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# Effect of some Treatments to Reduce the Injury of High Temperature on Sweet Pepper Grown in Late Summer Season

**El-Gazzar, T. M.; E. A. Tartoura; M. M. Nada* and Madiha E. Ismail**

Veget. and Flor. Dept., Fac. of Agric., Mansoura Uni., Egypt.


## ABSTRACT

Two field experiments were carried out at a private farm located in Khelala Village, Bilqas District, Dakahlia Governorate, Egypt, during the two successive summer seasons of 2018 and 2019 to investigate the effect of some treatments which reduce the injury of high temperature on sweet pepper grown in late summer season. Three different levels of shading (50, 63 and 75%), three different planting distances (30, 40 and 50 cm) and two foliar spray rates of potassium silicate (750 and 1500 ppm) and control treatment were investigated. Nine treatments were arranged in a randomized complete block design with three replications. The results show that shading at 75% is the superior treatment for plant height, leaf area, fresh and dry weights/plant, fruit set percent, falling flowers percent, fruit physical characteristics *i.e*, fruit length, diameter and flesh thickness and fruit chemical characteristics *i.e*, N, P and K%, VC and TSS compared to other treatments. As for planting distances treatments, all parameters values pronouncedly improve with an increase distances of planting, where the values are the best for distance 50 cm. Also, the values of vegetative, flowering, yield and its components significantly increase with foliar application of 1500 ppm potassium silicate. Meanwhile, the control treatment gives the lowest values for all parameters. According to the obtained results, individual treatments as shading level (75%), planting distance (50 cm) and foliar application with potassium silicate (1500 ppm) were beneficial to improve the growth, fruit quality and yield of sweet pepper plants grown in late summer season.

***Keywords:*** Shading, planting distance, potassium silicate and sweet pepper plants.

## INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) plant belongs to family Solanaceae. It is cultivated in almost all parts of the world as an essential fruit vegetable. It has occupied an essential rank in Egyptian agriculture because of its high income and nutritional values for human health (Ghoname *et al*. 2010). Temperature plays a significant role in both plant growth and productivity, where heat stress is affecting the productivity and adaptation of cultivated plants (Erickson and Markhart, 2001). According to Saha *et al.* (2010), high temperature decrease fruit-set in sweet pepper. The suitable temperature favorable for the sweet pepper growth is between 20 and 25°C. When the temperature exceeds 32°C or falls below 15°C, growth and yield usually decreases. Exposing sweet peppers to environmental stresses during the flowering and fruiting period may lead to abscission of flower buds and flowers. Abdel-Mawgoud *et al.* (1995) found that increasing shade led to increase of pepper fruit yield when 40% shade is used. Moderate shading could enhance the photosynthesis, thus increase yields and quality through improved efficient water use and carbohydrate supply (Shahak *et al.* 2008). The shading decreased the unmarketable yield of sweet pepper (Lopez-Marin *et al.* 2012). Shading is one of the solutions to overcome the effects of high temperature (Sivakumar *et al.* 2017). Potassium silicate ($K_2SiO_3$) is a source of highly soluble K and Si so it is used in agricultural purposes as a silicon amendment source and has used of supplying small amounts of potassium help to improve the quality of yield (Tarabih *et al.* 2014). Potassium silicate enhances vegetative criteria of potato, yield components and essential macronutrients concentration like N, P and K (Salim *et al.* 2014). Planting distance is of the essential aspects of the production system of various crops. Suitable planting distance ensures best growth and development of plant, thus maximum yield of the crop. The sweet pepper yield has been found to be dependent on the number of plants per unit area of soil (Islam *et al.* 2011).

Considering the above facts, the purpose of this study was to identify the role of some treatments such as net shading technology at the rate of (50, 63, 75 %), planting distance (30, 40 and 50 cm) and different levels foliar spray of potassium silicate (750 and 1500 ppm) in reducing the injury of high temperature on growth and fruit quality for sweet pepper crop in late summer season.

## MATERIALS AND METHODS

Two field experiments were carried out at a private farm located in Khelala Village, Bilqas District, Dakahlia Governorate, Egypt, during the two successive late summer seasons of 2018 and 2019 to study the response of sweet pepper (*Capsicum annuum* L cv Kortoba) to some treatments, which reduce the injury of high temperature.

**There are nine treatments under experiment as following;**

- $T_1$- Shading (50 %).
- $T_2$- Shading (63 %).
- $T_3$- Shading (75 %).
- $T_4$- Distance between cultivated plants is 30 cm.
- $T_5$- Distance between cultivated plants is 40 cm.
- $T_6$- Distance between cultivated plants is 50 cm.
- $T_7$- Potassium silicate (Citrocap 37.5% $K_2SiO_3$) is foliar applied at rate of 750 ppm, for three times after 15, 25 and 45 days from transplanting.
- $T_8$- Potassium silicate is foliar applied at rate of 1500 ppm, for three times after 15, 25 and 45 days from transplanting.

* **Corresponding author.**
**E-mail address: mohnada12@gmail.com, mohnada@mans.edu.eg**
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- $T_9$- control (untreated plant; no shading, no foliar spray and 30 cm planting distance).

