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Effect of Alternative Spraying with Silicate and Licorice Root Extract on Yield and Nutrients Uptake by Pea Plants

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GREEN APPROACHES for enhancing plant growth and production using natural occurring materials are highly needed such as licorice root extract. Silicon is an abundant element on Earth and its positive effects on plants make it important in agriculture. Silicon plays an important role in the mineral nutrition of plants, especially for the high accumulator species, such as pea plants. A field trialwas conducted through 2015 and 2016 growing seasons to study the effect of alternative spraying with silicate and licorice root extract on growth parameters, yield and nutrients uptake by pea plants (*Pisum sativum* L.). Licorice root extract was added as a foliar spray at a rate of 0, 2 and 5 g l^{-1} at 20, 30, and 40 days after sowing. Three concentrations of SiO_2 (0, 500, 750 mg SiO_2 L^{-1}) were spraying at 25, 35, and 45 days after sowing. Therefore, the experimental design was factorial randomized complete block, involving 2 factors; A: silicate rates, B: Licorice extract rates. Results indicated that spraying with silicon and licorice root extract significantly increased fresh pods yield, dry weight of shoots and seeds, protein content and nutrients uptake as compared to untreated plants**.** The best treatment was alternative spraying with silicate (750 mg SiO_2 L^{-1}) and 5 g L^{-1} licorice root extract.

Keywords: Silicon, Licorice extract, Photosynthetic pigments, Nutrients uptake, Pea.

Introduction

Pea (*Pisum sativum* L.) is considered as one of the important vegetables in common use in the world, it ranks among the top 10 crops of vegetables, and it is rich in protein (21-25%), vitamin A and C, calcium, phosphorus, carbohydrates and contains high levels of the amino acids lysine and tryptophan (Bhat et al., 2013 and Matthews & Arthur, 1985).The accelerating use of chemical fertilizers which have adverse heath effects, led to a common trend of using natural substances and natural plant extracts for enhancing plant growth and decreasing the use of chemical fertilizers as possible.

One of these natural plant extracts is licorice root extract (*Glycyrrhiza glabrag*) which is a family of Fabaceae plants. Using this extract in many practical studies for being a vegetarian alternative to extract natural growth regulators and manufacturers contribute to the improvement of plant growth and production. It also contains a substance glycyrrhizin, it is the calcium and potassium salts of glycyrrhizic acid and trihydroxy acid (Newall et al., 1996). Spraying with 3.0 g L^{-1} licorice root extract resulted in a significantly increase in the vegetative growth, *i.e*., plant length, leaf area, head circumference and leaf number (Marie & Al-Allaf, 2012). Abd El-Azim et al. (2017) found that the best growth, essential oil and chemical composition were obtained with water extract of Licorice root. Licorice extract at (4g/ L.) increased the leaf area, chlorophyll, shoot length, shoot diameter (Abd El–Hamied & El-Amary, 2015). Foliar spray with licorice root extract (15 g/L) significantly increased plant height, length of the tallest leaf and number of leaves of the local red onion (Babilie et al., 2015)

Silicon (Si) is the most abundant element in the earth's crust after oxygen, with an average content of about 28.8% (weight) (Wedepohl, 1995). Plants absorb silicon from the soil on uncharged silicic acid form because silicon is not present in the free form (Ranganathan et al., 2006). Silicon is the main component of plants ranging from 1 to 100g kg^{-1} in total dry weight (Ma et al., 2001). The accumulation of silicon varies greatly in plants because of the difference between the ability of the roots to absorb silicon (Ma et al.,

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2006). Although well known that silicon is not an essential element of plants, but there are many studies indicated that it can positively influence on plant growth and production (Balakhnina et al., 2012). Silicon impact on yield associated with depositing element under the leaf epidermis which results in the mechanism of physical protection, and decline the transpiration losses and increases the capacity of photosynthesis (Korndörfer et al., 2004; Crooks & Prentice, 2017 and Tubana et al., 2016). Spraying with Si improved the nutrient status of flax and increased straw and oil yield/ plant (Shedeed et al., 2016). The most crop yield components, harvest index and number of tillers were increased by the foliar application of silicon (Martin et al., 2017). The application of Si-rich materials to soil still remains the most effective method for enhancing Si uptake by plants and increased yield of rice (Agostinho et al., 2017). The application of Si positively affected agronomic and yield-related traits, yield and nutrient uptakes of rice (Cuong et al., 2017). The aim of this work was to assess the effect of alternative spraying with silicate and licorice root extract on growth, yield, some physiological characteristics and nutrients uptake in shoot and seeds of pea plants in sandy soil.

