Improving the Regularity of water Distribution of the Double-pipe Irrigation system and its impact on soil and Plant properties

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Abstract

A field experiment was conducted for the autumn agricultural season 2022 at the Agricultural Research Station - University of Basra - Karma Ali site Located between $^{-}30\ 50^{0}$ latitude and $^{-}47\ 74^{0}$, to study the effect of the experiment factors, which are the distance factor between the emitter holder with distances of 0-15-30 centimeters using double pipes, and the distance factor between the emitters by three coefficients 20-25-30 centimeters, between the emitters and the emitter discharge factor with two coefficients of 5-8 liters per hour^{-1}. In the values of moisture content and electrical conductivity, The experiment treatments are distributed into three replicates by using a factorial experiment conducted in a randomized complete block design (RCBD). showed that the use of double pipes at a distance of 15 cm between the pipes recorded the highest moisture content, followed by the zero distance between the pipes. While the highest moisture content was recorded at a distance of 20 cm between the emitters when using a discharge of 8 liters per hour^{-1}. As for the electrical conductivity, the coefficient of distance showed 15 centimeters between the emitter holder, followed by the zero distance coefficient between the emitter holder with less electrical conductivity, and increases with increasing distance from the center of the marz. While the lowest electrical conductivity was recorded at the distance of 20 between the emitters and increased with the distance between the emitters. As for the discharge, the discharge has achieved 8 liters hour^{-1} less electrical conductivity, with the highest moisture content and the lowest electrical conductivity recorded at the treatment 15-20-8 for the distance between the emitter holder and the distance between the emitters and discharge, respectively.

Keywords: Distance between emitters, moisture content, electrical conductivity.

Introduction

Despite the positive advantages of the drip irrigation system, there are some disadvantages caused by this method, the most important of which is the accumulation of salts on the soil surface between the emitters and between the drip pipes, and at the ends of the humidification front (16). The nature of the salt pool depends on both the drainage between the emitters as well as the quality of irrigation water, the average amount of irrigation water added, the period between irrigations in addition to soil salinity, and the amount of water absorbed by the roots of the plant, as the lowest concentration of salts is near and below the drip source and increases towards the hydration front, (23). Nedawei and Hassan (20) found when using different distances between emitters (15, 25, 35,) and 45 cm respectively in their study conducted on clay soils), that the concentration of salts increases with increasing distance between emitters, while the lowest concentration of salts was at the drip source and increases with increasing horizontal and vertical distance, where the electrical conductivity values as an average of 7.61, 8.90, 9.75 and 11.18 Ds m^{-1} for distances 15, 25, 35 and 45 cm on respectively, and attributed the reason for the low values of electrical conductivity by the lack of distance between the emitters to the nature of the moisture distribution in addition to the increase in the rate of movement of water in the soil, which in turn increases with the lack of distance between the emitters due to the increase in the average amount of water added to the space between the emitters. Shan et al., Zin El-Abedin (32) explained when designing the field of a drip irrigation network, the overlap is often made between the emitters along the drip pipe to equip the root area with appropriate moisture, as well as they confirmed that the distance between the emitters is one of the important factors that affect the distribution of moisture in the soil in the drip irrigation system, as the progress of the drip irrigation front increases with the decrease in the distance between the emitters at the same conditions, because the overlap time between the two horizontal advance fronts Between the two zones is less in this case. Chouhan (9) also found when he conducted a study of three distances between emitters of 50, 40 a, and 30 cm in mixed clay soils in India, that the values of moisture content decreased with increasing distance between emitters, as the distance between emitters of 30 cm recorded the highest rate of moisture content at 22.09%, while the coefficient of the distance between emitters of 50 cm recorded the lowest rate of moisture content at 19.27%. As explained by Danger et al., (10) that the humidity level increases with the lack of distance between field pipes regardless of the difference in distance between the emitters, as the distances between the field pipes and the emitters are a network of parallel discharges and dimensions. In a study in which two distances were used between the double field pipes 0.5, 1 meter on the homogeneity of the moisture distribution in the sandy soil mixture Zhou et al., (31) observed a significant superiority of the distance between the field pipes 0.5 meters over the distance of 1 meter with an increase of 4.43%, and attributed this to the increase in vertical water movement in the soil due to the increase in the distance between the field pipes, which affects the complete homogeneity of the moisture content and the horizontal movement of water per unit area, and this is in a cycle. It requires adding more depths of irrigation water to ensure complete homogeneity, which leads to deep penetration losses below the root zone. This study aims to evaluate the effect of the distance between field pipes, and the distance between emitters and emitter discharge on the moisture and saline distribution in the soil sector under the drip irrigation system adapted to the growth of field crops with vegetative aggregate and widespread root system.

Materials and methods

A field experiment was conducted during the agricultural season 2021/2022 at the research station of the College of Agriculture – the University of Basra, located at a latitude of 30° 50° N and a longitude arc74 47° E on the river Karmat Ali in soil with a clay tissue (Silt Clay) classified as Typical torrifluvent hyperthermia, calcareous clayey mixed (4).

Table 1. Physical and chemical properties of the soil of the study area in which appropriate analysis methods were used are given in Black et al., (1965), and Page et al., (1982).

