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Long term effect of integrated nutrient management on soil nutrient status under rice-wheat cropping system in Inceptisols

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Abstract
The present experiment "Long term effect of integrated nutrient management on soil nutrient status under rice-wheat cropping system in Inceptisols" was carried out during *Kharif-Rabi* season of 2015 - 2016 at the instructional cum research farm, IGKV, Raipur. The objectives of the study were the long term effect of INM on soil major nutrient status after 24th crop cycle under rice-wheat cropping system, to find out the best INM practice on the basis of cropping system productivity and economics. The experiment was laid out in Randomized block design and replicated three times with twelve treatments *i.e.* T1 (control), T2 - 50%RDF-50RDF%, T3 - 50%RDF-100%RDF, T4 - 75%RDF-75%RDF, T5 - 100%RDF-100%RDF, T6 - 50%RDF+50%FYM-100%RDF, T7 - 75%RDF+25%FYM-75%RDF, T8 - 50%RDF+50%RR-100%RDF, T9 - 75%RDF+25%RR-75%RDF, T10 - 50%RDF+50%GM-100%RDF, T11 - 75%RDF+25%GM-75%RDF, T12 - FP-FP. Result revealed that combined application of inorganic fertilizer and organic manure during *kharif* and *rabi* improve chemical properties of soil like organic carbon, available N, P and K status in soil. The highest available nitrogen (288.6 kg ha^{-1}) and available phosphorus (28.5 kg ha^{-1}) content was recorded in T10 - 50%RDF+50%GM-100%RDF. The higher available calcium and sulphur was recorded in T6 -50%RDF+50%FYM-100%RDF, treatment. The available micronutrient was observed in T6 - 50%RDF+50%FYM-100%RDF. Maximum number (448.67 m^{-2}) of effective tiller and test weight (46.19g) was recorded in T10 - 50%RDF+50%FYM-100%RDF. The yield of rice and wheat increased with increasing the levels of mineral nutrients from Treatment T10 - 50%RDF+50%FYM-100%RDF highest grain yield (61.25 Q ha^{-1}) of rice and wheat (31.46 Q ha^{-1}) was significantly superior. The Harvest index was observed highest (41.64%) in T3-50%RDF-100%RDF NPK. Agronomic efficiency was recorded maximum (51.31 kg kg^{-1}) under T10 - 50%RDF+50GM-100%RDF. The Factor productivity index was observed highest (62.91) under T10 - 50%RDF-50GM-100%RDF. Harvest index of these treatments was also higher. These results are also reflected in the net return and B: C ratio. Maximum total productivity (TP) in terms of rice equivalent yield (98.35q/ha) was recorded under treatment 100% RDF + 100% RDF during both *kharif* and *rabi* (T_5). The per cent change in TP in terms of rice equivalent yield (q/ha) and total net return (*Kharif +Rabi*) over farmer's practice were also highest 70.33% and Rs. 59,198/ha, respectively) under treatment 100% RDF + 100% RDF during both *kharif* and *rabi* (T_5) followed by 50% RDF+50% N through GM during *kharif* and 100% RDF during *rabi* (T_{10}) (64.60% and Rs 53,908 /ha, respectively).

Keywords: Integrated nutrient management, Inceptisols, rice-wheat cropping system, soil nutrient status

1. Introduction

The present experiment entitled "Long term effect of Integrated Nutrient Management on soil nutrient status under rice-wheat cropping system in Inceptisols". The evidence is clear that the soil's native ability to supply sufficient nutrients has decreased with the higher crop productivity levels associated with increased human demand for food. One of the greatest challenges and need of our generation will be to develop and implement soil, crop, and nutrient management technologies that enhance the quality of the soil, water, and air. If we do not improve and sustain the productive capacity of our fragile soils, we cannot continue to support the food and fibre demand of our growing population. In agricultural experiments, there are reasons to believe that fertilizer treatments once applied on an experimental unit on a crop may not fully react during the crop season on that particular unit. The treatments may leave residual effect on the succeeding crop. To formulate fertilizer recommendations for crops, it is, therefore, essential that the experiments should be repeated over time at the same site as the effects of climate, soil, fertilizer, agronomic practices, etc. get stabilized only after a period of years and responses to fertilizer treatments also become more stable and reliable.

The earliest long-term experiments called permanent manurial experiments were started at Rothamsted Experimental station, Harpenden, Herts, England between 1843 and 1856 by J.B. Lawes and J.H. Gilbert and are known as "Rothamsted classical Experiments". Based on the Rothamsted model many such experiments were started in several parts of the world. The principal aim of Long Term Fertilizer Experiments (LTFE) set up in the country in 1885 has been to evaluate the long term effect of the organic and inorganic manuring on crop production and soil health under high-input soil management technology. To carry out these experiments the ICAR sponsored the All India Coordinated Research Project on Long Term Fertilizer Experiments (Nambiar and Abrol 1989, Nambiar 1994) [17, 18] in different agro climatic regions of India since 1971.

