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EFFECT OF LATERAL POSITION IN FURROW ON MOISTURE DISTRIBUTION IN CLAYEY SOIL

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ABSTRACT

The effect of lateral position in furrow on moisture distribution pattern was studied in clayey soil under planted corn crop.

There are two different lateral positions used in the experiment; up-hill and down-hill under three soil water contents (SWC): 20%, 29% and 35%. In case of up-hill position, the maximum water volumes were found in third and fourth layers for all treatments in Y-direction, while the maximum were found in first and second layers in X-direction. Also, for the vertical Y-direction, the water moved further vertically by increasing soil water content.

In case of down-hill position lateral, the maximum water volume was found in third and fourth layers for all treatments in Y-direction, also found in third and fourth layers in X-direction. A saturated zone below the drip line was obtained only for the highest water content of soil. The total applied water volume in the first four layers increased with decreasing the soil water content in the last two layers. Decreasing in the soil water content allows more water to distribute in the horizontal direction, while increasing in the soil water content allows more water to distribute in the vertical direction.

INTRODUCTION

Moisture and salt distribution patterns are discussed in many previous papers due to large scale of irrigation systems, but here in this paper the moisture and salt distribution patterns are studied from a new point of view. Many researches discussed moisture and salt distribution patterns in drip irrigation system under emitters and lateral or in furrow irrigation system individually. This paper discusses the moisture and salt distribution patterns under both systems in the same time.

Moisture and salt distribution patterns are factors affecting on the root distribution system in the soil then finally the plant production. Lateral up-

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hill and down-hill positions in furrow are studied to ensure good moisture distribution patterns in the soil, especially for planting corn crop in furrows.

Corn crop is economically important in Egypt. It is used in many purposes such as; animal feeding, extracting oil and baking.

The main objective of the present work was to study the effect of up and down-hill position laterals in furrow on the moisture and salt distribution pattern and maintaining crop productivity under drip irrigation system.

Kahlon et al., 2004 reported that the moisture distribution pattern in rhizosphere under drip and furrow irrigation under drip irrigation was maximum in the surface soil layer (0-15 cm) and minimum in the bottom layer (45-60 cm), whereas in furrow irrigation, minimum moisture content was observed at the surface soil layer (0-15 cm) and maximum at the bottom layer (45-60 cm). Also they found that the salt distribution pattern in the rhizosphere under drip irrigation indicated that minimum salt concentration occurred beneath the emitter (which was also the base of plant) and increased with the distance from emitter, both along and across the row. In drip irrigation, the salts moved away from the rhizosphere and concentrated around the periphery of plant roots. Under furrow irrigation, however, maximum salt concentration was observed near the plant base and decreased as the distance increased. ***Koon et al., 1990*** investigated the effect of drip discharge rate on the water content distribution beneath a crop of sugar cane and they found that increasing the discharge rate resulted in an increased lateral movement of water and a decrease in the wetted depth, in agreement with the results of the laboratory experiment of ***Li et al., 2004*** for determining the geometry of the wetted volume under point source irrigation. ***Springer. 2000*** stated that infiltration and subsequent distribution of water and solutes under cropped conditions is strongly dependent on the irrigation method, soil type, crop root distribution, and uptake patterns and rates of water and solutes. He added that fertigation with poor quality water can lead to accumulation of salts in the root zone to toxic levels, potentially causing deterioration of soil hydraulic and physical properties. The high frequency of application under drip irrigation enables maintenance of salts at tolerable levels within the rooting zone. ***Badr et al., 2007*** indicated that the absence of a saturated zone can be obtained with conventional dripper discharges, depending on the water amount applied, the plant water uptake, and the soil hydraulic properties. ***Lubana et al., 2001*** reported that the overall wetted area, delimited by the wetting front was largest for the 2 l/h dripper, and smallest for the 8 l/h practically under subsurface drip irrigation.

MATERIALS AND METHODS

Experimental site

Experiments were carried out at experimental farm of the irrigation unit, Agricultural Engineering Department, Faculty of Agriculture, Cairo University (E 30°5', N 31°22', altitude 22.05 m). The total area of the field is equal to 5451.6 m^2 (1.298 fad.)

