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Effect of soil and foliar application of silicon on growth, yield and quality of blackgram [*Vigna mungo* (L.) Hepper] grown under organic farming

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Abstract
A field experiment entitled "Effect of Soil and Foliar Application of Silicon on Growth, Yield and Quality of Blackgram [*Vigna mungo* (L.) Hepper] Grown under Organic Farming" was conducted during kharif 2019-20 at Organic Farming Unit, Rajasthan College of Agriculture, MPUAT, Udaipur. The experiment was laid out in factorial randomized block design with three replications and 20 treatments. The treatment combinations consist of five levels of silicon (0, 25, 50, 75 and 100 kg ha^{-1}) as soil application and four concentrations of silicon as foliar spray (0, 1%, 2% and 3%). The combined effect of soil and foliar application of silicon enhances number of pods ($plant^{-1}$) and maximum number of pods ($plant^{-1}$) as well as seed yield of blackgram was recorded with the soil application of silicon @ 100 kg ha^{-1} and foliar application of silicon @ 2%. Similarly, increasing the level of soil application with increasing concentration of foliar application of silicon enhances the net return and benefit cost ratio but significant increase in both were observed upto the foliar application of silicon @ 3% with control. However, Maximum net return and benefit cost ratio of blackgram was recorded with the soil application of silicon @ 100 kg ha^{-1} and foliar application of silicon @ 2% as compared to the rest of combination of treatments.

Keywords: soil and foliar application, silicon, growth, yield, black gram, organic farming

Introduction
Blackgram is a rainfed crop predominantly grown in *kharif* season in the state of Rajasthan. It is cultivated mostly on marginal land in mono/mixed cropping system without any fertilizer under rainfed condition of southern Rajasthan (Jha *et al*., 2015) [9]. Throughout India, blackgram is used for different purposes. The major portion is utilized in making *dal*, curries, soup, sweets and snacks. In South India, the most popular snack foods, namely *idli* and *dosa* are prepared by mixing rice and blackgram flour usually in the ratio of 3:1.

The food value of blackgram lie in its high and easily digestible protein. Its seed contains approximately 25-28 per cent protein, 1.0 -1.5 per cent oil, 3.5 – 4.5 per cent fiber, 4.5 – 5.5 per cent ash and 62 – 65 per cent carbohydrates on dry weight basis (Darade *et al*., 2019) [4]. There may be some variability in protein percent, due to environmental and genotypic effects which may range from 19-29 per cent. Amino acid analysis indicates, as observed with most grain legume crops, that concentration of sulphur containing amino acids methionine and cystine are low. Lysine values are comparatively high and that is why the protein of blackgram is an excellent complement to rice in terms of a balanced and nutritive diet. Blackgram contains trypsin and other growth inhibitors also but these are denatured by heating. It is also reported to be rich in vitamins A, B and B_3 (Choudhary *et al*., 2017) [1]. Organic agriculture is gaining momentum in the world. There is a growing demand of organic food. Organic blackgram will be an important pulse crop of the world. The packages and practices for cultivation of blackgram under organic farming have been developed in Rajasthan (Ravisankar *et al*., 2017) [20]. In recent years, the use of panchgavya, jeevamrut, beejamrut, vermiwash and compost tea is being adopted and gaining popularity in Indian agriculture largely through the efforts of small groups of farmers (mainly marginal farmers). It has been felt that there is a need to enhance productivity of blackgram under organic production through better nutritional approaches. In India, blackgram occupies third place after gram andarhar. In organic based production, natural sources of silicon can be used to increase the growth and yield of crops.

The 100 per cent natural fresh water silicon flour is being used for cultivation of crops, vegetables and fruits as organic pesticide and bioenhancers. Therefore, use of silicon in cultivation of pulses can help in enhancing the growth and productivity and can also be used as 100 percent inorganic input. Balanced nutrition results in increased production potential for crop plants; thus, it is important that the plants are grown and developed in the presence of essential mineral elements, which must be made readily available to them. In addition to these essential elements, there are other elements that benefit plant nutrition, such as silicon (Takahashi and Miyake., 1977) [26]. It has been also suggested that silicon plays a crucial role in preventing or minimizing the lodging incidence in most of the cereal crops, a matter of great importance in terms of crop productivity (Singh *et al.*, 2005) [25].

