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Effect of Moisture Depletion and Perlite Levels on Specific Hydraulic Standards and Water Use Efficiency for Potatoes under Drip Irrigation System

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Abstract: A field experiment was carried out in Hamdhiya Research Station northern Ramadi in Iraq at fall season of 2019, to study the effect of moisture depletion (MDPR) and perlite levels (PL) on some water standards, growth, and yield of potatoes under the drip irrigation system. The experiment involved two factors: moisture depletion ratios (MDPRs) with two levels 25% (D_{25}) and 50% (D_{50}) of available water and three levels of perlite (PLs), 0% (P_0), 5% (P_1) and 10% (P_2) of soil volume. The Revara type B potato cultivar was sown on 11th September 2019 in silty loam texture soil. Irrigation was scheduled at 25 and 50% of available water based on the U.S. Evaporation Pan Class A. The $D_{25}P_2$ combination gave the lowest bulk density (1.390 MPCM) whereas the highest e was 1.488 MPCM for $D_{50}P_0$ combination. The values of water infiltration rate decreased at the end growing season compared with its pre-farm values (10.35 cm h^{-1}) for all treatments, the highest WIR was 9.46 cm h^{-1} of $D_{25}P_2$ combination, while the least e was 6.70 cm h^{-1} in $D_{50}P_0$ combination. The best WUE was in $D_{25}P_2$ combination (94.07 kg m^{-3} KPCM) compared with other combinations.

Keywords: *Solanum tuberosum* L., Perlite, Bulk density, Infiltration rate, Drip irrigation

The shortage of water resources is a real challenge for agriculture nowadays. Rainfall rates in Iraq are less than 250 mm per year and is located in arid and semi-arid areas. The lack of arable water sources is also a major problem in providing food security requirements to cope with increased population growth. Therefore, it requires the development of modern methods and techniques in irrigation to rationalize the consumption to bridge the gap between available fresh water and food security. In recent years, several studies were aimed at reducing water consumption in irrigated farming, including the use of some chemicals and natural substances added to the plant or soil to reduce evaporation and provide the largest amount of water to the roots of plants called moisture preservatives, and these materials are agricultural perlite. Verdonck and Demeyer (2004) and Salas-Perez (2017) observed that perlite granules are characterized by their capillary characteristics and maintains good water retention with easy drainage as well as high porousness and permeability, which improves the water infiltration in the soil, which contributes to the further growth of the plant's roots.

Tracking the movement of water from the surface of the soil to its depths is of great importance because of relation to the time of irrigation and the determination of quantity of irrigation water applied to the soil. Elhindi et al (2020) conclided that the values of bulk density increased significantly with increased rates of moisture depletion where the values of river water irrigation were 1.43, 1.45 and 1.47 Mg. m^3 at moisture depletion rates of 50, 60 and 70% of available water, respectively. Al-Jawadi (2015) confirmed that the increased addition of polymers to soil increased soil porosity as a result of its low bulk density and reached the best values at 120, 80, 40 and 0 kg ha^1. Al Khateeb et al (2019) confirmed an increase in water use efficiency for potato crop with an increase in the level of applied perlite at any level and interval of irrigation, the highest value of water use efficiency was 21.26 KPCM at perlite and irrigation levels of 8 and 100% respectively for three days' interval and was 17.71, 12.65 KPCM for perlite levels 4 and 0% respectively for the same irrigation and interval mentioned above. The study aims to investigate the role of moisture depletion ratios and perlite levels in improving some water standards and water use efficiency for potato crop when adopting surface drip irrigation system.

