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Studies on the nutritional requirements of a candidate rice genotype IR-6-25A evolved at NIA, Tando Jam

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Abstract

Field studies were conducted for two consecutive years to assess the nutritional requirements of newly evolved rice genotype IR-6-25A. The experiment comprising of seven fertilizer treatments with N applied at 90, 120 and 150 kg ha^{-1} and P_2O_5 at 60, 90 and 120 kg ha^{-1} with or without 25 kg ha^{-1} $ZnSO_4$ (36.4% Zn), was laid out according to RCB design with four replications. Paddy yield increased linearly with the increasing levels of N and P application. Zinc sulfate applied at 25 kg ha^{-1} provided an additional harvest of 14-35% over their respective N and P applications. A significant antagonism between P and Zn absorption in plant was observed. Zinc concentration and uptake were significantly reduced due to increased P application; the reverse was true for P concentration and uptake. Dilution of Zn within plants occurred by increasing levels of N application.

Key words: Rice, nitrogen, phosphorus, balanced fertilization, zinc

Introduction

Continuous cropping of high yielding crop varieties has caused rapid removal of essential nutrients from the soil which has resulted in poor soil fertility (Sadiq, 1992). Therefore, fertilizer today is the key input for increasing agricultural production and per unit area productivity. Fertilizer application practice in Pakistan is predominantly in favour of N only, which is further accentuating nutrient deficiencies particularly of P. Consequently, the yield potential of crops cannot be realized (Saleem *et al*., 1986). Balanced fertilization is one of the most important components of these technologies, which refers to the supply of plant nutrients not only in proper amounts but also in balanced proportions for improved efficiency of their utilization by crop plants.

Rice, *Oryza sativa*, is a principal food crop and grown exclusively in the tropical and subtropical regions. In the year 2003-04, total area under rice cultivation in Pakistan was 2.22 million hectares with a total production of 4.5 million tons with an average yield of 1994 kg ha^{-1} (Anonymous, 2005), which is far below than other rice producing countries. Imbalance fertilization of rice crop is one of the factors for lower yield.

Tremendous work has been done on nitrogen, phosphorous and potassium requirements of rice crop but very little work has been reported on Zn fertilization in Sindh province. The soils of Sindh like most parts of the country are alkaline in reaction where all micronutrients with the exception of Mo are feared to be less available. A large number of such soils have been recognized to be deficient in available Zn (Khattak and Khattak, 1990), which is the key factor for low yield of rice in the country. Whenever a plant breeder develops a new variety, it is essential to devise its production technology particularly with reference to the requirement of N and P as the nutritional demands of different cultivars of the same crop species always vary depending on their yield potential and agro-climatic conditions of the region.

The present studies were, therefore, undertaken to assess the nutritional requirements of a genotype IR-6-25A, which is a candidate variety of NIA, Tando Jam for obtaining maximum yield and economical returns.

Materials and Methods

Field studies were conducted during Kharif 2003 and 2004 at the Experimental Farm of the Nuclear Institute of Agriculture (NIA), Tando Jam to assess the nutritional requirements of a newly evolved candidate rice variety IR-6-25A of this institute. Pre-sowing soil samples up to 30 cm depth were collected and analyzed for various physico-chemical properties according to methods of Page *et al*. (1982). The experimental site was silty clay in texture; non-saline in nature (EC 0.66 dS m^{-1} in 1:2 soil water ratio), low in organic matter (0.72%), Kjeldahl N (0.04%), Olsen's P (6.2 mg kg^{-1}) and Zn (0.46 µg g^{-1}). The experiment comprising of seven fertilizer treatments with N applied at 90, 120 and 150 kg ha^{-1} and P_2O_5 at 60, 90 and 120 kg ha^{-1} with or without 25 kg $ZnSO_4$ was laid out according to randomized complete block design with four replications. Phosphorus in the form of Triple Super Phosphate and $ZnSO_4$ was applied at the time of transplanting according to the quantity required for each treatment. The required quantity of nitrogen in the form of urea was divided in two equal splits and applied half at transplanting and remaining half after twenty days of transplantation. Rice genotype

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"IR-6-25A" was transplanted at inter-row spacing of 20 cm. The requisite agronomic and plant protection measures were adopted uniformly for all the treatments during the growing period of crop. The plant samples were collected after harvesting the crop, dried in an oven at 70 °C to a constant weight for N and P determination. A uniform sub portion of the dried material was ground in Wiley's mill and required quantity of the material was digested by modified Kjeldahl method in which N is converted in NH_4^+ form by digestion with H_2SO_4. The NH_3 is distilled into boric acid and determined by titration with standard H_2SO_4 Jackson (1962). Total P and Zn were also determined by digesting the plant material in HNO_3. The digested material was analysed for total P by metavanadate yellow colour method as described by Jackson (1962) and for Zn on Atomic Absorption Spectrophotometer (NovAA 400). The results obtained were subjected to statistical analysis (Steel *et al*., 1997) using the computer software MSTATC. The differences among the treatment means were compared by using DMR test (Duncans, 1955).

