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Effect of Water Stress on the Growth and Yield of Sweet Pepper (*Capsicum annum* L.) under Greenhouse Conditions

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Abstract
An experiment was conducted to check the effect of different levels of irrigation treatments on the growth and yield of sweet pepper on a sandy soil, under greenhouse conditions by using drip irrigation system having flow rate of drippers 2 liters per hour (LPS). The field study was carried out on a randomized complete block design (RCBD) having seven different rates of irrigation treatments with four replications. The irrigation water applied in such a way that (T_1 = one time, T_2 = two times, T_3 = three times, T_4 = four times, T_5 = five times, T_6 = six times, and T_7 = seven times) application per day. The results revealed that different levels of irrigation water application brought a positive effect in sweet pepper production. Amongst all the treatments, T_5 was observed to be more suitable and economical as it took least days to develop flowers (24.41 days), give more number of fruits per plant (18.51 fruits), highest fruit length (8.20 cm), highest fruit diameter (7.09 cm), highest fruit weight (103.80 g), and highest fruit yield (7.62 tons donum^{-1}) respectively. However, treatment T_1 showed inadequate results regarding all the parameters. Results suggests that the five times application of water of three minutes long duration per day to the sweet pepper plants, with 15 minutes gap in between each water application were found suitable for best possible growth and yield of sweet pepper under greenhouse conditions using drip irrigation system.
Keywords: Sweet Pepper, Water Stress, Drip Irrigation, Greenhouse, Agriculture.

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INTRODUCTION

Sweet pepper (*Capsicum annuum L.*) is a genus of flowering plants in the nightshade family (*solanaceous*). It is not particularly sensitive to soil acidity and adapts well to a pH range between 5.5 and 7. However, in waterlogging and excessive rains adversely affected it both in growth and yield (Khan *et al.,* 2005). It has a unique annual growth cycle. This plant acquires many roots having a deep axle root system. Ample amount of light is imperative for its growth and flowering as its plays a very vital role in pertinent context. The ideal requisite humidity level ranges between 50% and 70% (Arora *et al.,* 2002). A sandy loam soil capable of holding moisture, supplemented with organic matter is an excellent choice to ensure maximal positive results. Careful selection of varieties, adoption of appropriate technology and good management of sweet pepper crops throughout the production cycle allows growers to maximize production of marketable fruit (Islam *et al.,* 2011).

Greenhouse cultivation has a cutting edge over the traditional techniques by adopting this farmers can attain a handsome yield for a long time period. In addition to this by growing sweet pepper in greenhouses the farmers can take good care of their vegetables in a less number of days which ultimately increase the production (Ahmed, 2014). It has been observed that standard sweet pepper plant density in Israel is 30,000 – 35,000 plants/ ha with an average yield of 50 – 70 T/ha depending upon how efficient and suitable fertilizers given to the plants. The sweet pepper plants requires plenty of nitrogen during the first phases of growth, phosphorous is necessary when the first flowers appear and throughout the seed ripening process. Potassium is required in order to obtain early fruit colour and quality, and magnesium is needed during the ripening stage (Aliyu, 2002).

The water requirement of sweet pepper depends on the soil and climatic conditions of the particular area. However, during warmer season irrigation requirement is more than

winter season. Therefore, the shortage of water during flowering and fruit development stage in soil may result in flowering and fruit dropping (Kaya *et al.,* 2005). In greenhouse farming, the plants usually being irrigated through drip irrigation system, as it minimizes the soil storage and provides optimum water supply to the roots and helps in controlling soil matric potential in the rhizosphere which ultimately reduce the plant water stress (Wang *et al.,* 2009). Various studies show that sweet pepper harvested yield was found more with drip irrigation system as the fruit parameters (length, diameter, number of fruits, and weight of fruit etc), were significantly affected by irrigation quantities (Zhang *et al.,* 2011).

Keeping the above facts in view the subject study was carried out in a greenhouse at Western Region of Abu Dhabi, UAE to evaluate the effect of different levels of irrigation treatments with constant doses of fertilizers on the growth and production parameters of sweet pepper under greenhouse conditions by using the drip irrigation system.

