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Effect of Irrigation Levels and Foliar Application with Some Growth Stimulants on Growth and Productivity of Sweet Pepper Plants for Increasing Drought Tolerance under Plastic Greenhouse Conditions

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ABSTRACT

A field experiment was conducted on sweet pepper plants (*Capsicum annuum* L.) Sensei F_1 hybrid at the Research Farm of Vegetables, Faculty of Agriculture, Benha University, Qalubia Governorate, Egypt, in the winter seasons of 2022/2023 and 2023/2024 under plastic greenhouse to examine the response of foliar application with four stimulants: proline at 100 ppm, salicylic acid at 500 ppm, melatonin at 100 ppm, or potassium silicate at 4 $ml.L^{-1}$ as well as spray with tap water on sweet pepper plants under drought conditions. The largest values for all evaluated growth characteristics, photosynthetic pigments, macronutrient content (NPK) and total carbohydrates, as well as yield and its components with the best physical and chemical quality, were found when plants were sprayed with potassium silicate at 4 $ml.L^{-1}$, followed by salicylic acid at 500 ppm every 15 days starting 30 days after transplanting under irrigation level 100% field capacity, followed by 80% field capacity. The lowest proline content, however, was found when plants were sprayed with 100 ppm of proline with 100% field capacity irrigation. However, except for proline concentration, irrigation using 60% field capacity and tap water as a foliar spray (control) exhibited the lowest values in every characteristic under study. Additionally, it was demonstrated that foliar treatment can produce excellent yields with high physical and chemical quality while reducing irrigation needs by 20%.

KEYWORDS: Sweet pepper, foliar application, water requirement, growth, fruit yield.

1. INTRODUCTION

Sweet pepper (*Capsicum annum* L.) is a major vegetable crop globally. It belonged to the nightshade family (*Solanaceae*). Domestically and for export, it is one of the most popular vegetables in Egypt. It originated in Mexico and Central America, and Christopher Columbus discovered it in 1493. According to Hasanuzzaman and Golam (2011) and Adeoye *et al.* (2014), pepper is considered the second most important solanaceous vegetable globally, after tomatoes. Around 2 million hectares of land were used for pepper cultivation worldwide in 2022, yielding an average yield of 18.3 tons per hectare, or around 37 million tons (FAO STAT, 2022). Thirty-eight thousand six hundred twenty-two hectares of peppers were grown in Egypt, yielding 681149 tons with an average output of 17.6 tons per hectare (FAO STAT, 2022).

Producing vegetables under greenhouses is becoming increasingly popular worldwide(Grafiadellis, 1999).

Water scarcity has recently been identified as restricting agricultural production in arid and semi-arid areas. Egypt may face significant water shortages; overuse of water resources and inadequate methods for irrigation are among the key problems affecting the country's water security.

To reduce the danger of loss in both quantity and quality of sweet pepper plants subjected to higher soil moisture tensions, it would be associated with applying resistance stimulants against abiotic stress (Pereira *et al.*, 2013).

Proline is a useful solute that is referred to as a proteogenic amino acid. For plants under stress or not, it functions as an inorganic osmoprotectant when it builds up (Dar *et al.*, 2016). It is essential for enhancing plant stress tolerance, functioning as a signaling molecule, scavenging ionic radicals like hydroxyl groups, maintaining protein stability, and nourishing plants in harsh environmental settings (Verbruggen and Hermans, 2008).

Vascular plants naturally use salicylic acid as a growth regulator. According to Jayakannan *et al.* (2013) and Plasencia and Vicente (2011), it controls several physiological and metabolic functions, including transpiration, photosynthesis, ion uptake, and transportation (Sahu, 2013). Generally, salicylic acid acts as a phytohormone and organic fertilizer to encourage the growth and development of plants. Several studies examined how salicylic acid affected sweet pepper plants' quantitative and qualitative traits. Salicylic acid was applied topically to three types of sweet peppers: "Cadia" (a pre-sowing treatment; Hanieh *et al.*, 2013), "California Wonder" (Abou El-Yazied, 2011), and "Twingo" (Elwan and El-Hamahmy, 2009) cultivated in greenhouses.

Melatonin is a naturally occurring antioxidant molecule with a low molecular weight and an indole ring structure essential for plant growth, development, and stress reactions. Melatonin reduces oxidative stress in plants by absorbing free radicals and removing reactive oxygen species (ROS) from the cell space (Ding *et al*., 2017).

Resistance inductors, including potassium silicate (K_2SiO_3), have been used for phytosanitary management in sweet pepper plants (Pereira *et al.*, 2015). Sweet pepper plants grown under severe water stress and sprayed with silicon sources showed good growth, physiological, and production parameters (Manivannan *et al.*, 2016).

Therefore, this study aimed to determine how different foliar application stimulants applied during irrigation water deficit affected sweet pepper plants' vegetative growth, yield, and fruit quality.

2. MATERIALS AND METHODS

2.1. Experimental setup:

A field experiment was conducted on sweet pepper plants (*Capsicum annumm L.*) Sensei F_1 hybrid during the winter seasons of 2022/2023 and 2023/2024 under plastic greenhouse at the Research Farm of Vegetables, the Faculty of Agriculture, Benha University, Qalubia Governorate, Egypt, to evaluate the impact of foliar application of various stimulants under water deficit levels on vegetative growth, yield, and fruit quality of sweet pepper plants cultivated under drip irrigation system in clay soil conditions. The used plastic greenhouse is 27*60 m. Latitude: 30º36"N, longitude: 31º22"E.

The experimental greenhouse's soil (0–30 cm depth) was sampled for representative purposes before the sweet pepper plants were transplanted. Table 1 displays the physical and chemical characteristics of the cultivated soil. Chemical analysis was determined by Page (1982), whereas physical analysis was calculated by Jackson (2005).

Table 1. Physical and chemical properties of experimental soil.

