pea (sole)			1.29
Green gram – sorghum			1.28
Groundnut + hybrid cotton			1.28
Maize – chickpea			1.25
Basmati rice – durum wheat – green manure	Jabalpur	Sub-humid	1.38
Basmati rice – chickpea – maize fodder			1.41
Basmati rice – berseem fodder and seed			1.41
Vegetable pea – sorghum fodder			1.39
Broccoli – carrot	Umiam	Humid	1.16
Basmati rice – broccoli – potato			1.16
Basmati rice – broccoli – French bean			1.10
Broccoli – tomato			1.14
Basmati rice – broccoli – sesbania green manure	Narendrapur	Humid	1.75
Paddy – mustard – green gram			1.88
Paddy – capsicum – green gram			1.86
Paddy – French bean – sesame			1.87
Groundnut – wheat – green gram	Sardarkrushinagar	Arid	1.51
Green gram – cumin – veg. cowpea			1.53
Green gram – fennel – fennel			1.51
Cassava – veg. cowpea	Thiruvananthapuram	Coastal	0.94
Cassava – groundnut			0.96
Taro – black gram			0.98
Taro – Green gram			0.91
Maize + black gram – durum wheat – sesbania green manure	Udaipur	Semi-arid	1.15
Sweet corn + black gram – chickpea			1.25
Black gram – wheat			1.15
Soybean – fenugreek			1.40
Total recorded results			
Cropping systems with lower respective values than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)			
Cropping systems where values are significantly lower (>20 per cent) than inorganic method and approach, calculated out of overall lower (in per cent)			
Range of difference in mean with inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)			

Note: (-) represents data not available; Bold numbers highlight highest values among methods and approaches; values in green cells indicate lower than inorganic method and approach, and values in red cells indicate higher than inorganic method and approach

Bulk density - mean difference compared to IOF method (%)					Bulk density - mean as per INO approach (g/cc)	Bulk density - mean difference compared to INO approach (%)	
OF	OIN	IN75	IN50	SR	INO (IOF+SR)	ORG	INT
-6.7	-3.9	-3.4	-3.6	-1.9	1.26	**-4.4**	-2.6
-8.1	-5.6	-3.6	-3.1	-3.3	1.27	**-5.4**	-1.9
-6.7	-3.4	-1.6	-1.9	-4.5	1.27	**-4.2**	-2.1
-8.0	-3.8	-0.8	-0.9	-1.6	1.27	**-5.4**	-0.7
-5.6	-2.6	-0.6	-0.8	0.3	1.25	**-3.7**	0.4
-8.8	-8.5	-3.8	0.0	-3.2	1.38	**-8.7**	-3.5
-9.2	**-9.8**	-6.4	-0.4	-5.4	1.41	**-9.3**	-5.7
-9.4	**-10.1**	-5.8	-0.9	-5.7	1.40	**-9.3**	-5.3
-8.1	**-8.2**	-5.3	-0.7	-4.7	1.39	**-7.7**	-4.7
-6.0	4.3	-	**-8.6**	-	1.16	-0.9	**-8.6**
-6.0	-1.7	-	-4.3	-	1.16	-3.9	**-4.3**
-0.9	-0.9	-	-4.5	-	1.10	-0.9	**-4.5**
-4.4	0.9	-	-1.8	-	1.14	-1.8	-1.8
0.0	-2.7	-1.5	**-6.8**	-3.0	1.69	2.2	1.2
-4.6	-3.0	**-8.5**	-0.5	0.5	1.88	-3.6	**-3.7**
-0.9	-2.1	**-4.1**	-1.1	-0.5	1.85	-1.0	**-1.8**
-0.4	-0.6	**-5.5**	-0.4	-0.4	1.87	-0.3	**-2.8**
-2.9	-2.9	-2.2	-2.2	-2.6	1.49	**-1.8**	-1.3
-3.3	-3.5	-2.6	-1.7	-3.5	1.51	**-2.5**	-2.2
-2.4	-1.1	-0.7	-0.4	-0.9	1.51	**-1.5**	-0.6
9.1	6.4	5.9	3.7	7.0	0.95	5.8	4.5
0.0	4.2	-6.2	-6.2	-6.2	0.93	5.4	**-3.2**
4.6	-2.1	-1.5	**-3.6**	0.0	0.96	3.1	1.0
5.5	1.1	-1.1	**-3.3**	1.1	0.90	5.0	1.7
9.1	6.4	**-3.5**	3.7	7.0	1.19	**-2.9**	-2.5
-1.6	4.2	**-8.8**	-6.2	-6.2	1.19	3.4	**-2.1**
2.6	**-1.7**	11.3	7.8	3.5	1.20	**-3.3**	3.3
-2.1	0.7	-11.4	**-13.6**	-5.0	1.31	6.5	**-1.5**
28	28	24	28	24		28	28
75	71	75	89	75		75	79
0.0	0.0	0.0	0.0	0.0		0.0	0.0
-9.4 – 9.1	-10.1 – 6.4	-11.4 – 11.3	-13.6 – 7.8	-5.7 – 7.0		-9.3 – 6.5	-8.6 – 4.5

INTEGRATED APPROACH

Out of 32 cropping systems, mean bacteria was highest in 13 per cent cropping systems at two centres.

Compared with inorganic approach, mean bacteria with integrated approach was higher than inorganic in 81 per cent cropping systems. Within these it was significantly higher in 65 per cent cropping systems. It was higher by up to 192 per cent (from 10.9 x10^6 cfu/g) in a particular cropping system.

With IN50 method, bacteria were higher in about 81 per cent of cropping systems; and with IN75 method, it was higher in about 78 per cent.

Cropping systems with higher mean available bacteria were part of eight centres. In six centres, bacteria were higher in all cropping systems. These centres were Bajaura, Coimbatore, Dharwad, Jabalpur, Ludhiana and Narendrapur. At Thiruvananthapuram, it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, beetroot, chillies, broccoli, vegetable cowpea, capsicum, cassava and taro among vegetables; black gram, chickpea, cowpea, pigeon pea (sole), cluster bean, summer moong, green gram among pulses; soybean, sunflower, safflower, groundnut, mustard and sesame among oilseeds; and wheat, durum wheat, maize, rice and basmati rice and sorghum among cereals.

INORGANIC APPROACH

Out of 32 cropping systems, mean bacteria was highest in only 3 per cent cropping systems with inorganic approach at three centres. At Bhopal it was higher in all cropping systems with inorganic approach. With inorganic (SR) method it was higher in 41 per cent cropping systems.

FUNGI IN SOIL

ORGANIC APPROACH

Out of 32 cropping systems, mean fungi was highest in 72 per cent cropping systems in seven centres.

Compared with inorganic approach, mean fungi with organic approach was higher in 78 per cent cropping systems. Within these, it was significantly higher in 76 per cent cropping systems. It was higher by up to 173 per cent (from 7.5 x10^6 cfu/g) in a particular cropping system.

Among organic methods (OF and OIN), OF method had higher mean fungi 81 per cent of the times and OIN method had higher fungi 63 per cent of the times.

Cropping systems with higher fungi were part of seven centres out of eight. In six centres, fungi were higher in all cropping systems. These centres were Bajaura, Bhopal, Coimbatore, Jabalpur, Ludhiana, and Narendrapur.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, beetroot, capsicum and chillies among vegetables; soybean, mustard, linseed sunflower, sesame and groundnut among oilseeds; black gram, chickpea, pigeon pea (sole), cluster bean, summer moong and green gram among pulses; and wheat, rice, basmati rice, maize, and sorghum among cereals**.**

INTEGRATED APPROACH

Out of 32 cropping systems, fungi was highest in 12 per cent cropping systems in two centres.

Compared with inorganic approach, mean fungi with integrated approach was higher in 66 per cent cropping systems. Within these it was significantly higher in 52 per cent cropping systems. It was higher by up to 56 per cent (from 9.0 x10^6 cfu/g) in a particular cropping system.

IN75 method had higher mean bacteria than the IN50 method in 69 per cent cropping systems. In case of IN50 method it was higher in 53 per cent.

Cropping systems with higher mean fungi were part of seven centres out of eight. In three centres, fungi were higher in all cropping systems. These centres were Bajaura, Jabalpur, and Ludhiana.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, and vegetable pea, beetroot among vegetables; soybean, mustard, sesame and groundnut among oilseeds; black gram, chickpea, pigeon pea (sole), cluster bean, summer moong and green gram among pulses; and wheat, rice, basmati rice and maize among cereals**.**

INORGANIC APPROACH

Out of 32 cropping systems, mean bacteria was highest in 16 per cent cropping systems with inorganic approach at two centres.

SOIL ACTINOMYCETES

ORGANIC APPROACH

Out of 32 cropping systems mean soil actinomycetes were highest in 69 per cent cropping systems at all centres.

Compared with inorganic approach, mean soil actinomycetes with organic approach were higher in 84 per cent cropping systems. Within these they were significantly higher in 56 per cent cropping systems. They were higher by up to 101 per cent (from 1.7 x10^6 cfu/g) in a particular cropping system.

Among organic methods, OF method led to higher mean soil actinomycetes in 88 per cent cropping systems. OIN method led to higher mean soil actinomycetes than inorganic method in 59 per cent cropping systems.

Cropping systems with higher mean soil actinomycetes were part of all eight centres. In four out of these eight centres, soil actinomycetes were higher in all cropping systems. These centres were Bhopal, Jabalpur, Ludhiana and Narendrapur. In Bajaura, Coimbatore, Dharwad and Thiruvananthapuram it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, vegetable pea, chillies, broccoli, capsicum, cassava and taro among vegetables; black gram, chickpea, cowpea, pigeon pea (sole), cluster bean, summer moong, green gram among pulses; soybean, linseed, sunflower, safflower, groundnut, mustard and sesame among oilseeds; and wheat, durum wheat, maize, rice and basmati rice among cereals.

INTEGRATED APPROACH

Out of 32 cropping systems mean soil actinomycetes were highest in 25 per cent cropping systems three centres.

Compared with inorganic approach, mean soil actinomycetes with integrated approach were higher than inorganic in 34 per cent cropping systems. Within these they were significantly higher in 73 per cent cropping systems. They were higher by up to 238 per cent (from of 10.5 x10^6 cfu/g) in a particular cropping system.

Both integrated methods (IN75 and IN50) had 31 per cent higher mean soil actinomycetes than inorganic (IOF) method.

Cropping systems with higher mean soil actinomycetes were part of four centres out of eight. In two out of these four, soil actinomycetes were higher in all cropping systems. These centres were Ludhiana and Thiruvananthapuram. In Bhopal and Dharwad, they were higher in one or more cropping systems.

Crops grown as part of these cropping systems were vegetable cowpea, cassava and taro among vegetables; black gram, chickpea, pigeon pea (sole), cluster bean, summer moong and green gram among pulses; soybean and groundnut among oilseeds; and wheat, maize and basmati rice among cereals.

INORGANIC APPROACH

Out of 32 cropping systems, mean soil actinomycetes were highest in 6 per cent cropping systems with inorganic approach at two centres.

PHOSPHATE SOLUBILIZING BACTERIA

ORGANIC APPROACH

Out of 21 cropping systems, mean phosphate solubilizing bacteria (PSB) was highest in 76 per cent cropping systems at all centres.

Compared with inorganic approach, mean PSB with organic approach was higher in 81 per cent cropping systems. Within these it was significantly higher in 47 per cent cropping systems. It was higher by up to 307 per cent (from 1.4 x10^6 cfu/g) in a particular cropping system.

Both organic methods (OF and OIN) had higher mean PSB than the other methods. Between the two, OF method had higher mean PSB in more cropping systems (81 per cent) than OIN method (57 per cent).

Cropping systems with higher mean PSB were part of five centres. In three out of these five centres, mean PSB was higher in all cropping systems. These centres were Bajaura, Jabalpur and Ludhiana. In Dharwad and Thiruvananthapuram, it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, cassava and taro among vegetables; black gram, cowpea, pigeon pea (sole), chickpea, green gram, cluster bean, summer moong and among pulses; safflower, soybean and groundnut among oilseeds; and sorghum, wheat, durum wheat, and basmati rice among cereals.

INTEGRATED APPROACH

Out of 21 cropping systems mean PSB was highest in 10 per cent cropping systems at two centres.

Compared with inorganic approach, mean PSB with integrated approach was higher than inorganic in 19 per cent cropping systems. Within these it was significantly higher in 50 per cent cropping systems. It was higher by up to 1,496 per cent (from 1.4 x10^6 cfu/g) in a particular cropping system.

Within integrated approach, with IN50 method, mean PSB was higher in 24 per cent of cropping systems and with IN75 method, in 19 per cent.

Cropping systems with higher mean PSB were part of two centres, Dharwad and Thiruvananthapuram. At these centres PSB was was higher in one or more cropping systems.

Crops grown as part of these cropping systems were cassava and taro among vegetables; green gram among pulses; groundnut among oilseeds; and sorghum among cereals.

INORGANIC APPROACH

Out of 32 cropping systems, mean PSB was highest in 14 per cent cropping systems with inorganic approach at two centres. With inorganic (SR) method it was higher in 33 per cent cropping systems.

Table 10: Comparison of mean bacteria, fungi, soil actinomycetes and phosphate solubilizing bacteria (PSB

Cropping systems	Centre (Ecosystem)	Bacteria - mean as per INO approach ($x10^6$ cfu/g)	Bacteria - mean difference compared to INO approach (%)	
			ORG	INT
Tomato – cauliflower – French bean	Bajaura (Humid)	10.9	**46.1**	27.6
Fallow – cauliflower – tomato		10.9	**40.4**	26.5
Black gram – cauliflower – summer squash		10.7	**29.8**	21.1
Lady finger – pea		11.1	**47.0**	22.7
Soybean – wheat	Bhopal (Semi-arid)	27.1	**23.0**	-0.8
Soybean – mustard		17.5	**14.3**	-24.9
Soybean – chickpea		31.8	**19.2**	-2.3
Soybean – linseed		17.4	**2.6**	-20.2
Cotton – maize	Coimbatore (Semi-arid)	8.8	**37.7**	20.8
Chilli – sunflower		8.0	**29.2**	12.5
Beetroot – maize		7.2	**34.9**	18.6
Cowpea – safflower	Dharwad (Arid)	15.9	**25.6**	16.0
Pigeon pea (sole)		14.1	43.3	**56.1**
Green gram – sorghum		18.7	-2.9	**14.3**
Groundnut + hybrid cotton		15.9	26.1	**35.3**
Maize – chickpea		17.8	**4.7**	1.9
Basmati rice – durum wheat - green manure	Jabalpur (Sub-humid)	42.4	**44.4**	16.9
Basmati rice – chickpea – maize fodder		38.8	**46.7**	14.9
Basmati rice – berseem fodder and seed		39.3	**46.1**	22.0
Vegetable pea – sorghum fodder		42.9	**44.2**	13.8
Basmati rice – chickpea – green manure	Ludhiana (Semi-arid)	12.5	**124.0**	100.0
Basmati rice – wheat – green manure		13.5	**118.5**	66.7
Cluster bean – wheat – summer moong		17.0	**41.2**	29.4
Soybean – wheat		16.0	**75.0**	56.3
Basmati rice – broccoli – sesbania green manure	Narendrapur (Humid)	14.9	**50.4**	19.7
Paddy – mustard – green gram		11.3	**50.4**	28.1
Paddy – capsicum – green gram		9.7	**85.0**	49.1
Paddy – French bean – sesame		10.8	**51.4**	25.7
Cassava – veg. cowpea	Thiruvananthapuram (Coastal)	6.8	**274.3**	91.3
Cassava – groundnut		15.0	-68.0	-1.0
Taro – black gram		10.9	-6.6	**191.6**
Taro – green gram		10.5	**20.5**	-21.0
Number of recorded results			32	32
Cropping systems with higher respective values among approaches (per cent)			91	81
Cropping systems where values are significantly higher (>20 per cent) than inorganic approach, calculated out of overall higher (in per cent)			86	65
Range of difference in mean from inorganic approach (INO=IOF+SR) (in percent)			-68 – 274.3	-24.9 – 191.6

Note: (-) represents data not available; Bold numbers reflect highest values among approaches; Values in green cells indicate higher than inorganic approach, and values in red cells indicate lesser than inorganic approach

3) in soil with different approaches (2014–19)

Fungi - mean as per INO approach (x10⁶ cfu/g)	Fungi - mean difference compared to INO approach (%)		Soil actinomycetes (SA) - mean as per INO approach (x10⁶ cfu/g)	SA - mean difference compared to INO approach (%)		PSB - mean as per INO approach (x10⁶ cfu/g)	PSB - mean difference compared to INO approach (%)	
	ORG	INT		ORG	INT		ORG	INT
11.0	**21.1**	15.5	11.6	**4.0**	-19.0	12.7	**6.8**	-16.9
10.9	**22.1**	16.1	11.7	**6.5**	-22.7	12.8	**0.4**	-13.2
11.1	13.9	**21.5**	12.3	**10.4**	-20.4	13.0	**9.0**	-16.4
10.4	22.3	**27.8**	12.4	-9.9	-20.7	12.6	**12.0**	-12.8
27.5	**16.5**	-3.0	49.8	**8.4**	-23.7	-	-	-
25.9	**25.4**	7.3	52.3	**16.3**	-36.7	-	-	-
28.2	**15.2**	-15.9	46.2	**39.5**	8.5	-	-	-
22.0	**12.3**	-17.3	48.4	**36.5**	-12.8	-	-	-
5.7	**23.5**	8.8	8.3	0.0	-22.0	-	-	-
5.3	**12.5**	-6.2	6.7	**10.0**	-15.0	-	-	-
5.9	**21.9**	7.0	4.8	-3.4	-17.2	-	-	-
7.6	-2.0	**6.5**	20.7	**24.4**	-15.1	15.9	**7.0**	-16.2
6.0	**46.8**	3.2	19.1	**29.2**	14.5	14.2	**29.9**	-15.7
7.6	**29.3**	-5.6	22.7	**11.3**	-10.4	14.3	**22.6**	3.8
7.0	-8.6	**2.3**	21.4	**10.1**	-9.5	14.8	-1.3	**2.5**
8.4	-15.6	-27.1	23.5	-9.5	**3.6**	17.2	-26.2	-21.0
32.3	**50.1**	33.3	19.0	**25.8**	-33.3	16.9	**10.0**	-15.5
29.9	**53.6**	22.5	15.0	**40.9**	-30.5	13.5	**34.9**	-8.1
30.3	**55.8**	30.3	16.3	**29.9**	-32.3	13.2	**30.7**	-22.3
31.3	**52.5**	21.7	18.7	**11.2**	-42.5	15.0	**13.2**	-27.3
10.5	**66.7**	11.9	11.5	91.3	**187.0**	12.3	**34.7**	-26.5
7.5	**173.3**	33.3	19.0	42.9	**107.9**	9.3	**11.9**	-45.9
8.3	**51.5**	15.2	10.5	37.6	**238.1**	10.5	**34.3**	-16.7
9.0	**94.4**	55.6	14.5	20.7	**124.1**	9.4	**16.5**	-30.9
7.4	**83.5**	46.9	21.9	**18.3**	-23.1	-	-	-
5.4	**76.8**	53.0	17.7	**19.4**	-19.0	-	-	-
6.9	**10.6**	-8.2	20.9	**15.1**	-21.0	-	-	-
8.0	**64.7**	37.5	17.7	**23.6**	-21.6	-	-	-
24.1	-50.8	-66.3	1.4	38.3	**65.6**	18.8	-83.8	-37.8
20.4	-65.6	-39.6	3.0	-56.2	**188.6**	1.4	307.4	**1,496.3**
14.9	-44.7	-37.4	1.7	100.7	**106.0**	8.3	-11.5	-43.0
10.7	-49.8	-15.5	2.8	**71.0**	24.2	8.2	**98.2**	37.2
	32	32		32	32		21	32
	78	66		84	34		81	19
	76	52		56	73		47	50
	-65.6 – 173.3	-66.3 – 55.6		56.2 – 100.7	42.5 – 238.1	-68 – 274.3	-83.8 – 307.4	-45.9 – 1496.3

5.5 Soil micronutrients: Available iron, manganese, zinc and copper

In case of available iron, manganese, zinc and copper, results recorded for 19 cropping systems at five centres for 2018–19 are analysed.

IRON

ORGANIC APPROACH

Out of 19 cropping systems at five centres, available iron was highest in 74 per cent cropping systems at five centres.

Compared with inorganic approach, available iron with organic approach was higher in 90 per cent cropping systems. Within these, it was significantly higher in 65 per cent cropping systems. It was higher by up to 87 per cent (from 40.7 ppm) in a particular cropping system (see *Table 11: Comparison of available soil micronutrients—iron, manganese, zinc and copper (ppm) with different approaches [2018–19]*).

Among organic (OF and OIN) methods, available iron was higher than inorganic in 84 per cent cropping systems with OIN method and in 89 per cent with OF method.

Cropping systems with higher available iron were part of five centres. In three centres, iron was higher in all cropping systems. These centres were at Bajaura, Pantnagar and Sardarkrushinagar. At Calicut and Dharwad, it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato; among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; safflower and groundnut among oilseeds; ginger, turmeric, cumin and fennel among spices; and wheat, maize, basmati rice and sorghum among cereals.

INTEGRATED APPROACH

Out of 19 cropping systems at five centres, available iron was highest in 21 per cent cropping systems at three centres.

Compared with inorganic approach, available iron with integrated approach was higher in all cropping systems. Within these, it was significantly higher in 53 per cent cropping systems. It was higher by up to 65 per cent (from 9.5 ppm) in a particular cropping system.

With IN50 method, available iron was higher than inorganic method in 100 per cent cropping systems. With IN75 method, it was higher in 84 per cent. In all five centres, available iron was higher in all cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato; among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; safflower and groundnut among oilseeds; ginger, turmeric, black pepper, cumin and fennel among spices; and wheat, maize, basmati rice and sorghum among cereals.

INORGANIC APPROACH

Out of 19 cropping system at five centres, available iron was highest in 5 per cent cropping systems at one centre.

MANGANESE

ORGANIC APPROACH

Out of 19 cropping systems, available manganese was highest in 63 per cent cropping systems at five centres.

Compared with inorganic approach, available manganese with organic approach was higher in 90 per cent cropping systems. Within these, it was significantly higher in 71 per cent cropping systems. It was higher by up to 58 per cent (from 9.9 ppm) in a particular cropping system.

Among organic (OF and OIN) methods, available manganese was higher than inorganic in 94 per cent cropping systems with OIN method and in 89 per cent with OF method.

Cropping systems with higher available manganese were part of all five centres. In four centres out of five, manganese was higher in all cropping systems. These centres were at Bajaura, Dharwad, Pantnagar and Sardarkrushinagar. At Calicut, it was higher in one or more cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato; among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; groundnut among oilseeds; turmeric, black pepper, cumin and fennel among spices; and wheat, maize, basmati rice and sorghum among cereals.

INTEGRATED APPROACH

Out of 19 cropping system, available manganese was highest in 37 per cent cropping systems at three centres.

Compared with inorganic approach, available manganese with integrated approach was higher in all cropping systems. Within these, it was significantly higher in 58 per cent cropping systems. It was higher by up to 58 per cent (from 6.7 ppm) in a particular cropping system.

With IN50 method, available manganese was higher than inorganic method in 100 per cent cropping systems. With IN75 method, it was higher in 94 per cent cropping systems. In all five centres, manganese was higher in all cropping systems.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato; among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; groundnut among oilseeds; ginger, turmeric, black pepper, cumin and fennel among spices; and wheat, maize, basmati rice and sorghum among cereals.

ZINC

ORGANIC APPROACH

Out of 18 cropping systems available zinc was highest in 89 per cent cropping systems at five centres.

Compared with inorganic approach, available zinc with organic approach was higher in all cropping systems. Within these, it was significantly higher in 89 per cent cropping systems. It was higher by up to 341.2 per cent (from 0.6 ppm) in a particular cropping system.

Among organic (OF and OIN) methods, available zinc was higher than inorganic in all cropping systems with OF method and in 94 per cent with OIN method.

In five centres, zinc was higher in all cropping systems. These centres were Bajaura, Calicut, Dharwad, Pantnagar and Sardarkrushinagar.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato; among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; groundnut among oilseeds; ginger, turmeric, cumin and fennel among spices; and wheat, maize, basmati rice and sorghum among cereals.

INTEGRATED APPROACH

Out of 18 cropping systems, available zinc was highest in 11 per cent cropping systems at only one centre.

Compared with inorganic approach, available zinc with integrated approach was higher in all cropping systems. Within these, it was significantly higher in 72 per cent cropping systems. It was higher by up to 250 per cent (from 0.6 ppm) in a particular cropping system.

Among integrated (IN75 and IN50) methods, available zinc was higher than inorganic in all cropping systems with IN50 method and in 94 per cent with IN75 method.

In all five centres, zinc was higher in all cropping systems. These centres were Bajaura, Calicut, Dharwad, Pantnagar and Sardarkrushinagar.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato;

among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; groundnut among oilseeds; ginger, turmeric, cumin and fennel among spices; and wheat, maize, basmati rice and sorghum among cereals.

COPPER

ORGANIC APPROACH

Out of 18 cropping systems, available copper was highest in 78 per cent cropping systems at five centres.

Compared with inorganic approach, available copper with organic approach was higher in 89 per cent cropping systems. Within these, it was significantly higher in 50 per cent cropping systems. It was higher by up to 133 per cent (from 01.2 ppm) in a particular cropping system.

Among organic (OF and OIN) methods, available copper was higher than inorganic in 89 per cent cropping systems with OIN method and in 83 per cent with OF method.

Cropping systems with higher available copper were part of all five centres. In three centres, copper was higher in all cropping systems. These centres were Bajaura, Pantnagar and Sardarkrushinagar.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger, vegetable pea, vegetable cowpea and potato; among vegetables; black gram, chickpea, cowpea, pigeon pea (sole) and green gram among pulses; groundnut among oilseeds; turmeric, cumin and fennel among spices; and wheat, basmati rice and sorghum among cereals.

INTEGRATED APPROACH

Out of 18 cropping systems, available copper was highest in 22 per cent cropping systems at three centres.

Compared with inorganic approach, available copper with integrated approach was higher in 61 per cent cropping systems. Within these, it was significantly higher in 46 per cent cropping systems. It was higher by up to 66 per cent (from 1.0 ppm) in a particular cropping system.

Available copper was higher with both integrated (IN75 and IN50) methods. It was higher in 94 per cent cropping systems with IN75 method.

Cropping systems with higher available copper were part of four centres except Pantnagar. In four centres, copper was higher in all cropping systems. These centres were Bajaura, Calicut, Dharwad and Sardarkrushinagar.

Crops grown as part of these cropping systems were tomato, cauliflower, French bean, summer squash, ladyfinger and vegetable pea; among vegetables; black gram, cowpea, pigeon pea (sole) and green gram among pulses; turmeric, cumin and fennel among spices; and wheat and maize among cereals.

Table 11: Comparison of available soil micronutrients—iron, manganese, zinc and copper (ppm) with differ

Centre (Ecosystem)	Cropping systems	Available iron with INO approach (ppm)	Difference in available iron with INO approach (IOF+SR)	
			ORG (%)	INT (%)
Bajaura (Humid)	Tomato – cauliflower – French Bean	8.9	**52.8**	51.1
	Fallow – cauliflower – tomato	10.2	**38.4**	32.0
	Black gram – cauliflower – summer squash	9.7	**63.4**	62.4
	Lady finger – pea	9.5	48.7	**65.1**
Calicut (Coastal)	Ginger – fallow	30.0	5.0	**6.7**
	Turmeric – fallow	25.9	**36.3**	26.4
	Black pepper – fallow	30.5	-20.3	**21.3**
Dharwad (Arid)	Cowpea – safflower	12.7	**13.0**	7.5
	Pigeon pea (sole)	13.5	5.2	5.2
	Green gram – sorghum	13.0	**24.3**	7.7
	Groundnut + hybrid cotton	13.0	**30.1**	10.8
	Maize – chickpea	12.9	-1.9	**0.0**
Pantnagar (Humid)	Basmati rice – wheat	40.9	**79.8**	39.1
	Basmati rice – chickpea	45.6	**75.4**	28.3
	Basmati rice – vegetable pea	42.1	**81.2**	40.4
	Basmati rice – potato	40.7	**86.6**	30.8
Sardarkrushinagar (Arid)	Groundnut – wheat – green gram	3.5	**8.7**	4.3
	Green gram – cumin – vegetable cowpea	3.3	**12.4**	4.2
	Green gram – fennel – fennel cont.	3.4	**11.4**	4.2
Number of recorded results			19	19
Cropping systems with higher respective values among approaches (in per cent)			89.5	100.0
Cropping systems where values are significantly higher (>20 per cent) than inorganic approach, calculated out of overall higher (in per cent)			64.7	52.6
Range of difference in mean with inorganic approach (INO=IOF+SR) (in per cent)			-20.3 – 86.6	0.0 – 65.1

Note: (-) represents data not available; Bold numbers reflect highest values among approaches; Values in green cells indicate higher than inorganic approach, and values in red cells indicate lesser than inorganic approach

rent approaches (2018–19)

Available manganese with INO approach (ppm)	Difference in available manganese with INO approach (IOF+SR)		Available zinc with INO approach (ppm)	Difference in available zinc with INO approach (IOF+SR)		Available copper with INO approach (ppm)	Difference in available copper with INO approach (IOF+SR)	
	ORG (%)	INT (%)		ORG (%)	INT (%)		ORG (%)	INT (%)
7.4	41.2	**55.4**	2.0	**73.8**	53.7	1.2	58.5	**58.8**
7.7	43.8	**50.3**	2.0	**60.8**	55.4	1.4	**82.1**	54.3
6.7	44.4	**57.9**	2.4	**44.9**	20.1	1.0	23.9	**66.4**
7.7	**43.8**	38.6	2.2	**41.3**	35.4	1.2	**133.2**	60.7
15.0	-0.3	**13.3**	1.7	**82.4**	58.8	10.0	-1.5	-218.5
13.9	**40.6**	24.1	0.6	**341.2**	250.0	1.2	47.9	**51.5**
1.1	0.00	**54.5**						
14.9	**23.6**	17.5	0.4	50.6	**100.0**	2.5	**12.9**	3.2
15.5	16.8	**24.2**	0.5	18.9	**24.4**	2.4	**7.8**	4.2
15.6	**25.6**	22.4	0.5	**42.4**	9.1	2.6	**11.5**	-0.7
16.2	**21.9**	12.3	0.5	**16.5**	9.2	2.6	**11.4**	-3.6
15.1	6.6	**7.6**	0.5	**32.7**	8.7	2.4	-2.3	**1.8**
10.4	**27.1**	16.4	0.9	**65.5**	40.2	3.7	**4.4**	-49.0
9.7	**43.3**	39.2	0.9	**67.4**	47.7	3.8	**18.7**	-67.1
9.9	**53.3**	25.4	0.9	**70.8**	40.4	3.7	**10.4**	-87.1
9.9	**58.4**	35.5	0.9	**65.9**	36.4	4.1	**13.2**	-181.3
5.7	**12.8**	8.9	0.3	**46.0**	25.4	0.4	**48.8**	18.2
5.4	**9.7**	6.2	0.4	**20.3**	9.5	0.4	**37.2**	20.0
5.4	**11.9**	5.1	0.3	**41.5**	18.9	0.4	**32.5**	17.5
	19	19		18	18		18	18
	89.5	100.0		100.0	100.0		88.9	61.1
	70.6	57.9		88.9	72.2		50.0	45.5
	-0.3 – 58.4	7.6 – 55.9		18.9 – 341.2	9.1 – 250		-2.3 – 133.2	-218.5 – 66.4

Analysis of results on energy under AI-NPOF project 2018–19

Under the AI-NPOF, impact of three approaches (organic, integrated and inorganic) on energy input, output, energy use efficiency and energy productivity were recorded at five centres. The centres are Bajaura, Bhopal, Ranchi, Gangtok and Sardarkrushinagar.

