

Original Research Article

<https://doi.org/10.20546/ijcmas.2020.911.034>

Performance of Wheat (*Triticum aestivum* L.) under Varying Levels of Silicon and Restricted Irrigation

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ABSTRACT

A field experiment was conducted during *rabi* season 2019-20 at Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan), to evaluate the effect of different irrigation and silicon levels on wheat productivity. Results revealed that three irrigations given to wheat crop improved growth characters *viz.*, plant height (45.42, 80.71 cm) at 50 and 75 DAS, dry matter accumulation (27.49 g) at 50 DAS as compare to other treatments. Days to 50 per cent heading (73.25) and maturity (107.33) also increase with three irrigations but statistically non significant with two irrigations. Advanced performance of yield attributes with three irrigations resulted in significant increased in grain yield (4297 kg ha⁻¹) and harvest index (38.92 %), it reflected economics of crop and the highest net return (₹ 67180 ha⁻¹) and B- C ratio (1.99) were obtained. Amongst different levels of silicon, 200 kg ha⁻¹ increased plant height, dry matter accumulation, days to 50 per cent heading and maturity but statistically non significant with 150 kg ha⁻¹. Increasing levels of silicon up to 200 kg ha⁻¹ also improved yield attributes *i.e.*, effective tillers (43.28 0.5 m row length), grains ear⁻¹ (42.75), weight of grains ear⁻¹ (1.76 g), ear length (7.34 cm) and test weight (40.79 g) compare to control. The maximum grain yield (3824 kg ha⁻¹), harvest index (37.30 %) and economics *i.e.*, net return (₹ 58770 ha⁻¹) and B-C ratio (1.79) were obtained under silicon 200 kg ha⁻¹ which was statistically at par with 150 kg ha⁻¹ but superior over rest of treatments.

Keywords

Irrigation, Silicon,
Yield and
Economics

Article Info

Accepted:

04 October 2020

Available Online:

10 November 2020

Introduction

Wheat (*Triticum aestivum* L.) is universally known as 'King of cereals' because of its wider adaptability & elevated productivity and such crop supply food in the form of groceries and nutrition for more than 60 per cent of the world's population. In India, it ranked second than rice in terms of its importance and role in food security. After

green revolution (1965-66), this crop has been contributed significantly towards country's success in food sufficiency. In global level, wheat also ranked second after rice crop in food grain production and it was grown in 220.4 million hectare area with the production of 768.49 million tonnes (FAOSTAT, 2020). With respect to global wheat production, India stands second position after China. In India wheat grown on 30.55 million

hectare area with production of 107.18 million tonnes and productivity 3508 kg ha⁻¹. In India, Rajasthan state takes fifth position in wheat production after Uttar Pradesh, Madhya Pradesh, Punjab and Haryana. In Rajasthan, it is cultivated in 3.20 million hectare area with the production of 10.57 million tonnes and having productivity of 3501 kg ha⁻¹ (IIWBR 2019-20).

Silicon (Si) is a chemical element having an atomic number of 14. It is a hard and brittle crystalline solid with a blue-grey metallic luster. Si is the second most abundant element both on surface of especially earth's crust and in the soil after oxygen. The earth's crust constitutes 27.72 per cent of silicon. The beneficial effects of Si are particularly distinct in plants exposed to abiotic and biotic stresses (Liang *et al.*, 2007). Si can increase plants capabilities stand with water stress because it decreasing the rate of transpiration process. Transpiration from the leaves mainly occurs through the stomata and partly through the cuticle of the leaves forming a silicon-cuticle double layer, the transpiration through cuticle may decrease due to silica deposition (Ma, 2004). Excess accumulation of Si within plant and soil does not damage the plants and it will be required for healthy plant growth and stable production. For this reason, Si has been recognized as an "agronomically essential element" in Japan and silicate fertilizers have been applied to paddy soils (Ma *et al.*, 2001).

Water given to the plants by artificial means is one of the very important practices to obtain higher productivity. Adequate soil moisture is required for proper development in terms of vegetative and reproductive growth of the plant. In India about 90 per cent area of wheat under irrigated conditions, generally four to six irrigations are required for maximizing wheat yield under clay-loam soil. Irrigation recommended for wheat crop in accordance to their critical stages are

namely at crown root initiation (21 DAS), tillering stage (40-45 DAS), jointing (60-65 DAS), flowering (80-85 DAS), milking (100-105 DAS) and dough stage (115-120 DAS). Irrigation given at crown root initiation stage is very important for successful growth of wheat and it has a great impact on higher grain yield (Randhawa *et al.*, 2004). Water supplied at booting to heading stages promoted both spike and grain development (Zhang-Xucheng *et al.*, 2011). Wheat yields are reduced by 50-90 per cent due to reduction of irrigation sources in the developing world (Devi *et al.*, 2012).

