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Effect of Irrigation Levels and Organic Matter on Water use Efficiency of Chilli Pepper

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Abstract: **-Chilli pepper recognized as small root system plant and available water in the rhizospher is a determental factor for growth and yield. Increasing water use efficiency (WUE) and available water in the root zone is the aim of this work. Eight organic matter treatments of four sources each of two levels in addition to recommended chemical fertilizer and control non-fertilizer treatments implemented. Depletion of water in the root zone at levels of 40%, 60%, and 80% are used. Treatments arranged in a split-plot design with three replicates where levels of depletion of available water are in main plots and fertilizers treatments sub plots under drip irrigation system.**

Number of irrigation events varied from 163, 98, and 69 times for the three levels of depleted available water respectively during the growing season (March to November). Fruit yield reduced as the depleted available water increased where fruit yield 30.35, 20.41, and 10.45 ton.ha^{-1} for the three levels of depleted available water respectively. Application of different organic matter sources (5 and 10% of chicken, 7.5 and 15% of spent mushroom compost, 10 and 20% of cow or sheep manure) improved fruit yield. The highest fruit yield produced when 20% of cow manure under 40% of depleted available water (39.45 ton. ha^{-1}) was applied compared to chemical fertilizer (37.45 ton.ha^{-1}) and control treatment (9.93 ton.ha^{-1}) under similar available water level. Evapotranspiration decreased as the percent of depletion of available water increased (1152.9, 1027.9 and 945.9 mm for the three levels respectively). WUE decreased as the percent of depletion of available water; however, application of organic matter at highest levels increased WUE as compared to chemical fertilizer in particular under water stress levels (60% and 80% depletion of available water). Conclusion could be made that exposing chilli pepper to water stress will reduce WUE and fruit yield, however application of organic matter regardless of the source will improve WUE and yield.

Keywords: irrigation, organic matter, WUE, chilli

I. INTRODUCTION

Hot pepper is an important horticultural crop, not only because of its economic importance, but also due to nutritional and medicinal value of its fruit. These are the excellent source of natural colors and antioxidants [1]. Total world production of hot pepper has been estimated to be 14– 15 million ton annually. Hot pepper cultivation is confined to warm and semi-arid countries where water is often a limiting factor for production. This necessitates optimization of water management.

Farmyard manures are responsible to nutrient availability for crop to demand, improve soil physical properties (aggregation) and hence improve water retention capacity, infiltration rate and biological activity of soil [2]. The advantage of farmyard manure application, however, greatly depends, among others, on proper application methods, which increase the value, reduce cost, and effectiveness [3].

Water application must be carefully studied, mainly when applied on plants under protected environment. [4] Determined the total water requirement of pepper crop and the optimum irrigation programmers. The average seasonal supplementary water requirement was 6375 m^3 ha^{-1} and the most suitable irrigation programmed approximately 25 applications at four to six days intervals for Capsicum (*Capsicum annuum* L.) or bell pepper is an important in cool season. [5] Reported that the total water requirement of pepper was 600 to 900 mm and even up to 1200 mm for long growing period cultivars. The water deficit during the period between flowering and fruit development reduced final fruit production. [6] reported that continuous water stress significantly reduced total fresh weight of fruit, and the highest marketable yield was found at irrigation of 120% and the lowest at 40% evapotranspiration (ET). This indicates that total pepper yield was less at lower levels of irrigation [7].

In recent years, there is declining trend in annual rainfall. Limited sources of irrigation water from wells and tanks can be advantageously used through drip irrigation to enhance water use efficiency in broadly spaced crops like chilli. In arid or semi-arid areas, crop growth is mainly dependent on irrigation. Irrigation methods and management are of importance to soil water status, and thus, to plant water status. Inappropriate irrigation could result in water stress. Drip irrigation provides more efficient water use for crops than furrow irrigation because drip irrigation applies frequent small amounts of water to the root zone and reduces adverse effects of cyclic over irrigated and water stress commonly caused by furrow irrigation. Limited supply of water necessitates a shift in the production objectives from attainment of potential yield per unit of land to potential yield per unit of water. Among different methods of irrigation, drip method results in a maximum water and nutrient use efficiency.