Increasing world population in the coming decades would require increased production of food, feed, fuel and raw materials from limited land area. The current world population of 7.2 billion is projected to increase by 1 billion over the next 12 years and reach 9.6 billion by 2050 (UN 2014). Recent estimates indicate that global crop demand will increase by 100 to 110 from 2005 to 2050 (Tilman *et al*. 2011) [11]. Other estimates suggest that 60% more cereals need to produce to meet world requirement in 2050 (FAO 2009). Glenn *et al*. (2008) [4] earlier predicted that food demand would double within 30 years which is equivalent to maintaining a proposal rate of increase of more than 2.4% per year. Sustainably meeting such demand is a huge challenge, especially when compared to historical cereal yield trends which have been linear for nearly half a century with slopes equal to only 1.2 to 1.3% of 2007 yields (FAO 2009).

Indian population is expected to be around 1.33 billion by 2020 (GOI, 2014), reaching 1.66 billion by 2050 (US, 2014). Summarized several studies that showed food grain demand in India reaching 293 mt by 2020 and increasing to 335mt by 2026. The national thrust has been on maximization of food production to feed the expanding population. The scope of horizontal expansion of cultivated area is limited, as the competition for scarceland resources between agriculture and urban interest are leading to a decline in per capita land availability. Unfortunately, it is often the best agricultural land that is used for urban expansion (Majumdar *et al*. 2013) [8]. Further, soils of India are generally poor in fertility as these have been depleted consistently of their nutrient reserves due to continuous cultivation. The expected food grain has to be attained by enhancing the productivity per unit area. Improving and maintaining soil fertility for enhancing and sustaining crop production is of worldwide importance. It is well recognized that long-term fertilizer experiments are valuable repositories of information regarding the sustainability of intensive agriculture. Many factors influence the complex chemical, physical and biological processes, which governs soil fertility and productivity.

Changes in soil fertility caused by imbalanced fertilizer use, acidification, alkalinity, salinity and declining in soil organic matter (SOM) may take up several years to appear. These properties can in turn influence by external factors such as atmospheric pollution, global climate changes or land use management practices. Long term experiments provides the best possible means of studying changes in soil properties and processes and identifying emerging trends in nutrient imbalances and deficiencies and to formulate future strategies for maintaining soil health. The purpose of long term fertilizer experiments at fixed sites in different agro-ecological zones (AEZ) and on important cropping system is not only to monitor the changes in yield response due to continuous application of plant nutrient inputs from fertilizers and organic sources, but also to help in the development of strategies and policies for rational fertilizer use and management and in improvement of quality of soil and the environment.

In view of these emerging requirements, the Indian Council of Agricultural Research decided to launch the All India Coordinated Research Project on Long Term Fertilizer Experiments in September 1970.The Objectives of the paper deals with:

1. Long term effect of Integrated Nutrient Management on soil major nutrient status after 24th crop cycle under Rice-Wheat cropping system.
2. To find out the suitable integrated nutrient supply and management system for rice-wheat crop sequence.
3. To assess the effect of inorganic fertilizers and organic manures on secondary and micro nutrient content in soil.
4. To find out the best Integrated Nutrient Management practice on the basis of cropping system productivity and economics.

2. Material and Methods

The present investigation entitled "Long term Effect of Integrated Nutrient Management on soil nutrient status under rice-wheat cropping system in Inceptisols" was conducted at the instructional cum research farm of AICRP on IFS experiment during the *Kharif* - *Rabi* season 2015-16.

There are 12 treatments in the experiment *i.e.* T1 (control), T2 - 50%RDF-50RDF%, T 3 - 50%RDF-100%RDF, T4 - 75-75%RDF, T5 - 100%RDF-100%RDF, T6 - 50%RDF + 50%FYM-100%RDF, T7 - 75%RDF + 25%FYM-75%RDF, T8 - 50%RDF + 50%RR-100%RDF, T9 - 75%RDF + 25%RR-75%RDF, T10 - 50%RDF+50%GM-100%, T11 - 75%+25%GM-75%RDF, T12 - FP-FP.A medium duration high yielding rice variety "Mahamaya" and wheat variety "GW-273" was taken as a test crop. The treatments are replicated 3 times in randomized block design and the plot size is 12m×5.2m.

Initial Status of soil

Table 2.1

pH	EC	Organic Carbon	Available N	Available P	Available K
7.21	0.20	5.1 g Kg^{-1}	234 kg ha^{-1}	11.5 kg ha^{-1}	280 kg ha^{-1}

Farm Yard Manure, Rice Residue, Green Manuring (Sun hemp) and the whole amount of P and K was applied as basal dressing, while nitrogen was applied in three splits as basal and remaining in two equal splits at active tillering and panicle initiation stage as per the treatment dose. The required quantity of basal doses of FYM and chemical fertilizers were broadcasted in the field before transplanting.

2.1. Observations recorded
2.1.1. Soil properties
The soil samples after harvest of wheat 2015-16 were used for following attributes:

2.1.2. Soil analysis
2.1.3. Sample preparation
The soil samples were taken up to 15cm depth from each plot at initial and after crop wheat harvest. The samples were air dried, grinded, sieved (2mm sieve) and used for the following soil chemical analysis.