MATERIALS AND METHODS

Location

The research work was conducted at a private farmhouse at Al Mezaira, Western Region of Abu Dhabi, UAE in September 2016. The soil of the farmhouse was mostly sandy in nature, with hydraulic conductivity (1.224 x 10^{-4} m/sec), bulk density (1.3 g/cm^3), and porosity (0.45) respectively. The moisture holding capacity of the soil was increased by mixing poultry manure with sand and irrigation was done through drip irrigation system by using a drippers having flow rate 2 liters per hour (LPS), respectively.

Greenhouse Size and Drip Irrigation System

The experimental area of the greenhouse comprised of 1 donum i.e. (10 x 100 m^2) and which was further divided in to 4 subplots i.e. (5 x 50 m^2) each. The drip irrigation system for each sub-plot contained 7 laterals, and each lateral was supplying water to 125 sweet pepper plants through emitters. The external diameter of mainline, submain line, and laterals were 60mm, 40mm and 20mm respectively. The distance between main water source from the submain line was kept 15m. The spacing among emitter was 0.4m and spacing among lateral was kept 0.7m. Water supplied to the drip unit at constant present head 20 psi (1.36 atm) pressure with 2 inch water pump respectively.

Field Experiment

The present research was carried out on a randomized complete block design (RCBD) having seven different rates of irrigation treatments with four replications. The irrigation water applied in such a way that (T_1 = one time, T_2 = two times, T_3 = three times, T_4 = four times, T_5 = five times, T_6 = six times, and T_7 = seven times) application per day respectively. The time of water application per irrigation was 3 minutes long in each treatment and there was a gap of 15 minutes between each irrigation application respectively (Arshad, 2017). Initially the seed bed was prepared by digging small holes adjacent to the emitters with the help of traditional hoes and drip irrigation lines were installed for the irrigation purpose accordingly (Wang *et al.,* 2009). For the cultivation of sweet pepper the nursery was initially developed with the help of plastic tray and coco peat respectively. The plastic trays were filled with coco peat and the sweet pepper seed (capsicum green bell variety) sown at the depth of 6mm. After the development of 2 or 3 well established leaves the plants were then transplanted with proper covering of plastic sheet and irrigated in such a way that the plant can take firm foot hold with regard to the root taking process (Sahin *et al.,* 2015).

The fertilizers are applied in equal amount to all sub-plots through drip irrigation system. The pruning, stacking and tying takes place after few days of transplanting to improve the aeration process within the plants and cultural practices i.e., hoeing and weeding were carried out throughout the growing season respectively (Zhang *et al.,* 2011). After 60 days of transplanting first harvesting was done. Twenty randomly selected plants from each treatment was taken to determine the plant growth and yield parameters during study i.e. plant height (cm), number of leaves per plant, leaf area (cm^2), days taken to 50% flowering, number of fruit per plant, fruit length (cm), fruit diameter (cm), average fruit weight per plant (grams), and fresh fruit yield (tons donum^{-1}). Finally all the data and statistical analysis were done through ANOVA procedure using SPSS software accordingly (Arshad *et al.,* 2016).

RESULTS AND DISCUSSION

The study revealed that the different agronomic parameters of sweet pepper i.e. (plant height, number of leaves per plant, leaf area, days taken to 50% flowering, number of fruit per plant, fruit length, fruit diameter, average fruit weight per plant, and fresh fruit yield) differed very significantly between application of different rates of irrigation water as elaborate in Table 1 and Table 2 respectively. The critical gathered observations and data for the above discussed parameters during the present research work are appended below:

Plant Height

Growth parameters observed during the field experiment like plant height; responded positively to the different irrigation treatments as shown in Table 1. At first harvest, the maximum height of plant (45.07 cm) was recorded with the treatment T_6, followed by T_5 (43.59 cm), and T_7 (40.87 cm) respectively. Whereas, minimum height of sweet pepper plant was recorded for the treatment T_1 (32.71 cm), were irrigation was applied once in a day. The increase in plant height mainly depends on the environmental and agronomic factors; therefore the plants receiving more amount of irrigation water may increase the water in root zone which ultimately boost the movement of macro-element from the

soil by plants on sweet pepper. Likewise soil condition and texture also plays a critical role in enhancing the root length. The present results supported by the findings of (Antony *et al.,* 2004), who stated that, plant height of sweet pepper was significantly increased with close spacing and high pulse irrigation up to some extent; however over-irrigation may reduce the plant growth, encourage disease, and yellowish/ brownish scars on the fruit.

