Horizontal and vertical distribution of soil moisture and salinity under the influence of distances and depths of subsurface drip lines of desert soil in southern Iraq

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Abstract

A field experiment was conducted during the 2018-2019 agricultural season in desert soil located in the southwest of Al-Diwaniyah province, southern Iraq, at latitude 31º 32' 47.20 north and longitude 44º 53' 40.90 east in order to study the horizontal and vertical distribution of soil moisture and salinity under the subsurface drip irrigation system. The experiment was designed according to the design of the nesting arrangement (Nasted design) with three replications. The experiment included the distances of the drip lines (50, 75 and 100 cm) and the depths of the drip lines (20 and 40 cm), in addition to the control treatment (surface irrigation treatment). An evaluation of the irrigation system was conducted before cultivation. The horizontal and vertical distribution of soil moisture and salinity was measured for the study parameters at distances (0,10,20,30,40,50) cm in the horizontal direction and at depths of (0,10,20,30,40) cm in the vertical direction and for the two phases at the beginning and end of the growing season .The results of the study showed an increase in the moisture content at the subsurface drip line and a decrease when moving away from it horizontally and vertically, in addition to a decrease in the moisture content with an increase in the distance between the drip lines, a decrease in the salt concentration at the drip source and an increase in the accumulation of salts by moving away from the drip line. In addition, the results showed that the best distance between the drip lines was 50 cm, as it gave the best moisture and salinity distribution of the soil volume.

Key words: subsurface drip irrigation, distances and depths of drip lines, moisture distribution, saline distribution.

التوزيع الافقي والعمودي لرطوبة وملوحة التربة تحت تأثير مسافات واعماق خطوط التنقيط تحت سطحي لتربة صحراوية جنوب العراق

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المستخلص :

نفذت تجربة حقلية خلال الموسم الزراعي 2018-2019 في تربة صحراوية تقع في الجنوب الغربي من محافظة الديوانية جنوب العراق على خط عرض 31º 32' 47.20 شمالا وخط طول 44º 53' 40.90 شرقا بهدف دراسة التوزيع الافقي والعمودي لرطوبة وملوحة التربة تحت نظام الري بالتنقيط تحت سطحي , صممت التجربة حسب تصميم الترتيب المعشش (Nasted design) بثلاث مكررات تضمنت التجربة مسافات خطوط التنقيط (50 و75 و100 سم) واعماق خطوط التنقيط (20 و40 سم) بالإضافة الى معاملة المقارنة (معاملة الري السيحي) , تم اجراء تقييم لمنظومة الري قبل الزراعة . تم قياس التوزيع الافقي والعمودي لرطوبة وملوحة التربة لمعاملات الدراسة وعلى مسافات (0,10,20,30,40,50) سم بالاتجاه الافقي وعلى اعماق (0,10,20,30,40) سم بالاتجاه العمودي وللمرحلتين في بداية ونهاية موسم النمو .اظهرت نتائج الدراسة زيادة المحتوى الرطوبي عند خط التنقيط تحت سطحي وانخفاضه عند الابتعاد عنه افقيا وعموديا بالإضافة الى ذلك انخفاض المحتوى الرطوبي مع زيادة المسافة بين خطوط التنقيط وانخفاض التركيز الملحي عند مصدر التنقيط وزيادة تراكم الاملاح بالابتعاد عن خط التنقيط . بالإضافة الى ذلك اظهرت النتائج ان افضل مسافة بين خطوط التنقيط 50 سم اذ اعطت افضل توزيع رطوبي وملحي لمقد التربة .

كلمات مفتاحية: الري بالتنقيط تحت سطحي , مسافات واعماق خطوط التنقيط ,التوزيع الرطوبي , التوزيع الملحي

