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Evaluation of Mineral Fertilizer with Silicon (Si) Foliar Application on Growth, Yield Production and Nutrient Status of Wheat Under Sandy Soil Conditions.

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In Loving Memory of Late Professor Doctor ""Mohamed Refaat Hussein Mahran""

Abstract

A field experiment was carried out at the experimental Station of National Research Centre, Nubaria District, Behira Governorate, Egypt. During two seasons 2020/2021. To study the effect of NPK (19:19:19) with foliar spraying of potassium silicate and its effect on yield and nutrients uptake of wheat plants. Data showed the highest values in the chlorophyll content and growth parameters (plant height, spike length number of spikes/m^2 and 1000-grain weight) from application of 30 kg fed^{-1} NPK (19:19:19) with potassium silicate at a rate of 100 ppm. The highest grain, straw and biological yield of wheat resulted from NPK treatments and foliar spraying with potassium silicate. The data also showed that a significant increase in the mentioned elements occurred with the use of NPK (19:19:19) fertilizers especially at a rate of 45 kg fed^{-1} as comparable to the control of grain and straw in both seasons respectively. A clear and noticeable effect on the protein and carbohydrate content of wheat grains and a clear decrease occurred with the comparison treatment. It led to an increase in micronutrient contents, with increases reaching as comparable to control for Fe, Zn, Mn and Cu in both seasons, respectively. Application of silicon resulted in a remarkable increase in wheat. This positive effect of potassium silicate application was particularly evident in wheat crops that were heavily fertilized with NPK grown under sandy soil conditions.

Keywords: Wheat, Mineral Fertilizer Potassium silicate, Nutrient content, Carbohydrate, Growth, Yield.

1. Introduction

Wheat (*Triticum Aestivum* L.) is a significant staple grain that is grown worldwide to meet the needs of the people for food in many different nations. Approximately 82 %, 85% of the world's population depends on the wheat crop because it contains a high percentage of calories and protein [1]. Increased productivity per unit area of wheat crop may be achieved by breeding high-quality and productive varieties and utilizing agricultural techniques that maintain soil fertility through their effects on the physical, chemical, and biological qualities of the soil [2].

The primary focus would be on enhancing wheat yield through the implementation of enhanced farming techniques that optimize nutrient management. Plant nutrition that is balanced is the second most crucial component in determining final crop production [3]. The most common way to provide plants with the vital nutrients they need is through soil application. To address the issue of poor fertilizer nutrient delivery from soil to plant, foliar spraying one or more nutrients to complement soil application of fertilizers has garnered more attention in recent years [4]. The crop may experience nutrient deficiencies later on because nutrients given by fertilizers at the time of planting are not completely utilized by the crop and are lost through leaching, fixation, etc. Nitrogen, phosphorus, and potassium each make up 19% of the NPK 19:19:19 fertilizer, which is 100% water soluble and has a low salt index [5]. Since nitrogen is essential for both rapid plant development and high output per hectare, it is one of the main nutrients that, if not given in the right proportions, lowers wheat yields. Heinemann [6] showed that the absence of nitrogen has a significant effect on the yield-related parameters and grain production by influencing the synthesis of biomass and the efficiency with which plants use solar energy. Variations in nitrogen accessibility and plant need may result from variations in soil and climate variables associated with farms that affect nitrogen components in the root zone and their relationship with the plant [7]. The capacity of a plant to use and store energy, including photosynthesis, is correlated with phosphorus. Additionally, potassium fortifies the

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plant's roots and keeps it from wilting in cold or dry conditions [3].

The foliar application presents assurance for the availability of nutrients to crops for attaining advanced yield [5]. Plants grow larger when the amounts of silicon in their tissues rise. It can strengthen defenses against a variety of abiotic stressors [8]. As SiO_2 phytoliths are formed in the lumen, cell walls, and intercellular spaces of plants, silicon is taken up and translocated throughout the plant. It is now very well documented that only a few kinds of plants silicophiles have a high concentration of silicon [9]. The capacity of different plant species to collect Si, however, varies, with values ranging from 0.1% to 10% Si on a dry weight basis [10]. As a result, Comparable to other plant species, some are only a little impacted by Si fertilization [11]. There has been much discussion on the necessity of silicon for plants since [12]. The use of potassium silicate topically resulted in a noteworthy rise in the yield components and grain yield of barley [12], [13]. regardless of water stress, as demonstrated by Farid Hellal et al. [13]. Silicone can be sprayed on leaves to enhance growth and productivity in maize, rice, and wheat [14]. Tian, *et al.*, [15] suggested that applied potassium fertilizer under control can enhance soil nutrient status and boost fertilizer utilization; earlier research has demonstrated that silicon use can decrease crop damage from drought and boost yield [16]. In view of these facts, this experiment studied the effects of mineral fertilization NPK (19:19:19) and when applied topically, potassium silicate promotes wheat growth and crop output in field settings in the sandy soil of Egypt.