Energy Input: Among the three approaches, the lowest mean energy input was found with organic approach (OIN method) at three centres namely Bajaura, Bhopal and Ranchi. At Sardarkrushinagar, it was lowest with integrated approach (IN75 method). At Gangtok, it was more or less the same with all organic approaches.

Energy output: With organic approach, the energy output was highest at three centres. These centres are Bhopal, Ranchi and Gangtok (with either OF or OIN method). At Bajaura, it was highest with integrated approach (IN50 method) and at Sardarkrushinagar, it was highest with integrated approach (IN75 method).

Energy use efficiency: With organic approach (either with OF or OIN method), the energy use efficiency was found to be highest at three centres. These centres were Bhopal, Ranchi and Gangtok. At Bajaura, it was highest with integrated approach (IN75 method) and, at Sardarkrushinagar with (IN50 method).

Energy productivity: With organic approach, the energy productivity was highest at four centres—Bhopal, Bajaura, Ranchi and Gangtok. At Sardarkrushinagar, it was highest with integrated approach (IN50 method).

Notes: Energy input is the sum total of energy from human labour, energy from power and energy from materials likes seed, fertilizer, pesticides and irrigation; and energy output is energy from main product and energy from by-product. The energy ratio (energy-use efficiency) is determined relatively assessing energy output with energy input. In case of energy productivity, it is total agricultural output relatively assessed with energy input.

*In Gangtok all five methods were organic.

Chapter 6: Review of scientific studies

In this section there are 33 scientific studies and results on organic and natural farming which are analysed on soil health and environment by different stakeholders in different settings and geographies. These studies were published or presented during 2010–20.

6.1 Benefits of organic and natural farming on soil health

A field experiment published in 2011, but conducted during 2006–08 at Govind Ballabh Pant University of Agriculture and Technology, Uttarakhand revealed that the addition of organic manures had a positive effect on bulk density of soil over a period of three years. The value of bulk density was found to be lowest (1.13 mg/m^3) in farmyard manure-treated plots.[79]

A long-term (2005–10) comprehensive experiment conducted by the Directorate of Rice Research, Andhra Pradesh, on the fine varieties of rice re-established that organic system significantly improves soil quality and sustainability index (organics 1.63 compared to inorganics 1.33), and also increases soil microbial population.[80]

A long-term experiment conducted under rain-fed conditions between 2006–07 and 2012–13, at Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University in Palampur, on maize, maize + soybean - wheat + gram during the dry season revealed that the use of organic manures in different combinations as farmyard manure (FYM) alone or in combination with vermicompost (VC) or himcompost improved the soil structure, enhanced soil fertility, leading to improvement in organic carbon, available nitrogen, phosphorus and potassium in the soil. Organic carbon increased from 0.62 per cent to 1.02 per cent, nitrogen from 188 to 269 (kg/ha), phosphorus from 9.5 to 15.6 (kg/ha) and potassium from to 179 to 288 (kg/ha). Increase in microbial count was also observed in soil with treatment of FYM+VC or FYM alone.[81]

Biofertilizer application improves soil biota (bacteria, fungi, archaea and algae) and the yield attributing characters. It also minimizes the sole use of chemical fertilizers, as cited in the journal published in 2013.[82] The importance of vermicompost and biofertilizer as cost-effective and eco-friendly inputs which can be generated at the farms, was also highlighted in another study presented in North East Agriculture Fair 2014 at Manipur. Vermicompost can act as a single source of all nutrients for crop needs. Biofertilizers can save up to 20 kg of nitrogen per hectare.[83]

A study undertaken during rabi 2015–16 at Mandan Bharti Agriculture College, Saharsa, Bihar, found that vermicompost and water hyacinth compost either alone or in combination with different levels of nitrogen, potassium and phosphorus fertilizers increased the status of soil organic carbon over control at each soil depth.[84]

A field study conducted in Peruvarappur village, Cuddalore, Tamil Nadu during 2013–16, highlighted that organic fertilization improved the soil fertility by increasing the total carbon, total nitrogen and ammonium concentration. The field with organic fertilizer showed appropriate bacterial and actinomycetes populations over crop cultivation. It was recommended that the continuous use of chemical fertilizers will reduce the soil quality of the field. Organic fertilization will maintain soil consistency and soil ecosystems for sustainable agriculture. [85]

A study conducted on soil organic carbon pool from organic farming at Jeevaka live laboratory, Mahatma Gandhi University, Kotayam, Kerala, published in 2018, found that with organic farming availability of feed and water enhances the diversity of earthworms, and it influences the microbial activity in the soil, which gives rise to a better carbon pool. The high values of carbon pool index revealed the existence of all forms of carbon in the soil. Overall findings indicate that carbon storage in soil improves as diversity of earthworms increases.[86]

From a long-term research work initiated in 2013 in Tamil Nadu Agriculture University, Coimbatore, soil samples were collected during 2018–19, where an experiment was done on three crops (brinjal, tomato and chilli) to find the influence of different cropping and nutrient management practices in Vertic Ustropep on soil carbon pools and carbon stock. Published in 2019, it found that brinjal crop can fix higher amount of organic carbon, labile carbon, water soluble carbon and soil carbon stock. It also found that the long-term application of 100 per cent organics exerted significant effect on the active pools of soil organic carbon, and concluded that the application of 100 per cent organic is best to maintain soil health.[87]

Field research conducted to study the physical, chemical and biological properties of soil, foliar constituents of mulberry and rearing parameters of the silkworm in Erode, Tamil Nadu, between January 2015 and December 2016, found that the repeated application of chemical fertilizers, either indiscriminately, or even as per the recommendations, showed adverse impact on soil health and affected its physical, chemical and biological properties. While soil bulk density decreased while porosity and water retention increased significantly with organic inputs. The application of organic manure showed higher soil moisture content, increased water holding capacity and enhanced porosity (by 50 per cent), leading to higher availability of major soil nutrients, i.e., nitrogen, phosphorus and potassium.[88]

An experiment conducted in August–September 2018, at ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra, and published in 2019, found that the application of cow urine-based organic formulations increases native rhizobial colonization by the formation of a greater number of root nodules, which has the potential to alleviate soil moisture stress and increase nitrogen fixation.[89]

Another study conducted on groundnut cultivation in Andhra Pradesh during 2016, published in 2020, found that the combination of organic manure, press mud cake and farmyard manure was most effective in increasing soil nutrients status and maintaining soil health. It highlights that available nitrogen, exchangeable magnesium, and diethylenetriamine pentaacetic acid (DTPA) extractable Fe, Zn and Cu were significantly higher in FYM applied treatment. Parameters like available potassium, exchangeable calcium and available sulphur are significantly higher in pressmud cake applied treatment. The study revealed that organic manure application improved the supplying capacity of all the essential nutrients in balanced ratio during crop growth. [90]

A review study published in 2020, by the National Organic Farming Research Institute, Central Agriculture University, Gangtok, Sikkim, highlights the utility of spent mushroom substrate in vermicomposting, bioremediation of contaminated soils, heavy metals, pesticides and preparation of organic-mineral fertilizer which is a boon to the organic farming system of the country. The addition of spent mushroom substrate in nutrient poor soil improves its health by improving the texture, water holding capacity and nutrient status. Spent mushroom substrate incorporation in soil leads to an increase in both pH as well as the organic carbon content.[91]

Natural farming

A study undertaken across thirteen districts of five states—Maharashtra, Karnataka, Kerala, Andhra Pradesh and Himachal Pradesh—by A.T.E Chandra Foundation and PRAXIS on natural farming, highlights that there was improvement in soil health and significant changes in the soil quality. The soil became loose, smooth and fertile with microbes and the number of earthworms increased. Humus content also increased in the soil. The soil turned out to be softer and the colour changed from red to dark black, water always remained on the topsoil due to which the irrigation process became easier and moisture retention capacity of soil increased. [92]

Another study was done in 2018–19, with 10 farmers each from all the districts of Andhra Pradesh who adopted all the practices of Zero Budget Natural farming (ZBNF). It highlights that ZBNF has contributed to ecosystem services like improvement in soil health, enhancement in the quality of output and increase in the resilience of crops to withstand dry spells and strong winds.[93]

The findings of the study carried out at a 180-acre farm of Gurukul in Kurukshetra, by Chaudhary Charan Singh Haryana Agriculture University, Hisar, published in 2018, found that the soil organic carbon was sufficient after a year of cropping under ZBNF. Also, there was no deficiency in micro nutrients (Zinc, Iron, Copper and Magnesium) in soil samples analysed and the results showed that the soil of Gurukul farm was loaded with microbial population in comparison to the farmers' soil used in the study. The total bacterial count in soil was 528 times that of the farmers' soil.[94]

A report published in 2018, by Council on Energy, Environment and Water, highlights that the use of various mulching techniques by ZBNF farmers leads to the fast build-up of soil microbiota and soil aeration, which is critical for enhancing water percolation and the water retention capacity of the soil.[95]

Another study published in 2019 observed that overuse of chemical fertilizer can lead to water eutrophication, especially the deleterious use of nitrogen and phosphorus, which can also lead to soil acidification and soil crust, thereby reducing organic matter content, humus content, beneficial organisms, stunting plant growth, changes in soil pH, increased pests, and even contributing to the release of greenhouse gases. Excessive use of nitrogen fertilizers results in the emission of nitrogen oxides (NO, N_2O, NO_2) and is responsible for severe air pollution. Thus, in order to ensure enhanced and sustainable agricultural production while safeguarding the environment, integrated use of different types of nutrient supplements should be adopted.[96]

A comparative analysis of soil samples from a farmers' horticulture (mango) field in Andhra Pradesh was published in 2019. The study highlighted that wherever ZBNF had been practised for 15 years, it showed improvement in soil organic carbon and higher availability of nitrogen (52 per cent and 70 per cent respectively). It also found that the nitrogen supplying power of soil (in ZBNF fields) was comparatively higher than that in non-ZBNF farmers' fields.[97]

A similar observation was made in a study conducted on ZBNF by Chandra Shekhar Azad University of Agriculture and Technology, Kanpur in seven districts with 35 farmers. The results presented in 2020 reveal that after adopting natural farming there was an increase in soil fertility, soil organic carbon, soil enzymes, earthworms, macro and micro nutrients, soil respiration and microbial biomass.[98]

6.2 Impact of organic and natural farming on climate and environment

A field study conducted for five years (2004–05 to 2009–10) on a black clayey vertisol soil at the Directorate of Rice Research, Hyderabad, found that soil organic carbon (SOC) stocks were higher with organics by 44 and 35 per cent, compared to conventional system during wet and dry seasons respectively. The sustainability index of the soil was maximum with organics (1.63) compared to inorganics (1.33) after five years. The carbon sequestration rate was also positive with organics (0.97 and 0.57 tonne/hectare/year during wet and dry seasons respectively), compared to conventional system that recorded negative SOC sequestration rate (-0.21 and -0.33 tonne/hectare/year during wet and dry seasons respectively).[99]

Another study published in 2013 highlighted that organic farming can be used as a mitigation strategy, which may address both emissions avoidance and carbon sequestration. Lower nitrous oxide (N_2O) (due to lower nitrogen input) suggests that 1–2 per cent of the nitrogen applied to farming systems is emitted as N_2O, irrespective of the form of the nitrogen input. It will ensure less CO_2 emissions through erosion (due to better soil structure and more plant cover). There usually is less erosion in organic farming systems than in conventional ones. It may also lead to lower CO_2 emissions from farming system inputs (pesticides and fertilizers produced using fossil fuel).[100]

An on-farm field experiment in tropical humid climate was carried out from 2010–13 in Dargakona village, Cachar, Assam on a traditional rice variety called lathma (Oryza sativa L.). It found carbon active and passive pool to be highest in a combination of organic and inorganic inputs, while with only organic inputs it was the second best. This can mitigate climate change as it stores more carbon in recalcitrant pool and does not easily oxidize with marginal increase in temperature under climate change scenario.[101]

A review study highlights that organic farming increases soil moisture levels, which in turn increases the biomass of earthworms by 30-40 per cent in comparison to the conventional system. Sustainable farming systems such as organic farming act as a possible solution to this continued loss of biodiversity. Additionally, the agricultural bio-diversity gives farmers some options to manage climate risks.[102]

The Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, published a technical report in 2017, which highlighted that organic farms have greater diversity due to mandatory crop rotations and preference for crop varieties with high tolerance to complex abiotic and biotic factors such as climate extremes, pests and diseases. Greenhouse warming potential in organic systems is 29 to 37 per cent lower because of omission of synthetic fertilizers and pesticides as well as less use of high energy feed. Carbon sequestration efficiency of organic systems in temperate climates is almost double (575–700 kg carbon per ha per year) as compared to conventional soils. Thus, organic farming, can potentially contribute to mitigate threats from climate change to vegetable production.[103]

A long-term study conducted from2004–05 to 2013–14, at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand reveals that after 10 years, all the cropping systems under organic, inorganic and integrated management practices contributed towards carbon sequestration. SOC content of the soil (0–15 cm) improved by 84 per cent under basmati rice-brassica napus-sesbania with organic management, whereas it increased by 28.8 per cent and 68.3 per cent with inorganic and integrated management respectively compared to initial levels (2004). The application of organic source of fertilizer significantly increased SOC content over the other management practices. It concluded that both basmati rice-wheat-sesbania or basmati rice-brassica napus-sesbania cropping systems with organic or integrated management are better for sequestering higher carbon in the soil than the present rice-wheat system with inorganic management.[104]

Natural farming

A report published in 2018 by Council on Energy, Environment and Water highlighted that ZBNF can help prevent over-extraction of groundwater, enable aquifer recharge and eventually contribute to increasing water table levels. Given that ZBNF eliminates the use of inorganic chemical inputs, it is likely to improve the quality of groundwater aquifers. By eliminating the use of chemical fertilizers and pesticides, ZBNF will vastly reduce the need for and use of energy along their value chain.[105]

A case study presented in a report published in 2020 by Centre for Science and Environment on AP-CRZBNF, highlighted through a survey with farmers that ZBNF had improved overall resilience of crops to adverse climatic conditions. Water needed for irrigation in ZBNF had either decreased or remained same and the crops had become drought tolerant and mulching had improved the moisture content of the soil. The survey highlights that soil became softer, smoother, porous, moist, aerated and with improved water-holding capacity. The case study also highlighted that there is an increase in the population of earthworms and beneficial insects.[106]

Similar observations were made in a study conducted by Chandra Shekhar Azad University of Agriculture and Technology, Kanpur in seven districts with 35 farmers on ZBNF. It highlights that there were quality improvements on water saving, environment protection and soil biological qualities.[107]

Detailed data from the Andhra Pradesh Community Natural Farming (APCNF) on crop production practices was collected from a survey of 1,467 farmers to characterize the range of field management practices in 2020. The study analysed greenhouse gas emissions which were assessed using methods consistent with life-cycle analysis. Analysis was done for six crops—paddy rice, groundnut, maize, chillies, cotton and Bengal gram—and it was found that APCNF has the potential to reduce emissions by a minimum of 23 per cent in comparison to conventional practices. If a transition to APCNF is done from conventional farming, on average it can mitigate 5.1 million tonnes of carbon dioxide equivalent (CO_2e) emissions per year, equal to mitigating 30 per cent of emissions from this cropland.[108]

Another study published in 2020 highlights how ZBNF practice can help rainwater harvesting and its efficient utilization. It conserves plant and animal biodiversity. With agroforestry, boundary plantation and border crops, it may reduce soil erosion and incidence of pest and disease.[109]

A systematic comparison between ZBNF and non-ZBNF fields was done in 2018 to find the difference in earthworm numbers and castings. A total of 480 samples was taken from all 13 districts in Andhra Pradesh. It was found that ZBNF fields hosted an average of 232 earthworms per square meter, compared with just 32 on non-ZBNF fields.[110]

A study published in 2020 by Centre for Study of Science, Technology and Policy, compared ZBNF and conventional farming in Andhra Pradesh. It highlights that the switch from non-ZBNF to ZBNF in irrigated crops can potentially save up to an average of 1400–3500 kl of water and about 12–50 gigajoule of energy, coupled with a 1.4–6.6 Mt CO_2e emission reduction, per acre in a crop period. Rainfed crops can ideally save up to 1.1–16 GJ of energy and reduce 0.5–11 Mt CO_2e of emissions.[111]

SECTION IV:
EVIDENCE ON FOOD QUALITY AND NUTRIENTS

Summary: Benefits of organic and natural farming on food quality and nutrients

Results of the year 2018–19 for 28 different food quality and nutrient parameters in 15 crops cultivated with three approaches (organic, integrated and inorganic) and six methods are analysed.

In 12 out of 15 crops, parameters are found highest with organic approach. In seven out of these, all parameters tested are highest with organic. These crops are cauliflower, French bean, soybean, mustard, black gram, rice and wheat (grown at Bhopal). In remaining five crops, one or more parameters are highest with organic or were same with all approaches. These crops are carrot, tomato (grown at Bajaura and Umiam), turmeric, black pepper and fennel.

In pea, parameters tested are highest with integrated approach. In ginger, results of one parameter are highest with integrated and the other with inorganic approach.

Coriander is the only crop where all parameters tested are highest with inorganic. In the case of wheat grown at Ranchi, results of all parameters tested are highest with inorganic approach.

Compared with inorganic approach, across 51 sets of test results, in 67 per cent cases the results are higher with organic and in 64 per cent cases with integrated approach. Only in the case of carrot and tomato (grown at Bajaura), in one or more parameters tested, the results are significantly higher with both organic and integrated approaches.

In addition to the AI-NPOF, evidence is reviewed and collated from 11 Indian scientific studies and results on food quality and nutrition parameters of crops with organic and natural farming published or presented during 2010–20. These studies which were conducted by different stakeholders in different settings and geographies add to the overall evidence in favour of organic farming and natural farming.

The studies had similar findings. In papaya, grown in Hyderabad and Bangalore, the quality parameters were higher with organic as compared to recommended dose of fertilizers. In case of taro grown organically in Kerala, nutrient content was higher with organic. Fruit quality parameters like total carotenoids, total soluble solids, vitamin C, total sugars and lycopene are also found higher with organic approach in vegetables and fruits. Organically grown corn, strawberries and Marion berries have significantly higher (around 30 per cent) levels of cancer-fighting antioxidants. Organic farming also improved the physical attributes of vegetables such as cabbage, tomato and cowpea. In case of rice, the nutritive values are higher with organic than for rice grown with chemicals. Another study found moderate improvement in nutritional quality of rice with organics; especially in brown rice in which protein, phosphorus and potassium were higher with organics in comparison with inorganics. Additional study reveals that organically cultivated green leafy, tomato and cauliflower are found superior in microbial quality than their conventionally grown counterparts.

Chapter 7: Comparison of different approaches as per AI-NPOF

In this section, recorded results are analysed for 15 crops across six centres in all five ecosystems in 2018–19. Twenty-eight different food quality and nutrient parameters with organic and integrated approaches have been compared to inorganic approach (see *Table 12: Comparison of food quality and nutrients with different approaches and methods [2018–19]*).

Vegetables—Five vegetables were tested for different quality and nutrient parameters:

- Cauliflower (vitamin C)
- Carrot (root diameter, total soluble solids, ascorbic acid, acidity, beta carotene, total carotenoids, total sugar and reducing sugar)
- French bean (protein)
- Tomato (total soluble solids, specific gravity, average fruit diameter, vitamin C at Bajaura and Umiam and reducing sugar, total sugar, lycopene in addition to the above only at Umiam)
- Pea (protein, total soluble solids)

Cauliflower that was cultivated at Bajaura, with tomato and French bean, had highest vitamin C content with the organic approach, followed by integrated approach. With both organic methods (OF and OIN), it was higher than other methods. Between the two, OF method was marginally better.

Carrot that was cultivated at Umiam with broccoli, had highest content of total soluble solids (TSS), beta carotene, total carotenoids, total sugar and reducing sugar with the organic approach, followed by integrated approach. Except in the case of total soluble solids and total carotenoids, all other parameters were significantly higher (>20 per cent) than inorganic approach. Ascorbic acid content and root diameter were highest with integrated approach. Among the methods, both organic methods (OF and OIN) were better than integrated (IN50) method across all parameters except one. Between the two, OF method was much better.

French bean that was cultivated with cauliflower and tomato at Bajaura, had highest protein content with organic approach followed by integrated approach. Both organic (OF and OIN) methods were better than the other methods. Between the two, OF method was better.

Tomato that was cultivated with cauliflower at Bajaura, in both kharif and summer seasons, had same level of TSS content with both organic and integrated approaches in kharif. In summer, both TSS and vitamin C content were highest with integrated approach, followed by organic. TSS content with both organic and integrated was significantly higher than inorganic. Among methods, vitamin C was highest with IN75 method and TSS in tomato grown in summer was highest with IN50 method. TSS in tomato grown with kharif was highest with organic (OF) method.

Tomato that was cultivated with broccoli at Umiam, had higher TSS, acidity, ascorbic acid and reducing sugar content with organic approach. Acidity and total sugar content were highest with integrated approach and only specific gravity was highest with inorganic approach. Among methods, most of the parameters were better with organic (OF) method. The remaining few were better with integrated (IN75) method.

Pea, that was cultivated with ladyfinger at Bajaura, had highest protein and TSS content with integrated approach, followed by organic. Among methods, the value of protein in pea was highest with integrated (IN50) method, while TSS was highest with inorganic (SR) method.

Oilseeds—Two oilseeds were tested for different quality and nutrient parameters:

- Soybean (protein, oil, methionine, tryptophan)
- Mustard (protein, phenol, glucosinolate)

Soybean that was cultivated with mustard at Bhopal, had highest protein, oil, methionine and tryptophan content with organic approach, followed by integrated approach. Within methods, all of these were highest with organic (OF) method.

Mustard cultivated with soybean at Bhopal, had highest protein, phenol and glucosinolate content with organic approach, followed by integrated approach. Within methods all of these were highest with organic (OF) method.

Pulses—Black gram was tested for protein quality and nutrients as below:

Black gram that was cultivated with cauliflower at Bajaura, had highest protein content with organic approach, followed by integrated. Among methods it was highest with organic (OF) method.

Spices—Five spices were tested for different quality and nutrient parameters:

- Black pepper (oil content, oleoresin, piperine)
- Coriander (protein, essential oil)
- Fennel (protein, essential oil)
- Ginger (oleoresin and oil content)
- Turmeric (oleoresin, oil content, curcumin)

Black pepper that was cultivated at Calicut, had highest piperine content with integrated (IN50) method, followed by inorganic (IOF) method. Oil content was at par with both methods. Oleoresin content was highest with inorganic (IOF) method.

Coriander that was cultivated with green gram and cluster bean at Ajmer, had highest protein and essential oil content with inorganic approach, followed by integrated. Within methods, these parameters were highest with integrated (IN75) method.

Fennel that was cultivated with cluster bean or green gram at Ajmer, had highest protein content with integrated approach, followed by organic. The essential oil content in fennel was same in all three approaches. Among methods, both parameters were highest with inorganic (IN75) method.

Ginger that was cultivated with organic approach at Calicut had highest oil content with integrated approach, followed by inorganic. Oleoresin content is highest with inorganic approach. Among methods, oleoresin was highest with IN75 method and oil content was highest with IN50 method.

Turmeric that was cultivated at Calicut, had highest curcumin content with organic approach. Oil content and oleoresin content were highest with inorganic. Among methods, curcumin and oleoresin were highest with OIN method. Oil content was highest with IOF method.

Cereals—Two cereals were tested for different quality and nutrient parameters:

- Rice (protein, moisture)
- Wheat (protein, moisture, globulin, gluten)

Rice that was cultivated with wheat at Ranchi, had highest protein and moisture content with organic approach, followed by integrated approach. Among methods, protein content was highest with OIN method and moisture with OF method.

Wheat that was cultivated with soybean at Bhopal, had highest protein globulin, moisture and gluten with organic approach, followed by integrated. Among methods, all of these were highest with both organic (OF and OIN) methods.

Wheat that was cultivated with rice at Ranchi, had highest protein and moisture content with inorganic approach. Among methods, both the parameters were highest with inorganic (IOF) method.