Particularly, the effective use of irrigation water has become a key component in the production of field crops and high-quality fruit crops in arid and semi-arid areas. Increasing water use efficiency (WUE) is one of the main strategic goals for worldwide researchers as well as decision makers due to water scarcity and continuing high demand of water for agricultural irrigation. With the low efficiency of irrigation water utilization, about another more 50% percent of water is required; indeed which part could be meet by increasing the effectiveness of irrigation.

The objective of present work is to examine the effects of depleted irrigation water levels and organic fertilization on hot pepper yield, and to investigate actual evapotranspiration (ETa) and WUE of hot pepper crop that gives maximum yield per unit volume of water per unit area.

II. MATERIAL AND METHODS

Field experiments on hot pepper were carried out in 2013 during the growing season (March to November) in Baghdad, Iraq (33°22'N, 44°24'E; altitude, 34.1 m), and a semi-arid climatic region. An average of total annual precipitation is 117.9 mm. Some soil characteristics (Table 1) were determined as follows: soil particles distribution by pipette method, soil bulk density was determined by the core method. Soil reaction (pH) and electrical conductivity (EC) were determined at the same soil water suspension 1:1 (W:V) by pH-meter and electrical conductivity-bridge, respectively. Organic matter determined by method of Walkly and Black, these methods as described by [8] and [9].

Selected, hot pepper (*Capsicum frutescens* L.) transplants were pricked out manually, on March 27, 2013, and fruits harvested from May 25, to November 19, 2013. The experiment was arranged in a split-plot design, with three irrigation depletion of available water as main plots and ten organic and chemical fertilizers including non-fertilized plants as control in subplots. Experimental plots measured 4.8 m^2 (3.2 m × 1.5 m) and plants spaced 0.75 m × 0.40 m. Plots were separated 2 m from each other. The treatments were:

1. Irrigation treatment as follows:
   a. Irrigation at 40% depletion of available water (W1).
   b. Irrigation at 60% depletion of available water (W2).
   c. Irrigation at 80% depletion of available water (W3).

2. Organic and chemical fertilizers treatment as follows:
   a. Control treatment (without chemical or organic fertilizers applied) (T_0).
   b. Chemical fertilizer treatment as recommended for pepper (120 kg urea, 340 kg super phosphate and 240 kg K_2SO_4.ha^{-1} after two weeks from planting, and 140 kg urea. ha^{-1} at flowering stage. (T_1).
   c. 5% v/v chicken manure treatment (T_2).
   d. 10% v/v chicken manure treatment (T_3).
   e. 7.5% v/v Spent Mushroom Compost treatment (T_4).
   f. 15% v/v Spent Mushroom Compost treatment (T_5).
   g. 10% v/v cow manure treatment (T_6).
   h. 20% v/v cow manure treatment (T_7).
   i. 10% v/v sheep manure treatment (T_8).
   j. 20% v/v sheep manure treatment (T_9). Table 2 show characteristic of organic fertilizers.

TABLE 1: Physic-chemical properties of the soil

Soil depth (cm)	BD	F.C	W.P	AW	Particle size distribution (gm/kg)				EC	pH	OM
	g. cm^{-3}	*cm^3.cm^{-3}*			*clay*	*Silt*	*sand*	*Texture*	*dS.m^{-1}*		*%*
0-30	1.40	0.314	0.172	0.142	350	480	170	SiCL	3.28	7.4	1.21

TABLE 2: Organic fertilizers properties

properties	Unit	Chicken manure	Spent Mushroom Compo	Sheep manure	Cow manure
EC	dS.m^{-1}	2.72	4.42	3.17	3.12
pH		6.5	7.1	6.8	6.7
Total N	g.kg^{-1}	31.0	24.0	24.0	25.0
Total P		17.7	12.6	11.8	12.3
Total K		23.4	11.6	20.7	21.2
Organic carbo		315	332	356	342
C/N ratio		10.16	13.83	14.83	13.68

A drip irrigation system used and one drip lateral served each plant row. In-line emitters with discharge rate of 5.0 $L.h^{-1}$ at 0.40 m spacing on lateral were used. The control unit of the system consisted of a pump, gravel and disk filters, a flow meter, control valves, fertilizer tank, and pressure gauges. Irrigations continued until one week before the final harvest. Irrigation water was supplied from a deep well, and has an electrical conductivity of 2.3 $dS.\ m^{-1}$. It does not contain any boron and residual sodium carbonate. To determine the amount of irrigation water and evapotranspiration (*ET*) was calculated with the Eq. 1, 2, 3, 4 and 5 [10].