Results and Discussion

Plant height

Plant height contributes significantly towards higher biological yield. Elements like N, P and Zn applied at different rates affected the plant height to a considerable extent. The stunted plants (66.8 cm) were observed in control plots while the tallest plant height (78.92 cm) was observed in the plots where 120 kg N, 90 kg P and 25 kg ha^{-1} $ZnSO_4$ was applied (Table 1). Acquisition of higher length by plants supplied with N and Zn may be attributed to growth promoting function of both N and Zn (Ali, 2005), which caused rapid cell division and auxin production (Mitra *et al*., 2005).

Number of tillers per plant

The data pertaining to tillering capacity of the crop applied with different rates of fertilizer have been presented in Table 1. It is obvious from the data that application of Zn increased the capability of the plant to produce more tillers. Although N and P application have positive impact on tillering, however, the effect of Zn application was more pronounced. The control plots have significantly lower number of tillers (16.5) while the highest number of tillers (30.8) was observed in treatments where $ZnSO_4$ was added at 25 kg ha^{-1} along with 120 kg N and 90 kg P ha^{-1}. Higher tillering production by Zn application determines its role in auxin production which in turn increased the tillers in plant (Lee *et al*., 2005).

1000 grain weight

The impact of fertilization on 1000 grain weight was quite positive as compared with control (Table 2). The lowest grain weight of 22.0 g recorded in control was improved significantly by the addition of P and Zn. The highest grain weight obtained from the treatment receiving 120 kg N, 90 kg P and 25 kg Zn SO_4 ha^{-1}, was significantly different from rest of the treatments. The similar results have also been reported by Hossain *et al*. (2005a) who suggested the N and P in appropriate proportion are vital for formation and development of grains.

Grains per panicle

The data regarding grains per panicle are presented in Table 2. The results showed that No. of grains per panicle increased significantly by the application of N, P and Zn. The lowest number of grains per panicle was recorded in control plots while the highest grains were recorded at higher doses of P along with Zn. Improved number of grains per panicle due to increasing P levels along with Zn indicates the effectivity of P (Alam *et al*., 2005) and Zn (Bouwman *et al*., 2005) for seed formation and grain filling.

Biological yield

The crop responded variably to different levels of N, P and Zn (Table 3). Generally yield increased with increasing N and P levels supplemented with 25 kg Zn ha^{-1}. The highest biological yield of 12.62 t ha^{-1} obtained with 120 kg N, 90 kg P and 25 kg Zn was statistically similar with that obtained at 150 kg N, 120 kg P and 25 kg Zn ha^{-1} but different from rest of the treatments. Although N and Zn played their striking role of increasing vegetative growth and grain weight, however, the higher P level (120 kg ha^{-1}) might has antagonized the Zn activities which restricted further plant growth (Awan and Baloch, 2005).

Paddy yield

Response of N, P and Zn fertilization to that of biological harvest, was also recorded for paddy yield (Table 3). Higher paddy yield was recorded at 120 kg N, 90 kg P (4:3 ratios supplemental with 25 kg Zn ha^{-1}) with maximum and significantly different harvest of 4.02 t ha^{-1}.

The yield trend clearly indicates that application of Zn is imperative for maximum harvest of paddy along with balanced N and P fertilization. Since IR-6-25A, the test cultivar produced maximum yield at 120 kg N, 90 kg P and 25 kg $ZnSO_4$, and this fertilizer treatment was enough to satisfy the crop nutrient requirements (Villar-Mir *et al*., 2002; Katyal *et al.*, 2004) hence, it may be considered as a balance and economical dose for the said genotype.

