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Effect of Some Soil Applications and Irrigation Levels 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 during winter seasons of 2022/2023 and 2023/2024 under plastic greenhouse at the Research Farm of Vegetables Faculty of Agriculture, Benha University, Qalubia Governorate, Egypt, to investigate the effect of soil applicants, i.e., humic acid at 10 $g.kg^{-1}$ soil or bentonite at 50 $g.kg^{-1}$ soil and or humic acid + bentonite at 10 + 50 $g.kg^{-1}$ soil and without soil application (control) under 3 levels of drought, i.e., 60, 80, 100% of field capacity on vegetative growth, yield and fruit quality of sweet pepper plants grown under drip irrigation system in clay soil conditions. The used plastic greenhouse is 27 * 60 m. The experimental site is at latitude 30º36" N and longitude 31º22"E. Three replicates were used in the split-plot design of the experiment. According to the obtained results, the soil application of humic acid + bentonite at 10 + 50 $g.kg^{-1}$ soil under 100% field capacity showed the lowest values of proline content and the highest values of all measured growth parameters, photosynthetic pigments, macronutrient contents such as NPK, and total carbohydrates. Moreover, the highest fruit weight, number of fruits. $plant^{-1}$, fruit $yield.plant^{-1}$, total fruit $yield.m^{-2}$ and water use efficiency were also obtained by applying humic acid + bentonite under 100% field capacity, followed by 80% field capacity. Meanwhile, control treatment came last in this respect. On the other hand, plants irrigated with 60% field capacity without soil application (control) showed the least values in all studied characteristics, except for proline content. It was also shown that soil application can reduce irrigation requirements by 20%, producing high yields with high physical and chemical quality.

KEYWORDS: Sweet pepper, Drought, Soil application, Fruit yield, Fruit quality.

1. INTRODUCTION

Capsicum annum L. belongs to the nightshade family. It's economically significant. Its high ascorbic acid and nutritional content boost health and immunity, making it popular. Sweet pepper fruits contain carotenoids, such as oxygenation and β-carotene, which help prevent cataracts, diabetes, and cancer. After tomatoes, pepper is the second most important vegetable in the Solanaceae family (Hasanuzzaman and Golam, 2011; Adeoye *et al.*, 2014). Around 2 million hectares of land were used for pepper production worldwide in 2022, yielding around 37 million tons with an average yield of 18.3 tons per hectare (FAO STAT, 2022). With an average output of 17.6 tons per hectare, Egypt's 38622 hectares of production area produced 681149 tons (FAO STAT, 2022). Pepper is the second most popular crop grown in greenhouses in Egypt, after cucumbers. The Egyptian Ministry of Agriculture, Economic Affairs Sector, Bulletin of Agricultural Statistics, estimates that during the 2021–2022 season, pepper was grown in over 18,000 greenhouses, occupying an area of about 9.98 million square meters.

Future projections indicate that by 2050, 50% of agricultural soils may be impacted by drought (Hasanuzzaman *et al.*, 2019). In addition to soil fertility, water scarcity still poses a major obstacle to plant development, growth, and yield (Dietz *et al.*, 2021; Çavdar *et al.*, 2021).

Increasing the yield with high-quality, sweet pepper fruits is seen as an important goal that can be accomplished by applying some stimulant compounds to the soil.

The basic building blocks of soil structure, and soil aggregates are essential to a variety of physical and chemical soil processes, including root penetration, soil erosion, nutrient cycling, soil density, and crop performance (Cates *et al.*, 2016; Bronick and Lal, 2005). To increase soil fertility and productivity, it is essential to improve soil structure and particle stability (Zhang *et al.*, 2016).

Since it improves soil qualities like aeration, aggregation, water-holding capacity, permeability, ion transport, availability via a pH buffer, soil workability, and drought tolerance, humic acid is one of nature's best resources. In reaction to the absorption of humic substances, it enhances nutrient absorption and preserves the levels of vitamins and amino acids in plant tissues. In comparison to the control, humic acid used as a soil amendment may significantly improve yield characteristics (AbdEllatif *et al.*, 2017; El-Sayed *et al.*, 2019).

Bentonite is a clay (Jawad and Baqir, 2009). It increased soil mineral nutrients, colloid content, and minimized nutrient loss (Sitthaphanit *et al.,* 2010). Bentonite can also boost soil moisture and nutrient storage, according to Iskander *et al.* (2011). Bentonite prevented soil phosphorus and potassium fixation. Early research revealed that adding bentonite to the soil throughout the growth season can increase potato tuber quantity and size (Jena and Kabi, 2012). Bentonite was widely used in agriculture. It can reduce organic material degradation and increase the humification coefficient, increasing organic matter quantity and quality and boosting sandy soil fertility, growth, yield, and plant chemical composition (Jawad and Baqir, 2009).

This study aimed to examine how applying specific stimulants to soil during drought conditions affected the vegetative development, yield, and fruit quality of Sensei F_1 hybrid sweet pepper plants cultivated in plastic greenhouses.

