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Response of Flax (*Linum usitatissimun* L.) Nutrients Content to Foliar Application by Two Different Sources of Silicon Fertilizers.

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ABSTRACT

Two sources of silicon i.e., potassium silicate and magnesium silicate were used as foliar application with rates 0, 4 and 8 cm^3/L on two flax varieties i.e., Sakha-2 and Amon during 2013/2014 and 2014/2015 growing seasons at the Experimental Station of National Research Centre, Al-Nubaria District, El-Behira Governorate, Egypt. The experiments were handled to investigate the effect of tested fertilizers on the nutrients content of the two studied flax varieties. Obtained results revealed that the two silicon sources showed significant differences with the majority of investigated nutrients of flax varieties. Potassium silicate recorded higher effect than magnesium silicate. On the other hand, Sakha-2 variety had favorable values of nutrients content with the two silicon fertilizers especially with the rate 8 cm^3/L. Also, the obtained data showed that the interaction between the nutrients and flax varieties treated by two silicon fertilizers had significant effect. Silicon foliar applications with the two sources in general, improved the nutrient status of flax varieties than the untreated plants.

Keywords: Flax varieties, foliar application, nutrients content, silicon fertilizers.

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INTRODUCTION

Flax has got importance as a source of fiber and oil under newly reclaimed sandy soil conditions, improvement of flax production can be achieved through using good varieties and selected fertilizers [1- 2].

Nowadays, Flax has passed all expectations by its benefits. Flax cultivars differed significantly in yield and its attributes as well as oil content [3].

Silicon (Si) has not been found up till now to be an essential element for higher plants, but its beneficial ramifications on growth have been reported in a wide variety of crops, including barley, rice, cucumber and wheat. In addition, it applied as fertilizer to crops in several countries for increasing productivity and sustainable production [4]. Silicon was reported to decrease the danger effects of various a biotic and biotic stresses including drought stress, radiation damage, metal toxicity, salt stress, various pests and diseases caused by both bacteria and fungi, nutrients imbalance, freezing and high temperature [5 , 6, 7]. The Si amount in soil may differ considerably from 1 % to 45 % [8]. However, its concentration significantly differ in plant aboveground parts, ranging from 0.1 to 10.0 % of dry weight and this extensive variation in Si concentration is attributed mainly to differences in the attribute of Si transport and uptake [9].

Many scientific researchers have reviewed the benefits of silicon application on crop growth, but the mechanisms of silicon action have not been systematically discussed [10].

Si application has been found to minimize the uptake of potassium and nitrogen but maximize the uptake of calcium, phosphorus, magnesium and the formation of carbohydrates in transplanted rice, to amplify K:Na selectivity ratio with attendant reduction in Na adsorption by plants [11] and to reduce the percentage of electrolyte leakage thus increasing the element content of tissues [12-13].

Foliar application of gerbera plants with potassium silicate ($KSiO_3$) and Sodium silicate ($NaSiO_3$), [14] reported that particularly $NaSiO_3$ increased flower diameter, increased height, flowered earlier and produced thicker flower peduncles than non-supplemented controls. However, [15] indicated that potassium silicate foliar application on flax was superior compound especially at the rate 8 cm^3/L.

Liquid silicates such as potassium silicates and sodium silicate are more effective products for foliar applications and used in greenhouses but are in general, not economical to use for the large rates needed for soil application [16]. Other natural sources of Silicon include magnesium silicate; dolomite, basalt dust and rock phosphate, but these only contain traces of silicon amount available for plant [17].

The purpose of this study is to investigate the effectiveness of two silicon fertilizers i.e., potassium silicate and magnesium silicate as foliar application on some nutrients contents on Sakha-2 and Amon varieties.

MATERIALS AND METHODS

Two varieties of flax i.e., Sakha-2 and Amon were grown at the Experimental Station of National Research Centre, Al-Nubaria District, El-Behira Governorate, Egypt, during the two successive winter seasons of 2013/2014 and 2014/2015. The soil of both experiment sites (0-30 cm) were sandy soils where mechanical and chemical analysis are reported in Table (1).

Seeds of flax varieties (Sakha-2 and Amon) were sown on the 17th November in both seasons in rows 3.5 meters long, the distance between rows was 20 cm apart, plot area was 10 m^2 (3.0 m in width and 3.5 m in length). All agronomic practices were applied as recommended throughout the season. Flax seeds were broadcasted at (2000 seeds/m^2).