Table 12: Comparison of food quality and nutrients with different approaches and methods (2018–19)

Crop	Centre	Ecosystem	Quality parameter	IOF method
Cauliflower	Bajaura	Humid	Vitamin C (mg/100g)	42.0
Carrot	Umiam	Humid	Root diameter (mm)	28.2
			TSS (%)	7.1
			Ascorbic acid (mg/100g)	35.9
			Acidity (%)	0.2
			Beta carotene (mg/100g)	6.6
			Total carotenoids (mg/g)	64.3
			Total sugar (%)	5.0
			Reducing sugar (%)	3.7
French bean	Bajaura	Humid	Protein %	13.2
Tomato			TSS (o Brix) (kharif)	3.8
			TSS (o Brix) (summer)	4.0
			Vitamin C (mg/100g)	30.2
	Umiam	Humid	Specific gravity (g/ml)	1.2
			Average fruit diameter (mm)	49.8
			TSS (%)	4.3
			Acidity (%)	0.7
			Ascorbic acid (mg/100g)	27.9
			Reducing sugar	2.5
			Total sugar (%)	4.8
			Lycopene (mg/100g)	16.6
Pea	Bajaura	Humid	Protein (%)	20.2
			TSS (o Brix)	13.4
Soybean	Bhopal	Semi-arid	Protein (%)	34.5
			Oil (%)	17.8
			Methionine (g/16gN)	1.6
			Tryptophan (g/16gN)	1.8
Mustard			Protein (%)	39.0
			Phenol (%)	9.7
			Glucosinolate (%)	91.5
Black gram	Bajaura	Humid	Protein (%)	13.2
Black pepper	Calicut	Coastal	Oil content (%)	3.3
			Oleoresin (%)	8.9
			Piperine (%)	5.7
Coriander	Ajmer	Arid	Protein (%)	15.8
			Essential oil (%)	0.2
Fennel			Protein (%)	16.7
			Essential oil (%)	1.2

Difference with IOF method					INO approach (IOF+SR)	Difference with INO approach (IOF+SR)	
OF	OIN	IN75	IN50	SR		ORG	INT
13.4	8.7	6.4	7.7	4.8	43.0	**8.5**	4.6
4.9	-6.9	-	**11.0**	-	28.2	-1.0	**11.0**
21.8	15.6	-	10.4	-	7.1	**18.7**	10.4
16.1	9.0	-	15.4	-	35.8	12.6	**15.4**
42.1	15.8	-	21.1	-	0.2	**28.9**	21.1
39.4	32.4	-	29.3	-	6.5	**35.9**	29.3
15.7	4.8	-	9.3	-	64.3	**10.2**	9.3
21.2	**23.2**	-	17.6	-	5.0	**22.2**	17.6
25.4	21.4	-	15.8	-	3.7	**23.4**	15.8
7.6	6.1	4.5	3.0	2.3	13.3	**5.6**	2.6
36.8	21.1	31.6	26.3	21.1	4.2	16.7	16.7
30.0	25.0	25.0	**37.5**	12.5	4.2	20.0	**23.5**
15.2	10.9	**17.2**	14.2	4.6	30.9	10.5	**13.1**
3.2	-4.0	-	-4.8	-	1.2	-0.4	-4.8
7.0	-6.9	-	-11.9	-	49.7	**0.1**	-11.9
13.1	2.8	-	-4.0	-	4.2	**7.9**	-4.0
-9.6	-2.7	-	**5.5**	-	0.7	-6.2	**5.5**
8.1	-6.7	-	-9.8	-	27.9	**0.7**	-9.8
6.8	3.6	-	-2.8	-	2.5	**5.2**	-2.8
-2.7	-1.0	-	**5.0**	-	4.8	-1.9	**5.0**
8.3	-7.7	-	-8.4	-	16.6	**0.3**	-8.4
4.0	1.5	3.5	**5.0**	3.0	20.5	1.2	**2.7**
20.9	15.7	15.7	28.4	**30.6**	15.4	2.6	**5.8**
2.5	0.4	1.7	0.3	0.1	34.5	**1.4**	0.9
1.0	0.6	0.7	0.3	-0.2	17.7	**0.9**	0.6
4.3	2.5	1.9	1.2	0.6	1.6	**3.1**	1.2
1.7	0.6	1.1	0.0	0.6	1.8	**0.8**	0.3
1.4	0.8	1.1	0.1	-0.1	38.9	**1.1**	0.7
2.3	0.9	1.7	0.5	-0.6	9.7	**1.9**	1.4
5.1	2.6	2.7	0.6	-0.7	91.2	**4.2**	2.1
7.6	3.0	3.0	6.1	4.5	13.5	**3.0**	2.2
-6.1	-	-	0.0	-	3.2	-6.1	0.0
-1.0	-	-	-1.7	-	8.9	-1.0	-1.7
-9.7	-	-	**15.4**	-	5.6	-9.7	**15.4**
-2.3	-12.7	**2.8**	-6.7	2.0	15.9	-8.4	-2.9
-10.0	-5.0	5.0	-5.0	5.0	0.2	-9.8	-2.4
3.7	6.0	**9.3**	2.2	7.1	17.3	1.2	**2.1**
0.8	0.8	**2.5**	-0.8	1.7	1.2	0.0	0.0

Crop	Centre	Ecosystem	Quality parameter	IOF method
Ginger	Calicut	Coastal	Oleoresin (%)	4.9
			Oil content (%)	1.92
Turmeric			Curcumin (%)	4.7
			Oil content (%)	5.7
			Oleoresin (%)	14.3
Rice	Ranchi	Sub-humid	Protein (%)	7.6
			Moisture (%)	14.0
Wheat			Protein (%)	9.9
			Moisture (%)	10.3
	Bhopal	Semi-arid	Protein (%)	11.7
			Globulin (%)	23.9
			Moisture (%)	10.9
			Gluten (%)	16.7
Number of recorded results				
Results higher than inorganic method (IOF) and approach (INO=IOF+SR) (in per cent)				
Results significantly higher (> 20 per cent) than inorganic method (IOF) and approach (INO=IOF+SR), calculated out of overall higher (in per cent)				

Note: (-) represents data not available; Bold numbers reflect highest values among methods and approaches; Values in green cells indicate higher than inorganic method or approach, and values in red cells indicate lesser than inorganic method or approach

Difference with IOF method					INO approach (IOF+SR)	Difference with INO approach (IOF+SR)	
OF	OIN	IN75	IN50	SR		ORG	INT
0.0	-3.1	**1.0**	-3.1	-	4.9	-1.5	-1.0
-4.8	-2.1	2.1	**4.3**	-	1.9	-3.5	**3.2**
-0.6	**2.1**	-7.6	-3.2	-	4.7	**0.7**	-5.4
-4.6	-2.1	-3.3	-4.2	-	5.7	-3.3	-3.8
-1.8	**1.4**	-1.7	-1.3	-	14.3	-0.2	-1.5
2.0	**3.5**	0.4	1.4	-2.0	7.5	**3.8**	1.9
1.3	0.8	0.6	0.3	-0.2	14.0	**1.1**	0.5
-1.9	-2.6	-1.9	-0.8	-1.1	9.8	-1.7	-0.8
-1.7	-1.1	-1.0	-0.7	-0.6	10.3	-1.1	-0.5
0.4	0.3	0.4	0.2	0.1	11.7	0.3	0.3
3.4	1.6	2.6	0.8	0.5	23.99	**2.3**	1.4
0.6	**0.7**	-0.3	-0.6	-0.3	10.9	**0.8**	-0.3
4.5	3.2	3.9	2.3	1.1	16.8	**3.3**	2.5
51	48	32	51	27		51	51
72.5	70.8	81.3	62.7	66.7		68.6	64.7
27.0	20.6	15.4	21.9	16.7		17.1	15.2

Chapter 8: Review of scientific studies

There are 11 scientific studies and results on organic farming which have been analysed on food quality and nutrition of crops by different stakeholders in different settings and geographies. These studies were published or presented during 2010–20.

8.1 Benefits of organic farming on food quality and nutrition

An experimental study published in 2010, conducted at Indian Council of Agricultural Research, Almora, Uttarakhand, during the rainy seasons (June–September) of 2001–06, found that better nutritional (phenol content in rice grain increased) and functional qualities of rice can be achieved in organically managed soils than in mineral-fertilized soils.[112]

Evidence from a field experiment conducted in 2009–10 at the Indian Institute of Horticultural Research, Bangalore (Karnataka) on papaya (surya) revealed that the fruit quality parameters like total carotenoids and lycopene increased, while ascorbic acid decreased marginally due to high nutritional content in the organic treatments involving biofertilizers and vesicular arbuscular mycorrhizal fungus. Organic inputs were also found effective in citrus fruits, mangoes, pomegranate and grapes.[113]

Another study published in 2013 and undertaken at the Department of Foods and Nutrition, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad found that organically grown amaranthus had significantly higher magnesium levels than conventionally grown amaranthus. The application of poultry manures also resulted in significant increase in iron and calcium in the edible part of leaves. The application of vermicompost to the crop significantly increased in vitro iron availability, total carotenes, crude fibre, vitamin C and zinc.[114]

A field study on rice conducted between 2004–05 and 2009–10 at the Directorate of Rice Research, Hyderabad, on a black clayey vertisol soil, found improvement in elongation ratio by 4.1 per cent and a moderate improvement in nutritional quality parameters such as protein, phosphorus and potassium with organic methods.[115]

A field study conducted between 2005–06 and 2011–12 in Meghalaya highlights that most of the quality parameters of tomato (lycopene content, total sugar, total soluble solids) and carrot (total soluble solids, ascorbic acid, beta carotene) were superior under organic farming followed by integrated.[116]

The Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, highlighted through a study published in 2017, that in organically grown cabbage, tomato and cowpea, vitamin C increased by 17, 35 and 36 per cent respectively. The protein content in cowpea improved by 30 per cent, while lycopene content in tomato improved by 39 per cent. Similarly, the total phenolic compounds and peroxidase activity also improved by 44 and 38 per cent respectively. Organic farming also improved the physical attributes of vegetables. The ascorbic acid, total phenol and antioxidant content in cowpea increased with organic approach when compared to inorganic.[117]

A field study done in 2018 in Andhra Pradesh on papaya (cv. Arka Prabhat) found that application of farmyard manure and sheep manure increased quality parameters like pulp thickness, fruit firmness, ascorbic acid content, total soluble solids, total sugars, lycopene and carotenoid content as compared to recommended dose of fertilizers.[118]

The results from a long-term experiment conducted at Regional Research Station, Arnej, Gujarat on durum wheat (cv. GW-1) compared the nutritional quality of organically and chemically amended wheat on many biochemical parameters (moisture, carbohydrate, oil, protein, ash, fibre and water-soluble vitamins), anti-nutrients (heavy metals and phytic acid) and mineral composition (Fe, Mn, Zn and Cu). The results published in 2018 revealed that durum wheat supplemented with chemical fertilizer lowers protein, zinc and water-soluble vitamin content. Wheat grown under organic fertilizers was at par with chemically supplemented wheat for nutritional quality, but was safer due to the significantly lower content of anti-nutritional factors.[119]

Another study conducted in 2020, in the mid-hills of Meghalaya, reveals that quality parameters like starch content and ginger powder yield were significantly higher under raised bed and integrated application of nutrients (farmyard manure and vermicompost) supply. [120]

A field study done on taro (tuber crop), at ICAR-Central Tuber Crops Research Institute, Kerala published in 2020, found that organic tubers had higher dry matter, starch, sugars, phosphorus, potassium, calcium and magnesium contents.[121]

A study was conducted at the Defence Food Research Laboratory, Defence Research and Development Organization, Mysore, Karnataka, on 145 fresh samples, which included 12 types of vegetables and three sprouts—namely green leafy vegetables such as amaranthus, coriander, fenugreek leaves, mint and palak, salad vegetables such as cucumber, cabbage, tomato, green chilli, cauliflower, French beans and brinjal—collected from certified outlets selling organic and conventionally grown vegetables from the city of Mysore, Karnataka. The study indicates that organically cultivated produce was found superior than their conventionally grown counterparts in microbial quality.[122]

SECTION V:
CONCLUSION AND WAY AHEAD

Chapter 9: Conclusion

A. It is clear that the consolidated holistic evidence is in favour of organic and natural farming over chemical-dependent inorganic farming. Organic and natural farming approaches are not only profitable and sustainable but also productive. It is also evident that organic approach has fared better than integrated approach on profitability and sustainability and is at par with it in the case of productivity.

Based on the consolidated evidence, it could be concluded that:

- **On productivity** (crop yield)**:** Based on long-term results of AI-NPOF, yields with organic approach are more than inorganic approach and almost at par with integrated approach across different crops representing multiple food groups (see *Table 13: Productivity (crop yield) based on AI-NPOF results during 2014–19*).

  Based on other scientific studies, there is evidence that in comparison to inorganic approach, yields improve with organic inputs and bio-inputs after some time.

- **On profitability** (cost of cultivation, income and livelihood)**:** Based on AI-NPOF, gross returns, net returns and benefit-cost ratio are much better with organic approach than with the inorganic and integrated approaches. This is despite high cost of cultivation observed with organic approach, largely due to external procurement of organic or bio-inputs for experimental farms. It is also clear that results with integrated approach were better than inorganic approach. Here too, this is despite high cost of cultivation observed with integrated approach (see *Table 14: Profitability based on AI-NPOF results during 2014-19)*.

  Most of the other scientific studies suggest that the cost of cultivation was low with organic approach due to on-farm inputs. They also indicate towards high profitability through better gross returns, net returns and benefit-cost ratio as well as secured and sustainable livelihoods with organic approach. With natural farming, it was clear that all these parameters were favourable due to low input costs as well as possibility of regular income due to multi-cropping.

- **On sustainability** (soil and environment): Based on AI-NPOF results, organic approach was much better than inorganic in soil macro and micronutrients, organic carbon and rhizosphere microbial population. It was also better than integrated approach in all except in the cases of potassium, iron, manganese and bulk density. Integrated approach also led to better results than inorganic in all cases suggesting that lesser chemicals lead to better results on sustainability parameters (see *Table 15: Sustainability based on AI-NPOF results during 2014-19*).

The other scientific studies, in addition to above parameters, also provided favourable evidence on earthworms, soil moisture content, soil water holding capacity and biodiversity with organic approach. This evidence also highlighted benefits with organic approach, related to carbon sequestration, carbon pool, and carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions. With natural farming, in addition to those with organic approach, studies pointed towards resilient crops, energy and water efficiency and conservation, plant and animal biodiversity, and climate mitigation.

- **On food quality:** Based on AI-NPOF results, it is clear that results with organic approach are much better than inorganic approach and slightly better than integrated approach. Results with integrated are better than inorganic.

  The other scientific studies revealed similar results with organic approach in comparison to inorganic on several additional crops and parameters.

B. It is also clear that the strength of this consolidated evidence is high. It is holistic, comprehensive and robust. This is because:

- **Instead of focussing on one or two aspects, it covers almost all relevant aspects such as yield, income, soil health and food quality.** The benefits of agro-ecological practices are best understood if all relevant aspects are collectively addressed; rather than just one, such as yield, which has been the focus historically.

- **In addition to the organic approach, evidence is also collated and presented for natural farming.** Both are non-chemical and holistic approaches with sustainable advantages.

- **Within all relevant aspects, the evidence deep-dives into multiple dimensions.** For example, to better understand income and livelihood benefits, results of cost of cultivation, gross returns, net returns and benefit-cost ratio are analysed. Similarly, to know about benefits to soil health, evidence presented includes soil macro and micronutrients, organic carbon, and rhizosphere microbial population.

- **The comparison of organic approach is made not only with the chemical-dependent inorganic approach but also with the integrated approach that involves a mix of chemicals as well as organic practices**. It also presents a comparison of integrated approach with the inorganic approach. This comparison among three approaches is based on six methods (two within each approach).

- **Two robust sets of results that complement each other are presented**. These include the research conducted over a long-term by a wide network of scientific community across several locations in the country reflecting multiple ecosystems and agro-climatic zones/regions.

C. It is also clear that one major part of this evidence, which is developed based on results of the AI-NPOF, failed to receive the attention that it deserved by policy makers and larger scientific community at the centre as well as in states.

AI-NPOF is the central government's long-term and large-scale project under the Indian Council of Agricultural Research, Ministry of Agriculture and Famers' Welfare and the results, which are published annually, are loud and clear in favour of organic and integrated farming approaches. On the other hand, the ongoing action to promote organic farming by the governments has largely been half-hearted, unambitious and underfunded. For example, flagship programme PKVY (Paramparagat Krishi Vikas Yojna) has an annual budget of just few hundred crore rupees compared to a subsidy of Rs 1,31,230 crore in 2020–21 for chemical fertilizers. This clearly suggests that policymakers and scientific community either ignored these results and/or were not adequately convinced by it and/or lacked the will to take ambitious steps away from chemical-centred ways of producing food.

Table 13: Productivity (crop yield) based on AI-NPOF results during 2014–19

Food groups	Instances where yields are highest with each of the three farming approaches (in %, based on actual values)	% times where organic or integrated approaches showed higher yield than inorganic (in %, based on mean values)	% times where organic or integrated approaches showed significantly higher yield (>20 per cent) than inorganic (% of overall higher yield, based on mean values)
Vegetables	ORG: 48 INT: 36 INO: 16	ORG: 70 INT: 63	ORG: 29 INT: 42
Oilseeds	ORG: 58 INT: 17 INO: 25	ORG: 45 INT: 45	ORG: 10 INT: 20
Pulses	ORG:32 INT:42 INO: 26	ORG: 67 INT: 62	ORG: 21 INT: 54
Spices	ORG: 32 INT: 54 INO: 14	ORG: 63 INT: 88	ORG: 80 INT: 43
Cereals	ORG: 35 INT: 32 INO: 33	ORG: 22 INT: 37	ORG: 27 INT: 17

Note: Mean values reflect mean of actual values for the year 2014–2019

Table 14: Profitability based on AI-NPOF results during 2014-19

Cost, income and profitability	% of cropping systems showing highest mean values with each of the three approaches	% of cropping systems showing higher mean values with organic or integrated approaches over inorganic	% of cropping systems showing significantly higher (>20 per cent) mean values with organic or integrated approaches over inorganic (% of overall higher)
Cost of cultivation	ORG: 63 INT: 8 INO: 29	ORG: 81 INT: 71	ORG: 67 INT: 36
Gross returns	ORG: 49 INT: 15 INO: 36	ORG: 74 INT: 67	ORG: 82 INT: 20
Net returns	ORG: 64 INT: 11 INO: 25	ORG: 67 INT: 56	ORG: 88 INT: 12
Benefit-cost ratio	ORG: 21 INT: 13 INO: 66	ORG: 56 INT: 34	ORG: 53 INT: 29

Note: Mean values reflect mean of actual values for the year 2014–2019

Table 15: Sustainability based on AI-NPOF results during 2014-19

Soil health parameters		% of cropping systems showing highest mean values with each of the three approaches	% of cropping systems showing higher mean values with organic or integrated approaches over inorganic	% of cropping systems showing significantly higher (>20 per cent) mean values with organic or integrated approach over inorganic (% of overall higher)
Organic carbon and soil available macronutrients	Organic carbon	ORG: 91 INT: 9 INO: 0	ORG: 97 INT: 94	ORG: 67 INT: 44
	Available nitrogen	ORG: 57 INT: 21 INO: 22	ORG: 74 INT: 62	ORG: 12 INT: 11
	Available phosphorus	ORG: 58 INT: 23 INO: 19	ORG: 74 INT: 69	ORG: 52 INT: 47
	Available potassium	ORG: 53 INT: 28 INO: 19	ORG: 69 INT: 76	ORG: 21 INT: 13

Soil health parameters		**% of cropping systems showing highest mean values with each of the three approaches**	**% of cropping systems showing higher mean values with organic or integrated approaches over inorganic**	**% of cropping systems showing significantly higher (>20 per cent) mean values with organic or integrated approach over inorganic (% of overall higher)**
Bulk density and rhizosphere microbial population	Bulk density*	ORG: 52 INT: 34 INO: 14	ORG: 75 INT: 79	ORG: 0 INT: 0
	Bacteria	ORG: 84 INT: 13 INO: 03	ORG: 91 INT: 81	ORG: 86 INT: 65
	Fungi	ORG: 72 INT: 13 INO: 16	ORG: 78 INT: 66	ORG: 76 INT: 52
	Soil actinomycetes	ORG: 69 INT: 25 INO: 06	ORG: 84 INT: 34	ORG: 56 INT: 73
	Phosphate solubilizing bacteria	ORG: 76 INT: 10 INO: 14	ORG: 81 INT: 19	ORG: 47 INT: 50
Soil available micronutrients**	Iron	ORG: 74 INT: 21 INO: 05	ORG: 90 INT: 100	ORG: 65 INT: 53
	Manganese	ORG: 63 INT: 37 INO: 0	ORG: 90 INT: 100	ORG: 71 INT: 58
	Zinc	ORG: 89 INT: 11 INO: 0	ORG: 100 INT: 100	ORG: 89 INT: 72
	Copper	ORG: 78 INT: 22 INO: 0	ORG: 89 INT: 61	ORG: 50 INT: 46

* In the case of the bulk density, values reflect lowest and lower instead of highest and higher.
** For soil available micronutrients, results are based on actual values for 2018-19

Chapter 10: Way ahead

1. **It is critical that the evidence consolidated is well recognized and accepted by the larger scientific community, which can play a big role in spreading awareness, building capacity and influencing policymakers.** The larger scientific community in the country, which has been trained in chemical-based agriculture, should not outrightly reject this due to any bias and instead carefully review results of the work done by their scientific colleagues in different parts of the country. Due recognition by them would go a long way in changing the mindset of all stakeholders including farmers and consumers. The scientific community is instrumental in creating an understanding about the evidence and pushing the message across the length and breadth of this country among decision-makers at the centre and states and those involved in delivering extension services on the ground.

2. **It is important that the holistic evidence consolidated on organic and natural farming is considered, while assessing their benefits and advantages, instead of just focussing singularly on yield.** This means that the paradigm of evaluating agro-ecological approaches should not be limited to yield as the benefits of these approaches are holistic. Focussing on just yield has so far prevented ambitious action. Food security related concerns of policymakers are now well addressed as results with organic are better than inorganic and almost at par with integrated approach in most cases. Wherever organic approach cannot be aimed for, integrated approach can be considered as an interim measure. Moreover, it is nutrition security that should be aimed at and which can be better achieved by agro-ecological approaches supporting multi-cropping instead of inorganic approaches that promote mono-cultures. In addition, benefits related to profitability and sustainability strongly outweigh those with inorganic approaches and, therefore, make the overall equation favourable for agro-ecological approaches.

3. **All ongoing and future action should be aligned and informed by the strong evidence consolidated in favour of organic and natural farming.** This means that status quo characterized by half-hearted, half-convinced action must not continue. There is enough evidence to support and move ahead systematically. The lack of evidence should no longer be a barrier to scale it up substantially. The existing programmes therefore need to be scaled up, expanded and properly funded. New programmes and policies on a wide range of issues must be created for an aggressive transformation.

4. **Develop a roadmap that sets the long-term agenda for adoption of agro-ecological approaches across different parts of the country** in view of its benefits on multiple and cross-cutting aspects such as nutrition, livelihood of farmers, natural resource conservation, biodiversity, resource efficiency, soil-health, disease resilience and mitigation of climate crisis. This roadmap should also consider mechanisms for incentivizing farmers to adopt agro-ecological practices such as payments for ecosystem services.

5. **Specifically, focus on supporting farmers during the transition to organic and natural farming through technical and financial support.** It is clear that apart from creating awareness and mobilizing farmers to adopt organic or natural farming, governments will have to invest in helping smooth transition, reducing their risk and creating a more sustained adoption of agro-ecological practices. This would need mission mode awareness creation, hand-holding, demonstration and incentives to cover risks, apart from ensuring availability of quality and cost-effective organic and bio inputs.

6. **A targeted, ambitious and well-funded nationwide programme developed to drive the change towards organic and natural farming**. This includes bringing together different ministries and several programmes, and outlining the centre–state relationship in terms of funds, accountability and coordination. It must also establish strong drivers such as a vibrant market that benefits farmers while addressing existing barriers.

7. **Promotion of organic fertilizers and biofertilizers instead of chemical fertilizers.** Necessary measures to adequately produce and make available quality organic fertilizers and biofertilizers at low cost should be the priority. This includes coordinated action to promote and make city compost available as an organic fertilizer along with locally produced organic inputs. Farmers should also be enabled to choose between chemical and organic fertilizers through transfer of the huge ongoing subsidies allocated for chemical fertilizers to chemical-free farming.

8. **Agriculture extension system to be enabled to lead and support the transition on the ground**. A systematic approach is required to build capacity among extension officials and enable them to be change-makers. Leveraging technology to bridge gaps in information exchange and last-mile connectivity as well as integrating practitioners in the community should be fundamental to the extension process. Organic and natural farming should be mainstreamed in agriculture education and research systems.

9. **Organic certification process should be improved to make it farmer-friendly and low cost**. Measures should be taken to address concerns about the PGS-India certification system and its implementation to make it more farmer-friendly. An alternative certification that is simpler for farmers and trustworthy for consumers could be explored for well-connected local markets. The problem could also be addressed by introducing traceability mechanisms. Implementing measures to increase the credibility and popularity of PGS certification among consumers is the need of the hour. Consumer trust will generate more demand.

10. **States should step up their action in a concerted way to promote organic and natural farming.** This should be done through a series of measures such as those related to organic seeds, bio-inputs, capacity building of farmers and providing market linkages. States can play an instrumental role in helping farmers sell their organic and natural produce by developing organic value chains, procuring organic produce and helping farmers get remunerative prices.

ANNEXURES

The graphs are based on recorded data available in AI-NPOF annual reports. It is captured for the years 2004 to 2019, wherein the first data reflects 2004–2011 followed by data for the subsequent years. In some cases, data is available for limited years and is accordingly presented. Overall data is captured for six methods with three methods starting 2014 onwards. In a few cases, it is not available entirely for six methods.

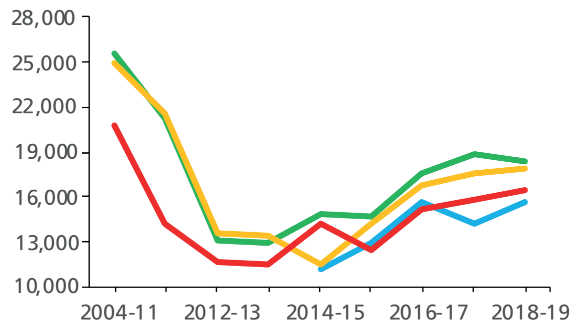
In terms of presentation, alternate years are mentioned in the graphs in view of space constraints. In a few graphs, all six methods are not visible as they are overlapped because of similar values.

In a few graphs, data for a particular year for a method is quite different from the rest, these have been retained but could possibly be outliers for multiple reasons including how the data is recorded in AI-NPOF annual reports.

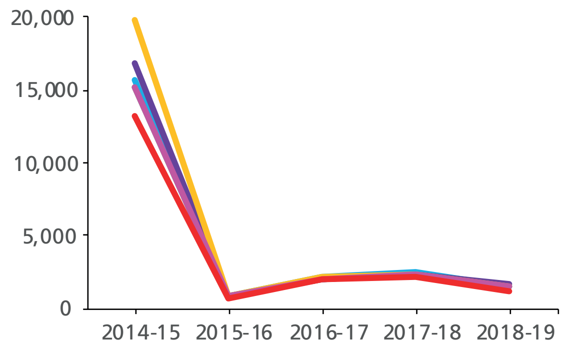
Annexure 1: Graphs showing long-term trends for yield, income and soil health

Figure 1.1: Graphs showing long-term trends for crop yield—Vegetables (kg/ha)

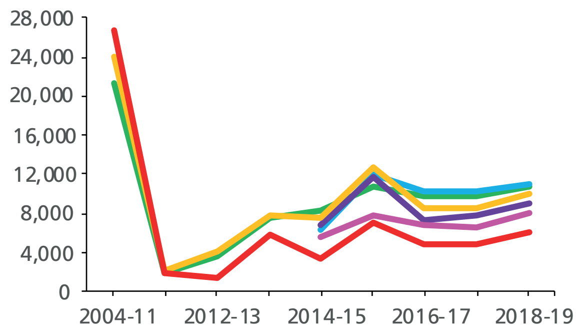
Graph 1: Tomato-Umiam (Rabi)



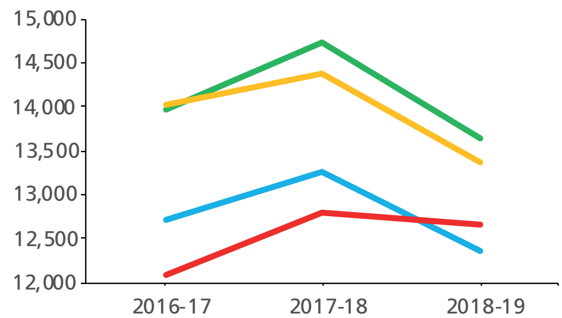
Graph 2: Tomato-Bajaura (Kharif)



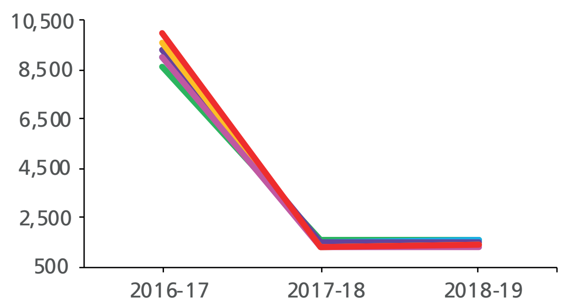
Graph 3: Tomato-Bajaura (Summer)



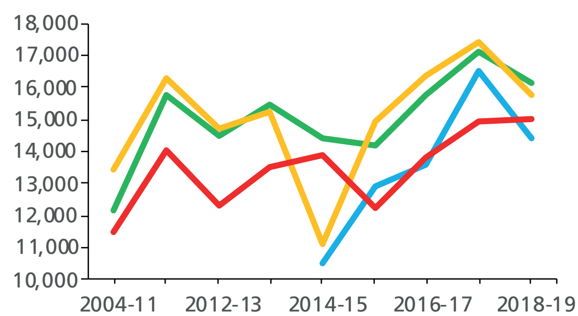
Graph 4: Broccoli-Umiam (Rabi)



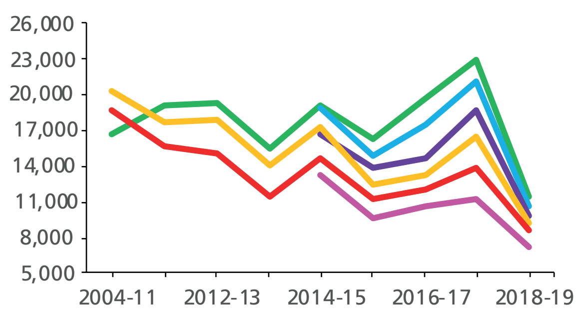
Graph 5: Broccoli-Narendrapur (Rabi)



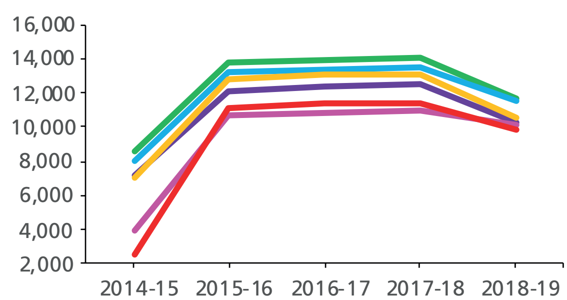
Graph 6: Potato-Umiam (Rabi)



Graph 7: Potato-Ranchi (Rabi)



Graph 8: Potato-Pantnagar (Rabi)



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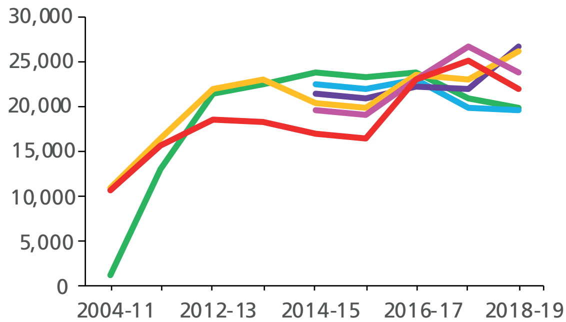
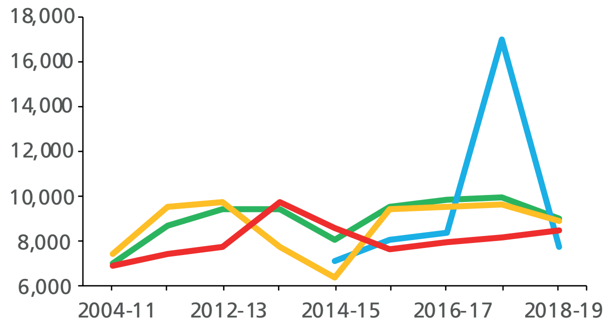
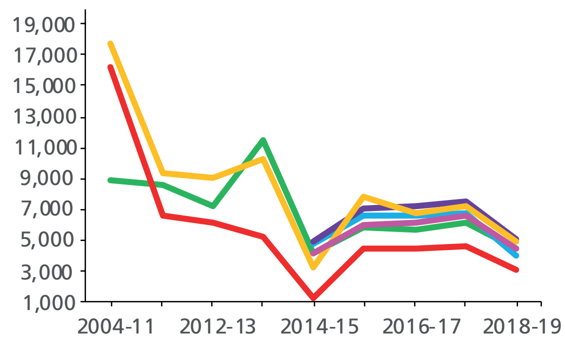
Graph 9: Potato-Modipuram (Rabi)