MATERIAL AND METHODS

Study site: A field experiment was conducted in silty Loam soil during the fall season 2019 at College of Agriculture, Hamdhiya Research Station northern of Ramadi. The field's soil was sampled as Latin Square system to 0.0-0.45 m depth. The pre-cultivation physical and chemical properties were estimated (Table 1). The experiment was conducted on with early maturing variety Revera (B order) cultivar. The crop was raised as per recommended agronomic practices were cultivated at 0.08-0.10 m depth as 25 tubers per unit average where the distances. The recommended 240, 120 and 400 $Kg.ha^{-1}$ of N, P and K respectively were added. Soil management were carried out and then the experiment land was divided into 24 experimental units, the area of each experimental unit was 10 (10 m long x 1m wide). The randomized complete block design according to split-plot arrangement was used with four replications; the moisture depletion ratios (25 and 50%) of available water represented the main plots symbol as D_{25} and D_{50} respectively, while the perlite levels 0, 5 and 10% represented the sub-plots symbol as P_0, P_5 and P_{10} respectively.

The moisture depletion ratio (MDPR) detects the quantity of water for every treatment using constant discharge for all various growth stages. The actual water consumption (Eta) which is equal to added water depth (d) was calculated as following equation:

$$Eta = d = \frac{\theta f.c - \theta pwp}{100} \times D$$

Where (d) is the depth of applied water (cm); θf.c is the soil's volumetric moisture at F.C. limits (%; θpwp is the soil's volumetric moisture at P.W.P (%); D = is the soil depth (depth of rhizosphere) (cm).

The referenced evapotranspiration (ET0) was computed according to equation (Uku and Malollari 2013):

$$ETo = \frac{ET_a}{Kc}$$

Where ET_0 is the referenced evapotranspiration ($mm.day^{-1}$); Kc is the crop factor.

The stages of growth, tubers emergence, tubers bulging, tubers maturity were depending on the Kc values of 0.75, 1.15 1.00, and 0.80 respectively (Thomas et al. 1999). The timing was set depending on evaporation measured from evaporation pan (Epan) and (Kc) which takes 0.8 value according to (Danierhan et al 2013). The irrigation period was estimated as follows:

$$T = \frac{V}{q}$$

Where q is the given discharge (cm^2); T is irrigation time; V volume of given water (m^3) which was computed as:

Volme of water = a x d x n

Where a is wetting zone area (cm^2); n is the experiment's plants number.

Soil's bulk density was calculated according to method of Blake (1965). The cumulative infiltration was predicted according to Kostiakove equation (Hajim and Yassin 1992).

$D = C t^m$

Where D is the cumulative infiltration depth (mm); T is the cumulative infiltration time; C and m are constants.

The WUE was estimated according to Cracium and Cracium (1996).

RESULTS AND DISCUSSION

Bulk density (BD): The moisture depletion ratios (MDPR) of 25% achieved the lowest value of bulk density (BD) 1.421 MPCM compared with MDPR of 50% (1.446 MPCM). The increased BD may be due to increased MDPR, which led to increased soil dryness and when irrigation shows the effect of sudden wetting, causing the destruction of soil aggregates and the rearranging of the particles and disjointed aggregates, as well as increasing BD due to soil compaction which caused by wetting-drying rotations (Elhindi et al 2020).

The increase of perlite levels (PLs) led to reduce of bulk density (BD). The P_2 gave the lowest (1.400 MPCM) compared with P_1 and P_0 (1.420 and 1.471 MPCM respectively). The use of polymers decreased BD values

Table 1. Pre-cultivation physical and chemical properties of soil

Traits	Value	Unit	Traits	Traits	Value	Unit
sand	212	G kg^{-1}	Cations	Ca^{2+}	5.03	–
Silt	554			Mg^{2+}	4.41	dS m^{-1}
Clay	234			Na^+	1.30	Mmole L^{-1}
Texture	Silty loam	Silty Loam		K^+	0.12	
Bulk density	1.34	Mg m^{-3}	Anions	CL^-	8.00	
Particle density	2.60			CO_3^-	Nil	
Saturated hydraulic conductivity	4.50	Cm H^{-1}		HCO_3^-	2.26	
Porosity	48	%		SO_4^-	0.6	
Gypsum	3.40	G kg^{-1}	pH	7.1		
Lime	166.00		EC	1.83		

compared with control treatment may be attributed to the increased PL additions which enabled the soil to reserve more water longer than other levels, thus reduces the effect of sudden hydration, expansion, contraction and destruction of soil aggregates, which in turn increase BD values (Al-Jawadi 2015).