2.1.4. Method of analysis
2.1.5. Chemical attributes
2.1.5.1. Soil pH
Soil pH was determined by glass electrode pH meter taking 1:2.5 soil water suspensions after stirring it for 30 minutes, method as described by Jackson (1973) [10].

2.1.5.2. Electrical Conductivity
The soil sample used for pH determination was allowed to settle down for 24 hours. The electrical conductivity of the supernatant liquid was determined by conductivity meter as described by Black's (1965) [2].

2.1.5.3. Organic carbon
It was estimated by Walkley and Black's (1965) [2] rapid titration method as described by Jackson (1973) [10]. In this method, organic matter is oxidized with chromic acid (potassium dichromate + sulphuric acid).The unconsumed potassium dichromate is back titrated against standardized ferrous sulphate or ferrous ammonium sulphate.

2.1.5.4 Available N
Available nitrogen content in soil was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956) [22]. The procedure involves distilling the soil with alkaline potassium permanganate solution and absorbs the ammonia liberated in boric acid which was then titrated with standards sulphamic acid.

2.1.5.5 Available P
Available phosphorus was estimated by the ascorbic acid method as described by Olsen, (1954) [19]. In this method, 2.5 gm soil sample was extracted with 0.5 M sodium bicarbonate at pH 8.5. After extraction from the soil, phosphate in the extract is measured by the reaction of phosphate with ammonium molybdate in an acid medium to form molybdo phosphoric acid which is then reduced to a blue colored complex through reaction with ascorbic acid. Absorbance readings were taken at an 882 nm wavelength using a double beam spectrophotometer. A standard curve constructed from absorbance readings of standards is used to deduce phosphate concentration of sample.

2.1.5.6 Available K
Available potassium was determined by the flame photometer after 5 minute shaking soil with 25 ml of 1 ammonium acetate (Hanway and Heidel, 1952) [9].

2.1.5.7 Available Secondary nutrients (Ca and Mg)
Available Ca and Mg were estimated in ammonium acetate extract method and titrate with standard EDTA solution as described by the method of Tucker and Kurtz (1961) [25].

2.1.5.8 Available S
Available Sulphur in soil was determined by the $CaCl_2.H_2O$ (0.15% Solution) extractant and estimated by turbidemetric method (Williams and Steinbergs, 1959).In this method weigh 10 gm of air-dry soil in a 150 ml conical flask and add50 ml of 0.15% $CaCl_2$extractantsolution. Shake for 30 minutes on a rotary shaker and filter through Whatman No. 42 filter paper. Take 10 ml of the clean filtrate in a 25 ml volumetric flask, add 1ml of 0.25% gum acacia solution, make up the volume with distilled water and shake well manually, add 1 gm of $BaCl_2$ crystal each flask and swirl to dissolve the crystals within 5-30 minutes for development of turbidity (white color) and read the absorbance at 440 nm through spectrophotometer.

2.1.5.9 Available Micro nutrients (Fe, Mn, Zn, Cu)
Micronutrients, i.e. Fe, Mn, Cu and Zn were extracted by using 0.005 M diethylenetriaminepenta acetic acid (DTPA), 0.01 M calcium chloride dehydrates and 0.1M triethanol amine (TEA) buffered at pH 7.3 and the concentrations of the nutrients in the filtrate were analyzed by atomic absorption spectrophotometer (Lindsay and Norvell, 1978) [15].

2.1.5.10 Available B
Available boron in soil determined by the Azomethine –H (John *et al*. 1975) [11]. Weigh 20 g of air – dry soil sample in 250 ml quartz or other boron –free conical flask and add 40 ml of distilled water. Add 0.5 g activated charcoal and boil for 5 minutes on a hot plate, filter immediately through Whatman No. 42 filter paper. Cool the contents to room temperature and transfer 1 ml aliquot in 10 or 15ml polypropylene tubes. Add 2 ml of buffer solution and mix. Add 2 ml of azomethene –H reagent, mix and after 30 minutes read the absorbance at 420 nm on a spectrophotometer.

2.2 Plant observation
2.2.1 Effective tillers
Number of tiller were counted manually and then divided by plant population for obtaining number of tiller hill^{-1}.

2.2.2 Test weight
Grain samples were taken from the produce of each net plot. Out of the samples, 1000 grains were counted and the same were dried in an oven at 60 °C to constant weight. Thereafter, weight was recorded on an electronic balance.

2.2.3 Grain yield
The weighed bundles were threshed, winnowed and cleaned separately from each net plot. The grain yield was observed at about 14% moisture content and converted to kg ha^{-1}.

2.2.4 Straw yield
It was calculate by deducting the grain yield from bundle weight and converted to kg ha^{-1}.

2.2.5 Harvest index
The harvest index was determined from mean value of seed yield ha^{-1} and biological yield ha^{-1} at the time of harvest using formula given by Donald (1962) [5].