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Introduction

Iraq is located in its central and southern parts within the conditions of a dry environment, where the average rainfall does not exceed 400 mm annually, where it is within the lands covered by desertification more than 90% of Iraq's lands are affected to one degree or another by desertification, to varying degrees, for several reasons, including: climate change,Decreased rainfall, misuse of natural pastures, overgrazing and urban sprawl at the expense of agricultural lands, the use of unsustainable farming methods and poor irrigation operations, and the low levels of surface running water for Iraq's rivers. (15th). lack of irrigation water is one of the most important factors affecting crop productivity. At the same time, there is an increasing demand from humanity on water resources, especially in dry and semi-arid areas. Irrigation agriculture is the largest consumer of water, especially that depends on surface irrigation, which is characterized by low irrigation efficiency, uneven water distribution, loss of quantities of irrigation water, as surface irrigation and deep infiltration. Therefore, the use of irrigation systems that save water and energy, reduce water losses and pollute the environment, and increase the yield is the reliable alternative (21,22). The main aim of any irrigation system is to provide an adequate and suitable bed for plant growth in the appropriate time, quantity and method in a methods that ensures homogeneous moistening of the effective root zone. The use of drip irrigation systems and adopting modern methods in agricultural irrigation management that help reduce water waste, improve production and achieve the highest efficiency of water and fertilizer use (20).(12) Subsurface drip irrigation (SDI) has been defined as the application of water below the soil surface by microirrigation emitters with a discharge of less than 7.5 L/h;The addition of water in small quantities and with high frequency in specific locations and areas in the field, few water merchandise, and high irrigation efficiency. The subsurface drip irrigation system is suitable in dry and semi-arid areas due to the low water loss by evaporation, surface runoff and deep permeation. It has been used for large areas in the United States of America and for several types of economic crops such as wheat, corn and feed crops such as Alfalfa , compared with other irrigation systems such as sprinkler and surface irrigation (1). The drip irrigation system depends on a basic principle of adding water in sufficient and semi-continuous quantities to the root growth area and distributed horizontally and vertically according to the type of soil. The design and proper management of subsurface drip irrigation systems requires accurate knowledge of moisture distribution around the drips to provide the appropriate and optimal distribution of water in the root zone of the plant without wetting the soil surface or leaching into groundwater (8).and to evaluate some engineering aspects of the surface and subsurface drip irrigation systems in clay soils between (17) that surface drip irrigation wets the soil surface, and then the water is distributed horizontally and vertically with depth in the form of a hemisphere whose dimensions are determined depending on the properties of the soil and Emitters' discharge average . As for the subsurface drip irrigation system, the shape of the wet area is closer to the ball, and the size of the wet soil and the surface area of the wet area are 46 and 62% larger compared to surface drip irrigation, respectively. (26), (3) and (25) mentioned that the dimensions of the wet area around the emitters for subsurface drip irrigation systems (radius of wet circumference, and the vertical wet distance above and below the drip line) are a function of soil texture and soil hydraulic properties. They indicated that the hydraulic properties of the soil have an effect on the wetted distance above the drip line and the depth of the drip line. One of the important aspects in planning and managing a subsurface drip irrigation system is the pattern of movement and distribution of moisture in the wetting area around the dripper, which has a major role in determining the depths of drip lines under the soil surface. The distance between the drip lines and the operating pressure of the system to deliver the amount of water needed to meet the water requirements of the crops (24 and 4). It was mentioned (10) that the vertical wetting front downward progression in sandy soil beds was greater than in the section of alluvial clay soils at the same average of added water, while there was a similarity in the rate of horizontal wetting front progress between the two soils.it also indicated that the highest values of moisture content of alluvial clay soils are located near the drip source.(Emitters).Emitters discharge is an influential factor in the horizontal and vertical moisture distribution (towards the bottom and up) around the emitters . (13) indicated that the horizontal movement from the emitters increased with the increase in the emitters discharge, while the vertical movement of water from the emitters with less drainage increased. The results of experiment (9) confirmed that the emitters with a discharge of 4 L .hour^{-1} gave an increase in the horizontal movement over the vertical movement by 6%.While the emitters with a discharge of 2.4 L. hour $^{-1}$ gave an increase in the vertical movement over the horizontal movement by 16% when placing the emitters at a depth of 0.30 m from the soil surface. (14) explained that predicting the moisture distribution pattern in the soil mound under the Emitters is difficult due to the complex and multi-directional nature of the water movement, as well as the frequency of irrigation, which is reflected in the complexity of the mathematical model to describe the movement and distribution of water from the emitters , so it is difficult to predict the behavior of water movement and distribution pattern.The problem of salinity is one of the soil problems in arid and semi-arid areas as a result of the presence of different percentages of salts in water sources, especially if the source was saline groundwater, in addition to the presence of percentages of salts in the soil originally due to drought conditions, increased rates of surface evaporation from the soil and the lack of water availability (7).Several factors affecting the accumulation and distribution of salts under the surface and subsurface drip irrigation system such as its texture, soil structure, the distance between emitters, the amount of water added, the salinity of the irrigation water, the salinity of the soil and the emitters drainage (7).This study aims to determine the best distribution of moisture and salinity in the root zone in the horizontal and vertical directions under a subsurface drip irrigation system in desert soil.

Materials and methods:

The field experiment was conducted in Al-Shanafiya sub-district / Al-Khasf area in the southwest of Al-Diwaniyah province in southern Iraq, 100 km from the center of Al-Diwaniyah city in desert soil. The site is located between latitudes 31º 32' 47.20 N and longitudes 44º 53' 40.90 E, at an altitude of 17.4 meters above sea level.The field soil was classified as a sedimentary soil with a sandy texture (Sandy loam; moderate medium, Typic, Torri fluevents) according to what was mentioned in (23).The field soil samples were randomly taken and collected in the form of a composite sample for depths of 0-20 and 40-20 cm. Then the samples were dried pneumatically, crushed and passed through a sieve with hole 2 mm in diameter, then a representative sample was taken from it and physical and chemical measurements were taken on it (11; 16) as shown in Table 1.

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Table 1. Some physical and chemical properties of field soil before cultivation.

properties	values
Sand (g. kg $^{-1}$)	**743**
silt(g. kg $^{-1}$)	**133**
Clay (g. kg $^{-1}$)	**124**
soil texture	**Sandy loam**
Bulk Density (mg-m^3)	**1.400**
Volumetric moisture content at 10 kPa (cm^3.cm^3)	**0.290**
Volumetric moisture content at 1500 kPa (cm^3.cm^3)	**0.062**
available water (cm3-cm3)	**0.288**
Organic matter (g. kg $^{-1}$)	**11.8**
Electrical Conductivity (DS.M^{-1})	**3.75**
pH	**7.2**
Carbonate minerals (g. kg $^{-1}$)	**271**

A subsurface drip irrigation system was used to irrigate the barley plant, and irrigation water was prepared from a well dug at the experiment location, and samples were taken from the irrigation water to determine the chemical properties of the water. According to the FAO classification for irrigation water (18) Table 2 shows the chemical properties of irrigation water, the type of water and the average of sodium adsorption.

