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# Production and Quality traits of two Flax Varieties as Affected by foliar application of Silicon Fertilizer under sandy soil conditions

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**ABSTRACT**

Field experiment was conducted in two winter seasons (2013/2014 and 2014/2015) at the Experimental Station of National Research Centre, Al-Nubaria District, El-Behira Governorate, Egypt to study the effect of potassium silicate at a rates of (0, 4 and 8 g/l) and magnesium silicate at a rates of (0, 4 and 8 g/l) as foliar application on production and quality of two flax (Sakha-2 and Amon) varieties under sandy soil conditions. Results show that significant differences among the two flax varieties in all studied characteristics. Sakha-2 variety surpassed Amon in plant height, fruiting zone length, number of fruiting braches/plant, number of capsules/plant, seed yield/plant, straw yield/ plant, seed, straw and oil yield/fed. However, Amon variety surpassed Sakha-2 in technical stem length and Oil %. Foliar application of K and Mg may offer the opportunity of correction the deficiencies more quickly and efficiency. Moreover, Si may help plant in correcting nutrient disorder. Potassium silicate foliar application at the rate 8 g/L gave the highest values for the majority tested characters. The greatest straw and fiber yields were obtained when sowing Sakha-2 variety and treated the plants by potassium silicate at the rate of 8 g/l.

**Keywords**: Flax varieties, production, quality, silicon fertilizers.

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## INTRODUCTION

Flax (*Linum usitatissimum* L.) it is an old economic crop grown as a dual purpose crop for seeds and fibers which is used for the Manufacture of linen. The oil is edible and also, due to its quick drying properly, is used for the preparation of paints, varnishes, printing ink, oil cloth and soap. The flax fiber is soft and flexible. It is, however, stronger than cotton or wool. The best grades of flax fiber are used for linen fabrics, the coarser grades for twines, canvas and bags. Raw flax fiber is also used to make high-quality paper and components for the motor industry. Linseed designates the varieties used for oil, human food and livestock feed. The cultivated area through the last 20 years was decreased from 60.000 to 30.000 sedans due to the great competition of other economic winter crops resulting in a gap between production and consumption. Therefore, it is necessary to increase flax productivity per unit area which could be achieved by using high yielding cultivars and improving the agricultural treatments (El-Hariri, 1998; El-Gazer, 2000; El-Hariri, 2002; El-Gazer, 2006; El-Sahrawi, *et al.,* 2008; Halifax, *et al*., (2011), Barky, *et al*., 2013; El-Hariri, *et al*., 2012; and Barky, *et al.,* 2015).

In Egypt, flax plays an important role in the national economy owing to export beside local industry. Increasing the production of flax from the present limited areas is considered as a basic target. Many investigators reported significant differences among flax varieties concerning seed, straw, oil and fiber yields and there components, El-Hariri, *et al*., (2012) and Barky, *et al*., (2013 and 2014)

Silicon (Si) fertilizer is applied to crops in several countries for increasing productivity and sustainable production (Ma, *et al.,* 2001). It helps to overcome multiple, alleviates metal toxicity and improve nutrient imbalance (Hellas, *et al.*, 2012). Kamenidou *et al.,* (2008 and 2009) indicated that beneficial or detrimental effects of the Si supplements of Zinnia and ornamental sunflower depended on the form of application, silicate source and concentration of Si applied. Foliar application of gerbera plants with potassium silicate ($KSiO_3$) and Sodium silicate ($NaSiO_3$), Sophia *et al.,* (2010) reported that particularly $NaSiO_3$ produced thicker flower peduncles, increased flower diameter, increased height and flowered earlier than non-supplemented controls.

Genetic specify to plant mineral nutrition is manifested, not only through the element content of certain plant organ but also in the morphological and physiological feature and the dry weight (Sari, 1981 and Barky *et al.,* 2012 and 2015).

The objective of the current work was to evaluate the effects of $KSiO_3$ and $MgSiO_3$ fertilizers on growth, yield and quality of flax varieties.

## MATERIALS AND METHODS

A field experiment was carried out at the Experimental Station of National Research Centre, Al-Nuaria 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 newly reclaimed sandy soils where mechanical and chemical analysis are reported in Table (1).