Soil characteristics

Soil bulk density and field capacity and some chemical analysis of the experimental soil is listed in Tables 1 and 2.

The soil analysis had been effectuated at Reclamation and Development Center for Desert Soils, Faculty of Agricultural-Cairo University

Table (1): Bulk density and field capacity of the experimental soil

Soil moisture characteristics		
Field capacity % per volume	:	40
Permanent wilting point % per volume	:	16
Available water % per volume	:	24
Bulk density g/cm^3	:	1.31
Texture	:	clayey

Table (2): Some soil chemical analysis of samples.

Depth cm	pH	EC ds/m	HCO_3^- me/L	CL^- me/L	So_4^{--} me/L	Ca^{++} me/L	K^+ me/L	Mg^{++} me/L	Na^+ me/L	SAR
00 – 20	7.74	2.43	1.0	3.6	19.84	7.8	1.14	6.4	9.10	1.13
20 – 40	7.69	1.92	0.9	3.0	15.9	5.6	0.82	5.4	7.98	1.20
40 – 60	7.81	1.78	0.8	3.2	13.62	4.0	0.82	5.0	7.8	1.32

Climatic characteristics

The field is located in a region having zero mm average annual precipitation during the last 5 years, only about 0 % of the precipitation occurs during the growing season of corn (from August to December). The mean annual temperature is 20.8 °C with annual evaporation from a free water surface being 1116 mm.

Experimental treatments

In this study, three different soil water contents involved in this experiment; one of them when the soil reach 20% of soil water content ($SWC_{0.20}$), second when the soil reach 29% of soil water content ($SWC_{0.29}$) and third when the soil reach 35% of soil water content ($SWC_{0.35}$). all treatments at two different lateral positions (up-hill and down-hill lateral position) under discharge rate of emitter 4 liter/hour as a popular dripper used with surface trickle irrigation method.

The effect of lateral in down hill position appears to move the water up-ward by capillary force, but by insufficient volume of water to germinate the seeds. Therefore, in the beginning of experiment, the laterals were put on top of furrow until seeds germinated, then the laterals were moved down of furrow. This effect allows the roots to distribute in vertical direction. The corn crop was planting in September 2008 at top of furrow. The distance between drippers 50 cm and the distance between laterals 50 cm as distance between furrows as shown in figure (1).

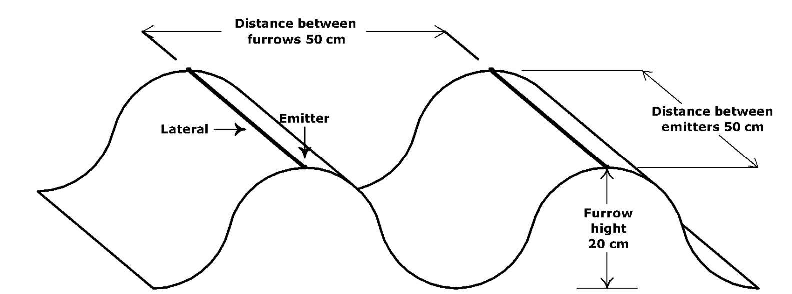

Figure (1): The furrows and laterals description.

The actual crop water requirement was estimated by multiplying reference evapotranspiration ET_o with crop coefficient K_c ($ET_c = K_c \times ET_o$) for different months based on crop growth stages using the model suggested by Penman-Monteith's formula (**Allen *et al.,* 1998**). Crop coefficient was found as 1.14 at full development of corn yield and evapotranspiration was found as 780.69 mm/period. Irrigation frequency was running after the soil has been reach the moisture content (depend on the moisture of each treatment) with well-water having EC 0.83 dS/m. The experiment was arranged in randomized complete block factorial design consisting of combinations of three volumes of water with two positions of lateral (up and down-lateral position) and was replicated three times in 2 m wide × 30 m long plots.