Water infiltration ratio (WIR): The cumulative WIR increased (with stability of PL) from 40.2 to 43.4 cm for P0 treatment, from 47.4 to 52.7 cm for P_1 and from 54 to 56.8 cm for P_2 at MDPs of 50% and 25% respectively. The rates of increase were 7.37, 10.05 and 4.92% respectively, when comparing cumulative WIR to MDPRs of 50 and 25% for different PLs (Table 2). The cumulative WIR values increased with the increase of PLs compared with control treatment (Fig. 1, 2 and Table 3). The values of cumulative WIR were increased from 43.4 to 52.7 and 56.8 cm for PLs of P_0, P_1 and P_2 respectively at MDPR of 25% with increase ratios of 17.64 and 25.37% for P_1 and P_2 compared with P_0 respectively. The cumulative WIR increased from 40.2 to 47, 4 and 54 cm for PLs of P_0, P_1 and P_2 respectively at MDPR of 50% with an increase ratio of 15.18 and 25.55% for P_1, P_2 and P_0 respectively. Due to the increased BD of the soil and its decreased porosity due to the high moisture content that led to the leaching of salts and cementing agents downwards. In addition, the lack of aeration has led to a decrease in the activity of aerobic microorganisms and the decrease in its organic secretions, which has negatively reflected on the soil's porosity and the distribution of its pore spaces, which are responsible for the movement of water and the rate of infiltration in it (Al-Duality 2011).

Table 2. Effect of MDPRs and PLs on BD values

Perlite	Moisture depletion ratios		Mean (P)
	D_{25}	D_{50}	
P_0	1.452	1.488	1.471
P_1	1.420	1.440	1.420
P_2	1.390	1.410	1.400
Mean (D)	1.421	1.446	
LSD (p=0.05)	D	P	D×P
	0.024	0.011	NS