$$PW(\%) = (FC - PWP) \times PA + PWP \ldots\ldots (1)$$

$$AW = \frac{SW}{SR} \times 100 \ldots\ldots(2)$$

$$NDI = RZD \times WHC \times \rho_b \times PA \times AW \ldots\ldots (3)$$

$$T = \frac{A_e \times d}{Q} \ldots\ldots\ldots(4)$$

$$A_e = 0.8 \times (Sw)^2 \ldots\ldots (5)$$

Pw= moisture content, *FC*= field capacity, *PWP*= wilting point, *PA*= percentage depletion of available water, *AW*= wetted area, *SW*= wetted diameter = 0.4 m, *SR*= distance between lines irrigation equal 1m, *NDI*= net depth irrigation, *RZD*= depth of root (m), *WHC*= water holding capacity (*FC-PWP*), ρb =bulk density $\mu g.m^{-3}$,*T*= irrigation time, *Ae*= wetted area for one emitter equal 0.128 m^2, *Q*= discharge, *d*= *NDI*.

Irrigation water use efficiency (IWUE) calculated as follows:

$$IWUE = \frac{yield\ \ (kg)}{total\ \ water\ \ applied\ \ (m^3)} \ldots\ldots\ldots (6)$$

$$yield\ \ = \frac{yield\ of\ unitt\ experiment\ (kg) \times hectar\ area\ (10000\ m^2)}{experimental\ unit\ area\ (4.8\ m^2)} \ldots\ldots (7)$$

Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield and water use efficiency. Least significant differences method (L.S.D) was used to differentiate means at the 0.01 level [11].

III. RESULT AND DISCUSSION

Data on the amounts of applied irrigation water and measured actual evapotranspiration for all treatments during the growing period are presented in Table 3. The number of irrigations events varied from 163, 98 and 69 for 40%, 60% and 80% depletion of available water, respectively. The drip-irrigated treatments required recorded 1035, 910 and 828 mm, for 40%, 60% and 80% depletion of available water, respectively. The mean ET_a measured during the season was 1152.9, 1027.9 and 945.9 mm. Early research reports revealed that seasonal hot pepper ET ranged from 600 to 1200 mm for different climatic and environmental conditions [12 and 13]. The yield for 40% was significantly the highest compared with 60% and 80% depletion of available water. The irrigation at 40% gave highest total yield 30.35 tons. ha^{-1} while the 60% and 80% gave 20.41 and 10.45 tons. ha^{-1} with percent increase of 48.7 and 190.4%, respectively. The organic fertilizer treatment 20% cow manure gave highest total yield (27.41 tons. $ha^{-1)}$, and the treatment of spent mushroom compost 15% produced 25.57 tons. ha^{-1} compared to control non-fertilized plants (6.43 tons. $ha^{-1)}$. The high content of N, P and K, and lower C/N ratio of chicken manure (Table 2) may be the cause of high fruit yield.

Data on irrigation water use efficiency (WUE) for all treatments are presented in Fig. 1, 2 and 3. The treatment W1 used the highest amounts of water than W2 and W3 treatments (Table 3). The results of Figures 1, 2, 3 showed irrigation level W1 had highest mean of irrigation water use efficiency IWUE (29.33 $kg.ha^{-1}$ mm^{-1}, while the treatment W2 had 22.43 $kg.h^{-1}$ mm^{-1} and W3 (12.62 $kg.h^{-1}$ $mm^{-1)}$. Due to the low efficiency of water use in the treatments W2 and W3, yield decreased by32.75% and 65.57% compared to the treatment W1. This may be related to the lower vegetative growth and small number of main branches, leaf area and abscission of flowers and small fruits due to water stress conditions.

Addition of organic fertilizers resulted in a significant increase in the irrigation water use efficiency for all treatments (Fig 1, 2, and 3), compared with non added organic matter in particular under stress conditions (60% and 80% depletion of available water). This may due to the fact that organic fertilizers reduce nutrients leaching and increase the efficiency uses [14]. In addition, organic matter application improved soil physical properties which raised the water use efficiency as a result of increased soil moisture content, which led to increase available water and improve its movement and distributed in the rhizospher and increased water use efficiency. Increasing the specific surface area of organic matter increases the ability of these surfaces to keep water thin membrane making it more water holding capacity and thus lower the actual water evapotranspiration and this mechanism may explain the increases in water use efficiency by the crop.