Data collection and measurements

To determine moisture content for each treatment, Theta-meter instrument was used. The location was defined according to its x, y and z coordinates with respect to the emitter. The sample locations with respect to the x-direction were taken at 5, 15, and 25 cm for all treatments. With respect to the y-direction, perpendicular to the drip line, the sample locations were taken at 5, 15 and 25 cm for all treatments. For each of these locations, moisture content was determined from different layer depths from soil surface, which were (0 – 10), (10 – 20), (20 – 30), (30 – 40), (40 – 50), and (50 – 60) cm.

Before starting the experiment, the initial moisture content of the soil was determined. It should be noted that the initial soil moisture content before water application ranged from 25.2 to 30.3 % by weight.

RESULTS AND DISCUSSION

Soil wetting patterns

Wetting patterns are characterized by x, y and z coordinates with respect to the emitter. The percentage of water found in the soil profile at different distances from the emitter at the end of irrigation time are given in tables 3 and 4. The main differences in the water content at the end of the irrigation for the three water requirements seem to be located away from the drip line. At the same amount of water applied, the highest water soil content ($SWC_{0.35}$) produced greater radius to depth ratio while the reverse was true for the lowest water soil content ($SWC_{0.20}$).

1. Effect of up-hill position lateral in furrow on water distribution

In the X-Z direction as indicated in table (3), the first and the second vertical layer (0 -10 cm) and (10 – 20 cm) had 46.6 % of the total applied water volume for the treatment $SWC_{0.20}$, while they had 44.8 and 45.6 % of the total applied water volume for other treatments of $SWC_{0.35}$ and $SWC_{0.29}$ respectively. The third and the fourth vertical layers (20 -30 cm) and (30 –

40 cm) had 32.7 % of the total applied water volume for the treatment $SWC_{0.29}$, while they had 30.9 and 31.9 % of the total applied water volume for other treatments of $SWC_{0.20}$ and $SWC_{0.35}$, respectively. The last two vertical layers (40 -60 cm) had 22.5 % of the total applied water volume for both treatments $SWC_{0.35}$ and $SWC_{0.20}$ respectively, while they had 22.4 % of the total applied water volume for the treatment of $SWC_{0.29}$.

In the Y-Z direction as indicated in table (3), the first and the second vertical layers (0 -10 cm) and (10 – 20 cm) had 33.4 % of the total applied water volume for the treatment $SWC_{0.20}$, while they had 32.4 and 31.6 % of the total applied water volume for other treatments of $SWC_{0.35}$ and $SWC_{0.29}$, respectively. The third and the fourth vertical layers (20 -30 cm) and (30 – 40 cm) had 39.8 % of the total applied water volume for the treatment $SWC_{0.29}$, while they had 39.6 and 38 % of the total applied water volume for other treatments of $SWC_{0.35}$ and $SWC_{0.20}$, respectively. The last two vertical layers (40 -60 cm) had 28.5 % of the total applied water volume for both treatments $SWC_{0.29}$ and $SWC_{0.20}$, respectively, while they had 27.9 % of the total applied water volume for the treatment of $SWC_{0.35}$.

Table (3): The percentage of water found in the soil profile of Up-hill position lateral in furrow

Depth, cm	Treatments		
	X – Z direction		
	$SWC_{0.35}$	$SWC_{0.29}$	$SWC_{0.20}$
0 -10	24.1	24.0	25.7
10 – 20	21.5	20.8	20.9
20 – 30	17.5	18.0	16.8
30 – 40	14.4	14.7	14.1
40 - 50	12.4	12.0	11.7
50 - 60	10.1	10.4	10.8
	Y – Z direction		
0 -10	13.6	13.6	14.7
10 – 20	18.8	18.0	18.7
20 – 30	21.6	21.8	20.7
30 – 40	18.0	18.0	17.3
40 - 50	15.3	15.0	15.0
50 - 60	12.6	13.5	13.5

Thus, in the Y-direction, the third and fourth layers had the maximum water volumes for all treatments (39.6, 39.8 and 38% for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$, respectively) because as illustrated in figure (2) the first and the second vertical layers had little soil volume back to furrow shape, but in the X-direction the first and second layers had the maximum water volumes for all treatments (44.8, 45.6 and 46.6% for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$, respectively) because all layers had the same volume of soil (fig. 2).

