Original Research Article

Effect of Iron and Silicon on growth and yield of Sorghum (*Sorghum bicolor* L.)

Abstract:

The Field experiment was conducted during *Zaid* season 2022 at experimental field of Crop Research Farm, Department of Agronomy, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj and Uttar Pradesh, India. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH7.3), low in organic carbon (0.48%), available nitrogen (230 kg/ha), available phosphorus (13.60 kg/ha) and available potassium (215.4 kg/ha). The treatments consist of Iron (0.5, 1.0, 1.5%) and Silicon (0.5ml/L, 1.0ml/L, 1.5ml/L) along with control. The experiment was layout in Randomized Block Design with ten treatments each replicated thrice. Highest Plant height (205.66 cm), maximum plant dry weight (133.24 g/plant) and the yield attributes namely test weight (25.82 g), grains per earhead (2368.33), grain yield (2850.00 Kg/ha), stover yield (4004.67 Kg/ha) was with treatment 9 [1.50% Iron and 1.50g/L Si]. Maximum gross return (84645.00 INR/ha), net return (52313.00 INR/ha) and benefit cost ratio (1.61) were also obtained highest in the treatment 9 [1.50% Iron and 1.50g/L Si].

Keywords:*Sorghum, Iron, Silicon, growth, yield and economics*

Comment [Ma1]: The abstract should include method of analysis of data collected from the experiment.

Comment [Ma2]: Two treatments (Iron and silicon were mentioned with three levels each. Explained what are the ten treatments in line with the two mentioned earlier.
Do same under Materials and Methods.

Introduction:

Sorghum (Sorghum bicolor) is the world's fifth most important cereal crop. It is grown as a rainfed crop over 42 million ha, mostly by subsistence farmers in the semi-arid tropics (SAT) of Africa, Asia, and Latin America. Sorghum grain is primarily consumed by humans in Asia and Africa, but it is also used as animal feed in the Americas, China, and Australia. In India, rainy season sorghum grain is primarily used for animal/poultry feed, whereas postrainy season sorghum grain is primarily used for human consumption. After grain harvest, crop residue (stover) is a valuable source of fodder and fuel in India and Africa. Because of its wide adaptation, rapid growth, high green and dry fodder yields with high ratoonability, and drought tolerance, sorghum has great potential to supplement fodder resources in India. Belum *et al.* (2004).

The sorghum area in Asia decreased from 23 million ha to 11 million ha between the early 1970s and 2007. However, production increased from 19 million t in the early 1970s to 21 million t in the late 1970s, but decreased thereafter to 11 million t in 2006. Yield has increased from 800 kg ha-1 in the early 1970s to 1,000 kg ha-1 in 2006. Belum *et al.* (2010).

Iron deficiency is a common nutritional disorder in many crop plants, resulting in poor yields and reduced nutritional quality. In plants, iron is involved in chlorophyll synthesis, and it is essential for the maintenance of chloroplast structure and function. The visual symptoms of inadequate iron nutrition in higher plants are interveinal chlorosis of young leaves and stunted root growth. Rout and Sahoo (2015).

The second most abundant element in soil is silicon (Si). Si occurs primarily in soil solution as monosilicic acid (H_4SiO_4) at concentrations ranging from 0.1 to 0.6 mm and is taken up by plants in this form. Silicon can mitigate the negative effects of abiotic stresses such as high temperature, freezing, drought, lodging, radiation, irradiation, and UV, as well as chemical stresses such as salt, nutrient imbalance, and metal toxicity. It has been reported that adding silicon to monocots, particularly Gramineae plants, promotes not only growth and development but also photosynthesis, reduces pest infestation, keeps the shoot upright, and alleviates salt stress. Lingayat *et al.* (2022).

