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Effect of Foliar Spray with Potassium Silicate and Glycine Betaine on Growth and Early Yield Quality of Strawberry Plants

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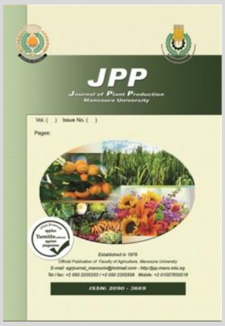

ABSTRACT

At private farm in Demiana village, Bilqas district, El-Dakahlia governorate, Egypt during the two consecutive winter seasons of 2018 and 2019, experimental field was carried out to study the response of vegetative growth, chemical components in leaves, yield and fruit quality of strawberry (*Fragaria ssp*.) cv. Fortuna to foliar spray with potassium silicate (KSi), glycine betaine (GB)and their interaction treatments. The experiment was done in split-plot within complete block randomized design. Potassium silicate treatments were four concentrations as (0.0, 0.2, 0.4 and 0.6 g/l) and glycine betaine were three concentrations as (0, 2.5 and 5 g/l). The obtained results referred to that KSi and GB significantly affected on vegetative growth, chemical components in leaves, yield and fruit quality. Furthermore, foliar application with KSi at 0.6 g/l gave the highest values of vegetative growth, leaves contents, yield and fruit quality. As well as, foliar application with GB at any concentration significantly improved vegetative growth, chemical components in leaves, yield and fruit quality compared to control. In general, the best interaction treatment in this concern was that KSi at 0.6 g/l interacted with GB at 5 g/l as foliar spray compared to the other ones under study. Thus, it can be recommended that spraying strawberry plants with potassium silicate at 0.6 g/l and glycine betaine at 5 g/l can promote vegetative growth and increase the early yield and fruit quality under cold condition that are likely to occur in this period (November to February) which meet main export season..

Keywords: Strawberry, foliar application, potassium silicate, glycine betaine, early fruit yield and quality.

INTRODUCTION

Strawberry (*Fragaria ssp* L.) is counted one of the most remarkable vegetables belongs to family *Rosacea*. In Egypt, it has taken place prominent in local consumption and exportation. Strawberries have a good scope during November to March for exportation to Europe united and Arab countries as well as USA. It contains high levels of vitamin C and high amounts of pigment as anthocyanin and other minerals. It considered a delicious fruit during winter season. The effect of climatic conditions have on agricultural productivity depends on the sensitivity to each environmental factor and relative changes in temperature, precipitation. The strawberry is a microclimatic crop cultivated almost worldwide and Egypt is the world's Fifth-largest strawberry producer. Total cultivated area in Egypt is 21143 fed. produced 362639 tons (FAOSTAT data, 2018). Strawberry production in Egypt has been affected by climate change in recent decades. Abiotic and biotic stress primary environmental factors controlling short-day strawberry plant growth and development. Temperature (cold during early yield and heat during late yield) is a limiting factor in crop productivity

The positive effect of potassium silicate (K_2SiO_3) might be reflected to the contained soluble potassium (K) and silicon (Si), potassium which plays a role in several of the fundamental regulatory functions in the plant (Abou-Baker *et al*., 2011). However, potassium plays a major status in plant under biological as well as non- biological stresses (Marschner, 1995). Also, potassium silicate (KSi) as a perfect source for silicon (Si) for vegetable crops especially strawberry as foliar application which utilized widely to raise resistant to biotic (powdery mildew disease) and abiotic (heat and cold stress) stresses which led to maximizing vegetative growth and yield of strawberry (Wang and Galeta, 1998 and Palmer, 2007). Furthermore, Si minimizes many stresses type in plants by saving water in the plant, increasing activity of photosynthetic and stomatal conductance as well as leaf erectness under high rates of transpiration (Crusciol *et al*., 2009 and Das *et al*., 2017). In addition, foliar spray with potassium silicate increased growth, yield and quality on strawberries (Wang and Galeta, 1998 and Zydlik *et al*., 2009), Jerusalem artichoke (Abou El-Khair and Mohsen, 2016), garlic (Mohamed *et al*., 2019), squash (Abd-Elaziz *et al*., 2019) and sweet potato (El Nagy *et al*., 2020).