2. Materials and methods

A field experiment was carried out at the experimental Station of National Research Centre, Nubaria District, Behira Governorate, Egypt. During the two successive winter seasons of 2019/2020 and 2020/2021. To study the effect of the efficiency of NPK (19:19:19) The impact of adding soil and applying potassium silicate topically on wheat plant (cv. Sakha 93) production and nutrient absorption. The experiment included 16 treatments with 3 replicates/plots, for a total of 48 plots. The experimental design was a factorial arranged as a split-blocks with three macronutrient NPK (19:19:19) at rates (0.0, 15.0, 30.0, 45.0 kg fed^{-1}) as main-plot and a foliar application of potassium silicate at the rates (0.0, 25, 50 and 100 ppm SiO_3) occupy the sub plots. The soil of both experiment sites (0 - 30 cm) was newly reclaimed sandy soils where the physical and chemical properties of the soil were determined according to Jackson [17] are shown in Table (1).

2.1 Estimation at heading stage:

Chlorophyll content: With the use of the Minolta-SPAD Chlorophyll Meter (Minolta Camera Co., Osaka, Japan), the amount of greenery present in a plant was assessed. The digital SPAD value produced by the SPAD-502 chlorophyll meter is proportional to the quantity of chlorophyll present in the leaf and is determined by measuring the absorbance of chlorophyll in the red and near-infrared bands. [18].

2.2 Yield and its components

In each experiment unit, samples were taken from randomly chosen plants to assess the average plant height (cm), the length of the spikes (cm), the number of spikes per square meter, and the 1000 seed weight.

2.3 Biological yield:

The whole biomass of the harvested plants was converted from kg $plot^{-1}$ to ton fed^{-1}.

Grain and Straw yield (ton ha^{1}):

Following threshing, it was measured as the plot's clean grain weight and converted to tone per fed.

Harvest index: Harvest index (H.I) calculated as follows:

$$\mathbf{H.I.} = \frac{\textbf{Grain yield (ton/fed)}}{\textbf{Biological yield (ton/fed)}} \mathbf{x\ 100}$$

Chemical constituents:

Chemical compositions of canola seeds were determined at the end of experiments, Total nitrogen was determined in dried leaves by the Kjeldahl method. While Phosphorus was determined by spectrophotometer method and Potassium and Sodium by flame emission and micronutrients (Fe, Mn and Zn) determined by atomic absorption spectroscopy, which were determined using the method of Cottenie **[19].**

2.4 Phytochemical determination:

Following A. O. A. C. [20] instructions, the crude protein % was extracted and calculated using the Macro-Kjeldahl technique. Total values of total-N were multiplied by factor 6.25 to determine the value of total crude protein. total carbohydrate utilizing Dubois *et al.*, [21] colorimetric technique.

2.5 Statistical analysis:

Using the Costat software (Version 6.4, Co Hort, USA, 1998–2008), all collected data were statistically examined in accordance with the plan. As demonstrated by Williams and Abdi, [22] the revised least significant difference test (LSD) was used at the 0.05 probability level to compare the means of several treatments.

3. RESULTS AND DISCUSSION

3.1 Chlorophyll content

Data in Figure (1) illustrated the effect of different rates from NPK component (19:19:19) with foliar application of potassium silicate considered as the silicon source on the chlorophyll content in the growth stages of the wheat plant.

Table (1): Some physical and chemical properties of the experimental soil.

pH	EC	OM	FC	$CaCO_3$	Particle size distribution			Texture
(1:2.5)	dSm^{-1}	%	%	%	Sand %	Silt %	Clay %	Class
7.44	0.73	0.32	9.16	1.41	91.36	3.62	4.82	Sandy
Cations (meq/ L)					**Anions (meq/ L)**			
Na^+	**K^+**	**Ca^{++}**		**Mg^{++}**	**CO_3^{--}**	**HCO_3^-**	**Cl^-**	**SO_4^{--}**
2.25	0.98	2.26		1.78	0	2.73	1.81	2.73
Available macronutrients (mg/100 g soil)					**Available micronutrients (mg/kg)**			
N		**P**		**K**	**Fe**	**Zn**	**Mn**	**Cu**
10.28		1.68		9.87	5.58	0.43	2.19	0.011