Although silicon is the second most abundant element in mineral rich soils. It is well known that diatomaceous earth (DE) is an inorganic source of naturally occurring substance, the fossilized remain of salt or freshwater organisms (unicellular algae-like plants) called diatoms (Pooja *et al.*, 2019) [16]. In crop production, the benefits from its application for fertilization may include increased yield, enhanced disease and insect resistance as well as tolerance to stresses such as cold, drought and toxic metals. Wheat, maize, paddy, cucurbits, turf grass and sugarcane are the crops that have been shown to be benefited and have gained popularity owing to silicon fertilization. Silicon thus plays a significant role in imparting both biotic and abiotic stress resistance and in enhancing productivity. It does not damage the plants upon overaccumulation. High accumulation of silicon in paddy, sugarcane and wheat has been notably responded and demonstrated to be necessary for healthy growth and found to have no adverse effect on yield. For this reason, silicon has been recognized as an "agronomically essential element" in Japan and silicate fertilizers have been applied to paddy cultivated soils (Ma, 2004) [12]. In recent years, silicon has been regarded as quasi-essential element (Epstein, 2005) [6]. Several studies suggest that it enhances disease resistance in plants, imparts turgidity to the cell walls and has a putative role in mitigating metal toxicities. The magnitude of the benefits of silicon and its effect on growth, yield and quality of cereals are known but in case of pulse crops, research on effect of silicon is very meagre. Keeping the above considerations, an experiment entitled “Effect of Soil and Foliar Application of Silicon on Growth, Yield and Quality of Blackgram [*Vigna mungo* (L.) Hepper] Grown under Organic Farming” was conducted during *kharif* 2019 at Organic Farming Unit, Rajasthan College of Agriculture, Udaipur to study the effect of soil and foliar applied silicon on growth, yield and quality to arrive at economically viable treatment of silicon application of blackgram grown under organic farming.

Methodology

The experiment was conducted at Organic Farming Unit, Rajasthan College of Agriculture, Udaipur which is situated in South-Eastern part of Rajasthan at an altitude of 582.17 m above mean sea level with 24˚35′ N latitude and 74˚42′ E longitude and this area falls under agro-climatic zone IVa (Sub-humid Southern Plains and Aravalli Hills) of Rajasthan. The climate of place is sub-tropical characterized by mild winters and moderate summer associated with high relative humidity during the months of July to September. The mean annual rainfall of Udaipur is 637 mm with a range between 373-1140 mm. The mean weekly meteorological parameters recorded at Agro-meteorological observatory, Rajasthan College of Agriculture, Udaipur during cropping period. These observations revealed that minimum and maximum temperatures ranged between 16.1 ˚C to 24.1 ˚C and 27.6 ˚C to 32.0 ˚C, respectively. The minimum and maximum relative humidity ranges between 46.3 to 84.4 per cent and 80.1 and 94.3 per cent, respectively during *kharif* 2019. Total rainfall received during blackgram crop season was 836.2 mm. Soil available N (251.2 kg ha^{-1}), P_2O_5 (20.8 kg ha^{-1}), K_2O (351.4 kg ha^{-1}), Zn (1.91 mg kg^{-1}), Fe (3.42 mg kg^{-1}), S (10.08 mg kg^{-1}), Electric conductivity (0.78 dS m^{-1} at 25 ºC) and pH was 8.32 before sowing of the crop. The treatment combinations consist of five levels of silicon (0, 25, 50, 75 and 100 kg ha^{-1}) as soil application and four concentrations of foliar spray silicon (0, 1%, 2% and 3%). The experiment was laid out in factorial randomized block design with three replications. The treatment combinations were randomized with the help of random number table (Fisher, 1950).

The blackgram variety Pratap Urd-1 (KPU 07-08) was developed at ARS, Kota (Raj.) and was released in year 2013. The variety matures in about 74-76 days and yield potential is 10-11 q ha^{-1}. It is tolerant to moisture stress and has better resistance against MYMV, leaf crinkle, anthracnose and bacterial leaf blight.

