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Fertilizer Responsiveness of Rice (*Oryza sativa* L.) Crop to Different Levels of NPK Fertilizers

Anju B. Raj, Jacob John

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ABSTRACT

In order to study the effects of different levels of NPK fertilizers on growth and yield traits of rice (*Oryza sativa* L.), an experiment as split plot design with three replications was conducted during 2020 year in the Integrated Farming System Research Station, Karamana, Trivandrum. In a split-plot design, the five rice based cropping systems were assigned as main plot factors, and the different levels of fertilizer treatments were the subplot factors, including F_1: 100% RDF: Full FYM +Full N +Full P + Full K (90:45:45 NKP kg ha^{-1}, as per the recommendation of Kerala Agricultural University), F_2: 75% RDF: 3/4 FYM+3/4 N+3/4 P + Full K and F_3: 50% RDF: 1/2 FYM+1/2 N+1/2 P + Full K. Characters measured were: Plant height, number of tillers, productive tillers m^{-2} , productive tillers m^{-2} , no. of grains per panicle, 1000 grain weight, grain yield, straw yield and harvest index. Results of growth analysis indicated that, nitrogen increasing rates of fertilizer caused the increment of growth indexes. Among the nutrient levels tested, NPK applied @ 90:45:45 recorded higher grain yield (4213.00 kg ha^{-1}), straw yield (6694.44 kg ha^{-1}), net returns (Rs 80571 ha^{-1}) and B:C ratio (1.95) as compared to lower nutrient levels tested. The study clearly revealed that fertilizers play a significant role in growth and yield attributes of rice.

Keywords Fertilizer responsiveness of rice, Oryza sativa, NPK fertilizers, 1000 grain weight, Grain yield.

INTRODUCTION

Rice (*Oryza sativa* L.) feeds two-third of the global population by serving as staple food. Globally, rice is cultivated on 167.13 million hectares with an annual production of 782 million tons (FAO 2019). Fertilizer use is one of the major factors for the continuous increase in rice production since the Green Revolution era. Efficient nutrient management in rice has assumed great importance because along with high production levels of rice, it ensures minimal leakage of applied nutrients to the environment.

Although crop production requires fertilizers,

Anju B. Raj*
[1]PhD Scholar, College of Agriculture, Kerala Agricultural University (KAU), Vellayani 695522. Kerala, India

Jacob John
[2]Professor and Head, Integrated Farming Systems Research Station, Karamana, Kerala, India

Email: anjubraj95@gmail.com
*Corresponding author

the overly large doses and use of fertilizers with chemically unbalanced NPK ratios and in intensive rice production has resulted in soil-related problems, such as acidification (Chen 2006), loss of organic matter, deterioration of the structure, and reductions in biological activities and fertility (Zhong and Cai 2007). Consequently, crop yields in several regions are stagnating or declining.

Nitrogen is vital due to its multi-dimensional roles in plant growth and metabolism. It is the integral part of chlorophyll, amino acids and genetic material i.e., DNA and RNA (Nawaz *et al*. 2017). Managing nitrogen fertilization in rice fields is a challenging task for farmers because of various kinds of losses due to de -nitrification, deep percolation and run-off in flooded soils resulting in low nitrogen use efficiency. While excessive nitrogen promotes lodging and diseases and results in low nitrogen use efficiency, low application of nitrogen will often reduce rice. As P fertilizer applications exhibit residual effects that can last several years maintenance of soil P supply requires long-term strategies tailored to site specific conditions that consider P inputs from all sources (Fairhurst *et al*. 2007). Potassium increases the number of spikelets per panicle, percentage of filled grains and 1000 grain weight but does not have a pronounced effect on tillering of rice (Singh and Singh 2017). With balanced fertilization (NPK), yield was increased primarily due to an increase in recovery and agronomic efficiency. Imbalanced use of fertilizers not only aggravates the deficiency of K as well as micronutrients in the soils (Ladha *et al*. 2003). By application of major nutrients at optimum levels to match the soil fertility, season and climate, the yield can be enhanced to 40 % (Murthy *et al*. 2015). Since fertilizer is an expensive and precious input, determination of an appropriate dosage of application that would be both economical and appropriate to enhance productivity and consequent profit of the grower under given situation needs intensive study. In this context, an investigation is conducted with an aim to evaluate effect of different levels of fertilizers on rice crop.