Before planting, surface soil samples (0-30 cm) were collected from the experimental area and analyzed as a routine work according to Dewis and Fertias (1970) as shown in Table1. The monthly mean temperature and relative humidity during growth period in 2018 and 2019 seasons are presented in Table 2.

**Table 1. Some characteristics of the experimental soil during 2018 and 2019 seasons.**

| Soil properties | | seasons 2018 | seasons 2019 |
|---|---|---|---|
| Particle size distribution (%) | C. Sand | 2.7 | 2.9 |
| | F. Sand | 19.0 | 19.2 |
| | Silt | 26.0 | 25.5 |
| | Clay | 52.3 | 52.4 |
| Textural class | | Clay | |
| EC $dSm^{-1*}$ | | 1.55 | 1.50 |
| pH** | | 8.25 | 8.20 |
| $CaCO_3$ % | | 2.29 | 2.27 |
| O.M % | | 1.17 | 1.10 |
| F.C % | | 36.0 | 36.0 |
| S.P % | | 72.0 | 72.0 |
| Soluble anions, meq $L^{-1}$ | $CO_3^-$ | -------- | --------- |
| | $HCO_3^-$ | 0.80 | 0.75 |
| | $Cl^-$ | 8.90 | 8.70 |
| | $SO_4^-$ | 5.30 | 5.55 |
| Soluble cations, meq $L^{-1}$ | $Ca^{++}$ | 5.80 | 5.90 |
| | $Mg^{++}$ | 2.50 | 2.40 |
| | $K^+$ | 3.10 | 3.20 |
| | $Na^+$ | 3.60 | 3.50 |

**Table 2. The monthly mean temperature and relative humidity during growth period in 2018 and 2019 seasons.**

| Months | Temperature 2018 | | | Temperature 2019 | | | Relative humidity 2018 | | | Relative humidity 2019 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| Jan. | 18 | 11 | 15 | 16 | 8 | 12 | 86 | 51 | 69 | 89 | 51 | 70 |
| Feb. | 20 | 11 | 16 | 18 | 10 | 14 | 85 | 51 | 68 | 87 | 48 | 68 |
| Mar. | 22 | 12 | 17 | 20 | 10 | 15 | 86 | 45 | 66 | 85 | 45 | 65 |
| Apr. | 24 | 13 | 19 | 22 | 12 | 17 | 85 | 45 | 65 | 86 | 47 | 67 |
| May | 29 | 22 | 26 | 28 | 20 | 24 | 84 | 42 | 63 | 85 | 44 | 65 |
| Jun. | 33 | 22 | 28 | 31 | 19 | 25 | 83 | 42 | 63 | 85 | 43 | 64 |
| Jul. | 35 | 23 | 29 | 34 | 22 | 28 | 84 | 42 | 63 | 86 | 44 | 65 |
| Aug. | 34 | 24 | 29 | 32 | 22 | 27 | 83 | 41 | 62 | 83 | 43 | 63 |
| Sep. | 31 | 21 | 26 | 29 | 18 | 24 | 83 | 40 | 62 | 85 | 41 | 63 |
| Oct. | 28 | 19 | 24 | 26 | 18 | 22 | 84 | 43 | 64 | 84 | 44 | 64 |
| Nov. | 22 | 13 | 18 | 22 | 12 | 17 | 85 | 44 | 65 | 86 | 47 | 67 |
| Des. | 19 | 11 | 15 | 18 | 9 | 14 | 86 | 44 | 65 | 86 | 46 | 66 |

**Data from Ministry of Agricultural (Agriculture Extension services).**

Nine treatments were arranged in a randomized complete block design with three replications. The experimental plot contained 5 ridges of 3 m long and 0.85 m wide thus making an area of 12.75 $m^2$. All agricultural operations were performed according to the traditional local agriculture management practices. Uniform sweet pepper seedlings (30 days old) were transplanted carefully on the 24th of June in the north side of the ridge and distance were 30 cm between plants for all treatments except treatment $T_5$ (40 cm apart) and treatment $T_6$ ( 50 cm apart) in both seasons of the study. The plants were irrigated using drip irrigation system, where the irrigation was carried out every two days during the growing season. During soil preparation, farmyard manure was applied at the rate of 20 $m^3$ $fed^{-1}$. The chemical fertilizers were used as recommended by Egyptian Ministry of Agricultural. Other cultural practices; such as plant protection against weeds, diseases and insects; were performed whenever they were thought to be necessary as recommended for commercial sweet pepper production. Plant samples were collected for vegetative growth characteristics measurements. Fruits of sweet pepper were harvested when reached full size of edible maturity, where the harvesting started on August 24st (after 60 days from transplanting) and continued until October 24. Number of pickings was 18 in each season.