Soil properties	Season	
	2022/2023	2023/2024
Clay %	52.0	52.0
Silt %	24.5	24.6
Sand %	23.5	23.4
Soil texture	Heavy clay	Heavy clay
Bulk density (g/cm^3)	1.26	1.25
pH (1:2.5 w:v)	7.9	8.1
EC (dSm^{-1})	1.96	2.16
OM (%)	2.14	1.96
$CaCO_3$(gkg^{-1})	1.51	1.53
Available N (mg kg^{-1})	23.4	23
Available P (mg kg^{-1})	9	10
Available K (mg kg^{-1})	115	120
Field capacity, FC (cm^3 cm^{-3})	37.92	37.89
Wetting point, WP (cm^3 cm^{-3})	14.76	14.74
Available water (cm^3 cm^{-3})	23.16	23.15
Saturation point (cm^3 cm^{-3})	69.80	69.78

Table 2. The chemical analysis of tap water samples used in irrigation.

pH	Ec ds.m^{-1}	Soluble cations (mmole.L^{-1})				Soluble anions (mmole.L^{-1})		
		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	$CO_3^{=}$	HCO_3^{-}
6.8	0.35	1.6	0.8	0.1	0.2	1	0.00	2.3

This experiment included 15 treatments which were the combinations between three irrigation water levels and five foliar applications. Three replicates were used in the split-plot design of this experiment. While foliar application treatments were dispersed randomly in the sub-plots (proline at 100 ppm, salicylic acid at 500 ppm, melatonin at 100 ppm, potassium silicate at 4 ml. L^{-1} and tap water as control), deficit water treatments were distributed in the main plots. Additionally, the plants were replanted on two sides of each ridge at a 30-cm interval between each row, making the experimental plot 12 m^2, 8 m long and 1.5 m wide. There were fifteen treatments with three replications in each season of the experiment. Three different irrigation levels, 60, 80, 100% FC, were applied to the experimental plots using a drip irrigation system. The dripper flow rate was 4 L.h^{-1}, and the irrigation lines utilized were of model GR 16 mm. When all lines were opened, the water pressure was 1.5 bar. Thirty days after transplanting, foliar application treatments and irrigation were initiated.

2.2.Irrigation scheduling

The following formula was used to determine the entire readily accessible water (RAW) capacity of the soil and the irrigation depths (di, mm) for 100% field capacity at the irrigation level.

$$RAW = p\ TAW$$

Where p (0-1) = the fraction of total available soil water (TAW) that can be depleted from the root zone before water stress occurs.

Hess *et al.* (1997) state that to minimize damaging water deficit, soil moisture at 100% field capacity must be retained up to more than half of the available soil water (AW). Accordingly, the soil water depletion fraction (p) for stress prevention is 0.5 (Savva and Frenken, 2002; Allen *et al.*, 1998).

$$IR = 1000\ (\Theta FC - \Theta P)\ Zr$$

where:

IR= the irrigation requirement (mm),

ϴFC = the water content at field capacity ($m^3.m^{-3}$),

ϴP = the minimum water content at a specified depletion rate($m^3.m^{-3}$),

Zr= the root depth (m).

Since RAW will vary over the growing season, the depth and the irrigation interval will also change.

Irrigation requirements were added in each irrigation by calculating the water requirements as previously mentioned. These water requirements were added by controlling the irrigation time.

We confirmed the dripper discharge rate by water collection test from the dripper for special times. Then, the dripper discharge rate was calculated from the following equation:

Dripper discharge rate ($Liter.hour^{-1}$) = $\frac{\textit{the amount of collection water (Liter)}}{\textit{time (hour)}}$

2.3.Foliar application treatments

1- **Proline ($C_5H_9NO_2$)** consists of (99% L-proline) at 100 ppm.
2- **Salicylic acid ($C_7H_6O_3$)** (99% Salicylic acid) at 500 ppm.
3- **Melatonin ($C_{13}H_{16}N_2O_2$)** (10 mg melatonin per capsule) at 100 ppm.
4- **Potassium silicate (K_2SiO_3)** (11% K_2O and 25% SiO_2) at 4 $ml.L^{-1}$.
5- **Control** (spray with tap water).

Foliar applications were added ten times, starting 30 days after transplanting and every 15-day intervals.

2.4.Data recorded

2.4.1. Vegetative growth characteristics:

From each experimental plot, three plants were selected at random. Ninety days post-transplantation, the following traits were identified:

a. Morphological characteristics

1. **Plant height (cm):** It was measured from the cotyledon nodal to the stem apex.
2. **Number of leaves.plant^{-1}**.
3. **Leaf area (cm^2):** The scanning device scanned the plant leaf.
4. **Leaf fresh weight (g):** Three leaves were picked up from Each replicate was weighed (one leaf per plant).
5. **Leaf dry matter (%):** Picked leaves were dried at 70°C for Seventy-two hours, and dry weight per leaf was calculated.

   Leaf dry matter (%) = $\frac{\textit{leaf dry weight (g)}}{\textit{leaf fresh weight (g)}} * 100$
6. **Leaf relative water content (LRWC)%:** Leaf fresh weight, leaf turgid weight (measured after the leaves were rehydrated in a test tube with tap water for 24 hours at 4°C in the dark), and leaf dry weight (measured after oven drying at 70°C for 48 hours) were used to calculate the relative water content. The following equation was used for the determination of LRWC according to (Kordi *et al.*, 2013):

   $$\text{LRWC \%} = \frac{FW-DW}{TW-DW} * 100$$

Where: FW= leaf fresh weight, DW = leaf dry weight, TW = leaf turgid weight.

b. Chemical characteristics of leaves:

1. **Total carbohydrates (%):**A spectrophotometer was used to determine it, as Stewart (1975) described.
2. **Chlorophyll a, b, and carotenoids ($mg.100g^{-1}$):** AOAC (2012) recommended using a spectrophotometer for measurement.
3. **Mineral elements: i.e. N (%), P (%) and K (%):**

   The initial step in determining the plant nutrient content of N, P, and K was to digest milled, dry leaves using the Kjeldahl digestion method. This involved mixing concentrated sulfuric acid and perchloric acid to break down the leaves (Wicks and Firminger, 1942). The Micro-Kjeldahl method was employed to find the nitrogen content of the digestate (Piper, 2019).

   Phosphorus was measured spectrophotometrically in the digestion product using the method given by King (1951). The Flame photometer was used to assess potassium in the digestion product, following Jackson's method (2005).
4. The free proline content ($Mg.100g^{-1}$ dry weight) was extracted with 3% (w/v) aqueous

sulfosalicylic acid and calculated using the ninhydrin reagent method published by Bates (1973).

