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Effect of Irrigation Water Quantities and Planting Spacing on Hot Pepper Yield and Efficient Water Use

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ABSTRACT

A study was carried out during 2001 growing season, at the Faculty of Agriculture Farm located at the Jordan University Experimental Station in Amman, to study the effects of irrigation quantities, planting density and their interaction on hot pepper yield, and to investigate actual Evapo-Transpiration (ET_c) of hot pepper crop that gives maximum yield per unit volume of water per unit area for a specified planting density. A split plot in a randomized complete block design was carried out with four replications using drip irrigation system on a clay soil. Three levels of in-row plant spacing were used (S1 (30cm), S2 (60cm) and S3 (90cm) and five levels of irrigation quantities (W1 ($^2/_6$), W2 ($^3/_6$), W3 ($^4/_6$), W4 ($^5/_6$) and W5 ($^6/_6$ times evaporation depth from Calss-A pan). Irrigation water applied was adjusted according to the crop growth stage in which $^1/_3$ of the desired amount was applied at the first stage of plant life (seedling), $^2/_3$ at the second stage (development) and $^3/_3$ at the last stage (maturity and late). Each plot was 13.5 m^2 with three laterals 5-m long, and 0.9 m between the laterals.

In general, increasing applied irrigation water and/or plant population increased actual consumptive use. Seasonal actual consumptive use varies from 397, 376 and 370 mm at W1 to 1153, 1116 and 1095 mm at W5 irrigation treatments, for S1, S2 and S3 treatments, respectively. Pepper yield increases with the increasing amount of irrigation water applied for all spacing treatments form W1 to W5, respectively. Also, yields increase with increasing plant population (reducing plant spacing).

The WUE is reduced as irrigation water applied increases because yield is increasing at decreasing increments as compared to the amount of irrigation water applied. Also, increasing in-row plant spacing from S1 to S3 significantly reduced the WUE. In general, among all spacing and irrigation treatments it is recommended to use 30 cm in-row plant spacing accompanied with W3 ($^4/_6$ times evaporation depth from Calss-A pan) for higher yield and WUE and wise water application.

KEYWORDS: Hot pepper, Irrigation, Plant spacing, Water use and Evapotranspiration.

INTRODUCTION

Water availability is a worldwide spread problem, especially in arid regions, which are characterized by low rainfall. Therefore, water is a limiting factor in expanding irrigated agriculture. Usually, maximization of crop productivity per unit irrigation water per unit area. could be achieved through the integration of many factors as: using modern irrigation systems; irrigation scheduling; determining actual water requirements of the different crops; maintaining irrigation system; irrigation practices; irrigating with good water quality and/or improving water quality; modifying plant population and spacing; controlling weeds; use of tolerable cultivars for water stress; usage of mulches; applying the appropriate tillage, fertilizers and organic matters. Therefore, the best configuration of the previous factors will result in a good water management and eventually maximizing crop productivity.

Thompson and Kelly (1957) have pointed out that most varieties of peppers are planted about 60 cm apart within row and 90 cm apart between rows. Small-growing varieties may be planted as close as 45 cm apart

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in row. Whereas very large growing varieties sometimes are planted at 75 cm within row spacing.

Ware and McCollum (1959) have mentioned that the pepper plants are planted with 90 to 105 cm apart between rows and 45 to 75 cm apart in the row.

Doorenbos and Kassam (1979) have proposed that pepper seedlings of 10 to 20 cm heights were transplanted into the field after 25 to 35 days. The length of the total growing period varies with climate and variety but in general it takes 120 to 150 days from sowing to the latest harvest. They recommend plant spacing of 40 to 60 cm between plants and 90 cm between rows.

Hochmuth and Vavrina (1997) pointed out that a standard planting arrangement for pepper crops would be single row with 1 meter between rows and 45 cm between plants within the row. Some early, small plant type varieties may be planted at 1-meter row centers and 30 cm between plants. Alternatively, peppers may be planted in twin rows on 1.5-meter centers, with 45 cm between the twin rows, and 45 cm between plants within the row. So, from the above it is obvious that pepper seedlings can be planted at different spacing.

Saamin (1978) found that there was no significant increase in pepper crop yield when in-row spacing was reduced from 50 to 25 cm. However, Ahmed (1984) showed that yields were higher with closer spacing 30cm in-row and 70 between rows than with wider spacing (70 x 70 cm).

Lan Chow Wing (1984) studied the effect of row arrangement and plant density on the yield of hot pepper “Piment Cipaye”. Three within-row spacings were used (30, 45 and 60 cm) in single rows 60-cm apart and double rows (60 x 90 cm). Yields were the highest (up to 6.2 tons/ha) in plants grown 30-cm apart in single rows (55550 plants/ha) and the second highest (up to 5.8 tons/ha) in plants grown 30-cm apart in double rows (44400 plants/ha). No differences in fruit weight among treatments were detected.

