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G Kiran Reddy
Scientist (Soil Science),
AICRP-IFS, Hyderabad,
Telangana, India

SHK Sharma
Professor (Soil Science),
College of Agriculture,
Hyderabad, Telangana, India

M Srilatha
Associate Professor (Soil Science)
College of Agriculture,
Hyderabad, Telangana, India

Corresponding Author:
G Kiran Reddy
Scientist (Soil Science),
AICRP-IFS, Hyderabad,
Telangana, India

Long term effects of organic and inorganic fertilizers on nutrient use efficiencies and nutrient balance in rice: Rice cropping system

G Kiran Reddy, SHK Sharma and M Srilatha

Abstract
Rice – rice cropping system is a predominant cropping system for livelihood security in India. Recent results indicate that agronomic efficiency, nutrient use efficiency are reducing due to continuous rice – rice cropping system. In this regard we analyzed the agronomic efficiency and nutrient use efficiency. The experiment consist of various combinations of organic and inorganic nutrients and was laid out in randomized complete-block design, with four replications. Greater agronomic efficiency and nutrient use efficiency were observed in 50% NPK and NPK+FYM treatments in general, lowest was observed in N alone treatment. This shows balanced application of major nutrients is essential for growth of crop. Nutrient balance was highest in NPK+FYM in N, P nutrition and for K nutrition it is highest in FYM treatment. Lowest was observed in control treatment.

Keywords: Cropping system, agronomic efficiency, nutrient use efficiency, nutrient balance, NPK

1. Introduction

The rice - rice crop system is a very important cropping system in India. Rice is one of the most important cereal crop, that allow the food self-sufficiency program of the country, playing a key role in the human diet and animal feed, providing adequate amounts of energy and protein (Wondesen and Sheleme, 2011) [2]. Presently, rice – rice cropping system is followed in all over India in general and South India in particular. Although the cropping has been in practice in the Indian for generations, it was catapulted to special prominence in the late 1960s with the advent of green revolution. This cropping system provides providing livelihood to millions of producers and consumers (Paroda *et al.*, 1994) [1]. Different fertilization treatments of a long-term field experiment can cause changes in nutrient use efficiency and nutrient balance.

Nitrogen availability influences uptake of other nutrients also to a great extent, as N-fertilization helps the plants to develop the larger root systems, which helps in uptake of other nutrients (Masaka, 2006) [3]. Nitrogen is a highly mobile nutrient in soil and plant, its importance is continuously increasing as years progressing, and it is subjected to high loss from the soil plant system. 30-50% of applied nitrogen is lost through leaching, volatilization etc. Nitrogen lose cost the farmer and also it as hazardous impact on the ecosystem. Rice cultivation requires huge amount of water so most of nitrogen is lossed in the form of leaching and denitrification making the nutrient unavailable during the critical crop growth stage. Many strategies have been developed to mitigate nutrient leaching and improve the nutrient use efficiency (NUE).

Chemical fertilizers as becoming vital source of plant nutrients and it is key contributor to enhanced crop production. In the last few decades, additional nutrients applied to crops (chemical fertilizers) have been responsible for increased crop yields by about 50 per cent in developing countries including India (Tewatia, 2012) [4]. The exist a positive relationship between the fertilizer consumption and food grain production in India (since the green revolution period. But the rate of increase in fertilizer application is much more than that of food production. This results in decline in NUE. The role of nutrients (fertilizer) with improved agronomic practices and genotypes is enormous in this achievement. More than 55% of the increase in global crop production, especially in emerging countries, comes from the use of chemical fertilizers with nitrogen (N) fertilizer being the dominant.

The objectives of this study were to (1) nutrient use efficiency (2) nutrient balance (budgeting) of N, P and K nutrients under different fertilizer managements.