MATERIALS AND METHODS

The field experiment was conducted at the Integrated Farming System Research Station, Karamana, Trivandrum (Kerala) during *kharif* season of 2020. The experiment was laid out in split-plot design (SPD) under three replications. The main plots were five cropping systems viz., C_1: Rice-rice-fallow, C_2: Rice-rice-sweet potato, C_3: Rice-sweet potato-amaranthus, C_4: Rice-(cassava+bush cowpea)-daincha, C_5: Rice-rice-daincha and sub plots were different fertilizer levels viz., F_1: Full FYM+Full N+Full P+Full K(As per the recommendation of Kerala Agricultural University), F_2: 3/4 FYM+3/4 N+3/4 P+ Full K and F_3: 1/2 FYM+1/2 N+1/2 P + Full K. The experimental soil was Sandy clay loam medium in available nitrogen (345.5 kg N/ha), phosphorus (14.8 kg P/ha) and potash (130 kg K/ha). The transplanting were done on 22nd June, 2020 with a plant geometry of 20 cm × 15 cm. Recommended dose of nitrogen, phosphorus and potassium were applied through urea, rajphos and MOP. Half of the nitrogen, full phosphorus and half of potash were applied as basal dose in individual plot and the remaining half nitrogen and potassium were applied before panicle initiation stage.

Observations on rice were taken from five hills per plot from tagged plants. Growth attributes were recorded at 20 and 40 DAT and at harvest. The height of the paddy plant was measured from the ground level to the tip of the longest leaf and expressed in cm. Number of tillers were counted and expressed as number of tillers per m^2. The number of productive tillers at harvest was recorded and expressed as number of productive tillers per m^2. Thousand numbers of clean, dry, fully filled grains were counted from the produce of each plot and weight was noted in g. Each net plot was harvested individually, threshed, dried, winnowed and air-dry weight of grains was recorded and expressed as kg/ha. The straw was harvested from each net plot, dried under sun to a constant weight and expressed as kg/ha. The ratio of grain yield to biological yield (grain + straw) was used for calculating the harvest index using the formula. Gross income was calculated by multiplying the marketable yield with market price of the produce and expressed in Rs/ha. Net income was calculated by subtracting cost of cultivation from gross income and expressed in Rs/ha. BCR was worked out as the ratio of gross income to cost of cultivation. The data generated from the experiment was analyzed by following the techniques of Analysis of Variance (ANOVA) for Split Plot Design. Wherever significant differences among treatments were observed, CD (critical difference) values at 5 % level of significance were calculated for comparison of means.

RESULTS AND DISCUSSION

Growth parameters

There were significant effects of different fertilizer treatments on growth attributes of rice (Table 1). Plant height shows a significant difference between main plot treatments. Cropping systems C_4 resulted in significantly taller plants and at 20 DAS and 40 DAS. The treatment C_4 at par with C_5 and C_1 at 20 DAS and on par with all other treatments except C_3. Since there is no variation in main plot treatments, the difference in plant height might be due to the variations in soil nutrient availability in each plot. Application of full dose of farmyard manure and NPK fertilizers significantly improved plant height at 20 DAS (40.37 cm) and 40 DAS (62.00 cm) (Table 1). The results on the effect of different levels of NPK on tillers per m^2 shows no significant difference between main plot treatments at 20 and 40 DAS. At harvest, main plot treatment shows significantly higher tillers per m^2. Application of full dose of farmyard manure and NPK fertilizers significantly improved number of tillers at 20, 40 DAS and harvest. Increased levels of N favors greater absorption of nutrients resulting in rapid expansion of foliage, better accumulation of photosynthates and eventually resulting in increased growth structure. Increased nutrient absorption by rice with increased fertilizer doses has also been reported by Singh and Namdeo (2004). The significant increase

Table 1. Effect of different levels of fertilizers on growth attributes.