**Data Recorded.**

Vegetative Growth: At 60, 90 and 120 days from transplanting, three plants of each treatment were randomly chosen to determine the number of branches, plant height (cm), leaf area ($cm^2$) $plant^{-1}$ measure according to (Koller, 1972), fresh and dry weights/plant (g). Flowering traits: Fruit set and falling flowers percent. Quality parameters: Fruit physical characteristics [*i.e.*; fruit length, diameter and flesh thickness (cm)] and fruit chemical characteristics [*i.e.*; N, P and K (%), Vitamin C (mg/100g) and total soluble solid (TSS) were determined at three different stages (60, 90 and 120 days from transplanting).

Digestion of fresh fruits and plant tissues was with a mixture of concentrated sulphoric ($H_2SO_4$) and perchloric ($HClO_4$) acids according to Gotteni *et al.* (1982). Total –N was determined using Micro kjeldahl apparatus as described by Jones *et al*. (1991). Total phosphorus was determined spectrophotometrically by Milten Roy spectronic 120 at wavelength 725 nm using stannous chloride reduced molybdosulphoric blue colour method in sulphoric system as described by Peters *et al.* (2003). Total potassium was estimated by using Jenway Flame photometer, Model corning 400 according to the modified method of Peters *et al.* (2003). Total soluble solids were estimated in fresh fruit juice by a hand refractometer according to A.O.A.C (1980). Vitamin C in fruits juice was determined according to the method described by Mazumdar and Majumder, (2003).

**Statistical analysis:**

The obtained data of experiment were subjected to the statistically analysis of variance procedure and means were compared using the LSD method at 5% level of significance according to Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

**1. Vegetative Growth Characteristics:**

Data illustrated in Tables 3 and 4 show the impact of different levels of shading (50, 63, 75 %), planting distance (30, 40 and 50 cm) and different concentrations of potassium silicate (750 and 1500 ppm) on vegetative growth parameters of sweet pepper plants grown expressed as fresh and dry weight /plant, plant height, number of branches per plant and leaves area at three different stages from transplanting (after 60, 90 and 120 days) during 2018 and 2019 seasons.

Significant variations among all investigated treatments are recorded on all growth criteria of sweet pepper plants at different growth stages (60, 90 and 120 days after transplanting).Where the highest values of all growth parameters at various growth stages are recorded with shading (75 %) compared to the control treatment, which gives the lowest values of all growth parameters in the both seasons, except the number of branches/plant at period of 60 days in the first season which gives the lowest value with shading (50 %) followed by control treatment. Shading (63%) comes in the second order for leaves area and plant height at all different growth stages (60, 90 and 120

days after transplanting) as well as fresh weight/plant at two periods only (60 and 90 days) and dry weight /plant at two periods only (90 and 120 days) and number of branches per plant at period of 90 days. While, spray $K_2SiO_3$ at rate of 1500 ppm come in the second order for fresh weight at period of 120 days and dry weight at period of 60 days and number of branches/plant at two periods (60 and120 days).

**Table 3. Effect of shading, planting distance and potassium silicate foliar spray on fresh and dry weights of sweet pepper plants at three different stages from transplanting (after 60, 90 and 120 days) in late summer season (high temperature stress) during 2018 and 2019 seasons.**

| Treatments | Fresh weight (g/plant) | | | Dry weight (g/plant) | | |
|---|---|---|---|---|---|---|
| | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days |
| First season (2018) | | | | | | |
| $T_1$ Shading (50 %) | 188.88 | 316.14 | 340.62 | 38.61 | 66.73 | 71.69 |
| $T_2$ Shading (63 %) | 194.08 | 345.70 | 367.56 | 40.05 | 72.56 | 77.72 |
| $T_3$ Shading (75 %) | 198.78 | 380.69 | 413.48 | 42.56 | 80.16 | 86.13 |
| $T_4$ distance (30cm) | 169.87 | 292.09 | 313.31 | 37.66 | 61.32 | 65.87 |
| $T_5$ distance (40cm) | 173.94 | 309.33 | 329.51 | 37.63 | 64.76 | 70.90 |
| $T_6$ distance (50cm) | 176.78 | 328.11 | 356.73 | 38.78 | 68.84 | 74.67 |
| $T_7$ (750 ppm $K_2SiO_3$) | 180.44 | 310.84 | 336.42 | 39.63 | 63.90 | 71.19 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 184.87 | 316.50 | 387.60 | 40.42 | 67.13 | 73.81 |
| $T_9$ Untreated plant ( distance 30cm) | 167.56 | 281.08 | 288.06 | 38.06 | 58.71 | 62.89 |
| LSD at 5% | 1.81 | 3.52 | 8.79 | 0.78 | 0.65 | 1.78 |
| Second season (2019) | | | | | | |
| $T_1$ Shading (50 %) | 192.40 | 316.51 | 340.34 | 39.53 | 66.91 | 71.89 |
| $T_2$ Shading (63 %) | 195.16 | 346.03 | 362.13 | 40.54 | 72.41 | 76.48 |
| $T_3$ Shading (75 %) | 199.55 | 388.06 | 412.19 | 42.89 | 80.49 | 87.24 |
| $T_4$ distance (30cm) | 170.68 | 293.69 | 316.44 | 38.12 | 62.05 | 66.61 |
| $T_5$ distance (40cm) | 174.61 | 309.82 | 341.99 | 38.56 | 64.89 | 72.19 |
| $T_6$ distance (50cm) | 177.66 | 330.67 | 357.71 | 39.49 | 68.31 | 74.16 |
| $T_7$ (750 ppm $K_2SiO_3$) | 179.38 | 307.41 | 345.26 | 40.01 | 65.50 | 72.14 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 181.38 | 324.31 | 380.70 | 40.19 | 67.71 | 72.36 |
| $T_9$ Untreated plant ( distance 30cm) | 167.41 | 281.05 | 289.67 | 37.85 | 59.26 | 63.79 |
| LSD at 5% | 1.81 | 4.15 | 2.62 | 0.86 | 1.03 | 1.02 |

