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Kajal Verma
Department of Soil Science and Agril. Chemistry, SG College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Tejpal Chandrakar
Department of Soil Science and Agril. Chemistry, SG College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

K Tedia
Department of Soil Science and Agril. Chemistry, SG College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Ashwani Kumar Thakur
Department of Agronomy, SG College of Agriculture and Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Devendra Pratap Singh
Department of Agril. Statistics and Social Science, SG College of Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Kajal Verma
Department of Soil Science and Agril. Chemistry, SG College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of long term nutrient management practices on yield of rice and nutrient use efficiency in Inceptisols

Kajal Verma, Tejpal Chandrakar, K Tedia, Ashwani Kumar Thakur and Devendra Pratap Singh

Abstract
An experiment has been conducted since year 2014 *kharif* on effect of long term nutrient management practices on yield of rice and nutrient use efficiency in Inceptisols under rainfed midland situation at Bastar plateau zone at the Shaheed Gundadhur College of Agriculture and Research Station, Kumhrawand, Jagdalpur, Chhattisgarh, India. The twelve treatments replicated thrice in randomized block design were T_1: Absolute control, T_2: RDF of 100:60:40 NPK kg/ha, T_3: 100% PK, T_4: 100% NK, T_5:100% NP, T_6: 100% NPK + 5 t FYM/ha, T_7: 100% NPK + 5 t FYM/ha + 25 kg/ha $ZnSO_4$, T_8: 100% NPK + 5 t FYM/ha + 25 kg/ha $ZnSO_4$ + 3 q/ha Lime, T_9: 50% NPK, T_{10}: 50% NPK + 5 t FYM /ha, T_{11}: 50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha and T_{12}: 50% NPK + 5 t FYM /ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha. The soil in the experiment field was Inceptisols, which had a slightly acidic pH, medium levels of organic carbon, little readily accessible nitrogen, and medium levels of P and K. During *kharif* 2022, T_8 (100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + Lime @ 3 q/ha) resulted highest grain and straw yield but at par with T_6 (100% NPK + 5 t FYM/ha).The most effective agronomic use efficiency and apparent nutrient recovery were given by the treatment T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg /ha + lime @ 3 q /ha); and better production efficiency was found maximum for N in T_9 (50% NPK); and for P and K, it was T_3 (100% PK).

Keywords: Rice, long term nutrient management, yield, nutrient use efficiency

Introduction

Rice (*Oryza sativa* L.) the most important and extensively cultivated food crop grown extensively in tropical and subtropical regions, which provides one in three people the equivalent of half their daily food needs. In Asia, more than two billion people obtain 60 to 70 percent of their energy intake from rice and its derivatives (Sharma *et al*., 2018) [14]. In India, rice is the staple food for around 60 percent of the population and also governs country's food security. It contributes about 40 percent to the total food grain production of the country and accounts for 29.1 percent of calories and 22.4 percent of protein intake daily by Indian population (GRiSP, 2013) [8].

In world, rice is cultivated over an area of 165.22 million hectares yielding 503.27 million tonnes during 2022-23 (Anonymous, 2023) [1]. India is the second largest producer and consumer of Rice in the world, cultivated over an area of 46.5 million hectares yielding 135.54 million tonnes during 2022-23 with productivity of about 23.9 q/ha during 2021-22 (Anonymous, 2022) [2]. Chhattisgarh is known as "Rice Bowl of India", and is cultivated over an area of 3.6 million hectares yielding 7.16 million metric tonnes with productivity of about 3212 kg/ha during 2021 (Anonymous, 2021) [3].

For optimum growth, rice plants require a sufficient supply of nutrients from various sources. Native sources such as soil minerals, soil organic matter, rice straw, manure, and water (rain, irrigation) provide these nutrients, but the amounts are typically insufficient to produce high and long-lasting yields. However, due to the relatively low levels of nutrients present, using organic manures alone may not be sufficient to meet the plant's needs. Therefore, in order to achieve the best yields, it is necessary to use organic manures in combination with inorganic fertilisers and to ensure that the soil is adequately supplied with all of the plant nutrients in the readily available form and to maintain good soil health. (Rama Lakshmi *et al.*, 2012) [12].

