RESEARCH | Egyptian Journal of Agricultural Research | Agricultural Climate

Effect of spraying with potassium silicate and phosphorus fertilizer levels on growth, yield, and fruit quality of eggplant plants under low temperatures stress

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Received: 22-01-2023; **Accepted**: 03-03-2023; **Published:** 13-04-2023 **DOI:** 10.21608/EJAR.2023.189007.1326

ABSTRACT

Low temperatures have a negative impact on eggplant growth and development. Also, cold stress especially causes yield-limiting during the Autumn growth season. So, the experiment was carried out in the net house at the Central Laboratory for Agricultural Climate, Giza, Egypt during the 2020/2021 and 2021/2022 seasons. These studied factors were three different levels of phosphorus fertilizer (50,100 and 150% from recommended before transplanting doses) and foliar spraying with potassium silicate (0, 1, 2, 4 and 8gl^{-1}). The effect of the two studied factors on growth, yield and quality of eggplant plants was tested. The experimental design was split-plot design with three replicates. The obtained results showed that applying 100% of phosphorus fertilizer has a significant positive effect on all studied traits. Otherwise, the least values were recorded by applying 50% of phosphorus fertilizer in the two seasons. Foliar spraying with potassium silicate at 1gl^{-1} increased all measured values on eggplant plants. On the contrary, the lowest values were reported by foliar spraying with potassium silicate at 8gl^{-1} in the two study seasons. The application combined 100% of phosphorus fertilizer rate and foliar spraying with potassium silicate at 1gl^{-1} had the best of all measured parameters. Alternatively, the lowest values were obtained by the application combined application 50% of phosphorus fertilizer and foliar spraying with potassium silicate at 8gL^{-1} under conditions trail.

Keywords: Eggplant (*Solanum melongena* L.), yield, low temperatures, phenol, flavonoid.

INTRODUCTION

The eggplant (*Solanum melongena* L.) is one of the important vegetable species in the world. It belongs to Solanaceae family. It is a perennial plant considered its economic production annually in tropical climates and annual plant in cool climates. The optimum growing temperature of eggplant range between 27-32°C during the day and 21-27°C at night (Oscar, 1980; Zipelevish, *et al.,* 2000). Eggplant growth in a protected glasshouse maintained at 22 to 21°C during winter as well as it's mineral composition was reported for a constant nutrient solution conductivity of 3.0dSm-1 (de Kreij and Basar, 1997; Zipelevish *et al.* 2000). In addition to featuring a host of vitamins and minerals, also eggplant contains important phytochemicals which have antioxidant activity. Phytochemicals contained in eggplant include phenolic compounds, such caffeic, chlorogenic acid, and flavonoids, such as nasunin. Where, eggplant phenolics work as inhibitors of key enzymes relevant for type 2 diabetes and hypertension (Dias, 2012). Eggplant fruit is an excellent source of carbohydrate, proteins, fats, fiber, water, salts, vitamins and other vital mineral sources. (Oniah et al., 2010; Rakha, 2014; Idio and Adinya, 2017). It is generally enlisted as classical commodity for both local consumption and exportation. It is grown in most cultivated area in Egypt. According to Economic Affairs Sector, 2018/2019 percentage production of eggplant in the winter season is 5.9% from the total production of vegetable crops, percentage of the cultivated area of eggplant is 4.8% from the total cultivated areas of vegetable crops.

Phosphorous is one of the essential nutrients; that plants need in a large amount in their life cycle. Where, this nutrient plays an essential role in energy transfer in cells, respiration, and photosynthesis, and is a structural component of nucleic acids, as well as various coenzymes, phosphoproteins, and phospholipids (Amiri *et al.,* 2012; Lima *et al.,* 2014). Then, Bechtaoui *et al.* (2021) showed that phosphorus fertilizer is supplemented, which could help the plants to survive under abiotic stresses. phosphorous (P) deficiency induces abscission of flowers, reducing the yield (Ribeiro *et al.,* 1999; Lima *et al.,* 2014). This means that adding the suitable fertilizer required in the soil leads to faster growth and yield. But, excessive application of fertilizers may lead to toxicity or interference with the absorption of other nutrients (Kehinde *et al.,* 2011; Lima *et al.* 2014). Although Mohamed *et al.* (2021) reported that using suitable fertilizer sources is a viable cultivation practice since it can increase phosphorus use efficiency and improve crop productivity and quality. Balanced use of different nutrient elements is one of the most important factors for increasing the yield potential of plants. In many agriculture production systems, Phosphorus has been identified as the most efficient essential nutrient after nitrogen (Darwesh *et al.,* 2013). Feleafel and Mirdad (2013) found that the application of fertigation NPK at 100% of recommended at three doses weekly gave the best measured parameters on eggplant. In addition, the concentration of phosphorus was 0.26% at 184 kg•P2O5 ha^{-1}, which was nearly equivalent to the critical level of the nutrient in the leaf blade for optimum crop yield (Setu, 2022). Then, average fruit weight and average number of fruits per plant were increased significantly with the increase in phosphorus levels. Marketable yield and total yield significantly were improved with phosphorus application on eggplant (Sat *et al.*, 2002). Fouda, (2017) found that soil application of phosphorus fertilizer levels significantly increased the average values of faba bean plant. Also, Setu (2022) explained that the application of phosphorus on potato plant gave a highly significant influence on available phosphorus.