Materials and Methods

Soil analysis and preparation, plant material and experimental procedures

Two field trials were conducted in two successive agricultural seasons of 2015 and 2016 (September, 2015 and September, 2016) in El-Salhia El- Gdida Country, El-Sharkia Governorate, Egypt. It is located at the South Western of Ismaillia city and to the East southern of El-Kassaseen City. It is bounded by (30.651437 latitudes and 31.867269 longitudes). Climate Classification System, where precipitation is less than 50% of potential evapotranspiration, Annual average temperature is over 18°C. In study area, the average rainfall is approximately 20 mm/year. The maximum values of rainfalls are registered in January with average values of 6.9 mm. The average maximum values of temperatures reach (34.6°C) in June. January represents the coldest month (19.0°C). The minimum temperatures range between 8.0°C in January to 21.5°C in August. Soil samples were taken from the study site before each agricultural season and analyzed according to Piper (1951), Black et al. (1968) and Jackson (1973) as shown in Table 1. Seeds pea (*Pisum sativum* L.) were planted in plots which were 3.0 m long × 3.50 m width, giving an area of 10.5 m^2. Pea seeds were obtained from the Crops Research Institute, Agriculture Research Centre, Giza, Egypt. Each plot was fertilized with 30 kg P ha^{-1} as ordinary super phosphate and 100 kg K ha^{-1} as potassium sulphate before sowing, while mineral nitrogen fertilizer was added at a rate of 50 kg N ha^{-1} as ammonium sulphateat two equal doses, the first dose after thinning and the second one before the 2nd irrigation interval. Drip irrigation is performed daily for 15 min in the vegetative growth stages and 30 min in the flowering and pod development stages (50-60 $m^3 ha^{-1}$ per interval).

Preparation and application of Licorice root extract

Licorice root was extracted by the weighting 2 or 5 g of licorice roots, dried and soaked in a liter of water at 50°C for 24 h and then filtered and supplement the final volume to liter. Licorice root extract was applied as a foliar spray at a rate of 2 g l^{-1} and 5 g l^{-1}(1200 L solutions per ha) at three times during the experiment, 20, 30 and 40 days after sowing.

Application of silicon

Silicon as K-silicate (12% SiO_2) was applied as a foliar spray. Two concentrations of 500, 750 mg SiO_2 l^{-1}(1200 L solutions per ha) were applied at three times during the experiment 25, 35 and 45 days after sowing. Potassium chloride was used to modify K concentrations in all applications to be constant so as not to interfere with the study factors. Untreated plants (Control treatment) were sprayed with distilled water. Therefore, the experimental design was factorial randomized complete block, involving 2 factors; A: Silicate rates, B: Licorice extract rates.

Photosynthetic pigments determination

The photosynthetic pigments, *i.e.,* chlorophyll a (Chl. a), chlorophyll b (Chl. b) and carotenoids (Car.) were extracted from fresh plant leaf sample (after 60 days from sowing) using pure acetone according to Fadeel (1962). The extracts were filtered; and then optical density of the filtrate was measured colourimetrically using the wave lengths of 662, 644, 440.5 nm for Chl. a, Chl. b and Car., respectively. The pigments as mg g^{-1} fresh weight were calculated according the formula adapted by Wettstein (1957).

TABLE 1. Physical and chemical properties of the investigated soil.

Soil characteristic	Value	
	1st season	2nd season
Soil particles distribution		
Sand ,%	92.6	91.3
Silt,%	4.18	4.75
Clay,%	3.22	3.95
Textural class	Sandy	Sandy
Field capacity,%	10.3	11.1
$CaCO_3$ (g kg^{-1})	4.64	4.77
Organic matter(g kg^{-1})	3.91	3.53
pH*	8.14	8.12
EC(dSm^{-1})**	1.07	1.18
Soluble cations and anions ($mmol_c l^{-1}$)**		
Ca^{2+}	3.91	3.94
Mg^{2+}	1.69	1.57
Na^{+}	3.47	3.58
K^{+}	0.93	0.99
CO_3^{2-}	-	-
HCO_3^{-}	2.64	2.68
Cl^{-}	3.71	3.67
SO_4^{2-}	3.65	3.76
Available nutrient (mg kg^{-1}soil)		
N	27.4	28.7
P	5.64	6.15
K	55.9	52.3

*Soil-water suspension 1: 1 ** Soil water extract 1: 2.5

Yield attributes determination

Randomly, plants were harvested and weighed. Pods and shoots were detached. The pods were separated manually for seed yield and chemical analysis. The shoot (leaves and stems) was dried at 65 to 70°C for three days until the weight became stable then the dried material is grinded using a mill.

Nutrient uptake determination

Total nitrogen and total potassium were determined in the seed and shoot using a micro Kjeldahl method and flame photometer device, respectively according to Chapman & Pratt (1982). Total phosphorus was determined colourmetrically using ascorbic acid method (Watanabe & Olsen, 1965). Iron, calcium and magnesium were determined by atomic absorption spectrophotometer according to AOAC (1984). Protein percent "yield quality" in seeds were calculated by multi plying N% × 6.25 (Bishni & Hughes, 1979).

Statistical analysis

Statistically significant differences between means were compared at $P \leq 0.05$ using Duncan's Multiple Range Test. The statistical analysis was carried out using COSTAT computer software (CoHort Software version 6.303, Berkeley, CA, USA).