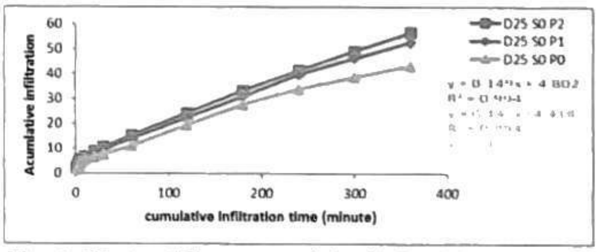

Fig. 1. Effects of PLs on cumulative WIR at MDPR of 25%

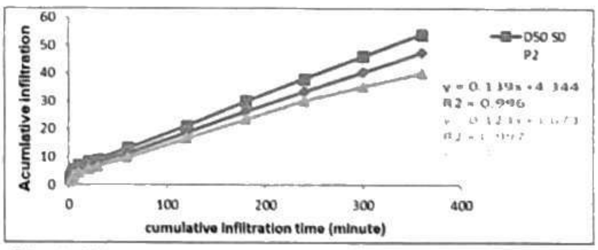

Fig. 2. Effects of PLs on cumulative WIR at MDPR of 50%

Table 3. Effect of MDPR and PL on cumulative WIR

Cumulative infiltration (minute)	Cumulative infiltration					
	$D_{25}P_0$	$D_{25}P_1$	$D_{25}P_2$	$D_{50}P_0$	$D_{50}P_1$	$D_{50}P_2$
1	1.6	2.1	2.3	1.5	1.8	**2.2**
2	2.4	3.2	3.3	2.2	2.7	**3.2**
3	3.1	3.9	4.2	2.8	3.5	**4.1**
4	3.7	4.6	5	3.3	4.2	**4.9**
5	4.3	5.21	5.7	3.7	4.8	**5.6**
10	5.5	6.3	6.8	4.6	5.5	**7.0**
20	6.7	8.3	8.8	5.8	6.9	**8.4**
30	7.8	9.6	10.5	6.7	8.4	**9.2**
60	11.2	13.9	15.2	9.9	11.5	**13.2**
120	19.5	22.4	24.2	16.9	18.9	**21.1**
180	27.8	31.1	33.4	23.6	26.4	**30.1**
15.18	34	39.8	41.5	30.2	33.4	**38.**
300	38.8	46.5	49.2	35.3	40.5	**46.1**
360	43.4	52.7	56.8	40.2	47.4	**54.0**
Sum	43.4	52.7	56.8	40.2	47.4	**54.0**
WIR (cm h^{-1})	7.23	8.78	9.46	6.7	7.9	**9.0**

Table 4. Impact of MDPR and PL on WUE

Perlite	Moisture depletion ratios		Mean (P)
	D_{25}	D_{50}	
P_0	60.19	47.13	53.66
P_1	75.65	66.64	71.14
P_2	86.17	79.89	83.03
Mean (D)	74.00	64.55	
LSD (p=0.05)	D	P	D×P
	4.718	5.238	NS

The addition of PL led to an increase in infiltration as it improves the soil physical properties and improves BD and porosity that responsible for the movement of water, improves its drainage and works to balance the moisture and gas contents in soil profile, which reflects on the activity and effectiveness of soil microbiology, increased organic secretions and then the distribution sizes of pore spaces. This increased water infiltration ratio WIR in soil, furthermore, the increased perlite level of addition has led to moisture retention, this reduces the process of sudden wetting and destruction of soil aggregates at irrigating, as well as reducing the process of expansion - shrinkage which increases the values of BD and improves soil aggregations (Al-Jawadi 2015). The decrease in the cumulative WIR of all study treatments from what they were at the beginning of the experiment (Fig. 1 and 2, Table 1). The WIR data in the above mentioned figures were depicted according to Kostiakove equation with determination factor R^2 of 0.994 for P_2 and P^1, 0,988 for P_0 at MDPR of 25% according to the nature of surface addition (Fig. 1). The R^2 in (Fig. 2) values were 0.996, 0.997 and 0.995 for PLs of P_2, P_1, and P_0 respectively at MDPR of 50%.

Water use Efficiency (WUE): The WUE for different indicated that 25% MDPR achieved the highest WUE of 74.00 KPCM with significant increase of 12.77% compared with the 50% MDPR of 64.55 KPCM (Table 4). This is because WUE decreases at high irrigation levels, which increase when the plant is absorbable as a result of the addition of this amount at once and with greater irrigation durations, whereas the addition of water in a lower amount and with less irrigation periods makes the plant more efficient to absorb and benefit and thus increase production in the water unit, which increases WUE. Fonda et al (2012) also stated an increase in WUE for tomatoes at MDPR of 25% of available water higher than irrigation treatment of 50% MDPR. Increased PLs gave the highest value of WUE. The P_2 treatment recorded WUE of about 83.03 KPCM with a significant increase of 14.32 and 35.37% compared with P_1 and P_0, respectively. The WUE was 71.14 KPCM and 53.66 KPCM, respectively. This variation is due to moisture retention by soil as a result to PL applications that improves physical properties of soils, their water retention and moisture increase by increasing the number of micro pores responsible for water retention that have affected the structural tension that is inversely proportional to the diameter of the pores, and this effect has been reflected in the increase in the overall outcome, which increases the WUE.

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CONCLUSIONS

The addition of perlite at 10% gave the lowest bulk density (BD) and achieved the best results of WIR and WUE values when moisture depletion ratio was 25%, and this shows the effective role of perlite when reducing moisture depletion to 25% in improving some water standards and water use efficiency by enabling the soil to retain water and rationalize its consumption.

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