Silicon (Si) is a beneficial nutrient that improves biotic and abiotic stress tolerance of several crop species, such as freezing, heat, drought (Mattson and Leatherwood, 2010; Shehata and Abdelgawad, 2019). It is described as a favourable element for plants, but it is not considered necessary. However, this element has a direct influence on the intensification of photosynthesis and resistance to fungal and bacterial diseases, insects, drought, low temperatures, mineral deficiency and salinity (Epstein & Bloom, 2006, Abou-Baker *et al.* 2011 and De Souza *et al.* 2017). Potassium silicate is a source of highly soluble K and Si. It is used in agricultural production systems primarily as a silica amendment and added to the plants small amounts of K. Moreover, K, present within plants as the cation K^+ plays an important role in the regulation functions as well as the osmotic potential of plant cells. It also activates many enzymes involved in respiration and photosynthesis (Abou-Baker *et al.* 2011; Shehata and Abdelgawad, 2019; Mahmoud *et al.,* 2019). The application of foliar spraying on plants is an efficient approach and has become a substitute technique in agriculture used to stimulate growth and alleviate any deleterious impact. Furthermore, Abd El-Gawad, *et al.* (2017) recommended the foliar spraying of potassium silicate at a 2000 ppm rate four times on potato plants. Eggplant plants sprayed three times two week with potassium silicate 1.5 gl^{-1} enhanced most studying characters (Hussein and Muhammed 2017). Meanwhile, Shaheen, *et al.* (2017) indicated that the effect of foliar spraying by potassium silicate (2 cm3l-1) was little on potato plants. Whereas the results of (Shehata *et al.,* 2018) indicated that foliar spray with potassium silicate at 4% or 3% significantly increased vegetative growth parameters, yield, its components, physical and chemical properties of cucumber fruit compared with other treatments or untreated plants (control). However, Abd-Elaziz *et al.* (2019) said that the optimal treatment is spraying 8.5 mM potassium silicate (K_2SiO_3) on summer squash. In addition, Hafez *et al.* (2019) found that using a foliar spray of K silicate at 10gl^{-1} was more than 5gl-1 on garlic plants in both seasons. Also, Mahmoud *et al.* (2019) concluded that the best results in these parameters were obtained with foliar application of potassium silicate at concentration of 3cm3l-1. Thus, the foliar application of potassium silicate 1% improved yield and quality traits at different growth stages on tomato plants (Soundharya *et al*., 2019). Nevertheless, foliar application of KSi at 6 gl^{-1} on strawberry plants encouraged vegetative growth, yield and fruit quality under cold conditions by Nada (2020). Meanwhile, the foliar application of KSi (6 cml^{-1}) led to a significant increase in growth and yield parameters of roselle plants (Abdou *et al.,* 2022). Through the data and results of Abd El-Samie *et al*. (2022), the study recommended planting the canola crop with the concentration of potassium silicate spraying at 600 ppm to achieve the highest yield in terms of quantity or quality in the study area.

Due to most country exposure to climate change, this study was conducted to face cold climatic conditions. Meanwhile, the work was planned to investigate the effect of three different doses of phosphorus fertilizers and five foliar spray concentrations of potassium silicate on the growth, yield and quality parameters of eggplant plants under low temperatures stress.

MATERIAL AND METHODS

This experiment was conducted in the net-house at the Central Laboratory for Agricultural Climate, Agricultural Research Center, Dokki, Giza, Egypt during the 2020/2021 and 2021/2022 seasons.

EXPERIMENT DESIGN:

The experiment was laid in a split-plot design with three replications. The phosphorus fertilizers (which were added to the soil before transplanting) by three levels (50, 100 and 150% of mono super- phosphorus "MSP" from recommended rates) were randomly arranged in the main-plots. While the five concentrations of potassium silicate as foliar spraying were randomly distributed in the sub-plots. Where, the five concentrations of potassium silicate as foliar spraying were 1, 2, 4 and 8g per liter water besides control treatment (tap water). These spraying treatments were started after 90 days of transplanting at a rate of three times per 15 days during two months December and January. In addition, Fertilization of eggplant was applied as in the bulletin for growers. Also, the addition of mono super phosphorus applicable rates 50, 100 and 150% were 100, 200 and 300kg respectively, for recommended rates to prepare land agriculture in the greenhouse.

TRANSPLANTING DATA:

The study was carried out inside an insect proof white net-house. It was 40 and 9 m long and wide respectively 360m^2, containing five terraces 1.20m and 50cm spaces between them. The transplants of eggplant petra (F1hybrid) were transplanted on the 15th and 20th of August in the first (2020/2021) and second seasons (2021/2022), respectively. Transplants were planted at a distance of 50 cm. The experimental plot included 13 plants.