2.4.2. Yield and its components:

1- **Number of fruits.Plant^{-1}:** This was documented as the total quantity of harvested fruits per plot over the growing season, divided by the number of plants per plot.
2- **Yield per plant (kg)**: It was calculated by dividing the total weight of collected fruits by the number of plants per plot throughout the harvesting season.
3- **Yield.m^{-2} (kg):** It was ascertained for all harvested fruits and computed as the total fruit weight per square meter.
4- **Water use efficiency (WUE) (kg.m^{-3}):** It was determined using the following equations given by Hoffman *et al.* (1990):

$$\textbf{WUE (kg.m}^{-3}\textbf{)} = \frac{yield\ (kg)}{applied\ irrigation\ water\ amount\ (m3)}$$

2.4.3. Fruit quality

a. Fruit physical quality

Data concerning fruit traits were collected when fruits reached the marketing fruit size according to the **E.E.C. standard**. Ten fruits were taken to determine the following parameters:

1. Fruit length (cm).
2. Fruit diameter (cm).
3. Fruit weight (g).
4. Fruit firmness (g.cm^{-2}): It was assessed in a random sample of five fruits from each experimental plot utilizing Digital's Penetrometer (PCE-PTR.MITPC, USA) equipped with an 8 mm diameter needle.

b. Fruit chemical quality

Fivefruits of each treatment were taken at the ripe maturity stage from the fourth harvest to determine the following traits:

1. **Reducing sugars, non-reducing sugars, and total sugars (%):** They were determined using the method described by Malik and Singh (1980).
2. **Total soluble solids (TSS) %:** It was determined by using a hand refractometer according to AOAC (2012).
3. **Vitamin C (mg.100g^{-1}):** was determined using the indicator of 2,6 dichlorophenol indophenol for titration as the method described in AOAC (2012).

2.5.Statistical analysis:

SPSS version 25 was used for the statistical analysis (IBM Corp. Released 2013). A split-plot design with three replicates was used for statistical analysis of all the data, and the least significant difference test (L.S.D.) was used to compare the various treatments at the 5% probability level (Snedecor and Cochran, 1991).

3. RESULTS AND DISCUSSION

3.1.Vegetative growth characteristics:

3.1.1. Effect of water requirement

Regarding the influence of water requirement levels on vegetative growth characteristics, the data in Table (3) appear to show significant effects in both seasons when compared to 100% field capacity (control). In irrigated sweet pepper plants at 100% field capacity level, it was observed that all vegetative growth characteristics were greatly boosted and produced the greatest values of plant vegetative growth. i.e., plant height number of leaves.plant^{-1}, leaf fresh weight, leaf dry matter, leaf area.plant^{-1} and relative water content in plants that received water requirement level of 100% of field capacity, decreased with water deficit following the 100 > 80 > 60% water requirement sequence during the two study seasons. In this tendency, some investigations supported the current results of Alomari-Mheidat *et al.* (2023) on tomatoes and pepper as Eldewini *et al.* (2023), Wassie *et al.* (2023) and Molla *et al.* (2023).

According to Fawzy (2019) and Shahein *et al.* (2012), this could be explained by the way that more water promotes the uptake of mineral elements from the soil and the transfer of photosynthetic assimilates, which in turn results in increases in vegetative growth.

According to Farooq *et al.* (2009), drought stress imposition on plants affects water passage from the xylem to the surrounding elongating cells, reducing shoot length.

Table 3. Effect of irrigation water requirements and foliar application substances on vegetative growth of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments	Characteristics											
	Plant height (cm)		No. of leaves. $Plant^{-1}$		Leaf fresh weight (g)		Leaf dry matter (%)		Leaf area (cm^2)		Relative water content (%)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Water requirements												
60% FC	85.17	100.58	70.45	77.38	1.93	3.02	10.89	12.13	16.36	16.84	56.83	58.01
80% FC	116.90	127.90	92.93	98.23	2.06	3.68	12.26	13.97	19.56	19.80	67.83	69.91
100% FC	154.67	157.58	105.50	108.58	2.85	4.43	14.39	16.40	21.87	22.05	78.29	79.53
LSD at 0.05	3.35	1.97	2.70	2.20	0.12	0.12	0.19	0.18	0.20	0.15	0.26	0.25
Foliar application												
Proline	116.50	127.28	88.11	93.31	2.13	3.53	11.79	13.39	19.14	19.46	66.61	68.03
Salicylic acid	121.78	130.33	91.28	96.36	2.44	3.96	13.39	15.04	19.39	19.71	69.05	70.53
Melatonin	118.89	128.61	89.69	94.75	2.26	3.67	12.49	14.26	19.32	19.58	67.78	69.32
Potassium silicate	124.39	131.97	92.78	97.97	2.61	4.17	14.13	15.72	19.51	19.83	70.15	71.69
Control	112.94	125.25	86.28	91.28	1.95	3.23	10.78	12.41	18.94	19.24	64.67	66.19
LSD at 0.05	4.33	2.54	3.48	2.84	0.15	0.16	0.25	0.23	0.26	0.20	0.33	0.33

The decrease in the number of leaves and leaf area expansion during stress is a defensive response of plants to maintain water loss by preserving the stability and extensibility of cell membranes (Anjum *et al.*, 2011).

High water stress levels and increasing resistance to water flow in plant stems and leaves decreased leaf-relative water content (Chen *et al.*, 2015).

3.1.2. Effect of foliar application

Table (3) reveals that spraying plants with potassium silicate at (4 ml.L^{-1}) recorded the highest significant values in plant height number of leaves.$plant^{-1}$, leaf fresh weight, leaf dry matter, leaf area.$plant^{-1}$ and relative water content during both seasons of study, followed in descending order by salicylic acid at (500 ppm), melatonin at (100 ppm) and proline at (100 ppm). Meanwhile, spraying plants with tap water (control) resulted in the lowest values of all studied vegetative growth parameters in both seasons. These results follow those of Pereira *et al.* (2019), Ajil and Jaafar (2022), and Rady *et al.* (2024)on pepper.

Potassium silicate enhances tissue elasticity and the volume of interconnected water associated with all expansion and growth (Shi *et al.*, 2016). This could be related to potassium's vital role in nutrition and enhancing the transport of substances and protein synthesis (Abd El-Gawad *et al.*, 2017). Fawzy (2019) and Shahein *et al.* (2012) have described increases in vegetative growth, which may be explained by the effect of increasing water on enhancing the uptake of mineral elements from soil and the transfer of photosynthetic assimilates.

3.1.3. Effect of the interaction

Table (4) reveals that all foliar application treatments (proline, salicylic acid, melatonin, and potassium silicate) increased all evaluated vegetative growth parameters comparable with the corresponding results for control (tap water as a foliar spray). In this context, potassium silicate treatment at 4 ml. L^{-1} combined with 100 % field capacity resulted in the greatest gains in vegetative growth parameters, followed by salicylic acid at 500 ppm at the same field capacity and then 80% field capacity. On the other hand, irrigation with 60% FC and tap water (control) as a foliar spray showed the lowest values in plant vegetative growth parameters.

