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Influence of Silicon Fertilization on the Growth, Yield, and Physical Properties of Bread Wheat Planted in Nubaria Soil

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Abstract

Two field experiments were conducted at the Experimental Station of National Research Centre, Nubaria District,EL-Behira Governorate, Egypt during two successive winter seasons 2021/2022- 2022/2023 to study the effect of two source of silicon (silicon sulphate and silicic acid) on growth and grain yield of two varieties of wheat crop i.e. Misr-1 and Gemiza-9. Generally, there was a physiological improvement in the tested varieties as a result of nutritional balance by spraying source of silicon which was reflected in the characteristics of growth and grain yield compared the control. There were no significant changes ($P \leq 0.05$) on the physical characteristics of wheat grains, except for the 1000-kernl weight it was significantly increased in both wheat varieties Misr-1 and Gemiza-9 with Silicon Sulphate 300ppm. It was observed that Gemiza-9 is superior to Misr-1. In majority of characteristics. In addition, acid at rate 100 ppm with Gemiza-9 wheat variety had a great effect with all growth parameters and yield characteristics.

Keywords: Triticum, Silicon Sulphate, Silicic Acid, Agronomy, Physical characteristics

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1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important crop plants worldwide with annual production of about 765 million metric tons [1]. There is an estimated annual loss of 12 billion US dollars to the world economy due to salinity, and it is still on rise [2]. There are several strategies to increase wheat production in the salt-affected areas such as direct leaching of salts, improving the surface, subsurface and vertical drainage systems of the soil and planting salt tolerant varieties. In Egypt, almost 35% of the agricultural land suffers from salinity [3]. The Egyptian government is exerting great efforts to increase agricultural land through establishing national projects to reclaim and cultivate new lands. Salinity of soil and irrigation water is among the biggest challenges facing cultivation in the new lands. Progress in breeding cereal cultivars with salinity tolerance is slow [4]. This is often attributed to the genetic and physiological complexities of the salt tolerance trait and lack of a reliable and rapid screening assay [5]. Therefore, the Egyptian wheat breeders should evaluate and characterize the bread wheat cultivars to salinity tolerance for salt affected and newly reclaimed soils. Zhang *et al.* (2015), who have found that straw incorporation increased grain yield and biomass yield [6]. Therefore, the application of Si with straw return should be considered an essential practice in maize farming for improving yield and promoting sustainable soil systems. Singh *et al.*, (2006) suggested that the increased dry matter and yield in rice. The indirect effects of silicon also cause increase in growth and yield in Cereals. Ma & Takahashi (1990) concluded that there is a high phosphate uptake in rice with silicon application which directly correlates the increased growth and yield [7,25]. Mukkram *et al.*, (2006) found that silicon increased growth and yield due to decreased Na^+ uptake in wheat under salt stress.

Since germination remains un-affected even under usual stress conditions because the seed itself has enough nutrients to germinate. Silicon is applied in the form of silicates, e.g. potassium silicate and sodium silicate as drenches or foliar applications, and it can be also added to medium mixtures, e.g. in the form of rice husk ash [8]. Si is translocated to the shoot via the xylem. Chemically, silicic acid polymerizes to form silica gel (SiO_2_nH_2O) when the concentration of silicic acid exceeds 2 mM. However, the concentration of Si in the xylem sap is usually much higher than 2 mM in rice and wheat, even though the major form of Si in the xylem has been identified as monomeric acid in these plant species [9]. Therefore, the present investigation aimed to study the effect of silicate fertilizers as foliar application on productivity and quality of wheat under sand soils to study the effect of some silicon source on growth, yield maximizing and quality parameters of Wheat crop.

2. Materials and methods

A field experiment was conducted in two winter season of 2021/2022 and 2022/2023 in the experimental station of Nubaria district, EL-Behira Governorate, Egypt to find out the effect of two source of silicon (Silicon Sulphate and *Silicic Acid*) as fertilizers on growth, yield and quality on growth and quality of two wheat varieties (Misr-1 and *Gemiza*-9). A representative soil sample was taken from the experimental site at the depth of 0 0-30 cm before planting to analysis of physical and chemical characteristics (Table 1).