DATA RECORDED

Three plant samples were taken for data recording at the end of the two seasons. Where it was presented of the required data, is as follows.

1-Vegetative characteristics: Plant height (cm), stem diameter (cm), number of leaves and branches/plant, fresh and dry weight of shoots (g) and leaf area (cm^2). However, leaf area/plant was token 10 leaves (fourth leaf) per plant and calculated by method described of Koller (1972) as the following.

Leaf area /plant (m^2) = (fresh wt. of inedible and edible leaves/ fresh weight of the 10 disks) x No. of disks x disk area. Also, stem diameter was measured by Vernier Caliper.

2-Yield characteristics: Number of fruits, average weight fruit (g) and yield (kg/m^2). However, the harvest began in November to the end of the two seasons. The average number of collects was in the range 12 of times throughout the two seasons.

3-Chemical characteristics: Total percentages of N, P and K for the fourth leaf (%) were estimated after finishing all treatments.

4-Quality characteristics: Total phenol and flavenoid content (mg/g), and Percentage of dry weight of fruits (g) appreciated after finishing all treatments.

5-Average temperatures were recorded by Central Laboratory for Agricultural Climate during the two seasons as shown in **Table (5)**.

Chemical constituents

Percentages N, P and K were determined in leaves samples. Micro-Kjeldahle method was used for N determination, while colorimetric method was used for P and K determination using spectrophotometer and flame photometer, respectively, as was described by Chapman and Pratt (1961). In addition, fresh fruit samples were taken for estimated total phenolic content and total flavonoid content (mg.g^{-1}). Where, the phenolic compounds (mg /g.fw) as described by (Shahidi and Naczk, 1995). Total flavonoids content was determined according to (Mabry *et al*., 1970).

Statistical analysis:

Averages data were taken from different studied treatments during the two seasons. Concluded data were statistically analyzed by split plot design with three replicates according to analysis of variance method according by Snedecor and Cochran (1981) which was obtained on the table ANOVA and the least significant differences (LSD). Then, the means of the treatments were compared using Duncan's multiple-range testing at a 5% level of probability.

RESULTS

Growth characteristics:

The results showed that growth characteristics (diameter, number of leaves, plant height, number of branches, total leaf area and fresh and dry shoots) were improved by applying 100% of fertilizer phosphorus "MSP". Conversely, applying 50% of "MSP" decreased the values as in **Table (1)** during the two study seasons.

Concerning, foliar spraying with potassium silicate at ($1gl^{-1}$) increased the growth characteristics. On the contrary, the lowest values were recorded by foliar spraying with potassium silicate at ($8gl^{-1}$) during both studied seasons. Similar results between the low values of plant height and number of branches were obtained by foliar spraying with potassium silicate at (4 and $8gl^{-1}$) during the first season and the two seasons, respectively.

However, the interaction between application 100% of "MSP" and foliar spraying with potassium silicate at $1gl^{-1}$ gave the highest values of all studied trails. Contrarily, the least values were explained by the interaction between application 50% of "MSP" and foliar spraying with potassium silicate at $8gl^{-1}$ during the two seasons. Also, application 150% of phosphorus fertilizer and foliar spraying with potassium silicate at ($8gl^{-1}$) gave the lowest values of number of branches and plant height in the two study seasons.

Yield characteristics:

Table (2) showed that the highest yield characteristics (average weight fruit, number of fruit, total yield (kgm^{-2}) and total yield (ton/$360m^2$)) were recorded by applying 100% of "MSP". On the other hand, applying 50% of "MSP" gave the lowest values during the two studied seasons.

In addition, foliar spraying with potassium silicate at ($1gl^{-1}$) increased the significance of the values. Otherwise, the lowest significant yield characteristics were detected by foliar spraying with potassium silicate at ($8gl^{-1}$) during both studied seasons.

In the first season, the values were positive significantly by the interaction between application 100% of "MSP" and foliar spraying with potassium silicate at ($1gl^{-1}$). On the contrary, the interaction between application 50% of "MSP" and foliar spraying with potassium silicate at ($8gl^{-1}$) had negative significant values. The same results were found in the second season.

Chemical & quality characteristics:

As illustrated, in the **Tables (3 and 4)** the values were raised by applying 100% of "MSP". Meanwhile, applying 50% of "MSP" gave the least values during the season 2020/2021 & 2021/2022.

Furthermore, foliar spraying with potassium silicate at ($1gl^{-1}$) affected positively the chemical and quality characteristics. The lowest values were applied by foliar spraying with potassium silicate at ($8gl^{-1}$) during both studied seasons. Similar results between the low values of potassium percentage were evaluated by foliar spraying with potassium silicate at (4 and $8gl^{-1}$) during the two seasons.