**Table 4. Effect of shading, planting distance and potassium silicate on plant height, Number of branches/plant and leaves area of sweet pepper plants at three different stages from transplanting (after 60, 90 and 120 days) in late summer season (high temperature stress) during 2018 and 2019 seasons.**

| Treatments | Plant height (cm) | | | Number of branches/plant | | | Leaves area ($cm^2$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days |
| First season (2018) | | | | | | | | | |
| $T_1$ Shading (50 %) | 86.08 | 127.32 | 134.92 | 4.47 | 7.45 | 8.18 | 1.46 | 2.10 | 2.62 |
| $T_2$ Shading (63 %) | 91.90 | 135.27 | 142.83 | 5.37 | 8.48 | 8.79 | 1.63 | 2.32 | 2.88 |
| $T_3$ Shading (75 %) | 94.37 | 139.84 | 147 .39 | 5.91 | 8.76 | 9.87 | 1.78 | 2.60 | 2.98 |
| $T_4$ distance (30cm) | 80.65 | 98.20 | 104.52 | 4.91 | 6.52 | 7.86 | 1.35 | 1.90 | 2.32 |
| $T_5$ distance (40cm) | 81.22 | 100.95 | 106.71 | 5.25 | 7.35 | 8.32 | 1.55 | 1.95 | 2.41 |
| $T_6$ distance (50cm) | 84.34 | 104.87 | 111.27 | 5.63 | 7.75 | 9.05 | 1.76 | 2.16 | 2.51 |
| $T_7$ (750 ppm $K_2SiO_3$) | 81.78 | 102.97 | 106.34 | 5.19 | 7.28 | 8.41 | 1.48 | 2.11 | 2.49 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 83.29 | 103.74 | 111.33 | 5.38 | 7.51 | 9.14 | 1.59 | 2.16 | 2.75 |
| $T_9$ Untreated plant ( distance 30cm) | 74.02 | 96.68 | 104.13 | 4.84 | 6.29 | 7.75 | 1.38 | 1.88 | 2.30 |
| LSD at 5% | 0.65 | 1.31 | 2.82 | 0.34 | 0.25 | 0.27 | 0.07 | 0.11 | 0.10 |
| Second season (2019) | | | | | | | | | |
| $T_1$ Shading (50 %) | 92.44 | 129.54 | 139.33 | 4.53 | 7.44 | 8.28 | 1.44 | 2.11 | 2.71 |
| $T_2$ Shading (63 %) | 95.61 | 135.66 | 146.94 | 5.15 | 8.43 | 9.08 | 1.63 | 2.33 | 2.88 |
| $T_3$ Shading (75 %) | 98.07 | 144.96 | 155.62 | 5.85 | 8.88 | 9.80 | 1.81 | 2.61 | 3.01 |
| $T_4$ distance (30cm) | 83.16 | 102.41 | 109.45 | 4.81 | 6.60 | 7.97 | 1.35 | 1.91 | 2.32 |
| $T_5$ distance (40cm) | 85.34 | 105.29 | 111.73 | 5.32 | 7.22 | 8.38 | 1.56 | 1.96 | 2.42 |
| $T_6$ distance (50cm) | 88.55 | 106.99 | 114.57 | 5.47 | 7.56 | 9.46 | 1.79 | 2.20 | 2.54 |
| $T_7$ (750 ppm $K_2SiO_3$) | 85.61 | 104.43 | 111.66 | 5.64 | 7.28 | 8.44 | 1.46 | 2.11 | 2.50 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 86.94 | 106.07 | 113.51 | 5.22 | 7.44 | 9.15 | 1.59 | 2.16 | 2.76 |
| $T_9$ Untreated plant ( distance 30cm) | 79.13 | 98.07 | 105.16 | 4.80 | 6.44 | 7.81 | 1.41 | 1.89 | 2.31 |
| LSD at 5% | 2.26 | 2.43 | 2.10 | 0.45 | 0.32 | 0.60 | 0.05 | 0.04 | 0.07 |

**2. Fruit Setting and Falling Percent:**

Listed data presented in Table5 show the values of fruit setting and falling (%) of sweet pepper plants as influenced by different treatments of shading (50, 63 and 75 %), planting distance (30, 40 and 50 cm) and potassium silicate (750 and 1500 ppm) during both seasons. The plants sprayed with potassium silicate at a rate of 1500 ppm give higher fruit setting % in the both studied seasons followed by plants cultivated at a distance of 50 cm (T6) while the lowest values of fruit setting % are realized with shading at 50%. In the first season, the less falling % is recorded when distance between cultivated plants is 50 cm followed by plants sprayed with potassium silicate at a rate of 1500 ppm, while the less falling % in the second season is recorded at 1500 ppm $K_2SiO_3$ followed by plants cultivated at a distance of 50 cm (T6). On the other hand, the highest values of falling % in both seasons are recorded with shading at 50%.