2. Materials and Methods

2a. Location and soil

The Long Term Fertilizer Experiment is being conducted at Regional Agricultural Research Station, Jagtial farm (Block No I, field numbers 7, 7a, 8, and 8a). Jagtial is located at 78^0 45' E to 79 ^{0}0' E longitude and 18 ^{0} 45' N to 19^0 0' N latitude. Jagtial is in the Deccan Plateau and Eastern Ghats agro ecological zone of the country (Agro ecological Zone no. 7 of India). Within Telangana state, it comes under the Northern Telangana Zone.

The experiment is being conducted in a black clay (Ustochrept) soil since kharif 2000-01 with rice-rice cropping system. The experimental soil at the initiation of the experiment (before kharif 2000-01) was clayey in texture, slightly alkaline in reaction and non-saline. It was low in available nitrogen, medium in available phosphorus and high in available potassium and organic carbon. Available sulphur and DTPA-extractable micronutrient cations were above critical limits.

2b. Treatments

The experiment consisted of 11 treatments and one fallow plot (table 1) in 4 replications. The control treatment comprised the crop but no fertilizer application. The fallow had no crop while the soil was puddled and unfertilized. Size of each plot was 12 x 9 m. The plants were spaced 15 cm between the rows and between the hills within the rows. The layout was a randomised block design.

2c. Formulas

Agronomic Efficiency

Agronomic Efficiency (Table 2) was calculated using the following formula:

Agronomic Efficiency =

Yield of fertilized treatment (kg ha^{-1}) – Yield of unfertilized treatment (control) (kg ha^{-1})
-- X 100
Quantity of fertilizer applied (kg ha^{-1})

Apparent nutrient use efficiency

Apparent nutrient use efficiency (Table 2) was calculated using the following formula

Nutrient use efficiency (%) =

Nutrient uptake in treatment plot (kg ha^{-1}) – Nutrient uptake in check (kg ha^{-1})
-- X 100
Nutrient applied in treatment plot (kg ha^{-1})

Nutrient Budgeting

Apparent nutrient use efficiency (Table 5) was calculated using the following formula:

Nutrient use efficiency (%) =

Nutrient uptake in treatment plot (kg ha^{-1}) – Nutrient uptake in check (kg ha^{-1})
---X 100
Nutrient applied in treatment plot (kg ha^{-1})

3. Results and discussion

3a. Agronomic efficiency

The results of agronomic efficiency were presented in table 2. It shows that agronomic efficiency was least for T7 (N alone application) both kharif (4.72) and rabi (10.01) seasons. Highest was observed in T1 (50% NPK) in both kharif (25.58) and rabi (28.05) seasons. Even 50%N in presence of half of PK has given the highest values. In both cases it was highest in rabi season compared to kharif season. In both seasons 50% NPK was followed by NPK+FYM (T8) 24.78 in kharif season and 23.98 in rabi season. 150% NPK has less agronomic efficiency compared to 100% NPK. Irfan *et al*. (2019) [8] observed that the mean agronomic efficiency increased linearly with the corresponding addition of N and P up to the treatment N120 – P90 with maximum value of 59.6% and illustrated non-significant response at higher levels.

3b. Apparent nutrient use efficiency

The results of apparent nutrient use efficiency of N, P, K were presented in table 2. Nitrogen use efficiency was highest in NPK+FYM treatment in both kharif (44.17) and rabi (42.69) seasons. It is least for 100%N (T7) treatment in kharif (26.92) as well as rabi (12.34) seasons. N alone application doesn't increased the nitrogen use efficiency, it shows the importance of balanced application of nutrients. Increase in N application i.e. 150% NPK (35.28 in kharif and 34.11 in rabi) also having less nitrogen use efficiency than the 100% NPK treatments. Zotarelli *et al*. 2009 [5] and Qu *et al*. 2019 [6], have observed that the maximum NUE occurs in the lower range of nitrogen supply. In rice NUE was (21.4 kg/kg N) reported by Halli (2016) [7]. Gajri *et al.*, (1993) [9] reported that higher NUE of 17.60 kg grain/kg fertilizer N at1 80 kg N/ ha was acheived.