2. MATERIALS AND METHODS

2.1.Experimental setup

A field experiment was conducted in a plastic greenhouse at the Research Farm of Vegetables, Faculty of Agriculture, Benha University, Qalubia Governorate, Egypt, during the winter seasons of 2022/2023 and 2023/2024 to examine the effects of soil application with specific stimulants on the vegetative growth, yield, and fruit quality of sweet pepper plants grown under drip irrigation in clay soil conditions. The plants were hybrid Sensei F1 plants. A plastic greenhouse measuring 27 by 60 meters has been found. The experiment site is located at 30°36'' N and 31°22'' E.

A soil sample was taken from the experimental greenhouse at a depth of 0–30 cm prior to the transplantation of sweet pepper plants. The purpose of this sample was to be representative. The physical and chemical properties of farmed soil are displayed in Table 1. Page (1982) was used to determine the chemical analysis, while Jackson (2005) was utilized to estimate the physical analysis.

Table 1. Physical and chemical properties of experimental soil.

Soil properties	Season 2022/2023	Season 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	Soluble cations ($mmole.L^{-1}$)				Soluble anions ($mmole.L^{-1}$)		
	$ds.m^{-1}$	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

Three replications and a split-plot design were used to set up this experiment. While soil application treatments have been dispersed among the subplots, deficit irrigation water treatments have been used in the main plots. The plants were transplanted on two sides of each ridge at a 30-cm interval between each row in the 12-m^2 experimental plot, which measured 8 m in length and 1.5 m in width. Twelve treatments with three replications were used in the experiment for each season. Using a drip irrigation system, three different volumes of irrigation water—60, 80, and 100% FC—were applied to the experimental plots. The drippers' flow rate was 4 $L.h^{-1}$, and the irrigation lines were of model GR 16 mm. When all lines were opened, the water pressure was 1.5 bar. After thirty days following transplantation, irrigation treatments were initiated.

2.2.Irrigation scheduling

The following formula was used to calculate the soil's full rapidly available water (RAW) capacity and the irrigation depths (di, mm) for a 100% field capacity 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.

For a 100% field capacity irrigation level, the following formula was used to calculate the soil's full readily available water (RAW) capacity and the irrigation depths (di, mm):

$$\mathbf{IR = 1000\ (\Theta FC - \Theta P)\ } \boldsymbol{Zr}$$

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).

The depth and the interval between irrigations will also fluctuate as RAW changes throughout the growing season.

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.Soil application treatments

1. **Humic acid®** consists of (75% humic acid, 10% K2O, 4% vulvic acid, and 2% Fe.) at 10 g.kg-1 soil.
2. **Bentonite®** (mainly silicon, iron, aluminium oxides and small amounts of Mg, K, and Ca) at 50 g.kg^{-1} soil.
3. **Humic acid® + Bentonite** at 10 + 50 g.kg^{-1} soil.
4. **Control** (without soil application).

Soil applications were added only once before transplanting.

2.4.Data recorded

2.4.1. Vegetative growth characteristics:

Three plants were selected at random from each experimental plot 90 days following transplantation, and subsequently, the following traits were assessed:

a. Morphological characteristics

1. **Plant height (cm):** was measured from the cotyledon nodal to the stem apex.
2. **Number of leaves.plant^{-1}**.
3. **Leaf area (cm^2):** The mature leaves were gathered from the three distinct sections of the plant and their area was measured using a planimeter. The plant leaf was scanned by the scanning device.
4. **Leaf fresh weight (g):** Three leaves were picked up from each replicate and weighed (one leaf per plant).
5. **Leaf dry matter (%):** Dry weight per leaf was determined after picked leaves were dried for 72 hours at 70°C.

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 distilled water for 24 hours at 4 ^oC in the dark), and leaf dry weight (measured after oven drying at 70 ^oC for 48 hours) were used to calculate the relative water content. The LRWC was calculated using the following formula (Kordi *et al.*, 2013).

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

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 (%):** At first, milled dry leaves were digested using the Kjeldahl digestion method as follows: To ascertain the plant's nutrient content of N, P, and K, leaves were digested using a solution of concentrated sulfuric and perchloric acids (Wicks and Firminger, 1942) as follows:

Nitrogen was measured using the Micro-Kjeldahl technique in the digested product (Piper, 2019).

Phosphorus was ascertained using the King (1951) method of spectrophotometry in the digested product**.**

Potassium was measured using Jackson's technique (2005) and the flame photometer in the digested product.

The proline content (Mg.100g^{-1} dry weight): was identified using Jackson's technique (2005) and the flame photometer in the digested product.

2.4.2. Yield and its components:

1- **Number of fruits.plant^{-1}:** was recorded as the total number of picked fruits per plot harvested throughout the growing season divided by the number of plants per plot .

2- **Yield.plant^{-1} (kg):** was calculated by dividing the total weight of the fruits harvested during the harvest season by the number of plants in each plot.

3- **Yield.m^{-2} (kg):** was was determined for all picked fruits and calculated as total fruits weight per quadrate meter.

4- **Water use efficiency (WUE) (kg.m^{-3}):** Hoffman *et al.* (1990) provided the following equations, which were used to determine it:

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

2.4.3. Fruit quality

a. Fruit physical quality

When fruits met the E.E.C. criteria for fruit size for marketing, data on fruit characteristics were gathered. The following parameters were ascertained by taking ten fruits:

1. Average fruit length (cm).

2. Average fruit diameter (cm).

3. Average fruit weight (g).

4. Average fruit firmness (g.cm^{-2}): was determined in a random sample of five fruits for each experimental plot using Digital's Penetrometer **(PCE-PTR.MITPC, USA)** with a needle 8 mm diameter.

b. Fruit chemical quality

Five fruits 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 (%): were ascertained by applying the Malik and Singh (1980) approach.