Table 2. Chemical properties of the well water used in the experiment

Class	SAR	B	NO_3^-	Mg^{++}	Ca^{++}	K^+	Na^+	pH	EC dSm^{-1}	Water Source
				mmole L^{-1}						
C4S2	5.53	0.19	0.53	10.5	14.5	0.82	27.6	7.86	5.03	Well

The field experiment was conducted to test the distances and depths of subsurface drip lines in the horizontal and vertical distribution of soil moisture and salinity. The distances included 50, 75 and 100 cm, and drip lines depths were 20 and 40 cm, in addition to the control treatment and represented the surface irrigation system. The experiment was designed according to the design of the nesting arrangement. (Nasted design) and three repetitions.The data were statistically analyzed and the averages were compared with the least significant difference (LSD) test at the 5% probability level using the GenStat program. The US Rain Bird XFS Drip line is designed for sub-surface drip irrigation with a copper shield technology that protects the emitters from root penetration and is enhanced with self-cleaning capacity with a constant discharge of 3.5 L/h and the distance between the emitters. and another 30.5 cm, The seeds of barley, Buhuth 244, were sown on 5/12/2018 with a seed quantity of 120 kg H-1 in the form of lines with a distance of 20 cm between them. Compound DAP fertilizer was added 18:46:0 by adding 160 kg H-1 during cultivation, as well as urea fertilizer (46 %N) at an average of 40 kg ha-1 in two batches, the first at cultivation and the second at flowering, and the weeds were controlled manually.Soil samples were taken 24 hours after the irrigation process and in two stages at the beginning and end of the growing season harvested by Auger, in the horizontal and vertical directions. The moisture content of the soil models was estimated by the gravimetric method as mentioned in (2). Soil salinity was measured by making (1:1) soil: water extract and measuring the electrical conductivity of soil samples .

Results and discussion :

Distribution of the volumetric moisture content of a subsurface drip irrigation system:

Figures 1, 2, and 3 show the effect of the distances and depths of subsurface drip lines on the volumetric moisture distribution in the soil profile horizontally and vertically after 24 hours of irrigation at the beginning of the growing season for barley. Homogeneity of moisture (Fig. 1), for depths of 20 and 40 cm, respectively, The volumetric moisture content values converged with each other and amounted to 0.25, 0.26, 0.24, 0.27, 0.28 and 0.29 cm 3 cm-3 at a depth of 20 cm and for horizontal distances 0, 10, 20, 30, 40 and 50 cm, respectively, with a standard deviation coefficient of 0.01 .It is noticed that the value of the moisture content at the position of the emitters approached the value of the moisture content of the field capacity, but the average values of the moisture content at the middle. The distance between the drip lines decreased from the field capacity value by 12%, which indicates a decrease in perfusion sufficiency. The values of the volumetric moisture content increased in the treatment of distance 50 cm and depth 40 cm and for the same horizontal distances above, which reached 0.38, 0.33, 0.35, 0.30, 0.32 and 0.36 cm 3 cm-3, respectively, while maintaining consistency in the distribution of moisture content with a coefficient of Standard deviation of 0.02 .These results show that the average values of the moisture content increased from the value of the moisture content of the field capacity by 17.2%, which means an increase in the sufficiency of irrigation. Figure 2 shows the distribution of moisture content for the treatment of the distance between the drip lines 75 cm and the depths 20 and 40 cm. The main objective of any irrigation system is to provide sufficient and appropriate moisture for plant growth at the appropriate time, quantity, and method in a manner that ensures homogeneously effective root zone moistening. The use of drip irrigation systems and modern methods of agricultural irrigation management help reduce water wastage, improve production, and achieve higher efficiency of water and fertilizer use (20). (12) Subsurface drip irrigation (SDI) is defined as the addition of water under the soil surface by micro-irrigation emitters with a discharge of fewer than 7.5 L/h, i.e. adding water in small quantities with the high frequency in specific locations and areas in the field, low water volumes, and high perfusion efficiency. The subsurface drip irrigation system is suitable in dry and semi-arid areas due to its low water loss by evaporation, surface irrigation, and deep permeation. It has been used for large areas in the United States of America and for several types of economic crops. Such as wheat, corn, and feed crops such as Alfalfa, compared with other irrigation systems such as sprinkler irrigation and surface irrigation (1). Therefore, knowing the patterns and distribution of moisture is very important to determine the amount and average of water addition, the specifications of the distribution network, the type of emitters and the distance between them. The drip irrigation system depends on a basic principle, which is to add water in sufficient and semi-continuous quantities to the root growth area, and it is distributed horizontally and vertically according to the type of soil. Therefore, knowing the patterns and distribution of moisture is very important to determine the amount and rate of water addition, the specifications of the distribution network, the type of droplets and the distance between them. The design and proper management of subsurface drip irrigation systems require accurate knowledge of moisture distribution around the drips to provide the appropriate and optimal distribution of water in the root zone of the plant without wetting the soil surface or leaching into groundwater (8).The results of the figure showed the inconsistency of the distribution of

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moisture content, as the values differed due to the increase in the distance between the drip lines, the highest values were near the drip line and it decreased at the midpoint of the distance between the drip lines, so the values of the moisture content were 0.25, 0.22, 0.14, 0.13, 0.15 and 0. 30 cm 3 cm-3 for horizontal distances 0, 15, 30, 45, 60 and 75 cm, respectively, for a depth of 20 cm, It is noticed that at the middle of the distance between the drip lines, the irrigation adequacy decreased by approximately 53.4% from the value of the moisture content of the field capacity, which indicates a watering deficit that does not meet the water requirements of the barley plant grown at the middle of the distance between the drip lines.The volumetric moisture content increased at the depth of 40 cm, reaching 0.30, 0.25, 0.19, 0.15, 0.23 and 0.30 cm 3 cm-3 for the same horizontal distances, respectively, with a standard deviation coefficient of 0.05.