Table 1. Effect of N, P and Zn on Plant height and Tillering capacity of Rice cv. IR -6-25A

Treatment	Plant height (cm)		Mean	No. of Tillers plant^{-1}		Mean
	2003	2004		2003	2004	
Control	65.90 d*	67.70 c	66.80	15.50 d	17.40 b	16.50
90-60-0	70.10 c	70.50 b	70.28	20.40 c	22.60 ab	21.50
90-60-25	75.60 b	71.50 b	71.03	25.40 b	23.60 ab	24.50
120-90-0	73.80 b	71.10 b	72.45	23.10 bc	21.80 ab	22.50
120-90-25	81.40 a	76.50 a	78.92	34.40 a	27.20 a	30.80
150-120-0	73.80 b	75.50 a	74.63	21.30 bc	20.50 ab	20.90
150-120-25	80.00 a	75.70 a	77.88	32.20 a	23.40 ab	27.80

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

Table 2. Effect of N, P and Zn on 1000 grain and No. of grains / Panicle of Rice cv. IR -6-25A

Treatment	1000 grain weight (g)		Mean	No. of grain Panicle^{-1}		Mean
	2003	2004		2003	2004	
Control	21.60 NS	22.40 d*	22.00	87 c	93 d	90
90-60-0	22.40	23.60 c	22.90	95 c	100 cd	98
90-60-25	22.90	24.20 abc	23.60	112 ab	113 bc	113
120-90-0	22.20	23.80 bc	23.00	97 bc	126 ab	112
120-90-25	23.30	25.00 a	24.20	128 a	138 a	133
150-120-0	22.40	23.80 bc	23.10	96 bc	114 bc	105
150-120-25	23.20	24.50 ab	23.80	115 a	122 ab	119

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance
NS = Non-significant

Table 3. Effect of N, P and Zn on Dry matter and paddy yield of Rice cv. IR -6-25A

Treatment	Dry matter Yield tons ha^{-1}		Mean	Paddy Yield tons ha^{-1}		Mean
	2003	2004		2003	2004	
Control	07.20 d*	08.96 d	08.08	1.31 d	2.81 e	2.06
90-60-0	08.37 c	12.29 c	10.33	2.14 c	3.44 d	2.79
90-60-25	09.81 ab	13.02 ab	11.42	2.88 b	3.96 b	3.42
120-90-0	09.11 bc	12.71 bc	10.91	2.77 b	3.85 bc	3.31
120-90-25	10.77 a	14.48 a	12.62	3.65 a	4.38 a	4.02
150-120-0	09.69 b	13.33 ab	11.51	2.66 b	3.65 cd	3.16
150-120-25	10.77 a	14.27 a	12.52	3.45 a	3.96 b	3.71

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

Nitrogen, phosphorus and zinc concentrations

The data regarding N, P and Zn concentrations have been presented in Table 4. The concentrations of N within rice grain and straw varied according to the amount of N applied in the soil. The maximum N concentrations in grain and straw were 1.59 and 0.76%, respectively when the crop was treated with 150 kg N ha^{-1}. The lowest N concentration of 0.95% in grain and 0.46% in straw were however, recorded in control treatment.

Phosphorus concentrations (Table 5) in the plant also varied according to the quantity of P applied in the soil. The plants managed to absorb more P in grain (0.23%) and straw (0.05%) at 120 kg P_2O_5 ha^{-1} as compared to other phosphorus application rates. The absorption of these nutrients at maximum by application of N and P relates to their higher availability to plants in such treatments (Hossain *et al*., 2005b). Zinc concentration in these plants varied with the application of Zn and P in the soil. Application of Zn increased the Zn concentration within plant and application of P reduced its quantity. The data have been presented in Table 6. Maximum Zn concentration in grain (24.88 µg g^{-1}) and straw (10.66 µg g^{-1}) was recorded in the treatment where 120 kg N, 90 kg P along with 25 kg Zn ha^{-1} was applied. The control has lowest Zn concentration.

Table 4. Effect of N, P and Zn on N concentration (%) in Rice cv. IR -6-25A

Treatment	Grain		Mean	Straw		Mean
	2003	2004		2003	2004	
Control	1.12 e*	0.77 d	0.95	0.48 c	0.45 d	0.46
90-60-0	1.50 cd	1.08 c	1.29	0.56 b	0.53 c	0.55
90-60-25	1.42 d	1.10 c	1.26	0.53 bc	0.54 c	0.54
120-90-0	1.66 b	1.28 b	1.47	0.59 b	0.61 b	0.60
120-90-25	1.58 bc	1.30 b	1.44	0.58 b	0.62 b	0.60
150-120-0	1.81 a	1.36 ab	1.58	0.73 a	0.77 a	0.75
150-120-25	1.74 ab	1.44 a	1.59	0.76 a	0.76 a	0.76