Meanwhile, the interaction between application 100% of "MSP" and foliar spraying with potassium silicate at ($1gl^{-1}$) led to the highest values. Contrary, the least values were recorded by the incorporated treatment application 50% of "MSP" and foliar spraying with potassium silicate at ($8gl^{-1}$) together) during the two seasons. Hence, foliar spray of potassium silicate was used during the winter season, which was lower temperatures than 15^{o}C in the two months of December and January as shown in **Table (5)**.

Table 1. Effect of three phosphorus fertilizer levels and five potassium silicate concentrations with on growth characteristics of eggplant plants during two the autumn growing seasons of 2020/2021 and 2021/2022.

Treatments	First season						Second season					
	Stem diameter (cm)											
	Control	1	2	3	4	Mean	Control	1	2	3	4	Mean
50%MSP	0.960i	1.080f	1.020h	0.820k	0.710m	**0.918C**	1.000e	1.100d	1.005e	0.830g	0.730h	**0.933C**
100%MSP	1.050g	1.470a	1.280c	0.850j	1.016h	**1.133A**	1.080d	1.500a	1.300c	0.930f	1.100d	**1.182A**
150%MSP	1.200e	1.240d	1.410b	0.860j	0.750l	**1.092B**	1.280c	1.262c	1.430b	0.870g	0.770h	**1.122B**
Mean	**1.070C**	**1.263A**	**1.237B**	**0.843D**	**0.825E**		**1.120C**	**1.287A**	**1.245B**	**0.877D**	**0.867D**	
	Number of leaves											
50%MSP	138.16h	139.25h	122.64i	107.59k	75.50n	**116.63C**	135.01h	146.22g	125.17i	108.25k	76.50n	**118.23C**
100%MSP	160.75e	241.50a	167.25d	88.25l	150.75g	**161.70A**	167.50d	243.72a	165.79e	90.55l	156.48f	**164.81A**
150%MSP	187.75c	153.60f	235.25b	115.00j	80.50m	**154.42B**	196.50c	155.52f	240.00b	120.08j	80.00m	**158.42B**
Mean	**162.22C**	**178.12A**	**175.05B**	**103.61D**	**102.25E**		**151.26C**	**181.82A**	**176.99B**	**106.29D**	**104.33E**	
	Plant height (cm)											
50%MSP	92.00i	118.75b	107.61f	88.05k	78.63m	**97.01C**	93.00g	117.36b	106.31e	90.05h	79.83j	**97.31C**
100%MSP	104.00g	120.25a	111.65d	80.19l	99.11h	**103.04A**	107.00e	122.53a	112.00c	83.50i	100.06f	**105.02A**
150%MSP	106.58f	109.63e	115.02c	90.00j	79.03lm	**100.05B**	108.95d	110.09d	116.21b	89.7h	80.5j	**101.09B**
Mean	**100.86C**	**116.21A**	**111.43B**	**86.08D**	**85.59D**		**102.98C**	**116.66A**	**111.51B**	**87.75D**	**86.80E**	
	Number of branches											
50%MSP	10.46f	13.33e	13.81e	8.00hi	6.00j	**10.36C**	10.75f	12.38e	12.75de	8.60g	5.30h	**9.96C**
100%MSP	13.33e	21.75a	15.60cd	7.80hi	9.50fg	**13.60A**	14.10c	20.28a	15.12bc	6.30h	10.60f	**13.28A**
150%MSP	16.00c	14.50de	17.66b	8.50gh	6.80ij	**12.69B**	15.05bc	13.98cd	16.30b	9.00g	5.80h	**12.03B**
Mean	**14.15C**	**16.59A**	**15.69B**	**8.10D**	**7.43D**		**13.30C**	**15.55A**	**14.72B**	**7.97D**	**7.23D**	
	Fresh Shoots (g)											
50%MSP	411.62g	334.44j	327.75k	255.70m	200.10o	**305.92C**	414.10g	329.00j	325.39k	261.69m	198.25o	**305.69C**
100%MSP	420.50f	1013.60a	577.59d	342.42i	454.32e	**561.69A**	425.75f	1004.96a	575.92d	338.86i	456.13e	**560.32A**
150%MSP	723.42c	396.47h	833.21b	306.08l	215.70n	**494.98B**	700.77c	405.35h	830.11b	308.40l	220.20n	**492.97B**
Mean	**518.51C**	**581.50A**	**579.52B**	**301.40D**	**290.04E**		**513.54C**	**579.77A**	**577.14B**	**302.98D**	**291.53E**	
	Dry Shoots (g)											
50%MSP	82.61fg	62.83h	61.52h	52.54k	34.03m	**58.71C**	80.42g	64.32h	62.18i	54.54l	36.83n	**59.66C**
100%MSP	83.08f	209.29a	115.00c	54.92j	90.16d	**110.49A**	81.51f	210.64a	118.31c	55.92k	89.92d	**111.26A**
150%MSP	84.65e	81.51g	152.33b	59.53i	39.05l	**83.41B**	83.88e	79.71g	150.33b	60.31j	40.85m	**82.80B**
Mean	**83.45C**	**117.88A**	**109.62B**	**55.66D**	**54.41E**		**81.94C**	**118.22A**	**110.27B**	**56.92D**	**55.87E**	
	Total leaf area/plant $(cm)^2$											
50%MSP	8919.6i	10197.3d	8746.7e	7479.7f	3964.5m	**7861.5C**	8199.2j	10533.7e	8908.3ef	7342.6g	3942.8m	**7785.3C**
100%MSP	10625.6h	20909.1a	12801.3c	5280.9k	10147.0g	**11952.8A**	10753.5i	20920.9a	12694.5c	5134.2k	10362.1h	**11973.1A**
150%MSP	13433.5e	11558.4c	18949.4b	7065.6j	4396.9l	**11080.8B**	13851.3f	11436.9d	18842.4b	7273.2j	4411.2l	**11163.0B**
Mean	**10992.9C**	**14221.6A**	**13499.1B**	**6608.7D**	**6169.5E**		**10934.6C**	**14297.2A**	**13481.8B**	**6583.3D**	**6238.7E**	