Results and Discussion

Growth parameters and photosynthetic pigments

Data presented in Table 2 elucidate that chlorophyll a and b, carotenoids, plant height, root length, number of pods, pod length and dry root weight were increased due to spraying silicate either alone or combined with licorice root extract. This trend was found true at both seasons.

TABLE 2. Effect of silicate and licorice root extract on growth parameters and photosynthetic pigments of pea plants at 2015 and 2016 seasons.

Silicate	Licorice Extract	Photosynthetic pigments ($mg\ g^{-1}$ f wt) Chl. a	Chl. b	Car.	Plant height (cm)	Root length (cm)	Pods number of plant	Pod length (cm)	Dry root weight ($g\ plant^{-1}$)
1st Season									
Without	Without	1.09^{f}	0.44^{e}	0.35^{e}	59.7^{d}	11.9^{f}	7.67^{g}	5.27^{e}	3.16^{g}
	L_1	1.23^{e}	0.48^{de}	0.41^{e}	61.7^{d}	13.5^{ef}	8.67^{f}	5.60^{de}	3.63^{fg}
	L_2	1.33^{de}	0.55^{d}	0.51^{d}	65.0^{d}	14.9^{e}	9.33^{f}	6.27^{d}	4.16^{ef}
Si_1	Without	1.41^{d}	0.65^{c}	0.53^{d}	68.4^{cd}	19.2^{d}	12.0^{e}	6.10^{de}	4.31^{e}
	L_1	1.61^{bc}	0.78^{b}	0.73^{bc}	86.1^{ab}	25.2^{c}	17.0^{c}	8.13^{c}	5.65^{cd}
	L_2	1.71^{ab}	0.88^{a}	0.79^{ab}	81.3^{bc}	25.9^{bc}	23.7^{b}	10.0^{b}	6.04^{bc}
Si_2	Without	1.54^{c}	0.70^{bc}	0.68^{c}	78.5^{bc}	20.5^{d}	14.3^{d}	7.33^{c}	5.23^{d}
	L_1	1.74^{a}	0.91^{a}	0.80^{ab}	84.7^{ab}	27.6^{ab}	24.7^{a}	10.3^{ab}	6.34^{ab}
	L_2	1.80^{a}	0.96^{a}	0.85^{a}	94.7^{a}	28.6^{a}	25.3^{a}	11.0^{a}	6.94^{a}
2nd Season									
Without	Without	0.99^{g}	0.37^{g}	0.33^{f}	55.9^{e}	11.7^{h}	6.50^{g}	4.93^{f}	3.52^{h}
	L_1	1.26^{f}	0.50^{f}	0.42^{e}	62.4^{de}	14.2^{g}	8.50^{f}	5.53^{ef}	3.82^{gh}
	L_2	1.38^{e}	0.57^{f}	0.52^{d}	65.9^{d}	15.7^{f}	9.50^{f}	6.40^{de}	3.92^{fg}
Si_1	Without	1.44^{e}	0.67^{e}	0.55^{d}	69.2^{d}	18.3^{e}	11.5^{e}	6.77^{d}	4.81^{ef}
	L_1	1.59^{d}	0.80^{cd}	0.73^{c}	85.8^{bc}	25.4^{c}	17.0^{c}	8.47^{c}	5.68^{cd}
	L_2	1.74^{bc}	0.88^{bc}	0.80^{b}	77.9^{c}	26.4^{c}	23.0^{b}	9.75^{b}	6.25^{bc}
Si_2	Without	1.67^{cd}	0.72^{de}	0.69^{c}	78.8^{c}	20.2^{d}	14.5^{d}	7.53^{cd}	5.18^{de}
	L_1	1.79^{ab}	0.93^{ab}	0.83^{b}	89.9^{ab}	27.9^{b}	24.5^{a}	10.6^{ab}	6.25^{b}
	L_2	1.88^{a}	0.99^{a}	0.94^{a}	94.9^{a}	29.9^{a}	26.0^{a}	11.62^{a}	7.15^{a}

Si_1: 500 mg $SiO_2\ L^{-1}$, Si_2: 750 mg $SiO_2\ L^{-1}$, L_1: 2 g L^{-1} licorice root extract and L_2: 5 g L^{-1} licorice root extract.