Amino acids behold organic nitrogenous compounds and they are the primary basis in the synthesis of proteins. Furthermore, glycine betaine as amino acid influences in IAA, gibberellins synthesis, and made transmission of effective compounds in the plants more easier, these reflect on physiological activities of lettuce plant growth (Kowalczyk and Zielony, 2008) and increase plant resistance against stress and pathogens (Rai, 2002), promote growth against stresses (Ahmed *et al*., 2016) on tomato. In addition, application with glycine betaine and amino acids increased yield and overall quality of strawberry (Abo Sedera *et al*., 2010, Alaei *et al*., 2016 and Adak, 2019). Exogenous foliar spraying of glycine betaine (2 mM) to unhardened plants enhanced the cold tolerance of leaves about twice within 72 h of application. As well as, indicated that glycine betaine is

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implicated in inducing cold tolerance during natural cold acclimation of strawberry plants (Rajashekar *et al.*, 1999).

The aim of this study was to investigate the effect of potassium silicate and glycine betaine and their interaction treatments as foliar spray on vegetative growth parameters, chemical components in leaves, yield components and fruit quality of strawberry (cv. Fortuna). Also, to increasing the strawberry tolerance to cold conditions during early crop harvest (November to February) and beyond, to increase the quality of the fruits for export during this period.

MATERIALS AND METHODS

Two field experiments were conducted at commercial strawberry fruit production Farm in Demiana Village, Bilqas District, El-Dakahlia Governorate, Egypt, during two winter consecutive seasons of 2018 and 2019. They aimed to study the effect of potassium silicate (KSi) and glycine betaine (GB) as safety substances and their interactions on vegetative growth parameters, chemical components in leaves, yield and its component and fruit quality of strawberry (*Fragaria ssp*.) cv. Fortuna. Some physical and chemical properties of the experimental soil are presented in Table 1 during both seasons, according to Chapman and Pratt (1978).

The plot area was 14.4 m^2 (3 beds ×1.6 m width × 3 m length) with 144 plants/ plot. Each bed has two drippers lines (distance at 25 cm and have 4 l/h flow rate) and four rows of transplants. Fresh transplants of strawberry were dipped in disinfectant solution (Rhizolex solution at a rate of 3.0 g /l for 30 minutes) before planting immediately. Then, transplanted at 25 cm between each and other on both sides of dripper line on 1st and 2nd September 2018 and 2019 seasons, respectively. Sprinkler irrigation was used for two weeks after transplanting. The drip irrigation was utilized from 3rd week until the end of the season. In the 5th week from planting removing runners and defoliation were done, after that the beds were mulched with 60 micron brown-silvery plastic mulch at the end of this week (35 days from transplanting).

Table 1. Some physical and chemical properties of experimental soil during 2018 and 2019 seasons

Seasons	Sand %	Clay %	Silt %	Texture soil	F.C %	W.P %	AW %	pH	E.C (dSm-1)	O.M %	$CaCO_3$ %	N ppm	P ppm	K ppm
2018	23.4	36.9	39.7	Clay loamy	34.**6**	19.**4**	17.**2**	8.15	1.64	1.93	3.27	51.7	5.8	294
2019	23.2	37.6	39.2	Clay loamy	35.3	19.8	17.9	8.11	1.62	2.02	3.36	53.2	6.1	289

F.C: Field Capacity - W.P.: Welting point - AW: Available water - OM: Organic matter

A split-plot design with three replicates was utilized in this experiment, where the four tested concentration of potassium silicate (0, 0.2, 0.4 and 0.6 g l^{-1}) were located at the main plots while the three spray treatments of glycine betaine (0, 2.5 and 5 g l^{-1}) were distributed randomly in the sub plots. The experimental included 12 treatments resulted from the combination between four concentration of potassium silicate and three concentration of glycine betaine as foliar spray application.

Application of treatments with potassium silicate and glycine betaine as foliar spraying of plants was done for ten times every 15 days after 30 days from transplanting through two seasons with hand pressure sprayer 20 L in volume at 200 liter/feddan. Water was used in control treatment (0 ppm for KSi and GB). Potassium silicate (KSi) prepared from trade compound named Silicate (32% K_2SiO_3) from United Agriculture Development company (UAD). While, Glycine betaine (GB) was obtained as pure powder from El-Gomhoria Chemical Company.

Fertilization program started in the 4th week from planting with drip irrigation system (Fertigation). Where, fertilizers divided during the growth season according to fertigation program applied in the experiment. All agricultural practices were conducted according to recommendation of Egyptian Ministry of Agriculture.

Data recorded:

Five plants were taken from each experimental plot on 1st February in the two seasons to determine the vegetative growth parameters, leaves chemical content and dry matter as following:

1. Vegetative growth parameters:

Plant height, foliage fresh weight, number of secondary crown per plant, number of leaves per plant and leaves area per plant.