Properties			0 -15	15 - 30
Sand		gm kg^{-1} Soil	151.41	133.13
Silt			486.07	492.26
Clay			362.50	374.58
Texture			Silty Clay	
MWD mm			0.24	0.22
pH			7.66	7.45
EC Ds m^{-1}			6.32	6.09
CEC Cmol kg^{-1}			27.40	26.90
O.M. gm kg^{-1}			1.53	1.37
Total CO_3 gm kg^{-1}			312.55	301.31
Bulk density Mg m^{-3}			1.34	1.36
Real densiry Mg m^{-3}			2.64	2.64
Porosity %			50.65	49.24
Soluble ion	Ca^{++}	mmol l^{-1}	6.12	6.89
	Mg^{++}		7.80	8.65
	Na^{+}		28.11	31.18
	K^{+}		4.35	4.87
	HCO_3^{-}		14.85	15.14
	$SO_4^{=}$		5.28	5.07
	Cl^{-}		54.71	55.13
	$CO_3^{=}$		0.00	0.00

The study included three factors: 1- The distance factor between the field pipes, as two double pipes were used for each experimental unit and with three distances/distance (0 cm) between the two double pipes (S0), and the distance of 15 cm (S15) and the distance of 30 cm (S30). 2- The factor of the distance between the emitters and three coefficients / the coefficient of the distance of 20 cm between the emitters (D20) and the distance of 25 cm between the emitters (D25) and the distance of 30 cm between the emitters (D30). 3- Emitter drain with two levels / low discharge 5 liters. 1-hour (L) and high discharge 8 liters. hour-1 (H). Due to the importance of knowing the changes in the properties and characteristics of the soil, the horizontal distance factor was added, which included distances 0, 15, and 30 cm from the drip source to study the change that occurs in the moisture and salt distribution.

Design and installation of double irrigation system:

The experiment was designed using the method of factorial experiment with three factors using the design of complete random sectors (R.C.B.D) with three replicates. One sector contains 18 experimental units with a length of 10 meters, the distance between the experimental units is 1.5 meters, and the distance between one sector and another is 3 meters, two double tubes were used in each experimental unit, and the factor coefficients were applied according to the factor combinations and included the coefficients of the distance factor between the field pipes (0, 15, 30) cm, and the coefficients of the distance factor between the emitters (20, 25, 30) cm respectively on both sides of the double field pipes for each experimental unit, and the emitter discharge factor coefficients (5, 8 liters.hour^{-1}) for all experimental units. The operating pressure was controlled using tight valves and piezometers at the end of each field pipe to achieve the emitter discharge rate.

Cultivation experiment

The seeds of yellow corn (*Zea mays*, L) of the Barekat Jovian variety were planted on the autumn date 18/9/2022, at a distance of 20 cm and the crop was reduced to one plant in each room. Crop service operations were carried out only (Mustafa 2018), with a fertilization rate for NPK fertilizer.

Experimental irrigation

The amount of water needed for irrigation was calculated based on the evaporation value measured directly from the American evaporation basin (Evap. Pan class-A), which was installed at the experiment site, and (20%) was added as leaching requirements.

Field and laboratory measurements and analyses during the experiment period: soil samples were taken (by the drill) and for all coefficients for depth (0-30) and horizontal distances (0, 15, 30) cm from the source of drip, and during two periods of measurement are a month after planting and at the end of the growing season, and the moisture distribution of the soil was estimated according to the method mentioned in (6) Black et al., and the electrical conductivity in the extract of saturated soil paste was estimated according to the method (21).

Results and discussion

The results of the statistical analysis show that there is a significant effect of the distance factor between the double field pipes of the drip irrigation system on the values of soil moisture content (PW) in the middle and end of the growing season and when comparing these coefficients, there were significant differences between all the coefficients in the middle and end of the season (Fig 1). In the middle of the season, the 15 cm transaction gave the highest value at 20.59%, followed by the 0 cm transaction at 19.61%, while the 30 cm transaction gave the lowest value at 18.57%. At the end of the season, the values were 21.17%, 20.29%, and 19.43% for transactions of 0,15, and 30 cm respectively. The reason for the increase in the moisture content of the close distances between the field pipes is due to the increase in the horizontal wetting space at the expense of horizontal vertical wetting as a result of the rapid confluence of the two humidification fronts, the increase in the tip of the water inside the soil body and the high initial moisture content, The best homogeneity and moisture distribution occurs as a result of the bilateral interference between the humidification fronts of the two adjacent pipes at the root zone of the drip irrigation system (8). As for the decrease in the moisture content of the soil by increasing the distance between the field pipes, the reason may be due to the nature of the horizontal movement of water in the soil resulting from the structural potential difference between the low-voltage area and close to the saturation degree and the high-voltage and unsaturated area, and therefore the increase in the distance between the field pipes leads to a lack of horizontal water movement and vice versa for the vertical movement as a result of the decrease in water resistance to this movement due to the hydraulic slope of the soil and the increase in ground attraction, as well as reported increasing the operating time of the emitter required to moisten the entire area, which increases the loss of irrigation water to the bottom of the root zone at the emitter as a result of increasing the time of vertical movement and deep leaching due to the gravitational of landy force of water (30,7).