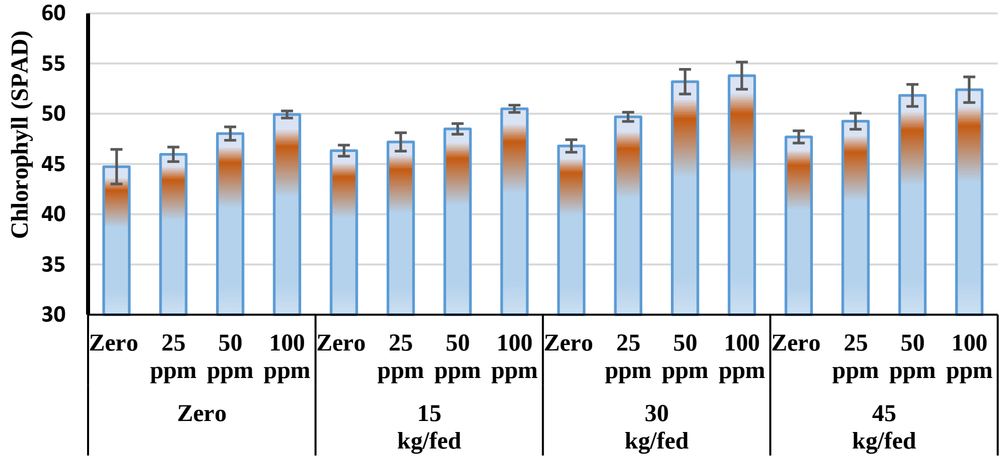

Fig (1): Chlorophyll (SPAD) as affcted by NPK with Potassium silicate foliar spray on wheat under sandy soil condations.

It is clear from the data presented in Figure (1) that there is a gradual increment in the chlorophyll content in wheat induced by compound mineral fertilizer (19:19:19) from 0 to 45 kg fed^{-1} as comparable to the control. Regarding the effect of NPK on photosynthetic pigments, the obtained results agree with those obtained by **Sarhan *et al.*, [23]** on Taxodium distichum, **Gad [24]** on Ficus benjamina, **Watfa [25]** on Aleppo pine seedlings and **[26]** on Populus nigra plants.

Foliar application of potassium silicate on plants led to a significant increase in chlorophyll content in wheat and the data showed the highest values in chlorophyll content induced by the interaction between potassium silicate at a rate of 100 ppm Si with complex mineral fertilizer (19: 19: 19) at a rate of 30 kg fed^{-1} as comparable with the control **[27], [28]**.

3.2 Growth parameters:

Concerning the effect of different rates (0.0, 15.0, 30.0 and 45.0 kg fed^{-1}) of compound mineral fertilizer NPK (19:19:19) and foliar application of potassium silicate (0.0, 25, 50 and 100 ppm Si) on the growth parameter of wheat plants, it is obvious from the data in Table (2) that increment in growth parameters (plant height, spike length, number of spikes/m2 and 1000-grain weight) progressively increased up to the harvest of the crop under all treatments Comparable with control. Soil application of NPK (19:19:19) showed the highest significant increase of plant height, spike length, number of spikes/m2 and 1000-grain weight by about 9.0, 6.47, 5.78 and 11.11 % Comparable with control, respectively. This increment was induced by application of NPK at a rate of 30.0 kg fed [1]. The use of mineral fertilizers is crucial for the development of ornamental plants. Fertilizing with NPK, which is found in commercial fertilizers, enhances the growth of foliage plants, especially when applied at the recommended rate **[29]**.

The experimental results revealed that mineral fertilizer NPK (19:19:19) at a rate of 45 kg fed^{-1} led to a significantly increased in most of the growth parameters under study Comparable to the other weight was 6.80, 6.13, 6.22 and 10.34 % as Comparable with control, respectively. Data observed that the application of potassium silicate at a rate of 100 ppm Si had significantly increased growth parameters, an average of increases by about 13.0, 13.31, 8.64 and 12.73 % in comparison with the control, respectively. The researchers noticed a boost n the growth parameters when different types of fertilizers were used, suggesting that the plants effectively utilized the applied fertilizer at this dosage **[30].**

treatments and control. The increment of plant height, spike length, number of spikes/m2 and 1000-grain

Table 2. Plant height, Spike length, Number of spike/m^2 and 1000 seed weight as affected by NPK with Potassium silicate foliar spray on wheat under sandy soil conditions.

NPK (19-19-19-)	K_2SiO_3	Plant height (cm)	Spike length (cm)	No, of Spike/m2	1000 seed wt.
Zero	Zero	84.33	12.99	213.4	42.34
	25 ppm (Si)	89.33	13.21	222.8	43.99
	50 ppm (Si)	92.67	13.97	238.9	50.42
	100 ppm (Si)	96.67	14.89	242.6	51.92
15 kg fed 1	Zero	89.33	13.21	223.8	46.37
	25 ppm (Si)	91.67	13.64	231.5	50.23
	50 ppm (Si)	94.67	14.06	239.3	51.61
	100 ppm (Si)	98.33	15.02	246.3	52.49
30 kg fed 1	Zero	90.67	13.52	233.5	49.69
	25 ppm (Si)	96.67	14.45	239.2	51.23
	50 ppm (Si)	101.67	15.12	247.0	54.11
	100 ppm (Si)	106.67	15.52	251.0	54.60
45 kg fed 1	Zero	92.00	13.89	238.6	50.24
	25 ppm (Si)	95.33	14.21	243.3	51.16
	50 ppm (Si)	99.33	15.01	245.0	53.17
	100 ppm (Si)	101.00	15.32	248.0	53.63
Mean NPK	Zero	90.75	13.76	229.44	47.17
	15 kg fed 1	93.50	13.98	235.23	50.18
	30 kg fed 1	98.92	14.65	242.69	52.41
	45 kg fed 1	96.92	14.61	243.70	52.05
Mean K_2SiO_3	Zero	89.08	13.40	227.34	47.16
	25 ppm (Si)	93.25	13.88	234.22	49.15
	50 ppm (Si)	97.08	14.54	242.52	52.33
	100 ppm (Si)	100.67	15.19	246.97	53.16
LSD 0.05	NPK	**1.582**	**0.524**	**1.068**	**0.536**
	K_2SiO_3	**1.271**	**0.516**	**1.177**	**0.348**
	Inter	**2.653**	**0.967**	**2.088**	**0.822**

