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Effect of Iron and Silicon on Growth and Yield of Sorghum (*Sorghum bicolor* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study highlights the effect of Iron and Silicon on growth and yield of Sorghum (*Sorghum bicolor* L.). Si occurs primarily in soil solution as monosilicic acid (H4SiO4) 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. A field experiment was conducted during *Zaid* season 2022 at experimental field of Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India. The soil at the test site had a sandy loam texture, a pH of 7.3 that was almost neutral, and low levels of available potassium (215.4 kg/ha), nitrogen (230 kg/ha), phosphorus (13.60 kg/ha), and organic carbon (0.48%). The treatments consist of foliar spray of iron (0.5, 1.0, 1.5 %) at 35, 45

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DAS and Foliar spray of Silicon (0.5, 1.0, 1.5 ml/L) at 50 DAS along with control (RDF: 80:40:40 NPK Kg/ha). The experiment was layout in Randomized Block Design with ten treatments each replicated thrice. Significantly higher plant height (205.66 cm), maximum plant dry weight (133.2 g) and the yield attributes namely test weight (25.82 g), grains/earhead (2368.33), grain yield (2850.00 Kg/ha), stover yield (4004.67 Kg/ha), maximum gross return (84645.00 INR/ha), net return (52313.00 INR/ha) and benefit cost ratio (1.61) were obtained in the treatment 9 with the application of 1.50% Iron along with 1.50ml/L Si.

Keywords: Sorghum; iron; silicon; growth; yield and economics.

1. 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. [1].

"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. [2].

"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 [3].

"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. [4].

2. 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 foliar spray of iron (0.5, 1.0, 1.5 %) at 34, 45DAS and foliar spray of silicon (0.5, 1.0, 1.5 g/L) at 50DAS respectively. The experiment was laid out in randomized block design with ten treatments each replicated thrice along with control i.e., recommended N, P and K (80:40:40 kg/ha).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

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

3.1.1 Plant Height (cm)

At 100 DAS, higher plant height (205.66 cm) was recorded significantly in the treatment 9 [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 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. [5]. Further with the application of silicon increased photosynthetic efficiency resulting in improving plant growth. Similar results are obtained by Choudhary et al. [6].

3.1.2 Dry weight (g)

At 100 DAS, maximum plant dry weight (133.23 g) was recorded significantly in the treatment 9 [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. [7].

3.1.3 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 treatment 8 [Iron - 1.5% + Silicon - 1.0ml/L]. However, treatment 9 [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 metabolic and enzymatic activities thereby increasing the growth of the crop. Similar results are obtained by Vaja, RP. et al. [8]. 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 A and Sreekanth B [9].

Yield attributes: Table 2 pertaining the details of effect of iron and silicon on yield attributes and yield of sorghum.

3.1.4 Grains/earhead

At harvest, the data recorded more grains/earhead (2368.33) in treatment 9 [Iron - 1.5% + Silicon - 1.5 ml/L]. However, treatment 8 [Iron - 1.5% + Silicon - 1.0 ml/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. [8]. Furthur with the application of silicon resulted in carbohydrates synthesis from photosynthetic 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 [9].

3.1.5 Test weight (g)

At harvest, the data recorded higher test weight (25.82 g) in treatment 9 [Iron - 1.5% + Silicon - 1.5 ml/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 [9].

3.1.6 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, treatment 8 [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. [10]. 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.

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

S. 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 and yield of sorghum

S. No.	Treatment combination	Grains/earhead	Test weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	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

S. No.	Treatment combination	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net returns (INR/ha)	B C ratio (INR/ha)
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

Similar results are obtained by Choudhary et al. [10].

3.1.7 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, treatment 8 [Iron - 1.5% + Silicon - 1.0ml/L] was statistically at par with treatment 9.

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. [11]. 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. [12].

3.1.8 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.

3.1.9 Economics

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

3.1.10 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.

3.1.11 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.

3.1.12 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.

3.1.13 Benefit cost ratio (B:C)

The maximum Benefit cost ratio (1.61) was recorded in treatment no.9 [Iron - 1.5% + Silicon - 1.5 ml/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. [7].

4. 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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