Treatment application

1. Soil application- DE (diatomaceous earth) powder was used as silicon source for soil application and it was applied once at the time of sowing in each experimental plot as per treatment details. It has low bulk density (0.38-0.45 gm ml^{-1}) and high porosity (50-70%). The chemical composition of oven dried diatomaceous earth is 82-86 per cent silica with 2-6 per cent alumina, 0.5-2.5 per cent iron oxide.
2. Foliar application- Different doses of silicon (from common source) were sprayed in experimental plots during crop growth period as per treatment details. Silicon solutions were prepared as per treatment applications, for example 1 per cent of silicon solution was prepared by mixing 1 g of silicon to every 1 litre of water. First foliar spray was done at flowering stage and second was done at 15 days after flowering stage.

In order to study of growth, yield and quality attributing characters and yield, nutrient content, their uptake and quality of crop, observations were recorded for each parameter as per method mentioned below.

Treatment evaluation

Plant population: The number of plants per m^2 recorded from three randomly selected spots in each plot at 20 DAS and at harvest and finally was converted into ‘000 ha^{-1}.

Plant height: The plant height from ground surface to the tip of the main stem was measured at 20 DAS and at harvest. Average height of the randomly selected five plants was recorded and expressed as plant height in cm.

Shoot length: The shoot from the base of the plant to the tip of the plant was measured at 20 DAS and at harvest. Average height of the randomly selected five plants was recorded and expressed as plant height in cm.

Root length: The root length from the base of the plant to the tip of the longest root was measured at 30, 45, 60 DAS and at harvest. Average length of the randomly selected five plants was recorded and expressed as root length in cm.

Number of effective nodules plant^{-1}: At flowering initiation stage, three plants were uprooted randomly from the outer rows of plant without disturbing the roots and their nodules. After drying plant in shade, nodules were separated from the roots with the help of forceps and their numbers are recorded.

Dry matter accumulation: The periodic changes in dry matter accumulation plant^{-1} was recorded at 30, 45, 60 DAS and at harvest by taking randomly selected five plants from border rows of each treatment. The samples were air dried for few days and then oven dried at 65 ºC till a constant weight was observed. The dry matter was expressed in g plant^{-1}.

Number of pods plant^{-1}: Pods of five randomly selected plants were counted per plant after harvest to calculate the mean number of pods plant^{-1}.

Number of seeds pod^{-1}: To calculate the average number of seeds pod^{-1}, 10 randomly selected mature pods from five randomly plants. The average values were mentioned as number of seeds per pod.

Test weight: One thousand grains from produce of each plot were taken and their weight was recorded. The thousand grain weight was expressed in g.

Seed yield: Seed yield per plot was recorded after threshing and winnowing the seeds from each net plot area. The seed yield per hectare was worked out and expressed in kg per hectare.

Haulm yield: Haulm yield in kg per plot was obtained by subtracting the seed yield from biological yield per plot recorded earlier and expressed in terms of straw yield kg ha^{-1}.

Biological yield: The harvested material from net area of each plot was thoroughly sun dried. After drying, the produce of individual net plot was weighed with the help of spring balance and weight was recorded in kg per plot. Later, biological yield per plot was converted into kg per hectare.

Harvest index: The harvest index was obtained by dividing the economic yield (seed yield) by total biological yield (seed + haulm yield) obtained from net plot and multiplied by 100 to express it in percent.

Results and Discussion

Growth attributes

Soil application of silicon: Results show that soil application of silicon @ 100 kg ha^{-1} significantly increased the plant height of blackgram at harvest stage, plant dry matter at harvest and at 60 DAS. It could be seen from the preceding chapter that all the components of plant biomass were favorably influenced by the application of silicon (Table 1 to 4). Similarly, significantly highest shoot length at 45 DAS, 60 DAS and at harvest was recorded with application of 100 kg silicon ha^{-1}. Soil application of 100 kg silicon ha^{-1} recorded significantly maximum root length at 45 DAS, 60 DAS and at harvest in blackgram but it was found to be at par with application of 75 kg silicon ha^{-1}. Similarly, number of nodules per plant at flowering initiation in blackgram was recorded highest with application of silicon @ 100 kg ha^{-1}. This might be due to the fact that silicon fertilization increases erectness of leaves and leaf blades which allow better light transmittance through plant canopies and thus indirectly improves whole-plant photosynthesis as reported in rice. (Savant *et al.*, 1997) [23]. Gholami and Falah (2013) [7] also reported an increase in silicon content of stem and leaves, number of tillers, dry leaves weight, 1000-grain weight, and yield upon silicon fertilization. Pati *et al.* (2016) [15] reported an increase in plant height with the addition of silicon fertilizer (600 kg DE ha^{-1}) over the control.

