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EFFECT OF CONTINUOUS APPLICATION OF FERTILIZER NUTRIENTS ON THE LONG TERM PRODUCTIVITY OF A RICE CROPPING SYSTEM

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Abstract: Field experiments conducted for a period of seven years to study the effect of continuous application of fertilizer nutrients on the long term productivity of a rice based cropping system revealed that nitrogen application increased grain yield in all the seasons for a period of seven years. Both the physical and economic optimum dose of N decreased @ 4.06 and 3.7% per season, respectively. Nitrogen application @ zero and 120 kg/ha per season continuously over a period of five years, decreased the grain yield @ 1.47 and 1.28 g/ha/year, respectively. But application of N @ 40 kg/ha during the same period increased grain yield 6 1.22 q/ha/year. The productivity of plots applied with N @ 80 kg/ha remained stable. The study clearly revealed the possibility of skipping P for four years and K for seven years in soils containing medium amounts of these nutrients. Application of N at optimum dose is important to maintain the long term productivity of a rice based cropping system involving rice-rice-fallow.

INTRODUCTION

Rice based cropping system is the most common and widely practised system of cropping in the low lands of Kerala. The requirement of N, P_2O_5 and K_2O for a medium duration variety was found to be 90:45:45 in the low lands of Kerala (KAU, 1986). It is worthwhile to know whether a field receiving a particular dose of nitrogen season after season and year after year requires the same dose continuously to maintain productivity. Hence in the present study the effect of continuous application of fertilizer nutrients on the long term productivity of a rice based cropping system involving rice-rice-fallow has been examined. The change in the N requirement of rice in a continuously fertilized plot in relation to time was assessed. The production dynamics of rice under different levels of N application, in relation to time was also sutudied.

MATERIALS AND MEHTHODS

Fourteen field experiments were conducted for a period of 7 years (from 1977 to 1983) with the rice variety Jaya. The soil of the experimental site was sandy clay loam with a pH of 5.3, EC 0.023 mmho/cm and CEC of 5.44 me/100 g soil. The soil contained 0.72% organic C, 156 kg of available N, 31 kg of available P_2O_5, 178 kg of available K_2O and 3.3 ppm 0.01 *N* HC1 extractable Zn.

The study involved a 3^2 x 2 factorial partially confounded experiment. The experiment was laid out in RBD with four replications. The treatments consisted of factorial combinations of three levels of N (40, 80 and 120 kg N/ha), three levels of P_2O_5 (0, 40 and 80 kg P_2O_5/ha) and two levels of K_2O (0 and 40 kg K_2O/ha). In addition to the above 18 treatment combinations, there was an absolute control (no application of N, P2O5 or K_2O) in each block. Nitrogen was supplied as ammonium sulphate, P_2O_5 as superphosphate and K_2O as muriate of potash.

The experiment was conducted during kharif and rabi seasons. Totally, 14 crops were raised of which two failed due to weather abnormalities. In all the seasons, the crops were raised by transplanting the variety Jaya, following standard procedures and techniques as recommended by the package of practices recommendations of KAU (1986).

Sufficient care was taken to ensure uniform management practices to the crops in all the seasons. The initial lay out of the experiment was retained as it is for 7 years and as such the plot receiving a particular treatment continued to receive the same treatment in all the 14 seasons. The pests and diseases were kept under check uniformly in all the seasons. The data on weather parameters recorded during the experimental period revealed that the weather conditions remained more or less normal except during rabi 1977 and rabi 1978 during which the crops failed.

The paddy yield at 14% moisture was recorded season-wise. As all the 14 experiments were conducted in the same field retaining the same lay out, the effect noticed in the second season onwards will be the sum total of the treatment effect of that particular season plus the residual effect accumulated till then. As the treatment effect and residual effect could not be separated here, the analysis of individual season's data as it is, as well as the usual pooled analysis gave erratic results. Hence the data on cumulative yield obtained over seasons were analysed to study the treatment effect and the results are presented. The quadratic response equations were fitted wherever possible and the physical optimum (PO) and economic optimum (EO) doses were worked out.

To study the pattern of change in productivity of rice due to continuous cropping in relation to time, the data on per year production of rice for five years (kharif + rabi yield from 1979 to 1983) under different levels of N application, were subjected to statistical analysis. The production dynamics of rice in relation to time due to levels of nitrogen are presented.

RESULTS AND DISCUSSION

a) Effect of nitrogen

The mean data on cumulative grain yield presented in Table 1 clearly revealed that the effect of N was consistently significant in all the seasons. During the first two years (kharif 1977 and kharif 1978) the response was linear up to the highest dose of N tried (120 kg N/ha). In the remaining five years (for 10 seasons) the response of rice to N application was quadratic (Table 2). The R^2 values obtained are not sufficient to draw meaningful conclusions on PO and EO doses of N. It was interesting to note that both the PO and EO doses on N showed a decreasing trend with advancement of season. The regression equations fitted to study the pattern of change in PO and EO doses of N in relation to seasons (1979 kharif to 1983 rabi) are PO = - 6.985 S + 207.81 and EO = - 6.125 S + 195.91 where S represents seasons from 1979 kharif to 1983 rabi (S_5 to S_{14}).