Apparent phosphorus use efficiency was least for 150% NPK (T3) in kharif (14.33) and NPK-S in rabi season (14.76) (table 2). It was highest for 50% NPK (T1) with 26.33 in kharif and 20.90 in rabi season. Extra addition of p fertilizer doesnot increased the phosphorus use efficiency indeed it reduced the efficiency. Bi *et al*. (2014) [10] reported that means of AEP were 50.1 kg grain/kg Pand 24.0 kg grain/kg P for the first and second rice crop.

Apparent potassium use efficiency was least for T3 (150% NPK) treatment in kharif (81.17) as well in rabi (83.84) seasons (table 2). It was highest for NPK+FYM (T8) treatment in kharif it as 109.25 and in rabi 116.03. T3 was followed by 50% NPK (T1) treatment, it has 108.0 in kharif and 102.38 in rabi season.

3c. Nutrient budgeting

Nitrogen: The results of nutrient budgeting of N were presented in table 3. Apparent nitrogen balance (difference between applied N and N uptake) at the end of *rabi* was negative in the treatments control (T_{11}), FYM (T_{10}) and 50% NPK (T_1) and positive in all the treatments. The change in available N (initial to *rabi*) was positive in all treatments.

Phosphorous: The results of nutrient budgeting of P were presented in table 4. Apparent balance of phosphorous was positive in all the treatments except where it was not applied (control, FYM and 100% N treatment). This lead to build up available P in all treatments and depletion of available P in (T_7 and T_{11}). This suggests that application of phosphorous in quantities higher than crop requirement through fertilizers may be the cause of available P buildup.

Potassium: The results of nutrient budgeting of K were presented in table 5. Apparent balance in potassium was negative in all the treatments except in FYM and available potassium depletion was observed in all the treatments. This shows the necessity of applying potassium fertilizers despite of lack of grain yield responses.

Table 1: Treatment combinations

Tr. No	Treatments (% of recommended NPK)	N - P - K (kg/ha)
T1	50% NPK	60-30-20
T2	NPK	120-60-40
T3	150% NPK	180-90-60
T4	NPK+ HW	120-60-40
T5	NPK + Zn	120-60-40
T6	100% NP	120-60-0
T7	100% N	120-0-0
T8	NPK+FYM	120-60-40
T9	NPK-S	120-60-40
T10	FYM	0-0-0
T11	Control	0-0-0
T12	Fallow	0-0-0

Table 2: Year-wise yield (kg/ha) for kharif and rabi season along with agronomic efficiency, nutrient use efficiency of Pooled data

Sl. No	Treatment	Agronomic Efficiency		N Apparent Nutrient Use Efficiency		P Apparent Nutrient Use Efficiency		K Apparent Nutrient Use Efficiency	
		Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
1	50% NPK	25.58	28.05	37.17	42.59	26.33	20.90	108.00	102.38
2	NPK	21.58	21.18	39.25	39.14	19.33	16.78	94.50	92.05
3	150% NPK	18.83	16.60	35.28	34.11	14.33	15.77	81.17	83.84
4	NPK + HW	21.61	21.88	44.08	38.66	18.83	16.24	94.25	88.14
5	NPK + Zn	22.27	21.88	42.83	42.59	17.83	16.61	95.75	93.84
6	NP	18.08	20.28	39.92	34.26	19.17	16.34		
7	N	4.72	10.01	26.92	12.34				
8	NPK + FYM	24.78	23.98	44.17	42.69	19.67	20.81	109.25	116.03
9	NPK - S	20.52	21.23	42.17	34.77	16.33	14.76	93.00	85.97
10	FYM								
11	Control								

Table 3: Nutrient budgeting of Nitrogen under long term fertilizer application (2000-01 to 2015-16 Kharif and 2000-01 to 2014-15 Rabi)