2. Total soluble solids (TSS) %: AOAC (2012) states that a hand refractometer was used to determine them.

3. Vitamin C (mg.100g^{-1}): was ascertained using the 2,6 dichlorophenol indophenol indicator for titration, following the procedure outlined in AOAC (2012).

2.5.Statistical analysis:

SPSS version 25 (IBM Corp., 2013) was used for the statistics. A split-plot design with three replicates was used to statistically assess all of the data. According to Snedecor and Cochran (1991), the L.S.D. test was used to compare the treatments at a 5% probability level.

3. RESULTS AND DISCUSSION

3.1.Vegetative growth characteristics:

a. Effect of water deficit

Table (3) shows that irrigated sweet pepper plants at 100% field capacity increased all vegetative growth traits and produced the highest plant height and number of leaves.plant^{-1}, leaf fresh weight, leaf dry matter, leaf area, and leaf relative water content in plants that received 100% field capacity decreased gradually with irrigation water deficit through 100 > 80 > 60% field capacity during both study seasons. The current outcome was supported by some investigations, such as Alomari-Mheidat *et al.* (2023 and 2024) on tomatoes as well as Eldewini *et al.* (2023), Wassie *et al.* (2023) and Molla *et al.* (2023) on pepper.

More water enhances the uptake of mineral elements from soil and the translocation of photosynthetic assimilates, according to Shaheen *et al.* (2012) and Fawzy (2019). Improvements in vegetative growth would be explained by this.

Fawzy (2019) and Shaheen *et al.* (2012) observed that increased water enhances the uptake of mineral elements from soil and the translocation of photosynthetic assimilates. Therefore, vegetative growth increases.

The reduction in leaf number and area expansion during stress has been identified as a protective response of plants to water loss by maintaining the stability and extensibility of cell membranes **(Anjum *et al.*, 2011).**

High water stress levels and higher water flow tolerance in plant stems and leaves resulted in a decrease in the leaf relative water content (LRWC) (Chen *et al.*, 2015).

b. Effect of Soil Application

Table (3) indicates that applying some soil substances, such as the combination of humic acid + bentonite at (10 + 50 g.kg^{-1} soil, respectively), recorded the highest values in plant height, number of leaves.plant^{-1}, leaf fresh weight, leaf dry matter, leaf area, and relative water content during the two seasons of study, followed by the effects of separate soil application of bentonite at (50 g.kg^{-1} soil) then humic acid at

Table 3. Effect of the single effect of irrigation water requirement levels or soil application substances on vegetative growth of sweet pepper plants during the winter seasons of (2022/2023) and (2023/2024).

Treatments	Plant height (cm)		No. of leaves. Plant^{-1}		Leaf fresh weight (g)		Leaf dry matter (%)		Leaf area (cm^2)		Leaf 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
Soil application												
Humic acid	112.16	124.93	86.02	91.51	1.67	3.20	10.41	12.15	18.96	19.24	64.92	66.36
Bentonite	125.51	132.51	93.40	98.67	2.69	4.29	14.72	16.31	19.58	19.87	70.65	72.28
Humic acid + Bentonite	139.13	140.27	101.07	105.24	3.67	5.20	18.51	20.18	20.18	20.47	76.54	78.13
Control	98.84	117.04	78.02	83.51	1.09	2.15	6.41	8.02	18.31	18.67	58.49	59.84
LSD at 0.05	3.87	2.27	3.12	2.54	0.14	0.14	0.22	0.21	0.23	0.18	0.30	0.29

(10 g.kg^{-1} soil), with significant variations among these treatments. Without soil application treatment (control), the least significant reductions in all vegetative growth characteristics in both seasons were recorded compared with all tested soil applications. Some research, such those by Lee *et al.* (2012) and Hafshejani *et al.* (2015) on pepper, Youssef (2013) on potatoes, and Dasgan *et al.* (2016) on tomatoes, corroborated the current findings in this trend.

Its capacity to promote meristematic activity, which can be crucial for the synthesis of structure (Monte *et al.*, 2009), as well as its vital role in a number of biochemical processes associated with plant growth (Marschner, 1997), may be the reason for the beneficial effects of bentonite application on plant growth. Additionally, El-Desuki (2004) found that humic acid application increased soil organic matter, which enhanced the growth of onion plants. El-Bassiony *et al.* (2012), Gülser *et al.* (2010), and Cimrin *et al.* (2010) all observed comparable findings with pepper.

b. Effect of the interaction

The interaction between irrigation requirement levels and soil application substances with humic acid, bentonite, or both at (10, 50, or 10+50 g.kg^{-1} soil, respectively) significantly affected vegetative growth traits in 2022 and 2023 compared to the control. Table (4) shows that the highest vegetative parameters were recorded with the soil application of humic acid + bentonite at 10+50 g.kg^{-1} soil, followed by bentonite at 50 g.kg^{-1} soil then, humic acid at 10 g.kg^{-1} soil under 100 % field capacity, followed by 80%. Control treatment (without soil application) when combined with all irrigation levels, especially 60% field capacity, came last for both seasons.

