Original Research Article

INFLUENCE OF SILICON AND PHOSPHORUS ON YIELD AND NUTRIENT CONTENT OF WHEAT IN LOAMY SAND SOILS OF SADARKRUSHINAGAR, BANASKANTHA, GUJARAT, INDIA

ABSTRACT

To investigate the influence of silicon and phosphorus application on yield and nutrient content of wheat, a field experiment was conducted at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during Rabi season of 2020-2021. Experimental soil was loamy sand in texture with pH 7.01 and electrical conductivity 0.19 dSm^{-1}. The soil was low in organic carbon (0.39%) and medium in available phosphorus (38.10 kg ha^{-1}) and potassium (191.25 kg ha^{-1}). Available silicon in soils was 60.75 mg kg^{-1}. The experiment was dispersed as four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and four levels of silicon (0, 100, 200 and 300 kg Si ha^{-1}) laid in randomized block design with factorial concept and replicated thrice. All the plots received a uniform recommended dose of nitrogen at 120 kg ha^{-1}. Yield and nutrient content *viz.*, nitrogen, phosphorus, potassium and silicon of grain and straw were noted. The results of experiment clearly indicated that the individual application of 60 kg ha^{-1} phosphorus and 100 kg ha^{-1} silicon recorded the significantly highest grain yield of 3808 and 3619 kg ha^{-1}, respectively. With respect to phosphorus and silicon content in grain (0.36 and 1.64%) and straw (0.32 and 1.67%), individual application 60 and 90 kg P_2O_5 ha^{-1} and 100 kg Si ha^{-1} and 300 kg Si ha^{-1}recorded maximum, respectively. As of interaction effect, significantly highest grain yield (4304 kg ha^{-1}), and phosphorus content in grain (0.39%) was found with interaction effect of 60 kg P_2O_5 ha^{-1} with Si level at 100 kg ha^{-1}. Whereas the significantly highest straw yield (6201 kg ha^{-1}), silicon content in grain (1.82%) and straw (4.21%) was found with interaction of 90 kg P_2O_5 ha^{-1} with Si level at 100 kg $ha^{-1}$and 90 kg P_2O_5 ha^{-1} with Si level at 200 kg ha^{-1}. From the results of experimentation, it is clear that application of 60 kg P_2O_5 ha^{-1} along with 100 kg Si ha^{-1} could be better for increasing yield and nutrient content in wheat in loamy sand soils under North Gujarat Agro-climatic conditions.

Keywords: Wheat, phosphorus, silicon, nutrient content, yield

1. INTRODUCTION

Wheat is an edible grain, one in every of oldest and most significant of the cereal crops. It's been cultivated for over 10,000 years in all probability, originates with the Fertile Crescent. India occupies second position next to China within the world with regard to area 30.15 million hectares and production 107 million tonnes with average productivity of 31.77 q ha^{-1} of wheat. It's a very important winter cereal contributing about 32.04 % of the total food grain production in India. In India, main wheat growing states are UP, Punjab, M.P., Haryana, Rajasthan and

Bihar. In Gujarat, wheat has an area of 10.18 lakh hectare with the production of 3332.4 thousand tonnes. The average productivity of wheat in the state is 30.0 q ha^{-1}[1].

World demand for wheat is increasing because of the distinctive viscoelastic and adhesive properties of gluten proteins. It is an important source of carbohydrates and leading source of vegetable protein in human food, having a protein content of about 13%. When eaten as the whole grain, wheat is a source of multiple nutrients and dietary fibre. It is used in the production of bread, biscuits, feeds, confectionary, *etc*.[2]

Next to nitrogen, phosphorus is that the most important nutrient needed by a wheat crop from seedling to maturity. It acts behind the scenes assisting with photosynthesis, energy storage and cellular division. Wheat uptakes P about 0.5-0.6 pounds of P_2O_5 per bushel. Without enough available P within the soil, plants will suffer from deficiencies like stunted growth, purple discoloration of stem and leaves, reduced root system and poor tillering [3]. [4] application of P @ 60 kg ha^{-1} improved phosphorus content in grain and straw at all the growth stages over control. [5] also reported that phosphorus application at 60 kg ha^{-1} has given higher grain and straw yield.