The aim of this work was to investigate the effect of two sources of silicon i.e. potassium silicate ($KSiO_3$) and magnesium silicate ($MgSiO_3$) on growth, yield and quality of flax (*Linum usitatissimun* L.) varieties (Sakha-2 and Amon) grown under newly reclaimed sandy soil. The experimental design was split plot design with three replicates, which flax varieties occupy the main plots and potassium silicate treatments at the rates of (0, 4 and 8 g/L) and magnesium silicate treatments at the rates of (0, 4 and 8 g/L) were allocated at random in subplots. Seeds of flax varieties (Sakha-2 and Amon) were sown on the 17$^{th}$ November in both seasons in rows 3.5 meters long, the distance between rows was 20 cm apart, plot area was 10.5 $m^2$ (3.0 m in width and 3.5 m in length).

The recommended agricultural practices of growing linseed were applied and the seeding rate was (2000 seeds/$m^2$). 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 1$^{st}$, 2$^{nd}$, 3$^{rd}$, 4$^{th}$ and 5$^{th}$ irrigations. Irrigation was carried out using the new sprinkler irrigation system where water was added every 5 days.

Flax plants were foliar sprayed with potassium silicate ($KSiO_3$) at the rate of 0, 4 and 8 g/L and magnesium silicate (Mg $SiO_3$) at the rate of 0, 4 and 8 g/L in both seasons, foliar application of silicon sources were carried out twice, the plants were sprayed after 45 and 60 days from sowing.

Flax plants were pulled when signs of full maturity were appeared, then left on ground to suitable complete drying. Capsules were removed carefully.

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

| Soil characteristics | Mean of two seasons |
|---|---|
| **Mechanical analysis** | |
| Sand % | 91.77 |
| Silt % | 3.33 |
| Clay % | 4.90 |
| Texture | Sandy |
| **Chemical analysis** | |
| pH (1 : 2.5 water) | 7.45 |
| E.C. (memos/cm) | 0.40 |
| $CaCO_3$ % | 1.53 |
| O.M. % | 0.27 |
| **Available** | |
| P | 0.23 |
| K | 11.09 |
| Ca mg/100 g soil | 91.0 |
| Mg | 18.0 |
| Na | 13.69 |
| **Available** | |
| Fe | 4.46 |
| Mn mg/kg soil | 3.55 |
| Zn | 0.09 |
| Cu | 0.09 |

At harvest the following characters were recorded on random samples of 10 guarded plants in each plot to estimate the following characters:

**Fiber yield and its related characters:**

- Plant height (cm)
- Technical stem length (cm)
- Straw yield/plant (g)
- Biological yield / (ton/fed.)
- Straw yield (ton/fed.)
- Fiber %
- Fiber yield (kg/fed) = straw yield (kg/fed.) after retting multiplied fiber percentage.

**Seed yield and its related characters:**

- No. of fruiting branches/plant
- No. of capsules/plant
- Fruiting zone length (cm)
- Seed yield/plant (g)
- 1000 seed weight (g)
- Seed yield (kg/fed.)
- Seed oil % : was determined by sox let apparatus using petroleum ether ($4^{o}$C – 60 $^{o}$C b.p) according to the official method (A.O.A.C. 2000)
- Oil yield (kg/fed.) was calculated by seed yield (kg/fed.) * seed oil %

Data were statistically analyzed separately for each season. The combined analysis was conducted for the data of the two seasons according to (Gomez and Gomez, 1984), the least significant differences (LSD) was used to compare between means.

## RESULTS AND DISCUSSION

### Effect of flax varieties:

Table (2) cleared that yield and yield components of the studied flax varieties differed significantly in all studied characters under this trails. Sakha-2 variety surpassed Amon variety in seed yield (375.36 kg/fed.) and oil yield (139.10 kg/fed.). The superiority of this variety may be due to the highest values of fresh and dry weight (4.34 and 2.64 g)/plant, Fruiting zone length (23.42 cm), number of fruiting branches/plant (10.93), number of capsules/plant (51.13), seed yield/plant (0.53 g) and seed oil %. Similar results were previously obtained by Gaffer *et al.,* (1985); Sorer *et al.,* (1992); El-Hariri *et al.,* (1998) and Barky *et al.,* (2012 & 2015).

