Impact of pulse drip irrigation and lateral spacing on soil moisture and roots distribution of chili pepper crop

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Abstract

This study was applied to examine soil moisture distribution with intermitted applications of drip irrigation (Drip Irrigation Pulses DIP) and lateral spacing, also the impact of water stress on the root distribution of chili pepper was studied. The measurements were taken at various distances from the water source (emitter) in a chili pepper crop planted on sandy soil underlined with chicken manure organic fertilizer. The experimental design was split spilt plots with three replications. The plots were irrigated every 48 hours. The soil water content was measured in three irrigation water regimes (W1,100%, W2,80%; W3,60% of crop evapotranspiration ETc), distances between the laterals (L1, 75 cm and L2, 150 cm), with 75 cm distance between plant rows, and three DIP: (P1, P2; P3) with one continuous drip irrigation pulse, two DIP with 30 minute-off time between irrigation pulses, and three DIP with 15 minute-off time, respectively. Many root samples of the plant base perpendicular to the lateral were weighted for different water regimes and lateral spacings. The results indicated that pulsed irrigation enhanced the distribution of soil moisture over the active root zone and increased the soil water's lateral movement. The highest soil water content value was about 15 cm depth. The root response of chili peppers helps us understand how vegetable plants can adjust their below-ground morphology to support their growth in sandy soil environments. Hence, under moderate water stress treatment (W3L1) there were more tendencies of chili roots to horizontally extent than vertically. Meanwhile, the vertical extension of chili roots was initially begun under extreme water stress treatment (W3L2).

Keywords: drip irrigation pulses, soil water, lateral spacing, root distribution pattern, chili pepper.

1. Introduction

The root system plays an important role in supporting the plant and absorbing the needed soil water and nutrients (Moran et al., 1994; Xu et al., 2017; Li et al., 2021; Wang et al., 2022; Xiong et al., 2023). So, its studying is rising in importance. In the earthen ecosystem, the encompassed soil environment and agricultural management activities impact root system morphological modification (Ren et al., 2011; Li et al., 2021). For example, in maize-tomato intercropping drip-irrigated system with plastic mulch, the soil moisture and Root Length Density RLD in the upper soil layer were raised by increasing the water applied. Meanwhile, the RLD is lower in the deeper layer (30-100 cm) (Li et al., 2017; Zheng et al., 2021). Hence, the horizontal and vertical distribution of roots is the basic indicator of a plant's ability to get water and nutrition. Root extension is related to climate factors, soil depth, and permeability (Zhang et al., 2019). Naturally, sandy soil has poor water distribution properties, it has macro pores that quicker fill with water, and retain less water per unit depth, soil water infiltrates fastly and deeply than silt or clay soil, and it has a lower capillary force furthermore, the relatively more gravity influence; resulting in a greater vertical flow of soil water. The maximum lateral water distribution in sandy soils ranges between 20.30 cm - 30.50 cm from the emitter based on initial moisture content and system operation time (Aziz, 2008). Under different soil types, it is commonly assumed that pulsed irrigation can enlarge the volume of the wetted zone. Pulsing irrigation is the method of irrigating for a little time, then pausing for another little time, and repeating this on-off cycle till the whole irrigation water is applied (Eric, 2004; Ramadan, 2009; Almeida et al., 2018; Lozano et al., 2020). Otherwise, increasing irrigation pulses associated with decreasing the applied water quantity is an urgent requirement for successful irrigation management in sandy soils, since this strategy tends to reduce losses due to deep percolation. In this case, pulse irrigation is suggested (Maller et al., 2019; Cruz et al., 2021; Rank and Vishnu, 2024). High irrigation frequency may create favorable circumstances for soil water movement and root uptake (Segal et al., 2000; Abdelraouf et al., 2019). Water splitting keeps water and soluble nutrients near the crop's active root zone, reducing the possibility of water and nutrients down under the rhizosphere (Zamora et al., 2019). The literature lists several effects of applying pulse irrigation on soil moisture, including an increase in the ratio between the stored volume of water in the root system and the applied amount and a greater volume of soil with moisture content equal to or higher than the field capacity (Maller et al., 2019). Characterization of root development and spreading is crucial for understanding crop response to irrigation and determining appropriate irrigation system management, especially with drip systems, because drip irrigation is generally assumed to restrict the extent of root extension (Khedr et al., 2019). Plants do not absorb water equally along their rooting depth. More water is typically extracted from shallow depths and less from deeper depths. The (4-3-2-1) rule approximates the extraction pattern, which states that 40% of the water comes from the top 25% of the root zone, 30% from the second 25%, and so on (Eisenhauer et al., 2021).

One of the great and most valuable vegetable crops worldwide is chili pepper. As a result, one of the key elements in improving chili pepper production and growth is fertilizer usage. Organic fertilizers can improve soil quality and plant growth. Thus, farmers must switch to more trustworthy organic fertilizers, like chicken manure, to ensure that crops are more productive and efficient, and do not degrade the soil. Additionally, adding organic manure is known to modify soil aggregation and significantly affect soil microbial remains (Mohd Kamaruddin et al., 2021). Chili peppers (*Capsicum annuum* L.) are sensitive to water stress. Chili peppers with only a few deep roots would, therefore, be subjected to far higher levels of water stress than a deep-rooting plant species under water deficit conditions in the top soil layers, but with sufficient water at lower depths (Hulugalle and Willatt, 1986). Since 90 % of pepper root was intensified in the upper 40 cm of soil (Mohammed and Hussen, 2023). Evidence demonstrates wetting patterns under drippers and controlled rhizome styles under partial soil water. However, the primary nutrients are delivered through drip irrigation systems, these restricted root systems may not affect crop growth (Clothier and Green, 1994).