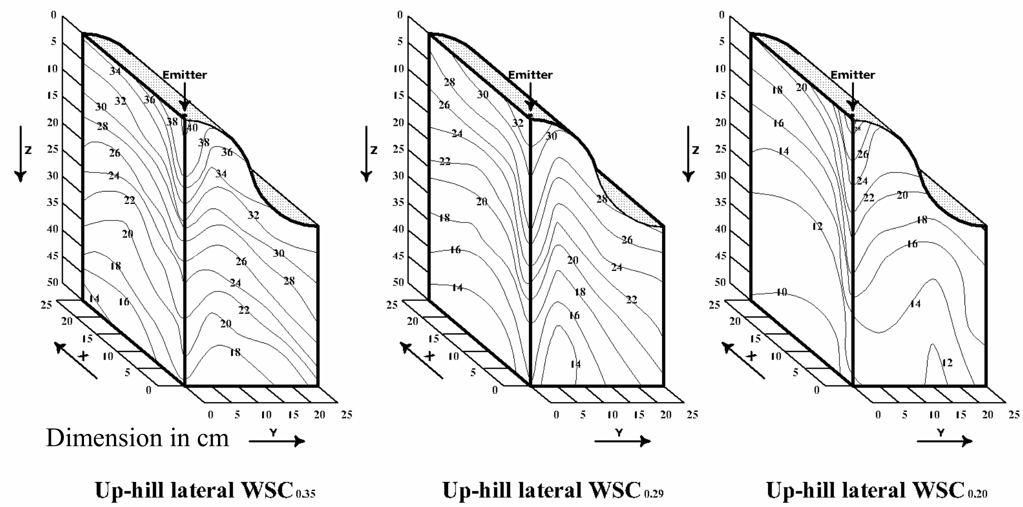

Figure (2): Distributions of water patterns in the up-hill position lateral in furrow for the three soil water contents.

A saturated zone below the drip line was not obtained for all treatments, and the water content at that point decreased with the decreasing SWC.

As shown in figure (2), the water content for all treatments in all vertical layers decreased until quarter of spacing between furrows then increased up to midpoint of spacing between furrows. Also for the vertical Y-Z direction, the water moved further vertically by increasing SWC.

2. Effect of down-hill position lateral in furrow on water content

In the X-Z direction as indicated in table (4), the first and the second vertical layer (0 -10 cm) and (10 – 20 cm) had zero % of the total applied water volume for all the treatments because the lateral in down-hill position in furrow (below the top of furrow by 20 cm). The third and the fourth vertical layer (20 -30 cm) and (30 – 40 cm) had 56.1 % of the total applied water volume for the treatment $SWC_{0.20}$, while they had 55 and 55.1 % of the total applied water volume for other treatments of $SWC_{0.35}$ and $SWC_{0.29}$, respectively. The last two vertical layers (40 -60 cm) had 45 % of the total applied water volume for the treatment $SWC_{0.35}$, while they had 44.9 and 43.9 % of the total applied water volume for the treatments of $SWC_{0.29}$ and $SWC_{0.20}$, respectively.

The results showed that the total applied water volume in the first four layers increased with decreasing the soil water content (SWC) in the last two layers. The total applied water volume decreased with decreasing the soil water content (SWC).

Table (4): The percentage of water found in the soil profile of down-hill position lateral in furrow.

Depth, cm	Treatments		
	X – Z direction		
	$SWC_{0.35}$	$SWC_{0.29}$	$SWC_{0.20}$
0 -10	-	-	-
10 – 20	-	-	-
20 – 30	28.0	28.7	29.8
30 – 40	27.0	26.4	26.2
40 – 50	24.1	24.5	23.8
50 – 60	20.8	20.4	20.1
	Y – Z direction		
0 -10	10.8	11.0	10.8
10 – 20	16.0	16.6	16.4
20 – 30	21.3	21.7	22.4
30 – 40	19.7	19.6	19.3
40 – 50	17.3	17.0	16.8
50 – 60	15.0	14.2	14.3