**3. Fruit Physical and Chemical Characteristics:**

Data presented in Tables 6, 7 and 8 reflect the effect of different treatments of shading (50, 63,75 %), planting distance (30, 40 and 50 cm) and potassium silicate (750 and 1500 ppm) on some fruit physical characteristics *i.e;* fruit

length, diameter and flesh thickness and some fruit chemical characteristics *i.e;* N, P and K (%), vitamin C and TSS of sweet pepper plants at three different stages from transplanting (after 60, 90 and 120 days) during both seasons.

**Table 5. Effect of shading, planting distance and potassium silicate on fruit setting (%) and falling percent of sweet pepper plants in late summer season (high temperature stress) during 2018 and 2019 seasons.**

| Treatments | Fruit setting % | Flower falling % |
|---|---|---|
| First season (2018) | | |
| $T_1$ Shading (50 %) | 19.81 | 80.19 |
| $T_2$ Shading (63 %) | 20.22 | 79.78 |
| $T_3$ Shading (75 %) | 20.61 | 79.39 |
| $T_4$ distance (30cm) | 20.97 | 79.03 |
| $T_5$ distance (40cm) | 21.81 | 78.19 |
| $T_6$ distance (50cm) | 22.29 | 77.71 |
| $T_7$ (750 ppm $K_2SiO_3$) | 21.88 | 78.12 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 22.31 | 77.96 |
| $T_9$ Untreated plant (distance 30cm) | 20.30 | 79.70 |
| LSD at 5% | 0.66 | 0.61 |
| Second season (2019) | | |
| $T_1$ Shading (50 %) | 20.13 | 79.87 |
| $T_2$ Shading (63 %) | 20.52 | 79.47 |
| $T_3$ Shading (75 %) | 20.92 | 79.08 |
| $T_4$ distance (30cm) | 21.19 | 78.81 |
| $T_5$ distance (40cm) | 21.96 | 78.04 |
| $T_6$ distance (50cm) | 22.41 | 77.59 |
| $T_7$ (750 ppm $K_2SiO_3$) | 22.00 | 78.00 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 22.45 | 77.55 |
| $T_9$ Untreated plant (distance 30cm) | 20.43 | 79.57 |
| LSD at 5% | 0.66 | 0.65 |

Significant variations among all investigated treatments are recorded on all quality parameters of sweet pepper plants at different growth stages (60, 90 and 120 days after transplanting). In the first season, the highest values of all aforementioned quality traits at various growth stages are recorded with shading (75 %), while the control treatment gives the lowest values of all aforementioned quality traits in the both seasons. Spraying $K_2SiO_3$ at rate of 1500 ppm come in the second order for fruit diameter at two periods (60 and 90 days) and fruit flesh thickness at period of 60 days as well as fruit length at period of 60 days. While, shading (63%) comes in the second order for both fruit diameter and flesh thickness at period of 120 days and fruit length at two periods (90 and 120 days). On the contrary, the planting distance 50 cm come in the second order for fruit flesh thickness at period of 90 days. The trend was somewhat similar during the both seasons. Also, the planting distance 50 cm come in the second order for all fruit chemical characteristics *i.e;* N, P and K (%), vitamin C and TSS of sweet pepper plants at three different stages from transplanting (after 60, 90 and 120 days) during both seasons.

Generally, high temperature stress has been strongly affected by shading level, where shading causes to reduce heat stress, thus increasing growth and fruit quality parameters of sweet pepper, where solar radiation decrease with increase of shading levels. Also, shading leads to improve falling percent and fruit setting % of sweet pepper plants. In this concern, many authors proved that shading affected growth and fruit quality parameters of sweet pepper (Ombodi *et al.* 2015 on sweet pepper; Masabni *et al.* 2016 on tomato and Semida *et al.* 2017 on cucumber).

**Table 6. Effect of shading, planting distance and potassium silicate as foliar spray on average fruit length, diameter and flesh thickness of sweet pepper at three different stages from transplanting (after 60, 90 and 120 days) in late summer season (high temperature stress) during 2018 and 2019 seasons.**