2. Chemical contents of leaves:

Chlorophyll a, b and carotenoids were determined according to A.O.A.C. (2012). Leaves dry matter as fresh leaves were oven dried at 80°C for 72 h till constant weight, then leaves dry matter was recorded as percentage (Dien et al., 2017).

3. Fruit yield and its components:

During the harvesting stage which started after 2 months from planting to the end of the season. Early yield (from first harvest to 15th February) and total yield (during harvesting season which ended at 31st May) were measured as following parameter:

- Marketable yield was calculated as weight of all desired fruits (homogenous color and have a good shape) per plot.
- Unmarketable yield was calculated as weight of undesired fruits (rotted fruit, green shouldered, malformed and water damaged) per plot.
- Total yield was calculated as weight of all harvested fruits (marketable and unmarketable) per plot.

4. Fruit quality:

After 5 months from planting (1st February), a random sample of 10 fruits at full ripe stage from each experimental plot was taken to determine the following properties:

Physical quality:

Average fruit weight as mean weight of ten ripe and fresh fruits per plot. Firmness was determined by hand Effegi-Penetrometer firmness using a penetrating needle of 4 mm of diameter and recorded as g/cm^2. Fruit dry matter was determined as fresh ripe fruit were oven dried at 80°C for 72h till constant weight, then fruit dry matter was recorded as percentage (Dien et al., 2017).

Chemical quality:

Total Soluble Solids (TSS %): Were determined by using hand Refractometer (Brix°). Also, the ascorbic acid content (V.C.) was determined as mg/100g fresh weight using 2.6 dichlorophenol indophenol as indicator for titration as outlined in A.O.A.C. (2012). Total sugar was determined in fresh strawberry fruits by using Lane and Eynon method according to A.O.A.C (2012). Anthocyanin content was determined by using spectrophotometer as described by A.O.A.C (2012). In addition, titratable acidity percentage:

was measured by titration the juice of fruits against 0.1 N NaOH and expressed as percent of citric acid according to A.O.A.C. (2012).

Statistical analysis:

Data were subjected to statistical analysis for calculation of means, variance and stander error according to Statistix 9 software (Analytical software, 2008). Mean separations were estimated by calculating LSD value at 5% level according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative growth:

Data presented in Table 2 revealed that all potassium silicate rates significantly increased strawberry growth parameters compared to control (sprayed with tap water). The tallest, heaviest, more crown and leaves number per strawberry plants were obtained from the highest rate of potassium silicate (0.6 g/l) compared to control and the other rates under study in both seasons. In gradual, increasing potassium silicate rate from 0.2, 0.4 to 0.6 g/l increased plant height, fresh weight per plant, secondary crown number per plant, number of leaves per plant and leaf area of strawberry plants.

Data in the same Table showed that the two rates of glycine betaine was significantly increased all vegetative growth parameters of strawberry compared to control in both seasons. The highest values of plant height, fresh weight per plant, crown number per plan, number of leaves per plant and leaf area of strawberry plants were obtained by spraying glycine betaine (5 g/l) in both seasons.

Concerning of interaction between potassium silicate and glycine betaine, Data in Table 2 presented that, all vegetative growth parameters of strawberry significantly increased by increasing concentration of potassium silicate and glycine betaine compared to control in both season. Furthermore, spraying strawberry plants by potassium silicate (0.6 g/l) and glycine betaine (5g/l) gave highest plant height, fresh weight/plant, crown number/plant, leaves number/plant and leaves area/plant.

In this regard, Safoora *et al*. (2018) reported that an increase in the rates of potassium silicate caused an increase in most of the quantitative characteristics such as specific leaf area and net photosynthesis rate of strawberry plant. Abdel-Latif *et al*. (2019) pointed out that the highest plant lengths, number of leaves as well as fresh and dry weights/plant of garlic were achieved from foliar application of 4000 ppm potassium silicate compared to the control.

Table 2. Effect of foliar spray with potassium silicate and glycine betaine as well as their interaction on vegetative growth parameters of strawberry in 2018/2019 and 2019/2020 seasons

