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EFFECT OF ADDED WATER DEPTH AND IRRIGATION INTERVAL ON SOME SOIL PHYSICAL PROPERTIES, GROWTH, AND YIELD OF WHEAT UNDER CENTER PIVOT SPRINKLER IRRIGATION SYSTEM WESTERN IRAQ

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Abstract

A field experiment was carried out during the winter season of 2021 in western Iraq to find out the effect of the depth-added water and the irrigation interval on some physical soil properties and the growth and productivity of wheat under the center pivot irrigation system (Valley). The study included two factors; the first factor is the water depth (d) with two levels, a complete water depth of 100% (d_f) and an overwater depth of 125% (d_o), while the second factor was the irrigation interval (I) with two levels of irrigation, every three days (I_1) and irrigation every six days (I_2), depending on soil texture and crop type. Wells water was used for irrigation. The results showed that the full water depth (d_f) achieved the best values of 1.380. MGm^{-3}, 2.000 kg cm^{-2}, 74.0 cm, and 4.367 ton ha^{-1} for the bulk density, soil resistance to penetration, plant height, and yield, respectively. The irrigation interval every three days (I_1) achieved the lowest values of 1.37 MG m^{-3} and 1.875 kg cm^{-2} for both bulk density and soil penetration resistance, respectively, while it achieved the highest values of 76.938 cm and 4.436 tons ha^{-1} for both plant height and yield, respectively.

Keywords: Water depth, Irrigation interval, Wheat, Soil physical properties, Center pivot Sprinkler irrigation.

تأثير عمق الماء المضاف وفاصلة الارواء في بعض خصائص التربة الفيزيائية ونمو وحاصل الحنطة تحت نظام الري بالرش المحوري غرب العراق

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الخلاصة

نفذت تجربة حقلية خلال الموسم الشتوي 2021 غرب العراق لمعرفة تأثير عمق الماء المضاف وفاصلة الارواء في بعض خصائص التربة الفيزيائية ونمو وانتاجية الحنطة تحت نظام الري بالرش المحوري نوع خريف (Valley)، وشملت الدراسة عاملين هما العامل الاول عمق الماء (d) بمستويين عمق ماء تام 100% (d_f) وعمق ماء زائد 125% (d_o)، فيما كان العامل الثاني فاصلة الري (I) وبمستويين ايضاً الري كل ثلاثة أيام (I_1) والري كل ستة أيام (I_2) اعتماداً على نسجة التربة ونوع المحصول، استخدمت مياه الابار في عملية الري. اوضحت النتائج ان عمق الماء الكامل (d_f) حقق أفضل القيم بلغت 1.380 ميكا غرام $م^{-3}$ و2.000 كغم $سم^{-2}$ و74.0 سم و4.367 طن $ه^{-1}$ لكل من الكثافة الظاهرية، مقاومة التربة للاختراق، ارتفاع النبات والحاصل بالتتابع. فيما حققت فاصلة الارواء كل ثلاثة أيام (I_1) اقل القيم بلغت 1.37 ميكا غرام $م^{-3}$ و1.875 كغم $سم^{-2}$ لكل من الكثافة الظاهرية ومقاومة التربة للاختراق، بالتتابع، بينما تحققت اعلى القيم 76.938 سم و4.436 طن $ه^{-1}$ لكل من ارتفاع النبات والحاصل، بالتتابع.

كلمات مفتاحية: عمق الماء، فاصلة الارواء، الحنطة، خصائص التربة الفيزيائية، نظام الري بالرش المحوري.

Introduction

Center pivot sprinkler irrigation is essential for rationalizing water use and reducing water losses. It is one of the most widely used irrigation systems for irrigating medium to large areas. This system is characterized by its flexibility, high efficiency, and the possibility of using it to irrigate most crops and most lands. This system has another advantage: it does not require a large workforce, which makes it superior to other irrigation systems. It can be used in most climatic conditions (1). The increasing need for freshwater resources requires agricultural producers to adopt modern irrigation technologies to increase the water unit and yield (22).