It is noticed at the position of the emitters that the sufficiency of irrigation increased by 3.44%, but at the middle of the distance between the drip lines, the sufficiency of irrigation decreased by 41% from the field capacity. Figure 3 shows the distribution of volumetric moisture content for treatment of 100 cm between drip lines and for depths of 20 and 40 cm. The volumetric moisture content at 20 cm depth was 0.22, 0.15, 0.10, 0.10, 0.13 and 0.25 cm 3 cm-3 for horizontal distances of 0, 20, 40, 60, 80 and 100 cm, respectively, with a standard deviation coefficient of 0.03.It is noticed that along with the horizontal distance between the drip lines a decrease in the irrigation sufficiency by 18.9% at the position of the emitters, and by 65.5% at the midpoint of the distance between the drip lines, and this indicates a large irrigation deficit that does not meet the water requirements of the plants grown between the drip lines.At a depth of 40 cm, the moisture content values were 0.30, 0.25, 0.20, 0.19, 0.22 and 0.25 cm 3 cm-3 for the horizontal distances above, respectively, with a standard deviation coefficient of 0.04. It was found that the moisture distribution is inconsistent and there is a clear decrease in the moisture content at the middle of the horizontal distance between the drip lines, where the percentage of decrease in the perfusion sufficiency amounted to 32.7%. In addition, the moisture content at the surface decreased to less than 0.10 cm3 cm-3.

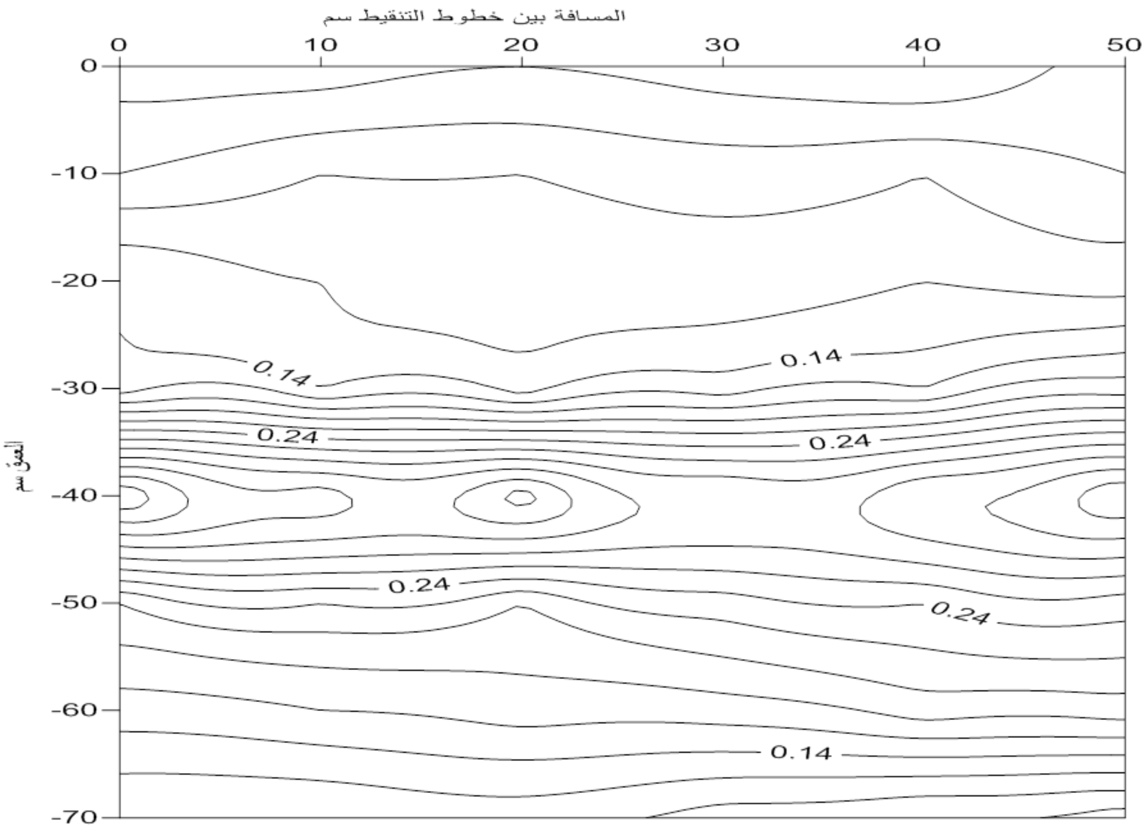
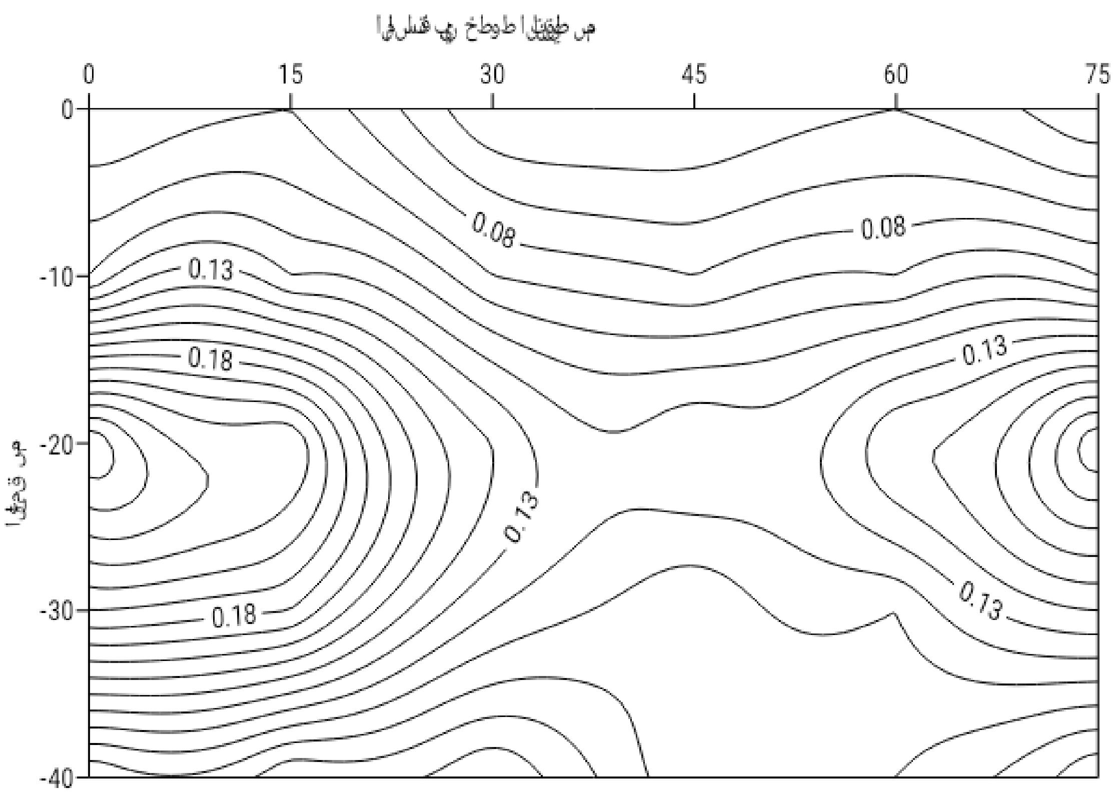