Foliar application of silicon: Results reveal that all growth attributes of blackgram *viz.*, plant height (69.22 cm) at harvest, dry matter accumulation at 60 DAS (6.24 g plant^{-1}) and at harvest (7.91 g plant^{-1}), shoot length at 45 DAS (50.33 cm), 60 DAS (60.72 cm) and at harvest (66.21 cm), root length at 45 DAS (17.24 cm), 60 DAS (22.73 cm) and at harvest (22.63 cm) increased significantly with foliar application of silicon @ 3% which was found to be statistically at par with 2% application of silicon (Table 1 to 4). Increased higher number of productive tillers and total number of tillers m^{-2} in rice were reported due to application of silicon (Li *et al.*, 2002) [11], (Rodrigues *et al.*, 2003) [22] and (Mobasser *et al.*, 2008) [14].

Table 1: Effect soil & foliar application of silicon on plant population and plant height in blackgram

Treatments	Plant population ('000)		Plant height (cm)	
Soil application (kg ha^{-1})	At 20 DAS	At harvest	At 20 DAS	At harvest
S_1– Control	317.98	318.94	24.02	50.72
S_2– 25 kg ha^{-1}	316.53	317.49	25.07	56.96
S_3– 50 kg ha^{-1}	316.02	316.99	26.81	59.84
S_4– 75 kg ha^{-1}	315.17	316.13	28.06	65.30
S_5– 100 kg ha^{-1}	314.37	315.33	28.95	66.74
S.Em ±	8.364	8.36	1.14	1.86
CD (P=0.05)	NS	NS	NS	5.32
Foliar application (%)*				
F_1– Control	317.00	317.97	26.15	44.61
F_2– 1 %	318.25	319.22	25.72	59.18
F_3– 2 %	319.13	320.09	26.70	66.64
F_4– 3 %	309.67	310.63	27.76	69.22
S.Em ±	9.351	9.35	1.27	2.08
CD (P=0.05)	NS	NS	NS	5.95

*Applied at flowering initiation & 15 days after flowering.

Table 2: Effect ofsoil & foliar application of silicon ondry matter accumulation in Blackgram

Treatment	Dry matter accumulation (g plant^{-1})			
Soil application (kg ha^{-1})	At 30 DAS	At 45 DAS	At 60 DAS	At harvest
S_1– Control	1.04	2.69	5.29	6.00
S_2– 25 kg ha^{-1}	1.06	2.84	5.75	6.08
S_3– 50 kg ha^{-1}	1.07	2.87	5.82	6.11
S_4– 75 kg ha^{-1}	1.08	2.92	6.43	7.53
S_5– 100 kg ha^{-1}	1.09	2.95	6.51	7.92
S.Em ±	0.02	0.07	0.11	0.14
CD (P=0.05)	NS	NS	0.32	0.41
Foliar application (%)*				
F_1– Control	1.04	2.74	5.66	6.20
F_2– 1 %	1.06	2.83	5.95	6.30
F_3– 2 %	1.08	2.93	5.99	6.50
F_4– 3 %	1.09	2.92	6.24	7.91
S.Em ±	0.02	0.08	0.12	0.16
CD (P=0.05)	NS	NS	0.36	0.46

*Applied at flowering initiation & 15 days after flowering

Table 3: Effect of soil & foliar application of silicon on shoot length in blackgram

Treatment	Shoot length (cm)			
Soil application (kg ha⁻¹)	**At 30 DAS**	**AT 45 DAS**	**AT 60 DAS**	**At harvest**
S_1– Control	26.12	46.29	53.92	56.43
S_2– 25 kg ha^{-1}	27.17	47.01	55.69	57.22
S_3– 50 kg ha^{-1}	28.91	47.89	56.00	59.52
S_4– 75 kg ha^{-1}	30.16	49.79	59.89	65.19
S_5– 100 kg ha^{-1}	31.05	50.40	60.01	66.23
S.Em ±	1.14	0.82	1.08	1.93
CD (P=0.05)	NS	2.34	3.09	5.52
Foliar application (%)*				
F_1– Control	28.25	45.70	55.15	56.00
F_2– 1 %	27.82	47.14	56.19	56.89
F_3– 2 %	28.80	49.92	56.35	63.30
F_4– 3 %	29.86	50.33	60.72	66.21
S.Em ±	1.27	0.91	1.21	2.16
CD (P=0.05)	NS	2.61	3.46	6.18