The ideal design and management of irrigation systems at the farm level is considered a critical aspect of water rationalization, agricultural economic progress, and environmental sustainability (Hossam, 2022). Some investigators have determined the ideal drip line spacing for irrigated crops in various regions worldwide; the assessments were based mostly on crop productivity, water use efficiency (WUE), evapotranspiration (ET), and economic benefit. Drip line spacing can vary based on the region and crop (Wang et al., 2014).

In this paper, the present study aims to determine the impact of different drip irrigation pulses and lateral spacings on soil moisture patterns and describe the root distribution behavior of chili pepper plants under water stress conditions in sandy soil.

2. Materials and Methods

2.1. Experimental site

An experiment was implemented at the experimental farm, Agricultural Research Station, Agricultural Research Center at El-Arish City, North Sinai Governorate, Egypt (31° 11′ N, 33° 83′ E, altitude 371.62 m), from 15th April to 17th of August 2021, Summer growing season. Chicken manure was applied before planting at a rate of 48.41 $t.ha^{-1}$ (4.84 $kg.m^{-2}$). Some soil physical and chemical properties, irrigation water, and organic matter at the experimental plot are summarized in Table (1) below.

Table 1. a- Soil mechanical analyses, b- chemical analysis of well water, c- chicken manure (organic fertilizer), of the investigated farm before cultivation.

a- Some physical properties of the studied soil.

Soil depth (cm)	Particle size distribution %			Tex. class	SP %	FC %	WP %	AW %	BD gm/cm^3
	Sand	Silt	Clay						
0-30	98.55	0.97	0.48	Sandy	29	15.3	6.11	9.19	1.30
30-60	98.79	0.68	0.53	Sandy	28	14.8	6.23	8.57	1.35
60-90	98.84	0.61	0.55	Sandy	29	15.1	5.73	9.37	1.38

SP: saturation percent, FC: field capacity, WP: wilting point, AW: available water, BD: bulk density.

b- The chemical analysis of well water (irrigation source); to evaluate water quality for irrigation.

pH	EC $dS.m^{-1}$	SAR	Cations ($meq.l^{-1}$)				Anions ($meq.l^{-1}$)		
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO_3^{-2}+HCO_3^{-}$	SO_4^{-2}	Cl^{-}
7.6	4.22	0.36	10.0	30.0	1.62	0.56	6.0	5.0	31.18

EC: electrical conductivity; $dS.m^{-1}$ (deci Siemens per meter) =1$mS.cm^{-1}$ (milli Siemens per cm).

c- Chemical analysis of chicken manure (organic fertilizer).

Item	Chicken manure
pH	6.90
EC, ($dS.m^{-1}$)	4.00
Organic carbon %	19.7
Organic matter %	33.94

2.2. The experimental treatments

The experimental design was a split split plot with three replications. The factors were: Two lateral spacings, with (75 and 150 cm), for L1 and L2, respectively, with a 75cm distance between plant rows. Where one lateral was used for every singular plant row (L1), and one lateral for every two plant rows (L2). Three irrigation water treatments; W1 represented full irrigation (100 %) of crop evapotranspiration (ETc), and (W2; W3) were deficit irrigation treatments by 80 and 60% of full irrigation, respectively. Three Drip Irrigation Pulses (DIP) treatments were applied: (P1, P2; P3), with one continuous pulse, two DIP with 30-minute intervals, and three DIP with 15-minute intervals, respectively, Fig. 1.

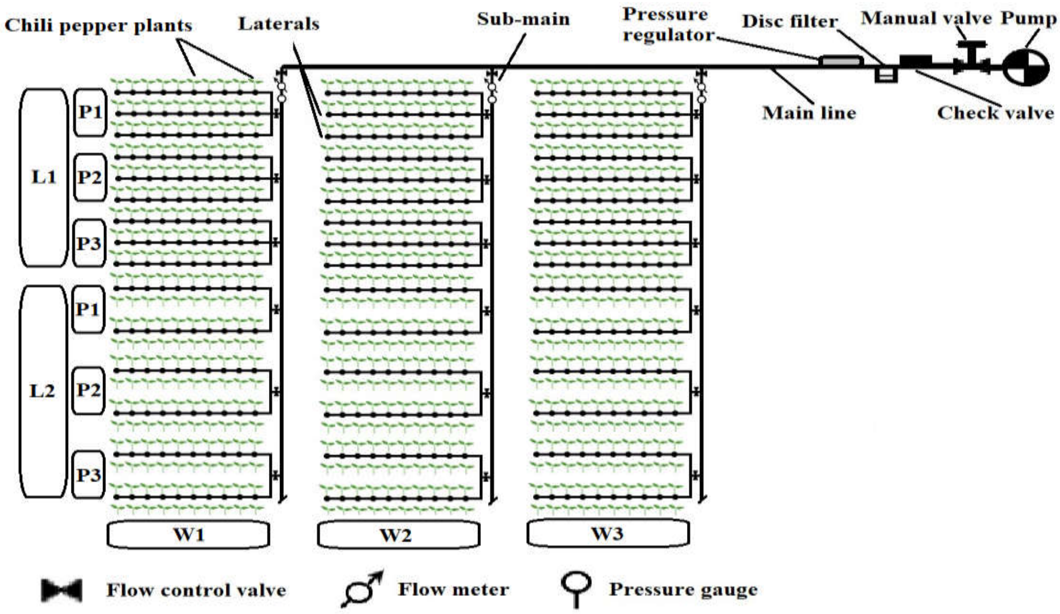

Fig. 1. Schematic diagram of the experimental plot and the distribution of the treatments.