The regression coefficient of PO on season indicates that the PO dose of N decreases at the rate of 6.98 kg N/ha/season, accounting for a 4.06% decline. Similarly the regression coefficient of EO on season explains that the EO dose of N decreases at the rate of 6.12 kg/ha/season amounting to a 3.70% decline. This means that a plot applied with optimum amounts of N in the beginning need not be supplied with the same amount of this nutrient season after season and year after year. This decrease in the requirement of fertilizer N in the subsequent seasons may be due to the residual effect accumulated till the previous season. This information assumes importance especially when the nutrient management of crops is considered on a system basis. Only furhther studies can prove as to whether this decreasing trend in the PO and EO doses of N for rice will continue indefinitely or not.

b. Effect of phosphorus

The mean data on grain yield (Table 1) revealed that phosphorus application did not influence the grain yield during the initial four years. It may be noted that the experimental soil contained medium amounts of available phosphorus. Perhaps the native reserve of soil phosphorus might have been sufficient to meet the crop demand during the initial years. Flooded rice is found to make better use of residual P (Meelu and Bhandari, 1978). This is due to the dominance and availability of iron bound phosphorus under reduced conditions (Singhania and Goswami, 1974). Stewart (1947) reported infrequent crop responses to fertilizer phosphorus. But from the 5th year onwards, the effect of P was found to be significant for the remaining seasons. The response equations revealed that during the remaining six seasons the effect of P was found to be significant and the nature of the response was linear. Continuous depletion of P from the control plots for a period of four years might be responsible for the observed trend. Mahapatra *et al.* (1974) reported that the crop removal of phosphorus in a rice-rice-rice sequence is in the order of 36 kg P_2O_5/ha. Biswas *et al.* (1977) based on the long term experiment on continuous application of fertilizer reported that there was considerable depletion of phosphorus in the plots which did not receive any fertilizer. In the present study, as the response of rice to P application was linear (in the last 3 years), optimum doses could not be worked out.

c. Effect of potassium

The effect of potassium on grain yield was not consistent throughout the experimental period (in all the seven years). The grain yield obtained from the plots applied with no potassium and from those applied with 40 kg K_2O/ha did not differ significantly. It may be noted that the soil of the experimental area was medium with reference to available potassium. From the above results it appears that the native reserve of soil potassium could meet the demand of the crop in all these years. Infrequent crop responses to applied potassium have been reported by Stewart (1947). It may be concluded from the study that in the sandy clay loam soils of Kerala containing meidium amounts of available potassium, the crop demand can be met from the soil reserve itself, at least for a period of seven years. The results thus suggest that in such soils K application can be skipped for a minimum of seven years. In general, the interaction effects between fertilizer nutrients on grain yield were not significant.

d. Effect of continuous cropping on productivity

To study the effect of N application on the long term productivity of rice under continuous cropping, regression equations of yield on year under different levels of N application have been fitted. The following regression equations were obtained.

$YN\ 0 = -1.47\ t + 64.59$
$YN\ 40 = +\ 1.22\ t + 66.22$
$YN\ 80 = -0.02\ t + 81.15$
$YN\ 120 = -1.28\ t + 86.53$

Where t = time in year (3, 4, 5, 6, 7 years) and YN = the yield in quitals due to levels (kg).

From the regression equations it can be seen that in the plots applied with N @ 120 kg/ha/season, there was a decline in yield § 1.28 q/ha/year between 1979 and 1983. Again in the control

Table 1. Mean data on cumulative grain yield (q/ha) 1977 to 1983 (7 years)

Year	1977		1978		1979		1980	
Treatment) (kg/ha	S_1 K	S_2 K	S_3 K	S_4 R	S_5 K	S_6 R	S_7 K	S_8 R
N40	44.93	-	79.92	-	121.90	149.22	198.78	226.57
N80	52.24	-	93.74	-	139.38	169.91	224.41	256.33
N120	56.61	-	104.09	-	148.62	179.32	233.83	264.46
SEm ±	0.87	-	1.33	-	1.63	2.13	2.39	2.94
CD (0.05)	2.50	-	3.80	-	4.67	6.09	6.81	8.40
PO	51.61	-	92.68	-	138.31	168.32	219.81	247.93
P40	51.12	-	92.17	-	135.00	163.00	214.98	145.93
P80	51.05	-	92.90	-	136.58	167.12	222.23	253.51
SEm ±	0.87	-	1.31	-	1.63	2.13	2.39	2.94
CD (0.05)	NS	-	NS	-	NS	NS	NS	NS
K0	51.70	-	93.67	-	138.52	167.59	219.85	248.99
K40	50.83	-	91.50	-	134.74	164.70	218.16	249.25
SEm±	0.71	-	1.08	-	1.33	1.74	1.95	2.40
CD (0.05)	NS		NS		NS	NS	NS	NS
Control	38.21	-	67.50	-	103.18	126.01	171.84	193.53

