Effect of Phosphorous and Zinc Fertilisation on the Productivity of Transplanted Aromatic Rice

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Abstract

The incidence of micronutrient deficiencies in crops and cropping systems has increased markedly in recent years in India. The important reasons are: increase in area under intensive cropping systems, decreased proportion of farm-yard manure (FYM)/organic manures compared to chemical fertilisers, increased use of straight fertilisers, losses of micronutrients through leaching/soil erosion, excess liming of acid soils, and cultivation of high-yielding varieties of different crops. The use and efficiency of macronutrients depend on the availability of micronutrients in the soil. The interaction of phosphorous (P), a macronutrient, and zinc (Zn), a micronutrient, is very important for rice cultivation. Therefore, a field experiment was carried out to study the effect of phosphorous and zinc fertilisation on growth, yield attributes, yield, and phosphorous uptake of aromatic rice. Application of 40 kg P_2O_5/ha (phosphorous pentoxide) in combination with 5 kg Zn/ha was found suitable for achieving greater productivity of aromatic rice. P uptake by aromatic rice increased significantly with each successive increase in P up to the highest level (i.e., 60 kg P_2O_5/ha). However, zinc application did not affect the P uptake significantly.

Introduction

Scores of assessments have been made of the occurrence of micronutrient deficiencies in Indian soils and crops (Katyal and Agarwala 1982; Katyal 1985; Takkar et al. 1997; Rattan et al. 1999). All estimates point to the possibility of wide-scale occurrence of Zn deficiency in Indian soils: the extent is almost 50%. Sustaining the supply of deficient micronutrients along with macronutrients in appropriate amounts and right proportions is a key to maximising productivity gains in rice. This is especially true for a country like India, where the chances of raising four to five million tons of additional food to feed 15 to 17 million more people every year through area expansion are very poor. The influence of micronutrients on the optimum use of macronutrients is rooted in the fact that if supply of the former falls short of what is needed for optimum crop growth and yield, response to the latter will be impaired in economic and environmental terms. Many studies have proven this relationship (Takkar et al. 1997; Rattan et al. 1997).

The macronutrients include nitrogen (N), phosphorous (P), and potassium (K), and the optimum use of these has been evaluated with or without the involvement of micronutrients, typically zinc (Zn), in rice-based cropping systems. Apart from the direct role of micronutrients in overcoming inherent deficiency and enhancing response to NPK treatment, they also assert an interactive effect on the uptake and use of macronutrients. P and Zn interaction is a typical example. Many controlled greenhouse studies have shown that Zn deficiency interferes with P metabolism (Safaya 1976; Loneragan et al. 1982; Nayak and Gupta 1995). As a consequence of this association, plants tend to accumulate more P, develop symptoms resembling Zn deficiency, and yield less. An optimum level of Zn application overcomes this antagonism and assures restoration of normal yields (Sakal et al. 1996). In some studies, the P and Zn interactive effect was found to be statistically non-significant (Sharma and Bapat 2000). In studies, where P and Zn were optimally balanced, this interactive effect disappeared and maximum yield and response to P application was obtained (Takkar et al. 1976). In instances in which P/Zn ratios turned out to be wider, either due to heavy dressings with P fertilisers or because of sub-optimal supply of Zn, deficiency of Zn became more severe leading to a measurable fall in Zn uptake and yield. Most of these studies on P and Zn nutrition are related to coarse/non-scented rice. Therefore, a field experiment was planned to study the effect of phosphorous and zinc fertilisation on growth, yield attributes, and yields of aromatic rice. Another aim was to estimate the uptake of P by aromatic rice as influenced by P and Zn fertilisation.

Materials and Methods

A field experiment was carried out during the rainy (kharif) season of 2002 at the experimental farm of the Indian Agricultural Research Institute, New Delhi, India, to study the effect of phosphorous and zinc fertilisation on the productivity and phosphorous uptake of aromatic rice under transplanted puddled conditions. The soil at the experimental site was sandy clay loam (sand 51.8%, silt 22.1%, clay 26.1%) with a pH value of 8.15, organic carbon 0.52%, available nitrogen 195 kg/ha, available P 16.2 kg/ha , available K 285.6 kg/ha, and diethylenetriaminepentaacetic acid (DTPA) extractable Zn 0.75 ppm in furrow slice soil. The treatments, consisting of 16 possible combinations of four phosphorous levels (0, 20, 40, and 60 kg P_2O_5/ha) in main plots and four zinc levels (0, 2.5, 5.0, 7.5 kg Zn/ha) in sub-plots, were allocated in a split plot design with three replications. Twenty-five day old seedlings of 'Pusa Basmati 1', a high yielding aromatic rice variety, were transplanted on 8 July 2002, at 20 x 10 cm spacing, keeping two seedlings per hill. The total amount of phosphorous and zinc, as per the treatment, was applied before transplanting in the form of single super phosphate and zinc sulphate, respectively. Nitrogen was applied through urea in three equal splits, 1/3 each at transplanting, active tillering, and panicle initiation stages, respectively. A five to six cm depth of water was maintained throughout the rice cultivation season rice; irrigation was stopped two weeks before the rice harvest. The crop was harvested on 15 October 2002. At harvesting, 10 hills from each plot were picked at random for measurement of panicles/hill, panicle length, panicle weight, spikelets/panicle, filled grains/panicle, and 1000-grain weight. A net plot area (4.8 x 1.6m) of eight rows from each plot was harvested and their respective weights recorded for total biomass and grain yield estimation. The harvest index (%) was obtained by dividing the grain yield with the biological yield (grain + straw) multiplied by 100. The recorded data and observations were tested for statistical significance using the analysis of variance technique (Gomez and Gomez 1984).