2.3. The description of the drip irrigation network

The drip irrigation network consisted of a pump, disc filter, check valve, pressure regulator, pressure gauges, water meters, ball valves, manifolds, drip lines (laterals), valves, and fittings and accessories. The irrigation water was applied using laterals of 16 mm diameter, polyethylene (PE), the laterals carrying on-line emitters with a water discharge rate of 3.8 ℓ/h with 50 cm emitter spacing.

The seeds of (HUMMER F1) chili pepper reputed variety were planted in the nursery. The chili seedlings were planted in the experimental plots with an age of 47 days, and the average seedling length was (17 - 20 cm) with 6 true leaves. The seedlings of chili pepper were sown manually on 15th April 2021 using a small shovel with 75 cm plant row spacing and 50 cm on-row spacing. There were 18 experimental plots; half of them (9 plots) with traditional drip irrigation L1, 75 cm lateral spacing, and the others with L2, 150 cm lateral spacing, Fig. 1

2.4. Irrigation scheduling

The Penman method was used for estimating the irrigation water requirements for the chili crop. The required climatic data were collected from the Agricultural Meteorological Station data in El-Arish city of the Central Laboratory for Agricultural Climate (CLAC).

2.5. Measurement of soil moisture distribution

The direct measurement of water content was needed in the field to determine the amount of water available for plant growth. The volumetric soil moisture percentage was measured by a soil moisture sensor (Model, HH2- Made in the United Kingdom). The moisture sensor was designed for field use, it was a multilateral readout unit for use with Delta-T soil moisture sensors, which specializes in accurate, reliable soil moisture measurement. The soil moisture distribution readings were taken at several points using the sensor before and after 2 hours of irrigation. Where the measurements were taken from the emitter point horizontally (X) and vertically (Y) with 37.5cm and 45cm, respectively, via digging an accurate rectangular sector with 37.5 * 45 cm^2 area, using a shovel, a trowel and a metal measuring tape. The horizontal soil moisture readings were taken from the emitter point at an increment of 12.5 cm at 0, 12.5, 25, and 37.5 cm in the X-direction. Also, the vertical soil moisture readings were taken from different depths from the soil surface, at 0, 15, 30, and 45cm in the Y-direction by an increment of 15 cm. Also, Surfer Program Release 32 was used to draw 3-dimensional contour lines at 0.02 m intervals for displaying the pattern of soil moisture distribution below the emitters and between laterals at the same time.

2.6. Root measurements

The chili pepper is a plant with a fibrous root system. The sampling points were selected in the same way as those had been selected for soil moisture. After the seasonal end, the root growth pattern was described by extracting a small fixed-size soil sample with a metal sharp-edged cylinder of (4.5 cm internal diameter, 6.29 cm length, and 100 cm^3 total volume) adjacent to the plant rows and carefully extracting roots. The roots were initially separated from the soil by naturally shade-drying and then oven-dried at 70^{o}C. After cooling in the oven, two suitable standard sieves were used for separating the roots. Finally, the roots were carefully picked out and weighted using a sensitive digital scale with four decimal digits (Model, Precisa 205A-Made in Switzerland).

2.7. Statistical analysis

All data were analyzed using SPSS program V. 22. Statistical analysis test was done by ANOVA test, least significant difference (LSD) at the 5% probability level, means were separated using the Tukey test, and Standard Errors (SE) were calculated.

3. Results

3.1. Soil moisture distribution

Soil water distribution in the profile is determined by soil properties, the method of application, and the amount of water applied and withdrawn from the profile. The presented data were measured during the vegetative growing period of the chili pepper crop.

3.2. Influence of lateral spacing on soil moisture distribution

An overview of the effect of line source spacing on soil water distribution patterns is present in Fig. 2, which clearly shows differences in patterns of soil water distributions among the two lateral spacings before and after irrigation. The soil water distribution for treatment L1 (75 cm spacing between drip lines) was slightly uniform for each depth interval, as indicated by contours of equal soil water distribution; because the 75 cm spacing of line sources was close enough to allow lateral flow from each line to partially overlap and form connecting contour lines between sources, see Fig. 2.