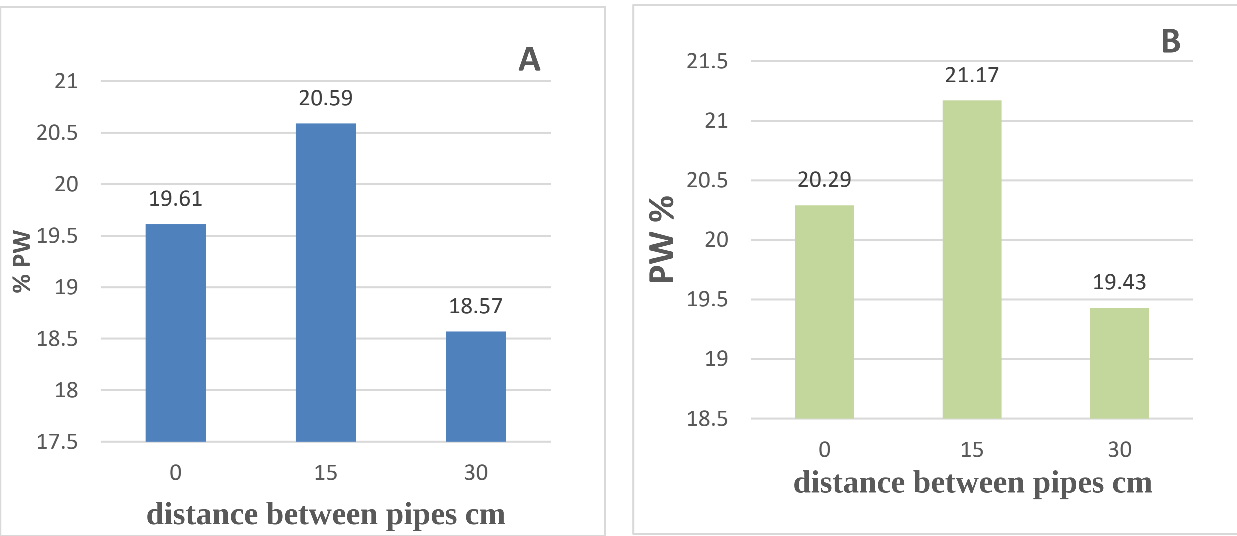


Figure 1. Effect of Distance between Pipes (cm) on Soil Moisture Content Values (%) Mid(A) and End (B) Growing Season.

The results of the statistical analysis show that there is a significant effect of the distance factor between the emitters in the values of the moisture content of the soil (PW%) at the beginning and end of the growing season, and when comparing these coefficients, there were significant differences between all the transactions at the beginning and end of the growing season (Figure 2), at the beginning of the season the treatment gave 20 cm the highest values and was by 20.96%, followed by the coefficient of 25 cm, which recorded 19.75%, while the transaction of 30 cm gave the lowest values, reaching 18.06%. At the end of the season, the values were 21.61%, 20.42%, and 18.36% for transactions of 20, 25, and 30 cm respectively. The reason for the increase in moisture content is due to the decrease in the distance between the emitters, which led to an increase in the amount of water added per unit area, which led to the speed of confluence and overlap of the humidification fronts between the emitters, as the amount of water increases with less distance between the emitters and thus increases the horizontal movement at the expense of vertical movement in the soil pot, which in turn led to an increase in the confluence of the two humidification fronts compared to the spaced emitters (14). On the other hand, the results generally show that there is an increase in PW values at the end of the growing season compared to the beginning of the season and for all transactions with an increase of 3.10%, 3.39%, 1.66% for transactions 20, 25 and 30 cm respectively. The reason for this is due to the occurrence of soil surface coverage as a result of the increase in the vegetative total, which in turn reduces the water lost by surface evaporation as a result of low temperatures at the end of the season, as well as improving soil construction as a result of plant growth and increasing the root system, as well as increasing vital activities and their various secretions at the end of the growing season 25).