Figure 1. Distribution of the volumetric moisture content (cm 3 cm-3) for the treatment of the distance between drip lines 50 cm at depths 20 and 40 cm at the beginning of the growing season



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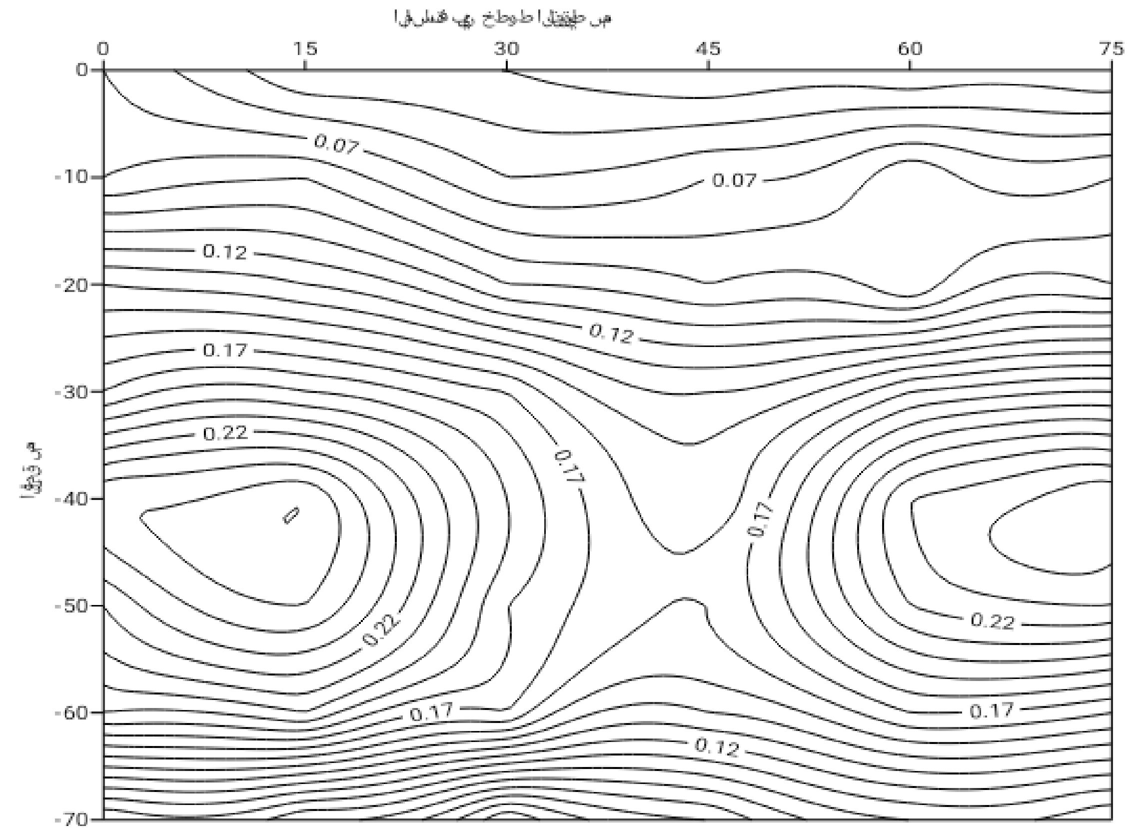
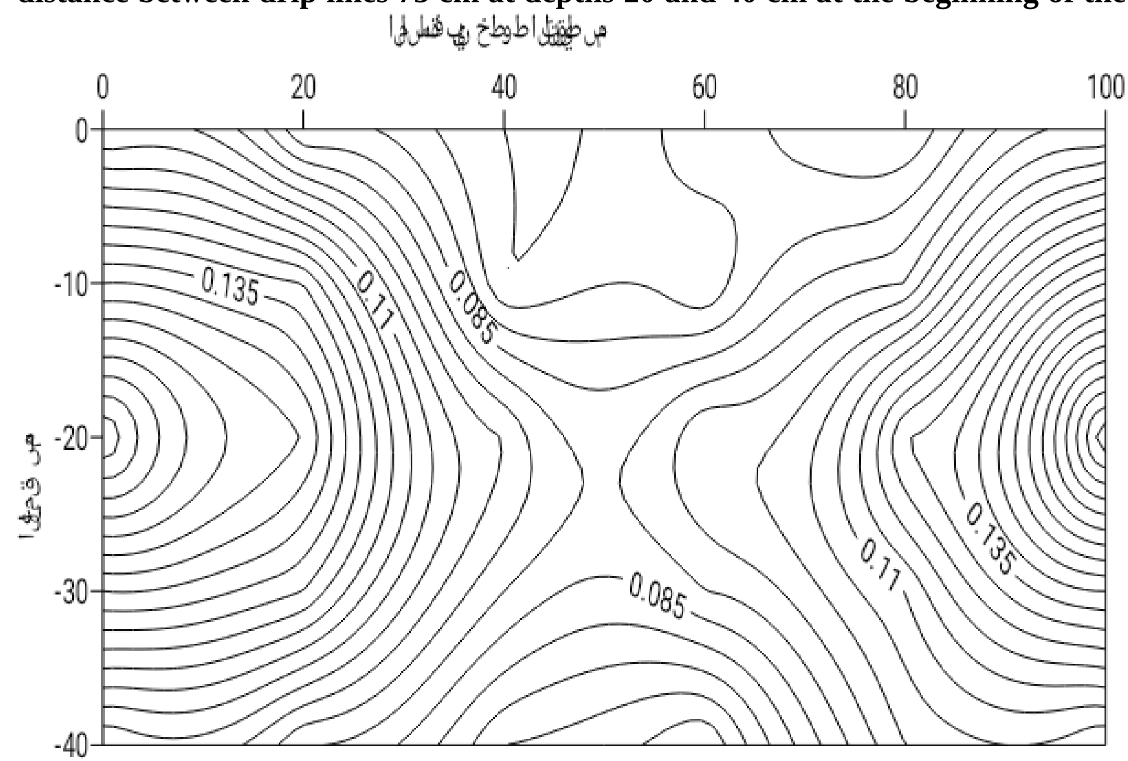