Materials and Methods

The experiment was conducted during *rabi* season of 2019-20, at the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, which is situated at 74° 42' E longitude, 24° 35' N latitude and 582.17 metre of height above mean sea level. The region falls under NARP agro-climatic zone IVa of Rajasthan *i.e.* Sub-Humid Southern Plains and Aravalli Hills. Udaipur zone possesses a typical sub-tropical climatic conditions characterized by mild winters and moderate summers associated with high relative humidity during the rainy season. The average rainfall of udaipur is 637 mm, out of this (80-85 %) is received through south-west monsoon during July to early September.

The experimental site soil was clay-loam and pH 7.75 which was slightly alkaline. However, experimental soil was medium in organic carbon (0.66 %), available nitrogen (286.5 kg ha⁻¹) and available phosphorus (21.6kg ha⁻¹). Whereas, availability of potassium in soil was high *i.e.*, 369.7kg ha⁻¹. The experiment was laid out in split plot with four irrigation levels (I₁: no irrigation, I₂: one irrigation at CRI, I₃: two irrigation at CRI and booting stage and I₄: three irrigation at CRI,

booting and milking stage) and four silicon levels (S₁: control, S₂: 100 kg ha⁻¹, S₃: 150 kg ha⁻¹ and S₄: 200 kg ha⁻¹), assigned respectively to main and sub plots and those were replicated three times. The seed rate of wheat was 100 kg ha⁻¹ seed.

The wheat variety “MP 3336” was sown during second week of November. The recommended dose of nitrogen, phosphorous and potash was 90 -60-40 kg ha⁻¹, respectively, which was applied through urea, DAP and MOP. During the season one third quantity of total nitrogen and whole amount of phosphorous and potash were applied as basal at sowing, while remaining quantity of nitrogen was applied in two split of equal quantity at first and second irrigation.

For total dry matter accumulation, plant samples were oven dried at the temperature of 70°C to achieve constant weight. Thereafter, the samples were weighed for computing the dry weight (g) of plants (0.5 m⁻¹ row length). The yield attributes were estimated by selecting five plants from each experimental plot, leaving the two border rows on the rows direction and half metre on opposite direction of the plot of wheat. Were harvested manually with stickles.

The produce was kept for sun drying in field for some days and after drying the biological yield was recorded and expressed in kg ha⁻¹. After threshing the bundles from each plot, the grains were cleaned, dried and weighed. The grain yield was expressed in kg ha⁻¹.

Harvest index was calculated by dividing the economic yield (grain yield) to the biological yield and expressed in percentage as suggested by Donald and Hamblin (1976).

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Results and Discussion

Growth

Irrigation levels had significant effect on plant height, dry matter accumulation at 50 to 75 DAS and days to 50 per cent heading and maturity (Table 1). The maximum plant height was recorded at 50 DAS (45.42 cm) and at 75 DAS (80.71 cm) was recorded under three irrigations which was statistically at par with one and two irrigations but significantly superior over the control. The maximum dry matter accumulation at 50 DAS (27.49 g) had recorded under three irrigations which was statistically at par with one and two irrigations but statistically higher over control. At 75 DAS the highest dry matter accumulation (74.83 g) was recorded under two irrigations, it was statistically at par with one and three irrigations but significantly superior over control. The maximum days to 50 per cent heading (73.25) and maturity (107.33) was recorded under three irrigations, it was statistically at par with two irrigations but significantly superior over control and one irrigation, respectively. Water is an elementary constituent of plant protoplasm and their adequate supplies enhance cell division and as well as cell elongation. Therefore, optimum availability of water with three irrigations to wheat might have improved the photosynthetic area of plants that cumulatively contributed to higher plant height and dry matter accumulation. The result of this study are in close conformity by Kharrou *et al.*, (2011), Sarwar *et al.*, (2010) and Mer *et al.*, (2014).

The application of silicon 200 kg ha⁻¹ was recorded the maximum plant height (43.75, 76.18 cm) and dry matter accumulation (25.38, 72.42 g) at 50 to 75 DAS, which was statistically at par with silicon 150 kg ha⁻¹ and silicon 100 kg ha⁻¹ but significantly superior over the control (Table 1).