Silicon is one of the primary components of virtually all soils. In fact, next to oxygen, Si is that the most prevalent element within the earth and varieties of Si such as quartz and aluminosilicates often contribute as much as 75-95% of the inorganic fraction of mass [6]. Each kilogram of soil usually contains Si ranging from 50 to 400 grams. Silicon dioxide (SiO_2) is the common form of Si in soil. Vermiculite, smectite, kaolin (rich minerals in soils), orthoclase, feldspars, plagioclase (silicates in the form of crystal), amorphous silica, and quartz are the main Si containing components in most soil structures. However, not all Si in soil is available to plants; most of it is locked up in recalcitrant silicate minerals and only a much smaller fraction is available for plants. The soluble fraction of Si is redox and pH dependent[7].

Plants belonging to Graminae family can take silicon as equivalent to maconutrient. High concentration of silicon in plants increase the mechanical strength and prevents lodging, besides it also protect the plants from abiotic and biotic stress. Deficiency of silicon reported to increase the susceptibility of plants to stress and lodging [8]. [9] reported that application of silicon to wheat which is grown under different salinity stress has increased the nutrient uptake. Mesoporous Si nanoparticles formed within wheat plant cells were shown to increase wheat seedling growth, seedling photosynthetic activity, and total protein content of seedlings [10].

The interaction between Si and P is not direct, but indirect. High soil sorption of phosphorus (P) in some P deficient low pH soils reduces the efficiency of P fertilizer use and crop yields. By increasing the monosilicic acid concentration in the soil solution, plants are able to absorb phosphates (P) directly. [10] revealed that application of silicon with nutrient medium in wheat crop has increased the content of S, Mg, Ca, B, Fe, P, and Mn and decreased the N, Cu, Zn and K content.

As wheat is one the important cereal crop which provides more than seventy percent of population's calorie intake, this research was carried to use of silicon and phosphorus to enhance the productivity and nutrient content in wheat plant. Thus the main objective of this study is to investigate the influence of silicon and phosphorus on yield and nutrient content as well as their interaction on nutritional status of wheat in loamy sand soils of Sardarkrushinagar.

2. MATERIALS AND METHODS

The experiment was carried out at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha, Gujarat during *Rabi*, 2020-21. Geographically, this place is located at 72°19' East longitude and 24°19' North latitude at 154.52 meters above the mean sea level and situated in North Gujarat agro climatic zone of Gujarat state. Soil of the experimental plot was loamy sand in texture, neutral in reaction, low in organic carbon, medium in available P_2O_5 and K_2O. The experiment comprises of four levels of phosphorus (0, 30, 60, 90 kg P_2O_5 ha^{-1}) and four levels of silicon (0, 100, 200, 300 kg Si ha^{-1}) and total sixteen treatment combinations were laid out in Randomized Block Design (Factorial) with three replications. The variety GW-451 was used with seed rate of 120 kg ha^{-1}.

All the plots are fertilized with recommended dose of nitrogen at 120 kg ha^{-1}. The half dose of nitrogen and full of phosphorus and silicon were applied basal. Remaining half dose of nitrogen was applied at 30 days after sowing. The source of fertilizers was nitrogen (urea 46%), phosphorus (Diammonium Phosphate 18% N, 46% P) and Silicon (calcium silicate 18%).

The straw and grain yield were recorded individually after harvest of crop. Grain and straw samples were collected separately from each plot after harvest, dried in hot air oven at 65^0C, powdered and used for analysis of nutrient content. The Chemical analysis of grain and straw samples were done by following the method of Micro-Kjeldahl's method [11] for nitrogen, Vanadomolybdo phosphoric acid yellow colour method [12] for phosphorus, Flame photometric method [12] for potassium and Colorimetric method [13] for silicon.

Data recorded during the investigation regarding the yield and nutrient content were statistically analyzed using the factorial randomized block design as represented by [14]. The summery tables for effect of treatments had been worked out using standard error of difference and critical difference (C.D.) at 5 % level of probability and are noted in the respective table.