3.2.Chemical constituents of plant foliage:

3.2.1. Effect of water requirement

Reflecting on the data in Tables (5 and 6), it appears that the 100% field capacity irrigation level resulted in the highest chlorophyll a and b contents, carbohydrates, and NPK contents in both study seasons. Conversely, the highest proline content was found in the leaves of plants irrigated with 60% field capacity level compared with all other irrigation levels in both seasons. The poor activity of the photosynthetic components under stress may be the reason for the decrease in chlorophyll pigments brought on by the utilization of 60% field capacity. According to Allakhverdiev *et al.* (2000), drought stress may cause decreased synthesis of the primary chlorophyll pigment complexes encoded by the Cab gene family. According to Anjum *et al*. (2011) as well as Kannan and Kulandaivelu (2011), reactive oxygen species during drought stress cause chloroplasts to be destroyed.

Numerous investigators obtained similar results, i.e., El-Sayed *et al.* (2019), Medyouni*et al.* (2021), Eldewini*et al.* (2023), Wassie*et al.* (2023), Molla *et al.* (2023) and Trejo-Paniagua *et al.* (2024) on pepper showed that decreasing irrigation water gradually reduced chlorophyll content in leaves. Chlorophyll content strongly depends on the physiological responses of used species and their ability to tolerate stress.

The increased absorbed and translocated water to the plant's foliage, which raised the concentration of macronutrients in the plant's leaf cells, may cause the rise in NPK concentrations in plant foliage brought on by raising the watering rate. The results obtained are comparable to those published by Arab *et al.* (2022) on tomatoes Mohammed (2021) and pepper Eldewini *et al.* (2023).

60% field capacity deficit irrigation water may cause tomato proline accumulation by activating proline synthesis through the glutamate

Table 4. Effect of the interaction between water requirement levels and foliar application treatments on vegetative growth of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments		Characteristics											
Water requirements	Foliar application	Plant height (cm)		No. of leaves. Plant^{-1}		Leaf fresh weight (g)		Leaf dry matter (%)		Leaf area (cm^2)		Relative water content (%)	
		2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Proline	82.83	99.25	68.83	76.08	1.73	2.83	10.33	11.45	16.20	16.73	55.78	56.96
	Salicylic acid	87.58	102.17	72.25	79.08	2.08	3.25	11.63	12.99	16.48	17.00	58.22	59.38
	Melatonin	85.33	100.58	70.42	77.50	1.98	3.00	10.90	12.17	16.50	16.88	56.94	58.13
	Potassium silicate	90.33	103.75	73.67	80.42	2.24	3.42	12.27	13.58	16.63	17.14	59.33	60.52
	Control	79.75	97.17	67.08	73.83	1.63	2.59	9.33	10.47	15.98	16.45	53.90	55.08
80% FC	Proline	114.50	126.17	91.58	96.92	1.90	3.50	11.53	13.20	19.44	19.71	66.87	68.74
	Salicylic acid	120.00	129.75	94.50	99.75	2.17	3.98	13.18	14.80	19.69	19.93	69.19	71.24
	Melatonin	116.75	127.67	93.00	98.25	2.07	3.67	12.27	14.19	19.57	19.81	67.99	70.06
	Potassium silicate	122.50	131.42	95.75	101.08	2.33	4.08	13.79	15.39	19.81	20.06	70.23	72.42
	Control	110.75	124.50	89.83	95.17	1.81	3.17	10.53	12.24	19.27	19.51	64.89	67.11
100% FC	Proline	152.17	156.42	103.92	106.92	2.75	4.25	13.50	15.53	21.77	21.94	77.20	78.38
	Salicylic acid	157.75	159.08	107.08	110.25	3.08	4.67	15.36	17.32	21.98	22.18	79.73	80.98
	Melatonin	154.75	157.58	105.67	108.50	2.75	4.33	14.30	16.43	21.89	22.06	78.39	79.78
	Potassium silicate	160.33	160.75	108.92	112.42	3.25	5.00	16.32	18.18	22.11	22.30	80.89	82.15
	Control	148.33	154.08	101.92	104.83	2.43	3.92	12.47	14.53	21.58	21.77	75.21	76.39
LSD at 0.05		6.03	7.5	4.4	4.91	0.26	0.27	0.40	0.43	0.45	0.34	0.57	0.57

Table 5. Effect of irrigation water requirements and foliar application substances on chlorophyll (a and b), carotenoids (mg.100g^{-1}f.w.) as well as carbohydrates content (%) in leaves of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments	Characteristics							
	Chlorophyll a (mg.g^{-1})		Chlorophyll b (mg.g^{-1})		Carotenoids (mg.g^{-1})		Carbohydrates (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
Water requirements								
60% FC	1.23	1.46	0.36	0.43	0.18	0.19	19.09	20.52
80% FC	1.50	1.72	0.53	0.64	0.27	0.29	21.37	22.30
100% FC	1.70	2.02	0.66	0.74	0.45	0.50	22.87	23.38
LSD at 0.05	0.03	0.04	0.03	0.03	0.03	0.03	0.20	0.21
Foliar application								
Proline	1.45	1.71	0.50	0.59	0.29	0.31	20.88	21.83
Salicylic acid	1.50	1.76	0.53	0.62	0.31	0.34	21.39	22.37
Melatonin	1.47	1.73	0.52	0.61	0.30	0.32	21.12	22.06
Potassium silicate	1.52	1.78	0.55	0.64	0.33	0.35	21.64	22.58
Control	1.42	1.68	0.48	0.57	0.27	0.29	20.51	21.49
LSD at 0.05	0.03	0.06	0.03	0.03	0.03	0.03	0.26	0.27

Table 6. Effect of irrigation water requirements and foliar application substances on NPK (%) as well as proline content (µg.g-1 f.w) in leaves of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments	Characteristics							
	N (%)		P (%)		K (%)		Proline (µg.g-1 f.w)	
	2022	2023	2022	2023	2022	2023	2022	2023
Water requirements								
60% FC	1.97	2.00	0.37	0.38	2.74	2.83	876.35	858.80
80% FC	2.15	2.26	0.42	0.43	2.93	3.02	753.25	739.90
100% FC	2.40	2.60	0.45	0.45	3.14	3.25	576.05	551.85
LSD at 0.05	0.19	0.19	0.11	0.12	0.18	0.17	1.79	1.81
Foliar application								
Proline	2.14	2.25	0.41	0.42	2.89	3.00	701.83	686.33
Salicylic acid	2.22	2.33	0.42	0.43	2.98	3.08	731.08	712.08
Melatonin	2.18	2.29	0.41	0.42	2.95	3.04	753.83	733.50
Potassium silicate	2.26	2.37	0.42	0.43	3.00	3.10	716.33	699.67
Control	2.08	2.19	0.40	0.41	2.84	2.94	773.00	752.67
LSD at 0.05	0.24	0.25	0.14	0.15	0.24	0.22	2.31	2.34

pathway via glutamyl kinase, glutamyl phosphate reductase, and pyrroline-5-carboxylate reductases. (Fujita *et al*., 2003; Bray, 1990). Mohammed (2021), Wassie *et al.* (2023) on pepper, Trejo-Paniagua *et al.* (2024) on chili pepper, and Arab *et al.* (2022) on tomato all made similar findings.