Table.1 Effect of irrigation and silicon levels on plant height, dry matter accumulation (g) and days to 50 per cent heading

Treatments	Plant height (cm)		Dry matter accumulation (g)		Days to 50 % heading	Days to 50 % maturity
	50 DAS	75 DAS	50 DAS	75 DAS		
Irrigation levels						
No irrigation	33.22	61.50	18.76	55.92	61.50	91.17
One irrigation	43.54	71.08	25.28	73.83	71.08	99.58
Two irrigation	45.02	72.58	26.46	74.83	72.58	104.00
Three irrigation	45.42	73.25	27.49	74.25	73.25	107.33
SEm±	0.91	0.48	0.73	1.77	0.48	1.22
CD (P=0.05)	3.15	1.65	2.52	6.12	1.65	4.23
Silicon levels						
Control	39.50	67.75	23.09	65.33	67.75	99.58
100 kg ha ⁻¹	41.78	69.17	24.45	69.83	69.17	99.17
150 kg ha ⁻¹	42.17	70.42	25.07	71.25	70.42	101.50
200 kg ha ⁻¹	43.75	71.08	25.38	72.42	71.08	101.83
SEm±	0.60	0.33	0.56	1.74	0.33	0.78
CD (P=0.05)	1.74	0.96	1.63	5.08	0.96	NS

Table.2 Effect of irrigation and silicon levels on yield attributes of wheat crop

Treatments	Yield attributes				
	Effective tillers (0.5 m row length)	Grains ear ⁻¹	Weight of grains ear ⁻¹ (g)	Ear length (cm)	Test weight (g)
Irrigation levels					
No irrigation	31.14	33.25	1.28	6.65	37.33
One irrigation	43.33	42.25	1.67	7.15	39.54
Two irrigation	45.09	43.33	1.78	7.38	41.04
Three irrigation	47.46	44.92	1.88	7.69	41.89
SEm±	0.67	0.78	0.03	0.20	0.49
CD (P=0.05)	2.33	2.69	0.09	0.67	1.70
Silicon levels					
Control	39.77	39.83	1.54	7.18	38.12
100 kg ha ⁻¹	41.33	40.33	1.64	7.20	40.35
150 kg ha ⁻¹	42.66	40.83	1.67	7.15	40.55
200 kg ha ⁻¹	43.28	42.75	1.76	7.34	40.79
SEm±	0.59	0.57	0.02	0.12	0.39
CD (P=0.05)	1.73	1.66	0.07	NS	1.15

Table.3 Effect of irrigation and silicon levels on grain yield, harvest index and economics

Treatments	Grain yield (kg ha ⁻¹)	Harvest index (%)	Economics	
			Net return (₹ ha ⁻¹)	B- C ratio
Irrigation levels				
No irrigation	2195	32.37	26066	0.88
One irrigation	3398	34.80	52529	1.70
Two irrigation	3860	35.91	61241	1.89
Three irrigation	4297	38.92	67180	1.99
SEm±	94.74	0.94	1526.30	0.05
CD (P=0.05)	327.84	3.25	5281.71	0.17
Silicon levels				
Control	3004	33.39	43959	1.43
100 kg ha⁻¹	3262	34.81	48345	1.52
150 kg ha⁻¹	3659	36.50	55942	1.73
200 kg ha⁻¹	3824	37.30	58770	1.79
SEm±	88.43	0.66	1601.06	0.05
CD (P=0.05)	258.10	1.93	4673.17	0.15

The maximum days to 50 per cent heading (71.08) was obtained with application of silicon 200 kg ha⁻¹, which was statistically at par with silicon 150 kg ha⁻¹ and but significantly superior over the control and silicon 100 kg ha⁻¹. Days to 50 per cent maturity was found non-significant due to different doses of silicon. Different studies have shown that silicon application affects crop growth, plant metabolism and physiology. In terms of plant height, deposition of silicon in cell wall can make the leaves and stems more erect and increase plant height even under drought conditions. Increase plant height can be attributed towards increased cell division and elongation caused by silicon. This finding is supported by Abro *et al.*, (2009), Ma (2004) and Jaleel *et al.*, (2009).

Yield attributes

The analysis of variance of data indicated that irrigation levels had significant effect on yield attributes of wheat *viz.*, number of effective tillers (0.5 m row length), grains ear⁻¹, weight of grains ear⁻¹ (g), ear length (cm) and test weight (g) (Table 2). The maximum number of effective tillers (47.46), grains ear⁻¹ (44.92), weight of grains ear⁻¹ (1.88), ear length (7.69 cm) and test weight (41.89 g) were registered under three irrigations. Whereas minimum number of effective tillers (31.14), grains ear⁻¹ (33.25), weight of grains ear⁻¹ (1.28), ear length (6.65 cm) and test weight (37.33 g) were registered under no irrigation. The application of three irrigations to wheat crop facilitates sufficient soil moisture for higher growth and development of the plants which enhanced photosynthetic efficiency by improving source-sink relationship of the plants leading higher growth and development reflected by higher yield attributes of plants. These findings were in accordance with Mubeen *et al.*, (2013) and Ali *et al.*, (2012).