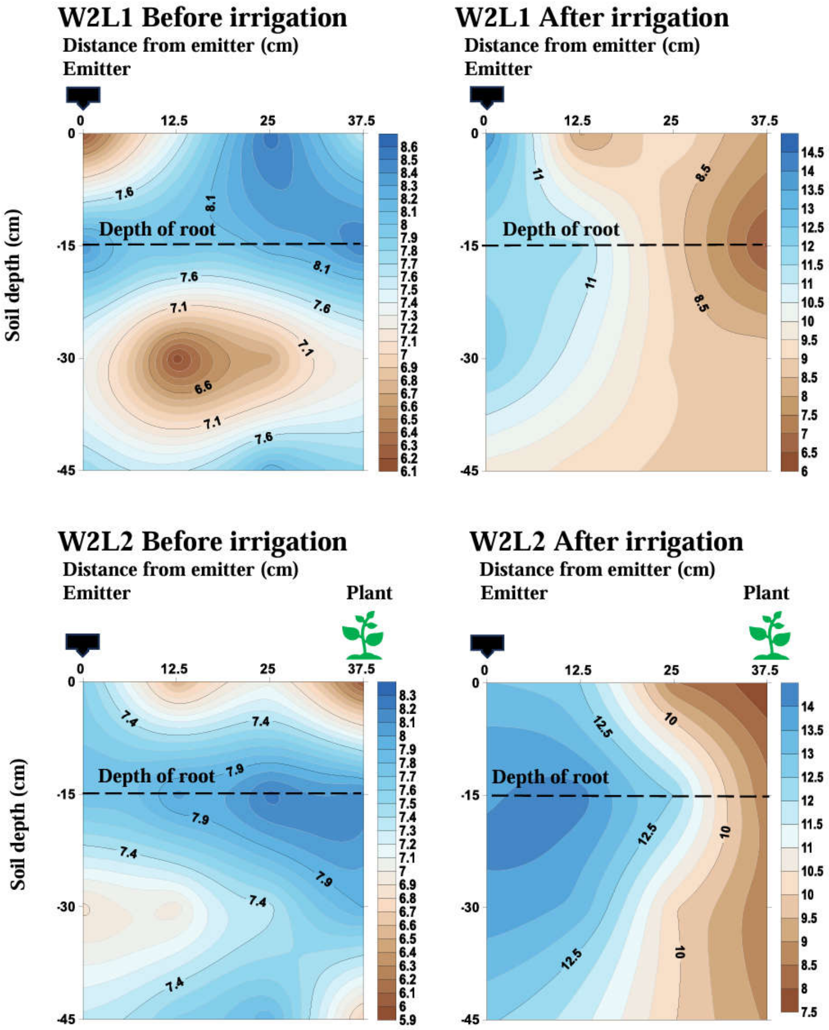

Fig. 2. Soil moisture distributions in the root zone for lateral spacing (L1 and L2) under P1 DIP before and after irrigation.

The patterns of soil water distributions change as the spacing between drip-line sources becomes wider under treatment L2 (150 cm spacing). The two-dimensional distributions of soil water are shown in (Fig. 2). After applying irrigation under continuous DIP (P1) with close laterals treatment (W2L1), where the plant roots concentrate uniformly around the emitter depicts that the increase in horizontal flow from the point source was less effective as compared to the increase in vertical flow. As a result, the somewhat cone-shaped wetting patterns developed below the point sources for 15-40 cm soil depth. While the plant was located at 37.5cm distance from the emitter for L2 treatment (W2L2); so, the soil moisture distribution after irrigation tends to expand horizontally towards the plant root, Fig. 2.

3.3. Influence of water regimes on soil moisture pattern

The W1L1 treatment had the maximum soil water contents of 8.2 and 12.5%, at 15cm depth before and after irrigation, respectively (Fig. 3).