The amount of nutrients removed by the crops far outweighs the amount of nutrients supplied by fertiliser, placing a much greater strain on the natural soil reserves. Nitrogen deficiency is the nutrient that has the greatest global impact on rice production. One of the main causes of the continuous rise in rice production is fertiliser use; in Asia, rice fields use more than 20% of the N fertiliser produced globally. The 92% of all rice is produced in lowland irrigation and rain-fed systems, and 20–25% of the cost of production in these systems is attributed to fertiliser nutrients. The productivity and efficiency of how nutrients are used in the rice crop are negatively impacted by the imbalanced and careless use of fertiliser. (Borah *et al*., 2016) [4].

It was found that the use of inorganic fertiliser to maintain cropping only temporarily increased yield and degraded the soil over time (Satyanarayana *et al.,* 2002) [13]. On the other hand, continuous organic fertiliser application on rice fields alone led to low yield and low N and K content at the mid-tillering stage of the rice plant (Javier *et al*., 2004) [10]. This suggests that integrated nutrient management is necessary for the production of rice. Therefore, by correcting minor deficiencies of secondary and micronutrients, increasing the effectiveness of the nutrients that are applied, and creating favourable soil physical conditions, the combined use of organic manures and inorganic fertilisers aids in maintaining yield stability. (Gill and Walia, 2014) [7].

Materials and Methods

A field experiment has been conducted since *kharif* 2014 in the Research Farm at the Shaheed Gundadhoor College of Agriculture and Research Station, Kumhrawand in Jagdalpur, Chhattisgarh. The state of Chhattisgarh is situated between latitudes of 17030" and 24045" N and longitudes of 70030" and 84015" E. having an elevation of 552 metres above the mean sea level, the Bastar district is situated in the southern region of Chhattisgarh, between 18.9215 and 19.2291 N latitude and 81.696 E and 81.860 E longitude. The research field is situated in the village of Kumhrawand in the Bastar district, which is located at latitudes 19.088838N and 81.963684E. The experimental was presented for the *Kharif* 2022, when temperatures ranged from a maximum of 36.6 °C to a minimum of 23.5 °C. During the crop period, 1931.1 mm of the total rainfall was recorded. Randomized Block Designs was used for the experiment, which included 12 treatments and 3 replications were- T_1: Control, T_2: 100% NPK (100:60:40 kg N: P_2O_5: K_2O/ha), T_3: 100% PK, T_4: 100% NK, T_5: 100% NP, T_6: 100% NPK + 5 t FYM/ha, T_7: 100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha, T_8: 100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha, T_9: 50% NPK, T_{10}: 50% NPK + 5 t FYM/ha, T_{11}: 50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha, T_{12}: 50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha.

The net plot of size 5.4 m x 5.4 m, the grain and straw yields were calculated. The bundles endured sun drying, weighing, and threshing before the seeds were cleaned and the yield was noted and converted to q/ha.

Harvest index (HI,%) is the ratio between grain yields to total biomass yield hence, expressed in percentage and calculated by the formula (Donald and Hamblin, 1976) [5].

$$HI(\%) = \frac{\text{Economicyield}(\text{q ha}^{-1})}{\text{Biological yield (q ha}^{-1})} \text{X } 100$$

Agronomic Use Efficiency (AUE, kg grain/kg nutrient applied) is calculated in units of yield increase per unit of nutrient applied. AUE was worked out by calculating the difference between the grain yield (kg) between the treated plot and control plot with respect to nutrients applied.

$$AUE = \frac{\text{grain yield of treated plot} - \text{grain yield of control plot}}{\text{nutrients applied}}$$

The apparent nutrient recovery (ANR, %) is calculated as the difference in nutrient uptake in plants above ground section between treated and unfertilized crops in relation to the amount of fertilizer applied.

$$ANR(\%) = \frac{(\text{Total uptake of nutrients in treated plot} - \text{Total uptake of nutrients in control plot})}{\text{nutrient applied}}$$