Treatment	Total N applied (kg ha^{-1})	Total N uptake (kg ha^{-1})	Apparent N balance (kg ha^{-1})	Initial available N (kg ha^{-1})	Avail. N after rabi 2014-15 (kg ha^{-1})	Change in avail. N (Final-Initial) (kg ha^{-1})
50% NPK	1740	2115.5	-375.5	107	156	49
NPK	3480	2796.4	683.6	107	166	59
150% NPK	5220	3238.1	1981.9	107	191	84
NPK + HW	3480	2908.8	571.2	107	172	65
NPK + Zn	3480	2829.1	650.9	107	172	65
NP	3480	2721.5	758.5	107	181	74
N	3480	2139.7	1340.3	107	156	49
NPK + FYM	4420	2939.5	1480.5	107	191	84
NPK - S	3480	2769.5	710.5	107	166	59
FYM	1725	2028.4	-303.4	107	206	99
Control	0	1436.7	-1436.7	107	150	43

Table 4: Nutrient budgeting of Phosphorous under long term fertilizer application (2000-01 to 2015-16 Kharif and 2000-01 to 2014-15 Rabi)

Treatment	Total P applied (kg ha^{-1})	Total P uptake (kg ha^{-1})	Apparent P balance (kg ha^{-1})	Initial available P (kg ha^{-1})	Avail. P after rabi 2014-15 (kg ha^{-1})	Change in avail. P (Final-Initial) (kg ha^{-1})
50% NPK	870	552.97	317.03	19.6	22.7	3.1
NPK	1740	663.2	1076.8	19.6	22.9	3.3
150% NPK	2610	740.7	1869.3	19.6	32.2	12.6
NPK + HW	1740	654.48	1085.52	19.6	22.7	3.1
NPK + Zn	1740	647.59	1092.41	19.6	22.7	3.1
NP	1740	658.1	1081.9	19.6	24.6	5
N	0	463.55	-463.55	19.6	23.3	3.7
NPK + FYM	1865	700.83	1164.17	19.6	32.2	12.6
NPK - S	1740	617.34	1122.66	19.6	24.4	4.8
FYM	335	473.56	-138.56	19.6	31.1	11.5
Control	0	350.63	-350.63	19.6	22.2	2.6

Table 5: Nutrient budgeting of Potassium under long term fertilizer application (2000-01 to 2015-16 Kharif and 2000-01 to 2014-15 Rabi)

Treatment	Total K applied (kg ha^{-1})	Total K uptake (kg ha^{-1})	Apparent K balance (kg ha^{-1})	Initial available K (kg ha^{-1})	Avail. K after rabi 2014-15 (kg ha^{-1})	Change in avail. K (Final-Initial) (kg ha^{-1})
50% NPK	580	1813.8	-1233.8	364	322	-42
NPK	1160	2292.6	-1132.6	364	321	-43
150% NPK	1740	2631	-891	364	296	-68
NPK + HW	1160	2262.7	-1102.7	364	340	-24
NPK + Zn	1160	2304	-1144	364	311	-53
NP	0	2245.5	-2245.5	364	301	-63
N	0	1737.7	-1737.7	364	306	-58
NPK + FYM	625	2507.1	-1882.1	364	322	-42
NPK - S	1160	2238.7	-1078.7	364	319	-45
FYM	1750	1642.1	107.9	364	413	49
Control	0	1225.9	-1225.9	364	357	-7

4. Conclusion

The study revealed that application of N, P, K in balanced application is required for good crop response. Application of one nutrient (N alone) don't serve the purpose of greater agronomic efficiency, nutrient use efficiency etc. For greater crop yields application of N, P, K are required. Agronomic efficiency was highest in 50% NPK followed by NPK+FYM. In the use efficiency it was highest for either 50% NPK or NPK+FYM, it is least for N alone application. Higher application of fertilizers reduced the Agronomic efficiency and nutrient use efficiency. Nutrient balance was highest for NPK+FYM, least for control. Except K nutrient balance, it is high for FYM treatment.

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