Figure 2. Distribution of the volumetric moisture content (cm3 cm-3) for the treatment of the distance between drip lines 75 cm at depths 20 and 40 cm at the beginning of the growing season



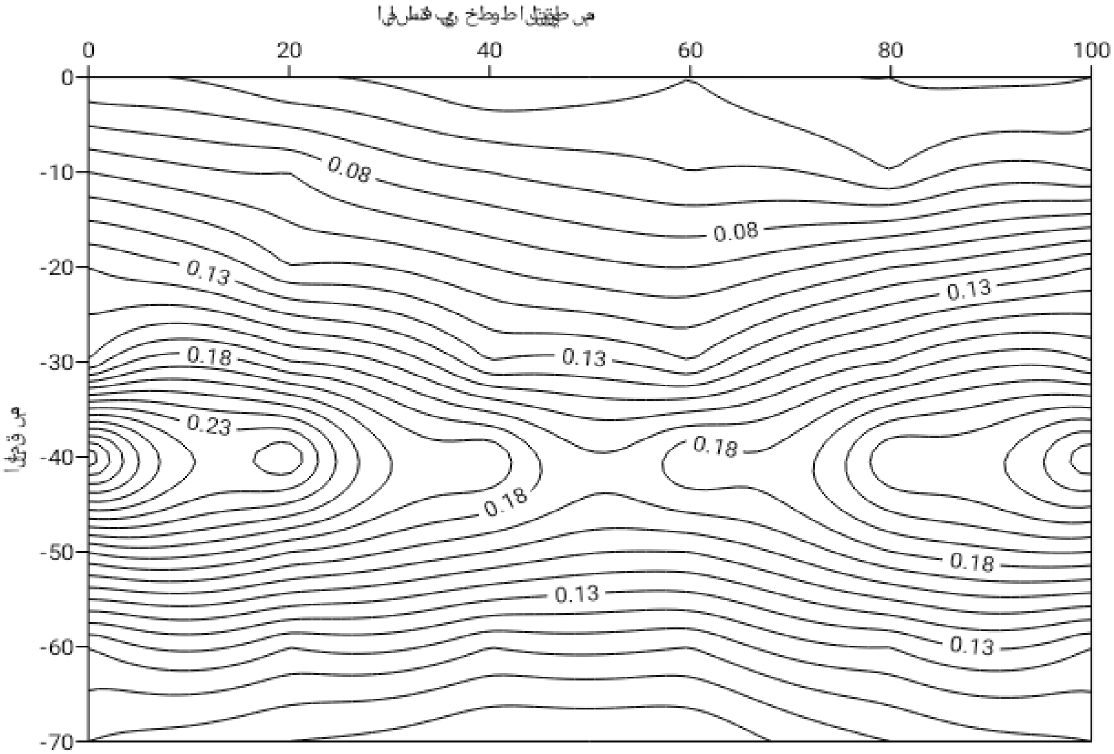
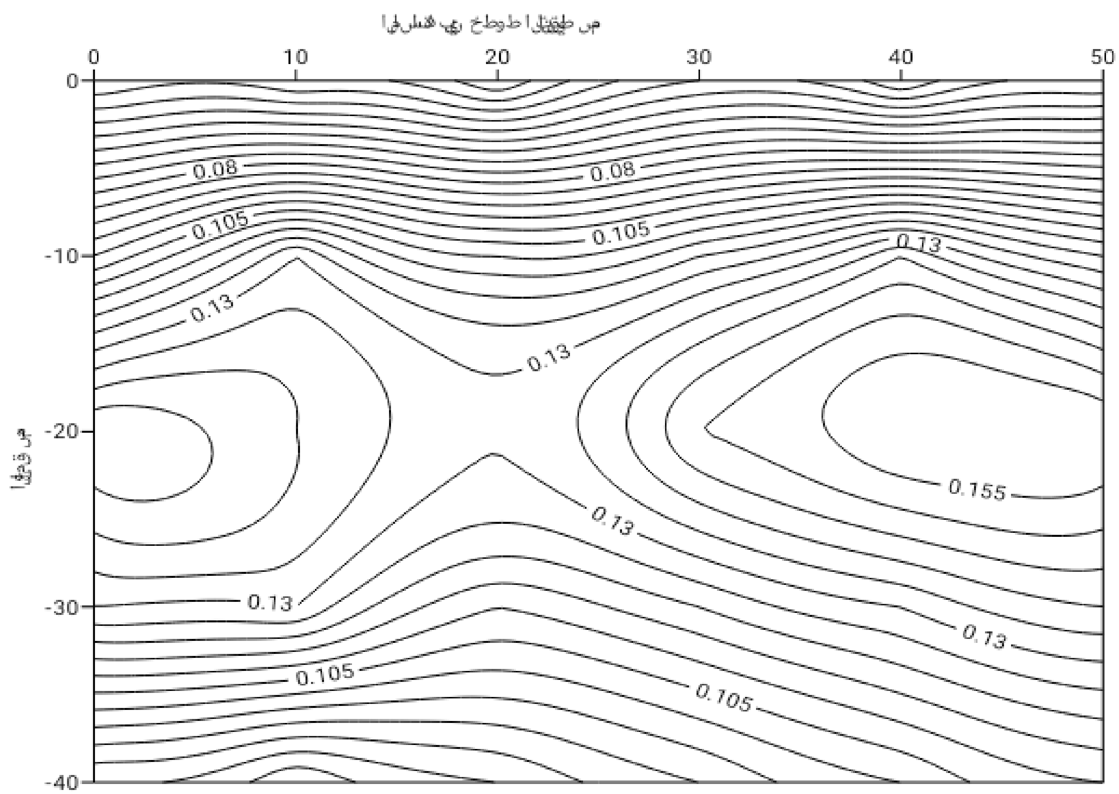