Production efficiency (PE, kg grain per kg nutrients absorbed) corresponds to an increase in yield per unit of nutrient absorbed.

$$PE = \frac{\text{grain yield of treated plot} - \text{grain yield of control plot}}{\text{total uptake of treated plot} - \text{total uptake of control plot}} \times 100$$

Results and Discussion

Grain yield

The combined use of organic and inorganic fertilisers had a noticeable impact on the rice grain yield as shown in Table1. Various fertiliser nutrient concentrations alone and in combination with manure caused a noticeable difference in grain yield. The highest yield was recorded in T_8 (100% NPK + 5 t FYM /ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) *i.e.* (51.87 q/ha) followed by T_7 (100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) 50.37 q/ha and T_6 (100% NPK + 5 t FYM) 47.47 q/ha which were at par. In comparison to applying only inorganic fertilisers, the application of inorganic fertiliser and organic manure (FYM) exhibits an integrated effect that is more advantageous. When compared to RDF, the integration of FYM and inorganic chemical fertilisers resulted in a significant increase in grain yield. *i.e.* T_2 (100% NPK) 45.30 q/ha. The 50% doses of RDF with FYM alone or when incorporated with lime and $ZnSO_4$ *i.e.* T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha and T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime3 @ q/ha) resulted in additional increase in grain yield in comparison with only inorganic fertilizer treatment and control plots. Also the grain yields in these treatments were at par with the T_2 (100% NPK). Similar findings were referenced by Urkurkar *et al*., 2010 [15].

Straw yield

The data shown indicates the significant impact of various treatments on rice crop straw yield. on Table1. The maximum straw yield was reported in T_8 (100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) 67.63 q/ha followed by T_7 (100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) 65.66 q/ha and T_6 (100% NPK + 5 t FYM) 62.70 q/ha which were at par; and were significantly higher than T_2 (100% NPK). The minimum straw yield was 30.53 q/ha reported in T_1 control plot (30.53 q/ha). The straw yield of rice in T_{11} and T_{12} were at par with T_2 (100% NPK). So we can save 50% of fertilizers by reducing the recommended doses to half and in addition we have to give 5 t/ha FYM. Dixit and Gupta (2000) [6] reported that applying FYM along with chemical fertiliser increased rice straw yield significantly when compared to applying chemical fertiliser alone. The outcomes agreed with Pandey *et al*., (2007) [11] findings as well.

Harvest Index
To study the partitioning behaviour of grain and rest of the vegetative biomass of plant influenced by different nutrient integration under study, harvest index values for treatments were calculated and presented in Table 1. The data reveals that the effect of integrated nutrient management on the harvest index was recorded significant effect on treatment T_7 (43.43%) but it was found at par with treatment T_2, T_5, T_6, T_8, T_9, T_{10}, T_{11} and T_{12} While, the lowest harvest index was recorded in control. Similar findings were reported by Gupta and Handore (2009) [9].

Table 1: Effect of long term nutrient management practices on the yield of rice

Treatment	Grain (q/ha)	Straw (q/ha)	HI%
T_1 Absolute Control	18.20	30.53	37.33
T_2 100% NPK	45.30	61.60	42.33
T_3 100%PK	23.50	34.44	40.30
T_4 100% NK	25.13	36.36	40.73
T_5 100% NP	29.03	39.90	42.10
T_6 100% NPK + 5 t FYM	47.47	62.70	43.10
T_7 100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha	50.37	65.66	43.43
T_8 100% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha	51.87	67.63	43.37
T_9 50% NPK	31.23	40.91	43.30
T_{10} 50% NPK + 5 t FYM	39.93	54.18	43.82
T_{11} 50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha	41.07	56.40	42.13
T_{12} 50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha	43.23	57.63	42.87
CD (5%)	4.66	4.66	1.76
CV (%)	7.46	5.49	6.46

Agronomic use efficiency
The agronomic use efficiency for N (AE_N) ranged from 6.9 to 50.1 kg/kg with the mean value of 29.3 kg grains/ kg N applied. Data revealed that the highest AE_N of 50.1 kg/kg recorded with T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) followed by T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) (45.7 kg/kg).