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \text{X} 100$$

Where,
Economic yield = Grain yield
Biological yield = Grain yield + Straw yield

2.2.6 Agronomic Efficiency
It refers to the additional produce obtained in kg grain kg-1 of nutrient (N) applied.

$$AE(kg\ kg^{-1}) = \frac{(Grain\ yield(kg)\ with\ N)(Grain\ yield(kg)\ without\ N)}{Kg\ N\ applied}$$

2.2.7 Factor productivity index
It was calculated by using the formula given by Cassman *et al*. (1996) [3] as follows

$$FPI = \frac{Grain\ yield(Kg\ ha^{-1})}{N\ rate(Kg\ ha^{-1})}$$

2.3 Statistical analysis
The experiment was laid out in Randomized Block Design (RBD). The data obtained from various characters under study were analyzed by the method of analysis of variance as described by Gomez and Gomez (1984) [8]. The level of significance used in "F" test was given at 5 per cent. Critical difference values are given in the table at 5 percent level of significance, wherever the "F" test was significant at 5 per cent level. The skeleton of analysis of variance and formula used for various estimations are given below:

Table 2.2: The skeleton of the analysis of variance

Source of variation	DF	SS	MSS	F cal	F tab (5%)
Replication(r)	(r-1)	RSS	RMS	RMS/EMS	-
Treatment(t)	(t-1)	TrSS	TrMS	TrMS/EMS	-
Error	(r-1)(t-1)	ESS	EMS	-	-
Total	rt-1	TSS	-	-	-

The following formula was used for standard error, critical difference and coefficient of variance estimations.

(a) SEm±	EMS/r
(b) CD	S.Em x √2 x t value at 5% error (df)
(c) CV (%)	√ SEM/GMx 100
Where,	
R = Number of replication	MSS = Mean sum of square
T = Number of treatment	SEm± = Standard error of mean
DF = Degree of freedom	EMS = Error mean squares
SS = Sum of square	CD = Critical difference

3. Result and Discussion
Continuous use of fertilizer, manure and their combination did not affect the soil pH even after 24 crop cycle. The organic carbon content of the soil decreased over the time on continuous cropping without application of fertilizer and manure from 7.43 to 7.23 g Kg^{-1}. On the other hand application of FYM singly or in combination with fertilizer increased its value significantly (Table 3.1).

Soil pH was determined after harvest of wheat crop in different treatments the data is presented in Table 3.1. The soil pH showed non-significant difference with respect to different organic manures and inorganic fertilizers applied. In all the treatments, there was no remarkable change in soil pH as compared to the control. At present higher value 7.43 of pH was recorded in T5- 100%RDF+100%RDF treatment and lower value 7.23 of pH recorded in T6-50%RDF+50FYM-100% RDF treatment.

The data on electrical conductivity (EC) is presented in Table 3.1. The effect of applied organic and inorganic fertilizer on EC was statistically non-significant. The higher value 0.24dSm^{-1} of EC was recorded in T3-50%RDF-100%RDF and T9-75%RDF+25RR-75%RDF however, lower value 0.21 dSm^{-1} of EC recorded in T2-50%RDF-50%RDF, T5-100%RDF-100%RDF, T6-50%RDF+50FYM-100%RDF, T7-75%RDF+25RR-75%RDF and T12-FP-FP treatment. Soil EC showed significant change over initial value with the applied organic manure and inorganic fertilizer treatment. The different treatment did not influence the pH and EC of soil. The values were almost constant and similar finding was also reported by Urkurkar*et al.* (2010) [14], with almost same set of treatment in rice crop.

The data on soil organic carbon (SOC) is presented in Table 1.1. The Initial SOC was 5.1 g kg^{-1}. The SOC vary from 5.2 to 6.8 g kg^{-1} amongst different treatments. The level of application of inorganic fertilizer along with organic manure significantly increased the organic carbon. SOC was recorded highest 6.8g kg^{-1} in T10-50%RDF+50GM-100%RDF while, lowest (5.03 g kg^{-1}) under T1-0-0 Treatment. The high values of SOC in integrated nutrient management practices might be due to long term incorporation of organics as compare to other treatments.

Table 3.1: Long term effect of fertilizer, manure and their combinations on chemical properties of the soil after 24 years of rice-wheat cropping system

Treatment	pH	EC (dSm^{-1})	OC (g Kg^{-1})	Available Nitrogen (Kg ha^{-1})	Available Phosphorous (Kg ha^{-1})	Available Potassium (Kg ha^{-1})
T1 -0-0	7.33	0.23	5.03	163	7.9	185.1
T2-50%-50%	7.37	0.21	5.27	219.3	16.9	250.1
T3-50%-100%	7.40	0.24	5.80	248.3	18.8	259.8
T4 75%-75%	7.37	0.22	6.20	257.6	21.1	267.8
T5-100%-100%	7.43	0.21	6.47	272.3	27.5	294.1
T6-50%+50%FYM-100%	7.23	0.21	6.77	275.3	23.8	303.4
T7-75%+25%FYM-75%	7.30	0.21	6.53	262.3	26.1	316.4