*Control= water foliar spray, 1= 1g, 2=2 g, 3=4g, $4=8gl^{-1}$ potassium silicate per liter water. Different letters indicate significant difference at 5%**.**

Table 2. Effect of three phosphorus fertilizer levels and five potassium silicate concentrations on yield characteristics of eggplant plants during two the autumn growing seasons of 2020/2021 and 2021/2022.

Treatments	First season						Second season					
	Average fruit weight											
	Control	1	2	3	4	Mean	Control	1	2	3	4	Mean
50%MSP	215.00k	245.71e	230.80g	220.71j	185.55n	**219.55C**	215.11k	236.95e	234.36f	217.92j	190.78n	**219.02C**
100%MSP	225.87h	260.86a	253.20b	209.00l	250.40c	**239.87A**	228.44h	257.93a	255.27b	208.04l	250.00c	**239.94A**
150%MSP	230.93g	248.36d	234.11f	222.97i	190.25m	**225.32B**	232.93g	246.39d	238.30e	225.93i	199.25m	**228.56B**
Mean	**223.93C**	**251.64A**	**239.37B**	**217.56D**	**208.73E**		**225.49C**	**247.09A**	**242.64B**	**217.30D**	**213.34E**	
	Number of fruit/m^2											
50%MSP	21.15k	27.97g	14.34n	14.89m	11.06o	**17.88C**	23.49i	31.35g	14.37n	15.04m	10.51o	**18.95C**
100%MSP	23.55h	50.25a	39.84d	33.26f	40.15c	**37.41A**	24.02h	50.34a	40.81c	33.73f	40.01d	**37.78A**
150%MSP	37.90e	21.48j	40.89b	22.88i	16.49l	**27.93B**	37.81e	21.33k	41.16b	22.86j	16.10l	**27.85B**
Mean	**27.54C**	**33.23A**	**31.69B**	**23.68D**	**22.56E**		**28.44C**	**34.34A**	**32.11B**	**23.87D**	**22.21E**	
	Total yield kg/m^2											
50%MSP	4.55k	6.87g	3.31l	3.29m	2.05o	**4.01C**	5.05k	7.43f	7.43l	3.28m	2.00o	**4.23C**
100%MSP	5.32h	13.11a	10.09b	6.95f	10.05c	**9.10A**	5.49h	12.98a	10.42b	7.02g	10.00c	**9.18A**
150%MSP	8.75e	5.33i	9.57d	5.10j	3.14n	**6.38B**	8.81e	5.26i	9.81d	5.16j	3.21n	**6.45B**
Mean	**6.21C**	**8.44A**	**7.66B**	**5.11D**	**5.08E**		**6.45C**	**8.56A**	**7.86B**	**5.15D**	**5.07E**	
	Total yield per greenhouse (ton)/360m^2											
50%MSP	1.64k	2.47g	1.19l	1.18m	0.74o	**1.44C**	1.82k	2.67f	1.21l	1.18m	0.72o	**1.52C**
100%MSP	1.92h	4.72a	3.63b	2.50f	3.62c	**3.28A**	1.98h	4.67a	3.75b	2.53g	3.60c	**3.31A**
150%MSP	3.15e	1.92i	3.45d	1.84j	1.13n	**2.30B**	3.17e	1.89i	3.53d	1.86j	1.15n	**2.32B**
Mean	**2.23C**	**3.04A**	**2.76B**	**1.84D**	**1.83E**		**2.32C**	**3.08A**	**2.83B**	**1.85D**	**1.83E**	

*Control= water foliar spray, 1= 1g, 2=2 g, 3=4g, $4=8gl^{-1}$ potassium silicate per liter water. Different letters indicate significant difference at 5%.

Table 3. Effect of three phosphorus fertilizer levels and five potassium silicate concentrations on chemical characteristics of eggplant plants during two the autumn growing seasons of 2020/2021 and 2021/2022.