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Table 1: Some physical, chemical and fertility characteristics of the experimental soil

Soil characteristics	Value	Soil characteristics.	Value
Particle size distribution	*%*	*Soil paste extract:*	
Sand	91.77	EC (dS/m)	0.40
Silt	3.33	*Soluble cations (m mole L^{-1}):*	
Clay	4.90	Ca^{++}	1.57
Texture	sandy	Mg^{++}	0.93
Infiltration rate (cm h^{-1})	8.35	Na+	1.10
$CaCO_3$%	1.53	K+	0.40
Available nutrients	*(mg kg^{-1} soil)*	*Soluble anions (m mol L^{-1}):*	
		CO_3^{--}	0.00
N (potassium chloride)	24.65	HCO_3^-	1.84
P (sodium bicarbonate)	4.39	Cl^-	1.15
Ca (ammonium acetate)	361.71	SO_4^{--}	1.01
Mg (ammonium acetate)	223.36	pH (1:2.5 soil water suspension)	7.45
K (ammonium acetate)	66.45	Organic matter %	0.27
Fe (DTPA)	4.86	CEC (c mole kg^{-1})	8.52
Mn (DTPA)	3.78	Soil total N %	0.013
Zn (DTPA)	0.12	Soil organic carbon %	0.157
Cu (DTPA)	0.10	Soil C/N ratio	12.08

Critical limits of nutrients in mg/kg after [18 , 19]							
Limits	N	P	K	Fe	Mn	Zn	Cu
Low	< 40.0	< 5.0	< 85.0	< 4.0	< 2.0	< 1.0	< 0.5
Medium	40.0-80.0	5.0-10.0	85.0-170.0	4.0-6.0	2.0-5.0	1.0-2.0	0.5-1.0
High	> 80.0	> 10.0	> 170	> 6.0	> 5.0	> 2.0	> 1.0

Pre sowing, 150 kg/fed. of calcium supper phosphate (15.5% P_2O_5) was applied to the soil. Nitrogen was applied after emergence in the form of ammonium nitrate (33.5% N) at rate of 75 kg/fed. was applied at five equal doses before the 1st, 2nd, 3rd, 4th and 5th irrigations. Irrigation was carried out using the new sprinkler irrigation system where water was added every 5 days.

Foliar application with potassium silicate ($KSiO_3$) at the rate of 0, 4 and 8 cm^3/L and magnesium silicate (Mg SiO_3) at the rate of 0, 4 and 8 cm^3/L in both seasons for each was carried out twice, the plants were sprayed after 45 and 60 days from sowing.

The plant samples were collected at harvest. Total nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc, manganese and copper were estimated in the plant digest according to the method described by **[20]**. The Si concentration in leaf tissue was determined by a colorimetric analysis on 0.1 g of dried and alkali digested leaf tissue [21].

Data were statistically analyzed separately for each season. The combined analysis was conducted for the data of the two seasons according to [22], the least significant differences (LSD) was used to compare between means.

RESULTS AND DISCUSSION

Flax varieties effect

Data in Table (2) show visibly that, Flax species were significantly different in both seasons in their K, P, N, Ca, Mg, Fe, Zn, Mn, Cu and Si content. Meanwhile, the highest values of the previous nutrients content were registered in cv. Sakha-2. However, cv. Amon gave the lowest amounts of the same nutrients content. The differences in chemical content of cultivars that observed are mostly due to the genotype effect of each variety.

Table 2: Genotypic variation in some nutrients content of flax plants (*Linum usitatissimun* L.) (combined of two seasons)

Varieties	K (%)	P (%)	N (%)	Ca (%)	Mg (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Si (%)
Sakha-2	1.48	0.21	2.41	0.35	0.55	249.57	67.93	49.27	12.68	8.93
Amon	1.22	0.19	2.14	0.34	0.42	245.77	62.07	42.53	12.09	6.08
LSD 5%	0.04	0.01	0.15	n.s	0.02	3.56	0.14	1.26	0.06	0.22

This result was in harmony with [23] who found that flax genotypes differed significantly in their response to cultural practices as well as production of fiber and oil and their growth habits. Also, the present results may be due to the genetical variation of the tested varieties. These results are in agreement with [24].

Potassium and magnesium silicate effects

Data in Table (3) show that foliar spray of different silicate sources to flax plants at all levels used led to an obvious increase in the endogenous content of mineral ions (K, P, N, Ca, Mg, Fe, Zn, Mn, Cu and Si) content. The highest amount of K, P, N and Ca % (1.50, 0.27, 2.72 and 0.41 %) respectively, Fe and Mn ppm (286.17 and 53.5 ppm) was recorded by using potassium silicate at a rate of 8 cm^3/L as a foliar spray compared with the other treatments. Furthermore, the highest amount of Mg and Si % (0.52, 8.25 %) was found by foliar application of magnesium silicate at a rate of 8 cm^3/L. On the contrary, the lowest amount of K, P, N and Ca % (1.26, 0.14, 1.86 and 0.28 %), Zn, Mn and Cu ppm (57.42, 35.75 and 11.43 ppm) respectively, was recorded by using magnesium silicate as a foliar spray at rates of 8 cm^3/L. Similar results were obtained by [11] that Si application has been found to minimize the uptake of nitrogen and potassium but increases the uptake of phosphorus, calcium and magnesium in rice and to decrease the percentage of electrolyte leakage thus increasing the mineral content of tissues [12-13].

Table 3: Some nutrients content of flax plants (*Linum usitatissimun* L.) as affected by two different sources of silicon fertilizers (combined of two seasons).