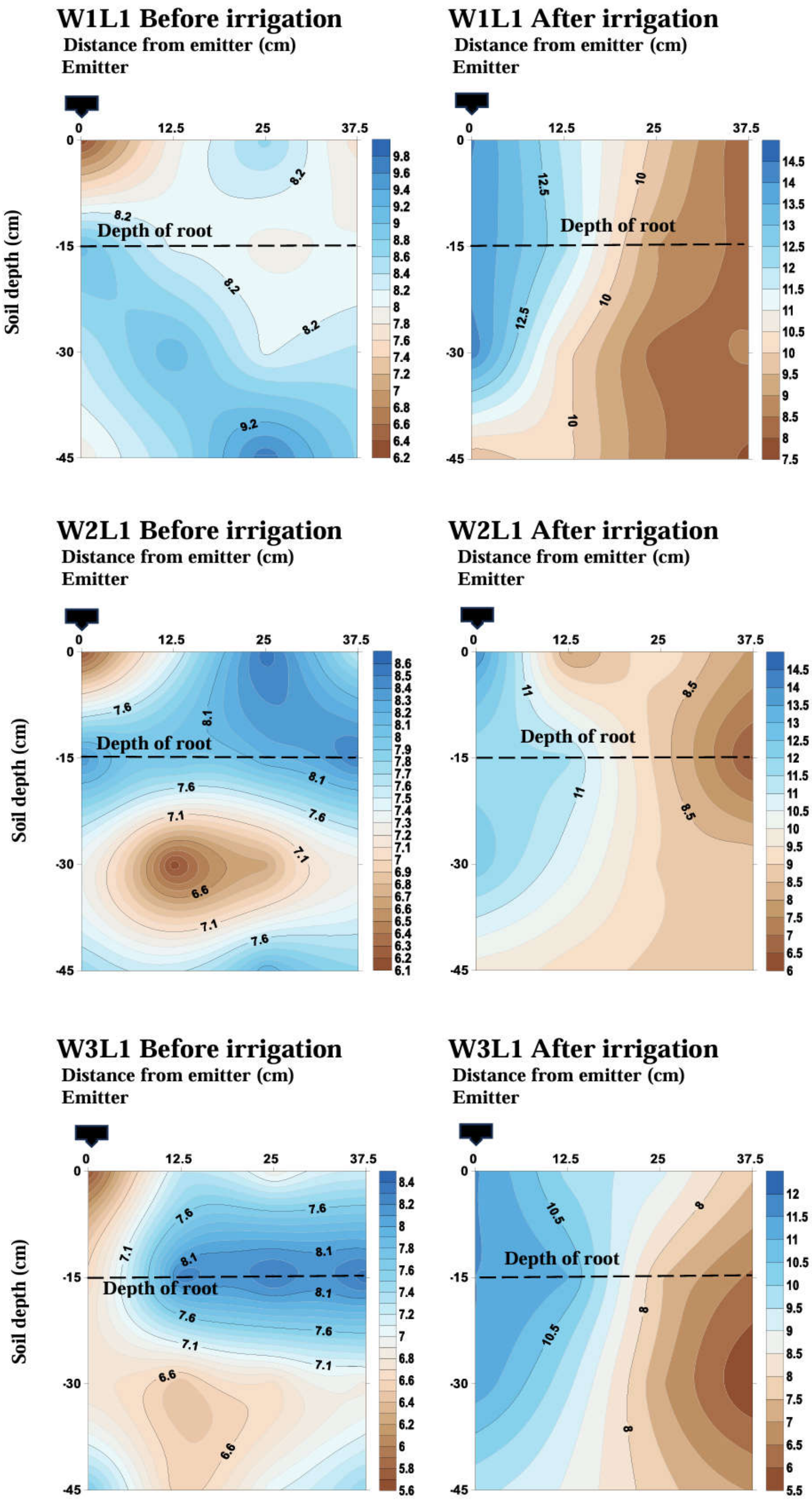

Fig. 3. Soil moisture distributions in the root zone for (W1, W2; W3) irrigation water regimes before and after irrigation for P1 DIP.

3.4. Influence of pulse drip irrigation on soil moisture distribution

The moisture distribution of the wetted soil sector for both continuous (P1) and pulsing irrigation (P2 and P3) are presented in Fig. 4.

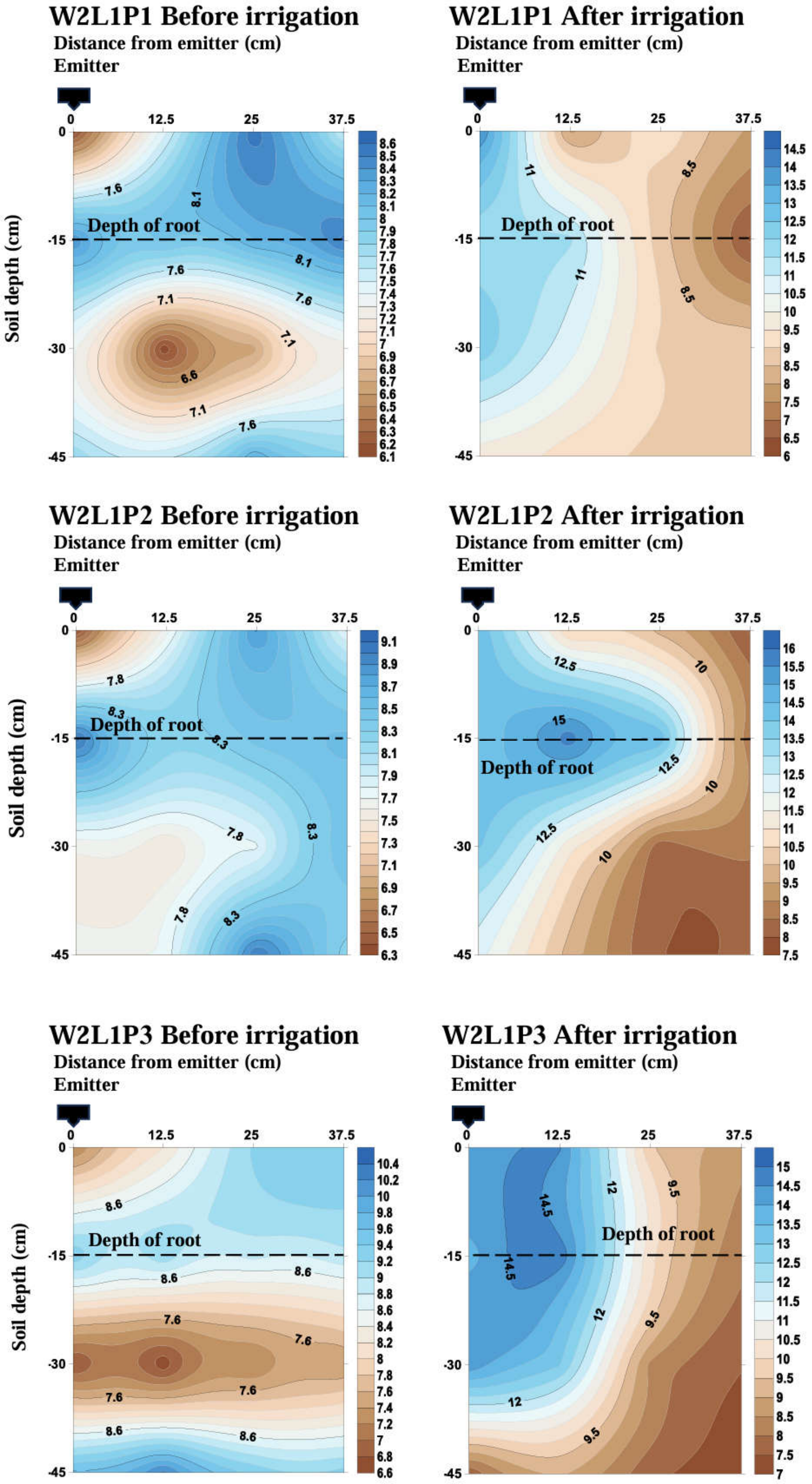

Fig. 4. Soil moisture distributions in the root zone for different DIP before and after irrigation.