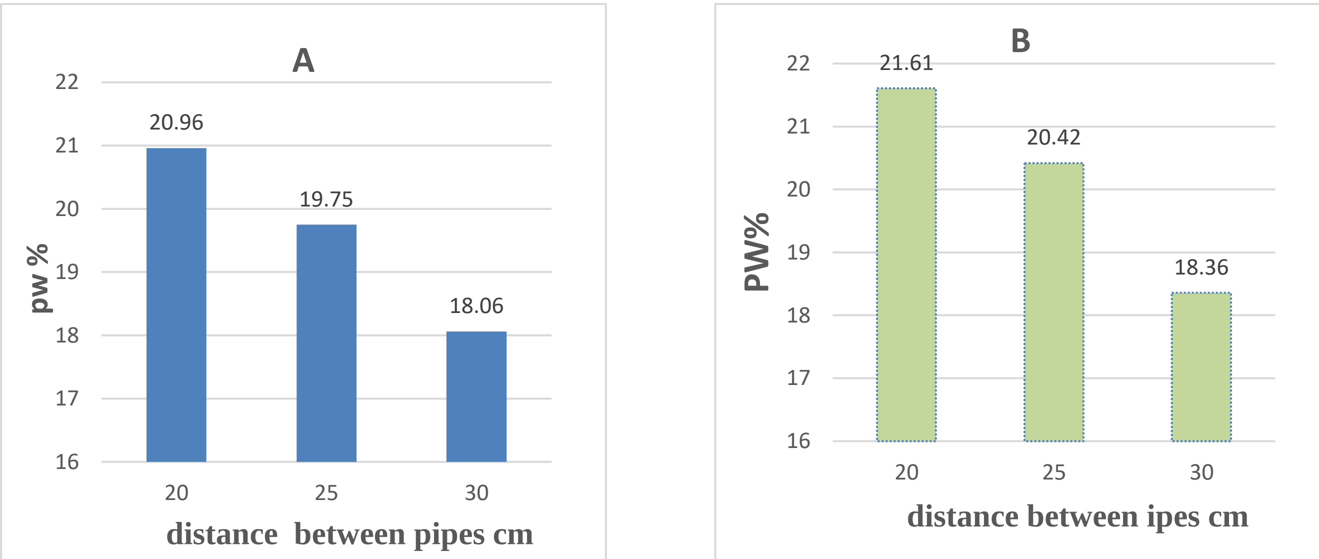
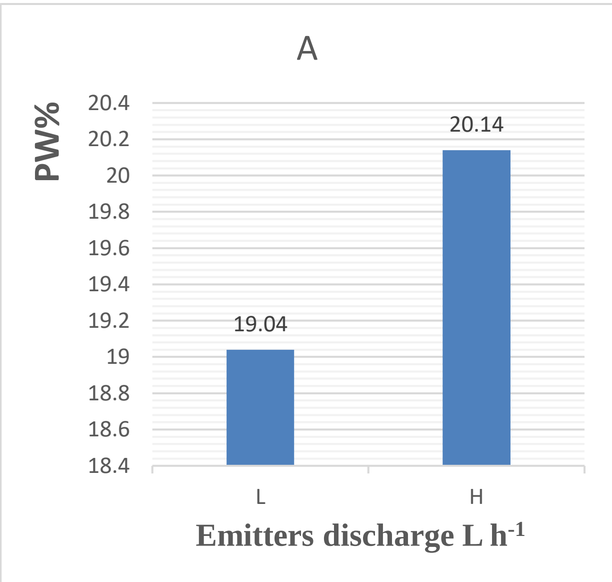


Figure 2. Effect of distance between emitters (cm) on soil moisture content values (%) Mid (A) and end (B) growing season.

The results show that there is a significant effect of the emitter discharge factor on moisture content values (PW) at the beginning and end of the growing season. When comparing these transactions, significant differences appeared between all transactions at the beginning and end of the growing season (Figure 3), at the beginning of the growing season, the highest value of the transaction was recorded (8 liters hour^{-1}) and was 20.14%, while the transaction (5 liter hour^{-1}) recorded a value of 19.04%, with a decrease of 5.66% compared to the transaction (5 liters hour^{-1}). At the end of the season, the values were 20.77%, and 19.83% for transactions of 8.5 liters per hour^{-1} respectively. An increase in moisture content is observed by increasing the discharge of emitters within the limits of the values of the experimentally used discharges due to the increase in the diameter of the wet surface area near the emitters as a result of the increased movement of water in the horizontal direction at the expense of the vertical movement downward by the effect of gravity, which in turn leads to an increase in the area of the horizontal wetting front (12).

On the other hand, the results generally show in Figure 3 that there is an increase in PW values % at the end of the growing season compared to the middle of the season and for all transactions with an increase of 3.12%, 4.14% for transactions 8.5 liters per hour^{-1} respectively. The reason for the increase in moisture content at the end of the growing season is due to the increase in the size of the vegetative system, which leads to an increase in the coverage area of the soil surface, which reduces evaporation, as well as due to the growth and spread of roots, which in turn improves soil construction and increases the ability of the soil to retain water by reducing the capillary movement upwards, which in turn reduces the water lost by surface evaporation, as well as a result of lower temperatures at the end of the growing season compared to the middle of the growing season.



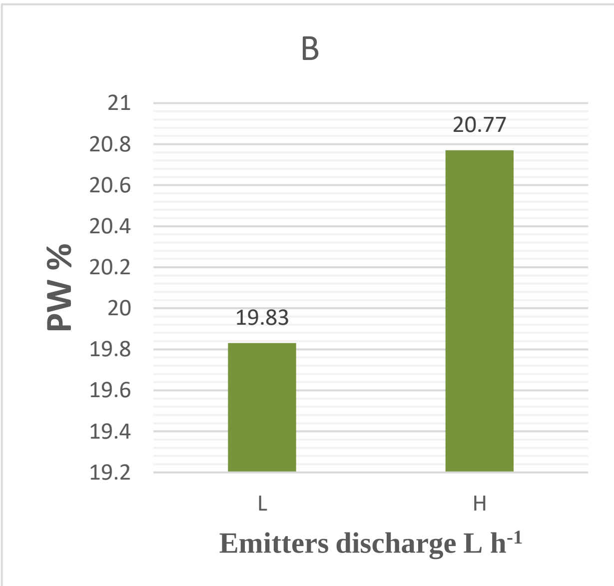
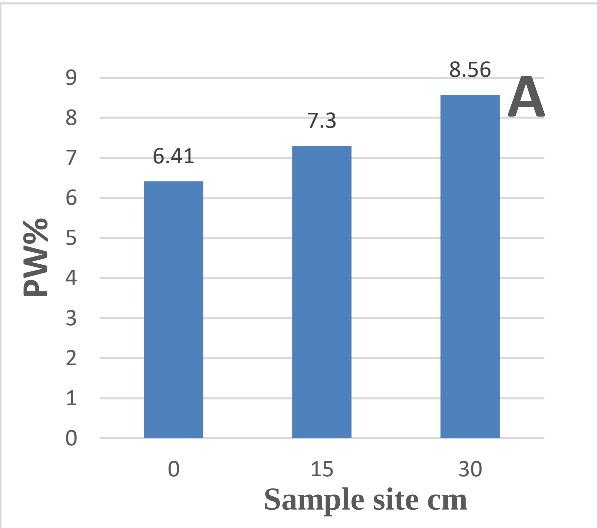