Treatments		Plant height (cm)		Foliage FW/ plant (g)		Secondary crowns No. / plant		Leaves number/ plant		Leaves area / plant (cm^2)	
		1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S
Potassium silicate (g L^{-1})											
Zero		18.90	18.05	106.6	101.8	6.52	6.23	38.31	36.59	961.0	917.8
0.2		19.38	18.54	109.3	104.6	6.68	6.40	42.41	40.59	985.1	942.8
0.4		19.93	19.11	112.4	107.7	6.88	6.59	42.92	41.14	1013.2	971.1
0.6		20.14	19.32	113.6	109.0	6.95	6.67	44.61	42.80	1023.9	982.3
LSD 5%		0.27	0.25	1.53	1.46	0.14	0.09	0.49	0.47	13.75	13.17
Glycine betaine (g L^{-1})											
Zero		18.78	17.88	105.9	100.8	6.48	6.17	40.03	38.12	954.6	909.0
2.5		19.73	18.89	111.2	106.5	6.81	6.52	42.40	40.61	1002.8	960.5
5.0		20.26	19.49	114.2	109.9	6.99	6.72	43.75	42.10	1029.9	991.1
LSD 5%		0.16	0.15	0.92	0.88	0.08	0.05	0.37	0.35	8.30	7.94
Interaction (Potassium silicate x Glycine betaine)											
zero	zero	18.26	17.35	102.9	97.8	6.30	5.98	36.84	34.99	928.1	881.7
	2.5	18.92	18.07	106.7	101.9	6.53	6.24	38.29	36.56	962.0	918.7
	5	19.53	18.74	110.1	105.7	6.74	6.47	39.81	38.22	992.8	953.1
0.2	zero	18.56	17.66	104.6	99.6	6.40	6.09	40.80	38.84	943.4	898.1
	2.5	19.50	18.66	109.9	105.2	6.73	6.44	42.60	40.76	991.3	948.6
	5	20.07	19.31	113.2	108.9	6.92	6.66	43.82	42.16	1020.5	981.8
0.4	zero	19.09	18.19	107.7	102.6	6.59	6.28	39.89	38.03	970.5	924.9
	2.5	20.05	19.23	113.1	108.4	6.92	6.64	43.74	41.94	1019.3	977.5
	5	20.65	19.89	116.4	112.1	7.13	6.86	45.14	43.47	1049.8	1011.0
0.6	zero	19.21	18.32	108.30	103.3	6.62	6.32	42.61	40.65	976.3	931.4
	2.5	20.44	19.62	115.23	110.6	7.05	6.77	44.99	43.19	1038.8	997.3
	5	20.78	20.03	117.20	113.0	7.17	6.91	46.22	44.56	1056.5	1018.5
LSD 5%		0.38	0.36	2.13	2.04	0.20	0.12	0.77	0.74	19.26	18.43

Exogenous application of glycine betaine can induce cold tolerance in both unhardened and cold acclimating plants with increasing strawberry growth and yield (Rajashekar et al., 1999). Using glycine betaine enhanced all aforementioned parameters compared to control treatment. In this concern positive effect of amino acids may be due to its effect on physiological activities in growth and development. In addition, it considered precursors of proteins that were important for cell growth, also play role in photosynthesis by involved in the enzymes formation (Rai, 2002). Also, glycine betaine has significant increment in growth parameters of alfaalfa and cowpea (Khadouri, 2015).

Chemical contents of leaves:

As for leaves chemical content of strawberry plants treated with potassium silicate, data in Table 3 exhibit that chl. a, chl. b, carotenoids and leaves dry matter were increased significantly by increasing potassium silicate concentrations. Also, the highest leaves chemical contents under study were obtained with the highest potassium silicate concentration sprayed with (0.6 g/l) compared to the other levels.

Also in the same Table, leaves chemical contents under study were increased as glycine betaine level was increased in both seasons. However, the highest level of glycine betaine (5 g/l) gave the highest values of chl. a, chl. b, carotenoids and leaves dry matter compared to the other one and the control under study. The interaction effect between potassium silicate and glycine betaine rates presented in Table 3 reveal that under each level of potassium silicate, chlorophyll a, chlorophyll b, carotenoids and leaves dry matter of strawberry plants were gradually increase with increasing potassium silicate rate in both seasons. In addition, spraying strawberry plants with potassium silicate at 0.6 g/l plus glycine betaine at 5 g/l, gave the highest values of chemical contents of leaves in both seasons.

Potassium silicate (KSi) is used as significant complement of K, such potassium impacts most of the biochemical and physiological processes that effectiveness plant growth and metabolism (Mengel, 2005). In this regard, Abd Elwahed (2018) demonstrated that utilizing of potassium silicate as foliar application at 300 ppm caused a significant increment in total chlorophyll and dry weight content compared to control in tomato. Likewise, Safoora *et al.* (2019) found that potassium silicate at 15 mmol/l significantly improved chlorophyll content in strawberry leaves compared to control and the other rates under study (5 and 10 mmol/l). Furthermore, Ahmed *et al.* (2016) stated that glycine betaine at 50 ppm treatment significantly increased different estimated pigments i.e., chlorophyll a and b of tomato leaves compared to those of the control during early seasons which cold stress occurs.