TABLE 3: Amounts of irrigation water, rainfall, actual evapotranspiration and yield

Irrigation treatment	Irrigation Water Applied (mm)	Rainfall (mm)	Drainage depth	Groundwater table	Eta (mm)	Yield (kg.ha^{-1})
W_1T_0	1035	117.9	0	0	1152.9	9930
W_1T_1	1035	117.9	0	0	1152.9	37450
W_1T_2	1035	117.9	0	0	1152.9	27220
W_1T_3	1035	117.9	0	0	1152.9	38350
W_1T_4	1035	117.9	0	0	1152.9	24640
W_1T_5	1035	117.9	0	0	1152.9	36200
W_1T_6	1035	117.9	0	0	1152.9	28090
W_1T_7	1035	117.9	0	0	1152.9	39430
W_1T_8	1035	117.9	0	0	1152.9	25490
W_1T_9	1035	117.9	0	0	1152.9	36720
W_2T_0	910	117.9	0	0	1027.9	5980
W_2T_1	910	117.9	0	0	1027.9	17530
W_2T_2	910	117.9	0	0	1027.9	17720
W_2T_3	910	117.9	0	0	1027.9	27420
W_2T_4	910	117.9	0	0	1027.9	16300
W_2T_5	910	117.9	0	0	1027.9	2810
W_2T_6	910	117.9	0	0	1027.9	18400
W_2T_7	910	117.9	0	0	1027.9	29890
W_2T_8	910	117.9	0	0	1027.9	15560
W_2T_9	910	117.9	0	0	1027.9	27220
W_3T_0	828	117.9	0	0	945.9	3390
W_3T_1	828	117.9	0	0	945.9	10250
W_3T_2	828	117.9	0	0	945.9	10400
W_3T_3	828	117.9	0	0	945.9	11450
W_3T_4	828	117.9	0	0	945.9	10700
W_3T_5	828	117.9	0	0	945.9	12400
W_3T_6	828	117.9	0	0	945.9	10930
W_3T_7	828	117.9	0	0	945.9	12910
W_3T_8	828	117.9	0	0	945.9	10550
W_3T_9	828	117.9	0	0	945.9	11540

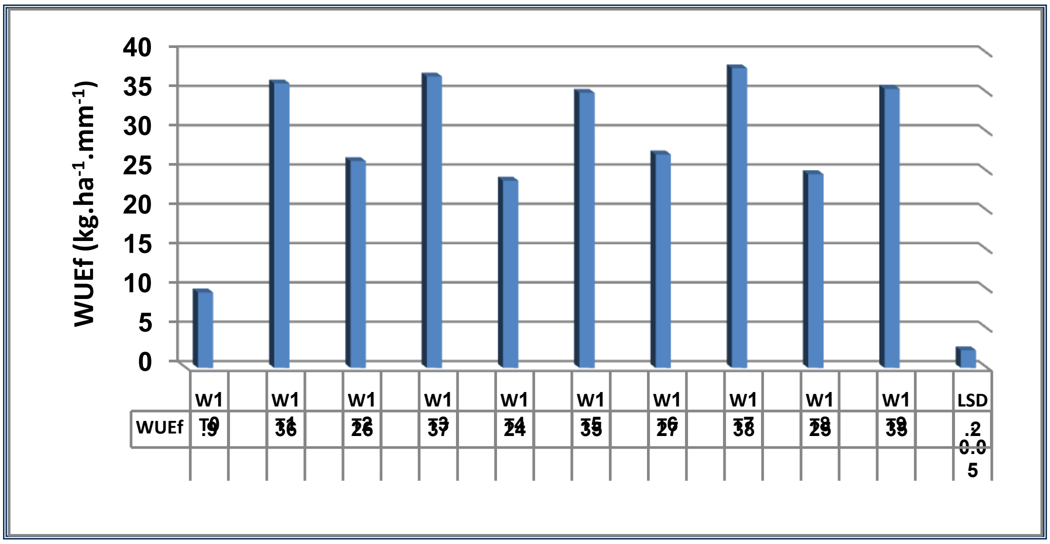

Fig. 1. Water use efficiency of 40% depletion of available water treatment.