Figure 3. Effect of drip drainage (1-liter hour) on soil moisture content values (%) mid(A) and end (B) growing season.

The results of the statistical analysis show that there is a significant effect of the horizontal distance factor from the drip source on the values of soil moisture content (PW) in the middle and end of the growing season. When comparing these coefficients, significant differences appeared between all transactions in the middle and end of the growing season (Figure 4, Table 1), in the middle of the growing season, the transaction recorded 0 (below the source of the drip) the highest values and was 20.66%, followed by the transaction (horizontal distance 15 cm), which recorded a value of 19.58%, while the transaction (horizontal distance 30 cm) was given the lowest values of 18.53%, but at the end of the season, the values reached 21.37%, 20.29%, 19.23% for transactions 0, 15, 30 cm respectively The reason for the decrease in humidity horizontally when moving away from the drip source is due to the nature of the movement of water in the case of drip irrigation, in which unsaturated movement prevails and decreases towards the boundaries of the humidification front, which is located at the far distance from the drip source (22). When comparing the mid-season and the end of the growing season, the results in Figure 4 show that there is an increase in the values of PW % for the transactions at the end of the season compared to the middle of the season, the increased rate was 3.43%, 3.62%, and 3.77% for the transactions 0, 15 and 30 cm respectively. The reason is due to the effect of the close distance between the field pipes that works to fully moisten all the space between the pipes in the form of a terrace with moisture homogeneity (13). The reason may be attributed to the decrease in moisture content while moving away from the emitter in the horizontal direction to the movement of water according to the hydraulic slope arising from the difference in moisture tension between the near and far points from the emitter, as the tension increases by moving away from the emitter and increasing the distance between the field pipes (5).



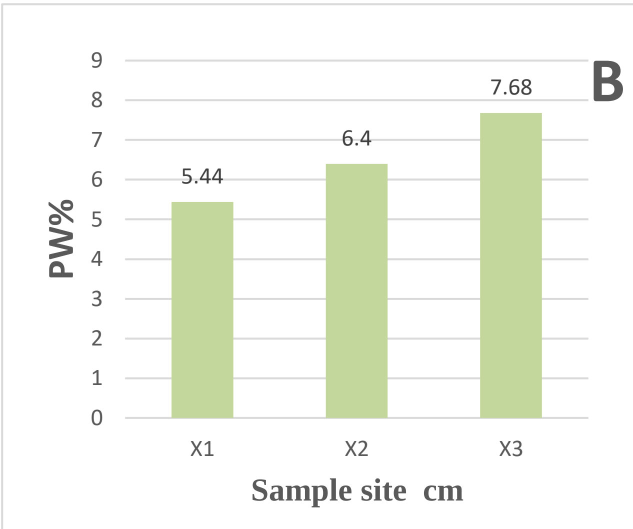
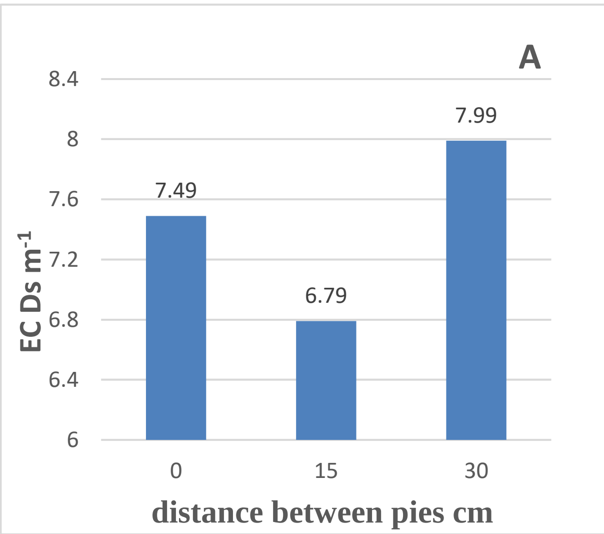


Figure 4. Effect of Sampling Site (Horizontal Distance from Marz Center) on Soil Moisture Content Values (%) Mid (A) and End (B) Growing Season.

