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Effect of Silicon and Phosphorus on Yield and Economics of Rice (*Oryza sativa* L.)

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Abstract
A field experiment titled "Effect of Silicon and Phosphorus on Yield and Economics of Rice" was conducted during *kharif* season of 2023 at Crop Research Farm Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India. The treatments consisted of 3 levels of silicon (100, 120 and 140 kg/ha) and 3 levels of phosphorus (50, 60 and 70 kg/ha). along with recommended doses of nitrogen, phosphorus and potash as control (120-60-60 kg N-P-K/ha). The experiment was laid out in a Randomized Block Design with 10 treatments and replication thrice. Application of silicon 140 kg/ha along with Phosphorus 70 kg/ha (Treatment 9) recorded significantly higher plant height (143.7 cm), number of Tillers/hill (21.09), dry weight (103.5 g), number of productive Tillers/m^2 (8.83), number of filled grains/panicle (111.4), number of unfilled grains/panicle (7.83), Grain yield (4.47 t/ha), and straw yield (7.33 t/ha). The aforesaid treatment also recorded maximum gross return (INR 178800.00), net return (INR 1,10,441.00) and B:C ratio (1.62).

Keywords: Economics, phosphorus, rice, silicon, yield

Introduction
One of the most significant staple cereal crops in the world, rice (*Oryza sativa* L.) provides almost half of the world's population with their primary supply of carbohydrates. But over 90% of the world's rice is grown and eaten in Asia, where it is a staple food for most people, including the 560 million starving people in the region. With a long history of rice growing, India is the world's largest rice producer and acreage (Yadav *et al*., 2010) [22]. In India, 47.83 million hectares of rice are cultivated, with a production level of 135.76 million tons (USDA 2023) [21] and an average productivity of approximately 2.67 t/ha (GOI 2022) [9]. After West Bengal, Uttar Pradesh is the second-largest rice-growing state in the nation. In 2021-2022, Uttar Pradesh produced 15.27 million tons of rice on 5.70 million ha of land, with a productivity of 2679 kg/ha. Basically, rice is a high-energy food. A third of the world's population depends on it as a staple diet.
Although silicon (Si) is not currently considered an essential nutrient, it is the second most abundant element in soil after oxygen. Soluble monosilicic acid (H_2SiO_4), a noncharged molecule that is the only form of silicon that plants can absorb, is important for imparting biotic and abiotic stress resistance (Ma, Nishiramra, and Takahashi 1989) [11]. Based on Elmer and Datnoff (2014) [7], Silicon can be found in all plants cultivated in soil, with 0.1-10% of the material found in plant tissue. Silicon treatment may increase the ideal nitrogen (N) rate due to the synergistic impact, which would increase rice yield (Bajiya *et al.* 2019) [4]. An increasing amount of data indicates that unless the plant is experiencing an external stress, the benefits of Silicon fertilization are negligible or nonexistent (Epstein, 2009) [8]. An adequate supply of silicon to paddy from tillering to elongation stage increases the number of grains per panicle and enhances ripening (Korndorfer *et al*., 2005) [10]. Phosphorus is an essential macro nutrient among the fertilizer elements, after nitrogen and if a plant suffers from phosphorus deficiency, it can't produce good yield. Phosphorus stimulates early root growth and development, encourages more active tillering and promotes early flowering, maturity and good grain development (Miller and Donahue, 1997) [12]. Large amount of phosphorus accumulation takes place in the soils which receives P fertilizers regularly. This is due to the reason that phosphorus will fix very quickly and retain in the top layers of the soil.

This will result in some nutritional imbalances. So it is necessary to know the requirement of phosphorus on that soils (Archana *et al*., 2016) [1].