Table 3. Effect of foliar spray with potassium silicate and glycine betaine as well as their interaction on leaves chemical contents of strawberry in 2018/2019 and 2019/2020 seasons.

Treatments		Chl. a mg/100 g FW		Chl. b mg/100 g FW		Carotenoids mg/100 g FW		Leaves dry matter (%)	
		1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S
Potassium silicate (g L^{-1})									
zero		81.39	77.74	40.25	38.44	22.80	21.77	26.21	25.03
0.2		85.43	81.77	42.25	40.44	23.93	22.90	26.86	25.71
0.4		88.08	84.41	43.56	41.74	24.80	23.77	27.63	26.48
0.6		92.83	89.07	45.91	44.05	26.18	25.12	27.92	26.79
LSD 5%		1.49	1.41	0.74	0.70	0.41	0.39	0.37	0.35
Glycine betaine (g L^{-1})									
zero		82.08	78.16	40.59	38.65	22.99	21.89	26.03	24.79
2.5		88.07	84.35	43.55	41.71	24.67	23.63	27.35	26.19
5		90.65	87.23	44.83	43.14	25.62	24.65	28.09	27.02
LSD 5%		1.06	1.01	0.52	0.50	0.30	0.28	0.23	0.22
Interaction (Potassium silicate x Glycine betaine)									
	zero	75.82	72.02	37.50	35.62	21.24	20.17	25.31	24.04
zero	2.5	82.59	78.87	40.85	39.00	23.14	22.09	26.24	25.05
	5	85.76	82.32	42.41	40.71	24.03	23.06	27.07	25.99
	zero	81.63	77.71	40.37	38.43	22.87	21.77	25.72	24.49
0.2	2.5	86.84	83.10	42.95	41.10	24.33	23.28	27.03	25.87
	5	87.83	84.49	43.43	41.78	24.61	23.67	27.83	26.77
	zero	84.79	80.80	41.93	39.96	23.75	22.64	26.46	25.22
0.4	2.5	88.70	85.06	43.87	42.06	24.85	23.83	27.79	26.66
	5	90.75	87.39	44.88	43.21	25.79	24.84	28.63	27.57
	zero	86.07	82.11	4257	40.60	24.11	23.00	26.62	25.40
0.6	2.5	94.15	90.38	46.56	44.70	26.37	25.32	28.33	27.19
	5	98.27	94.73	48.60	46.85	28.06	27.04	28.81	27.77
LSD 5%		2.28	2.17	1.13	1.07	0.64	0.60	0.52	0.50

Fruit yield and its components:

Data in Table 4 show that application of potassium silicate significantly increased marketable yield and total yield (ton) per feddan as early or total yields of strawberry plants compared to the control in 2018/2019 and 2019/2020 seasons. While, unmarketable early yield was gradually decreased as KSi increased in both seasons. Spraying strawberry plants with potassium silicate at 0.6 g/l recorded the highest values in this connection in the two seasons.

In the meantime, using the highest level of glycine betaine 5 g/l gave the highest values of each marketable or total early and total yield per feddan compared to the other one and the control in both seasons. In addition, significant decreasing of unmarketable yield was obtained with increasing glycine betaine level in comparison with the control.

Regarding of the interaction effects between potassium silicate and glycine betaine, it clear that the highest values of marketable yield and total yield (ton) per feddan of strawberry could been obtained by spraying plants with potassium silicate at 0.6 g/l plus glycine betaine at 5 g/l (Table 4).

Similarly, Mohamed *et al.* (2019) spraying garlic plants with K silicate at 2 ml/l increased bulb and total dry weight/plant, yield of grades 1, 2, 3 and 4, exportable, marketable and total yield/feddan. Also, Ismail and Fayed (2020) indicated that foliar spraying with potassium silicate at 3 cm^3/l increased dry seed yield and its components of faba bean compared to control. Generally, the values of marketable fruit yield of tomatoes were enhanced significantly with foliar application of glycine betaine at 10 mM/l by (12.86% and 13.91%) in the first and second seasons, respectively (Ragab *et al.*, 2015).