The range of soil water distribution before irrigation between the surface and 15 cm depth at the root zone was not markedly different for the treatments. Before irrigation, the pulse drip irrigation treatments (W2L1P2 and W2L1P3) have more maximum volumetric soil moisture contents of (8.3 and 8.6%), respectively, while the continuous treatment (W2L1P1), has the least soil moisture content of 8.1%. It is believed that such a range of soil water distribution provides a suitable moisture environment for the chili pepper plant. The allowable soil water depletion fraction was near the optimal range under all treatments, where it was 0.3 for no stress conditions for bell pepper (FAO-56).

Most contour plots after irrigation show that the highest soil water content after irrigation was near the emitter, it decreased gradually by expanding horizontally and vertically, Fig. 4.

After irrigation, the wetting fronts' horizontal location was shown to be influenced by the irrigation pulsing, as evidenced by careful observation. For the majority of treatments after irrigation, the highest moisture content value was about 15 cm depth (the depth where the root distribution density increased) at any plot. Through horizontal distance, the soil moisture's spread was limited with one continuous irrigation pulse P1in W2L1P1 treatment. Meanwhile, applying (W2L1P2; W2L1P3) treatments achieved more lateral spread of soil moisture compared with (W2L1P1) treatment. The most horizontal spread of soil water (after irrigation) through the active root zone at 15 cm depth was under two DIP treatment (W2L1P2), Fig. 4.

3.5. Roots distribution under water stress

The root distribution pattern varied under irrigation water regimes (W1, W2; W3) and Drip Irrigation Layouts DIL treatments: (L1; L2), Fig. 5.

Where the readings were taken at the last growth period, "ripening and harvesting" by an excavation method. Roots of plants under more water stress conditions (W1L2, W2L2; W3L2) were less dense under the plant base (0-15 cm) than those with (W1L1, W2L1; W3L1) treatments, respectively. Thus, root distributions of chili pepper plants for no or fewer water-stressed rows (W1L1; W2L1) were denser than other more water-stressed rows, especially in the vertical sector (0- 30 cm). The highest root densities appeared at (0-30 cm) depths, and lower densities in deeper sectors because of a plow pan layer, which was evident at 30 cm depth. For irrigation water regimes under L2 (150 cm lateral spacings): (W1L2, W2L2; W3L2) there are root hair extensions toward the emitters, Fig. 5. Meanwhile, the root extension towards the emitters was increased in W3L2 treatment; due to more water stress conditions compared with (W1L2; W2L2) treatments, which made more root elongation and raised its concentration around the emitters (water source). Also, for irrigation water regimes under L2: (W1L2, W2L2; W3L2) treatments, the maximum root concentration was under the plant base for W1L2 and W2L2; this may return to the bigger water bulb under W1and W2 irrigation water regimes, which does not force the roots to elongate strongly towards the emitter, in contrast with the extreme water stress condition (W3L2), Fig. 5. On the other hand, for irrigation water regimes under L1(75 cm lateral spacings): (W1L1, W2L1; W3L1), we found the maximum density of the roots just below both the emitters and plant base, at the same time.

Yet, the root behavior becomes more erratic (possibly due to their haphazard search for moisture) or they may even stop growing altogether, the further they are from the drip line. For water treatments of traditional drip irrigation layout L1: (W1L1, W2L1; W3L1), and W3L2 the root density is highly concentrated around the emitter (where the wet bulb should theoretically be), in contrast with (W1L2 and W2L2) treatments, it showed more roots concentrated around the base of chili pepper plant.