The bulk density of soil resulting from compaction operations depends on the soil texture and moisture content (14). The researcher (17) explained that the bulk density can be low after agricultural operations such as plowing, but it can increase under irrigation due to the movement of soil particles within its pores. The researcher (10) explained that the falling of raindrops on the soil surface causes the breakdown of the binding materials between soil particles and aggregates, thus affecting its structure. The study (19) showed that the intensity of this phenomenon can decrease significantly if the moisture content of the surface layer of the soil increases. This phenomenon is one of the problems of desert soils due to the direct falling of raindrops on the soil surface, an arid climate, and bright sunlight. One of the important physical properties of soil is the soil resistance to penetration, which is done by estimating this property to identify its physical state (20). The study (12) confirmed that soil resistance to penetration is one of the important mechanical properties that can indicate soil compaction. At the same time, (9) indicated that the growth of roots in compacted soils is restricted as a result of the pressure exerted on them and that the maximum value of the soil resistance to penetration that the roots can overcome is two megapascals, which was measured by a cone-type penetration resistance device. The study (8) confirmed that water droplets have energy that works to break down and move small soil particles of clay and silt, and then these particles settle in the spaces (pores) between the soil particles, thus reducing the size of the pores or closing them altogether. Plant height refers to the distance between the soil surface and the end of the terminal spike without the peduncle (23). The study (11) showed that water shortage leads to a decrease in the average carbon representation, leading to a decrease in stem elongation and leaf expansion due to a decrease in the water content in the cells of the sunflower crop. The researcher (18) found that increasing the number of irrigations led to a significant increase in the average plant height and that the most affected stages of plant growth by water shortage were the branching and stem elongation stages. The researcher (16) confirmed the positive effect of the elements in well water when the salinity level is less than the salt inhibition threshold, as these elements increase plant growth activity and build tissues. The results of the studies reached by (13 and 21) indicated that water stress resulting from withholding irrigation water during the different stages of wheat crop growth caused a decrease in grain yield by 50% or more, and this depends on the environmental conditions and the time and length of the period during which the plant is exposed to water shortage and the ability of the type used to recover growth after the water stress disappears. The researcher (2) reached a decrease in wheat grain yield if the soil moisture content decreased from 75% to 50% and 25% of the field capacity. The researcher (3) confirmed a significant relationship between water stress and wheat varieties. The results showed the superiority of the N70 variety in giving the highest grain yield, reaching 5.91 tons ha^{-1}, and there was no significant difference from the Iraq variety. There was a significant effect on grain yield due to the interaction between varieties and irrigation treatments, as the highest average yield was recorded in the full irrigation treatment, reaching 7.69 tons h^{-1}. However, in the case of severe stress, the N70 variety gave the highest average yield, reaching 4.07 tons h^{-1}, and the results reached by (4) showed that the crop production increased in the case of following the center pivot sprinkler irrigation system, reaching 5.360 tons h^{-1}, while in the case of continuous flood irrigation, it reached 4.230 tons h^{-1}.

Materials and Methods

A field experiment was conducted during the winter season of 2021 in the Al-Baghdadi district, 150 km west of Ramadi City, Iraq, to determine the effect of the depth of added water and the irrigation interval on some physical soil properties and the growth and productivity of wheat under the Valley type center pivot sprinkler irrigation system, according to the randomized complete block design (RCBD) and a factorial experiment with three replicates. The study included two factors; the first factor is the irrigation interval (I) and at two levels, irrigation every three days (I_1) and irrigation every six days (I_2), while the second factor was the depth of added water (d) and at two levels as well, a full water depth of 100% (d_f) and an excess water depth of 125% (d_o). Table 1 shows the physical properties of the field soil before the study, and Table 2 shows the chemical properties. The valley-type center pivot sprinkler irrigation system was used, which consists of four towers (Spans) connected by rubber dividers)) with a total arm length of 243.30 m, the total area of that system becomes 74.35 dunums. The bulk density was estimated using the cylinder method (Core sample) according to the method mentioned by (7). A soil penetration device called HUMBOLDT MFG was used to measure the extent of soil resistance to penetration, where five places were chosen randomly.