Concerning the effect of silicate, data show that all the previous characteristics increased with increasing of silicate concentration.The previous characteristics increased by 29, 48,51, 15, 61, 56, 16 and 36 %, respectively in the case of spraying rate of 500 mg SiO_2 L^{-1}, while increased by 41, 59 , 94, 31, 72, 86, 39 and 66 %, respectively for the treatments of spraying at a rate of 750 mg SiO_2 L^{-1}.This increase may be attributed to the effect of silicon on plant growth due to several mechanisms: configure the external protective layer as a result of silica deposition, as well as restrict silicon uptake of heavy metal ions inside the plants and also metabolic functions of silicon within plants (Guntzer et al., 2012 and Luyckx et al., 2017). These results are in agreement with those obtained by Kaya et al. (2006) who found that in semi-arid areas, the addition of silicon improved the growth of maize plant and yield and production. Mukhtar et al. (2012) revealed that the plant growth, physiological attributes and yield parameters were affected significantly by the effect of silicon nutrition. As for the effect of licorice root extract, data reveal that all the previous characteristics increased with increasing concentration of licorice root extract where the increase in chlorophyll a and b, carotenoids, plant height, root length, number of pods, pod length and dry root weight by 13, 9, 17, 3, 13, 13, 6 and 15 %, respectively in the case of licorice root extract (2 g L^{-1}), while the rate of increase was 22, 25 , 46, 9, 25, 22, 19 and 32%, respectively for the treatments of 5 g L^{-1} licorice extract. This increase may be due to the effect of licorice root extract which contains many different important compounds such as glycyrrhizin, polysaccharide, vitamins, mevalonic acid which is the initiator in the synthesis of gibberellins in plants, and many minerals which are mainly required in plant growth (Al-Sahaf & Al-Marsoumi, 2003; Zadeh et al., 2013 and Ghaloom & Faraj, 2012). In this respect, Zuhair (2010) who found that the addition of licorice root extract at a rate of 2.0g L^{-1} gave a significant increase in average leaf area, but 4.0 g L^{-1} of licorice root extract caused a significant increase in total chlorophyll content. Regarding to the effect of alternative spraying with silicate and licorice extract, data reveal that the same as previous characteristics were significant increased due to the spraying alternative of silicate and licorice root extract. The highest values of these characteristics were observed with spraying of 750 mg SiO_2 L^{-1} alternative with 5 g L^{-1} licorice root extract, where all the previous characteristics increased by 69,122, 154, 59, 146, 234, 110 and 123 %, respectively as an average for both seasons.

Yield parameters of pea plants

Data in Table 3 illustrate that the fresh pods weight, dry shoot weight, dry seed weight, biological yield and protein content of pea plants at harvest were improved significantly with increasing silicate rates up to 750 mg SiO_2 L^{-1} compared without addition in both seasons, reached to 54, 60, 99, 77 and 32 % for 1st season and 67, 59, 108, 80 and 31% for 2nd season, respectively. The spraying of silicon fertilizers on crops in many countries has led to increased production of many plants. It was found to increase the growth of wheat, maize, barley, cucumber, sugarcane,tomatoes, citrus and other crops (Epstein, 1994). Several studies have been conducted on silicon fertilization. These studies have suggested positive growth effects of silicon fertilization, as well as increased biomass and yield (Korndorfer & Lepsch, 2001; Crooks & Prentice, 2017; Tubana et al., 2016 and Cuong et al., 2017). For the effect of licorice root extract, data show that increasing the concentration of licorice root extract up to 5 g L^{-1} gave significant increases in values of above parameters compared to the treatment of not using licorice root extract in both seasons, reached to 38, 14, 30, 21 and 23% for 1st season and 36, 11, 36, 22, 23 % for 2nd season, respectively. This increase can be attributed to the fact that the licorice root extract contains more than 100 compounds. The most important of these compounds are phenolic compounds, mevalonic acid, triterpene saponins, protein amino acid (asparagin), lignins ,vitamins (B1, B2, B3, B6, E and C), biotin, folic acid, pantothenic acid and polysaccharide (glucose, fructose, sucrose, maltose) all of which play an important role in improving plant growth and thus increasing production (Rossi, 1999 and Arystanova et al., 2001). Generally, these results are in agreement with Zuhair (2010) who found that spraying two types of strawberries by extracting the roots of the licorice led to a significant increase in vegetative growth. Regarding the interaction effect between silicate rates and licorice root extract concentration, results in most cases, reveal that all parameters significantly increased by using the high rate of silicate (750 mg SiO_2 L^{-1}) alternative with higher rates from licorice root extract (5 g L^{-1}) in both seasons, reached to134, 94, 143, 116 and 65 % for average of the two seasons. On the contrary, the lowest ones were obtained without any addition in both seasons.

TABLE 3. Effect of silicate and licorice root extract on yield and protein content of pea plants at 2015 and 2016 seasons.