3.2.Chemical constituents of plant foliage:

a. Effect of irrigation water deficit

Tables (5 & 6) show that 100% field capacity irrigation exceeded the maximum chlorophyll (a & b), carotenoids, carbohydrates, and NPK amounts throughout both research seasons. In both seasons, plants irrigated at 60% field capacity had the highest proline concentration in their leaves. Water stress may reduce chlorophyll pigments due to reduced photosynthetic activity. Drought stress may also diminish the production of the main chlorophyll pigment complexes encoded by the CAB gene family (Allakhverdiev *et al.*, 2000). Under drought stress, reactive oxygen species destroy chloroplasts (Anjum *et al.*, 2011; Kannan and Kulandaivelu, 2011).

Because bentonite stimulates meristematic activity, which can be crucial for the synthesis of structure (Monte *et al.*, 2009), and because it plays a crucial role in a number of biochemical processes linked to plant growth (Marschner, 1997), it may have a positive effect on plant growth. Additionally, humic acid application increased soil organic matter, which enhanced onion plant development, according to El-Desuki (2004). These findings mirrored those of studies on pepper by Cimrin *et al.* (2010), Gülser *et al.* (2010), and El-Bassiony *et al.* (2012).

Several researchers, such 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) found that minimizing the irrigation water quantity gradually reduced chlorophyll content in leaves, which is greatly influenced by the physiological reactions of the used species and their ability to resist stress.

In tomatoes, proline synthesis can be triggered via the glutamate pathway, which includes enzymes like glutamyl kinase, glutamyl phosphate reductase, and -pyrroline-5-carboxylate reductase. This can result in proline buildup (Bray, 1990 Fujita *et al.*, 2003). Mohammed (2021), Wassie *et al.* (2023), and Trejo-Paniagua *et al.* (2024) reported similar results on pepper, whereas Arab *et al.* (2022) on tomato reported similar results on tomato.

b. Effect of Soil Application

Data recorded in Tables (5 & 6) show that the application of soil substances with humic acid + bentonite at (10+50 g.kg^{-1} soil) recorded the highest values in chlorophyll a, b and carotenoids as well as carbohydrates and NPK contents of plants followed by bentonite at (50 g.kg^{-1} soil), humic acid at (10 g.kg^{-1} soil) then without soil

Table 4. Effect of the interaction between water requirements and soil application treatments on vegetative growth of sweet pepper plants during the winter seasons of (2022/2023) and (2023/2024).

Water requirements	Soil application	Plant height (cm)		No. of leaves. $Plant^{-1}$		Leaf fresh weight (g)		Leaf dry matter (%)		Leaf area (cm^2)		Leaf relative water content (%)	
		2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Humic acid	79.40	97.07	67.27	74.13	1.27	2.67	9.15	10.25	16.05	16.46	54.12	55.22
	Bentonite	91.33	104.00	74.40	81.00	2.20	3.47	12.62	13.71	16.66	17.15	59.86	61.06
	Humic acid + Bentonite	103.53	111.80	81.67	87.93	3.33	4.40	16.28	17.87	17.28	17.75	65.62	66.87
	Control	66.40	89.47	58.47	66.47	0.91	1.54	5.51	6.70	15.43	15.99	47.73	48.90
80% FC	Humic acid	109.73	123.53	89.87	95.40	1.60	3.13	10.13	12.08	19.25	19.49	65.07	67.27
	Bentonite	122.73	132.27	96.47	101.67	2.40	4.33	14.46	16.23	19.88	20.11	70.78	72.96
	Humic acid + Bentonite	137.87	140.80	103.33	108.13	3.27	5.07	18.10	19.65	20.50	20.74	76.60	78.63
	Control	97.27	115.00	82.07	87.73	0.95	2.18	6.35	7.90	18.59	18.87	58.88	60.80
100% FC	Humic acid	147.33	154.20	100.93	105.00	2.13	3.80	11.94	14.11	21.59	21.77	75.55	76.60
	Bentonite	162.47	161.27	109.33	113.33	3.47	5.07	17.09	19.00	22.21	22.35	81.31	82.81
	Humic acid + Bentonite	176.00	168.20	118.20	119.67	4.40	6.13	21.16	23.02	22.77	22.93	87.41	88.90
	Control	132.87	146.67	93.53	96.33	1.41	2.73	7.37	9.46	20.91	21.15	68.87	69.82
LSD at 0.05		6.71	3.94	5.40	4.39	0.24	0.25	0.39	0.36	0.40	0.30	0.51	0.51

Table 5. Chlorophyll (a & b) and carotenoids (mg.100g^{-1} f.w.) as well as carbohydrates content (%) in leaves of sweet pepper plants as affected by water requirement or soil application 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
Soil application								
Humic acid	1.43	1.68	0.47	0.56	0.26	0.29	20.52	21.50
Bentonite	1.53	1.78	0.55	0.64	0.33	0.36	21.74	22.72
Humic acid + Bentonite	1.63	1.91	0.64	0.73	0.40	0.43	22.96	23.86
Control	1.31	1.56	0.39	0.48	0.19	0.22	19.22	20.18
LSD at 0.05	0.03	0.05	0.03	0.03	0.03	0.03	0.23	0.24