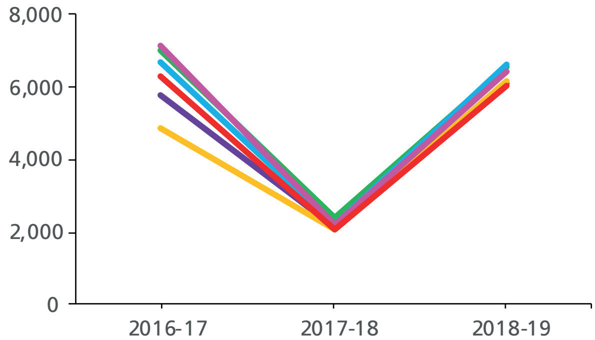
Graph 10: Frenchbean-Umiam (Rabi)



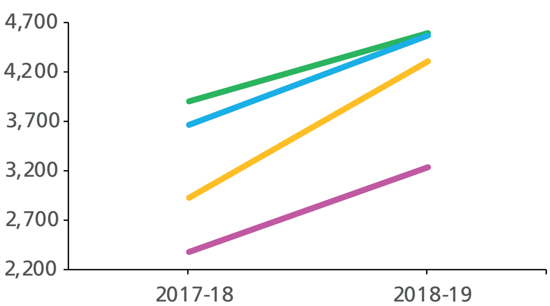
Graph 11: Frenchbean-Bajaura (Summer)



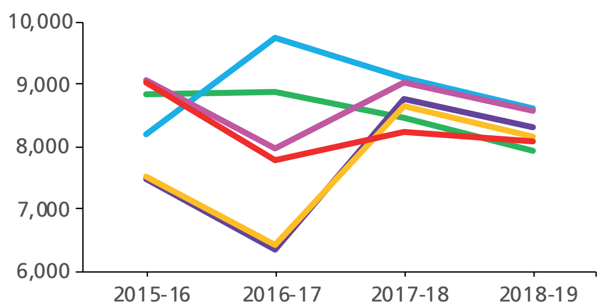
Graph 12: Frenchbean-Narendrapur (Rabi)



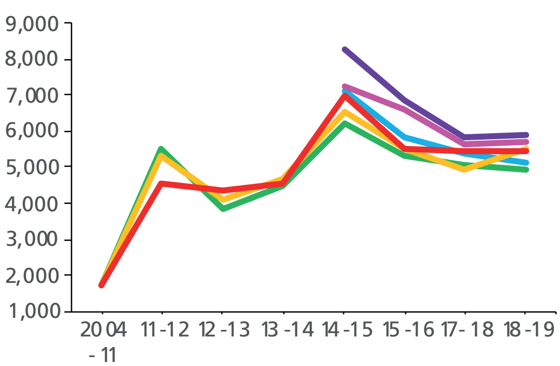
Graph 13: Frenchbean-Gangtok (Rabi)



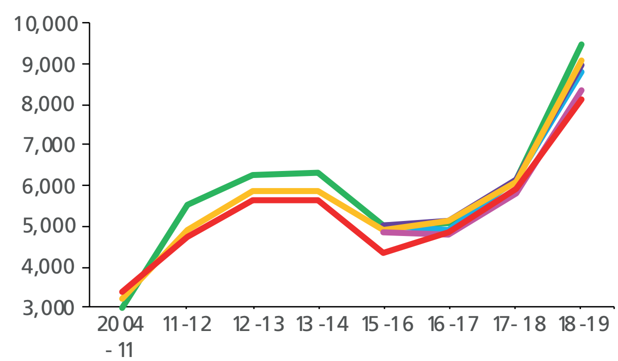
Graph 14: Chillies-Raipur-(Rabi)



Graph 15: Chillies-Coimbatore (Kharif)



Graph 16: Veg Pea-Pantnagar (Rabi)



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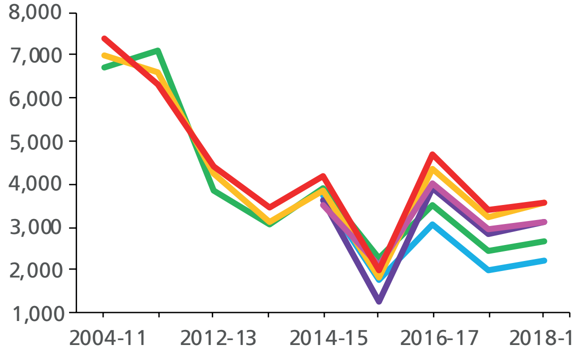
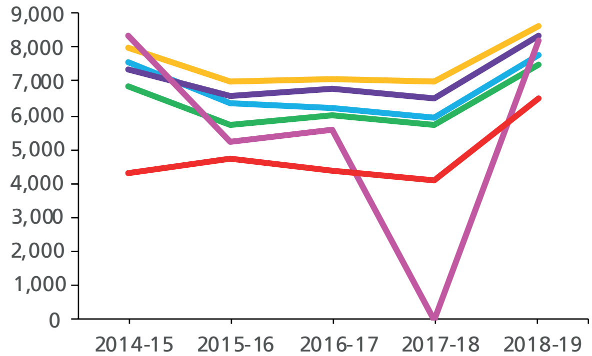
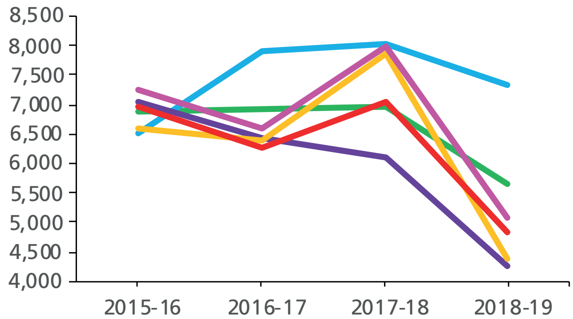
Graph 17: Veg Pea-Jabalpur (Rabi)



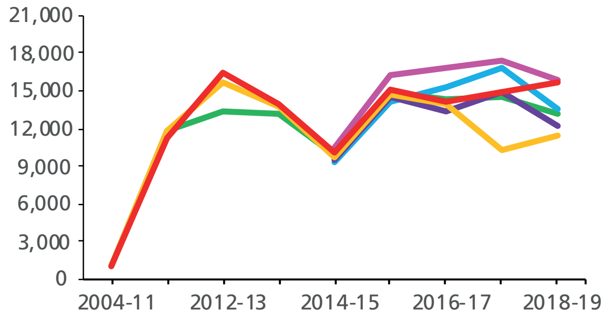
Graph 18: Veg Pea-Bajaura (Rabi)



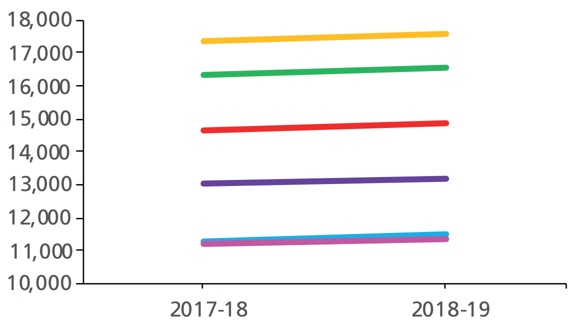
Graph 19: Veg Pea-Raipur (Rabi)



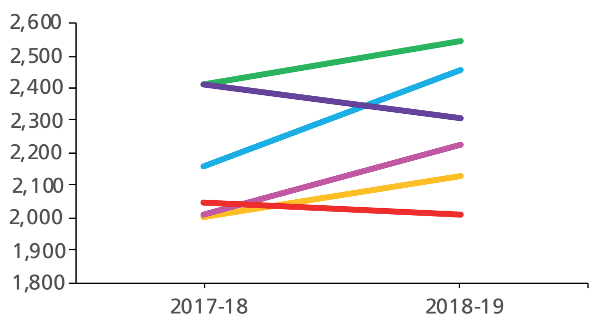
Graph 20: Onion-Raipur (Rabi)



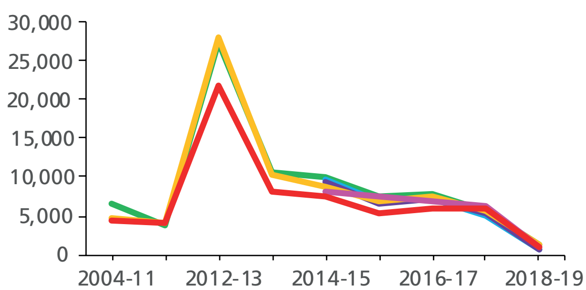
Graph 21: Onion-Karjat (Rabi)



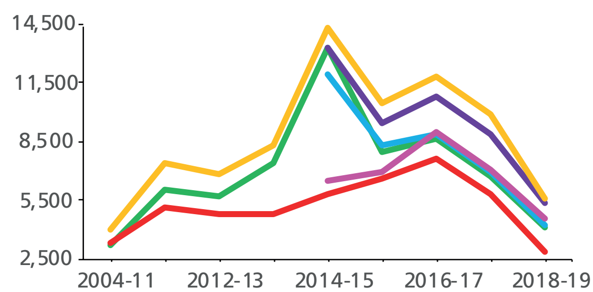
Graph 22: Capsicum-Narendrapur (Rabi)



Graph 23: Okra-Modipuram (Summer)



Graph 24: Okra-Bajaura (Kharif)



Graph 25: Cauliflower-Bajaura (Rabi)

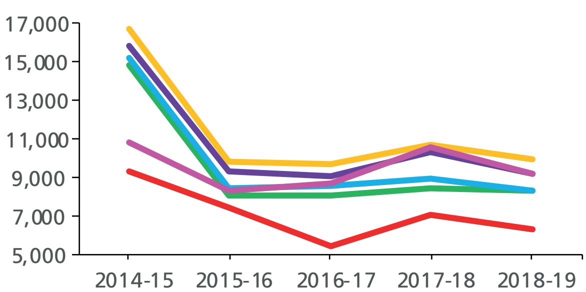
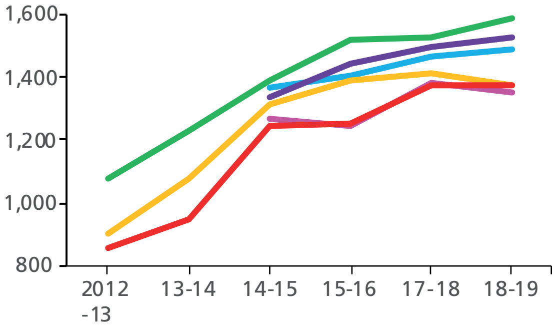
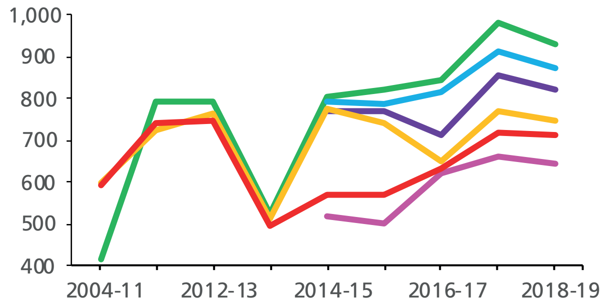


Figure 1.2: Graphs showing long-term trends for crop yield—Oilseeds (kg/ha)

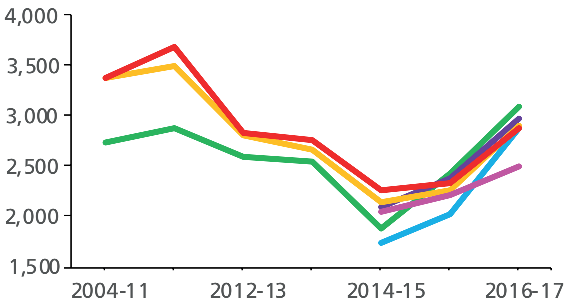
Graph 26: Linseed-Bhopal (Rabi)



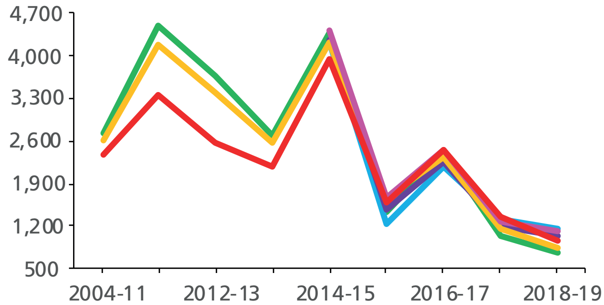
Graph 27: Linseed-Ranchi (Rabi)



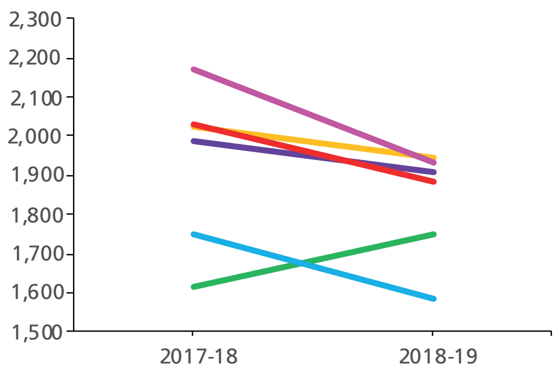
Graph 28: Groundnut-Karjat (Rabi)



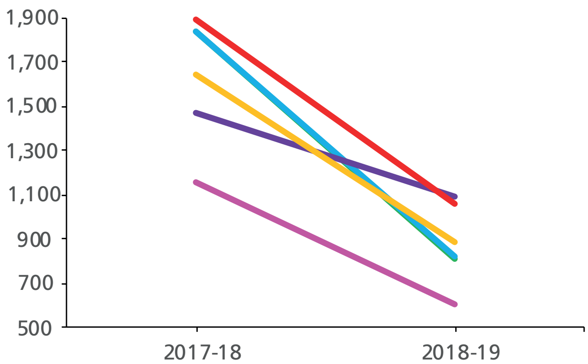
Graph 29: Groundnut-Dharwad (Kharif)



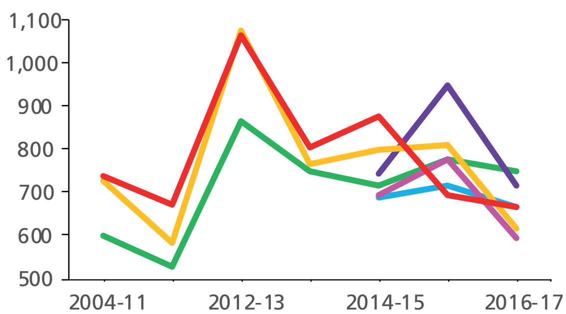
Graph 30: Groundnut -SK Nagar (Kharif)



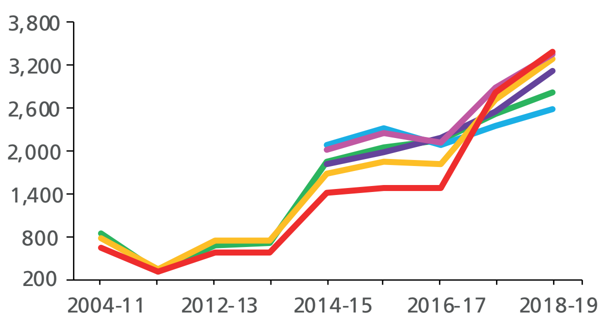
Graph 31: Groundnut-Thiruvananthapuram (Rabi)



Graph 32: Mustard-Karjat (Rabi)



Graph 33: Mustard-Modipuram (Rabi)



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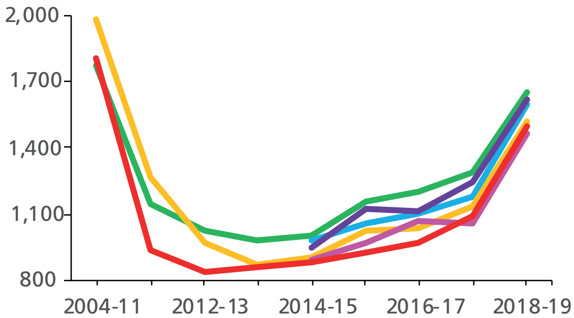
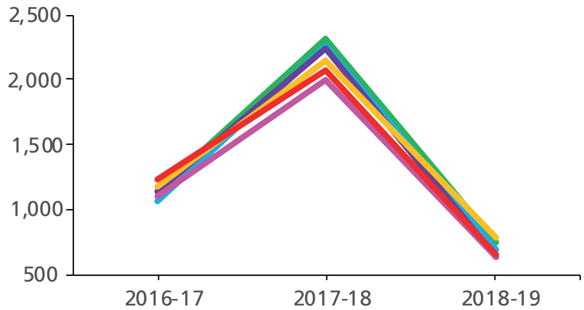
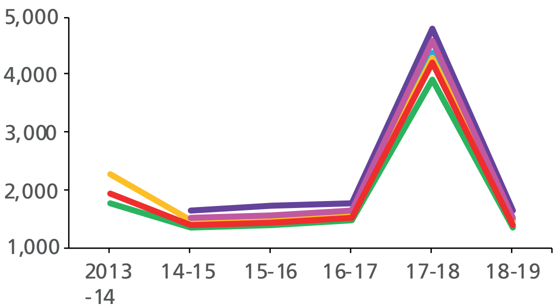
Graph 34: Mustard-Bhopal (Rabi)



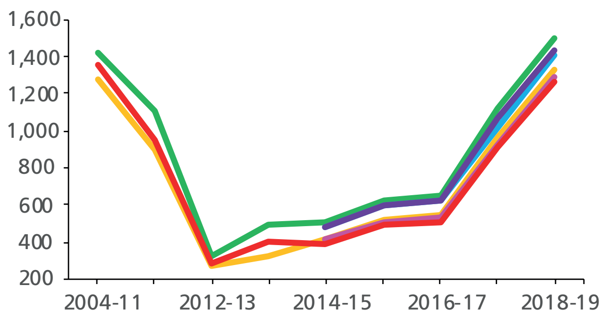
Graph 35: Mustard-Narendrapur (Rabi)



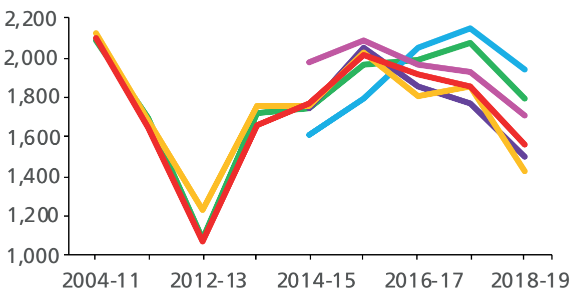
Graph 36: Sunflower (Chillies)-Coimbatore (Rabi)



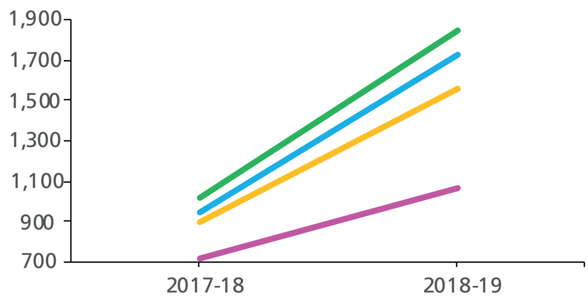
Graph 37: Soybean-Bhopal (Kharif)



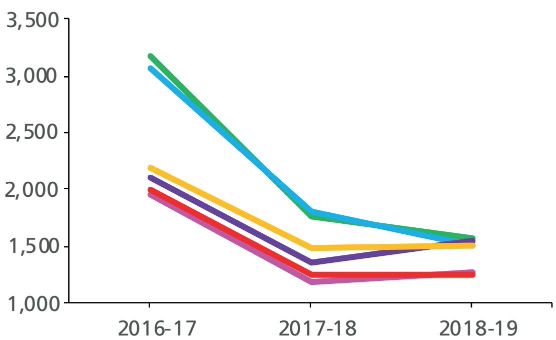
Graph 38: Soybean-Raipur (Kharif)



Graph 39: Soybean-Gangtok (Kharif)



Graph 40: Soybean-Ludhiana (Kharif)



Graph 41:Soybean-Udaipur (Kharif)

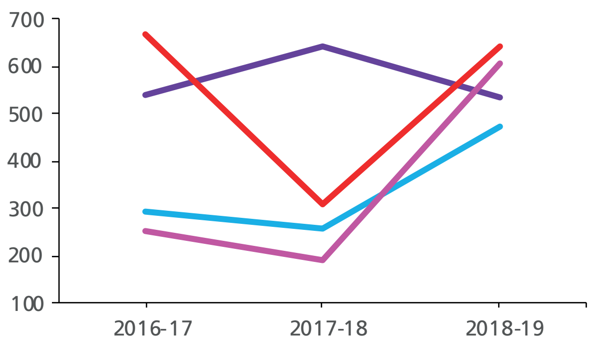


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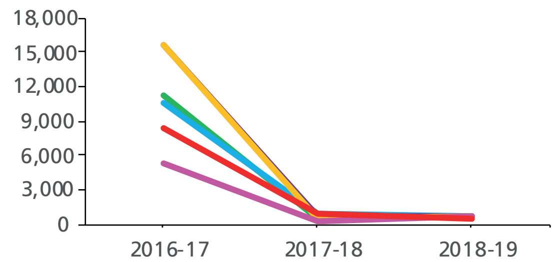
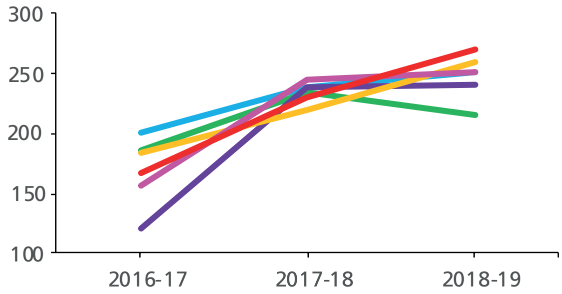
Figure 1.3: Graphs showing long-term trends for crop yield—Pulses (kg/ha)

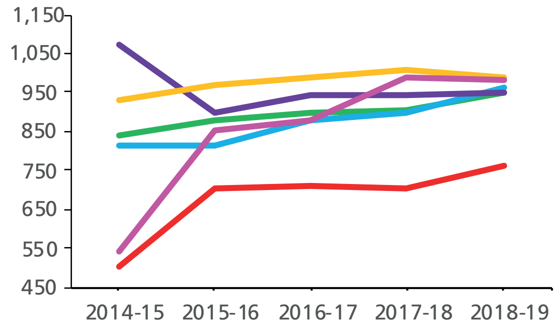
Graph 42: Blackgram-Thiruvananthapuram (Rabi)



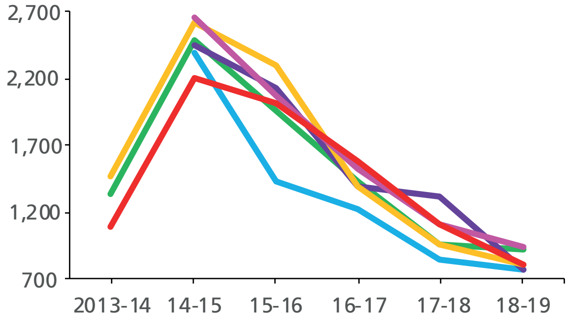
Graph 43: Blackgram-Udaipur (Kharif)



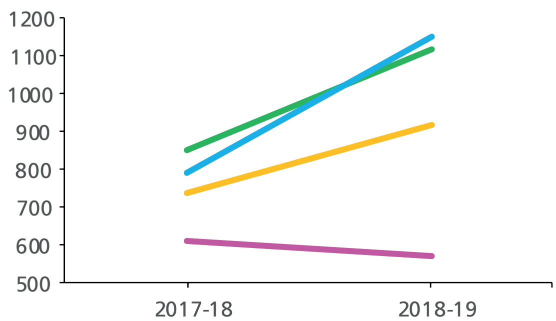
Graph 44: Blackgram -Bajaura (Kharif)



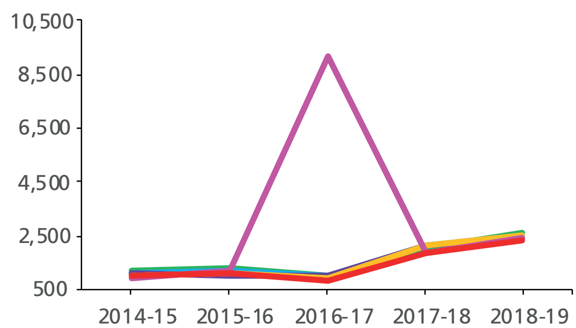
Graph 45: Pigeon pea-Dharwad (Kharif)



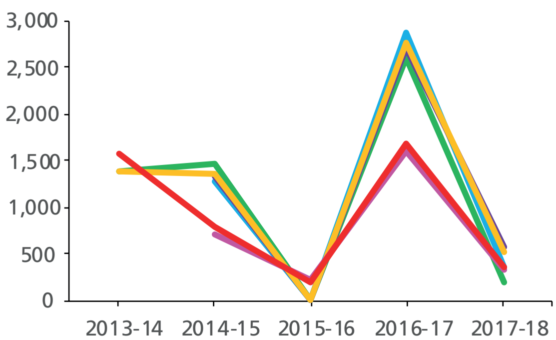
Graph 46: Pigeonpea-Gangtok (Rabi)



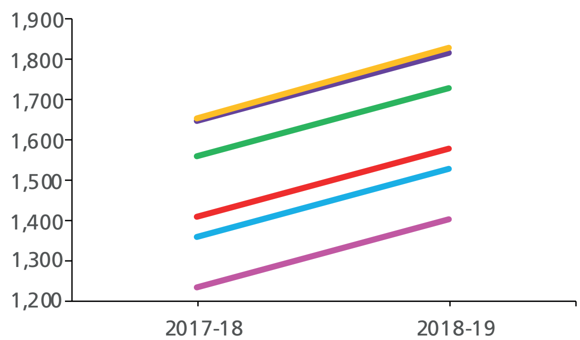
Graph 47: Chickpea-Pantnagar (Rabi)



Graph 48: Chickpea-Ludhiana (Rabi)



Graph 49: Chickpea-Karjat (Rabi)



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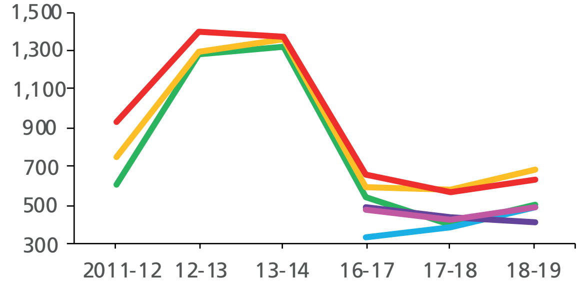
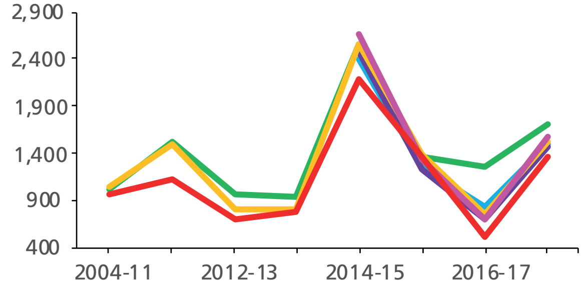
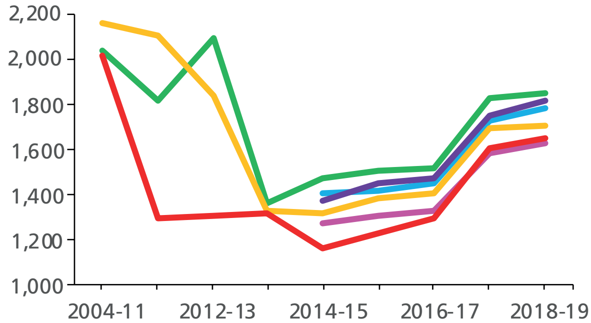
Graph 50: Chickpea-Jabalpur (Rabi)



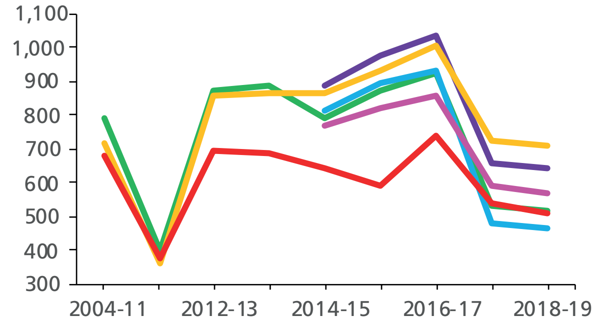
Graph 51: Chickpea (Maize)-Dharwad (Rabi)



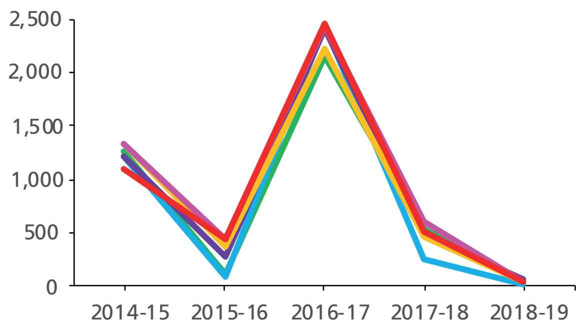
Graph 52: Chickpea-Bhopal (Rabi)



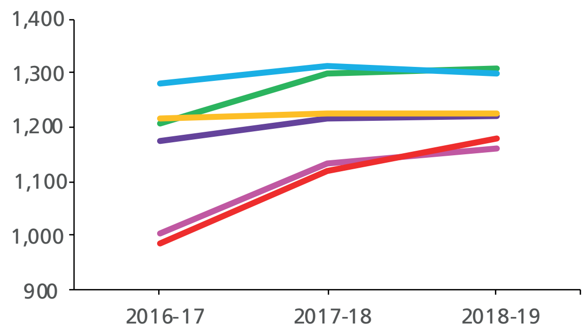
Graph 53: Green gram-Modipuram (Summer)