Table 1: Physical properties of field soil before the study for a depth of 0.0-0.30 m.

Property		Value	Unit
Soil separates	Sand	45.7	%
	Salt	25.4	%
	Clay	28.9	%
	Sand Clay Loam		
Calcic ($CaCo_3$)		31.2	%
Gypsum ($CaSo_4.2H_2O$)		15.8	%
Bulk density		1.35	Mg m^{-3}

Table 2: Soil chemical properties before the study for a 0.0-0.30 m depth.

Ec_e	**PH**	**O.M**	**Cations**				**Anions**			
			Meq L^{-1}							
ds m^{-1}		**(%)**	Na^+	K^+	Mg^{++}	Ca^{++}	CO_3^-	HCO_3^-	SO_4^{--}	Cl^-
4.2	7.8	0.82	16.4	0.7	4.9	19.5	Nill	2.3	27.2	11.6

Within each experimental unit, the rates were taken, and the measurement was done by inserting the device lever into the soil surface at a 45-degree angle. Then, the indicator was read to show the force required to penetrate the soil surface. The plant's height was measured using a measuring tape from the soil surface to the end of the spike for ten plants randomly selected from each experimental unit within the study parameters. The complete water depth df (100%) was calculated according to the following equation:

df = water depth/100 *pb*D do = df*125%

The highest water depth was obtained at 22.8 mm at a pressure of 30 lb/in and a velocity rate of 25%. Table 3 shows the calculations of the depths of added water according to the study treatments and the stages of plant growth. The yield of wheat grains was estimated by taking nine random samples within the study treatments. A wooden frame with an area of 1 m^2 was used. These squares were harvested when the crop was finally ripe. The yield was estimated, and the average for each treatment was calculated as 1ton h^{-1}.

Table 3: Calculations of scheduling of added water depths according to study treatments and growth stages of wheat yield.

stages of plant growth	Applied water depth calculations
Germination Stage (18 day) 30/11/2021 to 17/12/2021	d_f = 51.6 mm/6 = 8.6 mm at 3 day d_f = water depth/100 *pb*D 8.60mm*2 = 17.20mm at 6 day 38.22mm = water depth d_o = 64.5mm/6 = 10.75mm at 3 day 1.35MG m^{-3} = pb = 21.50mm at 6 day 10 cm = Root depth(D) d_f =38.22/100*1.35*10 =5.159 Cm = 51.6 mm d_o = 51.6*1.25 = 64.5 mm
Vegetative Stage (48 day) 18/12/2021 to 3/2/2022	d_f = 77.40 mm/16 = 4.837 mm at 3 day = 9.675mm at 6 day 15 cm = Root depth(D) d_o = 96.80mm/16 = 6.05mm at 3 day = 12.10mm at 6 day
Sanabel Stage (42 day) 4/2/2022 to 17/3/2022	d_f = 103.20 mm/14 = 7.371 mm at 3 day 20 cm = Root depth(D) = 14.742mm at 6-day d_o = 129.00mm/14 = 9.214mm at 3 day = 18.428mm at 6-day
Maturity Stage (48 day) 18/3/2022 to 4/5/2022	d_f = 129.00 mm/16 = 8.062 mm at 3 day = 16.125mm at 6 day 25 cm = Root depth(D) d_o 161.20 mm/16 = 10.075mm at 3 day = 20.150mm at 6-day

