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Research Article

Response of Basmati rice (*Oryza sativa* L.) yield to time of application of phosphorus in combination with zinc under anaerobic

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Abstract

To study the effect of different application timings of phosphorus (P) in combination with zinc (Zn) and phosphorus alone on rice. Indica rice cv. Super Basmati was assigned in randomized complete block design with four replications. The experimentaltreatments included were: T1 Phosphorus application at the time of last puddling,T_2: phosphorus application just before transplanting, T_3: phosphorus application 10 days after transplanting (DAT), T_4 phosphorus application 20 DAT, T_5P+Zn application at the time of last puddling, T_6P+Zn application just before transplanting,T_7P+Zn application 10 DAT and T_8 P+Zn application 20 DAT. It was observed that number of grains per panicle, number of branches per panicle, productive tillers, plant height, panicle length, 1000-grain weight and paddy yield were significantly affected by different phosphorus application timings alone and in combination with zinc. Among different timing of P+Zn application, maximum yield and yield components were attained by P+Zn application at the time of last puddling while minimum were observed in phosphorus application 20 DAT.It is concluded that under anaerobic conditions, P+Zn application at the time of last puddling can produce maximum yield. Therefore, it is suggested to use P in combination with Zn at the time of last puddling.

Keywords: Rice, P+Zn application, time of application, yield and yield contributing parameters

Introduction

Rice (*Oryza sativa* L.) is the second largest staple food crop after wheat in Pakistan and is also a major source of export earnings (Nadeem et al., 2013). It adds for 4.4 percent of value added in agriculture and 0.9 percent in GDP. Pakistan grows high quality aromatic rice to meet both local market demand and exports. Area cultivation under rice crop is estimated as 2.365 million hectares, with the total production of 4.823 million tons, giving an average yield of 2365 kg ha^{-1} (Govt. of Pakistan, 2010). To meet the increased requirement of food grain for rapidly increasing population, it is needed to have higher yield per unit area production of rice, which is currently attained through use of high-yielding varieties and greater fertilizer inputs. Method, dose and time of application of fertilizers are vital for securing higher yields (Oh *et al*., 1990; Sahoo*et al*., 1990; Irshad, 1996).

Among other macro nutrients phosphorus (P) is an essential element for vegetative growth and development. It plays basic role in metabolic and energy producing reactions in plants. It is a vital part of nucleic acids and is necessary for cellular respiration and in the metabolism of the starch, protein and fats. Application of P stimulates blooming and seed formation of maize. Proper amount and timely application of P will help in enhancing yield per unit area (Demkin and Ageev, 1990). It plays major physiological role in the accumulation and release of energy during cellular metabolisms (Khalil *et al*., 2002;Nadeem et al., 2013). The agronomic practices that influence the efficiency of applied fertilizer, time and method of application are of significant importance. There is need site specific as well as crop specific P fertilizer recommendations on scientific basis (Ahmed *et al.*, 1992). Factors affecting the P availability to plants include; soil texture, soil pH, the amount of P applied in the presence of other elements like zinc (Zn), Fe, Al,Mn and Ca in the soil, microbial activity and the timely application of P fertilizers (Yash*et al*., 1992).

Increased application of macronutrients alone is not sufficient to compensate over-use of cultivated land. High-yielding varieties rapidly depleted soil micronutrients, therefore recent literature highlighted deficiency of Zn in agricultural lands in general and paddy soils in particular (Doberman and Fairhurst, 2000). Deficiency of micronutrient is considered as a major risk to the food security (Ezzati et al., 2002; Nadeem et al., 2013).

Deficiency of Zn deficiency is common in lowland conditions due to reducing environment that develop following; submergence, which results in unavailability ofZn after reacting with iron compounds and other meta-stable compounds formed in reducing reactions. In flooded rice growing conditions deficiency of Zn causes multiple symptoms in plants that commonly show 14-28 days after transplantation (DAT) of paddy crop seedlings. Leaves of rice crop shows brown spots and streaks that may fuse to cover completely older leaves of plant, crop remains stunted in this deficiency and in severe conditions may causes death of plant, while those that plants recover shows a delays in crop maturity and reduce yield (Yoshida and Tanaka, 1969; Neue and Lantin, 1994; Van Breemen and Castro, 1980). This phenomenon was subsequently found to be a most widespread in flooded growing conditions of rice areas of Asia, after nitrogen (N) and P deficiency, Zn deficiency is now considered the most widespread and essential nutrient disorder in flooded rice (Neue and Lantin, 1994; Quijano-Guerta*et al*., 2002).

