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Effect of levels of nitrogen, phosphorus and potassium on performance of rice

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ABSTRACT

A field experiment was conducted on rice (*Oryza sativa* L.) for three consecutive *rabi* seasons of 2007, 2008 and 2009 on Godavari alluvials (Vertic chromusters) at Andhra Pradesh Rice Research Institute, Maruteru, with an objective to revise the existing fertilizer doses of major nutrients for *rabi* rice in Krishna Godavari delta regions of Andhra Pradesh. Grain yield was increased by 11.5% and 6.3% due to increase in recommended dose of N from 100% (120 kg ha^{-1}) to 125% and 150%. Increase in P & K doses from 100 to 125% (P from 60 to 75 and K from 40 to 50 kg ha$^{-1)}$ also improved grain yield significantly. Agronomic efficiency of N P and K was progressively increased with incremental doses of respective nutrients. Energy use efficiency of K is remarkably high particularly with first increment (4.87) followed by P and N. Highest gross returns, net returns and rupee per rupee invested were recorded with application of NPK @ 210-60-40 kg ha^{-1}. Incremental doses of N, P and K over the recommended dose recorded significant improvement in uptake of respective nutrients. Grain quality, milling characters were significantly influenced by incremental doses of N P & K. While considering the economics, nutrient depletion and quality parameters, application of N @ 180-90-60 kg ha^{-1} appears to be the most optimum dose for *rabi* rice in deltaic alluvial soils of Andhra Pradesh.

Key words: Economics, Incremental doses of N P K, Milling characters, Rice, Yield.

INTRODUCTION

As about 40 percent of yield increase is accounted against fertilizer use, the fertilizer recommendations should be matched to the basic soil fertility, season, target yield, climate *etc*. With the advent of modern production technology, the usage of higher doses of fertilizers in balanced manner is inevitable to exploit their full potential particularly under irrigated conditions. Modern high yielding varieties producing around 5 t/ha of grain can remove about 110 kg N, 15 kg P, 129 kg K, 5 kg S, 2 kg Fe, 2 kg Mn, 200 g Zn and 150 g B per hectare from the soil. Emergence of widespread multi-nutrient deficiencies, depletion of native nutrient reserves, imbalanced fertilization are of utmost concern, causing serious stagnation in yields and declining productivity of various rice ecosystems (Mangala Rai,2006). Excess use of fertilizer nutrients implies increase of cost and decrease of returns and risk of environmental pollution. On the other hand, under use of nutrients depress the scope for increasing the present level of nutrients to the economically optimum level to exploit production potential to a larger extent (Singh *et al.* 2001). Application of inadequate and unbalanced fertilization to crops not only results in low crop yields but also deteriorate the soil health(Sharma *et al.* 2003). The existing fertilizer recommendations for major nutrients in rice are proving to be sub-optimal for attaining higher productivity levels and need a fresh look to revise them to optimum and more balanced levels. In view of the above, a study was conducted to revise the existing major nutrient recommendations of *rabi* rice for delta soils of Andhra Pradesh to an optimum level duly considering yield, soil health and economics.

MATERIALS AND METHODS

Field experiments were conducted on rice (*Oryza sativa* L.) for three consecutive *rabi* seasons of 2007, 2008 and 2009 on Godavari alluvials (Vertic chromusters) at Andhra Pradesh Rice Research Institute, Maruteru, A.P. India (26.38^0 N, 84. 44^0 E and 5 m above mean sea level). The soil was clay loam having pH 7.1, CEC of 42 meq/100g of soil, organic carbon 0.9%, $KMnO_4$ extractable N of 297 kg ha^{-1}, Olsen's extractable P_2O_5 38 kg ha^{-1} and ammonium acetate extractable K_2O of 274 kg ha^{-1}. The experiment was conducted in randomized block design with three replications and ten treatments consists of different levels of NPK (kg ha^{-1}) *viz.* T_1: 120-60-40 (Recommended dose of NPK); T_2 :