3.2.2. Effect of foliar application

Data presented in Tables (5 and 6) demonstrate that spraying plants with potassium silicate at 4 ml.L^{-1} recorded the highest values in chlorophyll a, b, and carotenoids as well as carbohydrates and NPK contents of plants in both seasons of study, followed by salicylic acid, melatonin, proline then tap water (control). These results align with those reported by Rahim *et al.* (2023)on pepper.

Potassium-induced stomatal control and greater photosynthesis may cause these advantages in sweet pepper plants. Furthermore, potassium is believed to be essential for meristematic tissue growth and for raising nitrogen levels, both of which support vegetative growth. Additionally, the transfer of photoassimilates in roots and the expansion of the root surface, which increases the roots' intake of water and minerals, depend on potassium. Geeth and Abel-Aziz (2018).

3.2.3. Effect of the interaction

Tables 7 and 8 demonstrate that plants irrigated with 100% field capacity with a foliar spray of potassium silicate at 4 ml.L^{-1} exhibited the maximum chlorophyll (a and b), carotenoids, carbohydrates, and NPK contents in their leaves. Contrarily, the maximum proline concentration in leaves was found when plants were irrigated with 60% of field capacity combined with tap water (control). In this regard, it was also noted from the results in Table 8 that proline content in leaves gradually increased with water deficiency of less than 100% field capacity and the highest concentration was observed when interacting with tap water foliar spray.

Table 7. Effect of the interaction between water requirement levels and foliar application treatments on chlorophyll (a and b), carotenoids (mg.g^{-1}) as well as carbohydrates content (%) in leaves of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments		Characteristics							
Water requirements	Foliar application	Chlorophyll a (mg.g^{-1})		Chlorophyll b (mg.g^{-1})		Carotenoids (mg.g^{-1})		Carbohydrates (%)	
		2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Proline	1.20	1.44	0.34	0.41	0.16	0.18	18.81	20.25
	Salicylic acid	1.27	1.49	0.37	0.44	0.19	0.21	19.42	20.88
	Melatonin	1.22	1.47	0.36	0.43	0.18	0.19	19.09	20.53
	Potassium silicate	1.28	1.51	0.39	0.46	0.20	0.22	19.70	21.08
	Control	1.17	1.41	0.32	0.39	0.15	0.16	18.43	19.84
80% FC	Proline	1.48	1.69	0.51	0.63	0.26	0.27	21.18	22.11
	Salicylic acid	1.52	1.74	0.55	0.66	0.28	0.30	21.62	22.55
	Melatonin	1.50	1.72	0.53	0.64	0.27	0.29	21.38	22.31
	Potassium silicate	1.54	1.76	0.56	0.68	0.30	0.32	21.87	22.73
	Control	1.45	1.66	0.49	0.61	0.24	0.26	20.79	21.78
100% FC	Proline	1.68	2.00	0.64	0.73	0.43	0.48	22.66	23.13
	Salicylic acid	1.72	2.04	0.68	0.77	0.46	0.51	23.13	23.68
	Melatonin	1.69	2.01	0.66	0.75	0.45	0.50	22.89	23.33
	Potassium silicate	1.73	2.05	0.69	0.78	0.47	0.53	23.34	23.92
	Control	1.66	1.98	0.62	0.70	0.41	0.46	22.33	22.87
LSD at 0.05		0.06	0.1	0.06	0.06	0.06	0.06	0.45	0.47

Table 8. Effect of the interaction between water requirement levels and foliar application treatments on NPK (%) and proline contents(µg.g^{-1} f.w) of sweet pepper leaves during the winter seasons of 2022/2023 and 2023/2024.

Treatments		Characteristics							
Water requirements	Foliar application	N (%)		P (%)		K (%)		Proline (µg.g^{-1} f.w)	
		2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Proline	1.93	1.97	0.36	0.38	2.72	2.80	845.25	828.50
	Salicylic acid	2.01	2.05	0.38	0.39	2.79	2.88	872.75	855.00
	Melatonin	1.97	2.01	0.37	0.38	2.76	2.84	892.50	875.25
	Potassium silicate	2.05	2.08	0.38	0.39	2.82	2.92	857.75	842.25
	Control	1.88	1.90	0.35	0.37	2.59	2.69	913.50	893.00
80% FC	Proline	2.11	2.22	0.42	0.42	2.86	2.99	718.50	705.25
	Salicylic acid	2.19	2.30	0.42	0.43	2.98	3.06	745.25	733.25
	Melatonin	2.15	2.27	0.42	0.43	2.94	3.03	776.25	761.75
	Potassium silicate	2.23	2.35	0.43	0.44	2.99	3.09	731.75	719.00
	Control	2.05	2.14	0.41	0.42	2.88	2.95	794.50	780.25
100% FC	Proline	2.38	2.56	0.45	0.45	3.11	3.22	541.75	525.25
	Salicylic acid	2.45	2.63	0.46	0.46	3.18	3.28	575.25	548.00
	Melatonin	2.41	2.60	0.45	0.46	3.14	3.25	592.75	563.50
	Potassium silicate	2.48	2.68	0.46	0.46	3.20	3.29	559.50	537.75
	Control	2.30	2.52	0.44	0.44	3.07	3.18	611.00	584.75
LSD at 0.05		0.42	0.43	0.25	0.26	0.41	0.39	4.00	4.05

3.3.Yield and its components

3.3.1. Effect of water requirements

Table (9) shows that reducing irrigation water from 100% to 60% reduced yield and its components when field capacity decreased from 100% to 60% throughout the two experimental seasons. This may be due to severe nutritional intake and photosynthate buildup, which increases fruit length and breadth, weight, and volume. Sweet pepper production depends on fruit weight. The number of fruits, fruit yield per plant, and fruit yield per square meter all showed a similar trend. The results obtained are in line with those published on pepper by Abdelkhalik *et al.* (2020) and Tartoura *et al.* (2023) and on tomatoes by Alomari-Mheidat *et al.* (2024).