Most of the applied P becomes unavailable to growing plants due to alkaline and calcareous nature of the soils of Pakistan. The low availability of P is caused by its fixation. The efficient use of P-fertilizers depends on the crop requirements, rate and time of application and placement methods. Zn deficiency is common in calcareous soils where high pH reduces Znavailability. After absorption, P interacts in a complex manner with Zn, Mn, Fe and Cu affecting their mobility and translocation in the plant system (Warnock, 1970).

It is concluded that the application of phosphorus before active tillering gave good results but yield of rice enhance up to 10 percent by appropriate timing ofPapplication. Early timing of Zn application gave good results than later application. Application of P-fertilizer caused a progressive decrease in Zn concentration in root and shoot. Thus, the present study was planned with an idea of exploring the interactive effect of P in combination with Zn on rice yield at different timings and P alone at different timing before tillering to find out appropriate application timing.

Materials and Methods

A field experiment was conducted to study theresponse of fine rice (*Oryza sativa* L.), var.“Super Basmati”, to time of P application alone and in combination with Zn under anaerobic conditions, at Adaptive Research Farm, Gujranwala, Pakistan during Kharif season of 2010.The experiment was laid out in randomized complete block design along with four replications. The net plot size was kept3m×5m. Rice seedlings (35-days old) were manually transplanted on a well puddle field at hill to hill spacing of 22.5cm using two seedlings per hill.

The experiment was comprised of following treatments.

T_1: P application at the time of last puddling. P -DAT
T_2: P application just before transplanting. P 0 DAT
T_3: P application 10 days after transplanting. P 10 DAT
T_4: P application 20 days after transplanting. P 20 DAT
T_5: P + Zn application at the time of last puddling. PZ Puddling
T_6: P + Zn application just before transplanting. PZ 0 DAT

T_7: P + Zn application 10 days after transplanting.PZ 10 DAT

T_8: P + Zn application 20 days after transplanting.PZ 20 DAT

Crop husbandry

Paddy field was prepared by one deep ploughing with disc plough followed by two rounds each of cultivation and planking.Seeds were placed between the two layers of saturated jute bags up-to just appearance of radicles for about 48 hours (Basra *et al*., 2003). Recommended dose of NK (150-60 kg ha^{-1}) fertilizers were applied in the form of Urea and Potassium Sulphate. All K_2O and 50% of N were applied before at the time of last puddling,while the rest 50% N was top dressed at panicle initiation stage.

The crop was irrigated at continuous intervals according to need of crop. Irrigation was stopped about two weeks before harvesting of crop when the signs of physiological maturity appeared. The crop was grown at a weeds free site and weeds which emerged during crop growth and development were manually pulled from whole of the experimental area. All other agronomic operations were kept normal and uniform for all the treatments. Harvesting was done manually when panicles were ripened fully and threshing of each treatment was done separately.

At maturity, number of tillers was counted from an area of one m^2 from three different spots in each plot, averages values for each treatment and replications were used for analysis.Tillers which had mature panicle were counted from an area of one m^2 from three different spots in each experimental plot. The average number of tillers per m^2 was counted out thereafter. Panicle length of twenty randomly selected plants was measured with the help of a meter tape in each plot and then averaged. Ten panicles of primary tillers were randomly selected from each treated plot at harvest and saved in paper bags. Grains were separated from each panicle and count then average was calculated. Data regarding 1000-grains weight (TGW) of each plot was recorded in grams using an automatic electric balance. After harvesting and threshing, the clean rough rice of each plot was air-dried and weighed to record the grain yield. The grains weight was adjusted to 14% grain moisture content and expressed in t ha^{-1} by using the following formula:

Grain yield (t ha^{-1}) = Plot yield (kg) x 10000/ Plot size (m^2) x 1000

After manual threshing, biologicalweight from each plot was recorded after sun drying by using digital balance. The yield was expressed in t ha^{-1} by the same formula used for calculatinggrain yield. Harvest index is the ratio of grain yield to the total biological yield expressed in percentage. It was calculated as under

$$\text{Harvest Index (HI)} = \frac{\text{Grain yeild}}{\text{Biological yeild}} \times 100$$

Those grains which were unfilled and unfertilized were separated from each panicle and then average was calculated (Nagato and Chaudhry, 1969; Yan et al., 2010).

Sterility percentage =Sterile spikelets/ Total No. of spikelets x 100

The collected data were analyzed statistically using Fisher's analysis of variance technique and treatment means were compared by Least Significant Difference (LSD) test at 5% probability level (Steel *et al*., 1997). The data were analyzed by the "MSTAT-C" statistical package on a computer (Freed and Eisensmith, 1986).