In the Y-Z direction, as indicated in table (4), the first and the second vertical layers (0 -10 cm) and (10 – 20 cm) had 27.2 % of the total applied water volume for the treatment $SWC_{0.20}$, while they had 26.8 and 27.6 % of the total applied water volume for other treatments of $SWC_{0.35}$ and $SWC_{0.29}$, respectively. The third and the fourth vertical layers (20 -30 cm) and (30 – 40 cm) had 41.7 % of the total applied water volume for the treatment $SWC_{0.20}$, while they had 41 and 41.3 % of the total applied water volume for other treatments of $SWC_{0.35}$ and $SWC_{0.29}$, respectively. The last two vertical layers (40 -60 cm) had 32.3 % of the total applied water volume for the treatment $SWC_{0.35}$, while they had 31.2 and 31.1% of the total applied water volume for the other treatments of $SWC_{0.29}$ and $SWC_{0.20}$, respectively.

It can be concluded that decreasing in the soil water content (SWC) allows more water to distribute in the horizontal direction, while increasing in the soil water content (SWC) allows more water to distribute in the vertical direction.

Thus, in the Y-direction, the third and fourth layers had the maximum water volume for all treatments (41, 41.3 and 41.7 % for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$, respectively), because as illustrated in figure (3), the first and the second vertical layers had little soil volume back to furrow shape. Also in the X-direction, the third and fourth layers had the maximum water volume for all treatments because the lateral down-hill n the furrow (fig. 3).

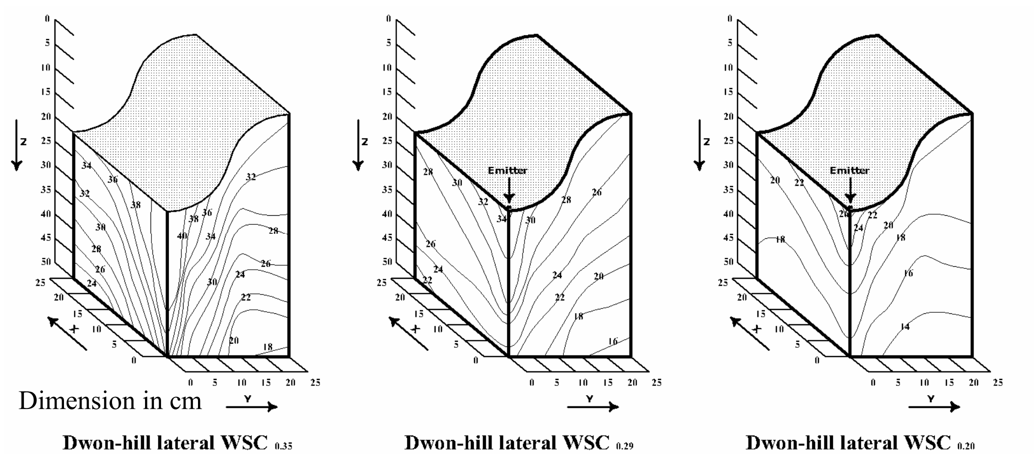

Figure (3): Distributions water patterns in the up-hill position lateral in furrow for the three soil water contents.

A saturated zone below the drip line was obtained only for the highest water content of soil ($WSC_{0.35}$) at a radius of 3.7 cm from the water source. For the two lower soil water contents, there was no saturated zone below the emitter, and the water content at that point decreased with the decreasing SWC. The wetting front depth below the drip line was 40, 19.1 and 17.1 cm for the $WSC_{0.35}$, $WSC_{0.29}$ and $WSC_{0.20}$, respectively.

The wetting front indicates the boundaries of the wetted soil volume. The location of the wetted fronts, contour lines 40, 38, 36 and 34 percent per weight, is presented in figure 3. Also tables (3) and (4) indicate the maximum width of the wetted area and its location under different SWC (soil water contents).

Table (5): Maximum width of the wetted area and its location under different SWC (water quantities added) in case of up-hill position lateral

Lateral position	SWC, %	Maximum width of wetted area, cm	Soil depth at maximum width, cm
Up-hill	20	14.2	10 – 20
	29	13.6	10 – 20
	35	13.2	10 – 20
Down-hill	20	25	0 – 10
	29	19.7	0 – 10
	35	15.2	0 – 10

Figures (1 and 2) and tables (3 and 4) indicate that water moved horizontally to greater width (14.2 cm for up-hill and 25 cm for down-hill position) for treatment $SWC_{0.20}$.