T8-50%+50%RR-100%	7.37	0.22	6.13	252.3	22.8	289.8
T9-75%+25%RR-75%	7.33	0.24	6.20	257.3	20	277.8
T10-50%+50%GM-100%	7.30	0.23	6.80	288.6	28.5	313.8
T11-75%+25%GM-75%	7.33	0.22	6.73	268.6	24.8	309.4
T12-FP-FP	7.30	0.21	6.07	236.3	20.7	273.1
Initial	7.12	0.20	5.1	234	11.5	280
SEm±	0.04	0.008	0.17	4.26	0.83	5.12
CD 5%	0.13	0.02	0.50	12.51	2.44	15.03

The data on available nitrogen content in soil was shown in Table 1.1 and the long term fertilizer experiment was started in 1999 and the initial available nitrogen content of soil was 234 kg ha^{-1}.The data on available N varies between 163 to 288.6 kg ha^{-1} amongst different treatments. Higher amount of available N (288.6 kg ha^{-1}) in T10 -50%RDF+50GM-100%RDF.and the lowest (163 kg ha^{-1}) was recorded in control. The T1-0-0 and T2-50%RDF-50%RDF treatment showed the negative balance of available N while other treatments had positive balance of available N. The losses of N were more from soil as compare to its addition in soil. Adding green manure favoured the soil conditions and might have helped in the mineralization of soil N leading to build up of increased available N.

The data on available phosphorus content in soil after harvest of wheat crop is arranged in Table 3.1 the initial data of available P was 11.5 kg ha^{-1}. The range of available P was vary from 7.9 to 28.5 kg ha^{-1} in various treatments. Available P content of soil was increased as compared to its initial status. Highest available P (28.5 kg ha^{-1}) was obtained with T10-50%RDF+50GM-100%RDF treatment followed by T5-100%RDF-100%RDF and lowest in control plot (7.9 kg ha^{-1}). Continuous application of balanced fertilizer since 1999-2014 is conducive for maintaining the soil available P. The results of the present study also revealed that higher available P content were recorded in integrated nutrient management treatments as compared to absolute control and devoid of its application. It was also observed that successive significant increase had occurred due to increasing levels of fertilizer application along with organic manure addition in soil. Similar results have also been reported by Thakur *et al*., (2010) [10]. They found that exclusion and/or omission of P in the fertilizer schedule had resulted in lowering the available P content in the soil. And he also reported the beneficial effects of organic matter on available P in soil.

The long term fertilizer experiment was started in 1999 and the available potassium value of soil was 280 kg ha^{-1}.The data on available K after harvest of wheat crop is presented in Table 3.1 Available K ranged between from 185.1 to 316.4 kg ha^{-1} amongst various combination of inorganic and organic nutrient management treatment. The higher available K (316.4kg ha^{-1}) was obtained with T7-75%RDF+25%FYM-75%RDF and lower (185.1 kg ha^{-1}) in control. The negative change in available K content in T1-0-0, T2-50%RDF-50%RDF, T3-50%RDF-100%RDF, T4-75%RDF-75%RDF, T9-75%RDF+25RR-75%RDF and T12-FP-FP treatments showed the luxury consumption of potassium while other treatments had positive change in available K content. Continuous use of N,P and K fertilizer over the years reduced the organic carbon status leading to a decline in the availability of macronutrients in soil whereas, FYM incorporation along with N,P and K fertilizers increased the organic C status of soil which consequently caused higher availability of N,P and K in soil. These findings are in agreement with those of Krishna (2003) [6].

At present the soil available calcium after the harvest of wheat crop showed significant difference with respect to different organic manures and inorganic fertilizers applied except T1-0-0, T2 -50%RDF+50%RDF and T3-50%RDF+100%RDFtreatments, there was perceptible change in soil available calcium as compared to the control. However, higher value (13813.3 kg ha^{-1}) of calcium was recorded in T6-50%RDF+50%FYM-100%RDF treatment, and lower value (9856 kg ha^{-1}) of calcium recorded in T1-Control due to continuous application of SSP and FYM over 24 years. The similar finding was observed by Tadesse *et al.* (2013) [13].

The effect of applied organic and inorganic fertilizer of soil available magnesium over a period of 24 years was statistically significant. However, higher value (6876 kg ha^{-1}) of available magnesium was recorded in T6-50%RDF+50%FYM-100%RDF treatment and lower value (5824 kg ha^{-1}) of available magnesium recorded in control plot.

Available sulphur status of the soil was significantly influenced by application by either chemical fertilizer or manure over the control (Table 1.2).The available sulphur of soil varies from 8.19 to 16.41 mg Kg^{-1}. Higher value of sulphur fertilizer recorded in T6-50%RDF+50%FYM-100%RDF (16.41 mg Kg^{-1}) and lower value in T1-0-0 (8.19 mg Kg^{-1}).

The significant changes in the status of soil available boron over a period of 24 years due to various treatments. The present study of available boron content in soil after harvesting of wheat crop ranged from 0.34 to 0.9 mg kg^{-1}.The highest value 0.9 kg ha^{-1} and lowest value 0.34mg kg^{-1} after harvesting of wheat crop was observed in treatment T6-50%RDF+50FYM-100%RDF and T10-50%RDF+50GM-100%RDF and T1-control, respectively.