Table 6. NPK (%) as well as proline content (µg.g-1 f.w) in leaves of sweet pepper plants as affected by water requirements or soil application 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
Soil application								
Humic acid	2.07	2.18	0.40	0.41	2.91	2.96	773.80	756.07
Bentonite	2.28	2.40	0.43	0.43	3.00	3.12	688.40	675.20
Humic acid + Bentonite	2.47	2.60	0.45	0.46	3.13	3.27	606.47	595.60
Control	1.86	1.96	0.37	0.38	2.70	2.78	872.20	840.53
LSD at 0.05	0.22	0.22	0.13	0.14	0.21	0.20	2.07	2.09

application (control) in both studied seasons. The results align with those reported by Lee *et al.* (2012) and Hafshejani *et al.* (2015) on pepper. According to Gan (2005) the use of bentonite and zeolite as carriers of chemical fertilizers, along with the modification of the fertilizers to long-acting ones, increased the use ratio of these components, decreased environmental pollution, and released available fertilizers that were in balance with crop needs. Additionally, Hinsinger (2001) observed that zeolite and bentonite increased the soil's macronutrients and micronutrients, which support plant growth because these components are crucial.

As for humic acid, increased chemical ingredient content and considerably reduced soil pH and EC while increasing exchangeable K, Ca, Na, and Mg (Mindari *et al.*, 2014), thus improving the chemical analysis of sweet pepper plants.

c. Effect of the interaction

From the data recorded in Tables (7 & 8), it can be noted that the highest content of chlorophyll a, b, and carotenoids, as well as carbohydrates and NPK contents in leaves, were attained for plants that were irrigated with 100% of field capacity, followed by 80% field capacity with the soil application of humic acid + bentonite at (10 + 50 g.kg^{-1} soil), followed by bentonite at (50 g.kg^{-1} soil) and humic acid at (10 g.kg^{-1} soil). Meanwhile, control treatment (without soil application) and all irrigation levels, especially 60% field capacity, came last in this respect.

The highest proline values were achieved for plants irrigated with 60% of field capacity without soil application (control) during the two seasons of the study. Regardless of all irrigation levels, the control treatment (without soil application) exhibited the highest values of proline. There is an inverse relationship between proline concentration and irrigation rate. When the irrigation rate increases, the proline concentration decreases, and the opposite is true.

3.3. Yield and its components

a. Effect of irrigation water deficit

In Table 9, reducing irrigation water levels from 100 to 60% reduced yield and its components in a progressive descending sequence from 100 to 60% of field capacity for the examined seasons. Improved nutrient uptake and photosynthate accumulation may increase fruit length and breadth, resulting in larger fruit weight and volume. Fruit weight and number, fruit yield per plant as well as fruit yield per square meter followed the same trend. The obtained results are consistent with the findings of Abdelkhalik *et al.* (2020) and Tartoura *et al.* (2023) on pepper, as well as Alomari-Mheidat *et al.* (2024) on tomato.

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

Treatments		Characteristics							
Water requirements	Soil 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	Humic acid	1.19	1.42	0.32	0.39	0.14	0.16	18.51	19.93
	Bentonite	1.29	1.52	0.39	0.46	0.21	0.22	19.84	21.24
	Humic acid + Bentonite	1.40	1.63	0.47	0.54	0.28	0.29	21.08	22.51
	Control	1.03	1.30	0.25	0.31	0.08	0.10	16.93	18.38
80% FC	Humic acid	1.45	1.67	0.49	0.60	0.24	0.25	20.83	21.89
	Bentonite	1.55	1.77	0.57	0.68	0.30	0.32	21.94	22.83
	Humic acid + Bentonite	1.66	1.88	0.66	0.77	0.37	0.40	23.09	23.79
	Control	1.33	1.54	0.40	0.52	0.17	0.18	19.61	20.67
100% FC	Humic acid	1.66	1.95	0.61	0.70	0.41	0.46	22.23	22.69
	Bentonite	1.73	2.04	0.70	0.79	0.48	0.54	23.44	24.08
	Humic acid + Bentonite	1.82	2.22	0.79	0.88	0.55	0.61	24.71	25.28
	Control	1.58	1.85	0.52	0.61	0.34	0.38	21.11	21.49
LSD at 0.05		0.05	0.09	0.05	0.05	0.05	0.05	0.40	0.42

Table 8. Effect of the interaction between water requirements and soil application treatments on NPK (%) & proline content (µg.g^{-1} f.w) as well as carbohydrates content (%) of sweet pepper plants foliage during the winter seasons of (2022/2023) and (2023/2024).