Results and Discussion

Plant height at maturity (cm)

Plant height is an important morphological trait of combined effects of genetic make up of a plant, soil nutrient status, seedling vigor and the environmental conditions under which the plant is grown. Data regarding plant height of fine rice as affected by different time of application in combination with Zn are presented in Table 1. It is clear from the table that there was significant difference in plant height of rice at maturity. Maximum plant height (102.25 cm) was measured in P + Zn application at the time of last puddling and it was at par with P + Zn application just before transplanting (101.90 cm) and P + Zn application 10 days after transplanting (100.02 cm) . The minimum plant height (92.23cm) was observed where P was applied 20 days after transplanting followed by P application 10 days after transplanting (94.55). Height of rice plant decreased as time of P application was delayed.

The results showed that Zn along with P fertilizer increased the height of rice plants over only P application, which could be attributed to the improved enzymatic activity and auxin metabolism in plants by Zn. These results are in agreement with those reported by Yoshida (1968) and Ghobrial (1979) who found taller plants of rice with Zn application. Similar results were also reported by Yaseen *et al*. (l999).

Number of tillers

Number of tillers shows the extent of plant population. It is the direct index of seedling establishment. Data regarding number of tillers/m^2 of rice as affected by different time of P application in combination with Zn are presented in Table 1. Perusal of the table indicated that more number of tillers of rice (372.86) was counted in P + Zn application at the time of last puddling and at par with P + Zn application just before transplanting that have (365.13) tillers/m^2. The minimum tillers count (322.35) was observed in P application 20 days after transplanting followed by P application 10 days after transplanting produced (333.13) tillers and closely followed by P + Zn application 20 days after transplanting (333.58).In general total tiller per m^2 decreased as time of P + Zn application delayed.

Application of Zn resulted in increased number of tillers per m^2. The results showed that application of Zn along with P (T_5,T_6,T_7 and T_8) resulted in more number of tillers/m^2as compared to sole application of P at various times (T_1,T_2,T_3 and T_4), Ghani *et al*. (1990), Hung *et al*. (1990), Maqsood *et al*. (1999) and Yaseen *et al*. (1999) reported almost similar results.

Number of panicle bearing tillers per m^2

Number of panicle bearing tillers per m^2 contributes towards the production potential of paddy crop. More the number of panicle bearing tillers more yield will be the yield increased and vice versa. Data regarding the number of panicle bearing tillers/m^2 of rice crop are given in Table 1. It is clear from the table that number of panicle bearing tillers per m^2 was significantly affected by different time of P application in combination with Zn. Maximum panicle bearing tillers (339.36) were recorded in P + Zn application at the time of last puddling followed by P +Zn application just before transplanting (325.88). While the lowest number of productive tiller (263.85) was observed in T_4 (P application 20 days after transplanting) followed by combine effect of P + Zn application 20 days after transplanting (280.33) and it at par with P application given 10 days after transplanting (285.38). It was further observed that time delayed number of panicle bearing tillers decreased which may be due to root development for absorption of other nutrient necessary for plant growth. Application of Zn along with P showed same trend also (Hung *et al*., 1990).

Number of non-productive tillers per m^2

The number of tillers lack of panicles is a yield reducing parameter in crop. Non-productive tillers are produced due to lack of essential plant nutrient at proper timing, environmental stress and inter plant competition. It is evident from the data shown in (Table 1) that the number of non-productive tillers per m^2 was affected by different application timing of P in combination with Zn. Minimum number of tillers without panicles (33.50) was recorded in P + Zn application at the time of last puddling followed by P + Zn application just before transplanting (39.25) and was at par with P application at the time of last puddling (41.50). More number of non-productive tillers (58.50) was recorded in P application 20 days after transplanting followed by P + Zn application 20 days after transplanting (53.25). Results also showed that number of non-productive tillers increased as time of application of P or Zn delayed. Combined application of Zn with P has lower non-productive tillers as compared to sole application of P which may be due to plant health. It is also evident from the table that application of Zn along with P decreased the value of non-productivetillers significantly over application of P only which might be due to adequate supply of Zn that increases the availability and uptake of other essential nutrient resulting improved metabolic activities of rice plants. Similar trends were found in the findings of Jalil *et al*.(1990).