In Mexico, Lopez and Silvas Rios (1986) examined planting distances between rows and plants in sweet pepper “California Wonder-300”. The plants were spaced at 15 to 60 cm apart within rows at 0.75 to 1.5-m apart. Fruit yields and quality were the highest at the closest spacing. Planting at 30 cm x 1.0 m is recommended for good yields and quality and ease of management.

Savic and Ilic (1992) studied the effect of spacing on pepper (Capsicum annum L.) yield. The plants were spaced at 15, 25, 30, 40 and 50 cm apart within rows that laid at 60-cm apart. The closest spacing (15 x 60 cm) produced the highest yield, while the widest spacing produced the lowest yield.

In Georgia, Batal and Smittle (1981) studied the response of “Bell” pepper (*Capsicum annum* L.) to irrigation, nitrogen, and plant population. They found that yield response to irrigation were significant only if water stress was severe enough to affect normal plant growth. In the fall, where the rainfall was inadequate, more frequent irrigation at lower soil-moisture tension significantly increased marketable yield. Also, yield increases with a population increase from 27,000 to 40,000 plants/ha in both spring and fall seasons.

Caixeta et al. (1981) studied the effect of different levels of water (2, 4 and 6 mm/day) and frequency (every 1, 2 and 3 days) of trickle irrigation system on yield of sweet pepper “Cascadura Ikeda”. Fruit production was positively correlated with the amount of water and negatively correlated with dry matter percentage. Fruit mean weight and the incidence of injured fruit did not differ between treatments but fruit wall thickness increased with decreasing water amount and greater irrigation frequency and decreased with rising water quantity and reduced irrigation frequency.

Ferreyra et al. (1985) studied the effect of different water levels on “Pimento” pepper yield. Plants were irrigated weekly to provide 0.3, 0.7, 1.0 and 1.3 times class-A pan evaporation. Fruit yields were the highest at 0.7 times pan evaporation depth. Yield and evapotranspiration were linearly related between 15 and 35cm Evapotranspiration.

El-Gindy (1984) examined optimization of water use for pepper crop using basin, furrow, drip and sprinkler irrigation systems. With the same amount of water, drip irrigation increased yields by 64% over furrow irrigation, and it was also economically the most efficient method. Sprinkler irrigation gave the lowest yields and was the least efficient method.

Callebaut et al. (1985) studied the response of “Beldi” pepper to irrigation in the semi-arid region of Tunisia on sandy loam soil. Varying fractions of Potential Evapotranspiration (PET), as calculated by Penman equation (1948), were used to define 4 irrigation treatments (40, 57, 75 and 92 % of PET). Results showed that the number of fruits of plants under the driest irrigation treatment was significantly lower. However, rather than assume an optimum depth of water, they define a range of optimum depths between 57 and 100 %

of the calculated potential Evapotranspiration, and limited irrigation is advisable to increase the water-use efficiency.

Abu-Awwad (1998) studied the effect of mulch and irrigation water amounts on soil evaporation, transpiration and yield for pepper in greenhouse pot experiment. Results showed that covering soil surface reduced the required amount of irrigation water. With deficit irrigation, the reduction in applied irrigation water was about 14 % and increased to 29 % with excess irrigation. With limited irrigation, increasing irrigation water applied decreased the percentage of soil evaporation and the contribution of soil evaporation to crop Evapotranspiration. With excess irrigation, increasing water applied increased the percentage of soil evaporation and its contribution to the total Evapotranspiration. Soil evaporation reduced pepper yield significantly due to the reduction in the available soil water associated with limited to complete irrigation.

In Jordan, the yield of chillies and peppers for open fields was 17.2 tons/ha for the year 1999 (FAO, 1999) and the Jordan total production is about 19000 tons according to the FAO estimates (FAO, 1999).

When to irrigate? how much water to apply? and plant spacing are important factors determining crop yield. This study was carried out to study the effects of irrigation quantities, planting density and their interaction on hot pepper yield, and to investigate actual Evapo-Transpiration (ET_c) of hot pepper crop that gives maximum yield per unit volume of water per unit area for a specified planting density.

Materials and Methods

A field experiment was conducted on hot pepper crop *(Capsicum frutescens* L.) of "Anaheim Chili" variety during the growing season of 2001 at the Faculty of Agriculture Farm at the Jordan University site in Amman at latitude of 32, longitude of 53 and an elevation of 980 above the sea level. The site represents an area of Jordan, which is characterized by cold winter with an annual average rainfall of 434 mm for the last ten years, falling during winter season, and hot summer with the month of August represents the warmest month during the 2001 growing season.