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150-60-40; T_3 180-60-40; T_4: 210-60-40; T_5: 120-75-40;T_6: 120-90-40;T_7: 120-105-40 ;T_8 120-60-50;T_9: 120-60-60; T_{10}: 120-60-70. A popular high yielding variety MTU 1010 (Cotton dora sannalu) with 120 days duration was used. 24-day old seedlings were planted at a spacing of 15 X 15 cm with 2-3 seedlings per hill. Weed control measure were taken up by application of pre emergence herbicide pretilachlore @ 0.75 kg a.i. per hectare followed by one hand weeding at 40 days after transplanting. Water level in the crop was maintained at a depth of 2 cm up to panicle initiation and 5 cm thereafter up to one week before harvest. The field was drained before application of fertilizers and one week before harvest. Fertilizers were applied as per the treatment through Urea, single super phosphate (SSP), muriate of potash (MOP). Entire P & K and 1/3 recommended N was applied as basal, remaining N was applied in two splits at active tillering and panicle initiation. Zinc Sulphate @ 50 kg ha^{-1} was applied at the time of last puddling. The experiments received uniform plant protection and cultural management practices throughout the period of crop growth. Data on growth, yield attributes and yield were collected following standard procedures from 10 randomly marked hills. The surface soil samples up to 15 cm depth before and after the harvest of the crop were collected and analyzed for soil organic carbon ,available N P and K by following standard procedures. The quality parameters were assessed as per the procedure given by Ghosh (1971). Economic parameters like gross returns, net returns and rupee returned per rupee invested were worked out treatment–wise taking prevailing market rates for different inputs and out puts. Agronomic efficiency was calculated by dividing kg grain by kg of applied nutrient in respective treatment as defined by Ladha *et al.*(2005). Energy use efficiency was calculated by dividing energy input by energy output as per the procedure given by Panesar and Bhatnagar(1994). Data were analyzed using ANOVA and the significance was tested by Fisher's least significance difference (p= 0.05) by pooling three years data.

RESULTS AND DISCUSSION

The three years data after pooled analysis revealed that the growth, yield attributes, yield, economics, nutrient uptake, soil nutrient status and quality parameters were significantly influenced by different levels of N P & K. Among three major nutrients, response to N was higher followed by K and P. Number of tillers m^{-2}, panicles m^{-2} and dry matter production per hectare was conspicuously augmented by increasing N level from 120 to 180 kg ha^{-1} (50 % increase) and further increase did not resulted in significant change (Table.1). Increased levels of N favours greater absorption of nutrients resulting in rapid expansion of foliage, better

TABLE 1: Effect of incremental doses of N P and K on growth yield attributes spikelet sterility, yield, Agronomic efficiency, energy use efficiency and economics of rice

(Pooled data of three years)

Treatments N,PK ($kgha^{-1}$)	Tillers/m^2	DMP* $kgha^{-1}$	Panicle/ m^2	Filled grains/ panicle	1000 grain wt (g)	Spikelet Sterility (%)	Grain yield ($kgha^{-1}$)	Harvest Index	AE of N/P / K ($kgkg^{-1}$)	EUE ($MJMJ^{-1}$)	Gross Returns ($Rsha^{-1}$)	Net Returns ($Rsha^{-1}$)	Rupee per rupee invested (Rs Rs^{-1})
120-60-40	430	12770	391	114	20.84	17	6068	47	-	4.49	48353	21446	0.80
150-60-40	466	14260	428	131	21.02	15	6767	47	2.80	4.59	53800	26548	0.97
180-60-40	494	15137	449	143	21.57	21	7146	47	3.85	4.47	56821	29224	1.06
210-60-40	509	15606	456	144	21.93	27	7333	47	4.08	4.26	58339	30398	1.09
120-75-40	459	13614	418	117	21.27	16	6449	47	1.62	4.73	51327	23995	0.88
120-90-40	472	14028	432	122	21.30	17	6664	48	2.38	4.85	53058	25301	0.91
120-105-40	489	14221	436	126	21.88	16	6689	47	2.34	4.83	53204	25022	0.89
120-60-50	451	13671	412	127	20.96	16	6595	48	2.29	4.87	52497	25511	0.95
120-60-60	459	14130	425	139	21.60	15	6764	48	2.90	4.97	53842	26776	0.99
120-60-70	462	14399	434	144	20.49	14	6898	48	3.32	5.06	54867	27721	1.02
SEm ±	7.35	266.8	6.02	2.254	0.635	-	128.6	-	-	0.12	897	545	0.03
CD (p= 0.05)	22	793	17.88	7	1.89	-	382	-	-	0.36	2665	1621	0.09

*DMP = dry matter production at harvest ; AE =Agronomic Efficiency; EUE =Energy use efficiency.