Table 4. Effect of foliar spray with potassium silicate and glycine betaine as well as their interaction on fruit yield and its components of strawberry in 2018/2019 and 2019/2020 seasons

Treatments		Early yield / Fed. (Ton)						Total yield / Fed. (Ton)					
		Marketable		Unmarketable		Total		Marketable		Unmarketable		Total	
		1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S
Potassium silicate (g L^{-1})													
zero		6.35	6.11	0.639	0.578	6.99	6.68	27.70	26.34	1.445	1.491	29.14	27.83
0.2		6.73	6.45	0.541	0.517	7.27	6.97	28.14	26.93	1.263	1.215	29.41	28.15
0.4		7.35	6.92	0.417	0.419	7.77	7.34	29.10	27.89	0.977	0.945	30.08	28.83
0.6		7.76	7.26	0.310	0.320	8.07	7.59	29.80	28.54	0.853	0.868	30.66	29.41
LSD 5%		0.13	0.15	0.006	0.008	0.14	0.15	0.33	0.32	0.013	0.011	0.34	0.33
Glycine betaine (g L^{-1})													
zero		6.47	6.15	0.525	0.500	6.99	6.65	27.52	26.14	1.264	1.272	28.78	27.41
2.5		7.16	6.76	0.471	0.453	7.63	7.22	28.82	27.56	1.126	1.119	29.94	28.68
5		7.52	7.14	0.433	0.422	7.96	7.57	29.71	28.57	1.014	0.998	30.73	29.57
LSD 5%		0.05	0.06	0.005	0.004	0.06	0.06	0.24	0.23	0.011	0.010	0.25	0.24
Interaction (Potassium silicate x Glycine betaine)													
zero	zero	6.04	5.78	0.670	0.606	6.72	6.39	27.03	25.54	1.573	1.630	28.60	27.17
	2.5	6.35	6.11	0.630	0.567	6.98	6.67	27.59	26.24	1.420	1.469	29.02	27.71
	5	6.67	6.44	0.616	0.560	7.28	7.00	28.46	27.24	1.343	1.373	29.81	28.62
0.2	zero	6.26	5.96	0.583	0.554	6.84	6.51	27.18	25.77	1.340	1.385	28.52	27.15
	2.5	6.81	6.52	0.537	0.513	7.34	7.03	28.30	27.08	1.243	1.187	29.54	28.27
	5	7.14	6.87	0.503	0.485	7.64	7.35	28.95	27.94	1.207	1.073	30.16	29.02
0.4	zero	6.54	6.29	0.470	0.474	7.01	6.77	27.56	26.24	1.116	1.093	28.68	27.33
	2.5	7.56	6.96	0.433	0.430	7.99	7.39	29.22	28.02	1.000	0.956	30.22	28.98
	5	7.96	7.50	0.346	0.353	8.31	7.85	30.52	29.40	0.813	0.787	31.34	30.18
0.6	zero	7.03	6.55	0.376	0.367	7.40	6.92	28.32	27.02	1.027	0.980	29.35	28.00
	2.5	7.92	7.47	0.287	0.303	8.20	7.77	30.17	28.91	0.840	0.864	31.01	29.78
	5	8.32	7.77	0.267	0.290	8.59	8.06	30.91	29.70	0.693	0.762	31.60	30.46
LSD 5%		0.16	0.17	0.010	0.010	0.17	0.18	0.52	0.49	0.022	0.020	0.54	0.51

Fruit physical quality:

The data illustrated in Table 5 indicate that the highest values in average fruit weight, fruit firmness and fruit dry matter were noticed with the treatment of 0.6 g/l with significant differences with control and the other two ones rates under study.

Table 5. Effect of foliar spray with potassium silicate and glycine betaine as well as their interaction on physical quality of strawberry fruit in 2018/2019 and 2019/2020 seasons

Treatments		Average fruit weight(g)		Fruit firmness(g/cm^2)		Fruit dry matter(%)	
		1st S	2nd S	1st S	2nd S	1st S	2nd S
Potassium silicate (g L^{-1})							
zero		20.06	19.16	350.6	329.4	8.633	8.246
0.2		20.32	19.45	356.4	340.0	8.878	8.499
0.4		20.91	20.04	375.9	353.1	9.115	8.738
0.6		21.06	20.20	385.3	360.1	9.255	8.881
LSD 5%		0.272	0.261	4.83	4.59	0.118	0.114
Glycine betaine (g L^{-1})							
zero		19.80	18.85	347.7	327.4	8.602	8.192
2.5		20.67	19.80	369.6	348.0	9.024	8.645
5		21.30	20.49	383.9	361.5	9.286	8.935
LSD 5%		0.165	0.157	3.75	3.51	0.092	0.087
Interaction (Potassium silicae x Glycine betaine)							
zero	zero	19.47	18.50	334.9	314.6	8.343	7.926
	2.5	20.08	19.18	352.2	330.9	8.663	8.274
	5	20.62	19.79	364.6	342.6	8.893	8.538
0.2	zero	19.50	18.56	338.1	322.6	8.497	8.089
	2.5	20.44	19.57	359.0	342.5	8.923	8.543
	5	21.02	20.23	372.1	355.0	9.217	8.864
0.4	zero	19.96	19.02	355.0	333.5	8.723	8.316
	2.5	20.85	19.99	378.1	355.1	9.180	8.802
	5	21.92	21.11	394.7	370.7	9.443	9.095
0.6	zero	20.26	19.33	362.8	339.0	8.846	8.437
	2.5	21.29	20.44	389.2	363.7	9.330	8.959
	5	21.61	20.83	404.1	377.6	9.590	9.245
LSD 5%		0.382	0.365	7.78	7.33	0.190	0.182