Figure 3. Distribution of the volumetric moisture content (cm 3 cm-3) for the treatment of the distance between drip lines 100 cm at depths 20 and 40 cm at the beginning of the growing season

Figures 4, 5, and 6 show the moisture distribution under the subsurface drip irrigation system at the end of the barley growing season. The results showed a decrease in the moisture content compared to the beginning of the growing season, and the effect of the distance factor between the drip lines was clear on the distribution pattern of the volumetric moisture content. Figure 4 shows the distribution of moisture content for the treatment of the distance of 50 cm between the drip lines and for the depth of 20 and 40 cm, respectively. The results indicated that the highest moisture content was at 20 cm depth and decreased towards the surface (0-10) cm, as well as towards depth (30-40) cm. The moisture content at 20 cm depth was 0.15, 0.14, 0.13 and 0.15 and 0.16 and 0.16 cm3 cm-3 for horizontal distances of 0, 10, 20, 30, 40 and 50 cm, respectively, with a standard deviation coefficient of 0.011.The moisture content decreased towards the surface to reach the moisture range between 0.03-0.14 cm3 cm-3. As for the depth of 40 cm, the moisture content values were 0.15, 0.14, 0.15, 0.14, 0.15 and 0.16 cm 3 cm-3 for the aforementioned horizontal distances, respectively, with a standard deviation coefficient of 0.007.Figure 5 shows the distribution of moisture content for the treatment distance of 75 cm and for depths of 20 and 40 cm. The results of the figure showed the inconsistency of the distribution of moisture content, where the values of the volumetric moisture content differed due to the increase in the distance between the drip lines. The values were the highest at the drip line and decreased at the midpoint of the distance between the drip lines. The values of Moisture content at depth 20 cm 0.14, 0.12, 0.08, 0.09, 0.11 and 0.13 cm 3 cm-3 for horizontal distances of 0, 15, 30, 45, 60 and 75 cm, respectively, with a standard deviation coefficient of 0.02.The values of moisture content at depth 40 cm were 0.16, 0.15, 0.09, 0.10, 0.12 and 0.16 cm 3 cm-3 for the same horizontal distances above, respectively, with a standard deviation coefficient of 0.03. Figure 6 shows the moisture distribution for the distance treatment of 100 cm and for the depth of 20 and 40 cm.It is noticed that the moisture content decreased with the increase of the distance between the drip lines, as the moisture content reached 0.16, 0.14, 0.11, 0.08, 0.12 and 0.17 cm 3 cm-3 for the horizontal distances 0, 20, 40, 60, 80 and 100 cm, respectively, and with a standard deviation coefficient Its value is 0.033. While the surface layer (0-10) cm has a low moisture content.While the moisture content at depth of 40 cm was 0.17, 0.16, 0.10, 0.09, 0.15 and 0.17 cm 3 cm-3 for the horizontal distances above, respectively, with a standard deviation coefficient of 0.035 with a decrease in the moisture content of the surface layer (0-10) cm.