accumulation of photosynthates and eventually resulting in increased growth structure. Similar results and opinions were expressed by Balasubramanian and Palaniappan (1991). Regarding phosphorus and potassium there was significant increase in tillers as well as dry matter production by enhancing dose by 25 % over the recommended dose. The panicle production was significantly augmented at 50 % increment of P and increase of K dose by 25 % and 25 to 50 %. There was a marked increase in filled grains per panicle with increase in N & K dose up to 50 % and increase in P dose by 50 %. There was measurable improvement in test weight with 50 % increase in N, 75 % increase in P & and 25 % increase in K levels. Increased number of panicles was produced with higher number of filled grains with greater test weight under adequate N content in rice plant. The effect of major nutrients particularly N on yield attributes is primarily a function of assimilates accumulation and in turn facilitating higher N assimilation with adequate supply of photosynthates to grain (Kumar,1986). Spikelet sterility was increased progressively with incremental doses of N whereas, it was decreased progressively with incremental doses of K up to additional dose of 50 % and unaffected by additional doses of P application. Potassium nutrition improves germination of pollen in the floret which leads to high spikelet fertility in rice (Uexkull 1978). Decreased spikelet sterility in rice with incremental doses of Potassium was reported by Raju *et al.* (1999). Harvest Index was unaffected by incremental doses of N,P & K in spite of marked influence on dry matter could be ascribed to better carbon assimilation and effective translocation of assimilates to reproductive parts . Similar findings were reported by Singh and Bharadwaj (2008).

The three years pooled data of grain yield revealed that, significant yield improvement was recorded due to increase in recommended N doses (120 kg ha^{-1}) from 100 to 125 % and 125 to 150 %, the yields were 11.5 % & 6.3 % higher over 100 % recommended dose, respectively (Table 1). Increase in recommended N doses from 100 to 175 % recorded 20.8 % higher grain yield over recommended dose (6068 kg ha^{-1}) however, the improvement beyond 150 % was not statistically measurable. Positive response of rice to incremental N supply has been universally reported (Raju and Reddy 1997,Blaise and Prasad 1996). Higher response of rice for major nutrients particularly for N during rabi was observed because of higher solar radiation, greater differences in day and night temperatures and improved water management compared to other seasons (Rao and Murthy,1987). Increase in P & K doses from 100 to 125 % improved grain yield significantly however, further incremental doses of P & K beyond 125 % did not result in significant yield improvement. 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).

Agronomic efficiency of N was progressively increased with incremental doses i.e. increase in N level from 120 to 150, 180 and 210 kg ha^{-1} recorded the AE values of 2.80, 3.85 and 4.08, respectively. Unlike N, the Agronomic efficiency of P progressively increased with incremental doses i.e. increase in P level from 60 to75 and 90 kg ha^{-1} recorded the AE values of 1.62 and 2.38, respectively and then the Agronomic efficiency was decreased by further increase of P level from 90 to 105 kg ha^{-1}. Where as Agronomic efficiency of K was progressively increased with incremental doses i.e. increase in K level from 40 to 50, 60 and 70 kg ha^{-1} recorded the AE values of 2.29, 2.90 and 3.32, respectively shows the increase in Agronomic efficiency was at diminishing rate . This may be due to better availability of nutrients and concomitant utilization by the crop with incremental levels of N,P and K. This is an indication of the fact that recovery efficiency of the incremental doses is good at initial increments and shows the scope for increased levels of respective nutrients. These results are in close agreement with those of Upadhyay and Patel (1992). Energy use efficiency of N was increased by increase in N level by 25 % only (application of NPK @ 120-60-40 to 150-60-40 kg ha^{-1}) then it declined with further increments of N. Energy use efficiency of P increased up to first two increments (application of NPK @ 120-60-40 to 120-75-40 and 120-90-40 kg ha^{-1}) and then decreased with further increment of P. Where as, energy use efficiency of K was remarkably high particularly with first increment i.e. application of NPK @ 120-60-40 to120-60-50 kg ha^{-1} (4.87) then it was increased at diminishing rate with further increments of K i.e. application of NPK @ 120-60-60 kg ha^{-1} (4.97) and 120-60-80 kg ha^{-1}(5.06). This shows the importance of incremental doses of K & P along with N to reap the maximum energy benefit.

Economic analysis of three years pooled data showed that the highest gross returns, net returns and rupee per rupee invested were higher with application of NPK @ 210-60-40 kg ha^{-1} (Table.1). Though the gross returns, net returns and rupee per rupee invested were increased progressively with incremental doses of N ,the increase was statistically measurable up to additional dose of N @ 60 kgha^{-1} (50 % increase). Increase in P and K dose by 25% only resulted in significant improvement in gross returns, net returns and rupee per rupee invested. Similar results were reported by Waheb and Prakash (1995). At 50 % N increase by spending Rs 691/- an additional net income of Rs 7778/- per hectare was realized, similarly, there was an additional net income of Rs 3855/- by spending Rs 851/- at 50 % P increment, Rs 5330/- by spending Rs 160/- at 50 % K increment.