Silicate	Licorice	Fresh pods weight (Mg ha^{-1})	Dry shoot weight (Mg ha^{-1})	Dry seed weight (Mg ha^{-1})	Biological yield (Mg ha^{-1})	Protein content (g kg^{-1})
			1st Season			
Without	Without	2.96^{f}	1.41^{e}	1.11^{f}	2.52^{e}	129^{f}
	L_1	3.42^{ef}	1.55^{de}	1.24^{ef}	2.78^{de}	148^{e}
	L_2	4.09^{de}	1.61^{d}	1.44^{de}	3.05^{d}	158de
Si_1	Without	4.27^{d}	1.91^{c}	1.66^{d}	3.57^{c}	158de
	L_1	5.39^{c}	2.35^{b}	2.30^{bc}	4.65^{b}	181^{c}
	L_2	6.14^{b}	2.40^{b}	2.34^{bc}	4.74^{b}	195^{b}
Si_2	Without	4.57^{d}	2.26^{b}	2.21^{c}	4.47^{b}	170^{cd}
	L_1	6.47^{ab}	2.60^{a}	2.54^{ab}	5.14^{a}	209^{a}
	L_2	7.04^{a}	2.70^{a}	2.68^{a}	5.37^{a}	211^{a}
			2nd Season			
Without	Without	2.81^{e}	1.47^{e}	1.06^{f}	2.53^{f}	131^{f}
	L_1	3.36^{e}	1.57^{d}	1.18^{ef}	2.75^{e}	143^{e}
	L_2	4.01^{d}	1.57^{d}	1.51^{de}	3.08^{e}	159^{e}
Si_1	Without	4.45^{d}	1.94^{c}	1.66^{d}	3.60^{d}	158de
	L_1	5.36^{c}	2.37^{b}	2.30^{c}	4.67^{bc}	178^{c}
	L_2	6.28^{b}	2.39^{b}	2.32^{bc}	4.72^{b}	193^{b}
Si_2	Without	4.69^{d}	2.34^{b}	2.21^{c}	4.55^{c}	172^{cd}
	L_1	6.48^{b}	2.63^{a}	2.57^{ab}	5.21^{a}	212^{a}
	L_2	6.83^{a}	2.77^{a}	2.72^{a}	5.50^{a}	215^{a}

Si_1: 500 mg SiO_2 L^{-1}, Si_2: 750 mg SiO_2 L^{-1}, L_1: 2 g L^{-1} licorice root extract and L_2: 5 g L^{-1} licorice root extract.

Nutrients uptake in shoots and seeds of pea plants

Nutrients uptake (N, P, K, Ca, Mg, Fe) by shoot and seed of pea plants illustrated in Tables 4 and 5 which show the existence of significant differences between treatments. For silicate effect, nutrients uptakewere significantly increased with increasing silicate rates up to 750 mg SiO_2 L^{-1} comparing to without addition in both seasons, reached to 115, 369, 110, 121, 247 and 89 %, respectively for shoot and 168, 232, 168, 183, 201 and 134 %, respectively for seed as an average of the two seasons. Nitrogen and phosphorus contents in grain and straw of rice plants significantly increased due to Si application up to 180 kg Si ha^{-1}. While significant improvement in K and Zn concentrations were recorded up to 120 kg Si ha^{-1}. Significant response to silicon application up to 180 kg ha^{-1} was found towards Si contents and its uptake at different growth stages as well as at harvest (Singh et al., 2006 and Martin et al., 2017). According to Mali & Aery (2008a, 2008b), they concluded that silicate fertilization has increased the availability of phosphorus in the soil and made it more accessible to plants. Eneji et al. (2008) also found that there is a correlation between silicon and phosphorus absorption by plants. Where they found that the addition of silicon under the phosphorus deficiency increases the availability of phosphorus in the soil, and that may be due to the increase in phosphorylation (Cheong & Chan, 1973) or a decrease in Mn concentration (Ma & Takahashi, 1990). Nutrients uptake (N, P, K, Ca, Mg, Fe) were increased by increasing the concentration of licorice root extract up to5 g L^{-1} compared to the treatment of not using licorice root extract in both seasons, reached to 19, 60, 29, 33, 83 and 21%, respectively for shoot and 68, 63, 67, 64, 82 and 48 %, respectively for seed as an average of the two seasons. This result may be due to the effect of licorice root extract in increasing of endogenous hormones like GA_3 in treated plants which increased the metabolic processes role and its effect on mineral content in tissue (Thanaa et al.,2016 and Ghaloom & Faraj, 2012). Foliar sprays with liquorice root extract at the rate of 2.5 g.L^{-1} significant increased the high of plant, number of leaves, leaf area, number of flower, the number of flower punches of tomato (Al-Obady, 2015). The spraying of plants with the licorice extract resulted in increased flowering (%) of the plant. This increase may be due to the similarity of licorice root extract in its behavior with GA3 in stimulating flowering. It contains the mephalonic acid which improves vegetative growth as a result of stimulating the enzymes necessary for the conversion of complex compounds into compounds simple, and energy-efficient processing required for plant growth. (Sahi, 2006; AL-Jebouri et al., 2010; Luyckx et al., 2017 and Cuong et al., 2017). According to interaction between silicate and licorice root extract, it was found that the highest average content of nutrients uptake (N, P, K, Ca, Mg, Fe) at the treatment of 750 mg SiO_2 L^{-1} alternative with the highest rate of licorice root extract (5 g L^{-1}) in both seasons, reached to 226, 894, 232, 239, 442 and 175%, respectively for shoot and 308, 432, 347, 344, 436 and 234 %, respectively for seed as an average of the two seasons. While the lowest average content was detected at the treatment of without any addition.

TABLE 4. Effect of silicate and licorice root extract on nutrients uptake by shoots of pea plants at 2015 and 2016 seasons.