| Treatments | Fruit diameter (cm) | | | Fruit flesh thickness (cm) | | | Fruit length (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days |
| First season (2018) | | | | | | | | | |
| $T_1$ Shading (50 %) | 4.55 | 5.89 | 6.06 | 0.31 | 0.34 | 0.32 | 8.77 | 10.30 | 10.57 |
| $T_2$ Shading (63 %) | 4.76 | 5.98 | 6.60 | 0.32 | 0.36 | 0.34 | 8.89 | 10.65 | 10.80 |
| $T_3$ Shading (75 %) | 5.10 | 6.41 | 6.46 | 0.36 | 0.42 | 0.36 | 9.21 | 11.27 | 11.23 |
| $T_4$ distance (30cm) | 4.25 | 5.53 | 4.17 | 0.24 | 0.31 | 0.24 | 7.94 | 8.85 | 6.38 |
| $T_5$ distance (40cm) | 4.69 | 5.66 | 4.53 | 0.27 | 0.35 | 0.28 | 8.19 | 9.18 | 6.76 |
| $T_6$ distance (50cm) | 4.98 | 5.87 | 4.93 | 0.34 | 0.38 | 0.31 | 8.86 | 9.92 | 7.16 |
| $T_7$ (750 ppm $K_2SiO_3$) | 4.77 | 5.77 | 4.93 | 0.33 | 0.36 | 0.24 | 8.42 | 9.87 | 6.71 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 4.99 | 6.13 | 5.02 | 0.35 | 0.37 | 0.29 | 9.02 | 10.24 | 7.02 |
| $T_9$ Untreated plant ( distance 30cm) | 4.22 | 5.39 | 4.08 | 0.23 | 0.29 | 0.23 | 7.71 | 8.74 | 6.24 |
| LSD at 5% | 0.15 | 0.24 | 0.17 | 0.03 | 0.04 | 0.04 | 0.30 | 0.21 | 0.25 |
| Second season (2019) | | | | | | | | | |
| $T_1$ Shading (50 %) | 4.62 | 5.90 | 6.12 | 0.30 | 0.34 | 0.32 | 8.83 | 10.54 | 10.85 |
| $T_2$ Shading (63 %) | 4.76 | 6.00 | 6.10 | 0.32 | 0.35 | 0.35 | 8.91 | 10.82 | 10.93 |
| $T_3$ Shading (75 %) | 5.16 | 6.62 | 6.49 | 0.36 | 0.41 | 0.36 | 9.45 | 11.53 | 11.34 |
| $T_4$ distance (30cm) | 4.31 | 5.51 | 4.21 | 0.23 | 0.32 | 0.25 | 8.15 | 8.95 | 6.57 |
| $T_5$ distance (40cm) | 4.63 | 5.60 | 4.47 | 0.27 | 0.34 | 0.26 | 8.50 | 9.35 | 6.99 |
| $T_6$ distance (50cm) | 5.02 | 5.86 | 4.92 | 0.35 | 0.37 | 0.29 | 9.17 | 9.90 | 7.35 |
| $T_7$ (750 ppm $K_2SiO_3$) | 4.30 | 5.73 | 4.93 | 0.31 | 0.34 | 0.27 | 8.84 | 9.93 | 6.84 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 4.87 | 6.03 | 5.03 | 0.34 | 0.38 | 0.29 | 9.20 | 10.18 | 7.09 |
| $T_9$ Untreated plant ( distance 30cm) | 4.29 | 5.31 | 4.18 | 0.21 | 0.28 | 0.22 | 7.89 | 8.88 | 6.50 |
| LSD at 5% | 0.18 | 0.16 | 0.16 | 0.04 | 0.05 | 0.04 | 0.27 | 0.19 | 0.27 |

Competition for available water and mineral nutrients from the soil and light is greater at high plant population densities and these environmental factors, especially light intensity, stimulate the process of photosynthesis which, in turn, positively affected the vegetative growth parameters of sweet pepper plants. Increasing the ability of sweet pepper plants to absorption of soil nutrients due to planting distance positively affect all fruit quality parameters. The result of the present study for this character is in agreement with the findings of Islam *et al.* (2011) on sweet pepper; Edgar *et al.* (2017) on green pepper and Lihiang and Lumingkewas (2017) on maize.

Also, the role of silica is analogous to lignin in that it is a compression-resistant structural component of cell walls (Gaafar, (2017). Many researchers reported that silicon increased resistance of plants to environmental stresses (Satish *et al.* 2017on chilli; Abd Elwahed, 2018 on tomato and Taheri and Haghighi, 2018 on the pepper). Most of Si absorbed by the plant is deposited in the leaf, in the tissues of the epidermis and, more precisely, in the cell walls (Agarie *et al.* 1998 on rice) which may beneficially be reflected on falling percent and fruit setting (%) of sweet pepper plants.Similar results were found by Jia *et al.* (2011) who showed that silicon material increase vitamin C and soluble solids of strawberry and eggplant.