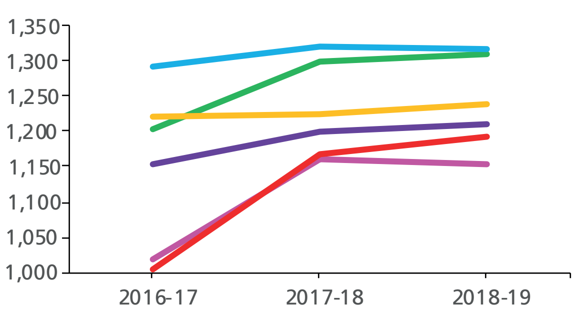
Graph 54: Green gram-Dharwad (Kharif)



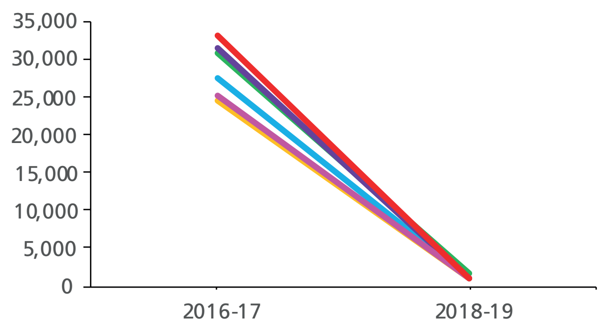
Graph 55: Greengram-Narendrapur (Summer)



Graph 56: Greengram (Paddy-Mustard)-Narendrapur (Summer)



Graph 57: Cowpea-Thiruvananthapuram (Rabi)



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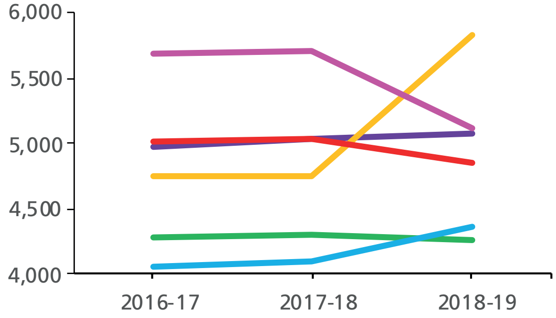
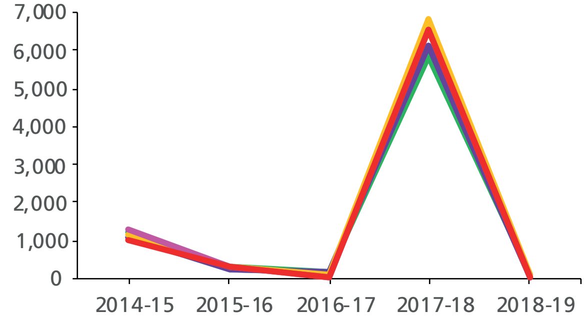
Graph 58: Cowpea-SK Nagar (Summer)



Graph 59: Cowpea-Dharwad (Kharif)



Graph 60: Lentil-Ranchi (Rabi)

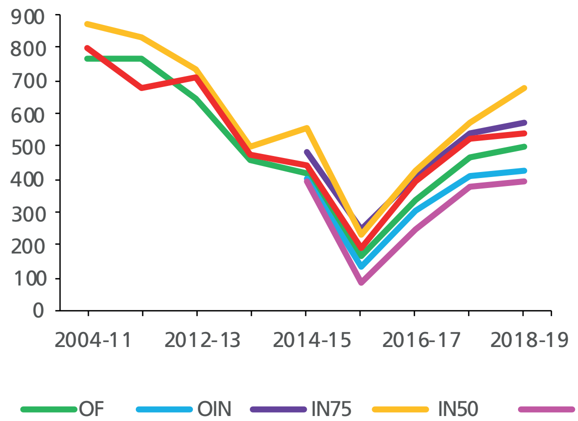
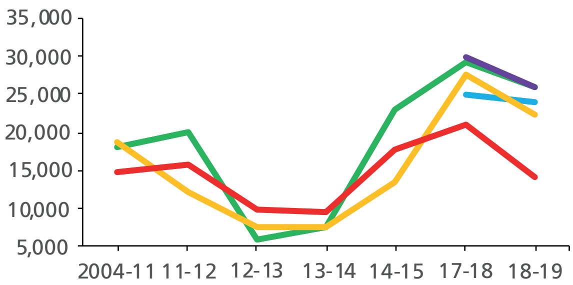
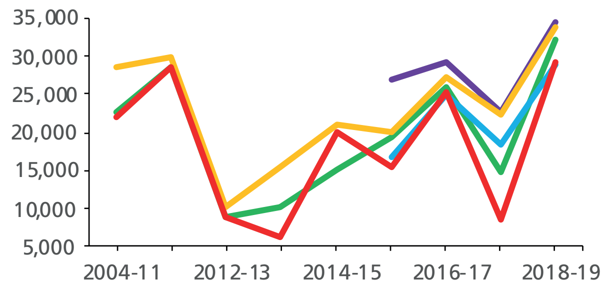


Figure 1.4: Graphs showing long-term trends for crop yield—Spices (kg/ha)

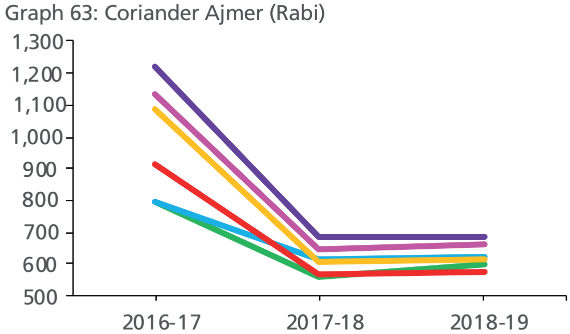
Graph 61: Ginger-Calicut (Kharif)



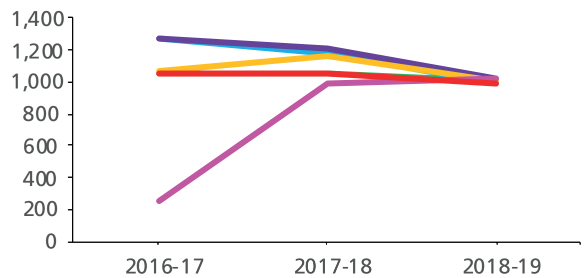
Graph 62: Turmeric-Calicut (Kharif)



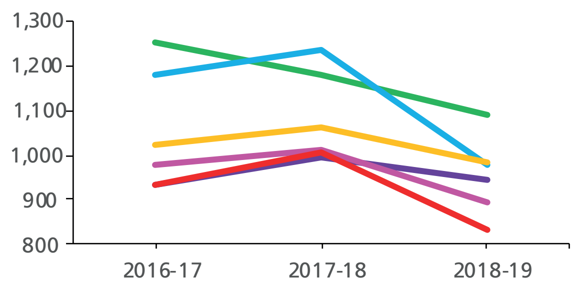
Graph 63: Coriander Ajmer (Rabi)



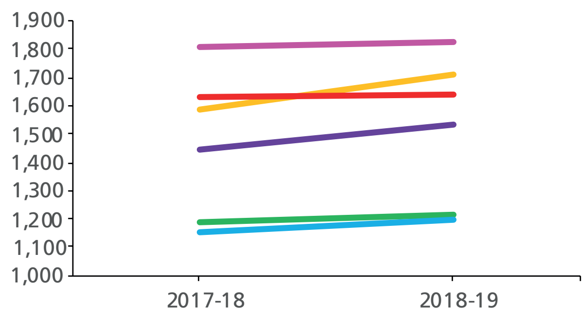
Graph 64: Coriander-Pantnagar (Rabi)



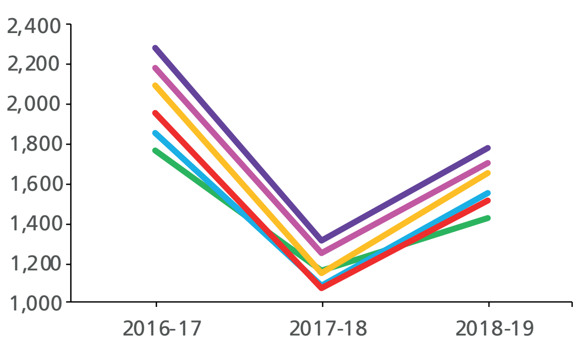
Graph 65: Coriander-Pantnagar (Rabi)



Graph 66: Fennel-SK Nagar (Rabi)



Graph 67: Fennel-Ajmer (Rabi)



Graph 68: Blackpepper-Calicut (Kharif)

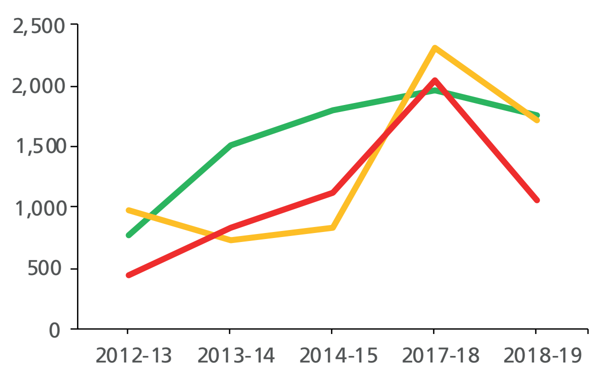


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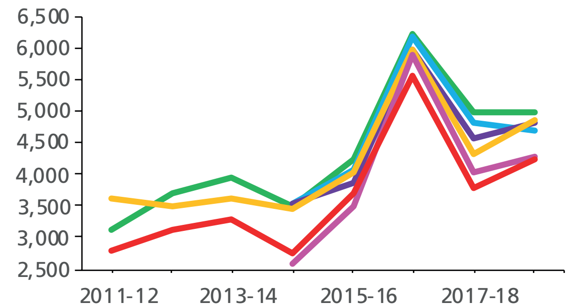
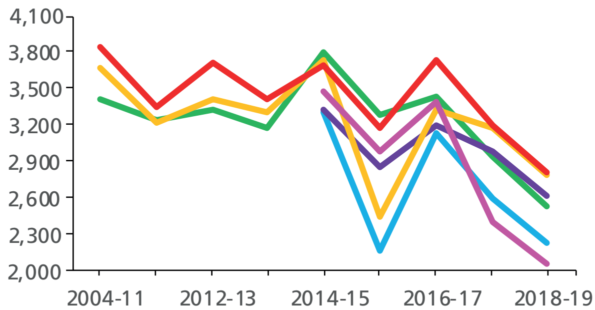
Figure 1.5: Graphs showing long-term trends for crop yield—Cereals (kg/ha)

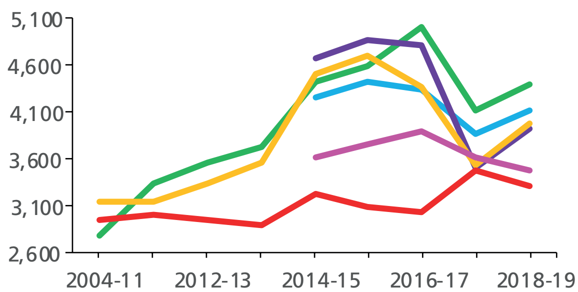
Graph 69: Basmati Rice-Pantnagar (Kharif)



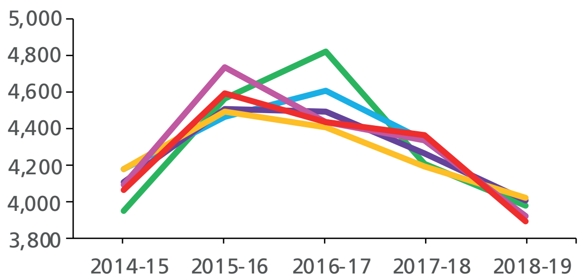
Graph 70: Basmati Rice-Jabalpur (Kharif)



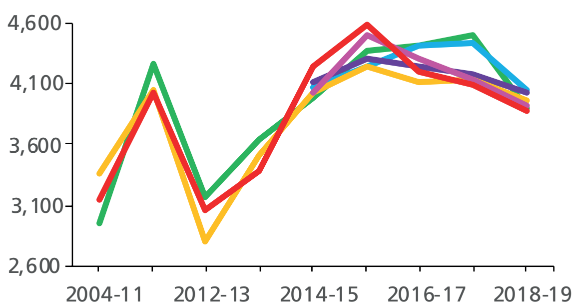
Graph 71: Basmati Rice-Modipuram (Kharif)



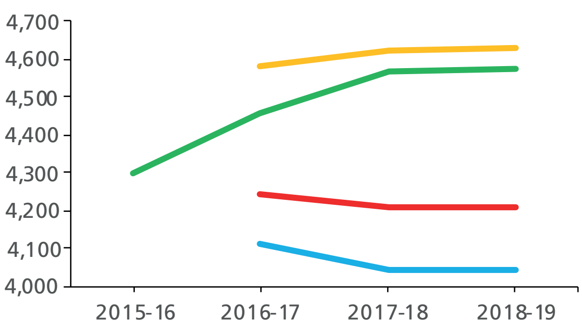
Graph 72: Basmati Rice (Chickpea)-Ludhiana (Kharif)



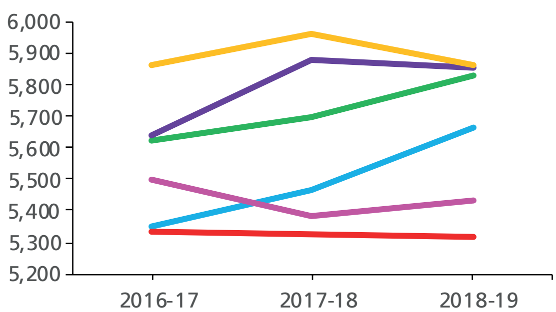
Graph 73: Basmati Rice-Ludhiana (Kharif)



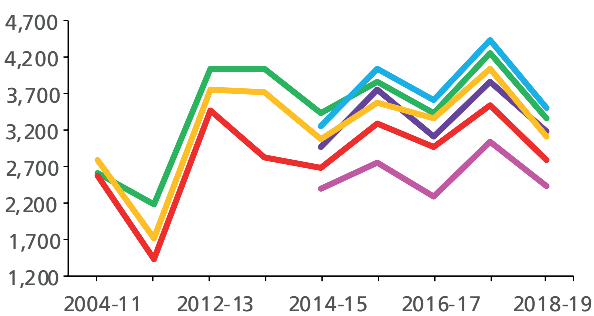
Graph 74: Rice-Umiam (Kharif)



Graph 75: Rice-Narendrapur (Kharif)



Graph 76: Rice-Ranchi (Kharif)



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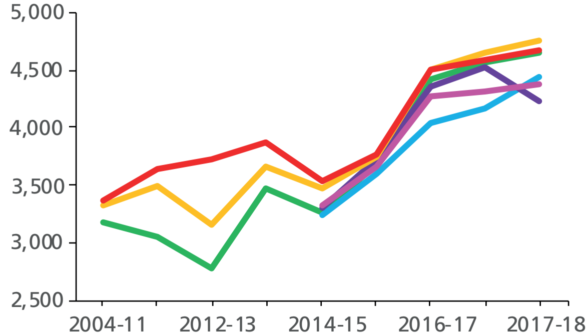
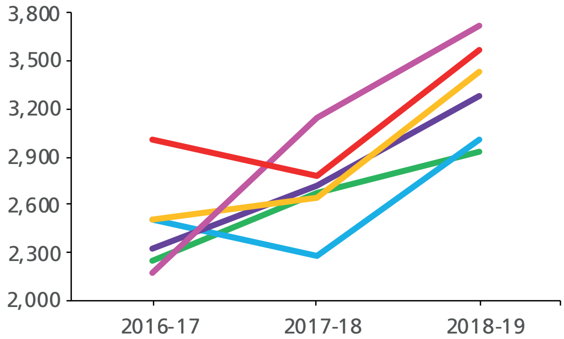
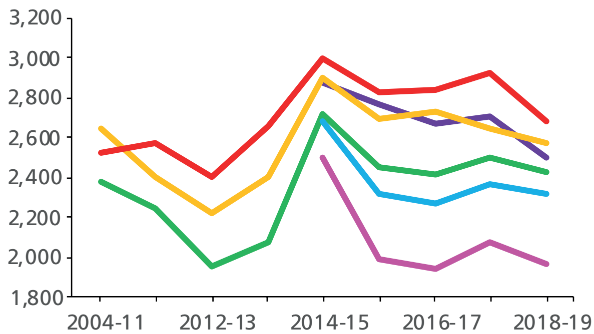
Graph 77: Rice-Karjat (Kharif)



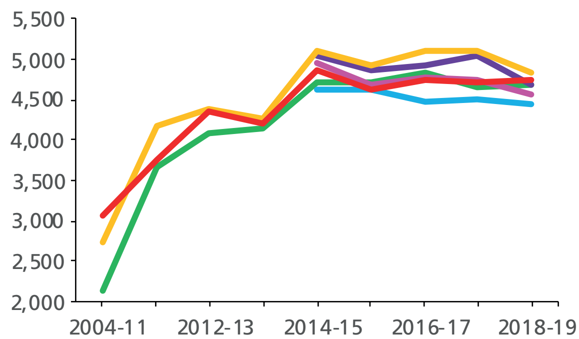
Graph 78: Wheat-Udaipur (Rabi)



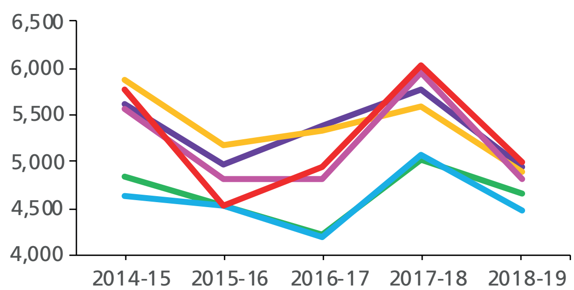
Graph 79: Wheat-Ranchi (Rabi)



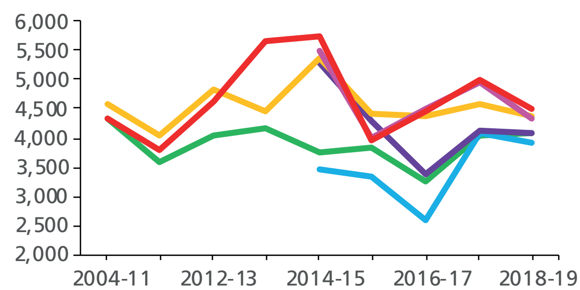
Graph 80: Wheat-Pantnagar (Rabi)



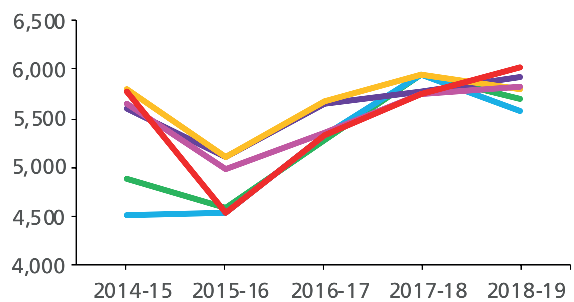
Graph 81: Wheat (with Soyabean)-Ludhiana (Rabi)



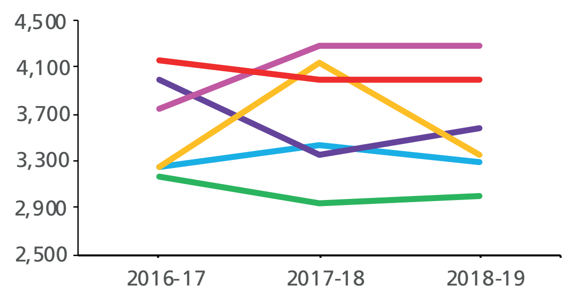
Graph 82: Wheat (with Basmati Rice)-Ludhiana (Rabi)



Graph 83: Wheat (with moong) Ludhiana (Rabi)



Graph 84: Durum wheat-Udaipur (Rabi)



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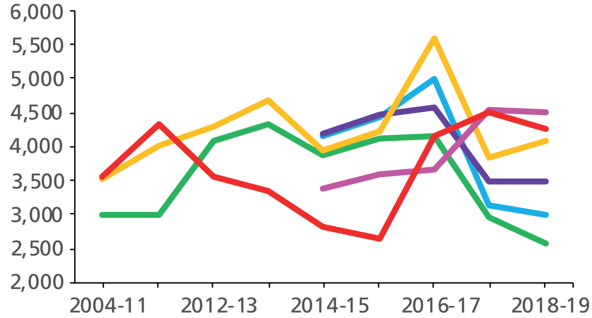
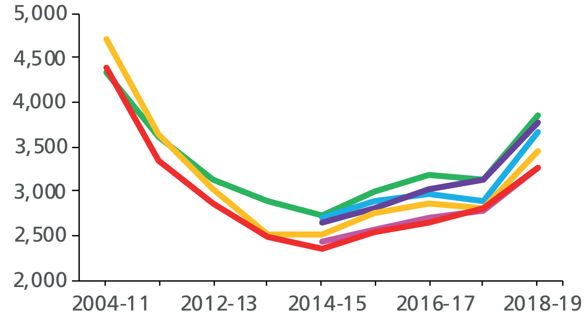
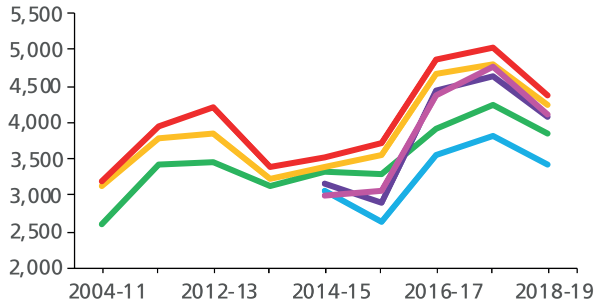
Graph 85: Durum wheat-Modipuram (Rabi)



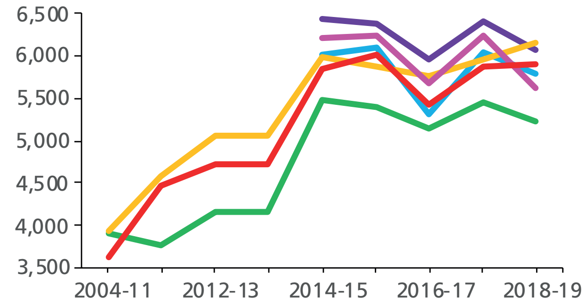
Graph 86: Durum wheat-Bhopal (Rabi)



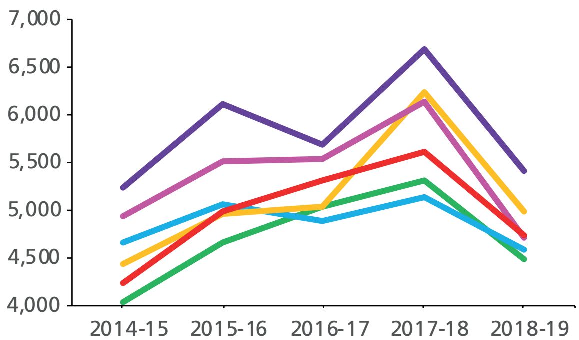
Graph 87: Durum wheat-Jabalpur (Rabi)



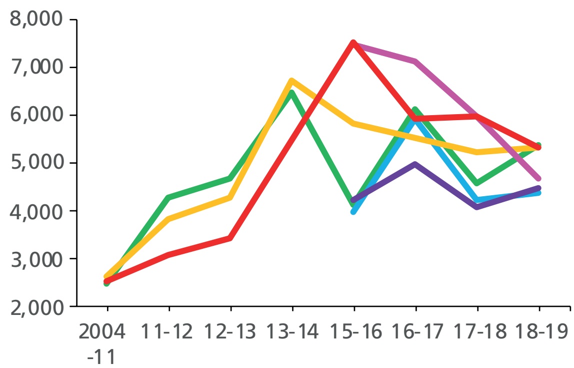
Graph 88: Maize (Cotton)-Coimbatore (Kharif)



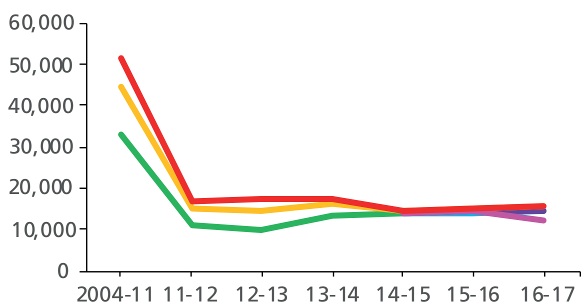
Graph 89: Maize (Beetroot)-Coimbatore (Rabi)



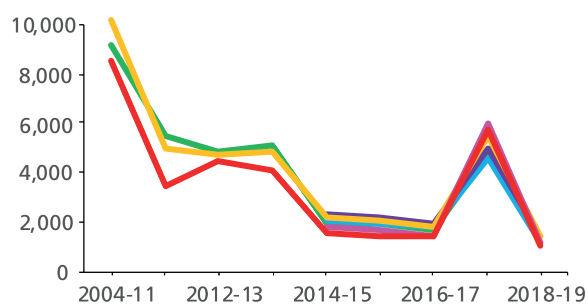
Graph 90: Maize-Dharwad (Kharif)



Graph 91: Maize-Karjat (Rabi)



Graph 92: Maize-Modipuram (Kharif)



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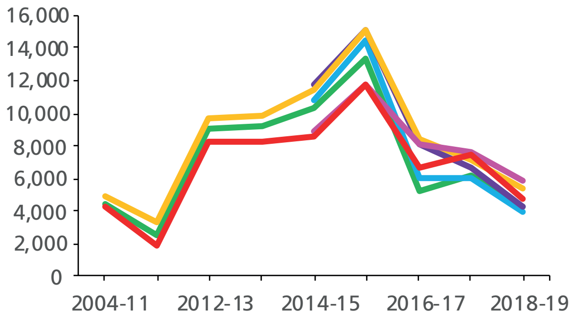
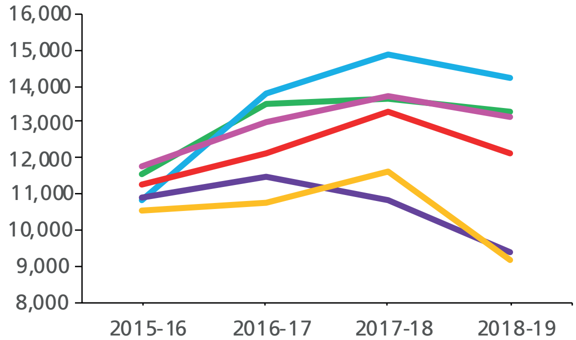
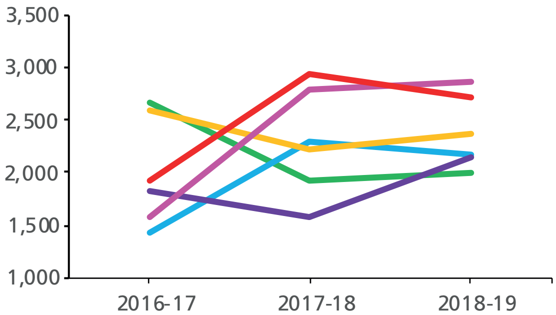
Graph 93: Maize (mustard)-Modipuram (Kharif)



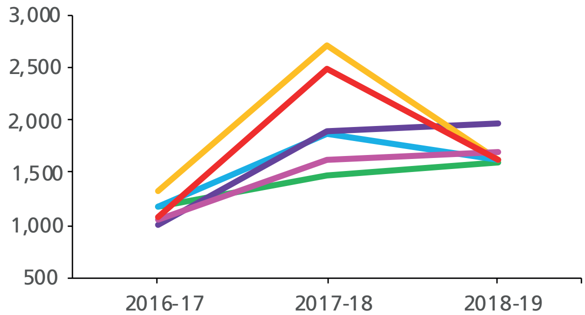
Graph 94: Maize-Raipur (Kharif)



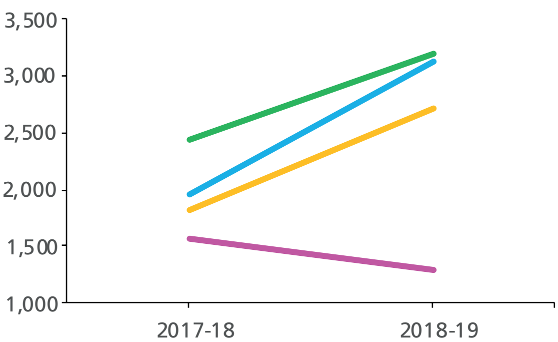
Graph 95: Maize-Udaipur (Kharif)



Graph 96: Maize-Udaipur (Kharif)



Graph 97: Maize-Gangtok (Kharif)



Graph 98: Basmati rice-Narendrapur (Kharif)