Results and Discussion

Growth and yield attributes

The increasing rates of phosphorous application encouraged the growth and yield attributes of aromatic rice (Tables 1 and 2). The highest P levels (40 and 60 kg P_2O_5/ha) resulted in the maximum recorded plant heights, both levels produced significantly taller plants compared to other P levels and the control. The significant effect of phosphorous application on yield attributes, viz. grain weight/panicle and 1000-grain weight, was only recorded up to

40 kg of P_2O_5/ha. However, effective tillers/hill, total grains/panicle, and filled grains/panicle continued to increase significantly up to the highest level of P, i.e., 60 kg P_2O_5/ha. The fertility percentage of rice grains also increased significantly as a result of phosphorous application compared with no P application. However, there was no significant effect on grain fertility beyond 20 kg of P_2O_5/ha. In general, application of phosphorous encourages the production of dry matter in rice, which eventually results in improved growth and yield attributes. Zinc application also increased the plant height and yield attributes, viz., effective tillers/hill, panicle length, panicle weight, total grains/panicle, filled grains/panicle, and 1000-grain weight, over control. No interaction effect between

Table 1: **Effect of phosphorous and zinc fertilisation on growth and yield attributes of aromatic rice ('Pusa Basmati 1')**

Treatment	Plant height (cm)	Effective tillers/hill (no.)	Panicle length (cm)	Grain weight (g/panicle)
Phosphorous levels (kg P_2O_5/ha)				
0	93.5	8.2	25.5	2.23
20	97.5	9.3	26.9	2.35
40	103.5	10.5	27.9	2.50
60	104.0	10.9	28.2	2.57
CD (P = 0.05)	2.21	0.11	1.78	0.08
Zinc levels (kg Zn/ha)				
0	96.0	8.5	25.7	2.07
2.5	98.2	9.4	26.7	2.42
5.0	101.0	10.2	27.7	2.55
7.5	103.2	10.6	28.3	2.60
CD (P = 0.05)	2.99	1.6	1.68	0.29

Table 2: **Effect of phosphorous and zinc fertilisation on yield attributes of aromatic rice ('Pusa Basmati 1')**

Treatment	Total (grains/panicle)	Filled (grains/panicle)	Fertility (%)	1000-grain weight (g)
Phosphorous levels (kg P_2O_5/ha)				
0	103.2	87.2	84.4	20.23
20	108.7	96.2	85.5	21.28
40	114.2	98.7	86.4	22.32
60	117.5	101.5	86.2	22.47
CD (P = 0.05)	0.41	1.37	1.00	0.28
Zinc levels (kg Zn/ha)				
0	106.5	90.7	85.0	19.87
2.5	108.7	93.7	86.1	21.53
5.0	113.0	97.0	85.7	22.25
7.5	115.5	99.2	85.8	22.68
CD (P = 0.05)	4.12	3.84	0.88	1.84

phosphorous and zinc applications was observed in this study. In general, the lower rates (2.5 kg/ha) of Zn application could not bring a significant increase in yield attributes, viz., effective tillers/hill, panicle length, total grains/panicle, filled grains/panicle, and grain weight/panicle over control. However, all the above parameters became significant ($P<0.5$) over control when the level of Zn was raised to 5 kg/ha. Further increase to 7.5 kg/ha did not exert any significant impact on any of the yield attributes studied. Overall, medium levels of zinc (5.0 kg/ha) had a favourable effect on most of the yield attributes. Rice has responded significantly to zinc application in many other studies elsewhere in India.