In general, potassium silicate treatments (0.2 and 0.4 g/l) enhanced fruit physical quality of strawberry compared to control during both seasons.

Moreover, these parameters of strawberry plant were increased as the glycine betaine increased up to 5 g/l, which showed the highest fruit physical quality of strawberry. Glycine betaine treatments significantly increased average fruit weight, fruit firmness and fruit dry matter percentage of strawberry plant compared to control in both seasons. In general strawberry fruit physical quality has been recorded when strawberry plants treated by 0.6 g/l KSi + 5 g/l GB in the first and second seasons. Such effects might be due to elevating the metabolic processes (anabolism) leading to extra vegetative growth and reflected in yield components.

In this regard, Rakha (2014) revealed that foliar application of potassium silicate significantly increased most of yield parameters and improved fruit quality of eggplant compared to control. In addition, Mahmoud *et al*. (2019) showed that the best values of potato tubers quality were obtained with application with potassium silicate at 3 cm^3/l compared to control.

Ragab *et al*. (2015) concluded that the fruit yield as well as fruit quality of tomato plants can be promoted by foliar application of glycine betaine with 10 mM/l. Moreover, El-Shoura (2020) indicated that foliar applications of glycine betaine and potassium silicate at 75 , 100 ppm, respectively to squash plants might be beholden as an optimal treatment for the production of high yield and fruit quality of squash under the Dakahlia Governorate environmental conditions and other comparable regions

Fruit chemical quality:

The results tabulated in Table 6 show that, potassium silicate treatments showed significant increase in strawberry total soluble solids, total sugar, vitamin C, acidity and anthocyanin content comparing to control during two seasons. Generally, as the potassium silicate rates increased up to 0.6 g/l, the fruit chemical quality was increased.

Table 6. Effect of foliar spray with potassium silicate and glycine betaine as well as their interaction on chemical quality of strawberry fruit in 2018/2019 and 2019/2020 seasons.

Treatments		TSS (%)		Total sugar(%)		Vitamin C(mg/100 g F.W)		Acidity(%)		Anthocyanin(mg/100g F.W)	
		1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S	1st S	2nd S
Potassium silicate (g L^{-1})											
zero		5.397	5.156	3.390	3.239	57.50	54.92	0.648	0.619	52.78	50.41
0.2		5.666	5.423	3.506	3.356	58.95	56.42	0.664	0.635	54.10	51.78
0.4		5.871	5.627	3.681	3.528	61.18	58.64	0.683	0.655	55.62	53.31
0.6		6.198	5.948	3.801	3.647	62.67	60.13	0.691	0.662	56.27	53.99
LSD 5%		0.098	0.093	0.063	0.059	0.796	0.762	0.001	0.009	0.790	0.759
Glycine betaine (g L^{-1})											
zero		5.443	5.184	3.388	3.227	57.49	54.75	0.637	0.606	52.45	49.95
2.5		5.841	5.595	3.617	3.464	60.29	57.74	0.676	0.648	55.10	52.77
5		6.067	5.837	3.779	3.636	62.46	60.10	0.701	0.674	56.54	54.40
LSD 5%		0.071	0.067	0.031	0.029	0.479	0.459	0.007	0.005	0.448	0.427
Interaction (Potassium silicate x Glycine betaine)											
zero	zero	5.027	4.777	3.257	3.096	55.54	52.76	0.619	0.588	51.00	48.45
	2.5	5.477	5.232	3.397	3.244	57.57	54.98	0.649	0.619	52.87	50.49
	5	5.690	5.460	3.517	3.375	59.41	57.03	0.676	0.649	54.48	52.13
0.2	zero	5.413	5.154	3.327	3.167	56.45	53.74	0.629	0.599	51.82	49.32
	2.5	5.760	5.512	3.527	3.374	59.32	56.77	0.669	0.640	54.48	52.13
	5	5.827	5.604	3.666	3.528	61.07	58.75	0.695	0.668	56.02	53.88
0.4	zero	5.623	5.359	3.453	3.290	58.08	55.35	0.647	0.617	53.31	50.80
	2.5	5.883	5.642	3.696	3.547	61.00	58.50	0.688	0.659	55.97	53.67
	5	6.107	5.881	3.893	3.747	64.47	62.08	0.714	0.688	57.61	55.47
0.6	zero	5.710	5.446	3.517	3.356	59.89	57.13	0.651	0.621	53.69	51.22
	2.5	6.243	5.995	3.846	3.691	63.27	60.73	0.701	0.672	57.09	54.80
	5	6.643	6.403	4.040	3.895	64.87	62.53	0.719	0.693	58.04	55.95
LSD 5%		0.151	0.144	0.081	0.076	1.113	1.066	0.018	0.012	1.074	1.028