Treatments		Characteristics							
Water requirements	Soil application	N (%)		P (%)		K (%)		Proline (µg.g^{-1} f.w)	
		2022	2023	2022	2023	2022	2023	2022	2023
60% FC	Humic acid	1.87	1.89	0.36	0.37	2.76	2.76	912.40	893.40
	Bentonite	2.07	2.11	0.38	0.40	2.79	2.93	836.00	817.80
	Humic acid + Bentonite	2.27	2.32	0.41	0.42	2.93	3.10	756.80	740.00
	Control	1.65	1.69	0.33	0.34	2.45	2.51	1000.20	984.00
80% FC	Humic acid	2.05	2.15	0.41	0.42	2.87	2.93	801.20	790.40
	Bentonite	2.27	2.37	0.43	0.44	3.01	3.10	701.00	695.00
	Humic acid + Bentonite	2.47	2.59	0.45	0.46	3.12	3.27	605.60	599.00
	Control	1.81	1.91	0.38	0.39	2.72	2.79	905.20	875.20
100% FC	Humic acid	2.31	2.49	0.45	0.45	3.09	3.19	607.80	584.40
	Bentonite	2.49	2.72	0.46	0.47	3.21	3.33	528.20	512.80
	Humic acid + Bentonite	2.69	2.90	0.48	0.49	3.33	3.43	457.00	447.00
	Control	2.13	2.27	0.41	0.42	2.93	3.03	711.20	662.40
LSD at 0.05		0.37	0.38	0.22	0.23	0.37	0.35	3.58	3.62

Table 9. Effect of the single effect of water requirement levels or soil 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
Soil application								
Humic acid	24.20	24.89	5.03	5.75	30.88	34.50	19.94	22.71
Bentonite	30.13	29.47	6.51	7.06	39.19	42.21	26.00	28.18
Humic acid + Bentonite	35.38	33.11	8.11	8.36	48.23	50.08	32.48	33.48
Control	18.42	20.51	3.73	4.54	22.20	27.24	14.61	17.67
LSD at 0.05	1.34	0.92	0.50	0.31	0.84	0.35	1.98	1.2

Sivakumar and Srividhya (2016) claim that in susceptible tomato cultivars, a reduction in photosynthesis during water stress may lessen the amount of assimilates available to developing floral organs, leading to the abscission of flowers and flower buds. Zik and Irish (2003) and Sun *et* *al.* (2021) discovered that many crops experience floral buds that abort due to water shortages. When soil moisture levels are low, this kind of reaction is common and may lower productivity (Singh *et al.*, 2021). By altering crucial plant metabolic pathways, drought stress reduces yield (Bashir *et al.*, 2021). Plant biomass production and quality are hampered by water deficits, an inevitable adverse factor in a variety of circumstances (Seleiman *et al.*, 2021).

b. Effect of Soil Application

Data in Table (9) shows that soil application with humic acid + bentonite at (10+50 $g.kg^{-1}$ soil) recorded the highest significant descending increases in yield and its components (number of fruits per plant, yield per plant, yield per square meter as well as water use efficiency) followed by bentonite at (50 $g.kg^{-1}$ soil), humic acid at (10 $g.kg^{-1}$ soil) then finally without soil application (control) for the investigated both seasons. Youssef (2013) on potatoes, Dasgan *et al.* (2016) on tomatoes, El-Basir and Swelam (2017), and Tartoura *et al.* (2023) on sweet peppers recorded similar results.

It was found that the plant growth and grain yield of maize plants and soil health were greatly upgraded due to the bentonite application in low-fertility soil (Zhou *et al.*, 2019).

c. Effect of the interaction

Concerning the effect of the interaction between water requirement levels and soil application substances, data in Table (10) indicate the highest values in the number of $fruits.plant^{-1}$, $yield.plant^{-1}$, $yield.m^{-2,}$ and water use efficiency $kg.m^{-3}$ were found for the plants that received 100% of field capacity with the soil application of humic acid + bentonite at (10 + 50 $g.kg^{-1}$ soil) followed by the application of bentonite at (50 $g.kg^{-1}$ soil) and humic acid at (10 $g.kg^{-1}$ soil). Meanwhile, control treatment (without any soil applicants) came at the last range. Water irrigation amounts can be saved by adding soil application substances.

3.4.Fruit physical characteristics

a. Effect of irrigation water deficit

Table (9) shows that fruit dimensions (diameter and length), fruit weight as well as fruit firmness decreased with deficit irrigation in the two seasons of study. Decreasing the irrigation level to up 60% of field capacity led to significant reductions in fruit diameter, length, weight and firmness. Improvement in physical fruit traits as a result of using full 100% of field capacity due to the increase in photosynthetic pigments and mineral elements content of plant foliage which positively affected plant growth and consequently quality of produced fruits as well as the main role of water on increasing number and size of fruit cells which in turn may affect on fruit size and weight. In this connection, using 80% of field capacity came in between. Abdelkhalik *et al.* (2020) and Kabir *et al.* (2021) on bell pepper as well as Medyouni *et al.* (2021) and Alomari-Mheidat *et al.* (2023) and (2024) on tomato, came to comparable results.

b. Effect of Soil Application

Regarding how soil application affects the physical characteristics of fruit, Table (11) indicates that, the application of humic acid + bentonite at (10 + 50 $g.kg^{-1}$ soil) produced the largest fruit dimensions (diameter and length), fruit weight, and firmness. This was followed by the application of bentonite, humic acid, and finally the control treatment. Similar findings were found by Dasgan *et al.* (2016) on tomatoes and El-Sayed *et al.* (2019) on sweet peppers.

c. Effect of the interaction

Table (12) reveals that the highest studied fruit dimensions (diameter and length), fruit weight, and firmness were obtained by the irrigation level 100% of field capacity with the application of humic acid together with bentonite as soil application followed separately either by bentonite or humic acid as compared with control (without soil applicants).