The experimental design was split plot arranged in randomized complete block design, with four replicates. The treatments consisted of five levels of water application: W1=$\frac{2}{6}$; W2=$\frac{3}{6}$; W3=$\frac{4}{6}$; W4=$\frac{5}{6}$ and W5=$\frac{6}{6}$ of the measured evaporation depth from class-A pan evaporation and three levels of in-row plant spacing: S1=30; S2=60 and S3=90 cm apart (equivalent to 3.8, 2.0 and 1.3 plants/m^2, respectively). Water treatments were adjusted according to the crop growth stages in which $\frac{2}{6}$ of the desired designed amounts were applied at the first stage (seedling), $\frac{4}{6}$ at the second stage (development) and $\frac{6}{6}$ at the last stage (maturity and late). Evaporation depth from an on site class-A pan evaporation was frequently monitored. For the period between two irrigation events, evaporation depth from calss-A pan was used to quantify the required amount of irrigation water to be added for each treatment. Irrigation was practiced when tensiometer readings reach 30-40 centibars at W3 treatment within each spacing. Each plot had 3 trickle irrigation laterals controlled by one valve. Each lateral was 5 meter long and contains 17 in-line emitters 30-cm apart with an emitter discharge of 4.0 l/h. The distance between the adjacent laterals was 90 cm. The plot area was 13.5 m^2. Figure 1 shows the experimental design layout. Hot pepper crop seedlings (*Capsicum frutescens* L.) of the variety "Anaheim Chili" was transplanted to the agricultural land thereafter in May 23, 2001.

Urea 46 % N and compound 20-20-20 % NPK fertilizers were used at the rate of 90-kg/ha of Urea and 25-kg/ha of compound fertilizers distributed along the growing season. Fertilizers were applied manually on weekly basis.

Evaporation depth from class-A pan evaporation was recorded daily. The amount of irrigation water before each-irrigation was calculated and applied according to the experiment design. Soil moisture before each irrigation was gravimetrically measured to determine crop EvapoTranspiration. Also, soil moisture was monitored using tensiometer at 15, 30 and 60-cm depths. During the experiment fresh pepper yields were harvested and weighted directly.

Crop EvapoTranspiration under standard conditions (ET_c) is the EvapoTranspiration from disease-free well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions (Allen *et al.*, 1990). ET_c has been calculated as follows:

$$ET_c = I + P - DP - R \pm \Delta\, SM$$

Where ET_c is the actual crop Evapotranspiration (mm), *I* is the irrigation water depth applied (mm), *P* is rainfall depth (mm), *DP* is deep percolation (mm), *Δ SM* is change in soil water contents (mm) and *R* is surface runoff (mm). Soil water depletion (crop Evapotranspiration, ET_c) for the period between irrigation was estimated from soil water content measurements. During short periods when field capacity was reached and/or exceeded due to water applied, drainage water was estimated as suggested by Abu-Awwad (2001):

$d_{ETc} = d2 - d1$

$d2 = d1 + d_w$, where $d2 \leq d_{FC}$

$d_D = 0.0$

If $d2 > d_{FC}$, then $d2 = d_{FC}$ and

$d_D = d_w - (d_{FC} - d1) = d_w - d_{ETc}$

where;

d_{ETc} is measured soil water depletion depth, d1 and d2 are the equivalent depths of moisture in the root zone just before and after irrigation, respectively, d_D is drainage water depth, d_{FC} is the equivalent depth of moisture at field capacity and d_w is water (irrigation plus precipitation) depth applied.

Crop coefficient (K_c) is defined as the ratio between crop Evapo-Transpiration (ET_c) and the reference EvapoTranspiration (ET_o), when both apply to large fields under optimum growing conditions (Vermeiren and Jobling, 1984). Crop coefficient was derived as

$$K_c = ET_c / ET_o$$

Water use efficiency (WUE in kg/ha.mm) is the yield of marketable fruit production per unit of water used to produce yield per unit area. Effects of in-row spacing treatments and irrigation treatments on the yield were statistically analyzed and the means of interactive effect that significantly differs were separated according to LSD test (Steel and Torrie, 1980).

Results and Discussion

The soil consists of 10 % sand, 28 % silt and 62 % clay on the average. Therefore, the textural class of the soil was clay for all depths and characterized with a high water holding capacity. In this experiment, the electrical conductivity of irrigation water used ranged between 0.7 and 1.0 dS/m during the growing season. Soil field capacity and permanent-wilting point were 445 mm/m and 297 mm/m, respectively.

Crop Water Use:

Accurate and reliable information of climatic data are important for the calculation of grass reference Evaptranspiration (ET_o), scheduling irrigation, estimating irrigation water requirements and designing irrigation systems, especially in dry areas where water resources are limited. The ET_o values were computed for each month using Penman-Monteith method. The month of July represents the peak ET_o values and the month of November represents the lowest values of ET_o (Table 1).