In comparison, between applications of different doses of foliar spray of silicon fertilizer with NPK fertilizer. Data showed that gave an augment of plant height, spike length, number of spikes/m2 and 1000-grain weight of wheat plant as Comparable to control. The highest value was obtained with 30 kg fed^{-1} complex mineral fertilizer NPK (19:19:19) and silicon fertilizer at a rate of 100 ppm Si. These results are in harmony with **Hanafy *et al.*, [31]**; According to **White *et al.*, [32]**, Numerous studies have demonstrated that by enhancing different yield components, foliar feeding with silicon can boost production. This includes spike density, number of kernels per spike, and mass of 1000 grains, which are particularly important for common cereals. The application of silicon enhanced the thickness and the roughness of wheat leaves thus improving light reception which results in increased yield [33].

3.3 Yield Components:

Regarding the yield characters, as demonstrated in Table (3) the obtained data showed that there is a considerable impact caused by the interaction between the two examined factors (NPK and foliar application of potassium silicate) on most of the studied characteristics in both seasons. Results showed that the treatments involved different rates (0.0, 15.0, 30.0 and 45.0 kg fed ^{1}) of compound mineral fertilizer NPK (19:19:19) and foliar application of potassium silicate (0.0, 50.0 and 100 ppm Si) on yield components of wheat. The maximum grain, straw and biological yield (ton fed ^{1}) of wheat resulted from plots that gave plants NPK treatments and foliar spraying of potassium silicate. Application of compound mineral fertilizer NPK (19:19:19) gave the greatest values of yield component (grain, straw and biological yield) particularly with at a rate 30 kg fed^{-1} an average of increment by about 13.21, 8.08 and 9.84 % in comparison to the control. Also, data revealed that the soil adding NPK at a rate 45 kg fed^{-1} achieved high increases by about 13.74, 8.03 and 9.99 % Comparable to the control.

These results are in harmony with **Abd El-Ghfar *et al.*, [34]** they indicated that the application of NPK nutrients led to a significant increment in weight of 1000 grains, straw yield, and grain yield. Specifically, there was a 45.92% increase in the weight of 1000 grains, a 46.91% increase in straw yield, and a 41.18% increase in grain yield Comparable to the control.

Table 3. Yield characterization as affected by NPK with Potassium silicate foliar spray on wheat under sandy soil conditions.

NPK (19-19-19-)	K_2SiO_3	Grain yield (ton fed ^{1})	Straw yield (ton fed ^{1})	Biological yield	Harvest Index	Grain yield (Ardeb fed^{-1})
Zero	**Zero**	1.76	3.37	5.14	34.30	11.74
	25 ppm (Si)	1.88	3.63	5.50	34.09	12.50
	50 ppm (Si)	1.95	3.78	5.72	34.06	13.00
	100 ppm (Si)	2.06	3.83	5.89	34.99	13.74
15 kg fed ^{1}	**Zero**	1.84	3.66	5.51	33.48	12.29
	25 ppm (Si)	2.03	3.74	5.76	35.15	13.51
	50 ppm (Si)	2.12	3.89	6.01	35.29	14.14
	100 ppm (Si)	2.15	3.94	6.08	35.30	14.32
30 kg fed ^{1}	**Zero**	2.08	3.82	5.90	35.30	13.89
	25 ppm (Si)	2.17	3.92	6.09	35.63	14.47
	50 ppm (Si)	2.19	3.99	6.18	35.47	14.61
	100 ppm (Si)	2.21	4.06	6.27	35.28	14.74
45 kg fed ^{1}	**Zero**	2.10	3.85	5.95	35.27	13.98
	25 ppm (Si)	2.18	3.94	6.12	35.62	14.54
	50 ppm (Si)	2.20	3.98	6.18	35.56	14.65
	100 ppm (Si)	2.22	4.00	6.22	35.69	14.81
Mean NPK	**Zero**	1.91	3.65	5.56	34.36	12.75
	15 kg fed ^{1}	2.03	3.81	5.84	34.81	13.56
	30 kg fed ^{1}	2.16	3.95	6.11	35.42	14.43
	45 kg fed ^{1}	2.17	3.94	6.12	35.53	14.50
Mean K_2SiO_3	**Zero**	1.95	3.68	5.62	34.59	12.98
	25 ppm (Si)	2.06	3.81	5.87	35.12	13.76
	50 ppm (Si)	2.11	3.91	6.02	35.09	14.10
	100 ppm (Si)	2.16	3.96	6.12	35.31	14.40
LSD 0.05	**NPK**	**0.0233**	**0.0566**	**0.0649**		**0.158**
	K_2SiO_3	**0.0261**	**0.0134**	**0.0341**		**0.173**
	Inter	**0.0459**	**0.0651**	**0.0921**		**0.308**

