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Growth, yield and economics of rice (*Oryza sativa*) as influenced by level and time of silicon application

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 1999 and 2000 at Research Farm, Department of Agronomy, Banaras Hindu Univeristy, Varansi, Uttar Pradesh, to study the effect of level and time of silicon application on growth, yield and economics of rice (*Oryza sativa* L.). Different silicon levels led to significant increase in plant height, dry-matter production, panicles/m², filled grains/panicle, test weight and yield of rice. The maximum grain yield (6,588 kg/ha) was recorded with highest level of silicon, i.e. 180 kg Si/ha. However, the maximum response was observed at 127 kg Si/ha and thereafter decreased with increase in silicon level. Highest net returns and benefit : cost ratio were recorded when silicon was applied @ 120 kg Si/ha full as basal. The apparent silicon recovery and agronomic efficiency were higher at the lowest silicon level (60 kg Si/ha) and decreased with increasing silicon levels. However, the highest nitrogen, phosphorus, potassium and silicon uptake was associated with 180 kg Si/ha. Among the application time, full basal application of silicon at the time of transplanting significantly increased the growth, yield attributes, yield and uptake of nutrients compared with the other time of silicon application.

Key words: Silicon level, Application time, Nutrients uptake, Apparent silicon recovery, Agronomic efficiency, Rice

Silicon application has been in practice as a component of balanced integrated nutrient management for sustained rice productivity. Rice is a known silicon accumulator and it was estimated that a rice crop giving 5 tonnes/ha grain yields removed on an average 230–270 kg Si/ha from soil (Nayer *et al.*, 1982). Due to synergistic effect silicon application has the potential to raise the optimum nitrogen rate leading to enhanced rice productivity. Fertilization with N tended to make rice leaves droopy, whereas silicon kept them erect which could easily account for a 10% increase in photosynthesis with similar increase in yield. Similarly, phosphatic fertilizer-use efficiency increased from 26 to 34% when it was applied along with silicon fertilizer, as its application reduced P-retention capacity of soils leading to increased water-soluble P level. Silicon application increased rice yield response to applied potassium. Silicon application to soil increased soil pH due to an excess of anions over cations in the rhizosphere and decreased the availability of toxic elements, i.e. aluminium, iron, manganese and calcium etc. (Hodson and Evanse, 1995). The present investigation was therefore undertaken to study the effect of level and time of silicon application on growth, yield and economics of rice.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) season of 1999 and 2000 at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The soil was Gangetic alluvial (typic ustochrept) having pH 7.3. It was moderately fertile, being low in organic carbon (0.39%), available N (185.02 kg N/ha) and medium in available P (19.75 kg P/ha) and K (208.6 kg K/ha). The soil had 301.2 kg Si/ha. Treatments comprised 3 silicon levels (60, 120 and 180 kg Si/ha) and 5 application timings (full basal, 50% basal + 50% at tillering stage, 50% basal + 50% at panicle-initiation stage, 25% basal + 50% tillering + 25% at panicle-initiation stages and 0 basal + 50%, tillering + 50% panicle-initiation stages) including the control. Thus, 16 treatments were laid out in randomized block design during the rainy season with 3 replications. Seedlings of 25 days age of 'MTU 7209' ('Swarna') rice were transplanted, keeping 2–3 seedlings hill on 16 and 17 July of 1999 and 2000, respectively, under puddled conditions. Nutrients were applied @ 120, 60, 60 kg/ha N, P_2O_5 and K_2O to rice through urea, diammonium phosphate and muriate of potash respectively. Silicon was applied as per treatment through calcium silicate. The silicon content in plant sample was determined by autoclave induced digestion for colorimetric determination (Elliot and Snyder, 1991).