Actual crop evapotranspiration (ET_c) for each treatment was calculated from the soil water content measurements for the period between irrigations (Table 2). The ET_c increases as the amount of water applied increases indicating that plants did not obtain their sufficiency of water in W1 as compared to W2 and so on. It is clearly that as water stress increases the plant close their stomata to prevent more water lose and reduce ET_c. The ET_c values also increase as the spacing is reduced (higher plant population) due to the competition for water among the adjacent plants and higher shading rate that decrease water loss as evaporation and giving greater chance for transpiration, which results in depletion of water from the root zone. This depletion is for S1 > S2 > S3 indicating higher plant population consumes more water compared to lower population. Therefore, actual consumptive use (Figure 2) was greater for S1 > S2 > S3 and for W5 > W4 > W3 > W2 > W1.

The ET_c for the treatment that gives maximum yield for each plant spacing has been used for the calculation of crop coefficient (K_c) using Penman Motieth grass reference EvapoTranspiration (ET_o). Seasonal actual consumptive use varies from 397, 376 and 370 mm at W1 to 1153, 1116 and 1095 mm at W5 irrigation treatments, for S1, S2 and S3 treatments, respectively. In general, increasing applied irrigation water and/or plant population increased actual consumptive use.

Crop coefficients are affected by many factors mainly crop characteristics such as resistance to transpiration (closed stomata, waxy leaves), sunlight reflection, crop planting or sowing date, rate of crop development, crop height, length of the growing season and climatic conditions. The recommended K_c values for pepper crop during mid season ranges between 1.05 and 1.15 (Allen *et al.,* 1990). In this study, the K_c during mid season varied from 0.92 to 1.09 with an average of 1.05 (S1W4), from 1.15 to 1.18 with an average of 1.165 (S2W5), and from 1.08 to 1.21 with an average of 1.145 (S3W5), for the months of August and September, respectively. The K_c values were around 0.48 and 0.57 during the seedling stage and reached the peak during August and September then declined again at the late stage (0.32 to 0.57). The K_c values greater than 1.0 indicate that the ET_c is greater than the grass reference EvapoTranspiration (ET_o).

Pepper Yield and Water Use Efficiency:

The total amount of irrigation water applied for each treatment is presented in Table (3). Even though the amount of irrigation water applied for any water level treatment should be the same and represents a fixed ratio of evaporation depth from Calss A pan, variation in the total amounts of irrigation water applied could be attributed to variation in irrigation frequency. Irrigation was practiced according to the tensiometer reading for the same in-row plant spacing.

Within each irrigation treatment from W1 to W5, it can be seen that plant spacing S2 received less irrigation water than S3 and S1, this is because irrigation frequency among the three in-row plant spacing was different. As irrigation frequency increases for large in-row plant spacing (low plant density) the soil-water will be more subject to evaporation and deep percolation. Therefore, S2 is considered more efficient than S1 and S3 in using soil water for transpiration.

Analysis of variance was performed to determine the differences in hot pepper yield among the five irrigation treatments for the three in-row plant spacing. Results showed that there are significant effects of irrigation treatments and in-row plant spacing on the yield. Pepper yield increases with the increasing amount of irrigation water applied for all spacing treatments form W1 to W5, respectively. Also, yields increase with the increasing plant population (reducing plant spacing) as shown in Table (4).

For the first in-row plant spacing (S1) yield varies from a minimum of 21.4 ton/ha at W1 treatment to a maximum of 40.1 ton/ha at W4 treatment. The increasing amount of irrigation water applied from 306.7 to 714.4 mm doubled hot pepper yields. The highest yield was at W4 treatment, which was significantly higher than W1 and W2 treatments, but not significantly higher than W3 and W5 treatments. Whereas, for the second in-row plant spacing (S2), yield varies from a minimum of 15.2 ton/ha at W1 treatment to a maximum of 31.8 ton/ha at W5 treatment. The increasing amount of irrigation water applied from 290.9 to 828.9 mm doubled hot pepper yields also. The highest yield was at W5 treatment, which is significantly higher than W1 and W2 treatments, but not significantly higher than W3 and W4 treatments. While for the third in-row plant spacing (S3), yield varies from a minimum of 14.2 ton/ha at W1 treatment to a maximum of 20.3 ton/ha at W5 treatment. Increasing amount of irrigation water applied from 295.8 mm to 842.3 mm increased hot pepper yield but not significantly, because the reduction of the number of plants per unit area increased the amount of water lost by evaporation, deep percolation and at the same time reduced contribution by plants for transpiration which in turn increased yield in decreasing increments as compared to the increments of irrigation water applied.