Materials and Methods:

In order to study the two micronutrients with foliar spray, Iron and Silicon were taken. The experiment was conducted at during *Zaid* 2022 April, at Crop Research Farm, Naini Agricultural Institute, SHUATS, Prayagraj. The experimental site of the study is geographically located at 25.28^{o}N latitude, 81.54^{o}E longitude and

98 m altitude above the mean sea level (MSL). The soil of the experimental field constituting a part of central Gangetic alluvium is neutral and deep. Pre- sowing soil samples were taken from a depth of 15 cm with the help of an auger. The composite samples were used for the chemical and mechanical analysis.The treatments consist of foliar spray of two micronutrients Ironat (0.5, 1.0, 1.5%) and Silicon at (0.5, 1.0, 1.5 g/L)respectively. The experiment was laid out in randomized block design with ten treatments each replicated thrice and control i.e., recommended N, P and K (20:40:40 kg/ha).

Results and Discussions:

Growth parameters

Table.1Pertaining the details of effect of iron and silicon on growth attributes of sorghum.

Plant height (cm)

At 100 DAS, higher plant height (205.66 cm) was recorded significantly in the treatment9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment8 [Iron - 1.5% + Silicon - 1.0ml/L] was found to be statistically at far with treatment 9.

This might be due to involvement of zinc in biosynthesis of Indole 3-acetic acid, a growth hormone, involved in stem elongation, Similar results are obtained by Teja *et al.* (2020). Further with the application of silicon increased photosynthetic efficiency resulting in improving plant growth. Similar results are obtained by Choudhary *et al.* (2022).

Dry weight (g)

At 100 DAS, maximum plant dry weight (133.23 g) was recorded significantly in the treatment9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment 8 [Iron - 1.5% + Silicon - 1.0ml/L] was found to be statistically at far with treatment 9.

This might be due to iron application which has many important functions in plant growth and development, such as involvement in the biosynthesis of chlorophyll, respiration, chloroplast development and improves the performance of photosystems, which resulted in higher dry weight. Similar results are obtained by Hamzeh, M. R. and Florin, S. (2015).

Crop growth rate (g/m^2/day)

During 80-100DAS, Highest crop growth rate (62.88 g/m^2/day) was recorded significantly in the treatment8 [Iron - 1.5% + Silicon - 1.0ml/L]. However, treatment9 [Iron - 1.5% + Silicon - 1.5ml/L] was found to be statistically at far with treatment 8.

This might be due to iron role in starch formation and protein synthesis as well as maintenance and synthesis of chlorophyll in plants. The increased in the availability of iron to plant might have stimulated the

Comment [Ma3]: Let the reader know what in your study constitute the block and replications.

Comment [Ma4]: The table should referred to where figures/contents of the table are used for easy identification.

metabolic and enzymatic activities thereby increasing the growth of the crop. Similar results are obtained by (Vaja, R, P. *et al.* 2020). Further with the application of silicon, increased the synthesis of carbohydrates and that might have increased the sink size and capacity. Similar results are obtained by Lokadal. Aand Sreekanth. B (2018).

Yield attributes:

Table. 2 Pertaining the details of effect of iron and silicon on yield attributes and yield of sorghum.

Grains/earhead

At harvest, the data recorded more grains/earhead (2368.33) in treatment9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment8 [Iron - 1.5% + Silicon - 1.0ml/L] (2325.67) was statistically at par with treatment 9.

This might be due to application of iron, might have provided potential for many of the enzymatic transformations. Several of these enzymes are involved in chlorophyll synthesis and grain formation resulting in more grains/head. Similar results are obtained by Vaja*et al.* (2020).Furthur with the application of silicon resulted in carbohydratessynthesisfromphotosynthetic activity for longer period might have resulted in efficient translocation of food material into the sink (grain) thereby increased the number of filled grains percentage. Similar results are obtained by Lokadal. A and Sreekanth. B (2018).

Test weight (g)

At harvest, the data recorded higher test weight (25.82 g) in treatment9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment 8 [Iron - 1.5% + Silicon - 1.0ml/L] was statistically at par with treatment 9.