Sakha-2 variety significantly exceeded Amon in straw yield (2.378 ton/fed.) and fiber yield (333.64 kg/fed.). These results may be attributed to the highest values of plant height (84.81 cm), Straw yield/plant (1.20 g) and fiber % (13.98). These results are in agreement with those obtained by El-Hariri *et al.,* (1998 and 2012), Halifax, *et al*., (2011) and Barky *et al.,* (2012, 2013 and 2015) and they showed that there were large differences in straw yield and its components among flax varieties. These results indicated that the variability among Sakha-2 and Amon varieties which may be expected due to the differences of these varieties in origin, growth habit, the high diversity in genetic constituent and the environmental conditions of investigated cultivars under sandy soils.

**Table 2: Effect of flax varieties on seed, straw, oil, fiber yields and their components (Combined 2013/2014 and 2014/2015 seasons).**

| Characters | Varieties | | $LSD_{0.05}$ |
|---|---|---|---|
| | Sakha-2 | Among | |
| Fresh weight (g) | 4.34 | 1.91 | 0.81 |
| Dry weight (g) | 2.64 | 1.40 | 0.47 |
| Plant height (cm) | 84.81 | 82.61 | 1.22 |
| Fruiting zone length (cm) | 23.42 | 12.63 | 3.15 |
| Technical stem length (cm) | 61.39 | 69.98 | 2.44 |
| No. of fruiting branches/plant | 10.93 | 4.33 | 1.74 |
| No. of capsules/plant | 51.13 | 12.80 | 3.13 |
| Seed yield/plant (g) | 0.53 | 0.32 | 0.11 |
| Straw yield/plant (g) | 1.20 | 0.60 | 0.21 |
| Seed yield (kg/fed.) | 375.36 | 336.15 | 33.55 |
| Straw yield (ton/fed.) | 2.378 | 2.192 | 61.12 |
| Fiber (%) | 13.98 | 12.87 | 0.88 |
| Fiber yield (kg/fed.) | 333.64 | 283.09 | 23.13 |
| Oil (%) | 36.98 | 38.47 | 0.43 |
| Oil yield (kg/fed.) | 139.10 | 129.42 | 5.14 |

### Effect of Si treatments on morphological characters:

The results given in Table (3) indicated that morphological characters, yield and yield components of flax at harvest were significantly affected by levels of potassium silicate and magnesium silicate. The same table shows that the mean values of studied characters of plants tend to increase with increasing potassium silicate levels (0.0, 4 and 8 g/L) and magnesium silicate levels (0.0, 4 and 8 g/L).

The highest values of plant height, technical stem length were obtained with potassium silicate at the rate of (8 g/L) and with magnesium silicate at the rate of (8 g/L). This may be referred to the role of K information of carbohydrate, proteins, photosynthesis translocation regulation, enzyme action (Nodal, *et al.,* 2011). In addition Salisbury and Ross (1992) mentioned that magnesium is responsible for the activation of many enzymes in photosynthesis, respiration and the formation of DNA and RNA. Moreover, the mechanism involved in the observed accelerated an thesis remains under even through several studies have associated Si supplementation with increased photosynthesis, decreased transpiration and photo hormone change especially on agronomical crops (Ma and Takahashi, 2002). However, Saves *et al.,* (2002) reported that gerbera flower quality and peduncle stem thickness increased when potassium silicate was included in the hydroponic nutrient solution.