The application of silicon 200 kg ha⁻¹ was recorded the maximum number of effective tillers 0.5 m row length (43.28), grains ear⁻¹ (42.75), weight of grains ear⁻¹ (1.76 g) and test weight (40.79 g) compare to other silicon levels. The application of silicon 200 kg ha⁻¹ enhanced the number of effective tillers by 9.43, 1.54 per cent, grains ear⁻¹ 7.33, 6.00 per cent, weight of grains ear⁻¹ 14.28, 7.31 per cent and test weight 7.00, 1.09 per cent over control and silicon 100 kg ha⁻¹. Ear length was not significantly affected owing of different silicon doses (Table 2) Silicon had many positive effects on the plant physiology and metabolism of the crop. Increase in yield attributes of wheat due to silicon application might be due to higher photosynthetic activity of plant, much more uptake of nutrients resulted enhance carbohydrate. Gholami and Falah, (2013) Wattanapayapkul *et al.*, (2011) have confirmed the similar findings.

Yield

The grain yield of wheat was influenced significantly by various levels of irrigation (Table 3). Grain yield increased significantly with increase in number of irrigations. The maximum grain yield (4297 kg ha⁻¹) of wheat was recorded with three irrigations, which was significantly superior over control one and two irrigations. The magnitude of increase in grain yield with application of three irrigations was 95.76, 26.45 and 11.32 per cent over control, one and two irrigations, respectively. The maximum harvest index recorded (38.92 %) with the three irrigations, it was statistically at par with two irrigations but significantly superior over control and one irrigation. The magnitudes of increase in B-C ratio with application three irrigations were 20.23 and 11.83 per cent over control and one irrigation, respectively. The higher grain yield and harvest index of wheat with three irrigations attributed can be to advance photosynthetic activity of plants owing to

optimum soil moisture for all the metabolic activities which leads to greater cell division, elongation resulted improve plant growth and development.

These results are in conformity with the findings of Yadav *et al.*, (2010) and Rahim *et al.*, (2010).

In case of silicon the maximum grain yield (3824 kg ha⁻¹) and harvest index (37.30 %) were recorded under application of silicon 200 kg ha⁻¹, it was statistically at par with silicon 150 kg ha⁻¹ but significantly superior over control and silicon 100 kg ha⁻¹. The increase in grain yield and harvest index of wheat might be attributed to the increase in growth and yield characteristics of wheat and also to the stimulating effect of silicon in reducing biotic and abiotic stress. Silicon application may enhance crop yield by several indirect action such as decreased shading due to greater leaf erectness. Erectness of leaves as a result of silicon fertilization could account for about 10 per cent in the photosynthesis, thereby indirectly increasing yield. Similar results were also noticed by Marschner *et al.*, (1988), Ma and Takahashi (1993) and Sorrato *et al.*, (2012).

Economics

Among the different irrigation levels, the maximum net return (₹ 67180 ha⁻¹) and B-C ratio (1.99) were recorded with the application of three irrigations. Whereas minimum value of net return (₹ 26066 ha⁻¹) and B-C ratio (0.97). The higher crop productivity might be the principal reason for higher net returns with application of three irrigations compared to other treatments. Similar results of higher farm profitability were also reported by Parihar *et al.*, (2003).

Application of silicon 200 kg ha⁻¹ was recorded maximum net return (₹ 58770 ha⁻¹)

and B-C ratio (1.79), it was at par with silicon 150 kg ha⁻¹ but statistically higher over silicon 100 kg ha⁻¹ and control. Silicon might be improve crop growth and yield characters along with make active photosynthetic activities and source- sink relationship which directly govern yield of crop (Table 3). Similar findings were observed by Sorrato *et al.*, (2012).

On the basis of one year investigation, it can be concluded that, maximum grain yield (4297 kg ha⁻¹), net return (₹ 67180 ha⁻¹) and B- C ratio (1.99) was obtained with three irrigation levels and in case of silicon application maximum grain yield (3824 kg ha⁻¹), net return (₹ 58770 ha⁻¹) and B- C ratio (1.79) was recorded under 200 kg ha⁻¹ compared to other treatments. However, B-C ratio was statistically at par in two and three irrigation levels and silicon doses *viz.*, 200 and 150 kg ha⁻¹ and also remained non significant with each other. Hence, two irrigations with the application of 150 kg ha⁻¹ silicon were proved economically viable in wheat crop under restricted irrigation conditions.

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How to cite this article:

Rajaram Sharma, J. Choudhary D. Singh, S. C. Meena and Vijay Kumar. 2020. Performance of Wheat (*Triticum aestivum* L.) under Varying Levels of Silicon and Restricted Irrigation. *Int.J.Curr.Microbiol.App.Sci.* 9(11): 285-293. doi: <https://doi.org/10.20546/ijemas.2020.911.034>