Treatments	Plant height (cm)			Number of tillers		
	20 DAS	40 DAS	Harvest	20 DAS	40 DAS	Harvest
Main plots						
C_1	37.522	59.078	96.288	234.267	440.000	390.11
C_2	35.639	60.667	98.933	248.556	425.333	357.222
C_3	35.989	57.411	96.530	234.089	396.000	335.667
C_4	39.439	61.000	96.766	234.111	450.444	424.70
C_5	39.017	60.656	96.207	231.652	410.333	354.444
CD	2.6309	2.3834	NS	NS	NS	14.6972
Sub plots						
F_1	40.37	62.00	98.572	246.547	474.933	426.333
F_2	35.927	58.600	96.279	239.751	382.667	331.667
F_3	36.270	58.680	95.983	223.307	415.667	359.267
CD	2.9818	1.8741	NS	13.2897	68.1538	23.1395
Interaction						
C_1F_1	41.100	63.133	99.017	265.000	572.000	554.000
C_1F_2	34.350	60.000	95.940	219.200	363.000	374.000
C_1F_3	37.117	59.867	93.907	218.600	385.000	346.000
C_2F_1	35.983	63.400	102.443	258.600	451.000	404.667
C_2F_2	37.633	57.667	96.897	248.533	385.000	295.667
C_2F_3	33.300	60.933	97.460	238.533	440.000	371.333
C_3F_1	35.167	61.333	97.107	218.533	451.000	385.000
C_3F_2	36.350	57.767	93.840	255.133	385.000	326.000
C_3F_3	36.450	58.133	98.643	228.600	352.000	296.000
C_4F_1	43.983	60.100	97.820	251.933	493.333	423.000
C_4F_2	36.800	58.467	97.173	241.733	385.000	320.333
C_4F_3	37.533	53.667	95.303	208.667	473.000	427.000
C_5F_1	45.600	62.067	96.473	238.667	407.333	365.000
C_5F_2	34.500	59.100	97.543	234.156	395.333	342.333
C_5F_3	36.950	60.800	94.603	222.133	428.333	356.000
CD						
MxS	NS	NS	NS	29.7168	NS	51.7414
SxM	NS	NS	NS	26.9374	NS	44.7102

in plant height and tiller count also be due to the presence of readily available nitrogen. Triveni *et al*. (2017) reported that nitrogen might have affected cell division and cell expansion resulting in taller plants and enhanced tiller production.

Yield parameters

In general, the rice crop treated with full dose of farmyard manure and NPK fertilizers was found to be superior in yield and yield attributes compared to other lower levels of nutrients.

The NPK levels exerted significant effect on number of panicles m^{-2}, 1000 grain weight, grain and straw yield of rice (Table 2). Similarly, Nanda *et al*. (2016) observed the maximum number of panicles m^{-2}, 1000 grain weight, grain and straw yields were recorded with 100% RDF where increasing NPK levels significantly increased number of panicles m^{-2}. Increased dose of N and K provided continuous and steady supply of nutrients into the soil solution to match the nutrient requirement of the crop which, consequently resulted in the production of longer panicles with more number of grains panicle^{-1}. Increased grain yield associated with added fertilizer levels might be due to the cumulative effect of increased translocation of photosynthates to sink resulting in enhanced level of yield components.The results confirm the findings of Rao *et al*. (2004). Artacho *et al*. (2009) stated that grain yield showed a significant quadratic response to N fertilization. High basal N fertilizer applications lead to higher tiller numbers, aboveground biomass and panicle and spikelet numbers, which have a positive relationship with yield (Ding *et al*. 2014). Positive response of rice to incremental N supply has been universally reported (Mandana *et al*. 2014). An optimum yield of rice was obtained

Table 2. Effect of different levels of fertilizers on yield and yield attributes.

Treatments	Productive tillers per m^2	No. of grains per panicle	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Main plots						
C_1	365.200	123.444	27.269	3302.469	4629.630	0.426
C_2	341.744	136.444	27.148	3611.111	5401.235	0.402
C_3	330.400	124.222	27.492	3379.630	4259.259	0.419
C_4	338.800	135.111	27.333	3641.975	4845.679	0.456
C_5	309.833	135.222	27.942	3688.272	5941.358	0.445
CD	NS	5.9623	NS	NS	NS	NS
Sub plots						
F_1	392.973	144.133	28.471	4212.96	6694.444	0.414
F_2	306.633	122.133	26.960	3203.704	4166.667	0.431
F_3	311.980	126.400	26.879	3157.407	4185.185	0.445
CD	27.9586	4.7002	0.7078	238.1249	1126.218	NS
Interaction						
C_1F_1	462.000	131.000	28.270	3981.481	5648.148	0.396
C_1F_2	310.200	113.333	27.313	2870.370	3240.741	0.377
C_1F_3	323.400	126.000	26.223	3055.556	5000.000	0.461
C_2F_1	389.667	147.667	28.710	4120.370	5740.741	0.437
C_2F_2	295.667	133.333	25.957	3287.037	5092.593	0.397
C_2F_3	339.900	128.333	26.777	3425.926	5370.370	0.410
C_3F_1	385.000	138.667	28.093	3796.296	5462.963	0.409
C_3F_2	310.200	112.000	26.993	3379.630	3796.296	0.382
C_3F_3	296.000	122.000	27.390	2962.963	3518.519	0.468
C_4F_1	389.400	153.667	28.587	4490.741	7962.963	0.484
C_4F_2	336.600	126.000	26.983	3194.444	3425.926	0.474
C_4F_3	290.400	125.667	26.430	3240.741	3148.148	0.421
C_5F_1	338.800	149.667	28.697	4675.926	8657.407	0.415
C_5F_2	280.500	126.000	27.553	3287.037	5277.778	0.464
C_5F_3	310.200	130.000	27.577	3101.852	3888.889	0.453
CD	NS	NS	NS	NS	NS	NS