Treatments	First season						Second season					
	Nitrogen percentage (%)											
	Control	1	2	3	4	Mean	Control	1	2	3	4	Mean
50%MSP	3.07k	3.35d	3.28g	3.15j	2.90m	**3.15C**	3.13j	3.25g	3.22h	3.13j	3.00l	**3.15C**
100%MSP	3.31f	3.64a	3.51b	2.96l	3.31f	**3.35A**	3.32e	3.66a	3.53b	3.06k	3.28f	**3.37A**
150%MSP	3.33e	3.25h	3.40c	3.30f	3.17i	**3.29B**	3.34d	3.26g	3.42c	3.28f	3.16i	**3.29B**
Mean	**3.24C**	**3.41A**	**3.40B**	**3.14D**	**3.13E**		**3.26C**	**3.39A**	**3.39A**	**3.16D**	**3.15E**	
	Phosphorus percentage (%)											
50%MSP	0.580l	0.760e	0.620j	0.590k	0.350o	**0.580C**	0.600i	0.751d	0.630h	0.568j	0.360m	**0.582C**
100%MSP	0.640i	1.050a	0.840c	0.370n	0.830d	**0.746A**	0.566j	1.031a	0.841c	0.367l	0.835c	**0.728A**
150%MSP	0.700g	0.670h	0.950b	0.712f	0.410m	**0.688B**	0.690f	0.676g	0.954b	0.707e	0.415k	**0.688B**
Mean	**0.640C**	**0.827A**	**0.803B**	**0.557D**	**0.530E**		**0.619C**	**0.819A**	**0.808B**	**0.547D**	**0.537E**	
	Potassium percentage (%)											
50%MSP	2.63h	3.18d	2.77g	2.34j	2.11m	**2.61C**	2.60i	3.10d	2.70h	2.36j	2.13k	**2.58C**
100%MSP	2.76g	3.65a	3.43b	2.31k	2.85f	**3.00A**	2.80fg	3.60a	3.40b	2.33j	2.87f	**3.00A**
150%MSP	3.06e	2.76g	3.26c	2.55i	2.22l	**2.77B**	3.01e	2.74gh	3.20c	2.60i	2.20k	**2.75B**
Mean	**2.82C**	**3.20A**	**3.15B**	**2.40D**	**2.39D**		**2.80C**	**3.15A**	**3.10B**	**2.43D**	**2.40D**	

*Control= water foliar spray, 1= 1g, 2=2 g, 3=4g, 4=8gl^{-1} potassium silicate per liter water. Different letters indicate significant difference at 5%.

Table 4. Effect of three phosphorus fertilizer levels and five potassium silicate concentrations on quality characteristics of eggplant plants during two the autumn growing seasons of 2020/2021 and 2021/2022.

Treatments	First season						Second season					
	Total phenol content (mg/g)											
	Control	1	2	3	4	Mean	Control	1	2	3	4	Mean
50%MSP	507.58k	594.00e	560.50f	542.00i	394.00n	**519.62C**	518.70l	680.00e	640.50f	535.20j	418.30o	**543.91C**
100%MSP	522.65j	808.80a	758.74b	405.00m	545.64h	**608.17A**	526.44k	838.20a	768.80b	425.10n	546.34h	**620.98A**
150%MSP	560.44f	660.33d	696.00c	553.00g	440.53l	**582.06B**	542.50i	682.50d	700.60c	550.30g	445.53m	**584.29B**
Mean	**530.22C**	**687.71A**	**671.75B**	**500.00D**	**460.06E**		**529.21C**	**733.57A**	**703.30B**	**503.53D**	**470.06E**	
	Total flavonoid content (mg/g)											
50%MSP	53.41j	63.25f	57.03h	54.74ij	38.26m	**53.34C**	55.98g	67.67de	61.14f	54.39h	39.51k	**55.74C**
100%MSP	55.98hi	96.62a	82.36b	47.07k	56.28h	**67.66A**	57.18g	94.13a	81.98b	47.84i	56.32g	**67.49A**
150%MSP	59.32g	64.84e	71.89c	68.16d	41.29l	**61.10B**	60.42f	66.50e	72.12c	68.28d	42.32j	**61.93B**
Mean	**56.24C**	**74.90A**	**70.43B**	**56.66D**	**45.28E**		**57.86C**	**76.10A**	**71.75B**	**56.84D**	**46.05E**	
	dry weight / 100(g) fresh fruit											
50%MSP	6.13hi	6.42de	6.26fg	6.20gh	5.78j	**6.16C**	6.10hi	6.39d	6.21fg	6.19fgh	5.70j	**6.12C**
100%MSP	6.33ef	7.25a	6.57c	6.06i	6.39de	**6.52A**	6.28ef	7.26a	6.55c	6.05i	6.40d	**6.51A**
150%MSP	6.51cd	6.26fg	6.85b	6.39de	6.14ghi	**6.43B**	6.46cd	6.20fgh	6.86b	6.37de	6.11ghi	**6.40B**
Mean	**6.32C**	**6.64A**	**6.56B**	**6.22D**	**6.10E**		**6.28C**	**6.62A**	**6.54B**	**6.20D**	**6.07E**	

*Control= water foliar spray, 1= 1g, 2=2 g, 3=4g, 4=8gl^{-1} potassium silicate per liter water. Different letters indicate significant difference at 5%.