The significant changes in the status of available zinc over a period of 24 years due to various treatments over control. The results showed that the available zinc content (after harvest of wheat) ranged from 1.10 to 2.08 mg kg^{-1} in amongst various combination of inorganic and organic nutrient management treatment. The available soil zinc was significantly highest was obtained with T6-50%RDF+50FYM-100%RDF (2.07 mg kg^{-1}) followed by T7-75%RDF+25%FYM-100%RDF (2.06 mg kg^{-1}), T5-100%RDF-100%RDF (1.95 mg kg^{-1}), T10-50%RDF+50%GM-100%RDF, T4-75%RDF-75%RDF (1.85 mg kg^{-1}), T9-75%RDF+25%RR-75%RDF and over control (1.10 mg kg^{-1}) but within the treatment all the treatment was at par with T6-50%RDF+50FYM-100%RDF. DTPA extractable Zn, Fe, Mn and Cu status of the in present study decreased after 24 crop cycle. The available micronutrients increased with the application of FYM alone or in combination with chemical fertilizers. The higher availability of micronutrients in soil on application of manures could be as cribbed to mineralization of these nutrients from added manures. Chelating action of FYM during decomposition of organic manures increases the availability of micronutrients cations and also protects these cations from fixations.

The significant changes in the status of soil available iron over a period of 24 years due to various treatments. The data on available iron content after harvest of wheat crop in various treatments was ranged from 17.53 to 31.10 mg kg^{-1} the highest available iron was recorded in treatment T6-50%RDF+50%FYM-100%RDF (31.10 mg kg^{-1}**)** which was at par over rest of the treatments except control (T1-0-0) and farmer practices (T12-FP-FP). However, lowest amounts of available iron (17.53 mg kg^{-1}) were observed in the unmanured control which was due to the continued exhaustion of available iron.

The significant changes in the status over a period of 24 years due to various treatments. The highest available manganese was recorded in treatment T6- 50%RDF+50%FYM-100%RDF(31.10 mg Kg^{-1}) which was significantly superior over control (23.50 mg kg^{-1}) but at par with rest of the treatments except alone application of chemical fertilizer and farmer practices. The available manganese content was found in the order of T6>T9>T7>T8>T10>T5>T4>T3>T2>T12>T1.The increased available manganese content may be due to application of manures & fertilizers.

The significant changes in the status of soil available copper due to various treatments over a period of 24 year crop cycle. The DTPA-extractable copper content in soils (after harvesting of wheat crop) varied from 2.61 to 3.37 mg kg^{-1}. The maximum value (3.37 mg kg^{-1}) and minimum value (2.61 mg kg^{-1}) after harvesting of wheat found in treatment T6-50%RDF+50%FYM-100%RDF and control T1-0-0 (Control) respectively.

Table 3.2: Effect of organic manures and inorganic fertilization on calcium, magnesium, sulphur, Boron, zinc, iron, manganese and copper after 24 crop cycle

Treatment	Available Calcium (Kg ha^{-1})	Available Magnesium (Kg ha^{-1})	Available Sulphur (mg Kg^{-1})	Available Boron (Mg Kg^{-1})	Available Zinc (mg Kg^{-1})	Available Iron (mg Kg^{-1})	Available Manganese (mg Kg^{-1})	Available Copper (Mg Kg^{-1})
T1 -0-0	9856.00	5824	8.19	0.34	1.10	17.53	23.50	2.61
T2-50%-50%	10826.67	5668.80	11.50	0.43	1.33	25.40	24.73	2.77
T3-50%-100%	11722.33	5712.00	12.37	0.43	1.43	26.07	24.77	2.80
T4-75%-75%	11797.33	6048.00	12.93	0.59	1.85	26.23	24.89	2.87
T5-100%-100%	12880.00	6563.20	12.36	0.62	1.95	26.67	25.57	3.13
T6-50%+50%FYM-100%	13813.33	6876.80	16.41	0.90	2.07	31.10	31.73	3.37
T7-75%+25%FYM-75%	134440.00	6764.80	13.23	0.78	2.03	29.07	28.80	3.33
T8-50%+50%RR-100%	13402.67	6575.20	12.39	0.62	1.85	25.30	28.57	3.13
T9-75%+25%RR-75%	12506.67	5956.80	11.69	0.63	1.85	25.97	30.23	3.23
T10-50%+50%GM-100%	12320.00	6720.00	13.37	0.90	1.87	29.83	27.60	3.07
T11-75%+25%GM-75%	12506.67	6406.40	10.71	0.58	1.80	29.07	25.33	2.98
T12-FP-FP	12320.00	5936.00	11.52	0.48	1.31	24.17	24.30	2.67
SEm±	693.7	285.4	0.75	0.01	0.07	2.17	2.40	0.13
CD(P=0.05)	1907.2	837.3	2.21	0.05	0.20	6.37	7.04	0.39

Data pertaining on number of effective tillers per m^2 (Table 3.3) showed that all the treatments had non-significant differences over the control. T10-50%RDF+50GM-100%RDF showed higher response on number of tillers as compare to other treatment combination. At harvest, all the treatments combination proved non-significantly superior over control in producing effective tillers per square meter. The T10-50%RDF+50GM-100%RDF gave maximum (448.67 m^{-2}) number of effective tillers followed by T6-50%RDF+50FYM-100%RDF (430.33 m^{-2}) and minimum in control plot (87.67m^{-2}).