Water Use Efficiency (WUE) is significantly affected by irrigation quantities and plant spacing (Table 5). The increasing amount of irrigation water applied for 30 cm in-row plant spacing from W1 to W2, W3 and W4 or from W2 to W3, W4 and W5 reduced WUE but not significantly. While increasing the amount of irrigation water applied from W1 to W5 significantly reduced WUE because the increase in irrigation water applied was greater as compared to the yield increase. For 60 cm in-row plant spacing, WUE did not reduce significantly from W1 to W5 indicating that the increase in the hot pepper yield and amount of irrigation water applied is proportional (both yield and water applied increases at a fixed ratio). While for 90 cm in-row plant spacing, WUE did not significantly reduced as irrigation water applied increased from W1 to W2 and W3 or from W2 to W3, W4 and W5. Whereas it is significantly reduced as irrigation water applied increased from W1 to W4 and W5. In general, WUE is reduced as irrigation water applied increases because yield is increasing at decreasing increments as compared to the amount of irrigation water applied.

Also, increasing plant spacing from S1 to S3 significantly reduced WUE as indicated in the following regression equations.

For S1 treatment:

$$WUE = - 0.0367\ W + 78.5416; \qquad R^2 = 0.76$$

For S2 treatment:

$$WUE = - 0.0273\ W + 62.8102; \qquad R^2 = 0.83$$

For S3 treatment:

$$WUE = - 0.0450\ W + 59.5383; \qquad R^2 = 0.95$$

Where W represents total amount of water applied in (mm).

From the WUE regression equations, the intercept for S1, S2 and S3 equals to 78.5, 62.8 and 59.5, respectively.

Therefore, WUE for S1 is greater as compared to S2 and S3, because more number of plants will get benefit from the same unit of irrigation water and produce more yields as the spacing is reduced.

With respect to WUE and yield together (Table 4 and 5), it is recommended to use for S1 in-row plant spacing treatment the level of W3 of irrigation treatments, because yield is not significantly different from maximum yield of W4 treatment, WUE is not significantly different from maximum WUE of W1 treatment and at the same time it is more efficient than W4 and W5 treatments. While for S2 in-row plant spacing treatment, it is recommended to use W3 of irrigation treatments, because the yield is not significantly different from maximum yield of W5 treatment, WUE is not significantly different from maximum WUE of W2 and at the same time it is more efficient than W4 and W5 treatments. Whereas for S3 in-row plant spacing treatment, it is recommended to use W1 of irrigation treatments, because WUE is maximum and at the same time the yield is not significantly different from the maximum yield of W5 treatment. In general, among all spacing and irrigation treatments it is recommended to use S1W3 for higher yield and WUE and wise water application as compared to S2W3 and S3W1 treatments.

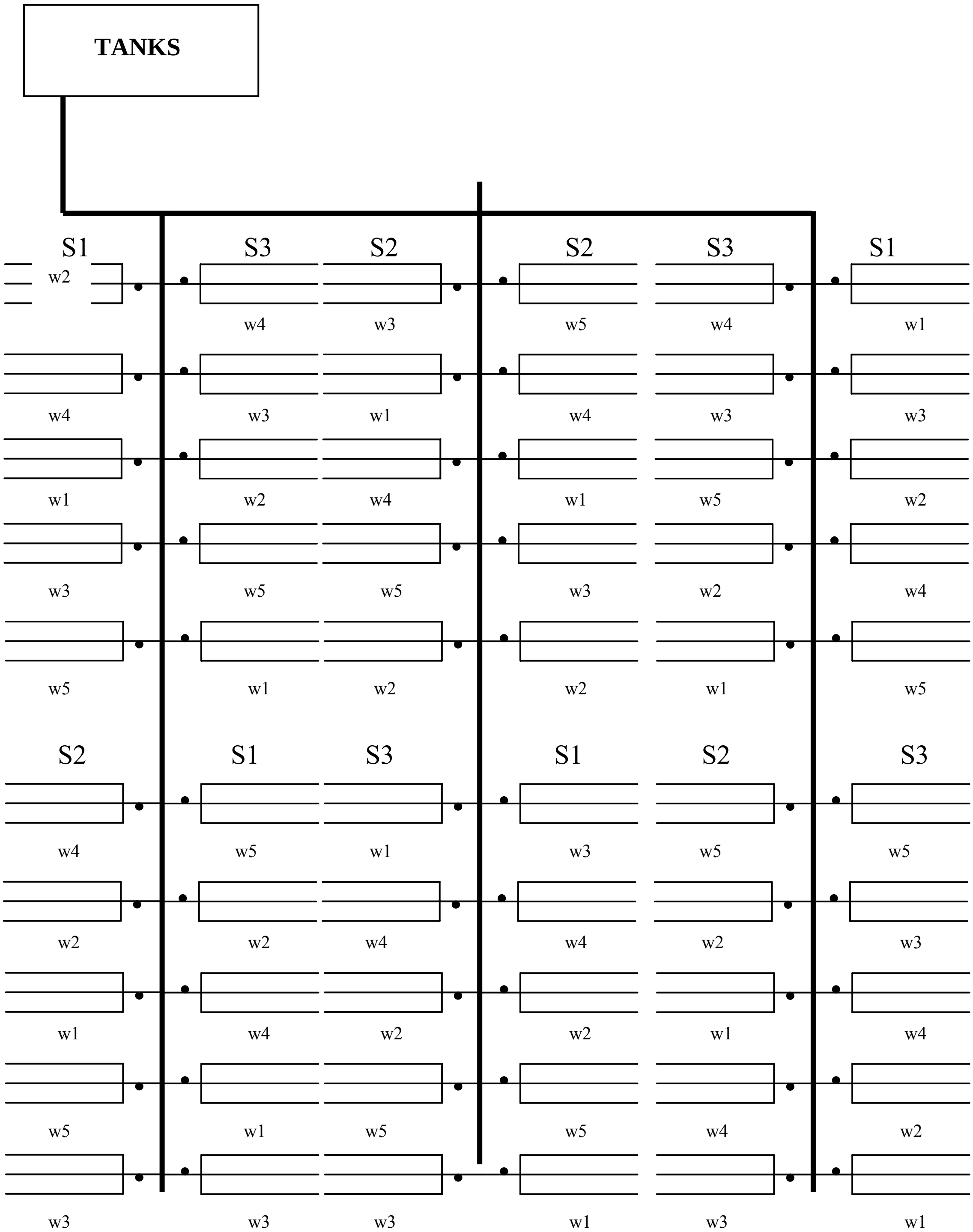
Yields usually respond to a certain crop-water production function. Yields of the three plant spacing S1, S2 and S3 were found to respond to the following regression equations:

For S1 treatment: $Y = 0.0471\ (W)$; $R^2 = 0.93$
For S2 treatment: $Y = 0.0361\ (W)$; $R^2 = 0.94$
For S3 treatment: $Y = 0.0224\ (W)$; $R^2 = 0.82$

Where Y and W represent yield (ton/ha) and total amount of water applied (mm), respectively.

The increasing in-row plant spacing from S1 to S2 and S3 reduces the slope of the production function from 0.0471 to 0.0361 and 0.0224, respectively. Therefore, reducing the increase in crop yield per unit increase of applied water due to the reduction of the number of plants per unit area. Thus, increases water loss by evaporation and/or deep percolation and reduces the beneficial use of water in transpiration and consequently reduces crop yield. The coefficient of determination (R^2) for S1, S2 and S3 were 0.93, 0.94 and 0.82, respectively. These high values of R^2 indicate that the yield for each in-row plant spacing in response to quantity of irrigation water can be predicted fairly well according to the previous equations. Also, reduction in the regression correlation in S3 treatment indicates that increasing plant spacing weaken the relation between yield and applied water.

During the growing season, it was observed that for the 30-cm plant spacing, adjacent plant leaves shade each other along the rows only, but not between the rows. Whereas the 60 and 90-cm plant spacing the plants did not shade each other either along or between the rows, and the yield was lower as compared to the 30-cm plant spacing treatments.



$S_{1,2,3}$: In-row spacing: 30, 60 and 90 cm (Main Plots).

$W_{1,2,3,4,5}$: Irrigation treatments $\frac{2}{6}$, $\frac{3}{6}$, $\frac{4}{6}$, $\frac{5}{6}$ and $\frac{6}{6}$ of evaporation depth from Class-A pan evaporation in (mm) (Sub-Plots).

Figure 1: Experiment Layout.