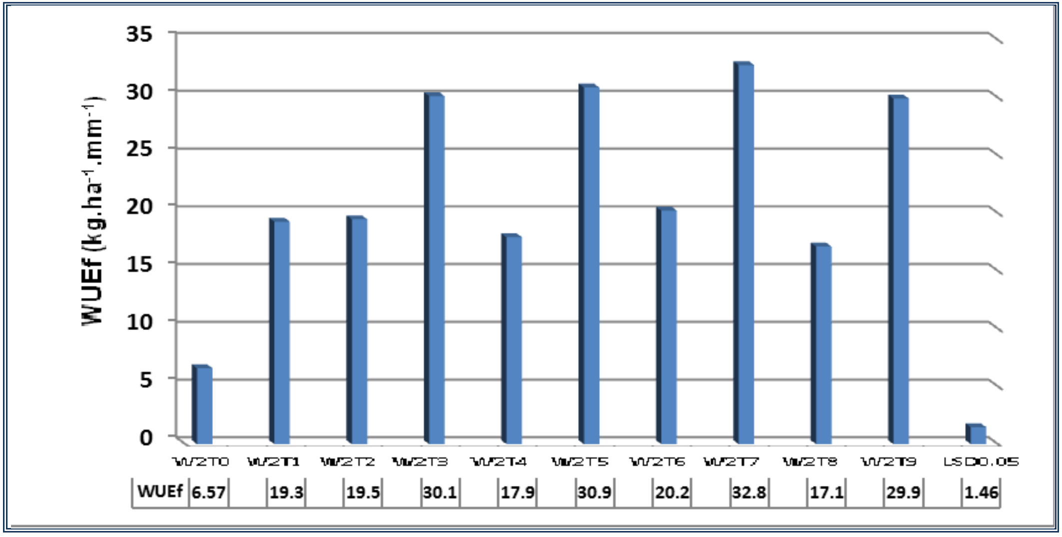

Fig. 2. Water use efficiency of 60% depletion of available water treatment.

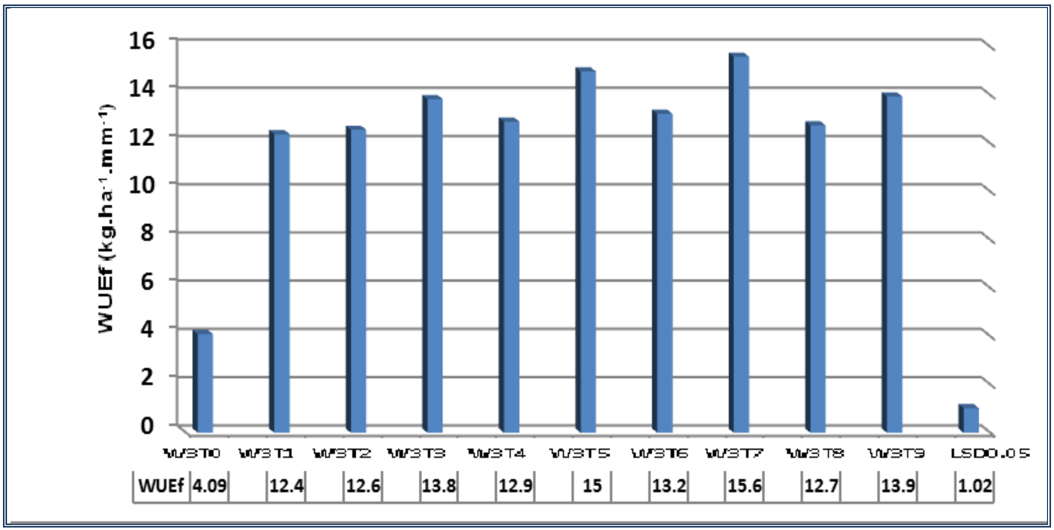

Fig. 3. Water use efficiency of 80% depletion of available water treatment.

IV. CONCLUSION

In general the results show achieved significantly highest water use efficiency for all treatment with organic fertilization between different fertilizer sources and mineral fertilization compared with treatment without adding (control), as well as distinguish method of drip irrigation in the highly efficiency is the result of the coordinated distribution of nutrients with water movement at the root zone, which encouraged pepper chilli crop and give best growth and healthy yield with improved significant in water use efficiency, because not transfer, losses water and leakage below the root zone. Drip irrigation is being extended from wide spaced crops to several row crops also. Applying the correct amount of water is particularly effective for high value crops like chilli.

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