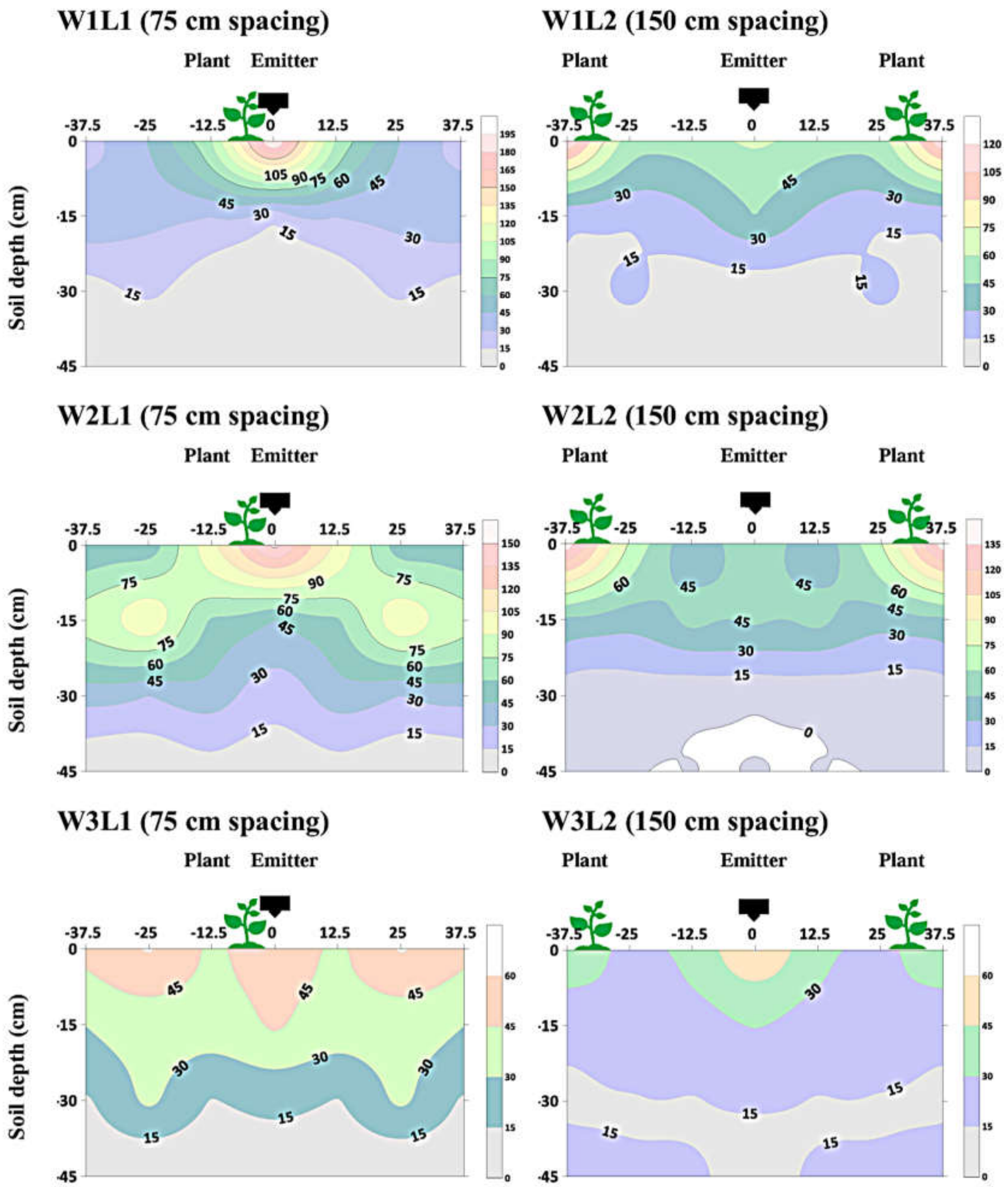

Fig. 5. The effect of two different lateral spacings (L1 and L2), and three water regimes (W1, W2; W3) on root distribution weight patterns (mg/100 cm^3), of chili pepper plant under continuous one-pulse drip irrigation (P1).

The statistical analysis of root intensity values (mg/100cm^3) for both horizontal distance (Hd) and vertical distance (Vd) under water stress treatments, including water regimes and lateral spacing, is presented in Table 2. The statistical comparison was applied individually between sectors of every treatment for horizontal and vertical profiles, to obviously show the root behavior under water stress conditions.

The root intensity for vertical distance Vd; there were highly significant differences in intensity distribution for all treatments (LSD = 0.000) except the extreme water stress treatment (W3L2), which showed a minimum significant vertical distribution of chili roots between vertical sectors (0.010*). This indicated a relatively uniform root distribution along soil vertical layer sectors (15-30 cm, and 30-45 cm) and more initial vertical extension of chili roots under the highest water stress treatment, Table 2. The soil under severe dry conditions could encourage the vertical elongation of roots to find essential water and nutrition.

Table 2. Statistical analysis of root intensity values (mg/100cm^3) of chili pepper for both horizontal distance (Hd) and vertical distance (Vd) under experimental treatments.

Treatments	Hd (cm)	Int. (mg/100cm^3) for Hd	Vd (cm)	Int. (mg/100cm^3) for Vd
W1L1	0-12.5	177.93±10.77 a	0-15	241.51±16.30 a
	12.5-25	117.03±4.71 b	15-30	82.05±11.21 b
	25-37.5	88.9±10.80 b	30-45	25.34±5.23 c
	LSD (0.05)	0.001**	LSD (0.05)	0.000
W1L2	0-12.5	118.83±4.07 a	0-15	195.71±14.81 a
	12.5-25	89.07±7.01 b	15-30	74.10±5.86 b
	25-37.5	102.70±7.10 ab	30-45	25.81±3.65 c
	LSD (0.05)	0.041*	LSD (0.05)	0.000
W2L1	0-12.5	214.10±2.31 a	0-15	320.96±3.58 a
	12.5-25	197.17±1.70 b	15-30	207.31±7.77 b
	25-37.5	175.90±3.81 c	30-45	68.98±2.07 c
	LSD (0.05)	0.000	LSD (0.05)	0.000
W2L2	0-12.5	155.70±0.23 a	0-15	238.96±2.45 a
	12.5-25	101.97±1.30 b	15-30	97.72±4.32 b
	25-37.5	96.00±1.39 c	30-45	11.15±3.14 c
	LSD (0.05)	0.000	LSD (0.05)	0.000
W3L1	0-12.5	108.80±4.91 a	0-15	178.51±13.79 a
	12.5-25	113.97±4.13 a	15-30	116.29±4.23 b
	25-37.5	114.80±13.34 a	30-45	45.05±4.44 c
	LSD (0.05)	0.868 (ns)	LSD (0.05)	0.000
W3L2	0-12.5	89.90±8.43 a	0-15	130.70±9.67 a
	12.5-25	85.10±9.87 a	15-30	77.34±8.13 b
	25-37.5	102.47±15.39 a	30-45	61.64±14.18 b
	LSD (0.05)	0.581 (ns)	LSD (0.05)	0.010*

* The statistical analysis with Tukey (for every three distances), the values represent means ± standard error (SE)., ** Fisher's least significant differences LSD at probability levels ≤ 0.05, ns: nonsignificant., For a given variable, means followed by the same letter are not significantly different, and mean values not sharing common letters are significantly different., Hd: horizontal distance; Vd: vertical distance.