2.1. Experimental design

The experiment site consisted of 48 plots in both growing seasons. The size of each plot was 6m^2 (3m^2 length x 2 m^2 width. Each plot represents one replicate of each treatment, which means 3 plots for each treatment, making a number of 48 plots of all. The experimental design was a split plot with three replications treatment. The varieties (Misr-1and Gemmayzeh-9) occupied the main plots and foliar application treatments Such as; Silicon Sulphate, Sylclic acids engrossed of sub plot. The experiment included 16 treatments included:

- Control by addition of recommended dose fertilizers (RDF) of Nitrogen, Phosphorus and Potassium.
- Three levels of foliar Silicon Sulphate at a rate of (50, 100 and 150 ppm) at two equal doses after 35,60 and 85 days from sowing. Three levels of foliar Silicic Acid at a rate of (150,300 and 450 ppm) at two equal doses after 35,60 and 85 days from sowing.
- The studied characters were the plant height (cm), spike length per plant (cm), number of spikes per plant, biological yield per plant, grains yield per plant (ton/fed).and spike weight (g/spike), Hectolitre (HL, Kg/L); thousand kernel weight (1000-KWT), cleanness (%), Width (mm), and Length (mm). The moisture (%) of the wheat grains was measured using the Hydromette G 86, GANN Model, Western Germany.

2.2. Color measurement of wheat grains

The color of wheat grains was measured in triplicate using a colorimeter (CR-400, Konica Minolta Sensing Inc., Japan). The color values were recorded as L^* = lightness (0 = black, 100 = white), a^* ($-a^*$ = greenness, $+a^*$ = redness), and b^* ($-b^*$ = blueness, $+b^*$ = yellowness).

2.3. Soil analysis

- Soil reaction (pH): Soil pH was determined in (1:2.5) soil water suspension using pH meter with glass electrode [10].
- EC (dSm^{-1}): was determined in the supernatant solution (1:5) soil water suspension using digital conductivity bridge [10].
- Organic matter (%): was determined by walkely and Blacks as described by Cottenie *et al*., (1982) [10-11].
- Particle size distribution: soil was determined by International Pipette Method as outlined by Piper, (1966).
- Soluble-Cations and Anions: A-Soluble Cations (Na, K, Ca and Mg) and anions (CO_3, HCO_3, CL and SO_4) were determined in (1:5) soil water extract by Black *et al*., (1965) [11].
- Nitrogen was extracted using KCL Jackson, (1973) [12].
- Phosphorus was extracted using Na_2HCO_3 (Olsen *et al*., 1954).
- Sodium and potassium were determined by flame photometer as described by Cottenie *et al*., (1982) [10].

2.4. Statistical analysis

The obtained data for the two seasons were computed according to Snedecor and Cochran (1980).

3. Results and Discussions

Plant Height (cm), Spike Length/Plant and Number of Spikes/Plant: The obtained data for wheat varieties in both seasons are shown in Table 4.

3.1. Influence of Silicon Sulphate rates

Concerning the effect of silicon application on growth of the wheat varieties, Table 4 presented the effect of foliar application different rates of silicon sulphate on plant height (cm), Spike length/plant and amount of spikes/plant in wheat varieties in both seasons (2021/2022) and (2022/2023). It was observed that, foliar application of silicon sulphate at a rate of 300 ppm increased the plant height by about 15.49, 18.05% and 8.52, 12.04% as compared with the control for wheat cultivars (Misr-1 and Gemiza-9) in both two seasons, respectively. Also, data revealed that the spraying of silicon sulphate at a rate of 450 ppm significantly increased the plant height by (10.36, 12.04%) and (5.44, 18.05%) as compared with the control in varieties of wheat (Misr-1 and Gemiza-9) in both two seasons, respectively. Data showed that the effect of silicon sulphate 350 ppm on spike length/plant of wheat under sandy soil, where application of 100 ppm of silicic acid significantly increased the spike length/plant by about 21.05, 32.14% and 12.22, 25.0% in varieties of wheat (Misr-1 and Gemiza-9) as compared with the control in both seasons, respectively. In addition, application of 450 ppm of silicon sulphate increased spike length/plant by (15.79, 25.0%) and (11.11, 32.14%) compared to a control treatment in wheat (Misr-1 and Gemiza-9) in both seasons, respectively. For another point silicon sulphate foliar spraying on wheat plants incremented significantly number of spike / plants compared with control plants.