The results of the statistical analysis show that there is a significant effect of the distance factor between field pipes on the electrical conductivity values in the middle and end of the growing season. In the middle of the growing season Figure 5, the treatment exceeded 15 cm and recorded the lowest values of 6.79 Ds m^{-1} with significant differences compared to the two coefficients 0 cm which recorded 7.49 Ds m-1, and 30 cm which gave the highest values by 7.99 Ds m^{-1}. With an increase of 9.34%, 17.67% for the two transactions 0 and 30 cm compared to the treatment of 15 cm. At the end of the growing season, the values were 6.53, 5.92, and 7.07 Ds m^{-1} for coefficients 0, 15, and 30 cm respectively. The reason for the low electrical conductivity values is due to the lack of distance between the field pipes as a result of the increase in the rate of moisture content in the surface layer of the soil, which led to an increase in the size of the wet area and the selective area, which in turn leads to an increase in the movement of salts associated with the movement of water vertically and horizontally towards the borders of the humidification fronts (1). On the other hand, the results generally show (Figure 5) that the lowest values of the electrical conductivity were at the source of the drip and increased by moving away from it horizontally and with significant differences in the middle and end of the growing season and for all transactions, and the reason for this is due to the high moisture content as well as the increase in the speed of water movement at the drip source and their decrease by moving away from it and thus leads to an increase in the dilution of salts and raising the efficiency of washing, which leads to a reduction in the values of electrical conductivity under the emitter directly, while the movement of water is slow As well as the low moisture content at the halfway between the pipes due to the increase in the distance between the pipes, which leads to a decrease in the process of dilution of salts in addition to reducing the efficiency of salt washing in the soil body (29). The convergence of the field pipes also leads to an increase in the speed of convergence of the two humidification fronts between the two adjacent field pipes, which in turn leads to an increase in soil moisture in different directions, which leads to an increase in the efficiency of washing salts in the soil pot and displacing it away from the root zone (24).



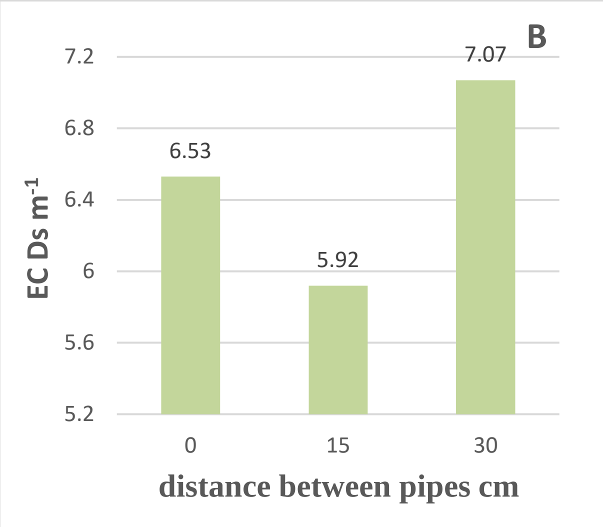


Figure 5. Effect of Pipe FigureDistance (cm) on Conductivity Values (Ds m^{-1}) Mid (A) and End (B) Growing Season.

The results of the statistical analysis show that there is a significant effect of the distance factor between the emitters on the values of the electrical conductivity of the soil (EC) at the middle and end of the season. When comparing these coefficients in the middle of the season, there were significant differences (Figure 6), as the 20 cm transaction excelled and recorded the lowest values, which were 6.55 decisions m-1, followed by the 25 cm transaction that recorded a value of 7.52 Ds m^{-1}, while the 30 cm transaction gave the highest values of 8.20 Ds m^{-1} with an increase of 14.80%, 25.19% for the two treatments 25 and 30 cm compared to the 20 cm transaction. At the end of the growing season, the values were 5.79, 6.57, and 7.68 Ds m^{-1} for coefficients of 20, 25, and 30 cm respectively. The reason for the increase in the values of electrical conductivity at a distance of 30 cm is due to the lack of complete moisture interference in the humid area as a result of the spacing of the distances between the emitters, which in turn led to an increase in the evaporation of water from the edges of the humid area and an increase in the percentage of salts in it compared to the distances of 20, 25 cm (28). The reason for the low values of electrical conductivity by the lack of distance between the emitters is due to the nature of the moisture distribution as well as the increase in the movement of water as a result of the increase in the amount of water added to the confined space between the emitters, which in turn facilitates the process of washing salts and keeping them away from the area of spread of roots and this is consistent with (2) who showed that the concentration of salts and their collection increases with increasing distance between emitters. On the other hand, the results generally show (Figure 2) that there is a decrease in the values of electrical conductivity at the end of the season with a decrease of 11.60%, 12.63%, 6.34% for transactions 20, 25, and 30 cm respectively compared to the middle of the growing season. The reason for this decrease is due to repeated irrigation operations during the growing season and the accompanying washing and displacement of salts towards the outer edges away from the area of spread of roots, in addition to increasing plant growth, as well as large root system and salt absorption and the accompanying increase in water conductivity (15).