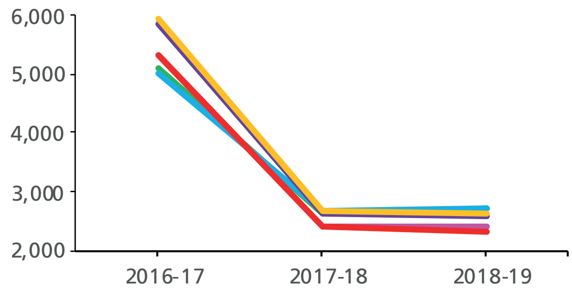


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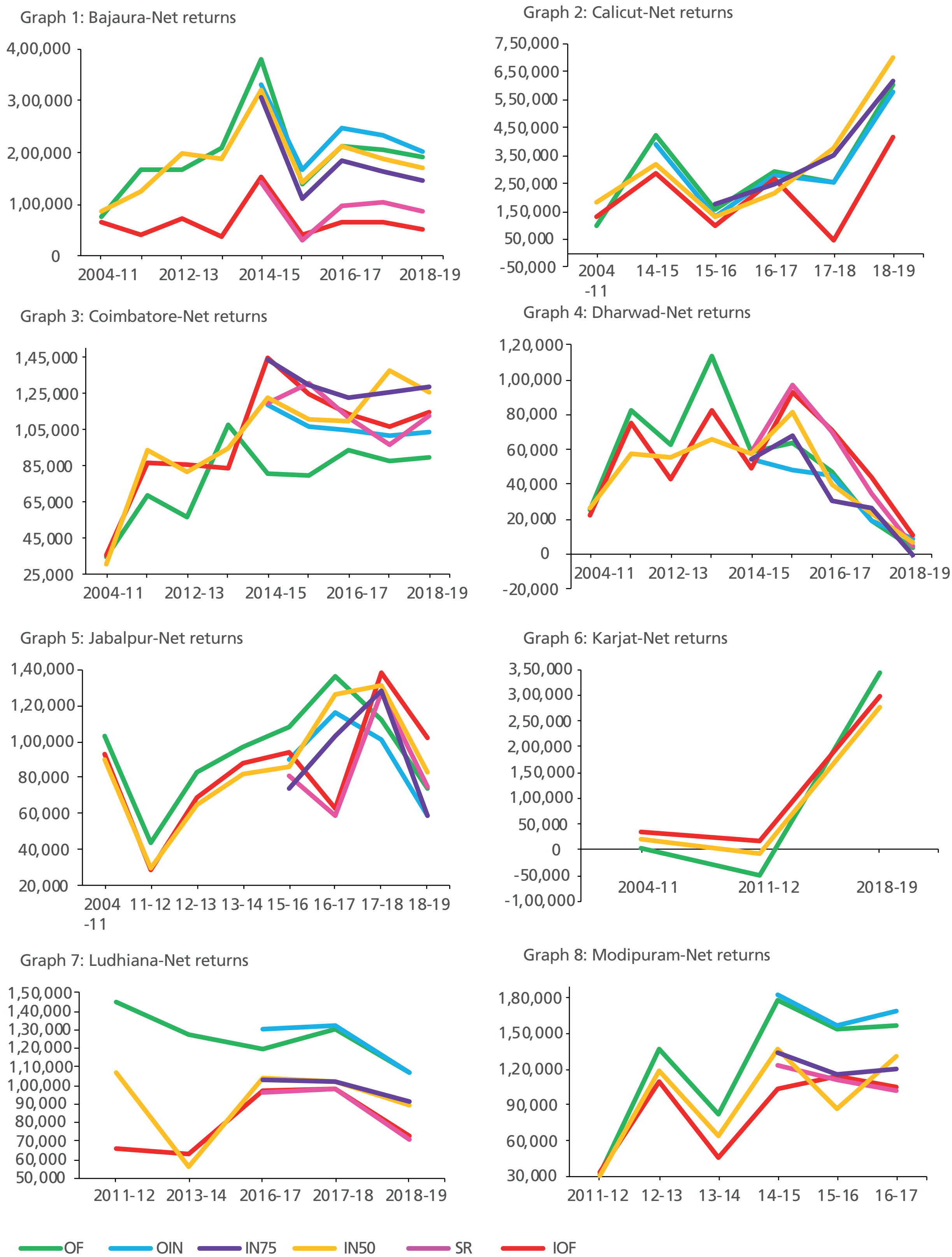
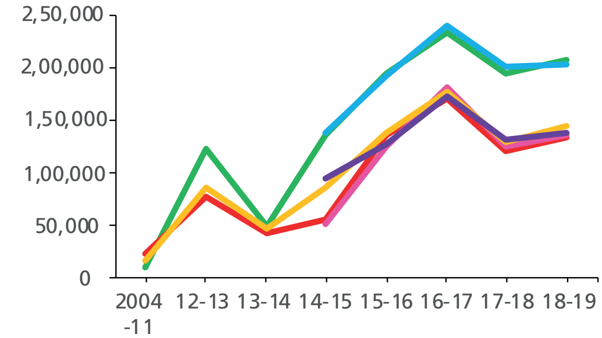
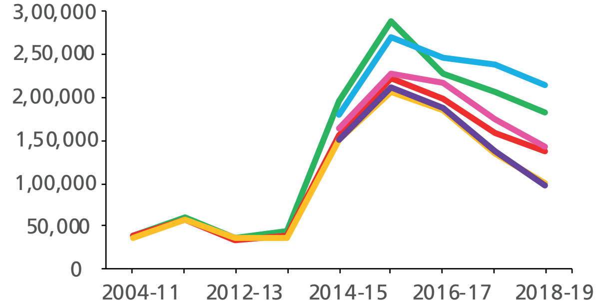
Figure 2: Graphs showing centre wise long-term trends for net returns (Rs/hectare) (2004–19)



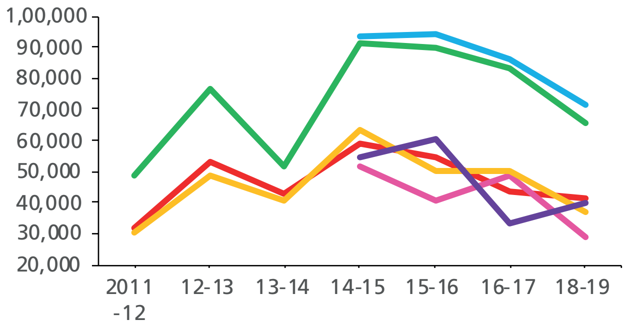
Graph 9: Pantnagar-Net returns



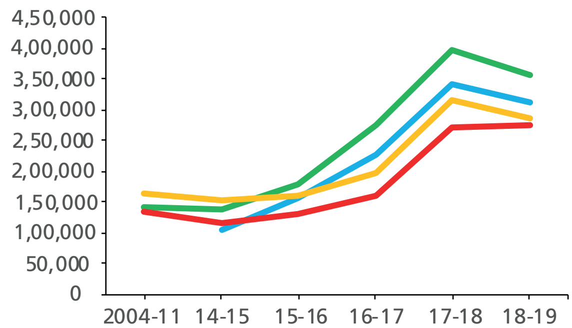
Graph 10: Raipur-Net returns



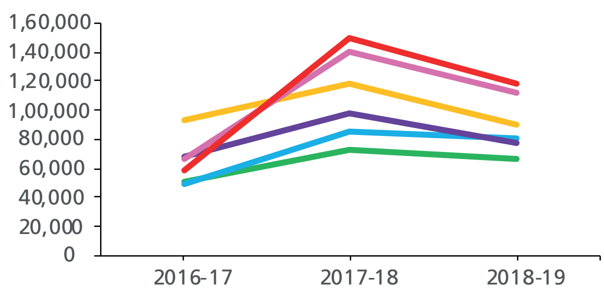
Graph 11: Ranchi-Net returns



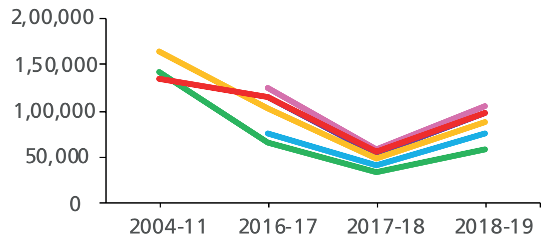
Graph 12: Umiam-Net returns



Graph 13: Udaipur-Net returns



Graph 14: Ajmer-Net returns



Graph 15: Sardar Krushinagar-Net returns

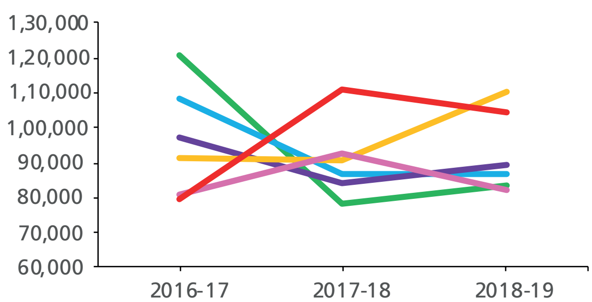
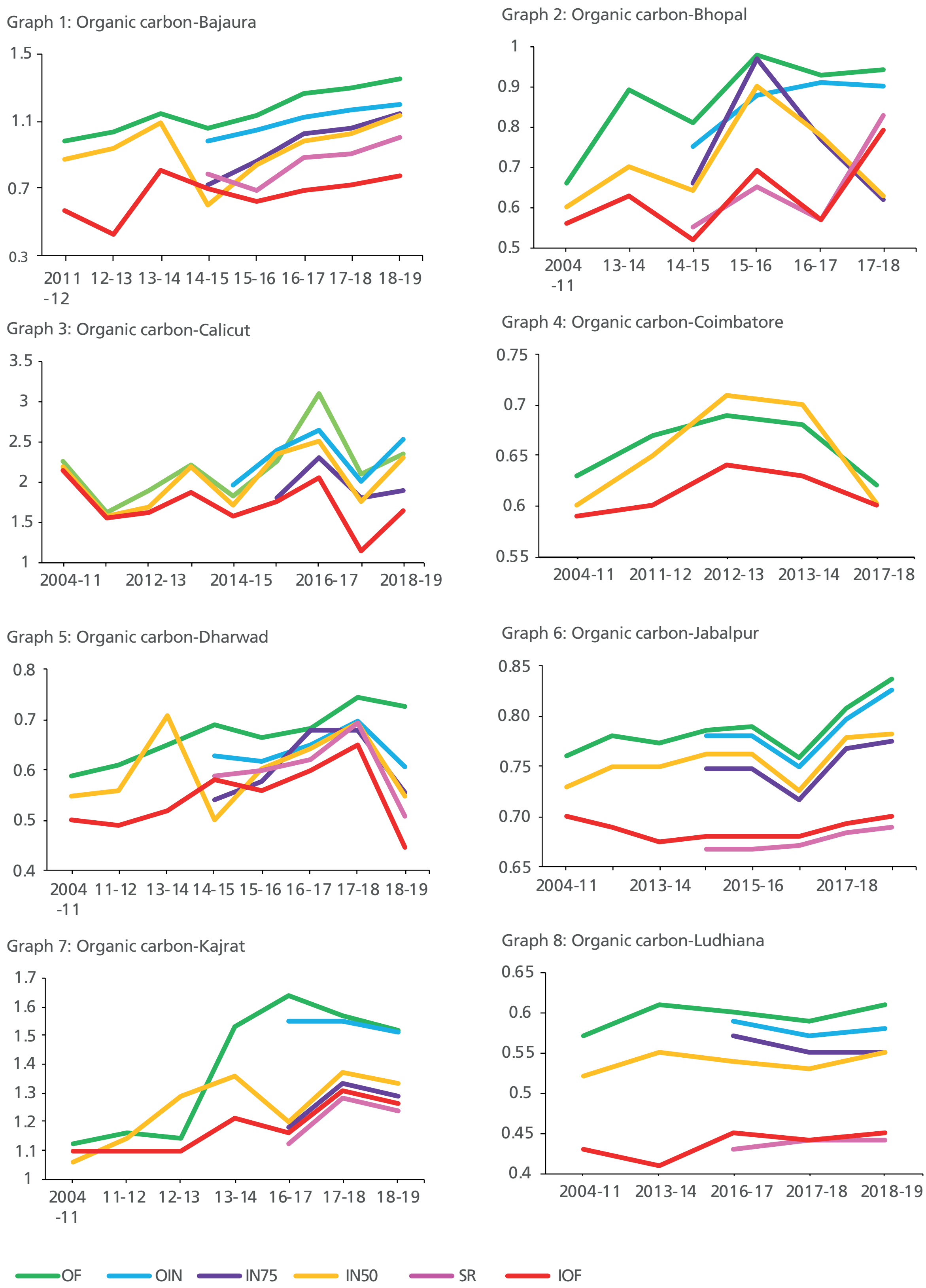
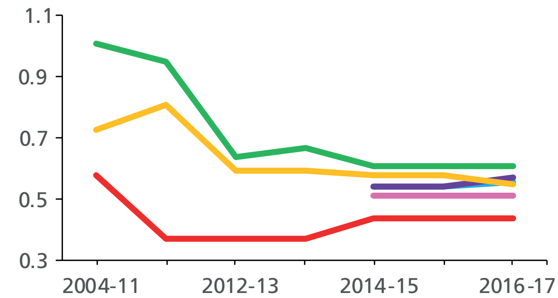


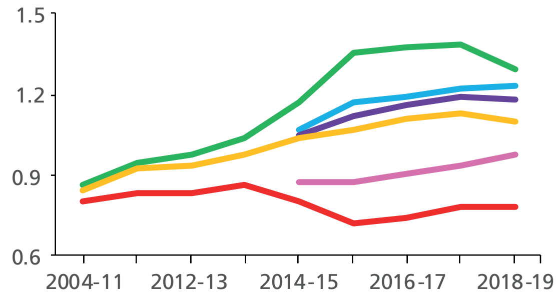
Figure 3.1: Graphs showing centre wise long-term trends for organic carbon (per cent)



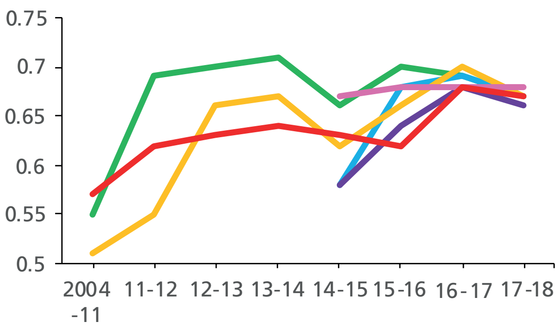
Graph 9: Organic carbon-Modipuram



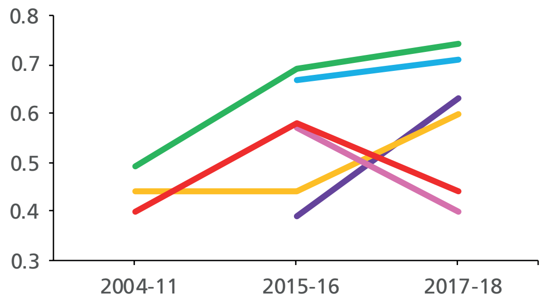
Graph 10: Organic carbon-Pantnagar



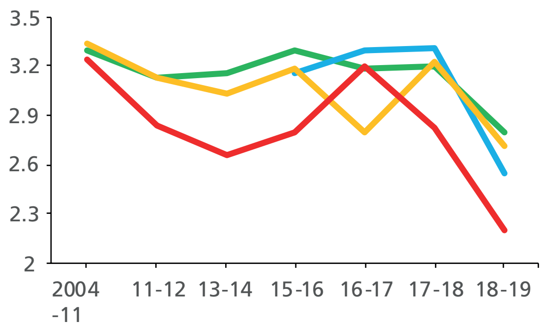
Graph 11: Organic carbon-Raipur



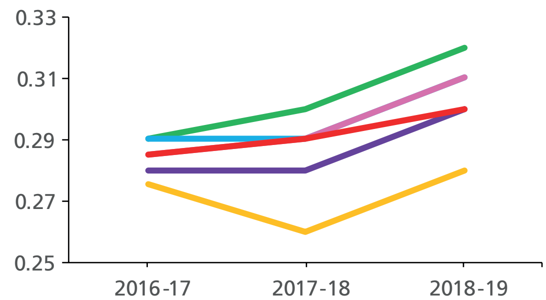
Graph 12: Organic carbon-Ranchi



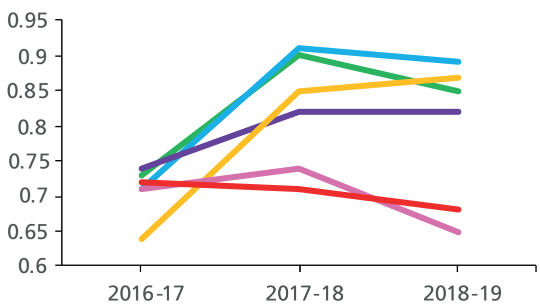
Graph 13: Organic carbon-Umian



Graph 14: Organic carbon-Ajmer



Graph 15: Organic carbon-Narendrapur



Graph 16: Organic carbon-SardarKrushinagar

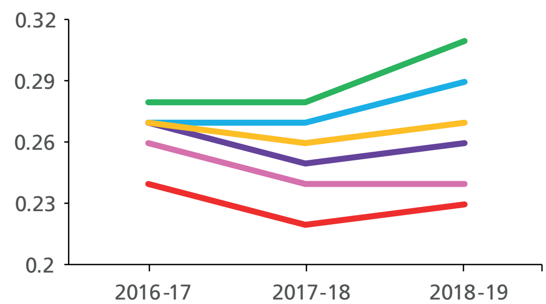


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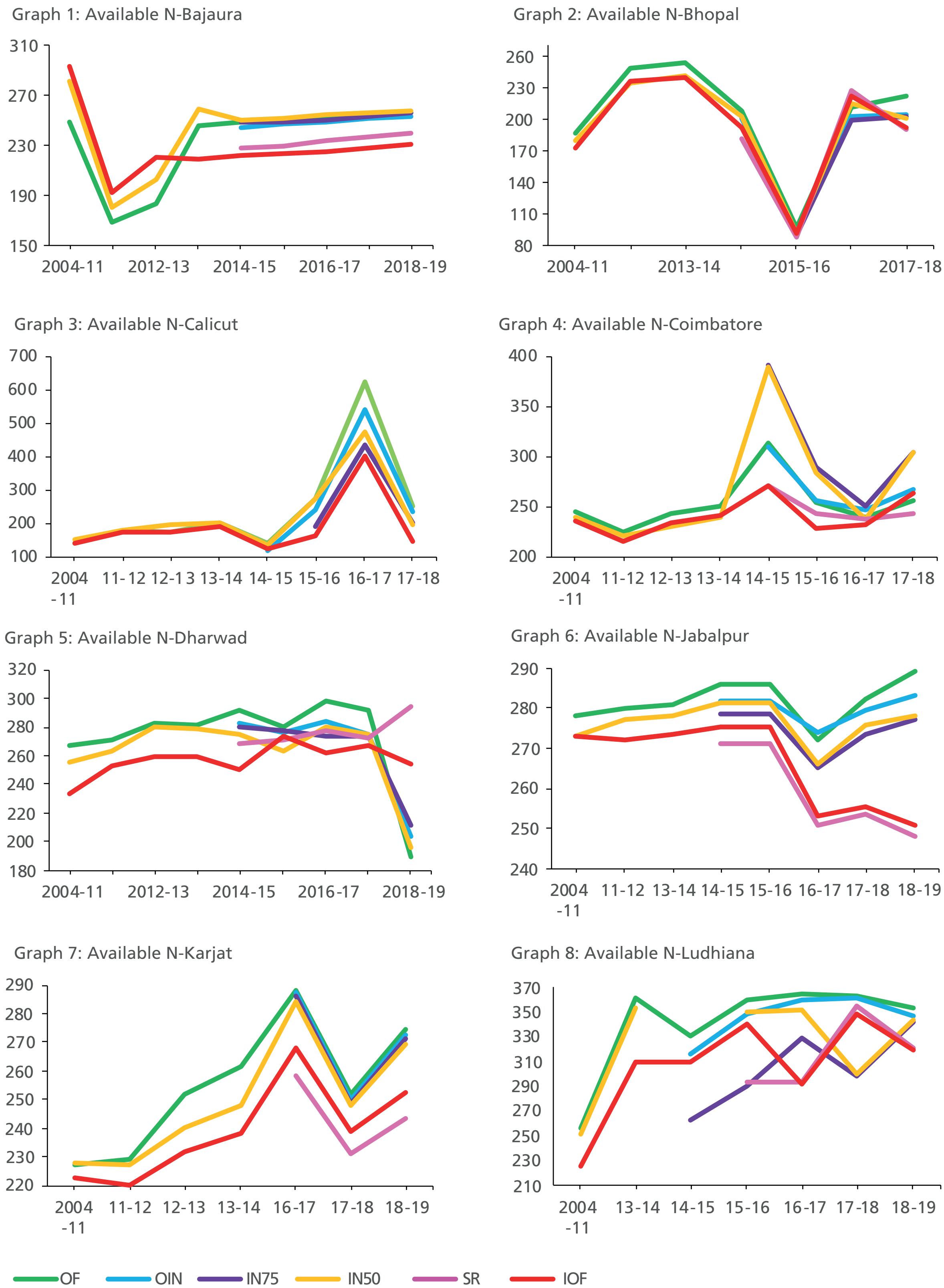
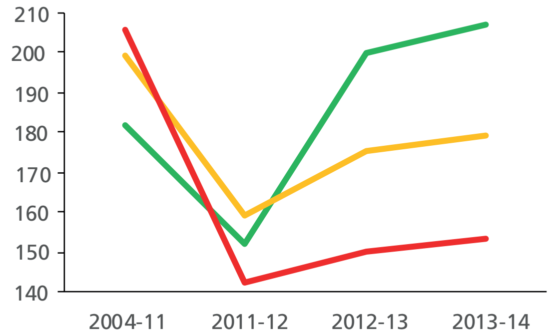
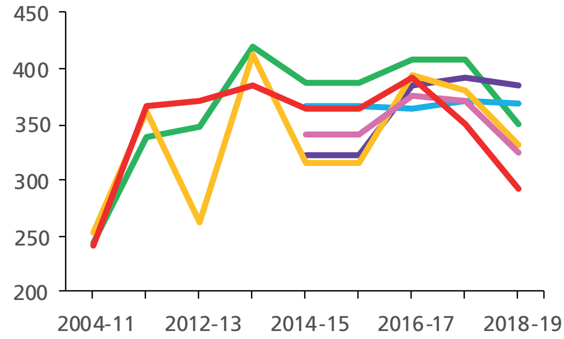
Figure 3.2 Graphs showing centre wise long-term trends for available nitrogen (Kg/ha)



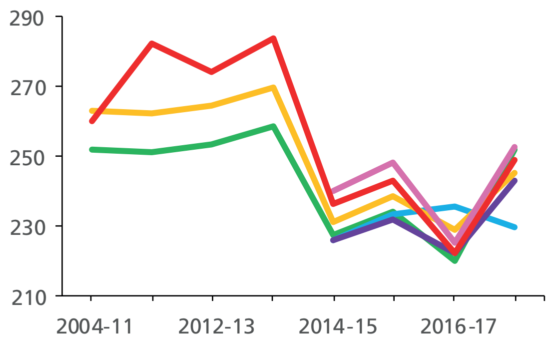
Graph 9: Available N-Modipuram



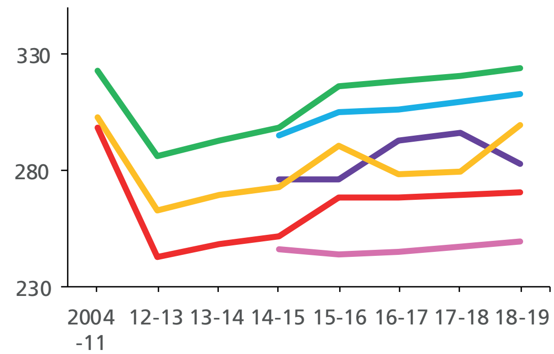
Graph 10: Available N-Pantanagar



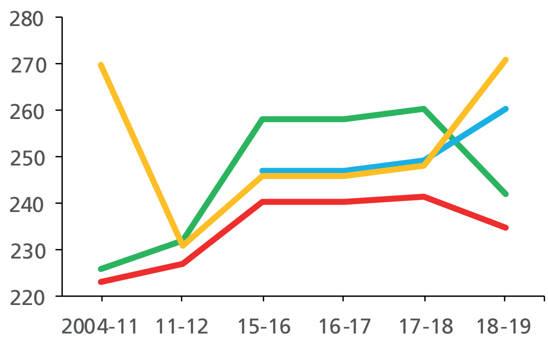
Graph 11: Available N-Raipur



Graph 12: Available N-Ranchi



Graph 13: Available N-Umiam



Graph 14: Available N-Sardarkrushinagar

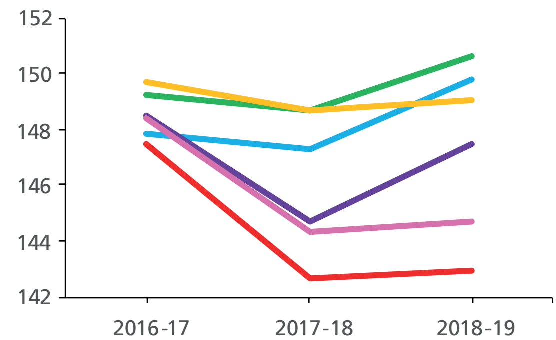


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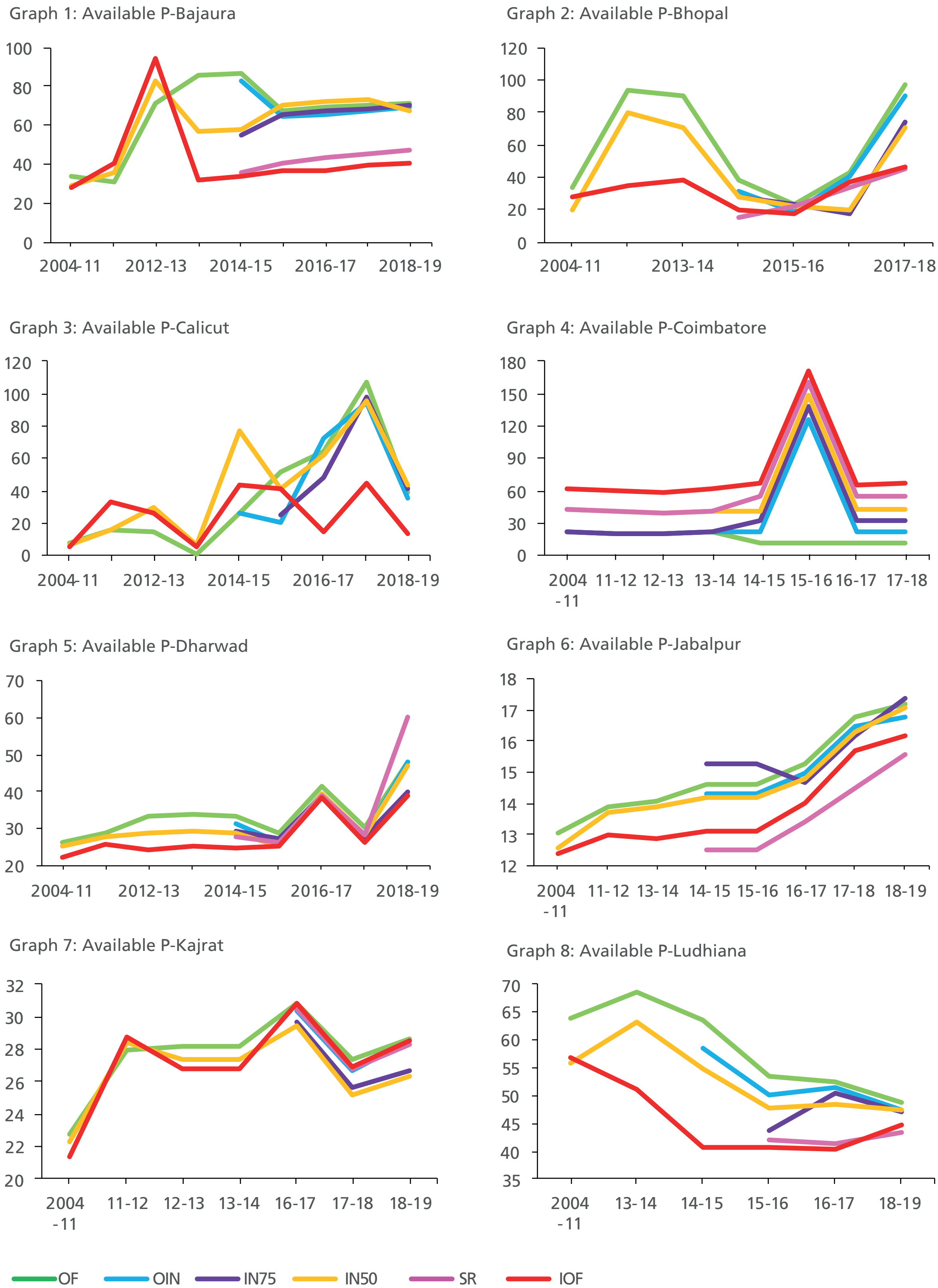
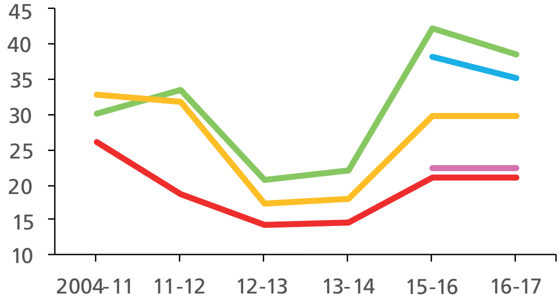
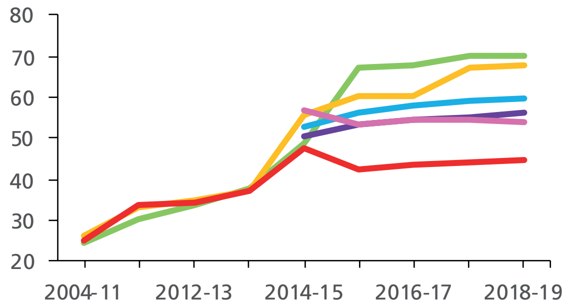
Figure 3.3: Graphs showing centre wise long-term trends for available phosphorus (Kg/ha)