3. RESULTS AND DISCUSSION

3.1 Grain yield (kg ha^{-1})

The results presented in data illustrate that wheat grain yield was significantly influenced by phosphorus and silicon application. The most grain (3808 kg ha^{-1}) yield was recorded thanks to application of 60 kg P_2O_5 ha^{-1} (Table 1). The most reason for increase in grain yield with different levels of phosphatic fertilizer may be because of more practical tillers per plant which may well be the result of higher rate of photosynthesis and better crop health which ultimately increased the ultimate grain yield. Plants showed normal growth with the appliance of phosphorus and resulted in improved agronomic traits which lead toward improved grain yield [15]. Similar findings were reported with [16] and [17].

The significantly higher grain (3619 kg ha^{-1}) yield was recorded thanks to silicon application at 100 kg ha^{-1}; while the bottom grain (2981 kg ha^{-1}) yield was recorded under Si_0 (Table 1). The rise in yield with Si application may well be because of the improving leaf erectness by decreasing mutual shading of leaves, reducing lodging, decreasing the incidence of pathogens and preventing manganese and iron toxicity or both.

Application of Si, increased water use efficiency probably may be because of prevention of excessive transpiration. Just in case of interaction effect, combination of phosphorus level *i.e.* 60 kg P_2O_5 ha^{-1} with Si level at 100 kg ha^{-1} showed significantly highest grain yield (4304 kg ha^{-1}). Very cheap grain yield (2565 kg ha^{-1}) was observed in P_0Si_0 (Table 2). [18] stated that silicon addition significantly increases phosphorus mobilization by mobilizing Fe (II)-P phases from mineral surfaces.

Table 1: Effect of phosphorus and silicon on yield and nutrient content of wheat grain

Treatments	**Grain yield (kg ha^{-1})**	**Nitrogen (%)**	**Phosphorus (%)**	**Potassium (%)**	**Silicon (%)**
Phosphorus levels					
P_0-0 kg P_2O_5 ha^{-1}	2789	0.24	0.83	1.42	0.24

P_1- 30 kg P_2O_5 ha^{-1}	3049	0.28	0.85	1.50	0.28
P_2- 60 kg P_2O_5 ha^{-1}	3808	0.36	0.89	1.64	0.36
P_3- 90 kg P_2O_5 ha^{-1}	3766	0.31	0.86	1.62	0.31
S.Em.$\pm$	77.00	0.01	0.03	0.03	0.01
C.D. (P=0.05)	222.40	0.03	NS	0.10	0.03
Silicon levels					
Si_0-0 kg Si ha^{-1}	2981	1.67	0.28	0.85	1.32
Si_1-100 kg Si ha^{-1}	3619	1.74	0.32	0.87	1.58
Si_2-200 kg Si ha^{-1}	3459	1.79	0.30	0.86	1.61
Si_3-300 kg Si ha^{-1}	3354	1.69	0.28	0.85	1.67
S.Em.$\pm$	77.00	0.05	0.01	0.03	0.03
C.D. (P=0.05)	222.40	NS	0.03	NS	0.10
Interaction					
P x Si	Sig.	NS	Sig.	NS	Sig.
C.V. (%)	7.96	10.49	10.25	11.25	7.68

Sig. – significant, NS- Non- Significant

Table 2: Interaction effect of phosphorus and silicon on grain and straw yield of wheat

Treatments	**Grain yield (kg ha^{-1})**				**Straw yield (kg ha^{-1})**			
	Phosphorus levels (kg ha^{-1})							
Silicon levels (kg ha^{-1})	P_0	P_1	P_2	P_3	P_0	P_1	P_2	P_3
Si_0	2568	2579	3123	3653	3739	5087	5450	5036
Si_1	2721	3503	4304	3946	5162	4800	6172	6201
Si_2	3034	3007	3939	3855	5262	4819	6094	5494
Si_3	2832	3109	3866	3610	5249	5441	5201	5292
S.Em. ±	154.00							
C.D. (P=0.05)	444.80							
C.V. (%)	7.96							

3.2 Straw yield (kg ha^{-1})

Application of various levels of silicon and phosphorus has exhibited a major influence on straw yield of wheat. All- time low straw (4853 kg ha^{-1}) yield was observed under P_0. The most straw (5729 kg ha^{-1}) yield was recorded thanks to application of 60 kg P_2O_5 ha^{-1}(Table 6). Early tiller formation is important to plant health and ultimately final yield potential. The initial tillers formed by the plant have higher yield potential than late tillers or delayed tillers. When adequate phosphorus is offered in soil, resulting tillers are healthier and productive. The results are in line with the findings of [4] and [17].