According to Sivakumar and Srividhya (2016), reduced photosynthesis during water stress may result in the abscission of flowers and flower buds in vulnerable tomato cultivars and a decrease in the supply of assimilates of growing floral organs. Furthermore, Sun *et al.*(2021) as well as Zik and Irish (2003) reported that water scarcity will cause flower buds to abort in several crops. This type of response is frequent when soil moisture is low. It may harm productivity(Singh *et al.*, 2021). Drought stress decreases yield by negatively influencing important plant metabolic pathways (Bashir *et al.*, 2021). Water deficits are an inevitable problem in many environments, hampering plant biomass output and quality (Seleiman *et al.*, 2021).

3.3.2. Effect of foliar application

For foliar application, it is noted from Table (9) that spraying plants with any of the four tested substances recorded positive results versus tap water regarding fruit yield and its components in both seasons of study. Moreover, spraying plants with potassium silicate at 4 ml.L^{-1} recorded the highest increases in yield and its components (number of fruits.plant^{-1}, yield.plant^{-1}, yield.m$^{-2,}$ and water use efficiency) for both investigated seasons. Spraying plants with salicylic acid at 500 ppm recorded comparable effects to those received potassium silicate as a foliar spray regarding all studied traits during the two seasons.

Table 9. Effect of irrigation water requirements and foliar application substances on fruit yield and its components of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments	Characteristics							
	No. of fruits.plant^{-1}		Yield.plant^{-1} (kg)		Yield.m^{-2} (kg)		Water use efficiency (kg.m^{-3})	
	2022	2023	2022	2023	2022	2023	2022	2023
Water requirements								
60% FC	17.08	18.03	3.88	4.11	23.10	24.55	20.85	22.09
80% FC	27.72	27.75	6.04	6.79	33.57	40.71	24.34	27.37
100% FC	36.30	35.20	7.62	8.39	48.70	50.26	24.58	27.07
LSD at 0.05	1.16	0.80	0.43	0.27	0.72	0.30	1.71	1.04
Foliar application								
Proline	26.17	26.31	5.54	6.21	33.45	37.26	22.04	24.64
Salicylic acid	28.08	27.97	6.17	6.71	37.24	40.20	24.57	26.67
Melatonin	27.17	27.08	5.88	6.46	35.27	38.68	23.38	25.63
Potassium silicate	29.28	28.61	6.45	6.94	38.63	41.56	25.73	27.61
Control	24.47	25.00	5.19	5.82	31.03	34.83	20.58	22.99
LSD at 0.05	1.50	1.03	0.56	0.35	0.94	0.39	2.21	1.34

Furthermore, all foliar applications, especially potassium silicate or salicylic acid, attained the highest water use efficiency in the two growing seasons versus proline, melatonin, or tap water foliar application.

Potassium is vital for agricultural production development and quality enhancement(Oosterhuis et al., 2014). This could be related to potassium's function in cell division and elongation, an important phase in crop growth and yield(Hepler et al., 2001; Hu et al., 2016).

3.3.3. Effect of interaction

The obtained data tabulated in Table (10) show clearly that the highest increases in yield components (number of fruits.plant^{-1}, yield.plant^{-1}, yield.m^{-2} and water use efficiency kg.m^{-3}) were detected by 100% of field capacity, followed by 80% field capacity combined with potassium silicate at (4 ml.L^{-1}), followed by salicylic acid at (500 ppm) as a foliar application during the two seasons of study (versus the tap water foliar application under the irrigation level 60% field capacity), meanwhile using either proline or melatonin lay in between.

3.4.Fruit physical characteristics

3.4.1. Effect of water requirements

Reflecting on the data in Table (11), it appears that fruit dimensions (length and diameter), fruit weight as well as fruit firmness had the highest significant increase under the irrigation level of 100% of field capacity, followed by 80% of field capacity in both seasons of study.

Decreasing the irrigation level to 60% of field capacity significantly reduced fruit diameter, length, weight, and firmness.

Improvement in physical fruit characteristics as a result of using full 100% and 80% of field capacity due to an increase in photosynthetic pigments and mineral element content of plant foliage, which positively affected plant growth (Table 3) and, as a result, the quality of produced fruits.In addition, water's vital role in increasing the number and size of fruit cells may affect fruit size and weight. In this connection, similar results were recorded by Kabir *et al.* (2021) on bell peppers and Alomari-Mheidat *et al.* (2023 and 2024) on tomatoes.

Table 10. Effect of the interaction between water requirements and foliar application treatments on fruit yield and its components of sweet pepper plants during the winter seasons of 2022/2023 and 2023/2024.

Treatments		Characteristics							
Water requirements	Foliar application	No. of fruits.plant^{-1}		Yield.plant^{-1} (kg)		Yield.m^{-2} (kg)		Water use efficiency (kg.m^{-3})	
		2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Proline	16.25	17.33	3.67	3.93	21.84	23.48	19.72	21.11
	Salicylic acid	17.83	19.00	4.16	4.36	24.94	26.13	22.36	23.43
	Melatonin	17.17	18.17	3.88	4.13	23.23	24.66	20.84	22.23
	Potassium silicate	19.08	19.67	4.38	4.55	25.83	27.30	23.52	24.46
	Control	15.08	16.00	3.31	3.58	19.67	21.21	17.79	19.23
80% FC	Proline	26.92	27.17	5.77	6.61	31.87	39.65	23.24	26.65
	Salicylic acid	28.92	28.67	6.29	7.03	35.57	42.21	25.38	28.36
	Melatonin	27.83	27.92	6.08	6.83	33.35	40.96	24.48	27.55
	Potassium silicate	30.00	29.33	6.64	7.28	37.59	43.67	26.78	29.38
	Control	24.92	25.67	5.42	6.18	29.46	37.05	21.84	24.90
100% FC	Proline	35.33	34.42	7.18	8.11	46.64	48.67	23.15	26.16
	Salicylic acid	37.50	36.25	8.05	8.75	51.20	52.26	25.97	28.22
	Melatonin	36.50	35.17	7.69	8.41	49.23	50.42	24.82	27.11
	Potassium silicate	38.75	36.83	8.33	8.99	52.47	53.70	26.88	29.01
	Control	33.42	33.33	6.85	7.71	43.98	46.24	22.10	24.85
LSD at 0.05		2.60	1.79	0.96	0.61	1.62	0.68	3.83	2.33

Table 11. Effect of irrigation water requirements and foliar application substances on physical characteristics of sweet pepper fruits during the winter seasons of 2022/2023 and 2023/2024.