*Applied at flowering initiation & 15 days after flowering

Table 4: Effect of soil & foliar application of silicon on root length and number of nodules plant⁻¹at flower initiation in Blackgram

Treatments	Root length (cm)				Number of nodules(plant⁻¹) at flower initiation
Soil application (kg ha⁻¹)	**At 30 DAS**	**At 45 Das**	**At60 DAS**	**At Harvest**	
S_1– Control	10.13	14.86	19.19	19.57	56.33
S_2– 25 kg ha^{-1}	10.44	15.71	20.12	20.93	59.11
S_3– 50 kg ha^{-1}	10.71	15.78	20.66	20.95	61.13
S_4– 75 kg ha^{-1}	10.84	16.46	22.33	22.39	62.56
S_5– 100 kg ha^{-1}	11.29	17.11	23.22	23.36	66.13
S.Em ±	0.251	0.394	0.610	0.554	1.56
CD (P=0.05)	NS	1.128	1.747	1.585	4.46
Foliar application (%)*					
F_1– Control	10.53	15.36	20.17	20.20	60.23
F_2– 1 %	10.70	15.55	20.49	20.91	60.47
F_3– 2 %	10.74	15.78	21.03	21.82	62.06
F_4– 3 %	10.76	17.24	22.73	22.84	61.45
S.Em ±	0.281	0.44	0.68	0.619	1.74
CD (P=0.05)	NS	1.261	1.953	1.772	NS

*Applied at flowering initiation & 15 days after flowering.

Yield attributes and yield

Soil application of silicon: Significantly higher number of pods per plant (22.99), number of seeds per pod (6.14) and 1000 grain weight (35.53 g) were recorded with soil application of silicon @ 100 kg ha^{-1}. Silicon as fertilizer, improved and enhanced the photosynthetic activity, density of grain by improving the translocation and accumulation of carbohydrates and other macro and micro molecules also increased in number of filled grains and influenced the biomass of grains, and ultimately grain weight increased. Similarly, significantly higher seeds yield (732.81 kg ha^{-1}), haulm yield (2201.82 kg ha^{-1}) and biological yield (2936.12 kg ha^{-1}) were recorded with soil application of silicon @ 100 kg ha^{-1}. A positive and significant correlation between seed yield and plant height at harvest (r=0.801**), dry matter accumulation at 60 DAS (r=0.646**), dry matter accumulation at harvest (r=0.646**), shoot length at 45 DAS (r=0.715**), shoot length at 60 DAS (r=0.668**), shoot length at harvest (r=0.636**), number of pods $plant^{-1}$ (r=0.843), number of seeds pod^{-1} (r=0.730**) and haulm yield (r= 0.785**). Jawahar *et al.* (2015) [8] reported that silicon is responsible to control stomatal activity, photosynthesis and water use efficiency which ultimately results in better vegetative and reproductive growth which ultimately increased the panicle weight in rice. Lavinsky *et al.* (2016) [10] mentioned silicon as a key player to enhance number of grains in rice. Prabhu *et al.* (2001) [17] reported 20%–40% increase in grain weight when silicon level was increased from 0 to 800 kg SiO_2 ha^{-2}. Dallagnol *et al.* (2014) [3] also mentioned a 12% increase in 1000-grain weight with application of silicon. The increase in both grain and straw yields might be attributed to the positive effect of silicon in increasing growth and yield characteristics (Prakash *et al.*, 2011) [18], (Pati *et al.*, 2016) [15], enhancing the pollen viability and photosynthetic activity (Detmann *et al.*, 2012) [5], reducing abiotic and biotic stress, improving structural support and biomass (Meharg and Meharg, 2015) [13] and improving nutrient uptake (Pati *et al.*, 2016; Crooks and Prentice, 2017) [15, 2]. Wattanapayapkul *et al.* (2011) [27] reported that due to application of silicon, grain yield was increased 19–43% and 2–14% over the control in two experiments. A positive and significant correlation between haulm yield and plant height at harvest (r=0.855**), dry matter accumulation at 60 DAS (r=0.775**), dry matter accumulation at harvest (r=0.738**), shoot length at 45 DAS (r= 0.817**), shoot length at 60 DAS (r= 0.751**), shoot length at harvest (r=0.704**) and number of pods $plant^{-1}$ (r= 0.810**).