Year	1981		1982		1983	
Treatment (kg/ha)	S_9 K	S_{10} K	S_{11} K	S_{12} R	S_{13} K	S_{14} R
N40	271.71	293.38	337.65	361.56	415.64	441.53
N80	316.64	341.67	391.00	417.71	474.50	498.97
N120	328.82	354.17	405.03	432.46	484.93	504.71
SEm±	4.07	4.50	5.12	5.95	6.74	7.24
CD (0.05)	11.63	12.85	14.61	16.98	19.24	20.67
PO	298.47	319.00	364.07	387.89	440.68	461.62
P40	301.72	326.53	375.57	402.30	458.21	481.92
P80	316.98	343.71	394.03	421.54	476.18	501.67
SEm±	4.07	4.50	5.12	5.95	6.74	7.24
CD (0.05)	11.63	12.85	14.61	16.98	19.24	20.67
K0	306.20	329.09	377.07	401.90	457.17	480.56
K40	305.24	330.39	378.71	405.92	459.54	482.91
SEm±	3.32	3.67	4.18	4.85	5.50	5.91
CD (0.05)	NS	NS	NS	NS	NS	NS
Control	229.85	243.98	276.75	293.75	332.10	353.82

K = Kharif; R = Rabi; S_1 to S_{14} are serial number of seasons; Crop failed during 1977 rabi and 1978 rabi

plots, yield decreased markedly @ 1.47 q/ha/year during the five year period. Yield reduction in the unfertilized plots due to continuous cropping is quite possible due to steady deterioration of soil fertility. The decline in yield noticed in the plots applied with higher doses of N (@ 120 kg/ha/season) might

Table 2. Response equations of rice to N and the physical optimum and economic optimum doses worked out based on the cumulative yield data

Year and season		Response euquation $Y = a + bN - cN^2$	R^2	Physical optimum dose kg/ha	Economic optimum dose kg/ha
1977	K	Linear			
1977	R	Crop failed			
1978	K	Linear			
1978	R	Crop failed			
1979	K	$Y=102.5137 + 0.5708 N - 0.001533 N^2$	0.5925	186.24	176.37
1979	R	$Y=125.1713 + 0.7213 N - 0.002222 N^2$	0.6058	162.31	155.54
1980	K	$Y=170.4213 + 0.8760 N - 0.002847 N^2$	0.5969	153.82	148.56
1980	R	$Y=191.7824 + 1.0964 N - 0.004029 N^2$	0.5847	136.06	132.32
1981	K	$Y=226.4337 + 1.4560 N - 0.004905 N^2$	0.6054	148.43	145.35
1981	R	$Y=240.6802 + 1.6823 N - 0.006023 N^2$	0.6048	139.65	137.15
1982	K	$Y=273.7293 + 2.0139 N - 0.007560 N^2$	0.6068	138.20	131.20
1982	R	$Y=290.9158 + 2.2127 N - 0.008511 N^2$	0.5953	129.99	128.22
1983	K	$Y=329.8374 + 2.6939 N - 0.011600 N^2$	0.5850	116.11	114.82
1983	R	$Y=351.7820 + 2.8389 N - 0.012970 N^2$	0.5397	109.47	108.28

K = Kharif   Price of N = Rs. 6.78/ kg
R = Rabi   Price of paddy Rs. 225/q

be due to the accumulation of residual N in the subsequent years and the consequent well known ill effects due to excess N nutrition.

In plots applied with N @ 40 kg/ha/season, there was an increase in yield @ 1.22 q/ha/year. It was further observed that the productivity of rice during the five year period remained more or less stable in plots applied with 80 kg N/ha/season. The theoretical rate of reduction noticed in this treatment was only 2 kg/ha/year which can be ignored. These results are quite encouraging and belie the belief that monoculture will deteriorate the poroductivity. The results further reveal that by adjusting the level of nutrient application the productivity over years can not only be increased but also be stabilized. Application of a suboptimal dose of N (@ 40 kg/ha) increases the productivity in the long run. But by applying N in optimum quantities (80 kg/ha) the long term productivity of rice remains stable. The results obtained from the present study emphasise the importance of optimum N nutrition to maintain the long term productivity of a rice based cropping system involving rice-rice- fallow.

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