The treatment of 19:19:19, at all tested doses, was identified as the most effective agricultural practice for achieving higher wheat yield and increased availability of nutrients.

The improvement in yield component (grain, straw and biological yield) of wheat by spraying with the potassium silicate at different rates. and the d Data presented that application of K_2SiO_3 at a rate of 100 ppm Si reached about 10.98, 7.62 and 8.78 % Comparable to control treatment (without foliar application) over both seasons of this study.

Data in Table (4) illustrated that the interaction between the application of different doses of foliar spray of silicon fertilizer with NPK fertilizer led to a remarkable achievement of harvest index and grain production (Ardeb/fed) of wheat, which may be attributable to combining the beneficial effects of these fertilizers. Results were noticed that the application of compound mineral fertilizer NPK (19:19:19) at a rate of 45 kg fed^{-1} interacting with different doses of potassium silicate fertilizer particularly rate of 100 ppm Si. It was observed that the maximum yield of grain wheat was 35.69 at harvest index and grain production (14.81Ardeb fed^{-1}), Such phenomenon may be related to the effect of NPK fertilization and Silicate, Silicon enhances nutrient content in the grain and straw of rice, submitting that silicon in minimum amounts can increase grain yield and growth of grain crops, In the case of sugar beet, foliar nutrition with silicon contributes, which determines the yield of sugar **[35]**. In potato cultivation, plants fertilized with silicon-developed tubers with a larger fresh mass **[36]**.

3.4 Macronutrient contents:

3.4.1 Nitrogen and Phosphorus

The obtained results clarified the interaction between two examined factors (NPK and potassium silicate) had significant effect on nitrogen and phosphorus in both grain and straw of wheat plants in two seasons (Table 4). It is clear from the table data that the addition of the NPK compound mineral fertilizer (19:19:19) led to a significant increase of macronutrient contents in both grain and straw, the results showed that adding NPK at a rate of 30 kgfed^{-1} gave a significant increase in nitrogen and phosphorus in each of grains and straw is estimated at about 13.64, 34.5, 13.47 and 5.36 % comparably to the control, respectively. These findings agree with **Kandeel *et al.*, [37]** on Taxodium distichum and **El-Assaly [38]** on Khaya senegalensis plant.

Table 4. Nitrogen and phosphorus content of grain and straw as affected by NPK with Potassium silicate foliar spray on wheat under sandy soil conditions.

NPK (19-19-19-)	K_2SiO_3	Nitrogen %		Phosphorus %	
		Grain	Straw	Grain	Straw
Zero	Zero	1.63	0.493	0.121	0.130
	25 ppm (Si)	1.74	0.527	0.124	0.134
	50 ppm (Si)	1.83	0.616	0.143	0.137
	100 ppm (Si)	1.95	0.704	0.151	0.140
15 kg fed 1	Zero	1.73	0.551	0.136	0.135
	25 ppm (Si)	1.84	0.612	0.140	0.136
	50 ppm (Si)	1.88	0.626	0.148	0.140
	100 ppm (Si)	1.98	0.729	0.154	0.143
30 kg fed 1	Zero	1.82	0.600	0.139	0.138
	25 ppm (Si)	1.96	0.721	0.151	0.141
	50 ppm (Si)	2.12	0.877	0.159	0.144
	100 ppm (Si)	2.23	0.950	0.164	0.148
45 kg fed 1	Zero	1.87	0.624	0.144	0.141
	25 ppm (Si)	1.97	0.700	0.150	0.144
	50 ppm (Si)	2.11	0.753	0.157	0.146
	100 ppm (Si)	2.10	0.786	0.159	0.149
Mean NPK	Zero	1.79	0.585	0.135	0.135
	15 kg fed 1	1.86	0.629	0.145	0.139
	30 kg fed 1	2.03	0.787	0.153	0.143
	45 kg fed 1	2.01	0.716	0.153	0.145
Mean K_2SiO_3	Zero	1.76	0.567	0.135	0.136
	25 ppm (Si)	1.88	0.640	0.141	0.139
	50 ppm (Si)	1.99	0.718	0.152	0.142
	100 ppm (Si)	2.06	0.792	0.157	0.145
LSD 0.05	NPK	0.0128	0.0057	0.0038	0.0019
	K_2SiO_3	0.0130	0.0211	0.0038	0.0025
	Inter	0.0239	0.0249	0.0071	0.0041