Moreover, the rates of 2.5 or 5 g/l of glycine betaine recorded a significant increase in dry weight of roots per plant compared to control in both seasons. The highest increases in TSS, total sugar, Vit. C, acidity and anthocyanin content of strawberry fruits were noticed when plants sprayed with the highest rate of GB compared to control in both seasons.

Generally, fruit chemical quality of strawberry recorded more/or less similar trend as mentioned in fruit physical quality of strawberry as a result of interaction treatments between potassium silicate and glycine betaine.

Also, increased amount of soluble sugars was achieved by using 5mM potassium silicate on potato (Talebi *et al*., 2015). Also, potassium silicate recorded the highest values of TSS % in summer squash fruits compared with other treatments (El-Shoura, 2020). The superior application was glycine betaine whilst control treatment recoded the lowest values in both seasons; however, glycine betaine in special 700 ppm gave the highest values of total soluble solids of okra pods (El-Afifi *et al*., 2018).

CONCLUSION

The results obtained in this study show that spraying potassium silicate at 0.6 g/l combined with glycine betaine at 5 g/l that increased strawberry growth, yield and fruit quality, also this treatment lets plants resistance to stress which expressed by high early marketable yield and fruit quality during months from November to February.

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تأثير الرش الورقى بسليكات البوتاسيوم والجليسين بيتين على نمو وجودة المحصول المبكر لنباتات الفراولة

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أجريت تجربة حقلية لدراسة تأثير الرش الورقى على الفراولة صنف فيرتونا بسليكات البوتاسيوم والجليسين بيتين على النمو الخضري والمكونات الكيميائية في الأوراق ومحصول الثمار وجودته في مزرعة خاصة بقرية دميانة بمركز بلقاس بمحافظة الدقهلية بمصر خلال موسمي الشتاء المتتاليين لعامي ٢٠١٨ و ٢٠١٩. تم إجراء التجربة في قطع منشقة مرة واحدة في قطاعات كاملة العشوائية. وكانت معاملات الرش بسيليكات البوتاسيوم بأربعة تركيزات (صفر، ٠,٢ ، ٠,٤ و ٠,٦ جم / لتر) والجليسين بيتين بثلاثة تركيزات (صفر، ٢,٥ ، ٥ جم / لتر). أشارت النتائج المتحصل عليها أن سليكات البوتاسيوم والجليسين بيتين أثرت معنوياً على النمو الخضري والمكونات الكيميائية في الأوراق والمحصول وجودته. علاوة على ذلك، أعطى الرش الورقي بسليكات البوتاسيوم بتركيز ٠,٦ جم/ لتر أعلى القيم لصفات النمو الخضري، محتوى الكلوروفيل أ ، ب في الأوراق، المحصول الكلي وجودة الثمار. بالإضافة إلى ذلك، فإن الرش الورقي بالجليسين بيتين بأي تركيز أدى إلى زيادة معنوية في النمو الخضري والمكونات الكيميائية في الأوراق والمحصول وجودة الثمار مقارنة بالكنترول. بشكل عام، كان أفضل معاملة تفاعل في هذا الصدد هي الرش الورقى بتركيز ٠,٦ جم للتر من سليكات البوتاسيوم مع ٥ جم جليسين بيتين للتر مقارنة بمعاملات التفاعل الأخرى تحت الدراسة. وبالتالي، يمكن التوصية برش نباتات الفراولة بسليكات البوتاسيوم (٠,٦ جم/ لتر) والجليسين بيتين (٥ جم/ لتر) لتعزيز النمو الخضري وزيادة المحصول المبكر وجودة ثمار الفراولة تحت ظروف البرودة المحتمل حدوثها خلال هذه الفترة (نوفمبر - فبراير) والتي تتوافق مع موسم التصدير الاساسى في محصول الفراولة.