Results and Discussion

Effect of added water depth and irrigation interval on bulk density: Table 4 shows significant differences in the added water depth and irrigation interval treatments in the bulk density values, as the treatment of excess irrigation water depth achieved the highest rate of bulk density value of 1.400 MG m^{-3}. In comparison, this rate decreased when treating the full irrigation water depth df, which reached 1.380 MG m-3 with a decrease rate of 1.4%. The reason for this difference can be attributed to the movement of soil particles in its pores as a result of the excess irrigation water depth and that the momentum of excess irrigation water droplets on the soil surface is expected to lead to the deterioration of the soil structure as a result of the destruction of the binding materials between its particles and aggregates and thus increase the value of bulk density, which is consistent with (17). The three-day irrigation interval treatment (I_1) achieved the lowest bulk density value, which amounted to 1.37 MG m^3, while the six-day irrigation interval treatment (I_2) achieved the highest rate, which amounted to 1.41 MG m^3, with an increase rate of 2.8%. The differences were significant, attributed to the soil's high moisture content, which significantly reduced the bulk density values, consistent with (19). However, the interaction between the two study factors (water depth and irrigation interval) did not significantly affect the bulk density values, and this is what the LSD values shown in Table 4 indicated.

Table 4: Effect of water depth and irrigation interval on bulk density for study treatments under center pivot irrigation system.

Bulk density values (Mg M^{-3})			
	Irrigation interval		
Water depth	I_1	I_2	Average
d_f	1.36	1.40	1.38
d_o	1.38	1.42	1.40
Average	1.37	1.41	
	d	I	d*I
LSD $_{0.05}$	0.016	0.016	NS

The effect of the added water depth and the irrigation interval on the soil resistance to penetration: Table 5 shows significant differences in the treatments of the added water depth and the irrigation interval in the soil resistance to penetration values. The full irrigation water treatment (d_f) achieved the lowest rate of soil resistance to penetration, which reached 2.000 kg $cm^{-2,}$ while the highest rate of soil resistance to penetration reached 2.750 kg cm^{-2} when treating the depth of excess water and with a percentage increase of 27.2%. The falling water droplets have energy that breaks down the soil particles and moves the small ones, represented by clay and silt particles. Then, these particles settle in the spaces or pores between the soil particles and thus reduce their size or close them, which causes the formation of a solid layer with high penetration resistance, and this is consistent with what was indicated by (8). As for the irrigation interval, the three-day irrigation interval (I1) treatment achieved the lowest rate of soil penetration resistance values, reaching 1.875 kg cm^2, while the six-day irrigation interval (I_2) treatment achieved the highest rate, reaching 2.875 kg cm^2, with an increased rate of 34.7% as in the above paragraph. This is attributed to the decrease in soil moisture and the increase in bulk density values when adopting the irrigation interval every six days (I_2), and thus the soil penetration resistance values were higher.

Table 5: Effect of added water depth and the irrigation interval on the soil resistance to penetration for study treatments under a center pivot sprinkler irrigation system.

Values of soil resistance to penetration (Kg cm^{-2})			
	Irrigation interval		
Water depth	I_1	I_2	Average
d_f	1.75	2.25	2.00
d_o	2.00	3.50	2.75
Average	1.87	2.87	
	d	I	d*I
LSD $_{0.05}$	0.351	0.351	0.496

This is consistent with what was mentioned by (15). As for the interaction between the study factors (depth of added water and irrigation interval), it had a significant effect on the values of soil resistance to penetration, as the dfI1 treatment achieved the lowest values, which amounted to 1.75 kg cm^2, while the doI2 treatment achieved the highest rate, which amounted to 3.50 kg cm^2, with an increased rate of 50%. This is attributed to the interaction effect of soil dryness on the one hand and the increase in bulk density values on the other hand, as a result of the formation of a hardened surface crust due to the impact of water droplets falling to the soil surface.