Meanwhile, the root intensity for horizontal distance Hd; the non-significant horizontal extension of chili roots initially happened under less water stress treatment (W3L1) compared with vertical root extension.

Hence, under less water stress conditions (W3L1 treatment), there were more tendencies of chili roots to horizontal extension than vertical extension. While chili roots were partially forced to vertical extension only under extreme water stress (W3L2 treatment). That indicated the importance of keeping the soil water as long as possible, especially at the upper horizontal sectors of the soil, which could be achieved by applying the pulse drip irrigation technique as it increased the lateral distribution of soil water, which could retain soil water and nutrients in the active rootzone for a long time, and decrease water loss by deep percolation, especially in sandy soils.

4. Discussion

The soil moisture distribution before irrigation for different DIP (P1, P2; P3) showed that the differences in soil water distribution between pulse (P2; P3) and continuous irrigation (P1) tend to vanish with time by the redistribution of water in the soil in accordance with other researchers (Elmaloglou & Diamantopoulos, 2007; Skaggs et al., 2010; Maller et al., 2019). Also, another study indicated that, after a few days of irrigation, the soil water profile was depleted due to evaporation and continued water uptake by plants. The same trend of water depletion was found for other crops, as water patterns rapidly changed near the surface during the first few days after irrigation (Allam et al., 2011).

Meanwhile, wetting patterns after irrigation typically consist of two zones: (i) a saturated zone near the drippers and (ii) a zone where the water content decreases toward the wetting front (Rafie and El-Boraie, 2017). Pulsed irrigation enhanced the distribution of soil moisture over the active root zone, and it increased the lateral movement of the soil moisture in agreement with (Ramadan, 2009; Allam et al., 2011). Meanwhile, continuous irrigation can maximize the moisture content surrounding the drip emitter point while decreasing the soil water content in the horizontal spreading when compared to pulse irrigation, particularly in profound soil layers (Huang et al., 2018).

The soil moisture under L2 treatment (with 150 cm lateral spacing) was expanded laterally towards the chili roots. Hence, the plant root activity affects the pattern of soil moisture distribution in accordance with (Rafie and El-Boraie, 2017).

Furthermore, the soil water content in the root zone was minimized rapidly after irrigation, especially with deficit irrigation treatments, in contrast with full irrigation, in accordance with (Colak, 2021).

One metric strongly tied to water uptake ability is a plant’s root architecture (the spatial configuration of roots within the soil), it still hasn’t been studied extensively, especially in broadleaf crops like chiles (McNamara, 2021). Water stress affects root behavior, under water stress conditions, plants may expand smaller roots with less mass to boost competitiveness, as less carbon investment is essential to preserve root structure and decrease root breathing (Berntson, 1994; Zhang et al., 2019; Ksenija et al., 2023). So, there was a weak capacity for soil exploration by the pepper crop (Zamora et al., 2019). Also, there was more vertical expansion of roots under extreme water stress, in agreement with (Zhang et al., 2019).

5. Conclusions

Although gravitational effects (especially in sandy soils) could result in water loss by deep vertical percolation with continuous drip irrigation (P1), as there was no pause time (time-off) between irrigation pulses. But pulse drip irrigation treatments gave the highest soil moisture content within the active root zone (15 cm depth), especially with two pulses (P2) after irrigation. The possible reason for this return to minimal deep percolation due to the off-time period between the two successive drip irrigation pulses. Also, P2 allowed more operational time of the individual irrigation water pulse with enough break time (30 minutes-off), compared with P3. Where the first drip irrigation pulse gave enough time for the soil to absorb the first water dose and increased the initial soil water content before applying the second pulse. Therefore, lateral movement should continue after applying the second pulse, because the saturation level of soil water was directly near the emitter. Where there was more lateral movement of soil water due to the capillary force of the soil, which widens the wetted area under the application of irrigation pulses.

Under less water stress treatment (W3L1), there were more tendencies of chili roots to horizontal extension than vertical extension. Only extreme water stress treatment (W3L2) forced chili roots to primary vertical extension. That indicated the importance of keeping the moisture in the first horizontal soil sectors as long as possible, which could be achieved by applying two drip irrigation pulses (P2). Also, the most horizontal spread of soil water through the active root zone at 15 cm depth was achieved by W2L1P2 treatment. Therefore, it is recommended to apply two drip irrigation pulses P2 "with 30 minutes off time between pulses - main irrigation every 48 hours" combined with W2, (80% from ETc) irrigation water regime and 75 cm lateral spacing (Ll) for irrigation water management in dry regions with chicken manure organic fertilization in sandy soils for chili pepper crop.

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