Foliar application of silicon: Data presented in table 5.1 & 6.1 show that foliar application of silicon significantly increased growth attributes hence increased seed and haulm yield of blackgram. Number of pods per plant (23.36), number of seeds per pod (5.64) and 1000 grain weight (35.05 g) were recorded a significant increase with foliar application of silicon @ 3%. Foliar application of potassium silicate in reducing diseases & contributes to increase yield (Rodrigues *et al.*, 2009) [21]. Foliar application of silicic acid significantly increased the haulm (18.70 q ha^{-1}), pod (35.07 q ha^{-1}) and seed yield (21.76 q ha^{-1}) of soybean over control (Shwethakumari *et al.*, 2018) [24].

Table 5.1: Effect of soil & foliar application of silicon on yield attributes in blackgram

Treatments	No of pods plant⁻¹	No of seeds pod⁻¹	1000 seed weight (g)
Soil application (kg ha⁻¹)			
S_1– Control	19.01	4.12	31.21
S_2– 25 kg ha^{-1}	19.66	4.45	32.75
S_3– 50 kg ha^{-1}	20.78	5.14	32.90
S_4– 75 kg ha^{-1}	21.19	5.45	33.11
S_5– 100 kg ha^{-1}	22.99	6.14	35.53
S.Em ±	0.26	0.11	0.62
CD (P=0.05)	0.74	0.33	1.77
Foliar application (%)*			
F_1– Control	18.06	4.69	31.60
F_2– 1 %	19.92	4.91	32.02
F_3– 2 %	21.56	5.00	33.73
F_4– 3 %	23.36	5.64	35.05
S.Em ±	0.29	0.13	0.69
CD (P=0.05)	0.82	0.37	1.98

*Applied at flowering initiation & 15 days after flowering.

Table 5.2: Effect of interaction between soil application and foliar application of silicon on number of pods plant^{-1} of Blackgram

Treatments	Number of pods plant^{-1}						
Foliar application of silicon	**Soil application of silicon**	**Control**	**25 kg ha^{-1}**	**50 kg ha^{-1}**	**75 kg ha^{-1}**	**100 kg ha^{-1}**	**Mean**
	Control	16.99	17.45	17.70	17.95	20.22	18.06
	1% silicon	18.88	19.48	19.79	20.45	21.01	19.92
	2% silicon	20.03	20.59	20.67	21.12	25.38	21.56
	3% silicon	20.12	21.14	24.97	25.24	25.34	23.36
	Mean	19.01	19.66	20.78	21.19	22.99	
		S.Em±			CD		
	S	0.26			0.74		
	F	0.287			0.823		
	S X F	0.575			1.646		

Table 6.1: Effect of soil & foliar application of silicon on yield of Blackgram

Treatments	(kg ha^{-1})			Harvest index (%)
	Seed yield	**Haulm yield**	**Biological yield**	
Soil application (kg ha^{-1})				
S_1– Control	578.00	1629.62	2185.39	26.01
S_2– 25 kg ha^{-1}	642.89	1838.24	2462.79	25.65
S_3– 50 kg ha^{-1}	665.02	1925.65	2610.65	25.42
S_4– 75 kg ha^{-1}	701.60	2070.25	2788.90	25.34
S_5– 100 kg ha^{-1}	732.81	2201.82	2936.12	24.97
S.Em ±	15.53	47.42	43.581	0.26
CD (P=0.05)	44.47	135.75	124.770	NS
Foliar application (%)*		0.00		0.00
F_1– Control	585.12	1677.01	2292.33	26.08
F_2– 1 %	634.47	1879.32	2486.09	25.43
F_3– 2 %	707.22	2007.92	2704.77	25.38
F_4– 3 %	729.44	2168.21	2903.89	25.02
S.Em ±	17.37	53.01	48.725	0.29
CD (P=0.05)	49.72	151.78	139.497	NS

*Applied at flowering initiation & 15 days after flowering.