The range of the agronomic use efficiency for P (AE_P) was 8.8 to 83.5 kg/kg among different treatments. The highest AE_P of 83.5 kg/kg recorded with T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) followed by T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) (76.2 kg/kg) and lowest 8.8 kg/kg with T_3 (100% PK).

The range of agronomic use efficiency for K was 13.2 to 125.2 kg/kg with mean value of 71.9 kg/kg. The maximum AE_K (125.2 kg/kg) observed in T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) followed by T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) (114.3 kg/kg). AE_K decreased with the increase of K rate.

Apparent nutrient use efficiency
The apparent nitrogen use efficiency (NE_N) ranged from 10.5% to 85.6% with the mean value of 49.7%. The data shows that the highest apparent nitrogen use efficiency of 85.6% recorded with T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) followed by T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) (79.7%).

Based on various treatments, apparent phosphorus use efficiency (NE_P) ranged from 2.2 to 33.8%. The highest NE_P of 33.8% recorded with T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) followed by T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) (31.9%) and lowest 2.2% with T_3 (100% PK).

The mean value of 117.5% was found for apparent potassium use efficiency (NE_K), which ranged from 15.2 to 195%. The maximum NE_K (195%) observed in T_{12} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha + lime @ 3 q/ha) followed by T_{11} (50% NPK + 5 t FYM/ha + $ZnSO_4$ @ 25 kg/ha) (188.3%) and lowest 15.2% with T_3 (100% PK).

Production efficiency
The production efficiency for N (PE_N) ranged from 57.4 to 68.4 with the mean value of 60.8 kg grain/kg. The highest PE_N of 68.4 kg kg^{-1} observed under T_9 (50% NPK) followed by T_5 (100% NP) (66.5 kg/kg).

Production efficiency for phosphorus (PE_P) recorded in the range of 239 to 394.3 kg/kg in different treatments with the mean value of 265.6 kg/kg. The highest PE_P of 394.3 kg kg^{-1} observed with T_3 (100%PK) followed by T_5 with 329.9 kg/kg.

Production efficiency for potassium (PE_K) ranged from 60.5 to 86.9 kg/kg with mean value of 63.5 kg/kg. The maximum PE_K 86.9 kg/kg observed in T_3 (100%PK) followed by T_9 (82.9 kg/kg) lowest 60.5 kg/kg with treatment T_2 (100% NPK).

Table 2: Effect of long term nutrient management practices on nutrient use efficiencies

Treatments	Agronomic use efficiency (kg grain/ kg nutrient applied)			Apparent Nutrient recovery (%)			Production efficiency (kg grain per kg nutrient absorbed)		
	N	P	K	N	P	K	N	P	K
T_1	-	-	-	-	-	-	-	-	-
T_2	27.1	45.1	67.7	46.7	16.6	112	58	272.3	60.5
T_3	-	8.8	13.2	-	2.2	15.2	-	394.3	86.9
T_4	6.9	-	17.3	10.5	-	21.9	65.7	-	78.9
T_5	10.8	18.0	-	16.3	5.5	-	66.5	329.9	-
T_6	29.3	48.8	73.2	50.4	17.2	118.3	58.1	283.4	61.9
T_7	32.2	53.6	80.4	54.9	20.2	131.6	58.5	265.1	61.1
T_8	33.6	56.1	84.1	57.7	22.0	135.9	58.3	254.5	61.9
T_9	26.1	43.5	65.2	38.2	15.3	78.7	68.4	284.5	82.9
T_{10}	43.5	72.5	108.7	70.1	28.6	154.4	61.2	253.2	70.4
T_{11}	45.7	76.2	114.3	79.7	31.9	188.3	57.4	239	60.7
T_{12}	50.1	83.5	125.2	85.6	33.8	195	58.5	247.2	64.2

Conclusion

Although T_8 yielded more in terms of grain and straw of rice and T_{12} proved to be more efficient in agronomic and nutrient use efficiency, the T_6 (100% NPK + 5 t FYM/ha) would be recommended as it may be more economical by negotiating the additional use of zinc sulphate and lime.

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