Significantly highest straw (5584 kg ha^{-1}) yield was recorded thanks to silicon application at 100 kg ha^{-1}; while lowest straw yield (4828 kg ha^{-1}) was recorded under Si_0 (Table 6). The rise in yield with Si application can be thanks to the improving leaf erectness, reduction in lodging and decreasing susceptibility to plant pathogens and pests and preventing manganese and iron toxicity or both. Application of Si, increased water use efficiency probably may be because of prevention of excessive transpiration.

In case of interaction effect, the best straw yield of wheat crop was observed because of combined application of 90 kg P_2O_5 ha^{-1} and 100 kg Si ha^{-1} (6201 kg ha^{-1}) over the remainder of the combinations (Table 2). [19] described that in water culture, when P is low Si causes a decrease in Fe and Mn uptake and thus promotes P availability within the plant. From these findings, it's clear that Si application alleviated the phosphorus uptakes which resulted within the increase in biomass of wheat crop.

3.3 Nitrogen content in grain (%)

Data presented in Table 1 indicates that individual application of different levels of phosphorous and silicon did not exert significant effect on nitrogen content in grain. The maximum nitrogen content was reported with 60 kg P_2O_5 ha^{-1} (1.78%) and 200 kg Si ha^{-} (11.79%) and minimum nitrogen content of 1.65% and 1.67% was observed with control respectively. The interaction effect was found to non- significant in all levels of treatments

3.4 Phosphorus content in grain (%)

Different levels of phosphorus and silicon significantly influenced the phosphorus content in wheat grain. Application of 60 kg P_2O_5 ha^{-1} has recorded significantly highest phosphorus content (0.36%) which is at par with 90 kg P_2O_5 ha^{-1} and 30 kg P_2O_5 ha^{-1}. The lowest phosphorus content (0.24%) was observed with control (Table 1). Significant difference phosphorus content is mainly due to application of phosphorus as moderately supply of phosphorus is needed for growing period of wheat for improving nutrient content in grain. The results are in close agreement with those reported by [20].

In case of silicon application, highest phosphorus content (0.32%) was found with 100 kg Si ha^{-1}; however it is at par with 200 kg Si ha^{-1} and 100 kg Si ha^{-1}. The lowest phosphorus content (0.28%) was observed with control (Table 1). It is mainly due to application of silicon which increased the root exudation of organic acids that mobilize the phosphorus in the rhizosphere region and unregulated the transport of phosphorous to root in wheat crops.

For interaction effect, combination of phosphorous *i.e.,* 60 kg P_2O_5 ha^{-1} with Si level at 100 kg ha^{-1} and 200 kg ha^{-1} showed significantly higher phosphorus content (0.39%); which was at par with P_{60} x Si_{300}, P_{90} x Si_0. The lowest phosphorus content (0.21%) is observed with control and P_0 x Si_{300} (Table 3). Studies have indicated that Si fertilization enhances plant phosphorus (P) utilization by increasing both P content of rice and phosphate fertilizer efficiency. The results are similar with the findings of [21].

Table 3: Interaction effect of phosphorus and silicon on phosphorus and silicon content in wheat grain

Phosphorus (%)					**Silicon (%)**			
Treatments	**Phosphorus levels (kg ha^{-1})**							
Silicon levels (kg ha^{-1})	P_0	P_1	P_2	P_3	P_0	P_1	P_2	P_3
Si_0	0.21	0.26	0.31	0.34	1.43	1.34	1.32	1.17
Si_1	0.28	0.30	0.39	0.32	1.30	1.46	1.75	1.82
Si_2	0.25	0.27	0.39	0.31	1.36	1.54	1.76	1.79
Si_3	0.21	0.29	0.35	0.25	1.58	1.67	1.72	1.71
S.Em. ±	0.02				0.07			
C.D. (P=0.05)	0.05				0.20			
C.V. (%)	10.25				7.68			

3.5 Potassium content in grain (%)

Data presented in Table 1 indicates that different levels of phosphorous and silicon application did not exert significant effect on potassium contents in wheat grain. The maximum potassium content 0.89% and 0.87% was recorded with 60 kg P_2O_5 ha^{-1} and 100 kg Si ha^{-1} respectively. Interaction between phosphorus and silicon application was found to be non-significant with respect to potassium content in grain.