Maximum improvement in number of spike /plants was obtained by using of silicon sulphate, the rate of 300 ppm which significant increase of amount of spike /plant by 75.0, 55.81% and 42.55, 25.0% as compared with the control. While, silicon sulphate application at a rate of 450 ppm increased amount of spike /plant about 57.50, 39.53% and 42.55, 39.58% as compared with the control in wheat (Misr-1 and Gemiza-9) in both two seasons, respectively. These results are agreement with those obtained by Kaya *et al.,* (2006) and Amin *et al.,* (2016) [13]. Silicon (Si) is closely related to plant growth and yield owing to strengthen the physiological attributes of the maize. Si has proved to enhance the photosynthesis process, improves the absorption of nutrients, and increases grain yield in maize [14].

3.2. Influence of Silicic Acid rates

Regarding the wheat varieties as affected by silicic acid application, the maximum values of the plant height (cm) were observed after foliar application of silicic acid, while the minimum ones were observed at the control of no foliar fertilizer applied. Data appeared that the highest increase of plant height (cm) found by application of silicic acid at a rate of 100 ppm were about 9.10, 14.84% and 13.60, 20.06 % as compared with the control in wheat (Misr-1 and Gemiza-9) in both seasons, respectively. Whereas applied of 150 ppm silicic acid highest increased plant height found by (17.81, 20.06 % and 9.43, 15.35%) as compared a control in two wheat varieties, respectively. Results in Table 4 revealed that, increasing level of silicic acid application gradually increased the spike length/plant of wheat at different varieties. Foliar application of 100 ppm of silicic acid significantly enhanced of spike length/plant by 10.53, 21.43% and 11.11, 21.43% as compared with the control. Also, application of 150 ppm of silicic acid increased spike length/plant by about (23.16, 26.19%) and (8.11, 11.90%) compared to a control treatment in wheat (Misr-1 and Gemiza-9) in both seasons, respectively. Improvement in number of spikes/plants was obtained by application of silicic acid, Data revealed that the effect of silicic acid on amount of spikes/plant with spraying of 100 and 150 ppm of silicic acid significantly increased the amount of spikes/plant by (25.0, 23.26% and 27.66, 14.58 %) and (57.50, 32.56 % and 14.89, 10.42%) as compared with the control in varieties of wheat (Misr-1 and Gemiza-9) in both two seasons, respectively. These results are in agreement with those obtained by EL-umolari and Rengasamy (2012) reported that application of silicon which stimulate the growth and yield of wheat plants [15].

3.3. Influence of Silicon Sulphate rates

Table 5 presented the effects of foliar application of various rates of silicon sulphate on biological yield/plant, grains yield (ton/fed), and spike weight (g/spike) in wheat varieties in both seasons (2021/2022 and (2022/2023) with regard to the effect of silicon application on wheat yield. For the wheat cultivars Misr-1 and Gemiza-9, it was shown that applying silicon sulphate to the leaves at a rate of 300 ppm enhanced the biological yield per plant by approximately 69.35, 114.58% and 73.02, 66.67%, respectively, as compared to the control. Additionally, data showed that the application of silicon sulphate at a rate of 450 ppm considerably improved the biological yield/plant in wheat varieties Misr-1 and Gemiza-9 in each of the two seasons by 43.55% and 114.58%, respectively, when compared to the control. The application of 300 ppm of silicon sulphate significantly increased the grains yield (ton/fed) in varieties of wheat (Misr-1 and Gemiza-9) as compared to the control in both seasons, with increases of approximately 34.78, 50.44% and 48.0, 45.83%. The data showed that this effect of silicon sulphate on grains yield (ton/fed) of wheat under sandy soil. Additionally, applying 450 ppm of silicon sulphate enhanced the yield of grains (ton/fed) in wheat (Misr-1 and Gemiza-9) in both seasons by (39.13, 37.17%) and (24.0, 33.33%) as compared to a control treatment. For an additional foliar application of silicon sulphate to wheat plants increased spike weight (g/spike) considerably in comparison to control plants. The rate of silicon sulphate used to achieve the maximum improvement in spike weight (g/spike) resulted in significant increases in spike weight (g/spike) of 31.67, 44.23%, and 25.93, 36.36% when compared to the control. In contrast, silicon sulphate application at a rate of 450 ppm increased spike weight (g/spike) in wheat (Misr-1 and Gemiza-9) by roughly 16.67, 25.0% and 16.67, 23.64% in comparison to the control in each of the two seasons, respectively. In addition, Remon. M. K. *(*2020) where they clarified that silicon sulphate affects essential nutrients, and plant hormone like auxin and cytokines which regulate plant growth. The obtained findings are in agreement with those by Nora, B. A. (2021) concerning the differences between the varieties. Similar results were obtained by Abd EL-Khalek (2019) [16].