Silicate	Licorice	N	P	K	Ca	Mg	Fe
		……kg ha^{-1}				……g ha^{-1}	
				1st Season			
Without	Without	19.6^{e}	1.59^{g}	16.0^{g}	17.8^{f}	5.44^{g}	306^{f}
	L_1	21.9^{e}	2.21^{g}	18.6^{fg}	21.9^{ef}	7.50^{fg}	350^{ef}
	L_2	24.0^{e}	2.46^{g}	21.1^{f}	24.4^{e}	9.48^{f}	382^{e}
Si_1	Without	32.1^{d}	4.66^{f}	25.2^{e}	30.5^{d}	12.4^{e}	453^{d}
	L_1	46.4^{bc}	9.11^{d}	39.2^{c}	44.9^{b}	18.4^{cd}	657^{b}
	L_2	50.0^{b}	11.0^{c}	43.6^{b}	48.1^{b}	19.8^{c}	712^{b}
Si_2	Without	41.6^{c}	7.35^{e}	33.2^{d}	39.0^{c}	16.3^{d}	573^{c}
	L_1	59.2^{a}	12.9^{b}	49.7^{a}	55.4^{a}	23.2^{b}	793^{a}
	L_2	64.2^{a}	15.2^{a}	52.5^{a}	60.3^{a}	26.8^{a}	842^{a}
				2nd Season			
Without	Without	19.8^{f}	1.59^{h}	16.3^{h}	18.6^{f}	4.60^{h}	306^{g}
	L_1	22.2^{f}	2.44^{gh}	18.2^{gh}	22.2^{ef}	7.26^{g}	356^{f}
	L_2	22.8^{f}	2.63^{g}	20.6^{g}	23.8^{e}	8.85^{f}	384^{f}
Si_1	Without	33.4^{e}	4.56^{f}	25.7^{f}	31.5^{d}	12.8^{e}	462^{e}
	L_1	46.3^{d}	9.10^{d}	38.7^{d}	44.8^{bc}	18.2^{d}	581^{d}
	L_2	51.8^{c}	11.0^{c}	44.7^{c}	47.8^{b}	21.2^{c}	724^{b}
Si_2	Without	43.0^{d}	7.56^{e}	34.5^{e}	41.5^{c}	18.1^{d}	637^{c}
	L_1	60.9^{b}	14.3^{b}	51.2^{b}	55.8^{a}	23.6^{b}	804^{a}
	L_2	64.2^{a}	16.4^{a}	54.7^{a}	63.1^{a}	27.2^{a}	852^{a}

Si_1: 500 mg SiO_2 L^{-1}, Si_2: 750 mg SiO_2 L^{-1}, L_1: 2 g L^{-1} licorice root extract and L_2: 5 g L^{-1} licorice root extract.

TABLE 5. Effect of silicate and licorice root extract on nutrients uptake by seeds of pea plants at 2015 and 2016 seasons.

Silicate	Licorice	N	P	K	Ca	Mg	Fe
		………………………kg ha^{-1}				………………………	g ha^{-1}
1st Season							
Without	Without	22.9^{f}	2.88^{e}	12.8^{d}	13.9^{f}	5.65^{e}	276^{f}
	L_1	29.4^{ef}	3.35^{de}	16.4^{cd}	17.5^{ef}	7.59^{de}	319^{f}
	L_2	36.8^{de}	4.27^{de}	21.3^{c}	22.0^{de}	9.63^{d}	389^{e}
Si_1	Without	41.9^{d}	5.40^{d}	22.5^{c}	26.5^{d}	11.3^{d}	455^{d}
	L_1	66.8^{bc}	10.4^{c}	40.0^{b}	43.3^{bc}	19.3^{c}	719^{b}
	L_2	69.8^{b}	10.5^{c}	41.6^{b}	45.7^{b}	19.5^{c}	752^{b}
Si_2	Without	60.1^{c}	8.82^{c}	34.1^{b}	38.2^{c}	16.7^{c}	633^{c}
	L_1	85.2^{a}	12.8^{b}	50.4^{a}	54.3^{a}	23.6^{b}	838^{a}
	L_2	90.5^{a}	15.3^{a}	57.7^{a}	59.8^{a}	28.3^{a}	891^{a}
2nd Season							
Without	Without	22.3^{f}	2.59^{g}	13.1^{f}	13.5^{g}	5.41^{g}	263^{g}
	L_1	26.8^{ef}	3.10^{fg}	14.8^{ef}	16.6^{fg}	6.91^{fg}	303^{f}
	L_2	38.9^{de}	4.62^{ef}	22.0^{e}	22.9^{ef}	10.5^{ef}	406^{e}
Si_1	Without	41.9^{d}	5.53^{e}	22.2^{e}	27.0^{e}	11.6^{e}	459^{e}
	L_1	65.5^{c}	9.74^{cd}	39.8^{cd}	43.5^{cd}	19.7^{d}	717^{c}
	L_2	71.8^{b}	10.5^{bc}	42.3^{bc}	46.5^{c}	20.3^{cd}	764^{c}
Si_2	Without	60.9^{c}	9.28^{d}	35.2^{d}	39.2^{d}	16.6^{bc}	630^{d}
	L_1	87.2^{a}	12.5^{b}	52.1^{b}	54.5^{b}	23.4^{b}	846^{b}
	L_2	93.7^{a}	15.8^{a}	58.0^{a}	61.7^{a}	30.9^{a}	910^{a}

Si_1: 500 mg SiO_2 L^{-1}, Si_2: 750 mg SiO_2 L^{-1}, L_1: 2 g L^{-1} licorice root extract and L_2: 5 g L^{-1} licorice root extract.