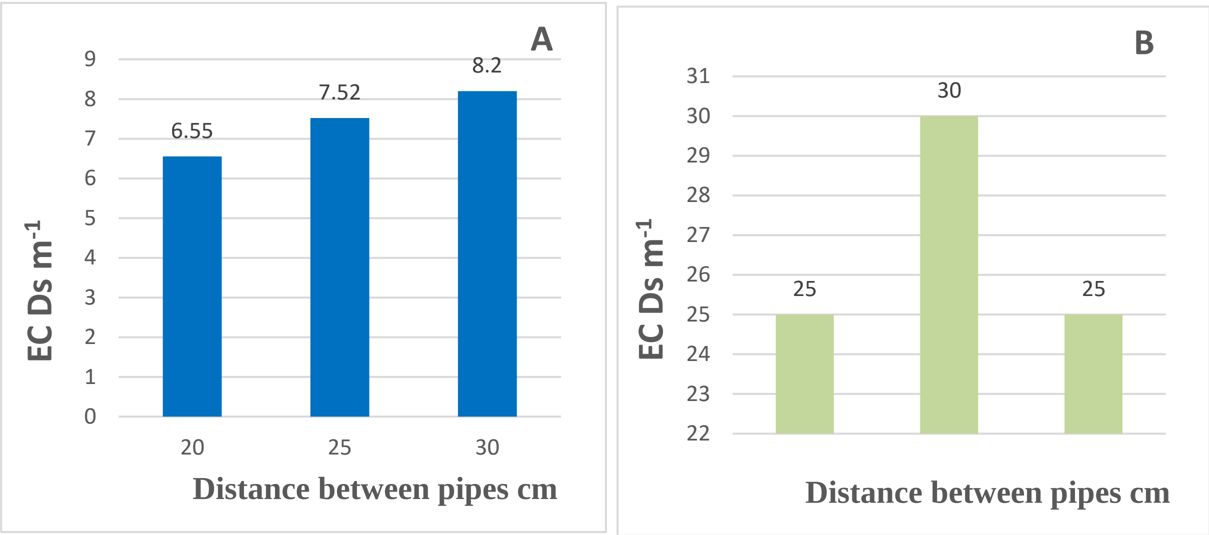


Figure 6. Effect of distance between emitters (cm) on soil conductivity values (%) Mid (A) and end (B) growing season.

The results of the statistical analysis show that there is a significant effect of the emitter discharge factor on the electrical conductivity values in the middle and end of the growing season. When comparing these coefficients, there were significant differences between all the transactions (Figure 7), as in the middle of the growing season, the 8 liter-hour transaction recorded the lowest value and was 7.07 dS^{-1} while the transaction recorded the highest value by 7.78 Ds m^{-1} with an increase of 11.31% compared to the transaction (8 liters $hour^{-1}$). At the end of the growing season, the values were 6.87 and 6.14 Ds m^{-1} for coefficients of 5.8 liters per $hour^{-1}$ respectively. The reason for the high values of electrical conductivity with low drip discharge is due to the lack of efficiency of salt washing due to the low moisture content and the accompanying slow movement of water and salts away from the drip source, which leads to high electrical conductivity values due to the accumulation of these salts within the limits of the humidification front, either the reason for the decrease in electrical conductivity by increasing the discharge of emitters to increase the movement of irrigation water in the horizontal direction by increasing the unsaturated water conductivity (3,12). As the results show in general (Figure 7) there is a decrease in the values of electrical conductivity at the end of the growing season compared to the middle of the season and for all transactions with a decrease of 11.63% and 13.15% for coefficients 8, 5 liters per hour $^{-1}$ respectively. The reason for this is due to the continued washing of salts and their vertical displacement towards the outer edges of the humidification front, especially at the source of drip, in addition to the growth and spread of roots, which works to reduce the apparent density of the soil and increase the water conductivity and thus increase the efficiency of salt washing, in addition to the high moisture content at the end of the season as a result of low temperatures, as well as the decrease in the evaporation process as a result of increasing the surface coverage of the soil due to the large vegetative system of the plant (17).

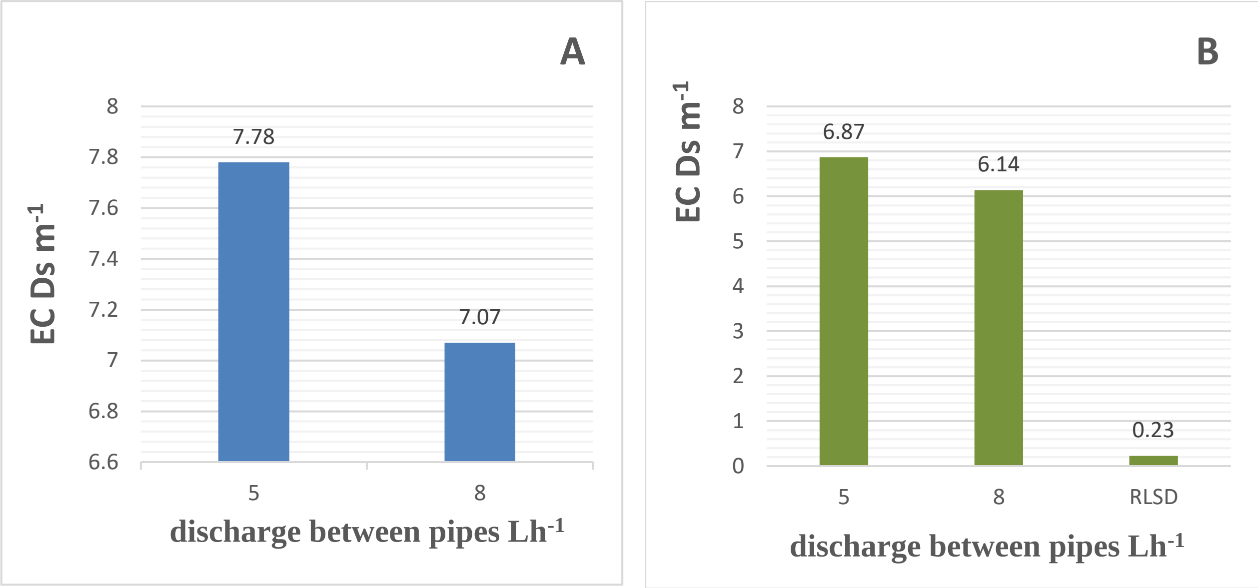
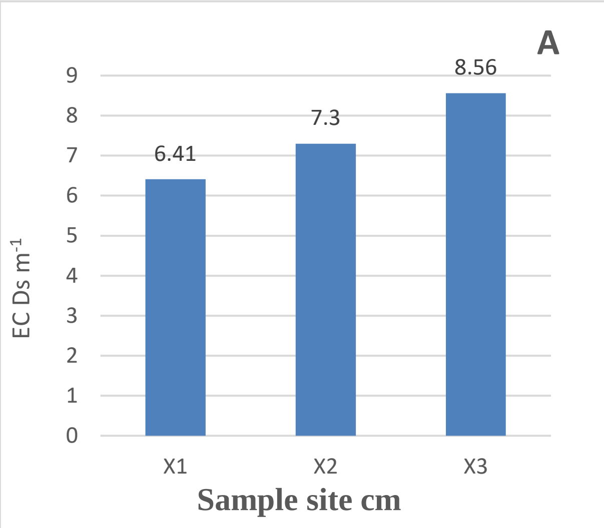