The yield of rice increased with increasing the levels and or increment of mineral nutrients from 50 to 100% RDF. Treatment T5 consisting of 100% registered highest grain yield (62.39 Q ha^{-1}) of rice which was non-significantly superior to 50% N and control plots. The grain yield was lowest (12.81 Q ha^{-1}) in control plot. The straw yield of rice was recorded highest in T5-100%RDF-100%RDF (82.91 Q ha^{-1}) and lowest in control (22.60 Q ha^{-1}) plot. The harvest index was observed highest (44.04%) in T7-75%RDF+25RR-75%RDF. Whereas minimum (36.23%) was estimated under control plot. Agronomic efficiency was recorded maximum (96.87 kg kg^{-1}) under T10-50%RDF+50GM-100%RDF and minimum in T5-100%RDF-100%RDF (49.58 kg kg^{-1}). The Factor productivity index was observed highest (122.5) under T10-50%RDF+50GM-100%RDF and lowest (62.39) in T5-100%RDF-100%RDF.

Table 3.3: Effect of integrated nutrient supply system on yield, yield attributes economics of rice 2015-16

Treatment	Rice								
	No. of tillers/m^2	Grain yield (q/ha) 2015	Mean of 24 years	Straw yield (q/ha)	Agronomic Efficiency (Kg Kg^{-1})	Factor Productivity Index	HI	NR (Rs/ha)	B:C ratio
T1 -0-0	87.67	12.81	19.50	22.60	-	-	36.23	-4063	-0.17
T2-50%-50%	319.00	41.67	43.38	66.85	57.70	83.33	38.37	37972	1.52
T3-50%-100%	326.67	45.00	47.85	68.54	64.39	90	39.62	42641	1.71
T4-75%-75%	319.33	51.15	52.12	68.19	51.11	68.19	42.74	50231	1.96
T5-100%-100%	429.33	62.40	59.49	82.92	49.58	62.39	42.93	66219	2.52
T6-50%+50%FYM-100%	430.33	56.08	57.78	73.75	86.54	112.16	43.27	56525	2.13
T7-75%+25%FYM-75%	414.00	55.73	56.01	70.77	57.22	74.3	44.04	55876	2.11
T8-50%+50%RR-100%	397.67	53.54	54.08	73.33	81.45	107.08	42.23	53282	2.02
T9-75%+25%RR-75%	408.00	56.77	55.35	76.56	58.61	75.69	42.61	57977	2.20
T10-50%+50%GM-100%	448.67	61.25	61.06	79.27	96.87	122.5	43.60	64492	2.47

T11-75%+25%GM-75%	427.00	57.71	59.03	77.50	59.86	76.94	42.70	59041	2.22
T12-FP-FP	272.00	39.17	45.42	61.29	52.70	78.33	38.96	33863	1.35
SEm±	9.33	2.43	-	3.09	3.9	3.7	1.53	-	-
CD 5%	27.37	7.13	-	9.08	11.4	10.9	4.48	-	-

Data pertaining to grain yield of rice as influenced by different nutrient management system revealed that the highest grain yield of rice was obtained under 100% recommended NPK dose through fertilizer in rice and 100% recommended NPK dose through fertilizer in wheat crop (T5) which was comparable to 50% inorganic +50% FYM-100% inorganic (T6) 75% inorganic+25% FYM-75% inorganic (T7), 75% inorganic + 25%RR-75% inorganic (T9), 50% inorganic +50% GM-100% inorganic (T10) and 75% inorganic + 25% GM-75% inorganic (T11). Similar results were also reflected in the net return and B: C ratio which was registered highest (Rs. 66,219/ha and 2.52) in 100% chemical fertilizer (T_5) and was in close comparison with 50% RDF + 50% N from green manuring (Rs 64492/ha and 2.47). It is clearly revealed from the Table 1.3 that the *in-situ* incorporation of green manure+50% RDF (T10) and 100% RDF maintained the grain yield of rice between 55-65 q/ha over the 24 years with a slight deviation around the respective mean grain yield. While a clear diminish in yield under control (T_1) during entire period of study could be seen in table 3.3. The yield of 50-50 RDF to both the crops also showed great reduction in yield.