The data also showed that a significant increase in the mentioned elements occurred with the use of compound mineral fertilizers especially with the rate of 45 kg fed^{-1} an average of increases was about 12.60, 22.36, 13.29 and 7.07 % Comparable to control of grain and straw in both seasons respectively. The results of increased N, P or K % attributed to chemical NPK treatments are like those obtained by previous studies **[29]**. On the other hand, the data illustrated that a foliar application of potassium silicate had a significant increase in nitrogen and phosphorus content in the grain and straw of wheat plant. Where achieved use of potassium silicate application markedly increments of N and P content at a rate of 50 ppm Si, an average of increases was about 12.76, 26.57, 12.61 and 4.06 % Comparable to control of grain and straw in both seasons respectively. While the application of potassium silicate at a rate of 100 ppm Si had a significant increase in N and P content of grain and straw, an average of increases was about 17.13, 39.63, 16.31 and 6.42 % comparably to control in both seasons, respectively. This may be due to the role of silicon in increasing the rate of absorption of nutrients and thus increasing its concentration in crops. The application of Si positively affects all aspects of nitrogen (N) nutrition, i.e., uptake, assimilation, and remobilization **[39], [40]**. It has been demonstrated that Si improves plant performance overall in situations with low, ideal, and high nitrogen supplies. Si availability affects nitrogen metabolism directly and modifies the stoichiometry of P and C in shoots **[41]**.

3.4.2 Potassium and Calcium

Regarding the effect of NPK and potassium silicate on potassium and calcium in both grain and straw of wheat plants, data in Table (5) showed that the addition of the NPK compound mineral fertilizer (19:19:19) led to a significant increase in potassium and calcium content in grain and straw in two seasons, as the results showed that adding NPK at a rate of 30 kg fed^{-1} had significantly increment of potassium and calcium is estimated at about 10.29, 7.01, 5.54 and 9.39 % as Comparable with the control, respectively. The data also showed that a significant increase in the mentioned elements occurred with the use of NPK (19:19:19) fertilizers especially with at a rate of 45 kg fed^{-1} increases at about 10.14, 10.17, 3.93 and 11.99 % Comparable to the control of grain and straw in both seasons respectively.

Table 5. Potassium, calcium content and Ca/k ratio of grain and straw as affected by NPK with Potassium silicate foliar spray on wheat under sandy soil conditions.

NPK (19-19-19-)	K_2SiO_3	Potassium %		Calcium %		Ca/K ratio	
		Grain	Straw	Grain	Straw	Grain	Straw
Zero	Zero	0.41	1.10	0.371	0.198	91.48	17.99
	25 ppm (Si)	0.41	1.11	0.379	0.207	93.25	18.54
	50 ppm (Si)	0.47	1.26	0.389	0.224	81.96	17.75
	100 ppm (Si)	0.48	1.31	0.393	0.231	81.43	17.66
15 kg fed 1	Zero	0.42	1.14	0.373	0.212	88.76	18.54
	25 ppm (Si)	0.46	1.22	0.380	0.221	83.37	18.09
	50 ppm (Si)	0.48	1.28	0.405	0.234	84.83	18.20
	100 ppm (Si)	0.49	1.35	0.416	0.245	84.99	18.17
30 kg fed 1	Zero	0.42	1.19	0.384	0.223	91.05	18.79
	25 ppm (Si)	0.49	1.26	0.390	0.228	80.07	18.10
	50 ppm (Si)	0.52	1.30	0.418	0.242	80.90	18.60
	100 ppm (Si)	0.53	1.38	0.425	0.248	80.79	18.03
45 kg fed 1	Zero	0.46	1.24	0.389	0.231	84.40	18.69
	25 ppm (Si)	0.48	1.30	0.356	0.237	74.07	18.33
	50 ppm (Si)	0.49	1.34	0.422	0.241	85.83	17.94
	100 ppm (Si)	0.52	1.40	0.426	0.254	82.51	18.13
Mean NPK	Zero	0.44	1.20	0.383	0.215	87.03	17.99
	15 kg fed 1	0.46	1.25	0.394	0.228	85.49	18.25
	30 kg fed 1	0.49	1.28	0.404	0.235	83.20	18.38
	45 kg fed 1	0.49	1.32	0.398	0.241	81.70	18.27
Mean K_2SiO_3	Zero	0.43	1.17	0.379	0.216	88.92	18.50
	25 ppm (Si)	0.46	1.22	0.376	0.223	82.69	18.26
	50 ppm (Si)	0.49	1.30	0.408	0.235	83.38	18.12
	100 ppm (Si)	0.50	1.36	0.415	0.245	82.43	18.00
LSD 0.05	NPK	0.0045	0.0172	0.0092	0.0022		
	K_2SiO_3	0.0079	0.0124	0.0067	0.0040		
	Inter	0.0115	0.0275	0.0148	0.0058		

A similar effect was found by **Youssef [42]** on Beaucarnea recurvata plants and **El-Habba *et al.*, [43]** on Populus Euramericana plants.