Correlation coefficient among different parameters in pea plants

The correlation coefficient value ranges from -1.0 to +1.0. Where the value of -1.0 indicates a complete negative relationship, while the value of + 1.00 indicates an ideal positive relationship. While the value 0.00 represents a lack of correlation. Correlation coefficients between different parameters (Chl.a, Chl.b, carotenoids, plant height, fresh pods weight, dry seed weight, dry shoot weight, nutrients uptake by shoot, nutrients uptake by seed) of pea plant at different growth seasons are shown in Tables 6, 7. Data reveal that positive and highly significant correlation coefficients among different parameters were obtained for both seasons.These results are in agreement with those of Shaban (2005) who found that the relationships between some characteristics (plant height, leaves number, plant fresh weight) and yield have different values. The correlation coefficient between fresh weight, plant height, and yield has positive values.

TABLE 6.Correlation coefficient among different parameters in pea plants in 1st season.

Character	Character																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
(1) Chlorophyll a	1.00																		
(2) Chlorophyll b	0.96**	1.00																	
(3) Carotenoids	0.99**	0.96**	1.00																
(4) Plant height	0.79**	0.81**	0.84**	1.00															
(5) Fresh pods weight	0.96**	0.96**	0.96**	0.80**	1.00														
(6) Dry seed weight	0.97**	0.94**	0.98**	0.85**	0.93**	1.00													
(7) Dry shoot weight	0.96**	0.95**	0.96**	0.85**	0.92**	0.96**	1.00												
(8) N uptake by shoot	0.94**	0.95**	0.94**	0.85**	0.96**	0.95**	0.98**	1.00											
(9) P uptake by shoot	0.94**	0.92**	0.93**	0.81**	0.95**	0.93**	0.96**	0.99**	1.00										
(10) K uptake by shoot	0.97**	0.95**	0.96**	0.82**	0.96**	0.95**	0.98**	0.98**	0.98**	1.00									
(11) Ca uptake by shoot	0.95**	0.94**	0.94**	0.88**	0.94**	0.95**	0.98**	0.98**	0.97**	0.98**	1.00								
(12) Mg uptake by shoot	0.96**	0.95**	0.95**	0.84**	0.96**	0.95**	0.98**	0.98**	0.98**	0.99**	0.98**	1.00							
(13) Fe uptake by shoot	0.96**	0.96**	0.95**	0.82**	0.95**	0.96**	0.98**	0.99**	0.98**	1.00**	0.99**	0.99**	1.00						
(14) N uptake by seed	0.97**	0.94**	0.97**	0.85**	0.96**	0.98**	0.96**	0.97**	0.97**	0.98**	0.97**	0.98**	0.98**	1.00					
(15) P uptake by seed	0.94**	0.93**	0.95**	0.82**	0.94**	0.95**	0.93**	0.96**	0.96**	0.95**	0.93**	0.95**	0.95**	0.97**	1.00				
(16) K uptake by seed	0.94**	0.92**	0.95**	0.86**	0.95**	0.96**	0.93**	0.96**	0.96**	0.95**	0.95**	0.95**	0.95**	0.98**	0.97**	1.00			
(17) Ca uptake by seed	0.96**	0.94**	0.96**	0.88**	0.95**	0.98**	0.97**	0.98**	0.97**	0.98**	0.99**	0.98**	0.98**	0.99**	0.96**	0.98**	1.00		
(18) Mg uptake by seed	0.93**	0.90**	0.92**	0.87**	0.93**	0.95**	0.96**	0.97**	0.96**	0.96**	0.98**	0.97**	0.97**	0.97**	0.93**	0.95**	0.98**	1.00	
(19) Fe uptake by seed	0.97**	0.96**	0.98**	0.86**	0.96**	0.99**	0.97**	0.97**	0.96**	0.98**	0.97**	0.97**	0.98**	0.99**	0.97**	0.98**	0.99**	0.96**	1.00

TABLE 7. Correlation coefficient among different parameters in pea plants in 2nd season.