Number of Leaves per Plant

The number of leaves per plant was significantly affected by different levels of irrigation treatments as shown in Table 1. At first harvest, the maximum number of leaves were recorded for treatment T_6 with (175.99 leaves), followed by T_7 with (175.16 leaves) and T_5 with (173.53 leaves) respectively. While the overall minimum number of leaves, once again recorded for treatment T_1 with (135.36 leaves). As plants receives optimum amount of water it directly improves cell permeability which enhances photosynthetic process and results in more number of leaves. These results are in agreement with (Simone *et al.,* 2006), who concluded that there is a proportional relation between pulse irrigation and number of leaves, as high pulse irrigation gives early maturity of bell pepper and vice versa.

Leaf Area

Statistically considerable results were observed for leaf area per plant (Table 1). Maximum leaf area per plant (321.43 cm^2) was recorded with the treatment T_6, followed by T_7 (318.82 cm^2), and T_5 (315.17 cm^2) respectively. Whereas, minimum leaf area of sweet pepper plant was recorded for the treatment T_1 (202.19 cm^2), were irrigation was applied once in a day. As the irrigation application is increasing and a plant root receives plenty of water with sufficient amount of soluble fertilizers which ultimately influence the plant vegetative growth and results in more number of leaves per plant and increased the specific leaf area. The results of the present study for this character are in agreement with the findings of (Dagdelen *et al.,* 2004), who stated that, leaf area of sweet pepper was significantly increased with high pulse irrigation.

Days Taken to 50% Flowering

Statistically remarkable results were observed for days taken to 50% flowering for all treatments as shown in Table 1. Treatment T_5 took less number of days (24.41 days) to produce flowers, followed by T_6 (24.53 days) and T_7 (24.65 days) respectively. While maximum number of days was recorded for T_1 with (35.12 days) to produce flowers. The plants which are irrigated with required amount water took fewer days to develop flowers. While, plants irrigated with less amount of water took more days to set flowers. These results are in agreement with (Arshad *et al.,* 2014), who concluded that continuous increase in irrigation levels with optimum amount of fertilizers can reduce the days taken to set flowers in capsicum green bell.

Table 1. The effect of different rates of irrigation treatment on plant growth parameters of sweet pepper plants.

Treatment	Plant Height (cm)	No of leaves per plant	Leaf Area $(cm)^2$	Days Taken To 50% Flowering
T_1	32.71d	135.36e	202.19d	35.12e
T_2	36.04cd	144.16d	266.62bc	33.70d
T_3	37.34c	148.57c	272.29b	29.35c
T_4	39.01b	171.58bc	280.31b	26.59b
T_5	43.59a	173.53b	315.17ab	24.41a
T_6	45.07a	175.99a	321.43a	24.53a
T_7	40.87ab	175.16a	318.82a	24.65a
LSD (P< 0.05)	1.61	1.85	19.44	1.74

Means followed by different letter shows significant result at 5% level of significance

Number of Fruits per Plant

The number of fruits per plant varied significantly for all the treatments as shown in Table 2. At first harvest the highest numbers of fruits were observed for treatment T_5 (18.51 fruits) followed by T_6 (18.05 fruits) and T_7 (17.53 fruits) respectively. The lowest number of fruits per plant was recorded for treatment T_1 (9.05 fruits) per plant. This effect can be positively correlated to the fact that optimum amount of water plays a vital role in metabolism and nutrient uptake. Proper amount of water application boost up the vigorous growth of sweet pepper which eventually increases the number of fruits per plant, which conforms the findings of (Aasouline *et al.,* 2006) for bell pepper when water is applied to the plants through pulse irrigation at high rate.

Fruit Length

Statistically significant results were observed for fruit length per plant as shown in Table 2. In general the length of sweet pepper were found usually more in those plants which received high pulses per irrigation as compared to those that

received less number of pulses per irrigation. The maximum fruit length (8.20 cm) was recorded for treatment T_5, followed by T_7 (7.40 cm) and T_6 (7.32 cm) respectively. Once again the overall minimum fruit length (4.46 cm) was observed for treatment T_1. As sweet pepper required ample amount of water during summer season, therefore increasing the amount of irrigation water to a certain level T_5, the fruit length may increased and vice versa. The result is in agreement with the report of (El-Mogy *et al.,* 2012) for green beans, who concluded that plants that do not get required amount of water produce undersized and deformed fruits.