On the other hand, data illustrated that a foliar application of potassium silicate had a significant increase in potassium and calcium content in grain and straw of wheat plant. Where achieved use of potassium silicate application markedly increments of K and Ca content at a rate 50 ppm Si, an average of increases was about 14.69, 11.24, 7.66 and 8.88 % Comparable to control of grain and straw in both seasons respectively. While the Also, application of potassium silicate at a rate of 100 ppm Si had a significant increase in K and Ca content in grain and straw, the average increases were about 17.98, 16.46, 9.49 and 13.23 % comparably to control in both seasons, respectively. According to reports, the primary positive impact of Si in K-deficient plants is increased absorption of K and restored physiological performance reduced by K deficit. When Si was supplemented to soybean and some forage crops (Panicum maximum and Brachiaria ruziziensis Brachiaria brizanth), the leaves' K content increased **[44], [45].**

3.5 Protein and Carbohydrate contents:

The obtained results in Figure (2) presented a relationship between two examined factors (NPK and potassium silicate) on the protein and carbohydrate contents of wheat plants in two seasons. It was observed from the data obtained from using mixture mineral fertilizer (NPK 19:19:19) with spraying with potassium silicate, a clear and noticeable effect on the protein and carbohydrate content in wheat grains and a clear decrease occurred with the comparison treatment. While application NPK at a rate of 30 kg fed^{-1} outperformed its counterpart in treatments, especially spraying with potassium silicate at a rate of 100 ppm. Thereby, the application of (NPK 19:19:19) at a rate 30 kg fed^{-1} and foliar spray of potassium silicate at a rate of 100 ppm gave the highest value for protein and carbohydrate content as Comparable to the control. These results are in conformity with those obtained by **El-Mahrouk *et al.*, [46]** on *Cestrum aurantiacum* and **El-Assaly [38]** on *Khaya senegalensis*.

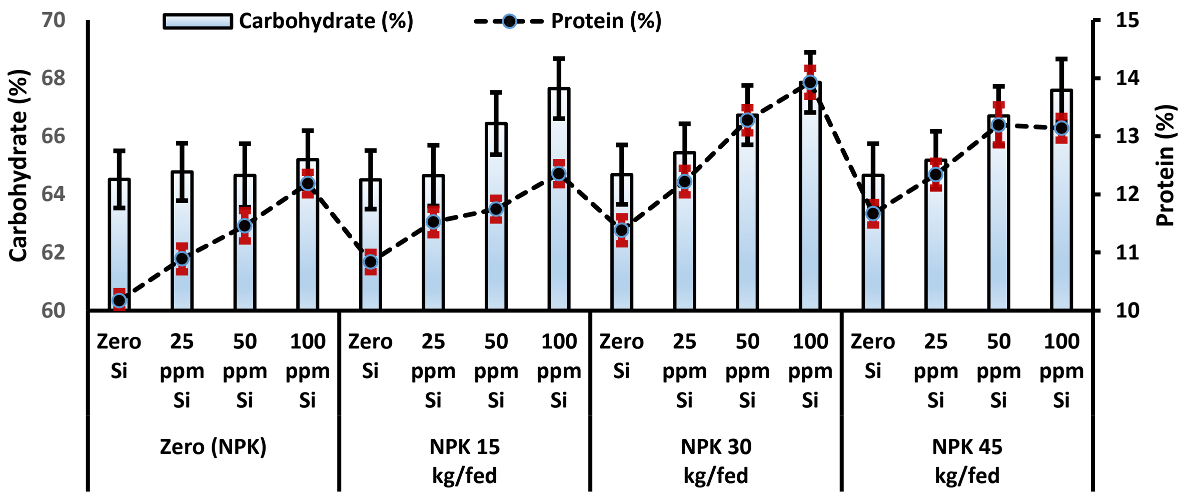

Fig (2): Protein and Carbohydrate content as affcted by NPK with Potassium silicate foliar spray on wheat under sandy soil condations.

In this context, it was also noted by earlier writers that strong light might have an impact on the enzymes in charge of producing proteins and amino acids. it also could inhibit auxins activity which regulate metabolism that adversely influence on pigments synthesis and carbohydrates accumulation which in turn affecting plant growth and development **[47]**.