**Table 3: Effect of potassium silicate and magnesium silicate on seed, straw, oil, fiber yield and their components (combined 2013/2014 and 2014/2015 seasons).**

| Characters | Control | Treatments | | | | L.S.D 0.05 |
|---|---|---|---|---|---|---|
| | | Potassium silicate | | Magnesium silicate | | |
| | | 4 g/L | 8 g/L | 4 g/L | 8 g/L | |
| Plant height (cm) | 75.30 | 80.87 | 95.85 | 80.22 | 86.33 | 1.15 |
| Fruiting zone length (cm) | 16.13 | 17.85 | 20.93 | 17.75 | 17.47 | 0.23 |
| Technical stem length (cm) | 59.17 | 63.02 | 74.92 | 62.47 | 68.87 | 1.03 |
| No. of fruiting branches/plant | 4.83 | 7.83 | 10.00 | 6.50 | 9.00 | 0.26 |
| No. of capsules /plant | 10.00 | 33.00 | 60.67 | 23.83 | 32.33 | 3.13 |
| Seed yield/plant (g) | 0.34 | 0.46 | 0.50 | 0.40 | 0.45 | 0.03 |
| Straw yield/plant (g) | 0.79 | 0.96 | 1.03 | 0.83 | 0.89 | 0.11 |
| Seed yield (kg/fed.) | 312.29 | 567.13 | 380.14 | 355.80 | 363.43 | 7.19 |
| Straw yield (ton/fed.) | 2.038 | 2.352 | 2.469 | 2.237 | 2.329 | 0.08 |
| Oil % | 36.21 | 37.84 | 38.49 | 37.69 | 38.40 | 0.11 |
| Oil yield (kg/fed.) | 113.03 | 138.82 | 146.09 | 134.00 | 139.34 | 2.35 |
| Fiber % | 12.00 | 13.85 | 14.49 | 13.21 | 13.59 | 0.18 |
| Fiber yield (kg/fed.) | 244.75 | 326.32 | 358.14 | 295.77 | 316.86 | 12.7 |

**Effects of Si treatments on yield and quality:**

It is worth to be mentioned in Table (3) that number of capsules/plant, number of branches/plant, seed yield/plant, straw yield/plant, seed yield/fed., straw yield/fed. Fiber %, fiber yield/fed, oil % and oil yield/fed. Were significantly increased by potassium silicate and magnesium silicate treatments.

The number of branches/plant was reached the highest increase with the rate 8 g/L of potassium silicate. In this connection Kamenidou *et al.,* (2008 and 2009) indicated that beneficial or detrimental effects of Si supplements on zinnia and ornamental sunflower depended on the form of application, silicate source and concentration of Si applied. In addition, Barky *et al.,* (2012 and 2015) showed that all potassium sources were significantly affected in all plant studied characters except technical length.

Data given in Table (3) revealed that the increase of seed yield/plant and fed. As well as oil yield (kg/fed.) were significantly increased by the two fertilizers with increasing the rates. This may be due to the negative effect of low organic matter content and poverty of sandy soils (Table 1).

Data as shown in Table (3) indicated that potassium silicate was superior compound especially at the rate 8 g/L and the increases of seed yield/plant and fed. May be attributed to the effect of potassium mineral in plant such as synthesis of nucleic acid, chlorophyll, oxidative, photospherylation and translocation of solution (Pansy and Sinhala, 1978).

Data presented in Table (3) cleared that the high rate of potassium silicate significantly increased seed yield/fed by 17.9%, straw yield/fed. By 17.5, oil % by 5.92 %, fiber % by 20.75 % and fiber yield/fed by 46.32 % over the control. In this connection, these increases of yield components may be due to potassium content in the experimental soil was not sufficient to meet the requirement of high production and consequently the improvement occurred in K-status by higher fertilization reflecting on the yield. In addition, Hellas *et al.,* (2012) cleared that silicon fertilizer helps to overcome multiple stress, alleviates metal toxicity and improve nutrient imbalance.

**Interaction effect:**

It is clear from data presented in Table (4) showed that there were significant affect of interaction between the flax varieties and treatments on yield and yield components.

Potassium silicate with the high rate recorded superiority among all the treatments with flax varieties. The greatest straw yield (2.523 ton/fed.) and fiber yield (389.05 kg/fed.) were obtained when sowing Sakha-2 variety and treated the plants by potassium silicate at the rate of 8 g/l. This was due to the obtained highest value of Fresh and dry weight /plant and fruiting zone length (29.27 cm), straw yield/plant (1.32g) and fiber % ( 14.12 ) while the best results of oil % (39.33) was achieved by Among variety was due to highest values of plant height (96.97) and technical stem length (84.37cm). Zaharieva (1982) and Mubarak *et al.*, (1992) reported that some plant species and varieties adapt better to unfausurable soil condition than others.