3.4. Influence of Silicic Acid rates

In terms of the wheat types influenced by silicic acid treatment, the highest biological yield/plant values were seen after silicic acid was administered topically, while the lowest values were seen at the control of no foliar fertilizer being used. According to data in Table 5, the biggest increases in biological yield/plant found by applying silicic acid at a rate of 100 ppm to wheat (Misr-1 and Gemiza-9) in both seasons were 54.84, 91.67% and 82.54, 141.67%, respectively. While applying 150 ppm silicic acid to two different wheat varieties resulted in the highest biological yield/plant increases (87.10, 139.58% and 50.79, 91.67%) as compared to a control, respectively. The grains yield (ton/fed) of wheat at different types gradually increased as the level of silicic acid administration was raised, according to the results in Table 5. In comparison to the control, foliar treatment of 100 ppm silicic acid considerably increased grain yield (ton/fed) by 39.13, 46.02%, and 32.0, 50.0%. Additionally, when applied to wheat (Misr-1 and Gemiza-9) in both seasons, 150 ppm of silicic acid enhanced grain yield (ton/fed) by around (65.22, 46.02%) and (28.0, 33.33%) when compared to a control treatment. Improvement in spike weight (g/spike) was obtained by application of silicic acid, Data revealed that the effect of silicic acid on spike weight (g/spike) with spraying of 100 and 150 ppm of silicic acid significantly increased the spike weight (g/spike) by (20.0, 36.54% and 35.19, 41.82 %) and (31.67, 46.15 % and 31.48, 34.55%) as compared with the control in varieties of wheat (Misr-1 and Gemiza-9) in both two seasons, respectively. These results may be due to the high content of silicic acid as foliar application caused an increase in grain yield and quality of wheat. Such results are in harmony with those obtained by Dawood *et al., (*2021) [17].

3.5. Influence of Silicon Fertilization on the Physical Properties of Bread Wheat Varieties

3.5.1. Moisture content of Wheat grains

Table 4 represents the influence of silicon fertilization on the moisture contents of bread wheat grains. Our present data showed that whether Silicon Sulphate 300 ppm nor Silicic Acid 100 ppm didn’t show any significant ($P \leq 0.05$) changes on the moisture content of Misr-1 or Gemiza 9. Many previous studies by Schaller et al., (2021), Salem et al., (2022) and Christian et al., (2023) showed that silicon fertilization significantly increase the moisture content of the soil especially in drought resistant [18-20].

3.5.2. Width and Length of Wheat Grains

Table 4 represents the influence of silicon fertilization on width and length of wheat grains. Our present data showed that whether Silicon Sulphate 300 ppm nor Silicic Acid 100 ppm didn’t show any significant ($P \leq 0.05$) changes on the Width and Length of Wheat Grains of Misr-1 or Gemiza 9. Except for, Silicic Acid 100 ppm was significantly ($P \leq 0.05$) changed Misr-1 grain width.

3.5.3. Hectoliter (HL)

Table 4 represents the influence of silicon fertilization on HL of wheat grains. The hectoliter weight is a significant physical quality criterion designating the flour yield. Hectoliter (HL, Kg/L) depends on the shape, size, and soundness of grains [21]. It could be noticed that HL were significantly ($P \leq 0.05$) changed in wheat variety Misr-1 and Gemiza-9, especially with Silicic Acid 100 ppm. However, Silicon Sulphate 300 ppm didn't show any significant ($P \leq 0.05$) changes. That is may be contributed to that HL is significantly correlated with width and length of wheat grains [21].

3.5.4. Thousands Kernel weight (1000-KWT)

Table 4 represents the influence of silicon fertilization on Thousands Kernel weight (1000-KWT) of bread wheat grains. It could be noticed that 1000-KWT were significantly ($P \leq 0.05$) increased in wheat variety Misr-1 and Gemiza-9, especially with Silicon Sulphate 300 ppm. However, Silicic Acid 100 ppm didn't show any significant ($P \leq 0.05$) changes for 1000-KWT in wheat variety Gemiza 9. White (2015) also, used $CaSiO_3$ at 0, 1, 2, 4.5, and 9 Mt ha^{-1} with no significant (0.1) changes [22]. These results were also agreed with Soratto et al., (2012) who found Orth silicic acid Si $(OH)_4$ at 2.0 Lha^{-1} was not affected the 1000 TKT [23].