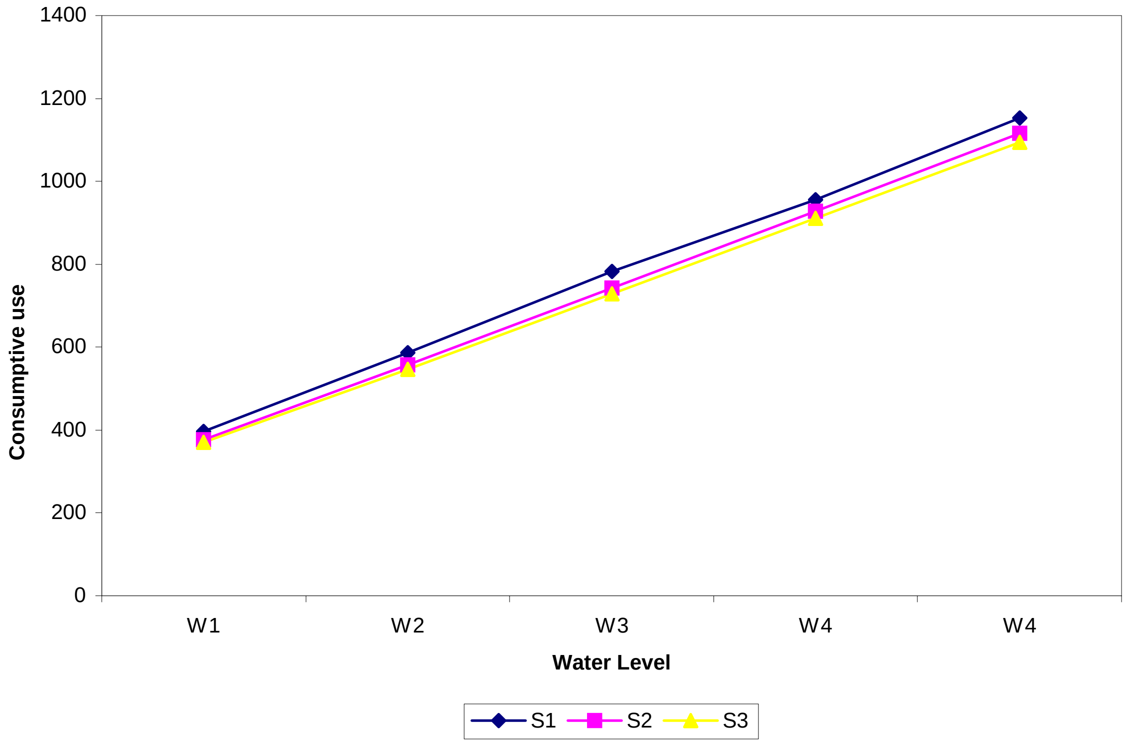


Figure 2: Seasonal actual consumptive use as influenced by the different water levels and in-row plant spacing.

Table 1: Reference (ET_0) and actual (ETc) evapotranspiration and crop coefficient (Kc) for maximum yield treatments.

Month	ET_o	ET_c			K_c		
		S1W4	S2W5	S3W5	S1W4	S2W5	S2W5
Jun.	8.48	4.09	4.84	4.84	0.48	0.57	0.57
Jul.	8.29	5.93	7.08	7.25	0.71	0.85	0.87
Aug.	7.93	7.31	9.12	8.59	0.92	1.15	1.08
Sep.	6.84	7.47	8.10	8.29	1.09	1.18	1.21
Oct.	7.15	5.10	6.79	6.67	0.71	0.95	0.93
Nov.	5.46	2.68	3.13	1.76	0.49	0.57	0.32

Table 2: Mean daily actual crop evapotranspiration (mm/day) as influenced by water levels and in-row plant spacing.

S1					
Month	**W1**	**W2**	**W3**	**W4**	**W5**
Jun.	2.12	2.90	3.86	4.09	4.98
Jul.	2.37	3.56	4.75	5.93	7.18
Aug.	2.92	4.39	5.86	7.31	8.84
Sep.	2.99	4.48	6.00	7.47	8.97
Oct.	2.06	3.06	4.08	5.10	6.13
Nov.	1.07	1.61	2.14	2.68	3.21

S2					
Month	**W1**	**W2**	**W3**	**W4**	**W5**
Jun.	1.77	2.38	3.17	3.97	4.84
Jul.	2.36	3.54	4.72	5.90	7.08
Aug.	3.04	4.57	6.08	7.60	9.12
Sep.	2.70	4.05	5.40	6.75	8.10
Oct.	2.25	3.37	4.49	5.62	6.79
Nov.	1.03	1.54	2.05	2.53	3.13
S3					
Month	**W1**	**W2**	**W3**	**W4**	**W5**
Jun.	1.77	2.38	3.17	3.97	4.84
Jul.	2.42	3.63	4.83	6.04	7.25
Aug.	2.87	4.32	2.73	7.17	8.59
Sep.	2.76	4.14	5.54	6.91	8.29
Oct.	2.22	3.34	4.45	5.56	6.67
Nov.	0.59	0.88	1.17	1.46	1.76

Table 3: Total amount of irrigation water (mm) applied for each treatment.

Treatment	W1	W2	W3	W4	W5
S1	306.7	444.9	588.2	714.4	858.3
S2	290.9	422.0	556.5	691.3	828.9
S3	295.8	429.4	566.6	703.5	842.3

Table 4: Mean pepper yield as influenced by water levels and in-row plant spacing.

Yield (Ton/ha)					
Treatment	**W1**	**W2**	**W3**	**W4**	**W5**
S1	21.4 b	24.7 b	35.3 a	40.1 a	38.1 a
S2	15.2 c	22.2 b	24.4 ab	25.1 ab	31.8 a
S3	14.2 a	17.1 a	17.8 a	18.5 a	20.3 a

* Values with the same letter in the same row are not significantly different at 5% probability level using LSD test.

Table 5: Water use efficiency (WUE) for the three plant spacing treatments.

Treatment Water Levels	S1	S2	S3
W1	69.8 a	52.1 a	48.2 a
W2	55.6 ab	52.7 a	39.9 ab
W3	60.0 ab	43.8 a	31.5 ab
W4	56.1 ab	36.3 a	26.3 b
W5	44.4 b	38.4 a	24.2 b

* Values with the same letter in the same column are not significantly different at 5% probability level using LSD test.