Table 10. Effect of the interaction between water requirement levels and soil 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	Soil 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	Humic acid	15.00	15.60	3.17	3.45	18.89	20.75	17.07	18.56
	Bentonite	19.60	20.87	4.51	4.78	26.89	28.51	24.22	25.69
	Humic acid + Bentonite	23.80	24.80	5.80	5.89	34.51	35.13	31.19	31.69
	Control	9.93	10.87	2.03	2.31	12.11	13.82	10.91	12.41
80% FC	Humic acid	25.13	26.20	5.33	6.27	29.20	37.56	21.48	25.27
	Bentonite	30.27	29.80	6.59	7.34	36.48	44.07	26.58	29.58
	Humic acid + Bentonite	36.00	33.33	8.04	8.51	46.67	51.05	32.41	34.34
	Control	19.47	21.67	4.19	5.03	21.91	30.15	16.89	20.28
100% FC	Humic acid	32.47	32.87	6.59	7.53	44.56	45.20	21.28	24.29
	Bentonite	40.53	37.73	8.43	9.07	54.19	54.03	27.21	29.25
	Humic acid + Bentonite	46.33	41.20	10.49	10.67	63.50	64.05	33.83	34.42
	Control	25.87	29.00	4.97	6.29	32.57	37.74	16.02	20.31
LSD at 0.05		2.33	1.60	0.86	0.54	1.45	0.60	3.43	2.08

Table 11. Effect of the single effect of water requirements or soil 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
				Soil application				
Humic acid	8.02	10.20	6.07	7.27	208.33	240.12	710.01	777.40
Bentonite	8.96	11.21	6.83	8.32	215.62	247.68	719.00	786.39
Humic acid + Bentonite	10.07	12.24	7.53	9.02	223.19	254.67	726.59	794.25
Control	6.81	8.80	5.33	6.54	200.16	231.60	700.52	767.68
LSD at 0.05	0.26	0.27	0.22	0.27	0.31	1.01	0.61	1.09

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

Treatments		Characteristics							
Water requirements	Soil 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	Humic acid	6.73	8.85	5.75	5.36	197.56	221.54	678.82	745.49
	Bentonite	7.79	9.94	6.45	7.09	205.05	229.44	690.34	757.80
	Humic acid + Bentonite	8.84	10.95	7.16	7.81	212.70	237.24	699.42	767.30
	Control	5.41	7.37	5.07	4.53	189.11	211.28	668.43	734.06
80% FC	Humic acid	8.09	10.31	6.00	7.47	206.26	238.76	717.26	783.05
	Bentonite	8.97	11.27	6.66	8.14	213.12	246.36	725.74	790.64
	Humic acid + Bentonite	10.08	12.34	7.23	8.86	220.52	254.56	733.10	797.80
	Control	6.89	8.94	5.28	6.83	198.58	231.84	706.98	773.90
100% FC	Humic acid	9.26	11.44	6.46	8.99	221.18	260.05	733.94	803.66
	Bentonite	10.14	12.41	7.38	9.74	228.70	267.24	740.92	810.72
	Humic acid + Bentonite	11.28	13.43	8.19	10.37	236.36	272.20	747.25	817.66
	Control	8.13	10.08	5.63	8.25	212.80	251.69	726.14	795.08
LSD at 0.05		0.45	0.46	0.39	0.46	0.54	1.75	1.05	1.89

3.5. Fruit chemical characteristics

a. Effect of irrigation water deficit

Table (13) shows that irrigation at 100% of field capacity increased fruit chemical features such as TSS, reducing non-reducing sugars, total, and vitamin C, followed by 80%. These features were lowest in 60% field capacity-irrigated plants. The findings match those published by El-Sayed *et al.* (2019), Abdelkhalik *et al.* (2020), and Tartoura *et al.* (2023) on pepper.

b. Effect of Soil Application

As for the effect of soil application on fruit chemical characteristics, the data in Table (13) show that the highest values of TSS, reducing, non-reducing sugars and total as well as vitamin C were obtained by the application of humic acid + bentonite at (10 + 50 $g.kg^{-1}$ soil), followed by bentonite at (50 $g.kg^{-1}$ soil) then humic acid at (10 $g.kg^{-1}$ soil) as compared to control treatment. These results are compatible with those obtained by Dasgan *et al.* (2016) on tomatoes, El-Basir and Swelam (2017), El-Sayed *et al.* (2019), and Tartoura *et al.* (2023) on sweet peppers.

c. Effect of the interaction

Table (14) shows that the irrigation level of 100% field capacity with humic acid + bentonite as soil applicants produced the highest values of TSS, total sugar, reducing sugar, non-reducing sugar, and vitamin C, followed by bentonite and humic acid.

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 apply soil with humic acid + bentonite at (10 + 50 $g.kg^{-1}$ soil) or bentonite at (10 + 50 $g.kg^{-1}$ soil) only once before transplanting the plants under water irrigation at 100% of field capacity, followed by 80% of field capacity. Moreover, these soil applications can reduce irrigation requirements by 20%, while maintaining high yield with high physical and chemical quality.

Table 13. Effect of the single effect of water requirements or soil application substances on chemical characteristics of sweet pepper fruits during the winter seasons of (2022/2023) and (2023/2024).