Panicle length (cm)

Panicle length is an important yield contributing factor. More panicle length more will be the more number of branches ultimately grains per panicle increase. Data regarding panicle length as affected by different application timing of P in combination with Zn are given in Table 1 which indicates that panicle

Table.1 Effect of different parameters on growth of plants

Treatment	**Fertilizer P-Zn**	**Plant Height**	**Total tillers**	**Prod. Tillers**	**Non-productive tillers**	**Panicle length**	**Grains panicle^{-1}**	**Spikelet Fertility**	**TGW***	**Biol. Yield**	**Grain Yield**	**Harvest Index**
		(cm)				**(cm)**		**(%)**	**(g)**	**(t ha^{-1})**	**(t ha^{-1})**	
T_1**	P (Last Puddling)	97.35 c***	350.31 c	308.81 c	41.50 de	24.30 c	86.108 cd	93.57 ab	16.79 b	10.57 cde	3.51 c	33.29 b
T_2	P (0 DAT)	96.92 c	341.61 d	296.36 d	45.25 cd	23.97 c	85.328 cd	93.21 bc	16.67 b	11.81 ab	3.35 cd	28.36 cd
T_3	P (10 DAT)	94.55 d	333.13 e	285.38 e	47.75 c	22.78 d	83.565 de	93.98 a	15.10 cd	11.24 bc	3.08 de	27.42 d
T_4	P (20 DAT)	92.23 e	322.35 f	263.85 f	58.50 a	20.67 e	80.325 e	92.79 cd	14.37 d	9.83 e	2.96 e	30.19 c
T_5	P+Zn (last Puddling)	102.25 a	372.86 a	339.36 a	33.50 f	27.06 a	97.830 a	92.45 d	18.76 a	12.16 a	4.38 a	36.00 a
T_6	P+Zn (0 DAT)	101.90 ab	365.13 b	325.88 b	39.25 e	26.00 ab	92.718 b	93.85 a	18.12 a	11.84 ab	3.90 b	32.91b
T_7	P+Zn (10 DAT)	100.05 b	355.29 c	310.04 c	45.25 cd	25.74 b	88.735 c	91.80 e	16.67 b	9.99 de	3.52 c	35.26 ab
T_8	P+Zn (20 DAT)	97.42 c	333.58 e	280.33 e	53.25 b	23.63 cd	81.325 e	93.55 ab	16.20 bc	10.71 cd	3.18 de	29.70 cd
LSD Value		2.18	7.28	7.8	4.74	1.177	3.7179	4.55	1.29	0.78	0.3247	2.63

length was significantly affected by various application timings. Among application timings, maximum panicle length (27.06 cm) was recorded in P + Zn application at the time of last puddling and was at par with P + Zn application just before transplanting that produced 26.00 cm panicle length and P + Zn application 10 days after transplanting (25.74 cm). Minimum panicle length (20.67cm) was observed in P application 20 days after transplanting and followed by P application 10 days after transplanting showing panicle length 22.78 cm. The increase in panicle length by application timings might beattributed to adequate supply of soil nutrients that are essential for growth and increased the uptake and availability of other nutrients and there by resulting in improvement of plant metabolic process, improving crop growth and ultimately more panicle length was occurred (Yan *et al*., 2010).

Number of grains per panicle

Total grain number per panicle contributes towards the final grain yield of rice. Data regarding the number of grains per panicle as affected by various fertilizer application timings are presented in Table 1. Table revealed that number of grains per panicle was significantly affected by fertilizer application timings. Application of P either alone or in combination with Zn produced significantly more number of grains per panicle as compared to late application. Among application timings, the highest number of grains (97.83)per panicle was recorded in P + Zn application at the time of last puddling and was followed by P + Zn application just before transplanting which exhibited 92.72 numbers of grains per panicle. Minimum number of grains (80.33) per panicle was recorded in P application 20 days after transplanting and it was at par with P + Zn application 20 days after transplanting (81.33). It was further observed that early application of P had good impact on yield component of rice than late one.

Increase in the number of grains per panicle due to Zn fertilizer might be its effect on growth and enhancing the physiological functions of the crop, such as photosynthesis and transportation of plant nutrients that led to more number of grainsper panicle. Similar results were reported by Lonov and Lonova (1977) who conducted trials on rice and noted that Zn application increased tillering, plant growth, panicle length, number of grainsper panicle, 1000-grain weight and paddy yield. The results are also supported by the findings of Hung *et al*. (1990) and Maqsood *et al*. (1999).

1000-grain weight (g)

Grain size is one of the important yield contributing factors, especially in cereals, and is expressed as 1000-grain weight (TGW). Usually paddy with bold grains results in higher grain yields. Data regarding TGW of rice as affected by P application time in combination with Zn are presented in Table 1. It is clear from the Table that TGW varied significantly by P application timing in combination with Zn. Maximum 1000-grain was recorded in P + Zn application at the time of last puddling (18.76 g) which was statistically similar to P + Zn application just before transplanting showing the TGW of 18.12g. On the other hand the lowest TGW (14.37 g) was observed in P application 20 days after transplanting was and it was at par with P application 10 days after transplanting (15.10 g). Application of P near sowing time resulted in better TGW than late application to rice crop.