The effect of the added water depth and the irrigation interval on plant height: Table 6 shows significant differences in the coefficients of the added water depth and the irrigation interval in the values of wheat plant height. The depth of the full irrigation water d_f achieved the highest rate of plant height, reaching 74.0 cm, while the depth of the excess irrigation water achieved the lowest rate, reaching 67.170 cm, with a decrease rate of 10.4%. The differences were significant. The reason for this difference in the rate of plant height may be due to the increase in the soil water reserve when treating the full irrigation and its sufficiency for water needs and its physiological role in plant growth, consistent with (4 and 6). As for the irrigation interval, the interval every three days (I1) achieved the highest rate of plant height, reaching 76.938 cm, while the irrigation interval every six days (I2) recorded the lowest rate, reaching 64.270 cm, with a decrease rate of 19.7%. Increasing the number of irrigations reduced the plant's water stress, which was reflected in the construction of plant tissues and its height, consistent with (18). The added water depth and irrigation interval interaction significantly affected plant height values.

Table 6: Effect of the water depth and the irrigation interval on plant height for study treatments under center pivot sprinkler irrigation system.

Wheat plant height (cm)			
	Irrigation interval		
Water depth	I_1	I_2	Average
d_f	79.87	68.20	74.038
d_o	74.00	60.10	67.170
Average	76.938	64.270	
	d	I	d*I
LSD $_{0.05}$	3.824	3.824	4.212

The d_fI_1 treatment achieved the highest value of 79.87 cm, while the d_oI_2 treatment achieved the lowest value of 60.10 cm, with a decrease rate of 32.9%. This is attributed to the practical and positive role of the study factors in achieving the appropriate moisture requirements for plant growth and increasing the heights of the wheat plant.

Effect of added water depth and irrigation interval on yield: Table 7 shows significant differences between the added water depth and irrigation interval treatments in the wheat yield rate values for the different study treatments. The results indicated the superiority of the full irrigation water treatment (df) by achieving the highest yield rate of 4.367 tons ha^{-1}, while the excess irrigation water depth (do) achieved the lowest yield rate of 4.061 tons ha^{-1}, with a decreased rate of 7.5%. The differences were significant, as indicated by the values of the least significant difference. This can be explained by the good and active growth of both plant height and the improvement of some physical properties of the soil (bulk soil density and soil resistance to penetration) at this depth, which was positively reflected in the yield and the water stress resulting from the decrease in moisture content for the excess irrigation treatment in the different growth stages of the wheat crop caused a decrease in grain yield, which is consistent with (13 and 21). The irrigation interval every three days (I_1) achieved the highest yield rate. The wheat yield reached 4.436 tons ha^{-1}, while the yield rate decreased at the irrigation interval every six days (I_2) to 3.992 tons ha^{-1}, with a decrease rate of 11%. The yield decrease values were significant, as indicated by the LSD values.

Table 7: Effect of water depth and irrigation interval on values of wheat yield for study treatments under center pivot sprinkler irrigation system.

Values of wheat yield (ton ha^{-1})			
	Irrigation interval		
Water depth	I_1	I_2	Average
d_f	4.622	4.111	4.367
d_o	4.250	3.872	4.061
Average	4.436	3.992	
	d	I	d*I
LSD $_{0.05}$	0.209	0.209	0.231

The large irrigation interval (every six days) gave more opportunity for soil drying, which is one of the most important factors determining crop production, as wheat crop tolerates moderate moisture stress, but high moisture stress in different stages of crop growth causes an apparent decrease in the yield, which is what was indicated by (3). As for the interaction between the depth of added irrigation water and the irrigation interval, it had a significant effect on the wheat yield rate; only the d_f I_1 treatment achieved the highest yield rate of 4.622 tons ha^{-1}, while the do I_2 treatment achieved the lowest yield value of 3.872 tons ha^{-1}, with a decrease rate of 19.4%. The small additions of irrigation water in a close manner, as occurs in irrigation by center pivot sprinkler, are likely to increase the amount of yield per unit area, which is what was reached by (5), who indicated that wheat crop production increased in the case of following the center pivot sprinkler irrigation system.

Conclusions

Adopting full water depth in irrigating the experimental land and an irrigation interval of three days achieved the best positive results for the physical properties of the soil studied and the growth and yield of wheat plants. Therefore, it is recommended that full water depth (100%) be adopted, and irrigation intervals should be every three days.

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