Table 6.2: Effect of interaction between soil application and foliar application of silicon on yield of Blackgram

Treatments	Seed yield (kg ha^{-1})						
Foliar application of silicon	**Soil application of silicon**	**Control**	**25 kg ha^{-1}**	**50 kg ha^{-1}**	**75 kg ha^{-1}**	**100 kg ha^{-1}**	**Mean**
	Control	542.99	617.63	624.68	594.18	546.14	585.12
	1% silicon	548.03	617.90	638.49	680.18	687.78	634.47
	2% silicon	553.59	666.05	669.42	742.43	904.60	707.22
	3% silicon	667.40	669.97	727.48	789.60	792.74	729.44
	Mean	578.00	642.89	665.02	701.60	732.81	
		S.Em ±			CD		
	S	15.534			44.474		
	F	17.368			49.723		
	S X F	34.736			99.446		

Economics

Soil application of silicon: Data (Table 7 & 8) reveal that soil application of silicon @ 100 kg ha^{-1} recorded highest net return (₹ 61242 ha^{-1}) and benefit cost ratio (1.92) of blackgram followed by a net return of (₹ 57458.12 ha^{-1}) & benefit cost ratio (1.82) with the application of 75 kg Si ha^{-1}.

Rao *et al.* (2018) [19] found that silicon application significantly influenced the economics of rice cultivation. Application of fine silica @ 50 kg ha^{-1} in combination with rice husk ash @ 250 kg ha^{-1} resulted in significant increase in the gross income (₹ 164470 ha^{-1}), net income (₹ 72503 ha^{-1}) and benefit cost ratio (1.78) ratio.

Table 7: Effect of interaction between soil application and foliar application of silicon on net return of Blackgram

Treatments	Net return						
Foliar application of silicon	**Soil application of silicon**	**Control**	**25 kg ha^{-1}**	**50 kg ha^{-1}**	**75 kg ha^{-1}**	**100 kg ha^{-1}**	**Mean**
	Control	38282.19	46201.02	46956.68	44195.61	38867.78	42900.65
	1% silicon	37378.14	48359.78	50058.22	54980.04	56314.80	49418.20
	2% silicon	41135.63	51892.40	54174.70	62431.67	80810.86	58089.05
	3% silicon	53407.38	55457.50	60851.05	68225.17	68974.65	61383.15
	Mean	42550.83	50477.67	53010.16	57458.12	61242.02	
		S.Em±			CD		
	S	1663.641			4762.880		
	F	1860.007			5325.062		
	S X F	3720.014			10650.124		

Table 8: Effect of interaction between soil application and foliar application of silicon on B:C of Blackgram

Treatments	B:C						
	Soil application of silicon	Control	25 kg ha $^{-1}$	50 kg ha $^{-1}$	75 kg ha $^{-1}$	100 kg ha $^{-1}$	Mean
Foliar application of silicon	Control	1.27	1.51	1.51	1.41	1.22	1.38
	1% silicon	1.23	1.58	1.61	1.75	1.77	1.59
	2% silicon	1.36	1.69	1.74	1.98	2.53	1.86
	3% silicon	1.76	1.80	1.95	2.16	2.15	1.96
	Mean	1.40	1.64	1.70	1.82	1.92	
		S.Em±			CD		
	S	0.054			0.156		
	F	0.061			0.174		
	S X F	0.122			0.349		

Foliar application of silicon: Data (Table 7 & 8) reveal that foliar application of silicon @ 3% recorded highest net return (₹ 61383 ha^{-1}) and benefit cost ratio (1.96) followed by a net return of (₹ 58089.05 ha^{-1}) and benefit cost ratio (1.86) with the foliar application of 2%. This might be attributed to the higher grain & haulm yield of blackgram with the foliar application of silicon.

Conclusion

On the basis of results of one-year experimentation and above findings this could be concluded that (i) soil application of silicon @ 100 kg ha^{-1} resulted into significantly higher seed yield (732.81 kg ha^{-1}) and net return (₹ 61242 ha^{-1}) in blackgram comparison to control and soil application of 25, 50 and 75 kg Si ha^{-1}. (ii) foliar application of silicon @ 3% gave highest seed yield (729.44 kg ha^{-1}) and net return (₹ 61383 ha^{-1}) of blackgram over control and foliar application of silicon @ 1 and 2%. However, these results are only indicative and require further experimentation to arrive at more and final conclusion.

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