The comparative increase in TGW with the application of Zn might be due to more efficient participation of this trace element in various metabolic processes for the production of healthy seeds. Many research workers have reported about the improvement in TGW of rice by the application of Zn. Ghani *et al*. (1990) and Maqsood *et al*. (1999) observed that the application of NPK along with other micronutrients like Zn increased TGW sharply over control.

4.1.8 Biological yield (t ha^{-1})

Biological yield indicates the vegetative growth behavior of the crop. Data regarding biological yield of rice as affected by P application timing are presented in Table 1. The perusal of Table indicated significant effects of application timing on biological yield of rice. Application of P with Zn application at the time of last puddling produced the highest tonnage of biological yield (12.16 t ha^{-1})and it was at par with P + Zn application just before transplanting that produced biological yield of 11.84 t ha^{-1}. Minimum biological yield of 9.83 t ha^{-1} was recorded in P application 20 days after transplanting it was followed by9.99 t ha^{-1} P + Zn application 10 days after transplanting. Delayed application of P resulted decreased in biological yield. Application of P, either alone or in combination with Zn, increased the biological yield of rice in early application than delay one which may be due to non-availability of these nutrients to rice crop at early growth stages

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Results further showed that application of Zn with P (T_4, T_5, T_7 and T_8) increased the biological yield over the only application of P (T_1, T_2, T_3 and T_4), which might have been due in the effect of Zn on the proliferation of roots thereby increasing the plant uptake of nutrients from the soil, supplying it to the aerial parts of the plant and ultimately enhancing the vegetative growth as shown in the Table 1. These results are in agreement with those reported by Sinha and Sakal (1983) and Nadeem et al. (2013) who observed maximum increase in total dry matter yield with the application of Zn. Mehdi *et al*. (1990) also recorded similar results.

Grain yield (t ha^{-1})

The final grain yield is a function of combine effects of different yield components developed under the certain set of environmental conditions. Data concerning grain yield of rice as affected by P application in combination with Zn are presented in Table 1. It is clear from the Table that grain yield was significantly affected by different time of P application in combination with Zn. The highest grain yield (4.38 t ha^{-1}) was recorded in P + Zn application at the time of last puddling followed by 3.90 t ha^{-1} for P + Zn application just before transplanting. Minimum grain yield (2.96 t ha^{-1}) was observed in P application 20 days after transplanting which was at par with P + Zn application 20 days after transplanting (3.18 t ha^{-1}) and P application 10 days after transplanting (3.08 t ha^{-1}). Yield decreased as the time of application of P delayed. Similar results were reported by Slaton *et al*. (2002).

Increase in yield by the addition of Zn along with P application over P applied alone might be attributed to the combined effect of many yield components like number of tillers, number of grains per panicle, 1000-grain weight (Table 1) etc. which was affected significantly by the application of Zn shown in Table. Similar results were reported by Shamim*et al*. (l991), Kumar *et al*. (1996), Nadeem et al. (2013) and Savithri *et al*. (1999) who observed that application of Zn to rice significantly affected all the yield components like number of tillers m^{-2}, 1000 grain yield, paddy and straw yield etc.

Harvest index (%)

Harvest index (HI) is an important parameter which reflects the physiological efficiency of a plant to convert total dry matter into economic yield. Higher the harvest index more will be the productive efficiency of a crop or vice versa. Data regarding harvest index value of rice crop are presented in Table 1. It is evident from the Table that harvest index was significantly affected by the different time of P application in combination with Zn. Among the fertilizer application timings, maximum harvest index value (36.00 %) was recorded in P + Zn application at the time of last puddling which was at par with P + Zn application 10 days after transplanting having a harvest index of 35.26 %. On the other hand minimum harvest index value (27.42 %) was measured in P application 10 days after transplanting which was statistically similar with P application just before transplanting and P application 20 days after transplanting showing harvest index (HI) value of 28.36 % and 29.70%, respectively. The results led to the conclusion that application of Zn along with P showed high harvest index over P application alone. This may be due to balance fertilization (Yan *et al*., 2010).

Conclusion

It is concluded that among different timing of P + Zn application in anaerobic rice, maximum production of yield and yield components was attained by P + Zn application at the time of last puddling. Therefore, it is suggested that P +Zn application in anaerobic rice should be applied at the time of last puddling.

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