This might be due to silicon application might have improved and enhanced the photosynthetic activity resulting in higher 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. Similar results are obtained by Lokadal. A and Sreekanth. B (2018).

Grain yield (kg/ha)

At harvest, the data recorded higher grain yield (2850.00 kg/ha) in treatment 9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment8 [Iron - 1.5% + Silicon - 1.0ml/L] was statistically at par with treatment 9.

This might be due to iron application which is a structural component of porphyrin molecules, cytochromes, hemes, hematian, ferrichrome and leghemogloben. These substances are involved in oxidation-reduction reactions in respiration and photosynthesis. Similar results are obtained by Choudhary *et al.* (2015).Further silicon application might have increased photosynthetic activity of plant resulting in more formation of carbohydrates and more uptakes of other nutrients which resulted in higher grain yield. Similar results are obtained by Choudhary *et al.* (2022).

Stover yield (kg/ha)

At harvest, the data recorded higher stover yield (4004.67 kg/ha) in treatment 9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment8 [Iron - 1.5% + Silicon - 1.0ml/L] was statistically at par with treatment9.

This might be due to favourable effect of iron on the proliferation of roots and thereby increasing the uptake of the plants nutrients from the soil supplying in to the aerial parts of the plant and ultimately enhancing the vegetative growth of the plant. Similar results are obtained by (Rao, S. G.B. *et al.* 2019).Further with silicon application might have resulted in more utilization of solar radiation, moisture and nutrients since silicon provides more erectness to plant for efficient utilization of solar radiation resulting in better stover yield. Similar results are obtained by Singh *et al.* (2016).

Harvest index (%)

At harvest, the data recorded maximum harvest index (41.46 %) in treatment 9 [Iron - 1.5% + Silicon - 1.5ml/L]. However, treatment 8 [Iron - 1.5% + Silicon - 1.0ml/L] was statistically at par with treatment 9.

Economics:

Table. 3 Pertaining the details of effect of iron and silicon on economics of sorghum

Cost of cultivation (INR/ha)

Cost of cultivation (32332.00 INR/ha) was found to be highest in treatment no.9 [Iron - 1.5% + Silicon - 1.5ml/L] and minimum cost of cultivation (29720.00 INR/ha) was found to be in control.

Gross return (INR/ha)

Gross return (84645.00 INR/ha) was found to be highest in treatment no.9 [Iron - 1.5% + Silicon - 1.5ml/L] and minimum gross return (60885.00 INR/ha) was found to be in control.

Net return (INR/ha)

Net return (52313.00 INR/ha) was found to be highest in treatment no.9 [Iron - 1.5% + Silicon - 1.5ml/L] and minimum net return (31165.00 INR/ha) was found to be in control.

Benefit Cost ratio

The maximum Benefit cost ratio (1.61) was recordedin treatment no.9 [Iron - 1.5% + Silicon - 1.5ml/L] which was superior to rest of all treatment combinations.

This could be due to a significant increase in yield with increased supply of available iron and correction of hidden iron deficiency in plant or improved crop nutrition with foliar application of this nutrient. It provided maximum iron recovery with minimal expenditure. Similar results are obtained by Vaja*et al.* (2020).

CONCLUSION

From the observations, it was concluded that with the combination of Iron 1.50% and Silicon 1.50g/L in treatment no. 9 significantly recorded higher in all the growth and yield attributes and can be recommended to farmers.

Comment [Ma5]: There is no evidence from your analysis to justify "significantly higher" because statistical test was not carried out. The use of Randomized Complete Block Design (RCBD) model is suggested where treatment(s) can be identified as having significant effect or not at a certain level of significant.

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Table 1: Effect of iron and silicon on growth attributes of sorghum.