3.5.5. Color values of wheat grains

Table 4 represents the influence of silicon fertilization on the color values of wheat grains. Our present data showed that whether Silicon Sulphate 300 ppm nor Silicic Acid 100 ppm didn’t show any significant ($P \leq 0.05$) changes on the lightness, redness or yellowness of Misr-1 or Gemiza 9. Our present data are complied with Ning et al. (2023) who stated that the color of wheat is mainly correlated with the shape of the wheat grains where he deeper the color, the smaller the shape, from our results we didn’t find any ($P \leq 0.05$) changes of the width and length of wheat grains, in consequences, there were no significant ($P \leq 0.05$) changes Color values of wheat grains [24].

Table 1: Some physical and chemical properties of soil sample under study (2021/2022) and (2022/2023).

Seasons	**Particle size distribution (%)**			**Texture class**	**pH (1: 2.5)**	**EC (dS m^{-1})**	**Organic Matter (%)**	**$CaCO_3$ (%)**
	Sand	**Silt**	**Clay**					
2021/2022	64.11	23.4	11.63	Sandy loam	7.34	0.71	0.74	2.05
2022/2023	68.24	21.6	9.45	Sandy loam	7.68	0.68	0.82	2.16
	Cations (meq L^{-1})				**Anions (meq L^{-1})**			
	Na^+	**K^+**	**Ca^{++}**	**Mg^{++}**	**CO_3^{--}**	**HCO_3^-**	**Cl^-**	**SO_4^{--}**
2021/2022	2.36	1.12	2.31	1.55	0.00	2.36	2.00	2.38
2022/2023	2.31	0.93	2.61	1.33	0.00	2.09	1.67	3.31
	Macronutrient contents (mg/100g)				**Micronutrient contents (mg/kg)**			
	N	**P**	**K**		**Fe**	**Mn**	**Zn**	**Cu**
2021/2022	18.73	2.86	5.82		9.86	3.44	0.41	0.0148
2022/2023	22.15	3.11	4.77		8.67	3.26	0.33	0.0113

Table 2: Morphological characters of wheat varieties as affected by foliar application with some source of silicate.

V	Treatments	Plant height (cm)		Spike length/plant		No. of spikes/plant	
		1st	2nd	1st	2nd	1st	2nd
Misr- 1	Control	103.3	99.7	9.5	8.4	4.0	4.3
	Silicon Sulphate 150 ppm	109.0	106.0	10.4	9.6	5.0	5.3
	Silicon Sulphate 300 ppm	119.3	117.7	11.5	11.1	7.0	6.7
	Silicon Sulphate 450 ppm	114.0	111.7	11.0	10.5	6.3	6.0
	Silicic Acid 50 ppm	107.3	111.7	9.9	9.9	4.7	4.3
	Silicic Acid 100 ppm	112.7	114.5	10.5	10.2	5.0	5.3
	Silicic Acid 150 ppm	121.7	119.7	11.7	10.6	6.3	5.7
Gemiza-9	Control	110.3	99.7	9.0	8.4	4.7	4.8
	Silicon Sulphate 150 ppm	115.3	106.0	9.5	9.6	5.7	5.6
	Silicon Sulphate 300 ppm	119.7	111.7	10.1	10.5	6.7	6.0
	Silicon Sulphate 450 ppm	116.3	117.7	10.0	11.1	6.7	6.7
	Silicic Acid 50 ppm	114.0	111.7	9.8	9.9	6.0	4.9
	Silicic Acid 100 ppm	125.3	119.7	10.0	10.2	6.0	5.5
	Silicic Acid 150 ppm	120.7	115.0	9.73	9.4	5.4	5.3
LSD 0.05	Varieties	1.479	1.609	0.261	0.194	0.3235	0.3379
	Treatments	2.768	3.010	0.488	0.363	0.6052	0.63215
	Interaction	3.914	4.256	0.690	0.513	0.85594	0.894
V: Varieties.							

Table 3: Influence of some source of silicate on yield characteristics of wheat varieties.