Corn yield

Yield reductions occurred with up-hill lateral position and the lowest reduction was under soil water content of 20% (Table 5). The highest yield was obtained from soil water content of 29% both in terms of seeds and shoots.

Table 5: Yield and yield components of corn plants as influenced by lateral position and soil water content.

Lateral position	SWC %	Number of plant per m^2	Plant length, cm	Number of leafs per plant	Number of ears per plant	Ear length, cm	Production, Kg/fad.
Up-hill	20	12	155 : 200	10 : 16	1 : 2	13 : 20	4011
	29	12	215 : 255	18 : 22	2 : 3	25 : 31	12948
	35	12	205 : 225	16 : 22	1 : 2	15 : 22	8926
Down-hill	20	12	160 : 210	12 : 18	1 : 2	15 : 21	4032
	29	12	225 : 270	22 : 26	2 : 3	25 : 33	14784
	35	12	215 : 240	18 : 24	1 : 2	18 : 27	9177

The maximum corn yield (14784 kg/fad.) was obtained under down-hill lateral position at 29% of soil water content while the lowest yield (4011 kg/fad.) was under up-hill lateral position at 20% of soil water content. Corn yield showed lateral position × soil water content interactions; yields were higher in down position laterals than in up position laterals with all soil water contents.

The lower corn yield observed with up-hill lateral positions in comparison with down-hill lateral positions was due to a reduction in both the seeds weight and the number of ears per plant. Meanwhile at the different soil water contents, the lower total yield was mainly attributed to a reduction in the mean ears weight. Plants grown with down-hill lateral positions gave more total yield than those grown with up-hill lateral positions because of good distribution of roots due to the good distribution of water leading to increasing in yield, especially at soil water content of 29%. Plant stress occurred at soil water content of 20%, while with soil water content of 35%, the root zone decreased because water availability was more in upper layers.

CONCLUSION

The objective of this work is to study the effect of lateral position on soil moisture distribution pattern. The experiment comprised two trickle lateral positions (up-hill and down-hill), and three soil water contents ($WSC_{0.35}$, $WSC_{0.29}$ and $WSC_{0.20}$).

The results showed that:

In case of up-hill position lateral:

- In the Y-direction the third and fourth layers had the maximum water volume for all treatments (39.6, 39.8 and 38% for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$ respectively), but in the X-direction, the first and second layers had the maximum water volumes for all treatments (44.8, 45.6 and 46.6% for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$ respectively).
- A saturated zone below the drip line was not obtained for all treatments, and the water content at that point decreased with the decreasing SWC.
- The water content for all treatments in the all vertical layers decreased until quarter of spacing between furrows then increased up to midpoint of spacing between furrows. Also for the vertical Y-Z direction, the water moved further vertically by increasing SWC.
- The water moved horizontally to greater width (14.2 cm) for treatment $SWC_{0.20}$.

In case of down-hill position lateral:

- In the Y-direction the third and fourth layers had the maximum water volume for all treatments (41, 41.3 and 41.7 % for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$ respectively). Also in the X-direction the third and fourth layers had the maximum water volumes for all treatments (55, 55.1 and 56.1 % for treatments $SWC_{0.35}$, $SWC_{0.29}$ and $SWC_{0.20}$ respectively)
- A saturated zone below the drip line was obtained only for the highest water content of soil ($WSC_{0.35}$) at a radius of 3.7 cm from the water source.
- The total applied water volume in the first four layers increased with decreasing the soil water content (SWC) in the last two layers. The total applied water volume decreased with decreasing the soil water content (SWC).
- Decreasing in the soil water content allows more water to distribute in the horizontal direction, while increasing in the soil water content allows more water to distribute in the vertical direction.
- The water moved horizontally to greater width (25 cm) for treatment $SWC_{0.20}$.

Corn yield:

- Corn yields in case of down-hill position lateral were 4032, 14784 and 9177 kg/fad. for treatments $SWC_{0.20}$, $SWC_{0.29}$ and $SWC_{0.35}$ respectively.
- Corn yields in case of up-hill position lateral were 4011, 12948 and 8926 kg/fad. for treatments $SWC_{0.20}$, $SWC_{0.29}$ and $SWC_{0.35}$ respectively.