by application of 120:60:45kg N:P_2O_5 :K_2O ha^{-1} in combination with farmyard manure (Satyanarayana *et al*. 2002).

Yield is a function of yield attributes. Significantly higher number of productive tillers m^{-2}, no. of grains per panicle and 1000 grain weight might have contributed to increased grain yield of rice. Data of grain yield and straw yield revealed that, significant yield improvement was recorded due to increase in NPK doses. Grain yield increased with incremental dose of N up to 90 kg N and K up to 45 kg K ha^{-1}. Application of 90:45:45 kg N:P_2O_5 :K_2O ha^{-1}) produced significantly greater grain yield (4212.96 Kg ha^{-1}) as compared to that obtained with lower fertilizer levels (3203.70 and 3157.40 kg ha^{-1}). Singh *et al.* (2014) reported that application of recommended dose of NPK (100% RDF: 120:60:60 kg ha^{-1}) recorded marked improvement in grain yield which was significantly higher than 75% RDF, 50% RDF and control. Each increment in NPK level enhanced the grain yield significantly over its lower level. For rice, the N, P, and K amounts absorbed during the panicle-initiation stage determine panicle primordia formation, panicle branching and the setting of spikelets. In addition, the flowering and grain-filling stages are critical for rice yields. Continuous supply of nutrients in balanced quantity throughout the growth stages enabled the plants to assimilate sufficient photosynthates and their effective translocation to reproductive parts increased the yield attributes and yield of rice. These findings are in close agreement with earlier reports (Singh *et al*. 2008, Singh *et al*. 2014, Srivastava *et al*. 2014). Nitrogen fertilization might have resulted increase in P and K uptake, which increase photosynthetic activity and translocation of photosynthetic from source to sink which might have promoted the growth and development of yield attributes which have positive correlation with grain yield (Dwivedi *et al*. (2006) and Xu-Da-Dong *et al*. (2007)).

Economics

A perusal of data clearly indicates that net return and B:C ratio was influenced due to different treatments (Table 3). The variations in cost of cultivation were recorded due to variation in levels of nitrogen because these are the major monitoring inputs. Grain yield was major factor, which cause differences in net income and net return per rupee investment. Maximum net returns (Rs 80571 ha^{-1}) and B:C ratio (1.95) was recorded with application of 100 % recommended dose of NPK (90:45:45 kg ha^{-1}) and 5 t ha^{-1} farm yard manure. This was mainly due to higher production of grain as compared to other treatments (Mishra *et al*. 2015).

Table 3. Effect of different levels of fertilizers on economics of rice crop.

Treatments	Net returns (Rs)	B:C ratio
Main plots		
C_1	38697	1.46
C_2	50703	1.60
C_3	40271	1.48
C_4	46629	1.55
C_5	49607	1.59
CD	NS	NS
Sub plots		
F_1	68868	1.81
F_2	34307	1.40
F_3	32368	1.38
CD	8756	0.103
Interaction		
C_1F_1	63025	1.74
C_1F_2	21011	1.25
C_1F_3	32054	1.38
C_2F_1	67655	1.80
C_2F_2	39437	1.47
C_2F_3	45016	1.53
C_3F_1	56543	1.67
C_3F_2	39066	1.46
C_3F_3	25202	1.30
C_4F_1	76544	1.90
C_4F_2	31659	1.37
C_4F_3	31683	1.37
C_5F_1	80571	1.95
C_5F_2	40363	1.48
C_5F_3	27887	1.33
CD	NS	NS

CONCLUSION

On the basis of above findings it may be concluded that an optimum yield of rice was obtained by application of 90:45:45 kg N: P_2O_5 :K_2O ha^{-1} in combination with 5 t ha^{-1} of farmyard manure. The higher yield obtained with integrated use of farmyard manure and inorganic fertilizers were attributed to increased nutrient availability and uptake, resulting in greater number of tillers, filled grains per panicles and 1000grain weight.

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