Fruit Diameter

Different irrigation levels varied significantly in respect of fruit diameter as shown in Table 2. The lowest fruit diameter were observed for treatment T_1 (3.79 cm), and maximum fruit diameter was recorded for T_5 with (7.09 cm) followed by T_6 (7.01 cm) and T_7 (6.96 cm) respectively. These results are in agreement with (Dalla *et al.,* 2002), who concluded that high pulse irrigation levels can significantly alter plant height, number of leaves, fruit length, and fruit diameter.

Fruit Weight

The results of fruit weight showed that the high pulse irrigation directly affected the weight of fruit and there were significant differences between the irrigation treatments. The overall maximum fruit weight (103.80 g) was recorded for treatment T_5 and minimum fruit weight (65.80 g) was recorded for treatment T_1 respectively. The results showed that high pulse irrigation along with appropriate amount of fertilizers can increase the fruit weight. The result is in agreement with the report of (Arshad *et al.,* 2014) for cucumber, who reported that the individual fruit weight increase by the application of appropriate amount of irrigation water and fertilizers.

Fresh Fruit Yield

Different irrigation levels had a significant effect on yield per plot and yield per donum (Table 2). After 60 days of transplanting first harvest was done when the skin of the sweet pepper fruit is completely dark green, shiny and they are large enough to use. The irrigation treatment T_5 increased the fruit yield up to (7.62 tons donum^{-1}), followed by T_6 (7.16 tons donum^{-1}) and T_7 (6.85 tons donum^{-1}) respectively. The minimum fruit yield was recorded for treatment T_1 (2.36 tons donum^{-1}). High pulse irrigation increased the vegetative growth and chemical composition of fruits which results in more fruit length and fruit weight and ultimately affects the fruit yield. It was also observed that the yield of fruits per unit area showed a little lesser yield in T_6 and T_7; which might be due to excess amount of water in the root zone which decreased the vegetative growth which reduces the fruit length and diameter and results in less fruit yield. Similar results were obtained by (Cresporuiz *et al.,* 1998), who also concluded that different level of irrigation water with proper dozes of fertilizers increased the fruit yield of sweet peppers.

Table 2. The effect of different rates of irrigation treatment on fruit yield and its component of sweet pepper plants.

Treatment	Number of Fruits Per Plant	Fruit Length (cm)	Fruit Diameter (cm)	Average Fruit Weight per plant (g)	Fresh Fruit Yield (ton/donum)
T_1	9.05d	4.46d	3.79e	65.80e	2.36ef
T_2	9.36cd	5.81c	4.20d	72.60d	2.70e
T_3	11.74c	6.97bc	5.46c	79.90cd	3.72d
T_4	15.88b	7.02b	6.64bc	86.89b	5.48c
T_5	18.51a	8.20a	7.09a	103.80a	7.62a
T_6	18.05a	7.32b	7.01a	100.03a	7.16a
T_7	17.53ab	7.40ab	6.96b	98.46ab	6.85b
LSD (P< 0.05)	1.42	0.15	0.09	5.40	0.73

Means followed by different letter shows significant result at 5% level of significance

CONCLUSION

From the results obtained it could be concluded that different levels of irrigation treatments with constant doses of fertilizers brought a positive effect in sweet pepper production under greenhouse conditions. Amongst all the treatments, T_5 was observed to be more suitable and economical as it took less days to develop flowers (24.41 days), give more number of fruits per plant (18.51 fruits), highest fruit length (8.20 cm), highest fruit diameter (7.09 cm), highest fruit weight (103.80 g), and highest fruit yield (7.62 tons donum^{-1}) respectively. However, treatment T_1 showed inadequate results regarding all the parameters. Too low or high irrigation application per day through drip irrigation system may negatively affect the vigorous growth and yield parameters of sweet pepper. Hence it can be

concluded that the five times application of water of three minutes long duration per day to the sweet pepper plants, with 15 minutes gap in between each water application were found suitable for best possible growth and yield of sweet pepper under greenhouse conditions using drip irrigation system. As an area under study was sandy; therefore these suggestions are applicable for only sandy soils while the results may vary for other types of soil.

CONFLICT OF INTEREST

There is no conflict of interest.

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