**Table 7. Effect of shading, planting distance and potassium silicate as foliar spray on N, P and K (%) of sweet pepper fruits at three different stages from transplanting (after 60, 90 and 120 days) in late summer season (high temperature stress) during 2018 and 2019 seasons.**

| Treatments | N% | | | P% | | | K% | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days |
| First season (2018) | | | | | | | | | |
| $T_1$ Shading (50 %) | 1.74 | 1.79 | 1.56 | 0.163 | 0.124 | 0.104 | 2.42 | 2.41 | 2.11 |
| $T_2$ Shading (63 %) | 2.31 | 2.26 | 2.02 | 0.193 | 0.156 | 0.133 | 2.62 | 2.65 | 2.42 |
| $T_3$ Shading (75 %) | 2.76 | 2.55 | 2.34 | 0.212 | 0.174 | 0.160 | 2.79 | 2.76 | 2.70 |
| $T_4$ distance (30cm) | 1.86 | 1.94 | 1.64 | 0.173 | 0.131 | 0.111 | 2.46 | 2.45 | 2.20 |
| $T_5$ distance (40cm) | 2.16 | 2.13 | 1.89 | 0.183 | 0.149 | 0.126 | 2.59 | 2.54 | 2.39 |
| $T_6$ distance (50cm) | 2.58 | 2.46 | 2.19 | 0.200 | 0.161 | 0.149 | 2.72 | 2.68 | 2.60 |
| $T_7$ (750 ppm $K_2SiO_3$) | 2.06 | 2.03 | 1.79 | 0.177 | 0.138 | 0.120 | 2.52 | 2.54 | 2.19 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 2.42 | 2.36 | 2.10 | 0.197 | 0.152 | 0.141 | 2.64 | 2.64 | 2.49 |
| $T_9$ Untreated plant ( distance 30cm) | 1.53 | 1.70 | 1.39 | 0.156 | 0.111 | 0.098 | 2.34 | 2.35 | 2.02 |
| LSD at 5% | 0.05 | 0.04 | 0.06 | 0.006 | 0.004 | 0.005 | 0.06 | 0.05 | 0.04 |
| Second season (2019) | | | | | | | | | |
| $T_1$ Shading (50 %) | 1.78 | 1.76 | 1.57 | 0.169 | 0.124 | 0.104 | 2.41 | 2.48 | 2.10 |
| $T_2$ Shading (63 %) | 2.36 | 2.27 | 2.00 | 0.196 | 0.157 | 0.134 | 2.63 | 2.73 | 2.43 |
| $T_3$ Shading (75 %) | 2.77 | 2.57 | 2.35 | 0.218 | 0.175 | 0.161 | 2.80 | 2.85 | 2.70 |
| $T_4$ distance (30cm) | 1.91 | 1.96 | 1.65 | 0.170 | 0.131 | 0.112 | 2.43 | 2.50 | 2.19 |
| $T_5$ distance (40cm) | 2.19 | 2.14 | 1.89 | 0.192 | 0.150 | 0.127 | 2.54 | 2.61 | 2.37 |
| $T_6$ distance (50cm) | 2.63 | 2.47 | 2.20 | 0.208 | 0.161 | 0.149 | 2.71 | 2.73 | 2.61 |
| $T_7$ (750 ppm $K_2SiO_3$) | 2.11 | 2.04 | 1.80 | 0.182 | 0.138 | 0.120 | 2.50 | 2.66 | 2.22 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 2.48 | 2.36 | 2.12 | 0.203 | 0.153 | 0.141 | 2.63 | 2.72 | 2.53 |
| $T_9$ Untreated plant ( distance 30cm) | 1.54 | 1.71 | 1.39 | 0.151 | 0.112 | 0.100 | 2.33 | 2.39 | 2.02 |
| LSD at 5% | 0.05 | 0.05 | 0.04 | 0.006 | 0.004 | 0.004 | 0.05 | 0.04 | 0.05 |

**Table 8. Effect of shading, planting distance and potassium silicate as foliar spray on VC and TSS of sweet pepper fruits at three different stages from transplanting (after 60, 90 and 120 days) in late summer season (high temperature stress) during 2018 and 2019 seasons.**

| Treatments | Vitamin C (mg $100g^{-1}$ fruit) | | | Total soluble solid (TSS %) | | |
|---|---|---|---|---|---|---|
| | 60 days | 90 days | 120 days | 60 days | 90 days | 120 days |
| First season (2018) | | | | | | |
| $T_1$ Shading (50 %) | 112.33 | 123.57 | 108.43 | 5.68 | 6.35 | 6.51 |
| $T_2$ Shading (63 %) | 120.28 | 135.53 | 122.00 | 5.89 | 6.67 | 6.83 |
| $T_3$ Shading (75 %) | 130.88 | 144.77 | 129.50 | 6.03 | 6.86 | 7.07 |
| $T_4$ distance (30cm) | 113.03 | 128.40 | 112.00 | 5.76 | 6.43 | 6.53 |
| $T_5$ distance (40cm) | 121.08 | 132.40 | 118.37 | 5.86 | 6.59 | 6.58 |
| $T_6$ distance (50cm) | 124.28 | 143.50 | 128.70 | 5.98 | 6.84 | 6.91 |
| $T_7$ (750 ppm $K_2SiO_3$) | 118.69 | 130.17 | 114.43 | 5.76 | 6.54 | 6.67 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 122.72 | 139.60 | 125.43 | 5.92 | 6.75 | 6.82 |
| $T_9$ Untreated plant (distance 30cm) | 108.47 | 123.50 | 105.70 | 5.63 | 6.26 | 6.37 |
| LSD at 5% | 3.05 | 1.61 | 2.28 | 0.07 | 0.04 | 0.11 |
| Second season (2019) | | | | | | |
| $T_1$ Shading (50 %) | 113.37 | 124.93 | 108.87 | 6.16 | 6.35 | 6.52 |
| $T_2$ Shading (63 %) | 127.27 | 135.17 | 122.37 | 6.39 | 6.68 | 6.84 |
| $T_3$ Shading (75 %) | 135.57 | 145.67 | 129.50 | 6.68 | 6.88 | 7.08 |
| $T_4$ distance (30cm) | 117.63 | 129.33 | 113.00 | 6.25 | 2.43 | 6.54 |
| $T_5$ distance (40cm) | 121.17 | 134.30 | 118.10 | 6.41 | 2.60 | 6.73 |
| $T_6$ distance (50cm) | 133.00 | 145.23 | 130.00 | 6.66 | 6.83 | 6.96 |
| $T_7$ (750 ppm $K_2SiO_3$) | 121.97 | 131.50 | 114.23 | 6.35 | 6.55 | 6.69 |
| $T_8$ (1500 ppm $K_2SiO_3$) | 130.10 | 140.63 | 127.03 | 6.57 | 6.75 | 6.92 |
| $T_9$ Untreated plant (distance 30cm) | 114.57 | 124.50 | 107.50 | 6.13 | 6.28 | 6.39 |
| LSD at 5% | 2.54 | 2.26 | 3.32 | 0.10 | 0.04 | 0.04 |