Treatments	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
Soil application										
Humic acid	8.14	8.52	5.01	4.94	0.36	0.43	5.39	5.39	85.63	95.47
Bentonite	8.79	9.16	5.19	5.14	0.34	0.39	5.54	5.55	90.84	101.33
Humic acid + Bentonite	9.43	9.76	5.36	5.25	0.40	0.55	5.77	5.83	96.43	107.02
Control	7.53	7.79	4.92	4.82	0.34	0.36	5.27	5.23	80.09	88.85
LSD at 0.05	0.11	0.09	0.12	0.12	0.04	0.05	0.14	0.14	0.85	0.40

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

Treatments		Characteristics									
Water requirements	Soil 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	**Humic acid**	7.76	7.90	4.73	4.61	0.27	0.31	5.00	4.92	73.68	85.57
	Bentonite	8.40	8.60	4.93	4.79	0.23	0.31	5.17	5.11	79.37	91.55
	Humic acid + Bentonite	9.04	9.27	4.96	4.69	0.28	0.50	5.26	5.25	84.53	97.42
	Control	6.97	7.11	4.64	4.41	0.25	0.34	4.91	4.75	67.96	78.73
80% FC	**Humic acid**	8.13	8.60	4.93	4.95	0.42	0.46	5.37	5.43	85.40	94.95
	Bentonite	8.74	9.24	5.09	4.96	0.43	0.54	5.55	5.53	89.54	100.71
	Humic acid + Bentonite	9.38	9.77	5.22	5.25	0.39	0.39	5.63	5.66	95.35	106.14
	Control	7.45	7.82	4.83	4.89	0.43	0.35	5.27	5.31	80.99	88.63
100% FC	**Humic acid**	8.53	9.07	5.37	5.27	0.41	0.53	5.80	5.83	97.82	105.90
	Bentonite	9.23	9.63	5.55	5.66	0.36	0.33	5.91	6.01	103.61	111.74
	Humic acid + Bentonite	9.87	10.25	5.89	5.81	0.52	0.76	6.43	6.59	109.41	117.49
	Control	8.17	8.45	5.29	5.16	0.36	0.39	5.65	5.62	91.33	99.21
LSD at 0.05		0.19	0.16	0.20	0.21	0.07	0.08	0.24	0.24	1.47	0.69

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الملخص العربي

تأثير بعض الاضافات الأرضية ومستويات الرى على نمو وانتاجية نباتات الفلفل الحلو لزيادة تحمل الجفاف تحت ظروف الصوب البلاستيكية

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أجريت تجربة حقلية على نباتات الفلفل الحلو هجين سينسى خلال موسمي الشتاء لعامى ٢٠٢٢/٢٠٢٣ و ٢٠٢٣/٢٠٢٤ تحت الصوب البلاستيكية بمزرعة بحوث الخضر بكلية الزراعة جامعة بنها، محافظة القليوبية، مصر، لدراسة تأثير الاضافات الأرضية بحمض الهيوميك بتركيز ١٠ جم.كجم$^{-1}$ تربة، وبنتونيت بتركيز ٥٠ جم.كجم$^{-1}$ تربة، وحمض الهيوميك + بنتونيت بتركيز ١٠ + ٥٠ جم.كجم$^{-1}$ تربة وبدون إضافة تربة (كنترول) تحت ٣ مستويات رى ٦٠، ٨٠، ١٠٠٪ من السعة الحقلية على النمو الخضري والمحصول وجودة الثمار لنباتات الفلفل الحلو المنزرعة فى تربة طينية تحت نظام الري بالتنقيط داخل الصوبة البلاستيكية المستخدمة ٢٧*٦٠ م. يقع موقع التجربة عند خط العرض: ٣٠ درجة و٣٦ ثانية شمالاً وخط الطول: ٣١ درجة و٢٢ ثانية شرقاً. وقد صممت التجربة بتصميم القطع المنشقة بثلاث مكررات. وقد أظهرت النتائج أن إضافة حمض الهيوميك + البنتونيت معا إلى التربة بمعدل ١٠ + ٥٠ جم/كجم$^{-1}$ تربة تحت مستوى رى ١٠٠٪ من السعة الحقلية أعطى أعلى القيم لجميع صفات النمو الخضرى والصبغات الضوئية ومحتوى العناصر الكبرى من النيتروجين والفوسفور والبوتاسيوم بالاضافة إلى الكربوهيدرات الكلية وأعطى أقل قيم لمحتوى البرولين فى الأوراق. علاوة على ذلك، تم الحصول على أعلى وزن للثمار وعدد الثمار. نبات$^{-1}$ والمحصول . نبات$^{-1}$ والمحصول الكلي . م$^{-2}$ عند إضافة حمض الهيوميك والبنتونيت إلى التربة بمعدل ١٠ + ٥٠ جم/كجم$^{-1}$ تربة يليها البنتونيت بمعدل ٥٠ جم.كجم$^{-1}$ تربة مرة واحدة فقط قبل الزراعة تحت مستوى رى ١٠٠٪ من السعة الحقلية بأفضل جودة فيزيائية وكيميائية للثمار. كما وجد أنه يمكن باستخدام الاضافات الأرضية المذكورة إنتاج محصول ثمرى عالى ذو صفات طبيعية وكيميائية جيدة، مع تقليل كميات مياه الرى بمعدل ٢٠٪ .

الكلمات المفتاحية: الفلفل الحلو، الجفاف، الاضافات الأرضية، المحصول، جودة الثمار.