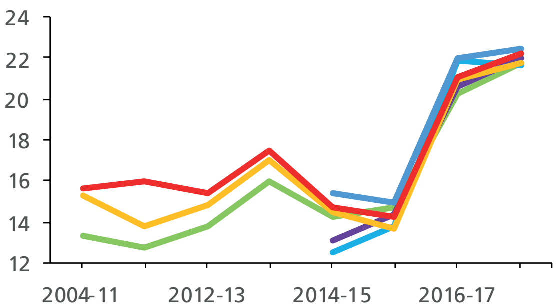
Graph 9: Available P-Modipuram



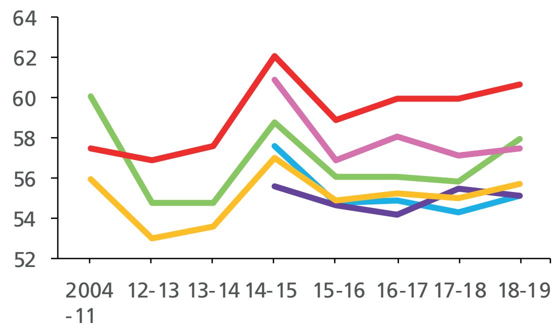
Graph 10: Available P-Pantnagar



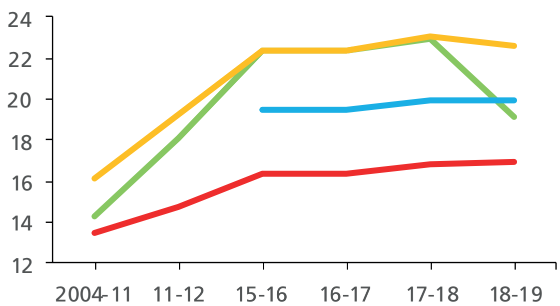
Graph 11: Available P-Raipur



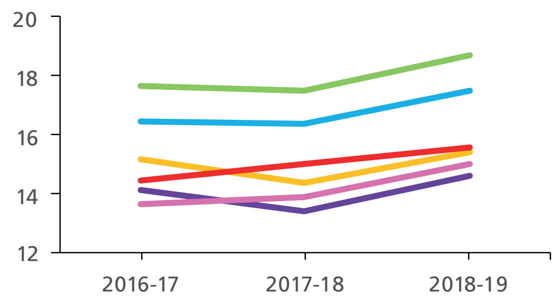
Graph 12: Available P-Ranchi



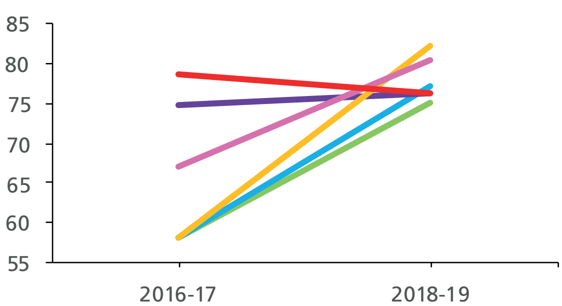
Graph 13: Available P-Umian(RB)



Graph 14: Available P-Ajmer



Graph 15: Available P-Narendrapur



Graph 16: Available P-Sardarkrushinagar

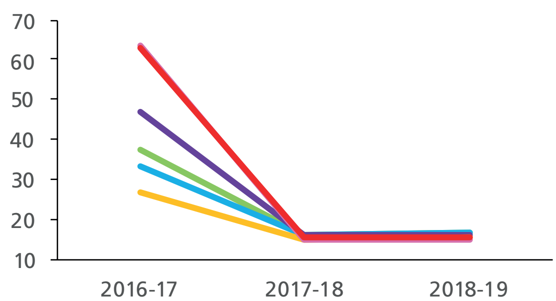


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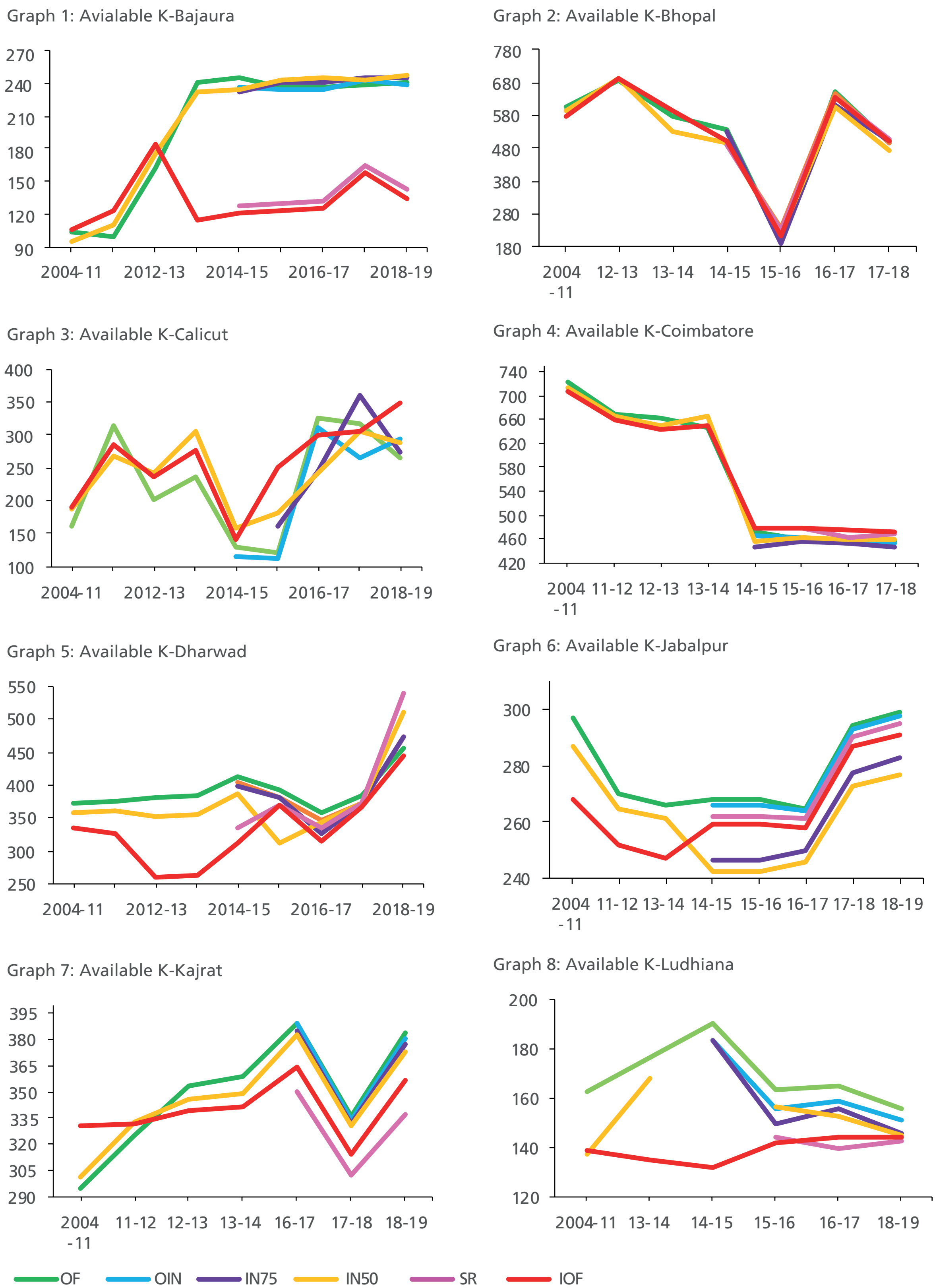
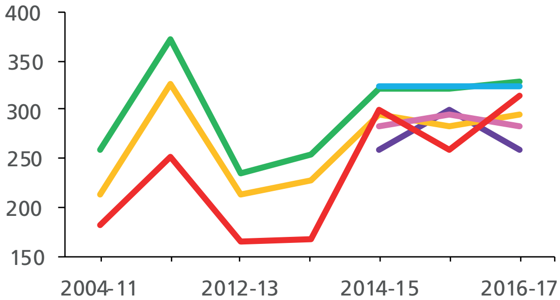
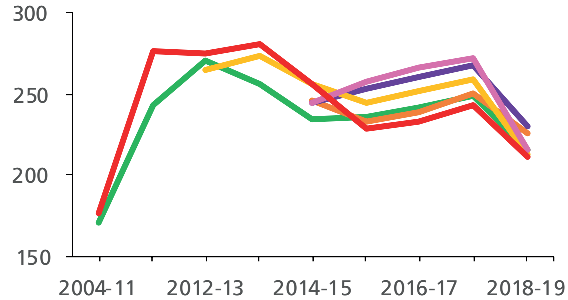
Figure 3.4: Graphs showing centre wise long-term trends for available potassium (kg/ha)



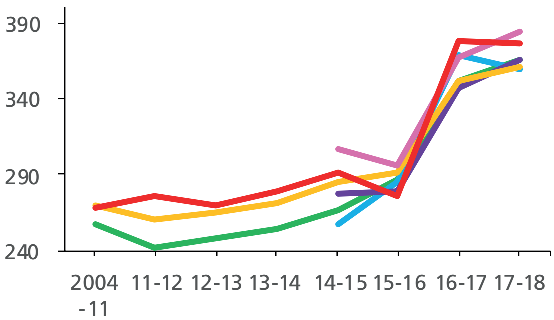
Graph 9: Available K-Modipuram



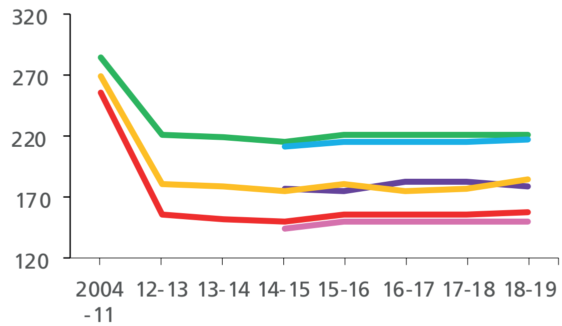
Graph 10: Available K-Pantnagar



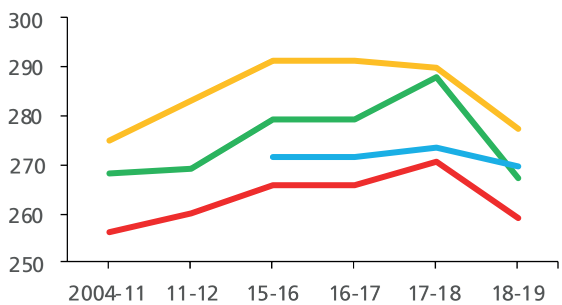
Graph 11: Available K-Raipur



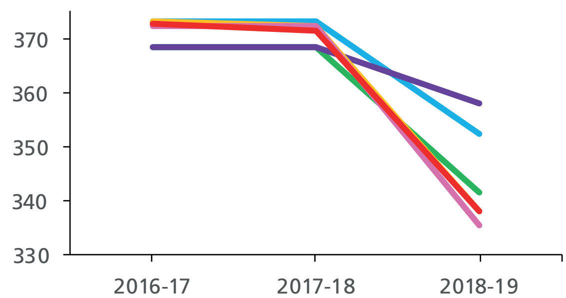
Graph12: Available K-Ranchi



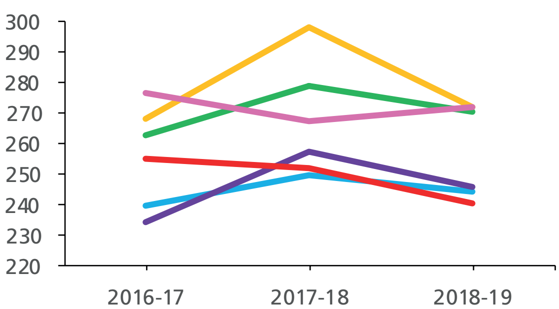
Graph 13: Available K-Umian (RB)



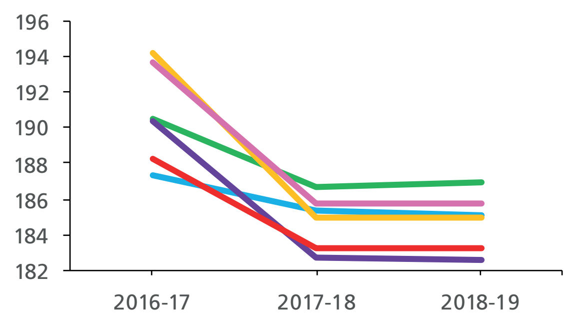
Graph 14: Available K-Ajmer



Graph 15: Available K-Narendrapur



Graph 16: Available K-Sardarkruhinagar



OF OIN IN75 IN50 SR IOF

Figure 3.5: Graphs showing centre wise long-term trends for bulk density (g/cc) (2014–19)

Annexure 2: Additional details and results of AI-NPOF

Table 1: Details of centres under the AI-NPOF (2004–19)

Centre	States	Ecsystem	Soil type	Rainfall (mm)	Location
Bajaura	Himachal Pradesh	Humid	Silty loam	499.7	CSK HPKVV Hill Agri. Res. & Extension Centre, Bajaura
Bhopal	Madhya Pradesh	Semi-arid	Vertisols, montmorillonite clay/smectite type	906.2	ICAR-Indian Institute of Soil Science, Nabi Bagh, Berasia Road, Bhopal
Calicut	Kerala	Coastal	Clay loam, Ustic Humitropept	4121	ICAR-Indian Institute of Spices Research, Marikunnu, Calicut
Coimbatore	Tamil Nadu	Semi-arid	Sandy, clay loam	967	Tamil Nadu Agricultural University, Coimbatore
Dharwad	Karnataka	Arid	Clay loam	582.8	University of Agricultural Sciences, Yettinagudda Campus, Krishinagar, Dharwad
Jabalpur	Madhya Pradesh	Sub-humid	Vertisoils, chromusterts	1096.1	Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur
Karjat	Maharashtra	Coastal	Red and medium black	3457	Dr. Balasaheb Sawant Konkan Krishi Vidypeeth, RARS, Karjat,
Ludhiana	Punjab	Semi-arid	Ustochrepts, alluvial, sandy & sandy loam	737	Punjab Agricultural University, Ludhiana
Modipuram	Uttar Pradesh	Semi-arid	Alluvium soils, typic ustochrept	747	ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut
Pantnagar	Uttarakhand	Humid	Hapludolls, very deep alluvium coarse loomy soils	1191.5	G.B.Pant University of Agriculture Sciences and Technology, Pantnagar, Udham Singh Nagar
Raipur	Chhattisgarh	Sub-humid	Deep black soil	830	Indira Gandhi Krishi Vishwavidyalaya, Raipur
Ranchi	Jharkhand	Sub-humid	Ultic Palesustalfs, very deep soils	1611.2	Birsa Agricultural University, Kanke, Ranchi
Umiam	Meghalaya	Humid	Clay loam	2631.9	ICAR Research Comple for NEH Region, Umiam
New centres introduced from 2015 onwards					
Ajmer	Rajasthan	Arid	-	450	ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer
Almora	Uttarakhand	Sub-humid	-	-	ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
Gangtok	Sikkim	Sub-humid	-	2853.3	ICAR Research Comple- for NEH Region, Sikkim Centre, Tadong, Gangtok
Narendrapur	West Bengal	Humid	-	-	School of Agriculture & Rural Development, Ramakrishna Mission Vivekananda University, Narendrapur, Howrah
Sardar-krushinagar	Gujrat	Arid	-	931.2	Sardarkrushinagar-Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha
Thiruvanan-thapuram	Kerala	Coastal	-	1297.7	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram
Udaipur	Rajasthan	Semi-arid	Clay loam	813.2	Agricultural Research Station, Maharana Pratap University of Agriculture and Technology, Udaipur

Table 2: Comparison of mean cost of cultivation, gross returns, net returns and benefit-cost ratio with dif

Cropping systems	Centre (Ecosystem)	Cost of cultivation - mean difference with inorganic						Gross returns - mean diffe inorganic			
		Mean IOF	% OF	% OIN	% SR	% IN50	% IN75	Mean IOF	% OF	% OIN	% SR
Tomato – cauliflower – French bean	Bajaura (Humid)	2,56,556	16	12	**36**	9	13	2,93,064	71	**76**	38
Fallow – cauliflower – tomato		1,69,845	21	16	**42**	11	14	2,39,182	89	**97**	29
Black gram – cauliflower – summer squash		2,31,413	17	14	**27**	15	19	3,71,625	50	**55**	27
Lady finger – pea		1,58,069	9	7	**35**	10	13	2,18,543	**56**	38	29
Ginger	Calicut (Coastal)	1,32,254	**30**	21	-	13	22	3,20,927	90	84	-
Turmeric		1,69,845	21	16	**42**	11	14	4,67,897	28	19	-
Maize – cotton – green manure	Coimbatore (Semi-arid)	61,101	**57**	41	21	23	39	1,49,365	-3	5	10
Chillies – sunflower – green manure		1,69,845	21	16	**42**	11	14	1,18,937	-6	3	-6
Beetroot – maize – green manure		79,702	**45**	28	28	22	33	2,83,217	1	3	7
Cowpea/green gram – safflower	Dharwad (Arid)	29,336	**69**	55	28	42	57	43,084	-3	-2	**11**
Pigeon pea (Sole)		1,69,845	21	16	**42**	11	14	72,992	**6**	-9	4
Green gram – sorghum		27,880	**74**	61	28	44	66	75,611	**19**	10	10
Groundnut + hybrid cotton (2:1)		35,148	**75**	61	31	35	49	1,21,614	3	1	**15**
Maize – chickpea		24,972	**98**	83	27	50	61	91,650	**6**	-8	2
Basmati rice – durum wheat – green manure	Jabalpur (Sub-Humid)	82,804	**13**	4	-14	-8	-9	1,76,890	**8**	-6	-15
Basmati rice – chickpea – maize fodder		80,993	**8**	3	-12	-6	-4	1,50,596	**2**	-11	-14
Basmati rice – berseem fodder and seed		94,592	-17	-22	-11	-32	-28	2,20,205	-1	-11	-13
Basmati rice – vegetable pea – sorghum fodder		1,00,168	-14	-23	-8	-27	-25	2,07,558	**4**	-8	-9
Rice – brinjal	Karjat (Coastal)	2,32,916	**38**	26	-3	19	27	8,94,398	**14**	4	-26
Rice – chickpea		98,450	**30**	19	-6	15	20	1,65,396	**29**	17	-8
Rice – field bean		1,11,827	**18**	10	-11	6	10	2,00,170	**12**	0.03	-20
Rice – onion (white)		1,56,207	**46**	32	-3	23	32	5,34,229	**37**	-0.3	-21
Basmati rice – chick – pea-green manure	Ludhiana (Semi-arid)	75,959	10	10	0.1	2	1	1,27,567	24	24	-1
Basmati rice – wheat – green manure		1,69,845	21	16	**42**	11	14	1,63,759	**33**	31	1
Cluster bean – wheat-summer moong		60,976	**16**	13	-0.1	-4	-7	1,63,937	**28**	26	0.4
Soybean – wheat		52,518	**21**	18	-0.1	-2	-5	1,56,981	**17**	15	-3

ferent methods (2014–19)

rence with		Net returns - mean difference with inorganic						Benefit-cost ratio - mean difference with inorganic					
% IN50	% IN75	Mean IOF	% OF	% OIN	% SR	% IN50	% IN75	Mean IOF	% OF	% OIN	% SR	% IN50	% IN75
61	55	36,508	456	**528**	52	424	348	1.1	47	**57**	1	47	37
62	51	69,337	254	**296**	-4	187	143	1.4	56	**70**	-9	46	33
47	46	1,40,212	105	**122**	28	101	91	1.6	28	**36**	1	29	23
51	42	60,474	**179**	121	16	159	118	1.4	**43**	30	-4	38	26
102	93	1,13,204	132	128	-	**165**	61	2.4	47	52	-	**79**	59
18	**32**	3,30,522	**30**	20	-	20	13	3.4	4	4	-	7	**20**
16	13	88,264	-45	-19	2	**11**	-5	2.4	-39	-25	-9	-6	-19
-0.4	**17**	70,675	-43	-15	-25	-10	**8**	2.5	-36	-18	-17	-12	-12
6	**19**	2,03,515	-17	-7	-1	-1	**13**	3.6	-32	-21	-18	-15	-12
5	-0.4	13,748	-156	-123	-24	-75	-123	1.6	-21	-20	-9	-12	-20
1	5	54,475	-14	-31	-4	-13	-13	3.9	-29	-37	-17	-25	-29
6	4	47,731	-13	-20	-1	-16	-33	2.7	-21	-25	-12	-20	-29
-4	-1	86,466	-26	-24	**8**	-19	-21	3.4	-34	-33	-11	-26	-28
-5	-17	66,679	-29	-43	-8	-25	-46	3.6	-37	-43	-21	-30	-41
-3	-8	94,086	**3**	-15	-16	2	-7	2.3	-7	-14	-2	-1	-0.2
-3	-15	69,603	-6	-28	-17	**1**	-27	1.9	-5	-14	-4	**0.3**	-12
-8	-17	1,25,613	**11**	-2	-15	9	-9	3.1	-6	-10	-7	**5**	-6
-6	-11	1,07,390	**20**	6	-9	14	3	2.5	5	5	-1	**10**	4
-6	-10	6,61,482	**6**	-4	-34	-16	-23	3.8	-17	-18	-24	-22	-29
7	5	66,946	**28**	15	-10	-4	-19	1.7	-1	-1	-2	-7	-13
-10	-17	88,343	**3**	-12	-30	-30	-50	1.8	-6	-9	-9	-15	-24
16	-10	3,78,022	**33**	-14	-28	13	-27	3.4	-6	-24	-18	-6	-32
2	3	51,608	43	**46**	-1	1	6	1.7	13	**14**	-1	-0.5	2
18	13	97,345	46	**65**	1	29	23	2.5	15	**330**	1	15	14
4	5	1,02,961	**35**	34	1	9	12	2.7	15	**16**	1	10	14
-1	-1	1,04,463	**15**	14	-4	-1	1	3.0	-1	0.3	-2	1	**4**

Cropping systems	Centre (Ecosystem)	Cost of cultivation - mean difference with inorganic						Gross returns - mean diffe inorganic			
		Mean IOF	% OF	% OIN	% SR	% IN50	% IN75	Mean IOF	% OF	% OIN	% SR
Basmati rice – durum wheat – sesbania green manure	Modipuram (Semi-arid)	56,444	**61**	48	20	21	35	1,23,907	63	63	12
Rice – barley (malt) – green gram		72,792	**43**	35	21	7	16	1,21,332	42	**44**	11
Maize (popcorn) – potato – ladyfinger – sesbania green manure		1,53,091	**29**	22	12	5	12	3,72,803	**49**	43	7
Maize (sweet corn) – mustard – sesbania green manure		50,435	**57**	45	23	10	23	1,44,372	34	**43**	16
Basmati rice – wheat	Pantnagar (Humid)	57,751	21	3	1	17	**22**	1,67,550	**34**	31	-1
Basmati rice – chickpea (4 rows + 2 rows coriander)		53,389	11	-4	2	**18**	17	22,7,680	**41**	36	-0.2
Basmati rice – vegetable pea (4 rows vegetable pea + 2 rows coriander)		60,957	8	-5	2	**13**	12	2,03,893	34	34	-0.05
Basmati rice – potato		80,903	8	1	2	15	**20**	1,48,367	**58**	53	4
Soybean – maize	Raipur (Sub-humid)	67,052	**7**	4	6	5	6	2,61,327	23	**25**	5
Soybean – pea		53,988	5	3	**8**	2	5	1,94,462	24	**28**	6
Soybean – chilli		60,431	4	0.4	**7**	0.4	3	2,29,024	22	**24**	4
Soybean – onion		60,238	2	-3	**6**	-1	2	2,54,304	15	**19**	10
Rice – wheat	Ranchi (Sub-humid)	51,158	**37**	22	-8	14	10	1,06,417	28	28	-13
Rice – lentil		47,207	**26**	14	-6	11	10	67,426	38	38	-8
Rice – potato		68,287	**24**	13	-6	9	5	1,65,272	**61**	54	-11
Rice – linseed		36,554	**30**	17	-6	12	8	62,889	52	**55**	-6
Broccoli – carrot	Umiam (Humid)	1,65,096	**30**	22	-	9	-	4,02,598	**35**	18	-
Broccoli – potato		2,01,961	**25**	15	-	10	-	3,52,374	**35**	18	-
Broccoli – French bean		1,49,895	**33**	21	-	13	-	3,92,622	**42**	25	-
Broccoli – tomato		1,78,197	**28**	16	-	10	-	4,18,355	**40**	26	-
Green gram – fennel	Ajmer (Arid)	37,249	**81**	56	27	40	60	1,89,566	-11	-8	**33**
Green gram – coriander		36,048	**61**	42	28	30	45	98,497	-4	-12	**36**
Cluster bean – fennel		37,462	**92**	64	27	46	68	2,28,800	-19	-14	-10
Cluster bean – coriander		36,261	**73**	50	28	36	53	1,03,162	-20	-14	13
Basmati rice – broccoli – sesbania green manure	Narendrapur (Humid)	1,69,891	**28**	19	-2	12	12	4,19,234	17	**18**	-7
Paddy – mustard – green gram		1,14,862	**36**	24	-2	11	15	1,98,873	**43**	41	-0.05
Paddy – capsicum – green gram		1,47,423	**33**	22	-3	13	15	2,81,309	**39**	33	-2
Paddy – French bean – sesame		2,10,837	**31**	26	-1	13	15	4,75,334	**37**	31	-5
Groundnut – wheat – green gram	Sardar Krushinagar (Arid)	96,734	37	25	**47**	18	28	2,23,697	5	9	9
Green gram – cumin – vegetable cowpea		1,17,663	-9	-11	**36**	-0.1	1	2,50,277	-15	-16	**16**
Green gram – fennel – fennel cont.		60,826	**44**	31	49	22	33	99,880	2	2	**9**

…rence with		Net returns - mean difference with inorganic						Benefit-cost ratio - mean difference with inorganic					
% IN50	% IN75	Mean IOF	% OF	% OIN	% SR	% IN50	% IN75	Mean IOF	% OF	% OIN	% SR	% IN50	% IN75
28	33	67,464	64	**76**	5	34	32	2.2	-0.5	**9**	-5	3	-4
7	13	48,539	41	**57**	-3	7	10	1.7	0	**8**	-6	1	1
5	12	2,19,712	**63**	59	4	5	12	2.4	15	**18**	-4	-1	0.1
8	16	93,937	22	**42**	12	7	13	2.9	-15	-2	-4	**1**	-2
8	10	1,09,799	42	**46**	-1	3	4	2.9	11	**28**	-1	-8	-10
8	8	1,74,291	**50**	48	-1	5	6	4.3	27	**43**	-3	-9	-8
10	8	1,42,935	46	**51**	-1	9	7	3.3	25	**42**	-2	-3	-4
22	19	67,465	**117**	116	8	31	18	1.9	43	**49**	3	2	-5
-11	-8	1,94,275	29	**32**	4	-16	-13	3.9	19	21	-1	-12	-10
-1	-5	1,40,474	31	**38**	5	-3	-8	3.7	24	**28**	-1	-1	-3
-7	-6	1,68,593	28	**32**	4	-10	-10	3.9	22	**26**	-2	-7	-7
-9	-6	1,94,066	19	**26**	12	-12	-8	4.4	19	**26**	4	-5	-3
2	-5	44,207	20	**33**	-17	-9	-20	2.1	-9	**2**	-6	-11	-16
6	3	16,175	67	**95**	-15	-6	-16	1.5	12	**25**	-3	-4	-4
6	2	77,588	**86**	83	-15	5	0.3	3.3	13	**23**	-4	-8	-15
13	9	21,068	83	**107**	-7	15	11	1.7	16	**31**	-1	2	1
12	-	2,37,502	**38**	15	-	14	-	2.4	**4**	-3	-	3	-
11	-	1,50,413	**49**	22	-	14	-	1.7	**9**	3	-	2	-
9	-	2,42,728	**47**	27	-	6	-	2.6	**8**	4	-	-3	-
11	-	2,40,158	**49**	32	-	12	-	2.3	**10**	9	-	1	-
6	4	1,48,528	-28	-20	**35**	1	-5	1.5	-40	-31	**7**	-14	-23
17	44	57,459	-41	-44	**44**	13	51	0.8	-35	-34	**9**	-5	7
-17	**5**	1,87,124	-40	-30	-18	-29	-7	1.8	-54	-45	-28	-40	-33
20	**22**	20,495	-86	-61	5	**8**	-1	0.8	-55	-45	-9	-13	-22
-0.3	0.1	2,49,343	9	**18**	-10	-9	-8	2.2	-3	**4**	-3	-9	-8
10	8	84,011	53	**63**	3	8	-2	1.7	8	**17**	2	-0.1	-7
4	3	1,33,885	45	**46**	-1	-6	-9	1.9	5	**10**	1	-7	-10
9	2	2,64,497	**41**	35	-8	6	-10	2.5	1	**6**	-2	-3	-15
-1	-2	1,26,963	-19	-4	-19	-16	-24	2.3	-23	-13	-26	-17	-23
-3	-1	79,568	-20	-21	-3	-6	-3	2.4	-16	-15	-20	-8	-8
-6	-3	35,597	-27	-17	-19	-26	-28	1.7	-26	-17	-27	-22	-29

Cropping systems	Centre (Ecosystem)	Cost of cultivation - mean difference with inorganic						Gross returns - mean diffe inorganic			
		Mean IOF	**% OF**	**% OIN**	**% SR**	**% IN50**	**% IN75**	**Mean IOF**	**% OF**	**% OIN**	**% SR**
Cassava – veg. cowpea	Thiruva-nanthapuram (Coastal)	1,20,011	33	40	6	49	**63**	4,96,155	**25**	11	-24
Cassava – groundnut		-	-	-	-	-	-	-	-	-	-
Taro – black gram		2,05,087	43	45	3	33	**47**	3,37,060	66	58	-36
Taro – green gram		-	-	-	-	-	-	-	-	-	-
Maize + black – gram – durum wheat– Sesbania green manure	Udaipur (Semi-arid)	51,565	**101**	82	23	51	76	2,45,832	-25	-17	**2**
Sweet corn + black gram – chickpea		44,578	**59**	51	19	29	44	2,14,350	-28	-20	-0.2
Black gram – wheat (Triticum aestivum)		57,608	**53**	46	17	27	40	1,80,498	-18	-17	**4**
Soybean – fenugreek		38,941	1	**32**	19	-10	22	85,221	-26	-15	-2
Number of recorded results			63	63	58	63	59		61	61	55
Cropping systems with higher respective values among methods (in per cent)			60	57	40	54	53		48	46	28
Cropping systems where value is significantly higher (>20 per cent) than inorganic method, calculated out of overall higher (in per cent)			73	54	60	33	47		73	63	21
Range of difference in mean with inorganic method (INO=IOF+SR) (in per cent)			-18 – 101	-23 – 83	-14 – 58	-32 – 63	-28 – 76		-28 – 90	-20 – 97	-36 – 57