Yield and phosphorous uptake

Grain, straw, and biological yields and harvest index of aromatic rice were influenced significantly by the application of both phosphorous and zinc (Table 3). Straw and biological yield of rice increased progressively and significantly with an increase in each successive level of phosphorous, i.e., up to 60 kg P_2O_5/ha. Phosphorous is known to increase the uptake of other nutrients, especially N, that may have caused an increase in dry matter production and hence eventually biological and straw yields of rice. Phosphorous application affected the grain yield of rice significantly during the present investigation, but it only increased significantly up to 40 kg of P_2O_5/ha, with no further significant increase at 60 kg of P_2O_5/ha. The increase in yield with application of 40 kg of P_2O_5/ha over lower P doses was caused mainly through a significant improvement in grain weight/panicle and 1000-grain weight. Also the significant increase in P accumulation in plants added to the improved grain yield under P application. The increase in grain yield of rice in India has been reported by Rao and Shukla (1999), Raju et al. (1992), and Kumar et al. (2002). The harvest index (%) of rice decreased slightly but significantly ($P<0.5$) at each successive increase in P level. The increasing levels of grain yield might have resulted in a decrease in harvest index at increased P levels.

The lower rates (2.5 kg/ha) of Zn application did not bring a significant increase in grain and biological yields over control. However, both the above parameters became significant ($P<0.5$) over control when the level of Zn was raised to 5 kg/ha. Further increase in the level

Table 3: **Effect of phosphorous and zinc fertilisation on grain, straw , and biological yields, and harvest index of aromatic rice ('Pusa Basmati 1')**

Treatment	Grain yield (mg/ha)	Straw yield (mg/ha)	Biological yield (mg/ha)	Harvest index (%)
Phosphorous levels (kg P_2O_5 /ha)				
0	4.29	7.89	12.17	35.2
20	4.56	8.61	13.17	34.6
40	4.71	9.46	14.17	33.2
60	4.74	9.74	14.47	32.8
CD (P = 0.05)	0.09	0.08	0.09	0.53
Zinc levels (kg Zn/ha)				
0	4.29	8.06	12.35	34.8
2.5	4.52	8.70	13.22	34.2
5.0	4.70	9.21	13.91	33.8
7.5	4.79	9.72	14.51	33.0
CD (P = 0.05)	0.38	0.62	0.98	0.81

of zinc to 7.5 kg/ha did not exert any significant impact on either grain or biological yield. The favourable effect of a medium level of zinc (5.0 kg/ha) on most of the yield attributes over the control resulted in significant improvement in grain yield at this level. Rice responded significantly to zinc application in many other studies elsewhere in India as reported by Kumar et al. (2002). The highest grain and biological yields were recorded with 7.5 kg Zn/ha, but these were at par with 5.0 kg Zn/ha application.

Phosphorous application significantly influenced the P concentration and uptake in grain and straw, and total P uptake in the present study (Table 4). P concentration in grain increased progressively and significantly with each successive increase in its level, i.e., up to 60 kg P_2O_5/ha. However, there was no significant change in P concentration of straw beyond 40 kg of P_2O_5/ha. P uptake in grain, straw, and total (grain + straw) increased significantly ($P<0.5$) with each successive increase in P level, i.e., up to 60 kg of P_2O_5/ha. It is known that only a very small fraction of applied P is bioavailable for uptake by plants, the increasing P levels increased the bioavailabe P proportionately in the soil, which caused the increased P concentration and uptake in rice parts. The increase in P uptake caused by increasing its levels has been reported in other studies in India (Kumar et al. 2002; Rao and Shukla 1999). Contrary to P application, zinc application did not affect either P concentration or uptake in grain and straw.

The interaction effect of phosphorous and zinc on growth, yield attributes, grain yield, and P uptake of rice was found to be not significant in the present investigation. The optimum proportion of both these nutrients is required to realise higher plant growth and yield. Excess application of P fertiliser can induce zinc deficiency and increase plant requirements for Zn (Robson and Pitman 1983). But in the present study the moderate levels of P did not induce zinc deficiency in the crop and subsequently the interaction effect of zinc and phosphorous was not significant.

Table 4: Effect of phosphorous and zinc fertilisation on grain P concentration, straw P concentration, grain P uptake, straw P uptake, and total P uptake of aromatic rice ('Pusa Basmati 1')

Treatment	Grain P concentration (%)	Straw P concentration (%)	Grain P uptake (kg/ha)	Straw P uptake (kg/ha)	Total P uptake (kg/ha)
Phosphorous levels (kg P_2O_5 /ha)					
0	0.14	0.08	6.05	6.29	12.36
20	0.16	0.10	7.33	8.64	15.97
40	0.18	0.12	8.52	11.40	19.91
60	0.19	0.12	9.03	12.23	21.26
CD (P = 0.05)	0.005	0.013	0.16	0.12	0.17
Zinc levels (kg Zn/ha)					
0	0.17	0.11	7.25	8.84	16.09
2.5	0.17	0.11	7.64	9.51	17.15
5.0	0.17	0.10	7.95	9.86	17.81
7.5	0.16	0.10	8.09	10.35	18.46
CD (P = 0.05)	NS	NS	NS	NS	NS

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