Treatments	Characteristics							
	Fruit length (cm)		Fruit diameter (cm)		Fruit weight (g)		Fruit firmness (g.cm^{-2})	
	2022	2023	2022	2023	2022	2023	2022	2023
Water requirements								
60% FC	7.19	9.28	6.11	6.20	201.11	224.88	684.25	751.16
80% FC	8.51	10.71	6.29	7.82	209.62	242.88	720.77	786.35
100% FC	9.70	11.84	6.92	9.34	224.76	262.80	737.06	806.78
LSD at 0.05	0.22	0.23	0.19	0.23	0.27	0.88	0.53	0.94
Foliar application								
Proline	8.28	10.48	6.29	7.64	210.53	242.61	712.57	779.89
Salicylic acid	8.71	10.88	6.59	7.93	213.51	245.25	715.92	783.63
Melatonin	8.49	10.64	6.43	7.79	211.97	244.13	714.19	781.48
Potassium silicate	8.93	11.10	6.73	8.11	214.87	246.01	717.23	785.21
Control	7.93	9.96	6.15	7.47	208.27	239.58	710.24	776.95
LSD at 0.05	0.29	0.30	0.25	0.30	0.35	1.13	0.68	1.22

3.4.2. Effect of foliar application

As for the effect of foliar application on fruit physical characteristics, the data in Table (11) show that the highest fruit dimensions (diameter and length), fruit weight, as well as fruit firmness were obtained by the application of potassium silicate at (4 ml.L^{-1}) followed by salicylic acid at (500 ppm). Supplementing with potassium silicate may have a role in these results since potassium is an essential mineral for increasing the rate of photosynthesis, activating enzymes, and maintaining cell turgor. This, in turn, may greatly improve plants' water status and ability to synthesize sugars and polysaccharides. A plant's biochemical and physiological activities rely on potassium, which contributes to the entire yield of sweet peppers. (Afzal, 2015). Furthermore, the positive effects of salicylic acid on the biosynthesis of kinase, "a special group of proteins" that plays an important role in cell division and development of the plant (Manzoor *et al.*, 2015 and Ennab *et al.*, 2020). So, it could lead to a significant increase in fruit number and size of pepper plants.

3.4.3. Effect of the interaction

The data in Table (12) reveal that the highest fruit dimensions (diameter and length), fruit weight, and fruit firmness were obtained by irrigation at 100% field capacity with potassium silicate application as a foliar spray, followed by salicylic acid for two consecutive seasons. Meanwhile, control treatment (spraying with tap water) always came last by any irrigation level from 60 to 100% field capacity.

Table 12. Effect of the interaction between water requirements and foliar application treatments on physical characteristics of sweet pepper fruit during the winter seasons of (2022/2023) and (2023/2024).

Treatments		Characteristics							
Water requirements	Foliar application	Fruit length (cm)		Fruit diameter (cm)		Fruit weight (g)		Fruit firmness (g.cm^{-2})	
		2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Proline	6.98	9.12	5.97	6.05	199.90	223.75	682.53	749.10
	Salicylic acid	7.46	9.59	6.23	6.34	202.97	227.15	686.85	754.10
	Melatonin	7.23	9.34	6.10	6.21	201.20	225.43	684.32	750.98
	Potassium silicate	7.64	9.79	6.35	6.57	204.10	228.58	688.45	755.80
	Control	6.65	8.55	5.91	5.81	197.36	219.48	679.13	745.83
80% FC	Proline	8.33	10.56	6.18	7.68	208.28	241.83	719.20	785.04
	Salicylic acid	8.72	10.98	6.43	7.96	211.30	244.43	722.78	788.23
	Melatonin	8.54	10.74	6.28	7.82	209.73	243.18	720.95	786.53
	Potassium silicate	8.96	11.20	6.56	8.13	212.63	245.78	724.25	789.95
	Control	7.99	10.09	6.03	7.53	206.18	239.20	716.68	782.00
100% FC	Proline	9.53	11.75	6.73	9.18	223.40	262.26	735.99	805.53
	Salicylic acid	9.97	12.07	7.12	9.48	226.28	264.18	738.13	808.55
	Melatonin	9.69	11.83	6.92	9.34	224.98	263.80	737.31	806.93
	Potassium silicate	10.18	12.31	7.28	9.62	227.88	263.68	738.98	809.88
	Control	9.16	11.25	6.53	9.08	221.28	260.06	734.91	803.03
LSD at 0.05		0.50	0.52	0.43	0.52	0.61	1.96	1.13	2.11

3.5.Fruit chemical characteristics

3.5.1. Effect of water requirement levels

Reflecting on the data in Table (13), it appears that the irrigation level of 100% of field capacity significantly increased fruit chemical characteristics, i.e., TSS, reducing, non-reducing sugars as well as total and vitamin C, followed by 80% then 60% of field capacity. Such descending effects on fruit chemical characteristics are due to the harmful impact of the deficit on the physiological activity of plants. These results are in line with those reported by El-Sayed *et al.* (2019), Abdelkhalik *et al.* (2020) and Tartoura *et al.* (2023) on pepper.

3.5.2. Effect of foliar application

In terms of the effect of foliar application of tested plant stimulants on fruit chemical characteristics, Table (13) shows that potassium silicate at (4 ml.L^{-1}) resulted in the highest values of TSS, reducing, non-reducing as well as total sugars and vitamin C, followed by salicylic acid, melatonin, and proline when compared to spraying with tap water (control). These results support the findings on pepper by Ibrahim *et al.* (2019) and Munshi *et al.* (2020) on salicylic acid, Ajil and Jaafar (2022) and Abdel Rahim *et al.* (2023) on potassium silicate.

The inhibiting action of salicylic acid on ascorbate oxidase enzyme activity could explain why its application increases the vitamin C content in pepper fruits (Umebese and Bankole, 2013).

Table 13. Effect of irrigation water requirements and foliar application substances on chemical characteristics of sweet pepper fruits during the winter seasons of 2022/2023 and 2023/2024.