RESULTS AND DISCUSSION

Silicon level

The silicon level significantly influenced the plant height, and it increased with each increment of silicon level and the tallest plant was observed with 180 kg Si/ha. Increase in plant height might be owing to increased cell-division, elongation and expansion caused by silicon nutrition. Maximum dry matter was accumulated with 180 kg Si/ha which was significantly superior to 60 kg Si/ha and the control but remained at par to 120 kg Si/ha. Silicon fertilization might improve the efficient utilization of light and translocation of assimilated product to sink which ultimately resulted in higher dry-matter accumulation. Similar results were also reported by Rani *et al.* (1997). All the yield-contributing characters, viz. panicles/m^2, filled grains/panicle and test weight (Table 1), significantly increased with increasing silicon level up to 120 kg Si/ha over 60 kg Si/ha and the control. However, 120 kg and 180 kg Si/ha remained statistically at par between themselves in respect of yield traits. The panicle formation is directly related with number of productive tillers which ultimately resulted in production of higher number of panicles. Increase in filled grains/panicle was owing to better assimilation of carbohydrates in panicle. Test weight of grain increased with increasing silicon levels and was attributed to better availability and translocation of nutrients as well as photosynthates from source to sink. These results are in conformity with the findings of Chaudhary and Bodiuzzaman (1992).

Grain and straw yields were also significantly affected owing to different silicon levels and 120 kg Si/ha outyielded 60 kg Si/ha and the control but remained at par with 180 kg Si/ha (Table 1). Adequate silicon supply might have improved the photosynthetic activity which enabled rice plant to accumulated sufficient photosynthates with increased dry-matter production and these together coupled with efficient translocation resulted in more panicles and more number of filled grains with increased test weight which ultimately led to higher grain yield.

Application of silicon @ 180 kg Si/ha significantly increased the N uptake compared with its lower levels (Table 2). Silicon application enhanced the N uptake and has potential to raise the optimum N rate. Nitrogen-use efficiency increased with increase in silicon concentration, as the Si-fertilized plant gain maximum benefits of the ample N available (Deren *et al.*, 1994). Silicon levels also significantly increase the P uptake and the highest value was associated with highest silicon, i.e. 180 kg Si/ha, as it decreases the P retention capacity of soil and thus increases the water-soluble P in soil leading to increase efficiency of phosphatic fertilizers (Subramanian and Gopalswamy, 1990). Increased K uptake was observed by applying silicon and the maximum value was associated with highest level. This is in conformity with the results of Padmaja and Varghese (1972). Silicon uptake was significantly enhanced by different silicon levels and maximum uptake was associated with highest level. The increased availability of silicon in soils due to the addition of silicate materials might have been the reason for higher silicon uptake.

Increasing silicon levels increased the benefit : cost ratio up to 120 kg Si/ha. The maximum average benefit : cost ratio (2.38) was with the application of 120 kg Si/ha. Further increase in silicon levels reduced the benefit : cost ratio. Increasing silicon level to rice reduced the value : cost ratio compared to its immediate lower dose. Value : cost ratio of silicon application in rice was 7.1, 4.8 and 3.6 with 60, 120 and 180 kg Si/ha respectively. Apparent silicon recovery in rice varied from 74.1 to 110.0%. The apparent recovery of silicon was highest with 60 kg Si/ha. On contrary to this, the lowest apparent recovery was associated with the highest dose of 180 kg Si/ha. Increasing silicon levels to rice drastically reduced the response of kg grain/kg Si and naturally the maximum agronomic efficiency was associated with the lowest level of 60 kg Si/ha (6.8), while the lowest value was linked with the highest level of 180 kg Si/ha (13.3).

Effect of time of silicon application

Application timings differed significantly with respect to growth and yield attributes, viz. plant height, dry-matter production, panicles/m^2, filled grains/panicle and test weight (Table 1). Basal application of silicon produced the tallest plant and accumulated highest dry matter. Similarly, different yield attributes, viz. panicles/m^2, filled grains/panicle and test weight, were also maximum when silicon was applied full as basal followed by silicon applied 50% as basal + 50% at panicle-initiation stage and both were significantly superior to other application timings as well as the control.