Note: (-) represents data not available; Bold numbers reflect highest values among methods; Values in green cells indicate higher than inorganic method, and values in red cells indicate lesser than inorganic method

rence with		Net returns - mean difference with inorganic							Benefit-cost ratio - mean difference with inorganic				
% IN50	% IN75	Mean IOF	% OF	% OIN	% SR	% IN50	% IN75	Mean IOF	% OF	% OIN	% SR	% IN50	% IN75
-26	-5	3,76,144	**22**	2	-33	-50	-27	4.1	-6	-21	-28	-50	-42
-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	85	1,31,973	101	78	-97	**165**	143	1.6	16	9	-38	**39**	26
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-4	-6	1,94,268	-58	-44	-3	-19	-28	4.8	-63	-55	-17	-37	-47
-17	-27	1,69,772	-51	-38	-5	-29	-45	4.8	-55	-46	-15	-35	-49
-4	-7	1,22,890	-51	-47	-2	-19	-30	3.3	-48	-45	-12	-27	-36
-16	-6	46,280	-48	-55	-21	-20	-31	2.2	-20	-36	-19	**1**	-21
61	57		61	61	55	61	57		61	61	55	61	57
37	33		41	36	17	33	23		29	32	8	20	14
24	30		85	89	24	27	39		34	53	0	30	50
-26 – 102	-27 – 93		-156 – 456	-123 – 528	-97 – 57	-75 – 424	-123 – 348		-63 – 63	-55 – 330	-38 – 57	-50 – 79	-49 – 59

Table 3: Comparison of mean available nitrogen, phosphorus and potassium with different methods (2014

Cropping system	Centre (Ecosystem)	Available N mean as per IOF method	Available N - mean difference compared to IOF method (%)				
			OF	OIN	IN75	IN50	SR
Tomato – cauliflower – French bean	Bajaura (Humid)	228.5	**11.4**	10.2	9.6	7.8	4.8
Fallow – cauliflower – tomato		242.1	2.2	**2.3**	-4.3	-4.1	1.7
Black gram – cauliflower – summer squash		207.1	17.3	14.5	**26.4**	25.3	5.4
Lady finger – pea		226.5	16.3	14.3	**19.9**	18.5	1.5
Soybean – wheat	Bhopal (Semi-arid)	164.0	**19.1**	8.4	7.5	12.0	5.1
Soybean – mustard		171.5	-2.6	2.9	**9.8**	1.3	1.2
Soybean – chickpea		185.0	-6.3	-7.4	-9.7	-11.2	-8.4
Soybean – linseed		177.5	**1.5**	-2.5	0.3	-3.4	-2.9
Ginger – fallow	Calicut (Coastal)	272.6	42.6	27.7	21.6	**55.4**	-
Turmeric – fallow		205.0	**47.9**	32.5	19.6	45.4	-
Black pepper		211.5	**33.7**	-3.1	15.7	-	-
Cotton – maize	Coimbatore (Arid)	242.8	7.1	7.2	16.5	**20.0**	-
Chillies – sunflower		249.0	7.1	8.0	31.6	**35.7**	-
Beetroot – maize		254.0	6.2	10.3	**18.0**	16.7	-
Cowpea – safflower	Dharwad (Arid)	224.8	22.1	17.6	18.2	15.7	**23.0**
Pigeon pea (sole)		263.8	1.8	0.2	-3.5	-0.2	**5.0**
Groundnut + hybrid cotton		264.0	-1.2	1.7	-1.7	-1.1	**5.8**
Green gram – sorghum		258.7	4.7	1.9	2.0	1.4	**7.5**
Maize – chickpea		264.1	4.3	-1.6	-3.0	-0.5	**5.2**
Basmati rice – durum wheat – green manure	Jabalpur (Sub-humid)	270.2	**7.3**	5.9	4.1	3.0	-1.3
Basmati rice – chickpea – maize fodder		258.0	**7.5**	6.1	5.9	5.3	-1.6
Basmati rice – berseem fodder and seed		260.2	8.5	**8.7**	7.4	6.8	-0.6
Vegetable pea – sorghum fodder		259.6	**8.6**	6.7	4.9	4.2	-1.3
Rice – groundnut	Karjat (Coastal)	281.5	5.4	**6.9**	3.9	5.4	-2.0
Rice – chickpea		257.8	5.4	3.8	5.4	5.4	-6.0
Rice – field bean		256.4	**12.5**	10.8	9.2	10.8	-5.5
Rice – onion (white)		275.9	7.6	7.6	6.1	6.1	-1.5
Basmati rice – chickpea – green manure	Ludhiana (Semi–Arid)	284.7	**28.1**	24.2	20.9	22.3	2.9
Basmati rice – wheat – green manure		297.3	15.3	13.0	13.6	**17.0**	3.2
Cluster bean – wheat – summer moong		299.2	**15.2**	14.2	12.5	10.0	0.3
Soybean – wheat		339.0	8.8	7.7	8.8	4.9	-9.8
Basmati rice – durum wheat – sesbania green manure	Modipuram (Humid)	-	-	-	-	-	-
Coarse rice – barley (malt) – green gram		-	-	-	-	-	-
Maize (popcorn) – potato – ladyfinger + sesbania		-	-	-	-	-	-
Maize (sweet corn) – mustard – sesbania green manure		-	-	-	-	-	-

–19)

Available P mean as per IOF method	Available P - mean difference compared to IOF method (%)					Available K mean as per IOF method	Available K - mean difference compared to IOF method (%)				
	OF	OIN	IN75	IN50	SR		OF	OIN	IN75	IN50	SR
37.1	**94.6**	83.4	67.3	9.6	17.3	121.9	99.1	**104.2**	94.8	95.9	6.3
39.5	**91.7**	79.5	8.4	79.6	61.2	137.2	79.0	**83.9**	75.1	72.7	4.3
36.5	**94.1**	89.7	11.6	90.8	79.2	145.8	53.6	45.6	60.5	**65.7**	4.5
36.4	**99.6**	95.5	15.1	79.4	92.3	123.5	100.8	91.8	104.7	**108.3**	5.1
29.6	**91.0**	66.5	12.6	24.8	16.7	493.0	0.8	-1.9	**1.0**	-5.7	0.3
32.5	**48.3**	34.7	-2.8	7.5	7.7	472.6	-0.1	**3.2**	-4.5	-4.2	-3.6
28.0	**59.8**	59.1	-5.0	19.8	35.3	442.7	**1.7**	-0.4	-0.2	-7.2	-2.7
30.1	**70.9**	43.6	-15.0	13.5	18.7	442.9	5.3	3.7	1.8	6.6	**10.0**
30.9	52.9	28.6	-	**107.5**	27.0	308.7	11.4	2.6	**18.1**	4.8	-
19.7	**220.1**	190.0	-	194.3	270.3	285.5	-22.5	-32.1	-19.1	-13.4	-
28.4	-46.3	-	-	**40.4**	-	166.4	**15.0**	-	-	10.4	-
12.6	-9.5	-4.6	**0.8**	-9.5	-9.7	423.0	5.3	2.6	**9.0**	7.9	2.7
13.5	-13.0	-16.0	**0.7**	-29.1	-23.4	457.6	3.0	4.0	**6.1**	5.7	3.7
9.5	2.9	4.0	6.9	8.2	**14.8**	470.3	-1.6	-1.1	**2.0**	0.9	-0.3
30.7	20.1	19.6	17.5	**25.3**	12.9	345.0	18.7	**20.5**	17.5	15.5	12.2
31.5	9.3	3.3	**11.3**	-0.1	3.8	353.0	9.3	6.5	9.8	**16.0**	13.9
29.4	20.0	**29.2**	19.0	16.5	4.3	340.9	18.9	**20.9**	9.7	11.0	11.0
32.6	16.8	1.2	**17.3**	-5.7	-2.1	361.3	11.6	8.6	9.5	11.8	**12.2**
29.5	24.7	12.5	**29.8**	16.7	9.1	348.0	**14.7**	10.3	8.3	12.5	12.0
15.0	**8.7**	6.7	-5.6	4.1	3.1	266.6	5.2	**4.2**	3.5	3.8	-0.7
14.1	**13.6**	10.5	-8.4	4.7	3.1	262.4	6.4	**7.4**	2.1	3.1	-1.6
14.8	3.4	1.6	-4.5	**4.6**	1.5	264.6	**5.4**	3.5	3.3	4.2	-2.6
13.9	10.5	8.4	-1.7	11.0	**30.2**	248.6	**11.3**	11.1	7.0	10.0	-2.3
30.7	**7.5**	2.6	1.6	1.0	2.6	364.5	3.5	**4.2**	2.8	2.8	-6.0
28.8	-1.4	-1.4	-2.4	1.4	**2.1**	364.5	7.0	7.0	5.6	5.6	-1.5
29.0	**6.9**	5.9	-2.1	1.4	5.2	355.2	**11.6**	10.1	10.1	8.5	-5.2
30.1	3.0	3.0	-0.7	**8.0**	6.3	371.3	**6.5**	6.4	5.0	3.7	-2.0
41.2	**30.6**	27.1	-1.0	18.1	15.9	140.7	**17.1**	10.2	11.0	2.5	-1.4
41.3	**29.8**	23.5	2.7	12.5	13.9	141.2	**18.7**	14.0	11.1	8.5	1.8
44.5	**17.0**	14.6	-0.3	12.0	14.2	144.7	**9.6**	5.9	6.6	6.9	0.7
41.7	18.3	12.1	-0.6	12.2	**19.3**	143.0	**14.2**	12.5	4.3	2.8	-2.7
26.2	55.7	**61.1**	7.6	10.3	5.7	182.6	**73.6**	69.9	45.6	32.5	7.9
28.4	**76.9**	66.2	11.6	48.6	52.8	321.4	**4.9**	2.1	-13.6	-11.8	-1.4
16.7	87.1	87.1	4.8	52.7	50.9	274.4	11.8	13.0	8.6	**15.5**	4.9
12.3	**217.1**	110.6	1.6	87.0	82.9	256.5	31.0	36.7	46.7	14.0	**48.0**

Cropping system	Centre (Ecosystem)	Available N mean as per IOF method	Available N - mean difference compared to IOF method (%)				
			OF	OIN	IN75	IN50	SR
Basmati rice – wheat	Pantnagar (Sub-humid)	364.6	-36.3	-38.4	-34.0	-37.7	-33.5
Basmati rice – chickpea (4 rows + 2 rows coriander)		361.2	-35.1	-35.7	-34.5	-36.4	-32.9
Basmati rice – vegetable pea		368.0	-36.6	-36.0	-36.7	-36.5	-34.8
Basmati rice – potato		333.8	-30.4	-30.6	-30.3	-30.5	-28.0
Soybean – maize	Raipur (Sub – humid)	237.3	-2.1	-5.3	1.3	-4.2	**2.1**
Soybean – pea		237.2	-1.1	-2.1	-0.2	-3.1	**2.1**
Soybean – chilli		238.4	-2.2	-1.3	-2.3	-1.9	**0.7**
Soybean – onion		236.6	-1.8	-2.1	-1.7	-2.0	**1.6**
Rice – wheat	Ranchi (Humid)	255.4	**21.0**	16.0	9.8	8.9	-2.2
Rice – lentil		265.4	**23.2**	19.9	8.7	7.0	-7.8
Rice – potato		283.5	**10.4**	8.9	4.8	5.1	-8.9
Rice – linseed		261.3	**17.6**	14.1	4.8	2.2	-11.4
Broccoli – carrot	Umiam (Arid)	232.3	8.0	**8.2**	6.6	-	-
Broccoli – potato		242.4	**4.7**	-0.8	-6.6	-	-
Broccoli – French bean		243.7	**16.5**	3.5	6.2	-	-
Broccoli – tomato		242.9	**4.9**	0.6	3.6	-	-
Green gram – fennel	Ajmer (Arid)	135.3	**3.5**	1.7	-0.2	-2.3	-1.7
Green gram – coriander		133.1	**4.9**	2.6	-0.4	-3.0	-2.3
Cluster bean – fennel		137.1	**3.0**	1.4	0.1	-1.9	-1.4
Cluster bean – coriander		133.1	**4.9**	2.6	-0.4	-3.0	-2.3
Basmati rice – broccoli – sesbania green manure	Narendrapur (Humid)	-	-	-	-	-	-
Paddy – mustard – green gram		-	-	-	-	-	-
Paddy – capsicum – green gram		-	-	-	-	-	-
Paddy – French bean – sesame		-	-	-	-	-	-
Groundnut – wheat – green gram	Sardar-krushinagar (Arid)	147.2	3.3	1.9	**4.2**	0.7	0.4
Green gram – cumin – vegetable cowpea		146.1	**3.8**	2.4	3.1	2.1	0.8
Green gram – fennel – fennel cont.		139.8	3.6	**3.9**	2.6	2.4	1.9
Number of recorded results			54	54	54	49	44
Cropping systems with higher respective values among methods (in per cent)			79.6	75.9	70.4	63.3	47.7
Cropping systems where values are significantly higher (>20 per cent) than inorganic method, calculated out of overall higher			16.3	7.3	10.5	16.1	4.7
Range of difference in mean with inorganic method (in per cent)			-36-6 – 47.9	-38.5 – 32.5	-36.7 – 31.6	-37.7 – 55.4	-34.8 – 23

Note: (-) represents data not available; Bold numbers reflect highest values among methods; Values in green cells indicate higher than inorganic method, and values in red cells indicate lesser than inorganic method

Available P mean as per IOF method	Available P - mean difference compared to IOF method (%)					Available K mean as per IOF method	Available K - mean difference compared to IOF method (%)				
	OF	OIN	IN75	IN50	SR		OF	OIN	IN75	IN50	SR
38.3	**68.8**	39.4	16.9	60.8	39.0	231.0	-4.9	2.2	**4.0**	3.8	-2.6
40.0	53.7	43.6	**61.0**	53.0	40.6	239.2	-1.1	0.8	5.3	-3.6	**11.5**
44.3	41.6	30.7	16.9	**41.9**	19.4	230.8	4.9	1.2	**17.2**	14.6	14.4
54.9	27.5	9.4	4.8	**16.6**	-3.6	234.6	2.6	3.1	2.9	3.9	**5.9**
18.0	-6.1	-4.3	**3.6**	-3.8	-3.6	331.9	-3.9	-6.0	-3.1	-1.2	**1.8**
17.3	**7.4**	5.5	4.2	3.5	0.6	328.0	-2.0	-2.9	-4.6	-1.7	**5.6**
18.3	-3.8	-4.1	**1.1**	-3.7	-2.9	329.8	-4.6	-3.1	-5.0	-3.7	**1.4**
18.8	-4.7	-10.0	**4.3**	-3.9	-6.0	332.0	-5.4	-3.9	-3.4	-3.5	**0.9**
61.5	-5.5	-7.4	-4.4	-10.2	-11.7	152.5	**44.8**	42.0	21.4	21.2	-3.1
58.5	-9.6	-13.1	-3.8	-5.5	-6.5	152.4	**49.0**	46.7	9.5	10.1	-3.6
62.5	-4.7	-6.6	-2.6	-8.8	-10.1	156.2	**32.2**	28.2	12.7	13.0	-6.0
59.1	-1.5	-4.7	-2.9	-6.3	**330.7**	159.9	**41.9**	39.0	16.7	17.7	-4.5
15.4	**43.5**	35.7	-	32.5	-	246.8	**17.5**	13.0	-	14.0	-
16.0	23.1	29.4	-	**30.6**	-	266.5	**5.6**	2.3	-	2.7	-
16.7	**59.9**	12.6	-	40.7	-	292.6	-10.7	-5.4	-	**4.8**	-
17.3	23.1	1.2	-	**42.8**	-	256.8	10.9	0.2	-	**18.3**	-
15.5	**15.9**	7.8	-8.8	-3.7	-9.7	330.9	2.8	6.8	**8.1**	-0.8	-1.8
14.4	**23.6**	17.4	-0.3	0.7	-3.5	361.8	-1.9	-0.4	0.4	**1.5**	0.6
15.9	**16.0**	6.7	-9.2	-1.9	-10.1	332.2	2.2	5.6	**7.2**	-1.1	-1.1
14.4	**23.6**	17.4	-0.3	0.7	-3.5	361.8	-1.9	-0.4	0.4	**1.5**	0.6
63.6	12.1	-7.6	-2.6	-12.5	**14.7**	259.8	-3.2	**13.0**	9.5	12.0	0.6
96.7	-22.5	-11.5	-15.0	**4.7**	0.1	241.8	**10.2**	-8.9	-4.1	8.8	8.4
82.9	-21.1	-18.8	-0.8	-22.4	-16.6	275.7	5.8	-14.7	-2.4	6.3	**7.9**
66.7	-17.2	-11.2	**3.5**	-11.0	-5.3	217.8	2.9	**13.1**	3.3	18.1	3.6
15.7	10.9	8.1	0.6	**13.2**	7.0	190.3	**3.9**	0.5	1.3	2.9	1.1
14.8	-3.2	-7.4	-0.5	-5.0	**0.7**	185.0	-0.9	-0.1	-1.0	0.2	**0.7**
14.2	4.7	**16.7**	-9.6	-12.5	7.3	180.3	1.5	0.7	-0.9	1.8	**2.8**
	62	61	55	62	57		62	61	57	62	55
	75.8	75.4	52.7	71	36.8		77.4	77	78.9	80.6	61.8
	59.5	47.8	10.3	40.9	31.7		20.8	25.5	15.5	12	2.9
	-46.3 – 220	-188.8 – 190	-15 – 67.3	-29.1 – 194.3	-23.4 – 330.7		-22.5 – 100.8	-32.1 –104.2	-19.1 – 104.7	-13.4 – 108.3	-6 – 48

Table 4: Comparison of bacteria, fungi, soil actinomycetes and phosphate solubilizing bacteria (cfu/g) wit

Cropping systems	Centre (Ecosystem)	Bacteria - mean difference compared to IOF method						Fungi - mear compared to		
		IOF (cfu/g)	OF (%)	OIN (%)	IN75 (%)	IN50 (%)	SR (%)	IOF (cfu/g)	OF (%)	OIN (%)
Tomato – cauliflower – French Bean	Bajaura (Humid)	9.3	**87.6**	55.8	56.9	43.1	35.0	9.2	**53.3**	38.8
Fallow – cauliflower – tomato		9.3	**76.5**	52.0	38.8	57.1	34.0	9.3	**51.8**	36.1
Black gram – cauliflower – summer squash		9.0	**68.9**	39.7	46.9	41.1	37.8	9.2	45.5	27.6
Lady finger – pea		9.5	**89.2**	53.3	49.1	37.0	33.1	9.3	46.8	27.7
Soybean – wheat	Bhopal (Semi-arid)	28.1	**27.6**	9.1	-6.6	-2.4	-7.5	29.0	**16.4**	4.6
Soybean – mustard		18.3	**21.9**	-3.8	-23.5	-33.3	-9.3	26.4	**31.5**	15.2
Soybean – chickpea		32.9	**24.9**	5.7	-11.9	1.0	-6.5	29.7	**22.6**	-3.9
Soybean – linseed		19.0	**1.6**	-14.2	-31.6	-22.6	-17.4	24.3	**5.8**	-2.5
Cotton – maize	Coimbatore (Semi-arid)	8.7	**46.2**	34.6	23.1	23.1	3.8	5.7	**29.4**	17.6
Chilli – sunflower		8.7	19.2	19.2	7.7	0.0	-15.4	5.3	**31.3**	-6.2
Beetroot – maize		7.0	**47.6**	28.6	23.8	19.0	4.8	6.0	**29.4**	11.7
Cowpea – safflower	Dharwad (Arid)	15.8	**28.8**	22.6	4.8	27.4	0.2	7.8	18.3	-26.3
Pigeon pea (sole)		15.7	31.1	24.9	**40.5**	38.4	-21.3	7.2	**67.7**	-23.8
Green gram – sorghum		21.9	-17.4	-17.4	-0.4	-5.2	-29.9	9.0	**42.4**	-24.3
Groundnut + hybrid cotton		16.3	21.5	24.5	28.9	**35.2**	-4.9	8.6	-7.9	-42.2
Maize – chickpea		17.6	-4.3	**16.0**	-1.3	7.3	2.2	10.4	-20.6	-41.9
Basmati rice – durum wheat – GM	Jabalpur (Sub-humid)	42.9	**43.6**	41.9	16.2	15.0	-2.2	33.2	**46.7**	45.1
Basmati rice – chickpea – maize (f)		38.5	**49.9**	45.7	16.5	15.0	1.5	30.5	**51.4**	49.6
Basmati rice – berseem (f & s)		39.3	**46.4**	45.8	22.7	21.2	0.0	30.7	**55.5**	52.4
Vegetable pea – sorghum (f)		43.1	**44.5**	42.6	14.5	12.0	-1.0	31.6	**51.7**	50.2
Basmati rice – chickpea – GM	Ludhiana (Semi-arid)	13.0	115.4	115.4	100.0	84.6	-7.7	11.0	**72.7**	45.5
Basmati rice – wheat – GM		14.0	**121.4**	100.0	64.3	57.1	-7.1	8.0	**187.5**	125.0
Cluster bean – wheat – summer moong		18.0	**38.9**	27.8	22.2	22.2	-11.1	8.5	**52.9**	41.2
Soybean – wheat		17.0	**70.6**	58.8	47.1	47.1	-11.8	9.0	100.0	88.9
Basmati rice – broccoli – sesbania GM	Narendrapur (Humid)	14.6	47.3	**60.5**	23.7	21.3	4.7	7.5	**73.8**	87.9
Paddy – mustard – green gram		11.1	51.0	**54.1**	35.9	24.1	2.9	5.5	**87.9**	60.7
Paddy – capsicum – green gram		10.0	68.5	**90.9**	48.6	41.0	-5.8	6.5	12.2	**21.4**
Paddy – French bean – sesame		10.9	44.8	**56.2**	25.5	24.3	-1.2	7.3	**80.0**	78.7
Cassava – veg. cowpea	Thiruva-nanthapuram (Coastal)	5.9	307.4	**357.1**	39.8	202.0	31.0	39.0	-69.6	-69.4
Cassava – groundnut		19.0	-56.3	-93.2	**24.7**	-68.4	-42.1	14.7	-84.4	-20.4
Taro – black gram		16.1	-20.5	-52.6	12.8	**183.2**	-64.2	13.2	-31.3	-44.2
Taro – green gram		10.0	**43.0**	10.0	-50.0	16.0	10.0	9.3	-38.7	-46.2
Number of recorded results			32	32	32	32	32		32	32
Cropping systems with higher respective values among methods (in per cent)			88	84	78	81	41		81	63
Cropping systems where values are significantly higher (> 20 per cent) with inorganic method, calculated out of overall higher			93	81	76	73	38		85	80
Range of difference in mean with inorganic (IOF) method (in per cent)			-56 – 307	-93 – 357	-50 – 100	-68 – 202	-64 – 38		-84 – 187	-69 – 125

Note: (-) represents data not available; Bold numbers represent highest values among methods; Values in green cells indicate

h different methods (2014–19)

h difference IOF method			SA - mean difference compared to IOF method						PSB - mean difference compared to IOF method					
IN75 (%)	IN50 (%)	SR (%)	IOF (cfu/g)	OF (%)	OIN (%)	IN75 (%)	IN50 (%)	SR (%)	IOF (cfu/g)	OF (%)	OIN (%)	IN75 (%)	IN50 (%)	SR (%)
44.8	33.9	41.3	12.3	**8.2**	-12.0	-34.5	-12.9	-11.4	13.1	**13.4**	-6.1	-29.8	-9.0	-5.9
42.3	31.5	35.8	12.2	**10.5**	-6.4	-34.3	-17.7	-8.4	13.0	**8.9**	-10.8	-26.2	-2.5	-2.7
52.0	39.3	39.8	13.1	**10.9**	-2.7	-38.8	-11.1	-11.5	13.3	**22.8**	-10.2	-25.8	-11.1	-4.9
47.8	39.0	24.5	12.8	-3.9	-21.3	-35.6	-10.6	-6.1	13.2	**20.7**	-5.9	-22.8	-9.9	-8.2
-8.4	-7.7	-10.3	52.2	**8.9**	-2.4	-28.3	-26.2	-9.4	-	-	-	-	-	-
-0.8	12.0	-3.2	58.7	**23.9**	-16.7	-44.6	-42.5	-21.8	-	-	-	-	-	-
-20.7	-19.6	-10.1	52.5	**37.1**	8.3	-15.5	6.4	-24.1	-	-	-	-	-	-
-23.0	-27.2	-18.9	51.7	**51.5**	3.9	-20.7	-16.2	-13.0	-	-	-	-	-	-
11.8	5.9	0.0	9.0	**3.7**	-18.5	-33.3	-22.2	-14.8	-	-	-	-	-	-
6.3	-18.8	0.0	7.3	**9.1**	-9.1	-27.3	-18.2	-18.2	-	-	-	-	-	-
15.0	-3.3	-2.2	5.0	**6.7**	-20.0	-20.0	-20.0	-6.7	-	-	-	-	-	-
24.4	-15.6	-4.0	19.8	**33.6**	26.7	-14.7	-7.7	9.3	16.7	**9.3**	-4.9	-6.9	-32.9	-8.9
-14.2	-14.4	-33.9	18.8	**73.9**	-11.9	-11.4	43.6	2.8	11.3	59.6	**65.2**	7.8	3.1	50.1
-12.4	-28.4	-31.3	27.3	**24.9**	-39.7	-25.0	-25.9	-33.6	15.6	**25.5**	-0.3	1.4	-10.7	-16.3
5.6	-37.8	-36.1	20.5	**29.4**	1.1	14.3	-25.0	9.2	11.9	24.0	21.8	16.2	38.9	**49.0**
-30.9	-50.4	-37.2	24.9	-12.3	-16.7	**1.0**	-5.2	-11.0	19.8	-42.5	-29.5	-26.5	-36.3	-26.4
31.0	28.3	-5.5	19.5	**26.6**	18.4	-32.5	-37.5	-5.2	16.9	**11.3**	9.3	-12.0	-18.6	0.6
21.7	18.5	-4.0	16.7	**31.9**	21.5	-34.7	-40.4	-20.2	14.0	**34.4**	25.3	-10.9	-12.2	-7.4
30.2	27.4	-2.3	17.3	**23.6**	21.0	-31.6	-40.9	-11.7	13.5	**33.4**	21.7	-22.1	-26.3	-4.9
21.4	19.4	-2.0	19.1	**10.6**	6.7	-41.0	-46.6	-4.6	14.3	**21.8**	14.8	-20.5	-27.6	9.0
9.1	4.5	-9.1	11.0	109.1	90.9	**218.2**	181.8	9.1	12.5	**44.0**	20.0	-20.0	-36.0	-4.0
37.5	12.5	-12.5	20.0	46.5	25.0	95.0	**100.0**	-10.0	9.5	**10.5**	7.4	-36.8	-57.9	-5.3
17.6	5.9	-5.9	10.0	30.0	59.0	220.0	**290.0**	10.0	10.0	**50.0**	32.0	-10.0	-15.0	10.0
100.0	11.1	0.0	13.0	38.5	30.8	123.1	**176.9**	23.1	9.0	**32.2**	11.1	-22.2	-33.3	8.9
42.1	47.4	-2.9	22.9	5.9	**20.3**	-25.6	-27.2	-8.7	-	-	-	-	-	-
52.0	49.6	-2.8	18.1	14.6	**18.3**	-18.5	-23.4	-4.9	-	-	-	-	-	-
-5.5	-0.7	11.2	21.1	-0.1	**28.0**	-18.9	-24.6	-2.0	-	-	-	-	-	-
52.8	46.8	17.8	18.4	16.9	**20.4**	-23.0	-26.6	-8.0	-	-	-	-	-	-
-83.6	-74.7	-76.1	1.2	34.3	89.4	**153.4**	34.0	34.0	34.9	-86.0	-96.6	-84.2	-48.7	-92.3
24.5	-57.1	**76.9**	4.0	-67.1	-67.1	**125.0**	107.9	-50.0	0.9	644.4	377.8	777.8	**3811.1**	100.0
-34.6	-24.5	**25.3**	1.4	23.0	**256.5**	130.4	161.8	38.9	11.9	-41.2	-36.1	-41.2	-79.8	-61.3
10.8	-17.2	**29.0**	2.3	**129.6**	86.4	59.0	43.2	43.2	10.0	-48.0	**173.0**	6.0	19.0	-36.0
32	32	32		32	32	32	32	32		21	21	21	21	21
69	53	28		88	59	31	31	28		81	57	24	19	33
68	53	78		61	68	80	90	44		71	58	20	50	43
-84 – 100	-75 – 50	-76. – 77		-67 – 130	-67 – 256	-45 – 290	-47 – 290	-50 – 43		-86 – 644	-97 – 378	-84 – 779	-80 – 3811	-92.3 – 100

higher than inorganic method, and values in red cells indicate lesser than inorganic method

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The report presents holistic evidence based on long-term research and projects in India. The evidence is in favour of organic and natural farming over chemical-dependent inorganic farming. Organic and natural farming approaches are not only profitable and sustainable but also productive.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phones: 91-11-40616000 Fax: 91-11-29955879
E-mail: cseindia@cseindia.org Website: www.cseindia.org