Figure 7. Effect of emitter discharge (liter hour-1) on soil conductivity values (%) mid(A) and end (B) growing season.

As for the effect of the sampling location according to the horizontal distance from the drip source, which was expressed as (distance 0 below the drip source), (horizontal distance 15 cm), and (horizontal distance 30 cm), the results appeared in (Figure 8) there is a significant superiority of the 30 cm treatment, which recorded the highest values in the middle of the growing season by 8.56 Ds m^{-1}, followed by the 15 cm treatment which recorded 7.30 decisions M^{-1}, while the 0 treatment recorded the lowest values and was 6.41 Ds m^{-1}. While at the end of the growing season, the values were 5.44, 6.40, and 7.68 Ds m $^{-1}$ for coefficients 0, 15, and 30 cm respectively. It is noted that there is a decrease in the values of electrical conductivity at the end of the growing season by 15.13%, 12.32%, and 10.28% compared to the middle of the growing season, and the reason for this is the frequent washing of salts, which leads to their displacement horizontally and vertically towards the outer edges of the wet area, specifically at the drip source, as well as increasing the growth and spread of roots, which helps to improve the physical properties of the soil represented by reducing the bulk density as well as raising the water conductivity and thus leads to an increase in salt washing (31). The results generally show that the salt distribution increases horizontally away from the drip source as a result of washing salts during irrigation operations for the soil near the drip source due to the high moisture content (Figure 4), which in turn leads to the movement and displacement of salts vertically and horizontally away from the drip source and this is consistent with Sharmiladevi et al.,(27) as they noticed that the salt concentration decreases at the horizontal distance near the drip source and increases with distance from it, and this is because the soil near the source of the drip Drip receives more quantities of irrigation water than distances far from the drip source, which in turn leads to increased washing and displacement of salts to sites far from the drip source, as well as a result of a gradual decrease in moisture content.



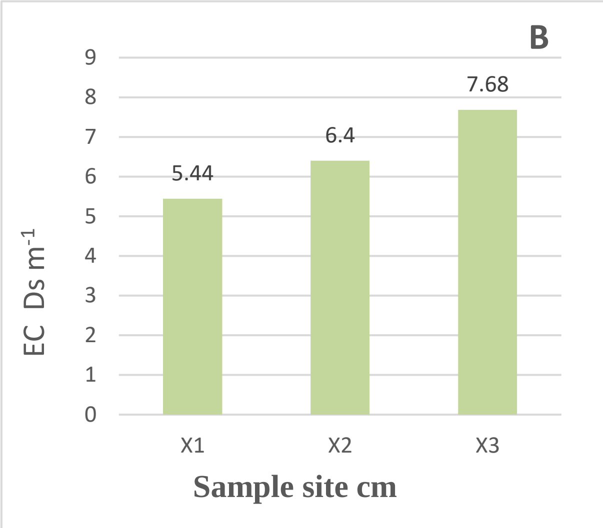


Figure 8. Effect of Sampling Site (Horizontal Distance from Al-Marz Center) on Soil Conductivity Values (%) Mid (A) and End (B) Growing Season.

Conclusion

The study was carried out at the site of the Agricultural Research Station of the University of Basra to evaluate the effect of the distance between the double field pipes and the distance between the emitters and the emitter discharge on the moisture and salt distribution in the soil sector under the drip irrigation system. The results of the research concluded that the moisture content increases with the decrease in the distance between the double pipes, the distance between the emitters, and the increase in discharge. Thus, the values of electrical conductivity decrease as a result of the confluence and overlap of the two hydration fronts, and the movement of salts is far from the center of the measuring, thus moving away from the plant and its effect decreases, and we get better production.

Conflict of interest

The authors declare no conflict of interest.

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