Treatment	characteristics									
	TSS (%)		Reducing sugars (%)		Non reducing sugars (%)		Total sugars (%)		Vitamin C (mg.$100g^{-1}$ f.w.)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Water requirements										
60% FC	8.04	8.22	4.81	4.62	0.26	0.37	5.08	5.01	76.39	88.32
80% FC	8.43	8.86	5.02	5.01	0.42	0.44	5.46	5.48	87.82	97.61
100% FC	8.95	9.35	5.52	5.48	0.41	0.50	5.95	6.01	100.54	108.59
LSD at 0.05	0.09	0.08	0.10	0.11	0.04	0.04	0.12	0.12	0.73	0.34
Foliar application										
Proline	8.37	8.70	5.10	4.99	0.34	0.41	5.46	5.46	87.48	97.18
Salicylic acid	8.62	8.96	5.05	5.10	0.48	0.44	5.55	5.56	89.85	99.33
Melatonin	8.49	8.83	5.14	4.97	0.33	0.50	5.49	5.49	88.27	98.37
Potassium silicate	8.75	9.08	5.26	5.19	0.31	0.39	5.58	5.61	90.35	100.74
Control	8.13	8.48	5.03	4.94	0.36	0.44	5.40	5.39	85.30	95.22
LSD at 0.05	0.12	0.11	0.13	0.14	0.05	0.05	0.16	0.15	0.95	0.44

3.5.3. Effect of the interaction

Data in Table (14) show that the highest values of TSS, reducing, and non-reducing sugars, as well as total and vitamin C, were obtained by the irrigation level 100% of field capacity with potassium silicate as a foliar application followed in descending order by salicylic acid, melatonin, proline and finally control for the two successive seasons. The gradual increase in fruit chemical characteristics was due to the importance of potassium silicate and salicylic acid.

Table 14. Effect of the interaction between water requirements and foliar application treatments on chemical characteristics of sweet pepper fruit during the winter seasons of 2022/2023 and 2023/2024.

Treatment		Characteristics									
Water requirements	Foliar application	TSS (%)		Reducing sugars (%)		Non reducing sugars (%)		Total sugars (%)		Vitamin C (mg.100g^{-1} f.w.)	
		2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Proline	7.94	8.13	4.76	4.63	0.28	0.36	5.06	5.00	75.33	87.38
	Salicylic acid	8.22	8.40	4.78	4.66	0.31	0.38	5.13	5.04	77.39	89.72
	Melatonin	8.08	8.25	4.84	4.59	0.23	0.38	5.08	5.02	76.24	88.56
	Potassium silicate	8.34	8.53	4.93	4.71	0.19	0.33	5.13	5.07	78.55	90.90
	Control	7.64	7.80	4.76	4.53	0.27	0.38	5.03	4.92	74.42	85.03
80% FC	Proline	8.31	8.74	5.05	5.02	0.38	0.35	5.45	5.44	87.60	96.69
	Salicylic acid	8.55	8.99	4.91	5.11	0.53	0.38	5.48	5.52	89.47	98.36
	Melatonin	8.44	8.87	5.07	4.99	0.38	0.47	5.47	5.49	87.94	97.88
	Potassium silicate	8.69	9.13	5.13	5.07	0.37	0.46	5.50	5.55	90.31	100.27
	Control	8.13	8.55	4.94	4.88	0.43	0.52	5.38	5.42	83.78	94.83
100% FC	Proline	8.87	9.24	5.50	5.32	0.35	0.52	5.87	5.93	99.52	107.48
	Salicylic acid	9.10	9.48	5.45	5.53	0.58	0.55	6.06	6.11	101.84	109.92
	Melatonin	8.96	9.37	5.53	5.32	0.38	0.64	5.92	5.98	100.63	108.66
	Potassium silicate	9.21	9.59	5.74	5.79	0.36	0.39	6.12	6.20	103.03	111.07
	Control	8.62	9.09	5.39	5.43	0.38	0.41	5.78	5.85	97.69	105.81
LSD at 0.05		0.21	0.18	0.23	0.24	0.08	0.09	0.27	0.26	1.64	0.77

4. CONCLUSION

Under these experimental conditions, the most effective agricultural strategy for increasing vegetative growth, total yield, and fruit quality for sweet pepper was to spray plants with potassium silicate at 4 ml.L^{-1}, followed by salicylic acid at 500 ppm, ten times, starting thirty days after transplanting and every fifteen days under irrigation level of 100% field capacity, followed by 80% field capacity. Moreover, these foliar applications can reduce irrigation requirements by 20%, while maintaining high yield with high physical and chemical quality.

5. REFERENCES

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الملخص العربي

تأثير مستويات الرى والرش الورقي ببعض منشطات النمو على نمو وإنتاجية الفلفل الحلو لزيادة تحمل الجفاف تحت ظروف الصوب البلاستيكية

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أجريت تجربة حقلية على نباتات الفلفل الحلو هجين سينسى خلال الموسم الشتوى لعامى ٢٠٢٣/٢٠٢٢ و ٢٠٢٤/٢٠٢٣ تحت الصوبة البلاستيكية بمزرعة بحوث الخضر بكلية الزراعة جامعة بنها، محافظة القليوبية، مصر، لدراسة استجابة الرش الورقي بأربعة منشطات نمو، وهي البرولين بتركيز ١٠٠ جزء في المليون، وحمض الساليسيليك بتركيز ٥٠٠ جزء في المليون، والميلاتونين بتركيز ١٠٠ جزء في المليون، وسيليكات البوتاسيوم بتركيز ٤ مل.لتر⁻¹ مقارنة بالرش بالماء المقطر (الكنترول) تحت ثلاثة مستويات من الرى هى ٦٠، ٨٠، ١٠٠٪ من السعة الحقلية على النمو الخضري والمحصول وجودة الثمار لنباتات الفلفل الحلو المزروعة تحت نظام الري بالتنقيط في ظروف التربة الطينية. أظهرت النتائج أن رش النباتات بسيليكات البوتاسيوم بتركيز ٤ مل.لتر⁻¹ يليها الرش بحمض السلسليك بتركيز ٥٠٠ جزء فى المليون سجلت أعلى القيم لجميع صفات النمو الخضرى، الصبغات الضوئية، محتوى العناصر الكبرى NPK والكربوهيدرات الكلية عند الرى بمستوى ١٠٠٪، يليها الرى بـ ٨٠٪ من السعة الحقلية. ومع ذلك، فإن رش النباتات بالبرولين بتركيز ١٠٠ جزء في المليون سجلت أقل محتوى من البرولين. علاوة على ذلك، تم الحصول على أقصى وزن للثمار وعدد الثمار .نبات⁻¹، والمحصول.نبات⁻¹، والمحصول الكلي.م⁻² عن طريق رش النباتات ١٠ مرات كل ١٥ يومًا بدءًا من ٣٠ يومًا بعد الشتل بسيليكات البوتاسيوم بتركيز ٤ مل.لتر⁻¹ يليها الرش بحمض السلسليك بتركيز ٥٠٠ جزء فى المليون، بأفضل جودة فيزيائية وكيميائية. من ناحية أخرى، أدى الري بمستوى الرى ٦٠٪ من السعة الحقلية والرش الورقى بأى من منشطات النمو المستخدمة إلى الحصول على أقل القيم في صفات النمو الخضري والمحصول وجودة الثمار.

الكلمات المفتاحية: الفلفل الحلو، الرش الورقي، الاحتياجات المائية، النمو، المحصول.