Materials and Methods

The experiment was conducted during *kharif* season of 2023 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P). The soil of the field constituting a part of central gangetic alluvium is neutral and deep. The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH -7.6), organic carbon (0.870%), available N (219 kg/ha), available P (41.8 kg/ha) and available K (261.2 kg/ha). The treatment consists of T_1: Silicon 100 kg/ha + Phosphorus 50 kg/ha, T_2: Silicon 100 kg/ha + Phosphorus 60 kg/ha, T_3: Silicon 100 kg/ha + Phosphorus 70 kg/ha, T_4: Silicon 120 kg/ha + phosphorus 50 kg/ha, T_5: Silicon 120 kg/ha + Phosphorus 60 kg/ha, T_6: Silicon 120 kg/ha + Phosphorus 70 kg/ha, T_7: Silicon 140 kg/ha + Phosphorus 50 kg/ha, T_8: Silicon 140 kg/ha + phosphorus 60 kg/ha, T_9: Silicon 140 kg/ha + Phosphorus 70 kg/ha, T_{10}: Control (RDF- N-P-K- 120-60-60 kg/ha).The experiment was laid out in Randomized Block Design, with 10 treatments replicated thrice. The Rice seedlings were transplanted at a spacing of 20 cm row to row and 15 cm plant to plant. Silicon was applied using the broadcasting method as a basal dose, with the exception of the control, in accordance with the treatment specifications. Phosphorus is applied in the form of Di-ammonium phosphate (DAP), which is applied in basal application. N and K are applied is four equal splits viz., basal, tillering, panicle initiation and heading stages. The yield contributing characters such as productive tillers/m^2, number of filled grains/panicle, number of unfilled grains/panicle, grain yield (t/ha), straw yield (t/ha) were recorded at the time of harvest. The collected data was subjected to statistical analysis by analysis of variance method.

Results and Discussion

Yield parameter

Maximum number of productive tillers/m^2 (8.83) were recorded in with application of silicon 140 kg/ha + phosphorus 70 kg/ha. which was found to be statistically at par with all treatments and there was no significant difference in between the treatments. The maintenance of high photosynthetic activity and higher utilization of light and translocation of assimilated product to sink (Rani and Narayanan 1994) [15] due to silicon application could be the possible reasons for increased dry matter production. Panicle formation is directly related with the number of productive tillers which resulted in higher number of panicles/unit area.

Significantly higher number of filled grains/panicle (111.04) were recorded in with application of silicon 140 kg/ha + phosphorus 70 kg/ha, whereas with application of silicon 120 kg/ha + phosphorus 70 kg/ha (103.82) was found to be statistically at par with the highest. The increase in the number of filled grains per panicle might be due to, the additional dose applied at maximum tillering stage along with basal dose can be contributed to adequate availability and uptake of nutrients and less fixation, which results in higher dry matter accumulation in early stages and subsequent transfer of carbohydrates to grains for grain filling. Ramakrishna reddy *et al.* (1984) [14] also reported that the increased number of filled grains per panicle might also due to increase in supply of phosphorus which resulted in increased assimilation and translocation of carbohydrates to panicles. These findings are in close conformity with Murumkar *et al.* (2015) [13], Sakhen *et al.* (2011) [16], Dey *et al.* (2014) [6], Tiwari *et al.* (2016) [20].

The significantly lowest unfilled grains/panicle (7.83) was recorded with application of silicon 140 kg/ha + phosphorus 70 kg/ha. However, with application of silicon 140 kg/ha + phosphorus 50 kg/ha (10.33) was found to be statistically at par with treatment 9. The reason might be that rice produces long roots and broad leaves that enable them to take up more nutrients and produce more grains. Similar results have also been reported by Bhuiyan *et al*. (2014) [5]. The higher percent of unfilled grains was probably due to severe less favorable environment and delay sowing subsequently more incidents of insect, pest and shortage of water at time of grain filling stage. The present results are in consonance with finding of Bahure *et al*. (2019) [3].

Significant and higher number of grain yield (4.47 t/ha) was recorded in with application of silicon 140 kg/ha + phosphorus 70 kg/ha, minimum was recorded in control (2.22 t/ha) whereas with application of silicon 140 kg/ha + phosphorus 70 kg/ha (4.00 t/ha) was found to be statistically at par with the highest. Silicon increases the light receiving posture of rice plants, thereby enhancing photosynthetic rate and yield (Babu Rao *et al*., 2018) [2]. Archana *et al.* (2016) [1] also reported that application of phosphorus in two equal splits at basal and tillering stage gave higher yields, as the phosphorus absorbed during the early tillering stage was more efficiently used for grain production. These results were in support with Srujana *et al*. (2013) [19], Dey *et al.* (2014) [6] and Tiwari *et al*. (2016) [20].