## CONCLUSION

According to the obtained results, all investigated treatments positively affected on sweet pepper plants grown in late summer season. The highest values of most quality traits of sweet pepper at various growth stages are recorded with shading (75 %) followed by the planting distance 50 cm, while the lowest values are with untreated plants. Generally, the improvement of plant gradually increases with increase of shading levels. The planting distance leads to declining competition between plants for available water and mineral nutrients from the soil. Foliar application of potassium silicate significantly enhances plant status. It can be concluded that, shading at the level of 75% may be beneficial to improve the growth of sweet pepper plants and obtain the highest fruits quality under high temperature stress.

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## تأثير بعض المعاملات لتقليل ضرر درجة الحرارة المرتفعة على الفلفل الحلو المنزرع في العروة الصيفية المتأخرة

**طه محمد السيد الجزر*، السيد أحمد احمد طرطورة، محمد مسعد احمد ندا ومديحة السعودي محمد إسماعيل**

**قسم الخضر والزينة، كلية الزراعة، جامعة المنصورة**

أجريت تجربتان حقليتان في مزرعة خاصة بقرية الخلالة -مركز بلقاس -محافظة الدقهلية بمصر خلال موسمين صيفيين متعاقبين ٢٠١٨ و٢٠١٩ لدراسة تأثير بعض المعاملات لتقليل الضرر الناشئ من درجة الحرارة المرتفعة على الفلفل الحلو المنزرع في العروة المتأخرة. المعاملات كانت ثلاثة مستويات مختلفة من التظليل (٥٠، ٦٣ و٧٥٪)، و ثلاث مسافات زراعة (٣٠، ٤٠ و ٥٠ سم) ومعدلين رش ورقي من سليكات البوتاسيوم (٧٥٠ و ١٥٠٠ جزء فى المليون) بالاضافة للكنترول. تسعة معاملات نفذت في تصميم قطاعات كاملة العشوائية مع التكرار ثلاث مرات. تظهر النتائج أن التظليل بمعدل ٧٥٪ هي المعاملة الأكثر تفوقا بالنسبة لكل من طول النبات، المساحة الورقية، الأوزان الطازجة والجافة للنبات، نسبة عقد الثمار، نسبة الأزهار المتساقطة، الخصائص الطبيعية للثمار (طول وقطر الثمرة وسمك اللحم) والخصائص الكيميائية للثمار (نيتروجين وفسفور وبوتاسيوم (٪) وفيتامين ج ومجموع المواد الصلبة الذائبة) مقارنة بالمعاملات الأخرى. أيضا بالنسبة لمعاملات مسافات الزراعة تتحسن قيم جميع المدلولات المدروسة بشكل واضح مع زيادة مسافات الزراعة، حيث تكون القيم هي الأفضل عندما تكون مسافة الزراعة ٥٠ سم . ايضا اعلى القيم بالنسبة لصفات النمو الخضرى، الزهرى، المحصول ومكوناته زادت معنويا مع زيادة مستوى سلكيات البوتاسيوم الي ١٥٠٠ جزء فى المليون. بينما تعطي النباتات الغير معامله تماما (كنترول) أدنى القيم لجميع لصفات المدروسة. وفقًا للنتائج التي تم الحصول عليها، فإن المعاملات المنفردة مثل التظليل بمعدل ٧٥% وكذلك مسافة الزراعة (٥٠ سم) والرش الورقي بسليكات البوتاسيوم بتركيز ١٥٠٠ جزء فى المليون مفيدة لتحسين صفات النمو الخضرى والثمرى والمحصول لنباتات الفلفل الحلو المنزرعة في العروة الصيفية المتأخرة.