Foliar application cm^3/L		K (%)	P (%)	N (%)	Ca (%)	Mg (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Si (%)
Control		1.33	0.19	2.29	0.33	0.47	218.25	66.44	43.42	11.56	7.06
Potassium silicate	**4**	1.38	0.22	2.46	0.38	0.48	275.75	71.50	52.50	13.97	7.02
	8	1.50	0.27	2.72	0.41	0.46	286.17	67.90	53.50	13.19	7.46
Magnesium silicate	**4**	1.28	0.16	2.05	0.31	0.49	232.67	61.74	44.33	11.79	7.72
	8	1.26	0.14	1.86	0.28	0.52	225.50	57.42	35.75	11.43	8.25
LSD 5%		0.06	0.01	0.11	0.02	0.03	5.62	0.21	1.99	0.10	0.16

Moreover, the lowest amount of Mg % and Fe ppm (0.47 % and 218.25 ppm) was recorded by control treatment and lowest content of Si % (7.02 %) was recorded by foliar spray of potassium silicate at a rate of 4 cm^3/L. The presence of sufficient plant available silicon may increase the oxidative power to precipitate toxic levels of Fe as for Mn at the root surface [26]. Also, Silicon has been shown to influence nitrogen, phosphorus, and the composition of other elements in plant tissue [27].

Interaction effect

The results of the interaction effects of flax plants varieties and different concentrations of potassium silicate and magnesium silicate were found statistically significant at 5% level (Table 4). The highest value of K, P, N and Ca%, Fe and Mn ppm (1.75, 0.27, 3.01 and 0.42 %, 297.17 and 58.33 ppm) respectively, was found by using Sakha-2 variety with potassium silicate as a foliar spray at the rate of 8 cm^3/L. Meanwhile, the highest value of Mg % (0.62) was recorded by treatment of Sakha-2 variety with foliar spray of magnesium silicate at the rate of 8 cm^3/L. Furthermore, the highest value of Zn and Cu ppm (75.90 and 14.39) was found by Sakha-2 variety with potassium silicate treatment at the rate of 4 cm^3/L. Regarding Si %, the highest amount of Si value (11.00) was found by Sakha-2 variety with foliar spraying of magnesium silicate at the rate of 8 cm^3/L. On the other hand, the lowest amount of all elements was recorded by using Amon variety with treatment of magnesium silicate as a foliar spraying at the rate of 8 cm^3/L except for K and Mg % (1.21 and 0.43%), the lowest value was found by Amon variety with foliar spray of magnesium silicate as the foliar spraying at the rate of 4 cm^3/L.

Table 4: Interaction effect of flax variety and two different silicon fertilizers on some nutrients content (combined of two seasons).

Varieties	Foliar application cm^3/l		K %	P %	N %	Ca%	Mg%	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Si %
Sakha-2	Zero		1.45	0.20	2.44	0.33	0.51	208.17	66.42	43.00	11.87	7.40
	Potassium silicate	4	1.50	0.23	2.55	0.37	0.53	278.67	75.90	55.17	14.39	7.92
		8	1.75	0.27	3.01	0.42	0.53	297.17	71.93	58.33	13.35	8.55
	Magnesium silicate	4	1.40	0.19	2.20	0.31	0.57	233.00	65.00	51.00	12.05	9.78
		8	1.31	0.15	1.89	0.30	0.62	230.83	60.38	38.83	11.76	11.00
Amon	Zero		1.21	0.19	2.15	0.32	0.42	228.33	66.46	43.83	11.26	6.73
	Potassium silicate	4	1.26	0.22	2.38	0.40	0.43	272.83	67.09	49.83	13.55	6.13
		8	1.25	0.27	2.43	0.40	0.39	275.17	63.87	48.67	13.02	6.37
	Magnesium silicate	4	1.16	0.14	1.90	0.31	0.42	232.33	58.47	37.67	11.54	5.67
		8	1.21	0.12	1.83	0.26	0.43	220.17	54.46	32.67	11.11	5.51
LSD 5%			0.05	0.02	0.11	0.02	0.05	10.51	0.40	3.73	0.19	0.30

The variability in the obtained results between different flax species used different sources of silicon fertilizers may be due to different in genetic, morphological and physiological characters of flax varieties which may cause different response to the foliar application of silicon fertilizers as was found by [15].

The optimization of silicon supply has been shown to have affirmative effects on plants. Plants differ in their ability to accumulate Si [28] but it must be able to acquire this element in high concentrations for any plant in order to have the beneficial effects from Si. This result may be due uptake of silicon varies by species and by plant group [29]. [28] Suggest that there is a gene that encodes a Si uptake transporter.

CONCLUSION

According to the aforementioned, it could be concluded from this study that potassium silicate fertilizer gave the best effect on some nutrients content of flax plants as a foliar application at the rate 8 cm^3/L. Sakha-2 variety showed a good response to the foliar application with the two different silicon fertilizers especially with potassium silicate at the rate 8 cm^3/L. whereas Amon variety surpassed the other in a very few cases. Generally, foliar application with the two different studied silicon fertilizers gave a best result as compared with control. It seemed evident that using potassium silicate fertilizer as a foliar application gave the best result especially with the rate 8 cm^3/L.

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