3.6 Silicon content in grain (%)

The different levels of phosphorus and silicon application to wheat significantly affected the silicon content in grains of wheat. The significantly highest silicon content (1.64%) was recorded with application of 60 kg P_2O_5 ha^{-1} and it was at par with 90 kg P_2O_5 ha^{-1}, while the lowest (1.42%) was recorded with control. The highest silicon content (1.67%) was recorded with 300 kg Si ha^{-1} and lowest (1.32%) was recorded with control. But, it was at par with 200 kg Si ha^{-1} and 100 kg Si ha^{-1} (Table 1). The increase in silicon content in wheat grain is due to the mobilization of silicon which increases the availability of silicon for uptake. The results are line with the finds of [22].

The data on interaction of P x Si (Table 3) revealed that significantly highest silicon content (1.82%) was observed due to the combined effect of 90 kg P_2O_5 ha^{-1} and 100 kg Si ha^{-1} over rest of the treatment combinations. However, it was at par with treatment combination with

P_{60} x Si_{100}, P_{60} x Si_{200} and P_{90} x Si_{200}. The lowest silicon content (1.30%) was recorded with P_0 x Si_{100}. The decrease in P adsorption in soil with increase in the availability of P in soil and plants result in increase in phosphorus content in crop.

3.7 Nitrogen content in straw (%)

The different level of phosphorus and silicon presented in the Table 4 clearly indicates that there's no significant influence in nitrogen content in wheat straw. Maximum nitrogen content of 0.98% and 0.99% was recorded with application of 90 kg P_2O_5 ha^{-1} and 100 kg Si ha^{-1} whereas minimum nitrogen content of 0.95% and 0.96% was observed with control. The interaction effect was found to be non-significant between the treatments.

Table 4: Effect of phosphorus and silicon on yield and nutrient content in wheat straw

Treatments	Straw yield (kg ha^{-1})	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Silicon (%)
Phosphorus levels					
P_0-0 kg P_2O_5 ha^{-1}	4853	0.95	0.19	1.05	3.13
P_1- 30 kg P_2O_5 ha^{-1}	5037	0.96	0.22	1.09	3.56
P_2- 60 kg P_2O_5 ha^{-1}	5729	0.97	0.25	1.17	3.56
P_3- 90 kg P_2O_5 ha^{-1}	5506	0.98	0.26	1.08	3.76
S.Em.$\pm$	118.66	0.02	0.01	0.03	0.09
C.D. (P=0.05)	342.72	NS	0.02	NS	0.25
Silicon levels (kg ha^{-1})					
Si_0-0 kg Si ha^{-1}	4828	0.96	0.20	1.07	3.15
Si_1-100 kg Si ha^{-1}	5584	0.99	0.24	1.12	3.52
Si_2-200 kg Si ha^{-1}	5417	0.95	0.24	1.13	3.64
Si_3-300 kg Si ha^{-1}	5296	0.96	0.25	1.08	3.71
S.Em.$\pm$	118.66	0.02	0.01	0.03	0.09
C.D. (P=0.05)	342.72	NS	0.02	NS	0.25
Interaction					
P x Si	Sig.	NS	Sig.	NS	Sig.
C.V.(%)	7.78	8.06	10.27	10.43	8.46

Sig. – significant, NS- Non- Significant

3.8 Phosphorus content in straw (%)

The various levels of phosphorus and silicon application have a big effect on phosphorus content in wheat straw (Table 4). The highest phosphorus content (0.26%) was found with the appliance of 90 kg P_2O_5 ha^{-1}. However, it had been at par with 60 kg P_2O_5 ha^{-1}. The lowest phosphorus content (0.20%) was observed with control. Just in case of silicon application, application of 300 kg Si ha^{-1} recorded the maximum utmost phosphorus content of 0.25% in straw. It is at par with 100 kg Si ha^{-1} and 200 kg Si ha^{-1}. The bottom phosphorus content (0.20%) was recorded with control. (Table 4)