Significant and higher number of straw yield (7.33 t/ha) was recorded in with application of Silicon 140 kg/ha + phosphorus70 kg/ha, minimum was recorded in control (5.86) whereas with application of Silicon 120 kg/ha + phosphorus 70 kg/ha (6.91) was found to be statically at par with the highest. An increase in the straw yield with the top dressing of phosphorus at maximum tillering stage might be due to increased growth parameters like more number of tillers/m^2, and greater dry matter production as a result of better availability of phosphorus and nitrogen at early crop growth stages. This is in accordance with the results reported by Singh *et al.* (1988) [18], Dey *et al*. (2014) [6] and Tiwari *et al*. (2016) [20].

Economics

Data represented in Table 2. Shows that the economics performance of different treatment combination based on cost of cultivation (INR/ha), gross return (INR/ha), net return (INR/ha) and benefit cost ratio (B:C). Highest cost of cultivation (INR 68358.00/ha), gross return (INR 178800.00/ha), net return (INR 110441.00/ha) and benefit cost ratio (1.62) were found with the application of T9 i.e., Silicon 140 kg/ha + phosphorus 70 kg/ha. The 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. Singh *et al.* (2005) [17]

Table 1: Influence of Silicon and Phosphorus on yield attributes of Rice

S. No	Treatments	Number of productive tillers/m^2	Number of filled grains/panicle	Number of unfilled grains/panicle	Grain yield (t/ha)	Straw yield (t/ha)
1.	Silicon 100 kg/ha + Phosphorus 50 kg/ha	7.24	95.1	14.50	3.66	6.04
2.	Silicon 100 kg/ha + Phosphorus 60 kg/ha	7.39	94.7	13.39	3.54	6.13
3.	Silicon 100 kg/ha + Phosphorus 70 kg/ha	7.53	99.2	12.93	3.67	6.85
4.	Silicon 120 kg/ha + Phosphorus 50 kg/ha	7.41	97.6	13.14	3.48	6.43
5.	Silicon 120 kg/ha + Phosphorus 60 kg/ha	8.27	108.3	9.96	4.00	7.01
6.	Silicon 120 kg/ha + Phosphorus 70 kg/ha	7.93	103.8	11.41	3.70	6.91
7.	Silicon 140 kg/ha + Phosphorus 50 kg/ha	8.02	107.1	10.33	3.81	7.00
8.	Silicon 140 kg/ha + Phosphorus 60 kg/ha	8.27	110.2	9.82	4.13	7.08
9.	Silicon 140 kg/ha + Phosphorus 70 kg/ha	8.83	111.4	7.83	4.47	7.33
10.	Control (RDF) - 120-60-60 kg N-P-K/ha	7.00	88.0	15.17	2.22	5.86
	SEm (±)	0.24	2.98	0.78	0.11	0.20
	CD (p=0.05)	0.73	8.84	2.30	0.33	0.60

Table 2: Influence of Silicon and Phosphorus on Economics of Rice.

S No	Treatments	Total Cost of cultivation (INR)	Gross return (INR)	Net return (INR)	B:C Ratio
1.	Silicon 100 kg/ha + Phosphorus 50 kg/ha	58858.00	138400.00	79541.00	1.35
2.	Silicon 100 kg/ha + Phosphorus 60 kg/ha	60108.00	141600.00	81491.00	1.36
3.	Silicon 100 kg/ha + Phosphorus 70 kg/ha	61358.00	146800.00	85441.00	1.39
4.	Silicon 120 kg/ha + Phosphorus 50 kg/ha	62358.00	139200.00	76841.00	1.54
5.	Silicon 120 kg/ha + Phosphorus 60 kg/ha	63608.00	160000.00	96391.00	1.52
6.	Silicon 120 kg/ha + Phosphorus 70 kg/ha	64858.00	148000.00	83141.00	1.28
7.	Silicon 140 kg/ha + Phosphorus 50 kg/ha	65858.00	152400.00	86541.00	1.31
8.	Silicon 140 kg/ha + Phosphorus 60 kg/ha	67108.00	165200.00	98091.00	1.46
9.	Silicon 140 kg/ha + Phosphorus 70 kg/ha	68358.00	178800.00	110441.00	1.62
10.	Control (RDF) - 120-60-60 kg N-P-K/ha	35108.00	89200.00	54091.00	1.23

Conclusion

From the results, it is concluded that better production and economic returns in Rice were recorded with the application of Silicon 140 kg/ha and Phosphorus 70 kg/ha in treatment 9.

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