**Table 4: Effect of interaction between flax varieties and treatments (combined 2013/2014 and 2014/2015).**

| Characters | Sakha-2 | | | | | Among | | | | | L.S.D 0.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Potassium silicate | | Magnesium silicate | | Control | Potassium silicate | | Magnesium silicate | | |
| | | 4 g/L | 8 g/L | 4 g/L | 8 g/L | | 4 g/L | 8 g/L | 4 g/L | 8 g/L | |
| Fresh weight(g) | 2.32 | 3.61 | 7.00 | 4.16 | 4.60 | 1.00 | 2.52 | 2.85 | 1.65 | 1.54 | 0.33 |
| Dry weight (g) | 1.55 | 1.80 | 4.12 | 2.60 | 3.12 | 0.66 | 1.94 | 2.19 | 1.10 | 1.10 | 0.13 |
| Plant height(cm) | 75.40 | 83.40 | 94.73 | 84.87 | 85.67 | 75.20 | 78.33 | 96.97 | 75.57 | 87.00 | 2.43 |
| Fruiting zone length (cm) | 16.27 | 26.23 | 29.27 | 21.40 | 23.93 | 16.00 | 9.47 | 12.60 | 14.10 | 11.00 | 1.05 |
| Technical stem length(cm) | 59.13 | 57.17 | 65.47 | 63.47 | 61.73 | 59.20 | 68.87 | 84.37 | 61.47 | 76.00 | 1.20 |
| No. of fruiting branches/plant | 7.00 | 10.67 | 14.33 | 9.33 | 13.33 | 2.67 | 5.00 | 5.67 | 3.67 | 4.67 | 0.32 |
| No. of capsules/ plant | 13.67 | 51.33 | 99.00 | 39.00 | 52.67 | 6.33 | 14.67 | 22.33 | 8.67 | 12.00 | 2.01 |
| Seed yield/ plant (g) | 0.42 | 0.56 | 0.61 | 0.51 | 0.57 | 0.26 | 0.35 | 0.38 | 0.29 | 0.32 | 0.03 |
| Straw yield/ plant (g) | 1.09 | 1.23 | 1.32 | 1.15 | 1.21 | 0.49 | 0.69 | 0.73 | 0.51 | 0.57 | 0.05 |
| Seed yield (kg/fed.) | 315.40 | 389.75 | 407.55 | 378.45 | 358.66 | 309.18 | 344.51 | 352.73 | 333.15 | 341.19 | 5.37 |
| Straw yield (ton/fed.) | 2.145 | 2.478 | 2.523 | 2.315 | 2.427 | 1.930 | 2.225 | 2.415 | 2.158 | 2.230 | 0.18 |
| Fiber (%) | 12.23 | 14.35 | 15.42 | 13.76 | 14.12 | 11.77 | 13.35 | 13.55 | 12.65 | 13.05 | 0.25 |
| Fiber yield (kg/fed.) | 262.33 | 355.59 | 389.05 | 318.54 | 342.69 | 227.16 | 297.04 | 327.23 | 272.99 | 291.02 | 13.33 |
| Oil (%) | 35.05 | 37.38 | 37.65 | 37.26 | 37.55 | 37.36 | 38.30 | 39.33 | 38.12 | 39.25 | 0.03 |
| Oil yield (kg/fed.) | 110.55 | 145.69 | 153.44 | 141.01 | 144.82 | 115.51 | 131.95 | 138.73 | 127.00 | 133.92 | 1.13 |

## CONCLUSION

According to the aforementioned, it could be concluded that the studied growth and yield characters response significantly to the investigated factors. Sakha-2 variety showed its superiority to the most characters under study, whereas among variety surpassed the other in a few cases. It seemed evident that the fertilization with potassium silicate gave the best result especially with the rate 8 g/L.

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