As for the interaction effect between phosphorus and silicon, they're found be significantly influenced the phosphorus content in straw (Table 5). The highest phosphorus content (0.30%) was observed with combination of phosphorus *i.e.*, 90 kg P_2O_5 ha^{-1} with Si level at 300 kg ha^{-1} but it was absolutely at par with P_{60} x Si_{100}, P_{90} x Si_{100},P_{60} x Si_{200}, P_{90} x Si_{200},P_{60} x Si_{300}.The lowest phosphorous content (0.19%) was observed with control andP_0 x Si_{300}. Application of silicon together with phosphorus by which silicon solubilizes phosphorus and increase its use efficiency may be reason more phosphorus content in straw.

Table 5: Interaction effect of phosphorus and silicon on phosphorus content in wheat straw

Phosphorus (%)					**Silicon (%)**			
Treatments	**Phosphorus levels (kg ha^{-1})**				**Phosphorus levels (kg ha^{-1})**			
Silicon levels (kg ha^{-1})	P_0	P_1	P_2	P_3	P_0	P_1	P_2	P_3
Si_0	0.19	0.21	0.21	0.20	3.45	3.31	2.93	2.93
Si_1	0.22	0.22	0.25	0.27	3.28	3.36	3.60	3.83
Si_2	0.17	0.23	0.28	0.26	2.89	3.82	3.68	4.21
Si_3	0.19	0.24	0.26	0.30	2.93	3.76	4.09	4.07
S.Em. ±	0.01				0.17			
C.D. (P=0.05)	0.04				0.49			
C.V. (%)	10.27				8.46			

3.9 Potassium content in straw (%)

Data presented in Table 4 indicates that different levels of phosphorous and silicon application didn't exert significant effect on potassium contents in wheat straw. The utmost potassium content of 1.17% and 1.13% was reported with 60 kg P_2O_5 ha^{-1} and 200 kg Si ha^{-1} application. The minimum potassium content of 1.05% 1.07% was noted under control of both treatments. In case interaction effect, there was no significant different between the treatments.

3.10 Silicon content in straw (%)

The results reported in Table 4 indicated that silicon content of wheat straw was significantly stricken by different levels of phosphorus and silicon application. For phosphorus levels, significantly the best silicon content (3.76%) was observed with 90 kg P_2O_5 ha^{-1} and therefore the lowest (3.13%) was recorded with control. However, it was at par with 60 kg P_2O_5 ha^{-1} and 30 kg P_2O_5 ha^{-1}. In case of silicon levels, the highest silicon content was observed with

300 kg Si ha^{-1} (3.71%). However, it absolutely was at par with 100 kg Si ha^{-1} and 200 kg Si ha^{-1}. The rock bottom silicon content (3.15%) was noted under control.

Meanwhile, the interaction effect was found to be significant. The data on interaction of P and Si (Table 5) revealed that significantly the highest silicon content (4.21%) was observed due to the combined effect of 90 kg P_2O_5 ha^{-1} and 200 kg Si ha^{-1} over rest of the treatment combinations. However, it had been at par with treatment combination with P_{90}x Si_{100}, P_{30} x Si_{200}, P_{30} x Si_{300}, P_{60} x Si_{300} and P_{90} x Si_{300}. The lowest silicon content was recorded with P_0 x Si_{200} (2.89%).

4. CONCLUSION

From the result, it could be clear that individual application of silicon at 100 kg Si ha^{-1} and phosphorus 60 kg P_2O_5 ha^{-1} and their interaction in loamy sand soil had enhanced the yield and nutrient in both grain and straw of wheat. It can release phosphorus and silicon into soil solution by solubilizing the phosphorus and also through cationic exchange and making it readily available to the plant. So, this present study suggest that application of phosphorus at 60 kg P_2O_5 ha^{-1} and silicon at 100 kg Si ha^{-1} to wheat under loamy sand for obtaining high yield and nutrient content to Sadarkrushinagar, Banaskantha district farmers.

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