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تأثير مستويات مختلفة من مياه الري ومسافات الزراعة على إنتاجية الفلفل الحار والاستخدام الأمثل لمياه الري

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ملخـص

أجريت تجربة بحثية على محصول الفلفل الحار (*Capsicum frutescens* L.) من صنف (Anaheim Chili) خلال الموسم الزراعي 2001 في مزرعة كلية الزراعة التابعة للجامعة الأردنية في عمان، وذلك لدراسة تأثير كميات الري المضافة ومسافات الزراعة بين النباتات على الإنتاج وتحديد معدل استهلاك المحصول (ET_c) .

اشتملت الدراسة على خمسة مستويات من الري وهي: إضافة 2/6 و3/6 و4/6 و5/6 و 6/6مما يتبخر من حوض البخر (Class A)، وثلاث معاملات تمثل مسافات الزراعة بين النباتات وهي 30 و60 و90 سم. استخدم تصميم القطاعات العشوائية المنشقة المكونة من أربعة مكررات، حيث وزعت معاملات المسافات على القطع الرئيسية ومعاملات الري على القطع تحت الرئيسية. تم تعديل إضافة كميات مياه الري طبقا لمراحل نمو النبات بإضافة ثلث الكمية المقررة في المرحلة الأولى من عمر النبات، وثلثي الكمية في المرحلة الثانية، والكمية كاملة في المرحلة الأخيرة. أضيفت كميات مياه الري باستخدام نظام الري بالتنقيط على تربة طينية. وكانت المساحة لكل معاملة 13.5 م^2 وتحتوي على ثلاثة خطوط ري فرعية، وبين كل خط وآخر 0.9 م وطول الخط 5 م. وكانت النتائج كالتالي:

زيادة كمية المياه المستهلكة بواسطة النباتات بزيادة كمية المياه المضافة و/أو زيادة عدد النباتات في وحدة المساحة، حيث تراوح الاستهلاك المائي الموسمي بين 397 و376 و370مم عند المعاملة 2/6 من التبخر وبين 1153 و1116 و1095مم للمعاملة 6/6 من التبخر لمسافات الزراعة 30 و60 و90سم بين النباتات في الخط الواحد على التوالي.

كما ان زيادة كمية المياه المضافة أدت إلى زيادة إنتاجية الفلفل لكل مسافات الزراعة، كما ازدادت الإنتاجية بزيادة عدد النباتات في وحدة المساحة. لمسافة الزراعة 30سم من النباتات في الخط تراوح الإنتاج بين 21.4 طن/هكتار للمعاملة 2/6 من التبخر و40.1 طن/هكتار للمعاملة 5/6 من التبخر، حيث بلغ الإنتاج حده الأقصى عند إضافة 5/6 من التبخر وكانت الزيادة معنوية عند مقارنتها بالإنتاج للمعاملتين 2/6 و3/6 من التبخر، ولم يكن هناك اختلاف معنوي في الإنتاج عند مقارنته بالإنتاج للمعاملتين 5/6 و6/6 للتبخر. ولمسافة الزراعة 60سم بين النباتات تراوح الإنتاج بين 15.1 طن/ هكتار عند إضافة 2/6 من التبخر و31.8 طن/ هكتار للمعاملة 6/6 من التبخر. وكانت الزيادة في الإنتاج معنوية عند مقارنة الإنتاج للمعاملة 6/6 من التبخر والإنتاج للمعاملتين 2/6 و3/6 من التبخر، ولم تكن معنوية عند مقارنتها بالإنتاج للمعاملتين 4/6 و5/6 من التبخر. ولم تكن هناك فروقات جوهرية في الإنتاج لكل معاملات الري (2/6، 3/6، 4/6، 5/6، 6/6 من التبخر) عند مسافة الزراعة 90سم بين النباتات في الخط، حيث تراوح الإنتاج بين 14.2 طن/هكتار للمعاملة 2/6 من التبخر و20.3 طن/هكتار للمعاملة 6/6 من التبخر. ان زيادة المسافة بين النباتات تزيد من فقد المياه بواسطة التبخر والتسرب العميق التي لا يستفيد منها النبات. وقد بينت النتائج أيضا أن كفاءة استهلاك مياه الري تقل بزيادة كمية مياه الري المضافة حيث ان الإنتاجية ازدادت زيادة متناقصة لوحدة المياه المضافة، كما ان زيادة المسافة بين النباتات في الخط أدت إلى تناقص في كفاءة الاستهلاك المائي. وبشكل عام فانه ينصح باستخدام مسافات زراعة مقدارها 30سم بين النباتات في الخط وإضافة مياه الري بمعدل 4/6 من عمق التبخر من حوض التبخر للحصول على إنتاج عالٍ للفلفل وكفاءة استهلاك مائي عالية أيضا.

الكلمات الدالة: الفلفل الحار، الري، مسافات الزراعة، الاستهلاك المائي والبخر- نتح.

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