Application time exerted significant influence on rice grain and straw yields. The highest grain yield (Table 1) was recorded with full basal application of silicon, being significantly superior to other application time as well as control except 50% as basal + 50% at panicle-initiation (PI) stage. In the present study, the yield increased with the application of silicon full basal followed by 50% basal

Table 1. Effect of levels and time of silicon application on growth, yield-attributing characters yield and economics of rice (pooled data of 1999 and 2000)

Treatments	Growth characters		Yield-attributing characters			Yield		Economics			Benefit: cost ratio
	Plant height (cm)	Dry-matter production (g)	Panicles/ m^2 (No.)	Filled grains/ pancile	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	
Silicon (kg/ha)											
60	90.7	31.9	336.4	99.6	18.4	6,164	10,144	33,356	14,105	19,251	2.36
120	92.3	36.5	341.3	101.2	19.0	6,453	10,609	34,915	14,667	20,247	2.38
180	93.2	36.9	344.3	101.5	19.1	6,588	10,800	35,637	15,230	20,408	2.34
CD (P=0.05)	1.1	0.9	3.7	0.8	0.3	179	231	-	-	-	-
Application time											
Full basal	94.9	38.7	347.1	103.0	19.2	6,821	11,124	36,883	14,467	22,416	2.55
50% basal + 50% at tillering	91.9	34.4	341.3	100.2	18.8	6,349	10,416	34,346	14,667	19,679	2.34
50% basal + 50% at PI	94.2	37.9	346.3	102.1	19.2	6,737	11,003	36,436	14,667	21,768	2.48
25% basal + 50% at tillering + 25% at PI	90.9	33.5	337.0	99.8	18.6	6,197	10,260	33,547	14,867	18,680	2.26
0 basal + 50% at tillering + 50% at PI	88.3	31.0	331.5	98.8	18.2	5,905	9,788	31,969	14,667	17,302	2.18
CD (P = 0.05)	1.4	1.2	4.7	1.0	0.3	232	298	-	-	-	-
Control	86.2	26.2	323.8	97.0	17.0	5,369	9,117	29,124	13,342.35	15,781.90	2.18
CD (P = 0.05)	1.8	1.5	6.0	1.2	0.4	293	377	-	-	-	-

PI, Panicle initiation

Table 2. Effect of levels and time of silicon application on nitrogen, phosphorus, potassium and silicon uptake by rice (pooled data of 1999 and 2000)

Treatment	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)	Silicon uptake (kg/ha)
Silicon (kg/ha)				
60	99.0	19.6	162.6	421.8
120	114.3	21.4	178.6	464.7
180	125.5	22.6	184.5	489.2
CD (P=0.05)	4.8	0.8	4.4	8.5
Application time				
Full basal	129.7	24.0	195.7	527.8
50% basal + 50% at tillering	110.0	20.8	170.5	447.5
50% basal + 50% at PI	125.3	23.2	190.3	494.7
25% basal + 50% at tillering + 25% at PI	106.2	19.9	166.1	427.7
0 basal + 50% at tillering + 50% at PI	93.5	18.0	153.5	395.0
CD (P = 0.05)	6.2	1.0	5.7	11.0
Control	75.1	15.0	135.6	355.8
CD (P = 0.05)	7.8	1.3	7.2	13.9

PI, Panicle initiation

+ 50% at PI stage may be due to the fact that Si absorption starts from transplanting and continues to flowering. Arthanari *et al.* (2002) also found that basal application of Si fertilizer and top-dressing at tillering stage was equally effective.

The uptake of N, P, K and Si by rice was significantly influenced by different Si application timings and the maximum value was obtained when silicon was applied full as basal. The increased uptake was mainly due to increase in their concentration of grain and straw along with increase in yield (Table 2).

Thus highest benefit : cost ratio was obtained when silicon was applied full as basal which was closely followed by 50% basal + 50% at panicle-initiation stage, this might be due to lower cost of cultivation and higher yield.

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