The uptake studies of N P K at harvest showed that incremental doses of N, P and K recorded significantly progressive improvement in uptake of respective nutrients (Table 2).The higher uptake of N ,P and K with incremental doses might be due to the fact that plant absorbed the nutrients proportionately as the pool of available nutrients increases in soil solution .Increased nutrient absorption by rice with increased fertilizer doses has also been reported by Singh and Namdeo (2004). Increase in N dose by 25 % ,increased the uptake of P and K conspicuously besides increase in uptake of N . Similar results of increase in K content and uptake due to increase in N level, increase in N content and uptake with increase in P, K levels were reported by Singh *et al*.(2005). Application of additional doses of fertilizers enriched the available nutrient status consequently results in higher nutrient uptake. The results were in accordance with the reports of Rayar (1990).

Post harvest soil nutrient status revealed that, incremental doses of N by 50 % and above only improved the status of organic carbon and available N over initial value of 0.9 % and 297kg ha^{-1} respectively(Table 2). The status of available P_20_5 was unaffected by incremental doses of N P and K. However, slight decrease in status of available P_20_5 was noticed by increasing N & K doses making P constant. The status of available K_20 was also shown decreasing trend by increasing N & P doses making K constant and the difference was measurable at additional dose of 75% over 100 % recommended. Further, the buildup of available K_2O in soil by increasing K dose by 75 % only over present recommendation ,this might be due to the fact that higher doses of fertilizers only can satisfy the sorption sites of clay surfaces and able to build up the status of potassium (Grimme,1976).

Grain quality in terms of grain Protein content was progressively increased with the incremental doses of N & P , however the increase was measurable up to 50 % additional dose of N and up to 25 % increment of P only (Table.2). This might be due to higher availability of N & P in plant and in grain for more assimilation of nitrogen and protein synthesis. Though the differences were not conspicuous, the grain protein content was progressively decreased with incremental doses of K, which probably was due to dilution effect of potash. The results were in line with the Parida *et al*. (1994). The milling characters were significantly influenced by incremental doses of N P & K (Table 2). Hulling (%) was significantly improved up to first incremental doses of N (125 %) and further increase in N reduced the hulling percentage to a little extent. Whereas incremental doses of P and K progressively increased the hulling% but the differences were measurable up to first increment only. The milling (%) and per cent head rice recovery were increased up to 50 % increase in N though the differences were conspicuous up to 25 % N increase. It is known that protein content imparts strength to the grain, higher protein content thus resulted in higher head rice recovery. Significant increase in hulling % and head rice recovery due to increase of N dose from 40 to 80 kg/ha was also reported by Adhikari *et al*. (2005). Whereas incremental doses of P & K were progressively enhanced the milling (%) and percent head rice recovery up to third increment (75% increase) though the improvement was noticeable up to first increment.

TABLE 2: Effect of incremental levels of N P and K on uptake of N,P and K by rice at harvest, post harvest soil available nutrient status, protein content and milling characters of rice (Pooled data of three years)

Treatment N,PK (kgha-1)	Organic Carbon (%)	Available status (kg ha^{-1})			Nutrient uptake (kgha^{-1})			Protein content (%)	Hulling (%)	Milling (%)	Head Rice Recovery (%)
		N	P_2O_5	K_2O	N	P	K				
120-60-40	0.88	294	39.01	272	107	20.39	118	7.68	76.9	68.8	52.4
150-60-40	0.90	319	38.96	257	129	22.98	137	8.01	79.8	69.4	56.2
180-60-40	0.91	329	37.14	251	141	24.13	152	8.52	79.0	70.1	57.4
210-60-40	0.93	336	36.17	243	149	24.74	168	8.94	78.3	68.8	56.8
120-75-40	0.89	292	40.45	267	117	25.16	129	8.21	81.6	71.4	58.1
120-90-40	0.90	299	41.62	263	120	30.73	143	8.59	82.1	72.2	59.0
120-105-40	0.90	304	43.12	258	121	32.62	147	9.03	82.4	74.1	59.8
120-60-50	0.90	305	37.96	276	122	20.56	161	7.60	81.8	74.3	60.4
120-60-60	0.91	303	37.27	283	125	21.66	185	7.51	82.9	76.1	62.1
120-60-70	0.91	316	35.57	302	128	22.32	198	7.46	83.6	78.0	63.7
SEm ±	0.01	7.73	1.19	7.2	2.62	0.71	5.25	0.16	0.88	0.76	1.00
CD (p=0.05)	0.02	23	3.52	21	8.00	2.11	16	0.47	2.6	2.3	3.0

Based on the above results , though the yield improvement was significant up to 50 % increase over present recommendation of N, 25 % increase in P & K, while considering the economics , nutrient depletion, energy efficiency and quality parameters, 50 % increase of N and 25 % increase in P and K i.e. 180-75-50 kg ha^{-1} appears to be the optimum dose for *rabi* rice in deltaic alluvial soils of Andhra Pradesh.

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