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

Table 5. Effect of N, P and Zn on P concentration (%) in Rice cv. IR -6-25A

Treatment	Grain		Mean	Straw		Mean
	2003	2004		2003	2004	
Control	0.166 f*	0.166 d	0.171	0.026 f	0.025 c	0.026
90-60-0	0.192 d	0.203 bc	0.201	0.046 d	0.043 b	0.045
90-60-25	0.185 e	0.191 c	0.191	0.036 e	0.040 b	0.040
120-90-0	0.217 b	0.207 ab	0.211	0.061 b	0.060 a	0.061
120-90-25	0.204 c	0.203 bc	0.201	0.051 bc	0.055 ab	0.053
150-120-0	0.238 a	0.222 a	0.230	0.054 a	0.054 ab	0.049
150-120-25	0.216 b	0.209 ab	0.210	0.050 c	0.051 ab	0.055

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

Table 6. Effect of N, P and Zn on Zn concentration (μg g^{-1}) in Rice cv. IR -6-25A

Treatment	Grain		Mean	Straw		Mean
	2003	2004		2003	2004	
Control	13.30 c*	9.44 c	11.37	7.66 bc	5.22 c	6.44
90-60-0	15.70 c	10.81 c	13.26	8.34 b	4.87 c	6.61
90-60-25	39.80 a	24.52 a	32.16	13.49 a	9.29 a	11.39
120-90-0	15.10 c	10.53 c	12.82	6.48 bc	5.52 c	6.00
120-90-25	28.50 b	21.25 b	24.88	12.50 a	8.81 a	10.66
150-120-0	14.40 c	09.95 c	12.18	6.95 bc	5.72 c	6.34
150-120-25	24.20 b	21.69 b	22.95	12.05 a	7.12 b	9.59

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

Nitrogen, phosphorus and zinc uptake

The uptake of nutrients was significantly affected by their respective fertilizer application rates (Table 7, 8). Nitrogen uptake by rice was escalated from 46.1 to 125.1 kg ha^{-1} when N application rate was increased from 0 to 150 kg ha^{-1}. Successive increments in P fertilization at each N dose significantly improved the efficiency of N usage, which reflects strong synergism between both elements. Phosphorus harvests also increased linearly with the corresponding increase in P application rates. The highest P uptake of 12.3 kg ha^{-1} was recorded with 120 kg P_2O_5 ha^{-1} and the lowest (4.9 kg ha^{-1}) in the control treatment. Similarly, maximum Zn uptake (191.5 g ha^{-1}) was recorded in the treatment where Zn was supplemented with N (120 kg) and P (90 kg ha^{-1}).

Conclusions

The genotype (IR -6-25A) performed efficiently with increasing N and P_2O_5 levels and their ratios. The maximum yield was produced by 120 kg N, 90 kg P_2O_5 and 25 kg $ZnSO_4$ ha^{-1} hence, it can be considered as the most economical dose for this genotype when grown on medium textured soil.

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Table 7. Effect of N, P and Zn on N and P uptake (kg ha^{-1}) in Rice cv. IR -6-25A

Treatment	N uptake		Mean	P uptake		Mean
	2003	2004		2003	2004	
Control	42.74 e*	49.39 e	46.11	3.71 d	6.18 d	4.95
90-60-0	67.00 d	84.03 d	75.51	6.97 c	10.74 c	8.90
90-60-25	77.58 c	92.11 cd	84.85	7.78 c	11.72 bc	9.80
120-90-0	83.23 b	103.27 c	93.30	9.88 b	13.26 b	11.60
120-90-25	99.08 ab	118.85 b	108.97	11.39 a	14.37 a	12.90
150-120-0	101.09 a	122.90 b	112.00	10.12 ab	13.82 ab	12.00
150-120-25	113.10 a	137.18 a	125.14	11.11 a	13.56 ab	12.34

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

Table 8. Effect of N, P and Zn on Zn uptake of Rice cv. IR -6-25A

Treatment	Zn uptake (g ha^{-1})		Mean
	2003	2004	
Control	62.0 c*	58.6 d	60.3
90-60-0	86.0 b	80.4 c	83.2
90-60-25	189.0 a	182.1 a	185.5
120-90-0	88.0 b	89.3 c	88.6
120-90-25	199.0 a	184.0 a	191.5
150-120-0	87.0 b	89.4 c	88.2
150-120-25	171.0 a	162.1 b	166.5

*Means followed by different letters in the same column are significantly different from each other at 5% level of significance

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