Table 3.4: Effect of long term application of inorganic fertilizers and organic manures on wheat yield

Treatment	Wheat								
	No. of ears/plant	Test weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Agronomic Efficiency (Kg Kg^{-1})	Factor Productivity Index	HI	NR (Rs/ha)	B:C ratio
T1 -0-0	67.33	33.23	5.80	9.69	-	-	37.40	-6998	-0.40
T2-50%-50%	193.00	43.42	16.47	26.06	21.33	32.93	38.76	10392	0.56
T3-50%-100%	208.33	44.28	26.46	37.04	41.31	52.91	41.67	25724	1.28
T4-75%-75%	207.00	44.20	25.38	37.39	26.11	33.84	40.45	24911	1.29
T5-100%-100%	231.67	44.98	33.48	48.20	27.67	33.47	41.09	38134	1.90
T6-50%+50%FYM-100%	224.67	44.81	31.18	44.00	50.75	62.35	41.49	33958	1.69
T7-75%+25%FYM-75%	213.00	43.73	25.67	39.90	26.48	34.22	39.20	25824	1.33
T8-50%+50%RR-100%	222.00	45.46	29.92	42.81	48.23	59.83	41.13	31891	1.59
T9-75%+25%RR-75%	228.33	44.04	25.40	38.19	26.12	33.86	39.96	25088	1.30
T10-50%+50%GM-100%	237.67	46.19	31.46	45.03	51.31	62.91	41.09	34572	1.72
T11-75%+25%GM-75%	218.33	43.97	26.90	40.37	28.12	35.86	40.01	27701	1.43
T12-FP-FP	171.67	42.01	17.29	27.21	22.98	34.58	38.84	11292	0.59
SEm±	5.20	0.65	0.91	1.61	4.8	1.5	1.11	-	-
CD 5%	15.26	1.90	2.67	4.71	14.1	4.5	3.26	-	-

The yield of wheat increased with increasing the levels and or increment of mineral nutrients from 50 to 100% RDF. Treatment T5 consisting of 100% RDF registered highest grain yield (33.48 Q ha^{-1}) of wheat which was non-significantly superior to 50% N and control plots. The grain yield was lowest (5.80 Q ha^{-1}) in control plot. The straw yield of wheat was recorded highest in T5 -100%RDF-100%RDF (48.20 Q ha^{-1}) and lowest in control (9.69 Q ha^{-1}) plot. The Harvest index was observed highest (41.64%) in T3-50%RDF-100%RDF NPK. Whereas minimum (37.40%) was estimated under control plot. Agronomic efficiency was recorded maximum (51.31 kg kg^{-1}) under T10-50%RDF+50GM-100%RDF and minimum in T2-50%RDF-50%RDF (21.33 kg kg^{-1}). The Factor productivity index was observed highest (62.91) under T10-50%RDF-50GM-100%RDF and lowest (32.93) in T2-50%RDF-50%RDF.

The data on test weight (1000 seeds) is presented in Table 3.4 revealed that there was non-significant difference amongst various treatments on test weight. However, the highest test weight, (46.19g) was recorded in T10-50%RDF+50GM-100%RDF followed by T8-50%RDF+50RR-100%RDF(45.46g), T5 - 100%RDF-100%RDF (44.98g), T6 - 50%RDF+50FYM-100%RDF (44.81g) and T7 - 75%RDF + 25RR-75%RDF (44.73g), T3 -50%RDF-100%RDF (44.28g), T4 - 75%RDF-75%RDF (44.20g) and T9-75%RDF+25RR-75%RDF (44.04g) and lowest in control (33.23g) plot.

Judicious integration of organic manures *viz*. FYM, green manuring and rice residue with chemical fertilizers showed its direct effect on rice and residual effect on wheat yield during 2015-16. Productivity of rice and wheat is almost stable over 24^{th} years. After producing maximum yield of rice (62.40 q/ha) during *kharif*, 100% RDFin *kharif* and 100% RDF in *rabi* registered maximum grain yield of wheat (33.48 q/ha) which was significantly higher over rest of the treatments except T6 (50% inorganic + 50% FYM- 100% inorganic) and T10 (50% inorganic+50% GM–100% inorganic) which produced comparable yield to that of highest yielder treatment i.e. T5. Similarly comparable yield attributes like test weight and no. of ears $plant^{-1}$ were obtained in T5 100% RDF followed by 50% RDF + 50% N as received from green manuring in *kharif* (T10), straw yield of wheat was also showed the similar trend and 100% RDF to both the crops produced the highest straw yield, comparable to 50% RDF + 50% GM to rice and 100% RDF to wheat crop (T10). Harvest index of these treatments was also higher. These results are also reflected in the net return and B:C ratio (Table 3.4).

4. Summary and Conclusion

This study can be concluded that Continuous application of chemical fertilizers alone or integration with any of the organics did not influence pH, electrical conductivity, calcium, magnesium, zinc, manganese and iron of soil.

The inorganic fertilizer and organic manure *i.e.* integrated nutrient management practices maintained and/or sustained highest levels of organic carbon, available nitrogen, phosphorous recorded in T10 - 50%RDF+50%GM-100%RDF and potassium in T7-75%RDF+25%FYM-75%RDF and available zinc, iron, manganese and copper content and due to its long-term application recorded highest in T6 (50%RDF+50%FYM - 100%RDF).

After harvesting of wheat crop zinc was significantly influenced by T6 - 50%RDF + 50%FYM-100%RDF. The available zinc was highest in this treatment over control.

It was noticed that continuous applications of balanced fertilizers significantly influenced the available Nitrogen, phosphorus and potassium content in soil.

All the yield attributing characters and yield of rice significantly increased with increasing the levels of mineral nutrients from 50 to 100% RDF in rice which was at par with 50% RDF+50%FYM-100%RDF.

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