3.6 Micronutrient contents:

Data presented in Table (6) showed that application of compound mineral fertilizer (NPK 19:19:19), potassium silicate and their interaction on the concentration of micronutrient contents (Fe, Zn, Mn and Cu) of wheat grains in both seasons. Results observed that a significant increment in Fe, Zn, Mn and Cu contents due to NPK added and foliar feeding with silicon were obtained. Application of 30 kg NPK (19:19:19) fed ^{1} resulted in increasing micronutrient contents. The increments reached 2.05, 8.94, 12.40 and 21.88 % as Comparable to control one (0.0 kg NPK fed^{-1}) for Fe, Zn, Mn and Cu in both two seasons, respectively. Also, data showed that application of 45 kg NPK (19:19:19) fed ^{1} resulted in increasing micronutrient contents. The increments reached 1.86, 8.22, 12.38 and 15.77 % as comparable to control for Fe, Zn, Mn and Cu in both two seasons, respectively. Similar results were found by **[48], [49] and [50].**

On the other hand, increases reached to 2.41, 11.56, 16.74 and 26.00 % over the control treatment (0.0 ppm Si) for Fe, Zn, Mn and Cu in both seasons, respectively by spraying wheat plants with 50 ppm Si. While spraying wheat plants with potassium silicate at a rate of 100 ppm Si highest of micronutrient contents were achieved, as there was an increase estimated at about 3.33, 14.90, 23.17 and 37.16 % as Comparable to the control. Thereby the interaction effects between the two studied factors were also significant. The most elevated calculated micronutrient contents in both seasons of wheat seeds were found, due to their interaction between NPK (19:19:19) at a rate of 30 kg fed^{-1} foliar application of potassium silicate at a rate of 100 ppm Si. Several plant species maintained in ideal, poor, or high Fe environments have amply established the impact of Si on iron (Fe) feeding **[51].** The main mitigating impact of Si appears to be enhanced Fe distribution toward apical shoot parts and tissue buildup of Fe-mobilizing chemicals such citrate (in leaves and roots) and catechin (in roots). **[52]**. Under Zn toxicity stress, the positive benefits of Si have been seen in a number of crop species, including rice **[53]**, cotton **[54]** and maize **[55]**. **Pascual *et al.*, [56]** suggested that when soybean plants were exposed to a zinc deficit, the silica treatment increased zinc accumulation in the root apoplast and its transfer to shoots **De Oliveira *et al.*, [57]** demonstrated that Si controls the physiology and activity of antioxidative enzymes to lessen the impacts of oxidative stress brought on by Mn shortage in sorghum plants.

4. Conclusion

This study presented the incredible impact that potassium silicate on wheat crops, as foliar spraying with potassium silicate let to a significant enhancement in the quality and productivity of the crop, and the plants become stronger and more resistant to diseases and pests. This means that growers can expect higher profits and healthier crops. Potassium silicate does its by strengthening the plant's cell walls, making them tougher especially with macronutrient content NPK (19:19:19) at a rate of 30 kg fed^{-1}, Which increases its ability to grow better under sandy soil conditions.

Table 6. Micronutrient contents as affected by NPK with Potassium silicate foliar spraying on wheat under sandy soil conditions.

NPK (19-19-19-)	K_2SiO_3	Micronutrient contents			
		Fe ppm	Zn ppm	Mn ppm	Cu ppm
Zero	Zero	131.4	12.23	16.3	2.29
	25 ppm (Si)	132.6	12.44	17.8	2.29
	50 ppm (Si)	135.2	13.75	19.7	2.40
	100 ppm (Si)	137.3	14.29	21.8	2.95
15 kg fed 1	Zero	133.4	12.69	18.0	2.30
	25 ppm (Si)	134.8	13.41	19.3	2.33
	50 ppm (Si)	135.3	13.86	19.9	2.83
	100 ppm (Si)	137.6	14.32	22.0	2.99
30 kg fed 1	Zero	134.4	12.83	18.4	2.31
	25 ppm (Si)	135.9	14.15	21.3	2.94
	50 ppm (Si)	138.5	15.16	22.5	3.34
	100 ppm (Si)	138.7	15.29	22.8	3.51
45 kg fed 1	Zero	134.9	13.56	19.5	2.34
	25 ppm (Si)	135.5	13.94	21.0	2.85
	50 ppm (Si)	137.9	14.48	22.2	3.08
	100 ppm (Si)	138.2	15.07	22.3	3.22
Mean NPK	Zero	134.1	13.18	18.90	2.48
	15 kg fed 1	135.3	13.57	19.82	2.61
	30 kg fed-1	136.9	14.36	21.25	3.02
	45 kg fed 1	136.6	14.26	21.24	2.87
Mean K_2SiO_3	Zero	133.5	12.83	18.05	2.31
	25 ppm (Si)	134.7	13.48	19.85	2.60
	50 ppm (Si)	136.8	14.31	21.08	2.91
	100 ppm (Si)	138.0	14.74	22.24	3.17
LSD 0.05	NPK	**0.835**	**0.080**	**0.478**	**0.030**
	K_2SiO_3	**0.367**	**0.077**	**0.614**	**0.064**
	Inter	**1.118**	**0.147**	**1.015**	**0.087**

Conflicts of Interest

Regarding the publication of this manuscript, all authors declare no conflict of interest in this manuscript.

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