V	Treatments	Biological yield/plant		Grains yield / plant (ton/fed).		Spike weight (g/spike)	
		1st	2nd	1st	2nd	1st	2nd
Misr -1	Control	6.2	4.8	2.3	2.26	6.0	5.2
	Silicon Sulphate 150 ppm	7.6	6.6	2.7	2.43	6.3	6.0
	Silicon Sulphate 300 ppm	10.5	10.3	3.1	3.4	7.9	7.5
	Silicon Sulphate 450 ppm	8.9	8.0	3.2	3.1	7.0	6.5
	Silicic Acid 50 ppm	8.6	7.4	2.8	2.8	7.0	6.4
	Silicic Acid 100 ppm	9.6	9.2	3.2	3.3	7.2	7.1
	Silicic Acid 150 ppm	11.6	11.5	3.8	3.3	7.9	7.6
Gemiza- 9	Control	6.3	4.8	2.5	2.4	5.4	5.5
	Silicon Sulphate 150 ppm	8.3	6.7	3.2	2.7	6.1	6.2
	Silicon Sulphate 300 ppm	10.9	8.0	3.7	3.5	6.8	7.5
	Silicon Sulphate 450 ppm	8.9	10.3	3.1	3.2	6.3	6.8
	Silicic Acid 50 ppm	9.9	7.4	2.7	2.5	6.7	6.4
	Silicic Acid 100 ppm	11.5	11.6	3.3	3.6	7.3	7.8
	Silicic Acid 150 ppm	9.5	9.2	3.2	3.2	7.1	7.4
LSD 0.05	Varieties	0.50805	0.29774	0.108	0.109	0.1850	0.20037
	Treatments	0.95047	0.55703	0.202	0.203	0.3462	0.37487
	Interaction	1.34416	0.78776	0.285	0.287	0.4896	0.530
V: Varieties.							

Table 4: Influence of silicon fertilization on Physical Properties of Bread wheat varieties.

V	T	Moisture (g/100)	1000-KWT	Hectoliter (kg/L)	Cleanness (%)	Width (mm)	Length (mm)	Color		
								L*	***a****	***b****
Misr- 1	Control	12.3±0.21[a]	48.98±1.6[c]	212.2±0.05[b]	8.7±1.06[a]	3.7±0.58[b]	6.8±0.29[a]	57.4±3[a]	5.3±0.46[a]	16.2±0.88[a]
	Silicon Sulphate 300 ppm	12.2±0.06[a]	62.6±2.1[a]	212.5±0.85[b]	6.0±0.1[b]	4.7±0.58[ab]	7.2±0.29[a]	60.3±2.3[a]	5. 6±0.24[a]	18.2±0.22[a]
	Silcic Acid 150 ppm	12.2±0[a]	54.2±0.32[b]	217.6±0.12[a]	7.7±2.1[ab]	4.8±0.29[a]	6.8±0.29[a]	63.8±2.9[a]	5.4±0.4[a]	17.7±2.2[a]
Gemiza -9	Control	12.4±0.06[a]	56.7±2.7[b]	218.5±1.15[a]	7.8±0.85[ab]	4.0±0.0[ab]	7.3±0.58[a]	59.2±5.7[a]	5.5±0.44[a]	16.9±0.76[a]
	Silicon Sulphate 300 ppm	12.2±0.2[a]	61.2±0.49[a]	217.1±0.12[a]	1.9±0.56[c]	4.3±0.58[ab]	7.7±0.58[a]	59.4±3.9[a]	5.3±0.5[a]	16.8±0.84[a]
	Silcic Acid 100 ppm	12.3±0.15[a]	54.2±0.87[b]	210.9±3.5[b]	11.5±0.54[a]	4.0±0.0[ab]	6.5±0.5[a]	62.4±2.3[a]	4.4±2.1[a]	17.2±1.3[a]

KWT: kernel weight, **T**: treatments, ***L*** (lightness with L = 100 for lightness, and L = zero for darkness), ***a*** [(chromaticity on a green (−) to red (+)], ***b*** [(chromaticity on a blue (−) to yellow (+)], Data are presented as means ± SDM (n=3) & means within a column with different letters are significantly different at $P \leq 0.05$.

4. Conclusions

Generally, it can be concluded that the best source of silicon was silicic acid, followed by silicon sulphate. In addition, the silicic acid at the rate of 100 ppm recorded the best results with Gemiza-9.

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