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الملخص العربي

تأثير مكان خط التوزيع فى الرى بالتنقيط فى الخط على التوزيع الرطوبى في الأراضي الطينية

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يعتبر الري بالغمر بطريقة الرى بالخطوط من أفضل الطرق لزراعة محصول الذرة الشامية ولكنها تفقد الكثير من المياه ولما كانت طريقة الرى بالتنقيط من أفضل طرق الرى من حيث الحفاظ على المياه من الفقد فانه تم زراعة الذرة الشامية بنظام الرى بالتنقيط على خطوط وقد تم دراسة تأثير مكان خط التنقيط (على الخط وفى بطن الخط) على التوزيع الرطوبى في الأراضي الطينية. وقد أظهرت النتائج ما يلي:

في حالة خرطوم التوزيع أعلى الخط:

- في اتجاه Y كانت أقصى نسبة من حجم المياه الكلى المضاف يوجد في الطبقة الثالثة والرابعة في جميع المعاملات (39.6 , 39.8 , 38 % للمعاملات $SWC_{0.35}$, $SWC_{0.29}$, $SWC_{0.20}$ على الترتيب) بينما كانت في الطبقة الأولى والثانية في اتجاه X (44.8 , 45.6 , 46.6 % للمعاملات $SWC_{0.35}$, $SWC_{0.29}$, $SWC_{0.20}$ على الترتيب).
- لم تحدث أي حالة من حالات التشبع في جميع المعاملات تحت خط التنقيط.
- المحتوى الرطوبي في جميع المعاملات في الطبقات الرأسية يقل حتى الربع الأول من المسافة بين الخطوط ثم تزاد مرة أخرى حتى منتصف المسافة بين الخطوط. كذلك فان المياه تتحرك رأسياً بزيادة نسبة المحتوى الرطوبي للتربة
- كان أقصى عرض لتحرك المياه أفقياً هو 14.2 سم للمعاملة $SWC_{0.20}$.

في حالة خرطوم التوزيع في بطن الخط:

- في اتجاه Y كانت أقصى نسبة من حجم المياه الكلى المضاف يوجد في الطبقة الثالثة والرابعة في جميع المعاملات (41 , 41.3 , 41.7 % للمعاملات $SWC_{0.35}$, $SWC_{0.29}$, $SWC_{0.20}$

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على الترتيب) وكذلك كانت في الطبقة الثالثة والرابعة في اتجاه X (55 , 55.1 , 56.1 % للمعاملات $SWC_{0.35}$, $SWC_{0.29}$, $SWC_{0.20}$ على الترتيب).

- حدوث حالة واحدة من حالات التشبع تحت الخط في المعاملة $WSC_{0.35}$ بقطر 3.7 سم من النقاط.
- حجم المياه الكلى المضاف في الطبقات (0 – 40 سم) تزداد بنقصان المحتوى الرطوبى للتربة عكس ما يحدث في أخر طبقتين (40 – 60 سم) تقل بنقصان المحتوى الرطوبى للتربة.
- بنقصان المحتوى الرطوبى للتربة (SWC) يؤدي إلى انتشار المياه أفقياً بينما زيادة المحتوى الرطوبى للتربة (SWC) يؤدي الى انتشار المياه في الاتجاه الراسي.
- كان أقصى عرض لتحرك المياه أفقياً هو 25 سم للمعاملة $SWC_{0.20}$.

إنتاجية محصول الذرة:

- كانت إنتاجية محصول الذرة في حالة خرطوم التوزيع في بطن الخط 4032, 14784, 9177 كجم/فدان للمعاملات $SWC_{0.20}$, $SWC_{0.29}$, $SWC_{0.35}$ على التوالي.
- كانت إنتاجية محصول الذرة في حالة خرطوم التوزيع في أعلى الخط 4011, 12948, 8926 كجم/فدان للمعاملات $SWC_{0.20}$, $SWC_{0.29}$, $SWC_{0.35}$ على التوالي.