No.	Treatment combination	Plant height (cm)	Dry weight (g)	CGR ($g/m^2/day$)
1.	Iron - 0.5% + Silicon - 0.5ml/L	194.45	111.17	40.66
2.	Iron - 0.5% + Silicon - 1.0ml/L	196.27	112.89	42.11
3.	Iron - 0.5% + Silicon - 1.5ml/L	199.47	117.21	50.89
4.	Iron - 1.0% + Silicon - 0.5ml/L	198.56	116.35	46.94
5.	Iron - 1.0% + Silicon - 1.0ml/L	200.28	121.31	51.11
6.	Iron - 1.0% + Silicon - 1.5ml/L	203.30	127.92	58.34
7.	Iron - 1.5% + Silicon - 0.5ml/L	201.43	124.06	53.23
8.	Iron - 1.5% + Silicon - 1.0ml/L	204.97	131.87	62.88
9.	Iron - 1.5% + Silicon - 1.5ml/L	205.66	133.23	62.69
10.	Control (RDF: 80:40:40 NPK Kg/ha)	191.24	108.14	36.33
	F Tab (5%)	S	S	S
	SEm (±)	0.80	0.77	1.30
	CD (p=0.05%)	2.37	2.28	3.85

Table 2: Effect of iron and silicon on yield attributes of sorghum.

No.	Treatment combination	Grains/earhead	Test weight	Grain yield	Stover yield	Harvest Index
1.	Iron - 0.5% + Silicon - 0.5ml/L	1803.67	21.68	2205.00	3360.33	39.67
2.	Iron - 0.5% + Silicon - 1.0ml/L	1853.33	22.43	2274.00	3400.67	40.07
3.	Iron - 0.5% + Silicon - 1.5ml/L	1904.33	23.31	2396.00	3539.33	40.36
4.	Iron - 1.0% + Silicon - 0.5ml/L	1867.33	22.82	2330.00	3483.33	40.08
5.	Iron - 1.0% + Silicon - 1.0ml/L	1957.33	23.71	2410.00	3545.67	40.46
6.	Iron - 1.0% + Silicon - 1.5ml/L	2133.00	24.97	2560.00	3711.33	40.82
7.	Iron - 1.5% + Silicon - 0.5ml/L	1990.33	24.12	2480.00	3712.33	40.70
8.	Iron - 1.5% + Silicon - 1.0ml/L	2325.67	25.45	2745.00	3985.67	40.78
9.	Iron - 1.5% + Silicon - 1.5ml/L	2368.33	25.82	2850.00	4004.67	41.46
10.	Control (RDF: 80:40:40 NPK Kg/ha)	1749.67	20.87	2050.00	3176.33	39.22
	F Tab (5%)	S	S	S	S	S
	SEm (±)	15.27	0.13	12.27	6.49	0.13
	CD (p=0.05%)	45.36	0.39	36.45	19.29	0.40

Table 3:Effect of iron and silicon on yield attributes of sorghum.

Sl. No.	Treatment combination	Cost of cultivation	Gross return	Net returns	B C ratio
1.	Iron - 0.5% + Silicon - 0.5ml/L	30590.00	65488.50	34898.50	1.14
2.	Iron - 0.5% + Silicon - 1.0ml/L	30601.00	67537.80	36936.80	1.20
3.	Iron - 0.5% + Silicon - 1.5ml/L	30612.00	71161.20	40549.20	1.32
4.	Iron - 1.0% + Silicon - 0.5ml/L	31450.00	69201.00	37751.00	1.20
5.	Iron - 1.0% + Silicon - 1.0ml/L	31461.00	71577.00	40116.00	1.27
6.	Iron - 1.0% + Silicon - 1.5ml/L	31472.00	76032.00	44560.00	1.41
7.	Iron - 1.5% + Silicon - 0.5ml/L	32310.00	73656.00	41346.00	1.27
8.	Iron - 1.5% + Silicon - 1.0ml/L	32321.00	81526.50	49205.50	1.52
9.	Iron - 1.5% + Silicon - 1.5ml/L	32332.00	84645.00	52313.00	1.61
10.	Control (RDF: 80:40:40 NPK Kg/ha)	29720.00	60885.00	31165.00	1.04