Table 5. Average, maximum and minimum temperatures of net-house during two the autumn growing seasons of 2020/2021 and 2021/2022.

Months	Frist season (2020/2021)			Second season (2021/2022)		
	Average (^oC)	Max (^oC)	Min (^oC)	Average (^oC)	Max (^oC)	Min (^oC)
September	28.60	38.51	23.51	28.47	34.76	23.21
October	25.11	34.82	20.12	25.07	30.99	20.42
November	20.31	28.69	15.56	21.42	27.68	17.01
December	16.55	23.79	11.31	15.52	21.10	11.17
January	15.69	22.14	10.97	12.42	19.18	7.81
February	15.93	23.26	10.30	14.38	21.63	8.96

DISCUSSION

The optimum temperature of eggplant is 22-30 ^oC. This is the temperature range under which the plant is not suffering any damage caused by temperature. Also, the optimum temperature is different according to different stages of growth. Moreover, the optimal daytime temperature is between 20-31.3 ^oC and the optimal night temperature varies between 15-20 ^oC for proper vegetative growth (Helyes *et al.,* 2015). The eggplant plant is more sensitive to low temperatures than other Solanaceae crops and gives abnormal growth with disordered metabolism and physiological (Helyes *et al.* 2015; Shimira and Taşkin, 2022). During the winter season, low temperatures limit root growth, reduce plant vigor, a slowdown in eggplant growth and produce deformed fruits. Whereas low temperatures stress (temperature below 15^{o}C) causes on engenders gradual loss of pollen fertility and leads to the development of seedless fruit (Shimira and Taşkin, 2022). These physiological changes have an adverse effect on pigment composition, chloroplast development, chlorophyll fluorescence and decrease photosynthetic efficiency (Pasbani *et al*., 2020; Shimira and Taşkin 2022). On the other hand, the relative increase for fertilizer was significantly greater at low temperatures than at high temperatures. This was due to a decrease in the percentage of phosphorus in fertilized plants grown at higher temperatures, while the opposite was true at lower temperatures on corn plants (Ketcheson, 1956). So, the application of 100 % mono superphosphate fertilizer from recommended doses to prepare land agriculture of eggplant plants is suitable, which gives the best results in the trial. These results indicated the beneficial effect of potassium silicate spraying at (1gl^{-1}) in improving all characteristics recorded during the two seasons. This mean, foliar spraying with potassium silicate at (1gl^{-1}) contributed to alleviating cold stress on eggplant crop.

Likewise, spraying potassium silicate led to increasing leaf area, fresh and dry weight, the leaves area, yield/plant and yield/feddan of potato plants (Abd El-Gawad *et al.,* 2017). In addition, Shehata *et al*. (2018) explained that foliar spray with potassium silicate significantly increased plant height, number of leaves/plants, fresh weight of plant, fruit weight and total yield/plant, physical and chemical properties of cucumber fruit. the optimal spray potassium silicate treatment improved the production of high yield and good quality on summer squash (Abd-Elaziz *et al.* 2019). It has achieved vegetative growth parameters, yield, characteristics of tubers quality and elements (nitrogen, phosphorus and potassium) and phytochemicals (phenols and flavonoids) on potato plants (Paulo et al., 2014; Mahmoud *et al.,* 2019). Meanwhile, foliar spraying with potassium silicate at 1% had shown significant increase in number of fruits and yield per plant (Soundharya *et al.,* 2019). Furthermore, strawberry growth, yield and fruit quality were improved by using foliar application of KSi to plants resistance to stress during months from November to February (Nada, 2020). These results disagreed with Shaheen *et al.* (2017) on potato plants and Hafez *et al.* (2019). Whereas, (Hussein and Muhammed 2017) found that spraying eggplant plants with potassium silicate significantly increased on plant height, leaves number, leaf area, yield, fruits number, P and K percentage. The results of Abd El-Samie *et al.* (2022) showed that the application of potassium silicate spraying to improve plant height (cm), number of branches per plant, the highest yield in terms of quantity or quality on the canola crop.

However, the application of potassium silicate showed improvement in all characteristics. This may be due to increased root activity and enhanced nutrient availability which increased nutrient uptake. Higher silicate content in the constituent of cell wall in eggplant shoots. So, it causes an increase in the erectness of leaves which gave the chance for lighting to penetrate most of the eggplant leaves. Consequently, it increased photosynthesis, activated other biological processes and lessened climate stress to the improvement of plant growth and yield (Wissa, 2017, Hafez *et al.* 2021 and Abdou *et al.* 2022).