Character	Character																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
(1) Chlorophyll a	1.00																		
(2) Chlorophyll b	0.92**	1.00																	
(3) Carotenoids	0.96**	0.96**	1.00																
(4) Plant height	0.88**	0.89**	0.91**	1.00															
(5) Fresh pods weight	0.93**	0.95**	0.96**	0.91**	1.00														
(6) Dry seed weight	0.94**	0.95**	0.97**	0.93**	0.93**	1.00													
(7) Dry shoot weight	0.93**	0.95**	0.96**	0.92**	0.92**	0.97**	1.00												
(8) N uptake by shoot	0.92**	0.94**	0.96**	0.93**	0.95**	0.96**	0.98**	1.00											
(9) P uptake by shoot	0.90**	0.93**	0.95**	0.93**	0.95**	0.95**	0.96**	0.99**	1.00										
(10) K uptake by shoot	0.91**	0.95**	0.96**	0.90**	0.96**	0.96**	0.96**	0.98**	0.98**	1.00									
(11) Ca uptake by shoot	0.91**	0.95**	0.95**	0.94**	0.95**	0.96**	0.98**	0.98**	0.97**	0.98**	1.00								
(12) Mg uptake by shoot	0.95**	0.96**	0.98**	0.92**	0.96**	0.97**	0.98**	0.99**	0.97**	0.98**	0.98**	1.00							
(13) Fe uptake by shoot	0.92**	0.96**	0.96**	0.90**	0.95**	0.96**	0.98**	0.99**	0.98**	0.99**	0.98**	0.99**	1.00						
(14) N uptake by seed	0.93**	0.95**	0.97**	0.94**	0.96**	0.99**	0.96**	0.97**	0.97**	0.98**	0.97**	0.97**	0.98**	1.00					
(15) P uptake by seed	0.91**	0.93**	0.96**	0.91**	0.95**	0.97**	0.94**	0.96**	0.96**	0.98**	0.96**	0.96**	0.96**	0.97**	1.00				
(16) K uptake by seed	0.89**	0.92**	0.95**	0.94**	0.95**	0.97**	0.93**	0.96**	0.97**	0.97**	0.96**	0.95**	0.95**	0.99**	0.97**	1.00			
(17) Ca uptake by seed	0.91**	0.95**	0.96**	0.95**	0.96**	0.98**	0.96**	0.97**	0.97**	0.98**	0.99**	0.97**	0.97**	0.99**	0.98**	0.98**	1.00		
(18) Mg uptake by seed	0.91**	0.94**	0.95**	0.93**	0.94**	0.96**	0.96**	0.97**	0.97**	0.97**	0.98**	0.97**	0.97**	0.97**	0.95**	0.95**	0.98**	1.00	
(19) Fe uptake by seed	0.93**	0.96**	0.98**	0.93**	0.96**	0.99**	0.97**	0.97**	0.97**	0.98**	0.97**	0.98**	0.98**	0.99**	0.98**	0.98**	0.99**	0.97**	1.00

Conclusion

In conclusion, spraying silicon and licorice root extract improved plant growth, nutrients uptake and consequently yield of pea plants. In particular, treatment of silicate (750 mg SiO_2 L^{-1}) alternative with 5 g L^{-1} licorice root extract were the best compared to the rest of spray treatments. These natural compounds can be used as an alternative to chemical fertilizers and growth regulators to improve growth and increase production of pea plants which are harmless to health and to the environment.

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تأثير تناوب الرش بالسليكون ومستخلص جذور العرقسوس على المحصول وامتصاص العناصر بواسطة نباتات البازلاء

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هناك حاجة ماسة إلى تعزيز نمو النبات وإنتاجه باستخدام المواد الطبيعية مثل مستخلص جذور نباتات العرقسوس. أيضاً يلعب السيليكون دوراً هاماً في التغذية المعدنية لمعظم النباتات مثل نبات البازلاء. أجريت تجربة حقلية خلال موسمي الزراعة 2015 و2016 ، وذلك بهدف دراسة تأثير تناوب الرش بالسليكات ومستخلص جذور العرقسوس على صفات النمو والمحصول وامتصاص العناصر الغذائية بواسطة نباتات البازلاء. تم استخدام مستخلص جذور العرقسوس كرش ورقى بتركيزات ٠ ، 2 ، 5 جم لتر$^{-1}$ حيث تم الرش بعد 20 ،30، 40 يوم من الزراعة. أيضاً تم رش السليكات بتركيزات 0 ، 500 ، 750 ملجم SiO_2 لتر$^{-1}$ وذلك بعد 25، 35 ، 45 يوم من الزراعة. وكان تصميم التجربة يتبع القطاعات كاملة العشوائية. أوضحت النتائج المتحصل عليها أن الرش بالسليكات ومستخلص جذور العرقسوس أعطى زيادة معنوية فى كل من محصول القرون الطازج، الوزن الجاف للعرش والبذور ومحتوى البروتين وامتصاص العناصر الغذائية بواسطة نباتات البازلاء، وذلك مقارنة بالنباتات الغير معاملة. وكانت أفضل معاملة تم التحصل عليها هي تناوب رش نباتات البازلاء بالسليكات بمعدل750 ملجم SiO_2 لتر$^{-1}$ ومستخلص جذور العرقسوس بمعدل 5 جم لتر$^{-1}$.