On the other hand, Data recorded in all the tables in this research showed the importance 100 % of fertilizer phosphate on eggplant plants for increasing the vegetative growth, yield, quality and percentage of the total elements content in leaves of eggplant as well as active ingredients. Balanced use of phosphorus plays a vital role in the physiology of eggplant resulting in higher yield, whereas, phosphorus considers from major important nutrient of plants (Sat, *et al.* 2002). Whereas, an important role of phosphorous (P) in various plant metabolic processes. It is a constituent of nucleic acid, phospholipids, the coenzymes, DNA and NADP, and most importantly ATP. It activates coenzymes for amino acid production used in protein synthesis; it decomposes carbohydrate production in photosynthesis and is involved in many other metabolic processes required for normal growth such as photosynthesis, glycolysis, respiration, fatty acid synthesis (Ahmed *et al.,* 2016). Phosphorus supply enhances the plants' resistance capacity to low-temperature stress. It strengths the root system and increases the absorption of plant to large amounts of water and nutrients. This result indicated that P fertilization significantly increased the vegetative growth, yield, and its components, chemical constituents and quality which is agreement with Feleafel and Mirdad 2013 on eggplant, Ahmed *et al.* (2016) on Damsisa plant, Tanwar *et al.* (2014) on broccoli and Fouda (2017) on faba bean plant. But Tanwar *et al.* (2014) found that higher P concentrations of fertilizer led to lower growth of broccoli. Also, Lima *et al.* (2014) said that the levels of phosphorus applied were not different on eggplant. Setu (2022) found that the application of phosphorus fertilizer enhanced soil-accessible phosphorus, increasing the concentration of phosphorus in the leaf of the potato plant. But (Yali *et al.,* 2021) said that all phosphorus fertilizer levels had a significant effect on the yield and quality parameters than controlled (0 kg /haP_2O_5) on onion plants. Otherwise, the interaction between application 100% of phosphorus fertilizer and foliar spraying with potassium silicate at (1gl^{-1}) from recommended doses to prepare land agriculture improved all measured parameters on eggplant plants. From the previous results, the suitable concentration of potassium silicate with the recommended dose of phosphorus in eggplant plants may be to improve phosphorus availability and uptake. So, it led to a balance of nutrients and encouraged growth due to improved yield and quality. Similar results were found by Parimala and Singh (2022) on horticultural crops, Abou-Baker *et al*. (2011) on bean plants.

CONCLUSION

Silicon is helpful in improving both the quantity and quality of production, however, is conducive to the healthy growth of plants directly or indirectly. Besides this, we could be concluded that the optimum fertilization rate for obtaining high production of eggplant yield and active ingredients by applying mono super phosphate 100%. Finally, the application of 100% of phosphorus fertilizer for recommended rates to prepare land agriculture in the greenhouse and foliar spraying with potassium silicate at 1gl^{-1} during the autumn growing season gave superior on all studied traits.

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تأثير الرش بسليكات البوتاسيوم و مستويات السماد الفوسفاتى علي نمو و محصول وجوده ثمار نباتات الباذنجان تحت اجهاد درجات الحرارة المنخفضة

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لدرجات الحرارة المنخفضة تأثير سلبي على نمو الباذنجان وتطوره. أيضًا حيث يتسبب إجهاد البروده بشكل خاص في الحد من الإنتاج خلال موسم النمو الخريفى. لذلك أجريت التجربة في البيت الشبكي بالمعمل المركزي للمناخ الزراعي، جيزة، مصر خلال موسمي 2021/2020 و2022/2021. كانت عوامل الدراسة ثلاثة مستويات مختلفة من السماد الفوسفلاتى (50 و100 و150٪ من المعدلات الموصى بها قبل الزرع) والرش الورقى بسيليكات البوتاسيوم (0, 1, 2, 4, 8جم / لتر). تم اختبار تأثير دراسة العاملين على النمو وإنتاج و جودة نباتات الباذنجان. تم تصميم التجربة لقطع منشقة مرة واحدة بثلاث مكررات. أظهرت النتائج المتحصل عليها ان اضافة100٪ من السماد الفوسفورى له تأثير معنوي ايجابي علي جميع الصفات المدروسة. وبخلاف ذلك سجلت أقل القيم بإضافه 50٪ من السماد الفوسفورى في الموسمين. أدى الرش الورقي بسيليكات البوتاسيوم بمعدل 1جم / لتر لزيادة جميع القيم المقاسة على نباتات الباذنجان. على العكس من ذلك، سجلت أقل القيم بالرش الورقي بسيليكات البوتاسيوم بمعدل 8جم / لتر في موسمي الدراسة. أعطى اتحاد التطبيقين 100 % من السماد الفوسفورى و الرش الورقي بسيليكات البوتاسيوم بمعدل1جم / لتر أفضل القيم المقاسه. بدلا من ذلك، تم الحصول على أقل القيم باتحاد التطبيقين50٪ من السماد الفوسفورى و الرش الورقي بسيليكات البوتاسيوم بمعدل 8 جم / لتر تحت ظروف التجربة.

الكلمات المفتاحية: الباذنجان، المحصول، درجات الحرارة المنخفضة، الفينول، الفلافونويد.