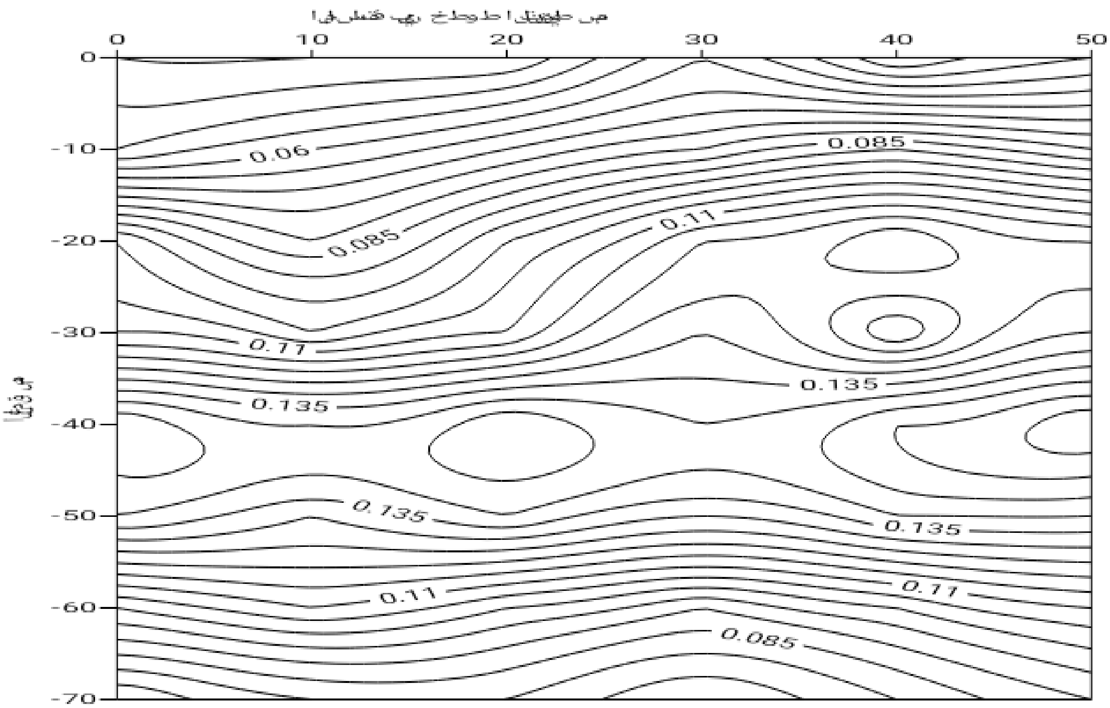
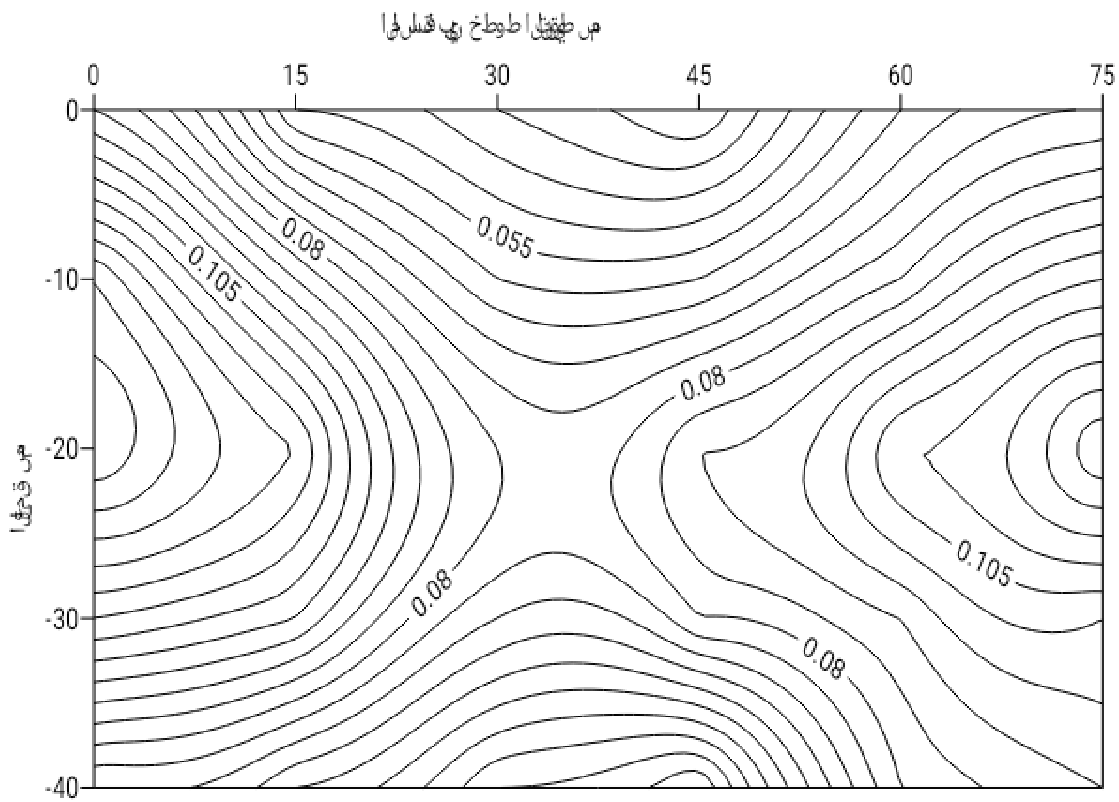


Figure 4. Distribution of the volumetric moisture content (cm 3 cm-3) for the treatment of the distance between the drip lines 50 cm at the depths of 20 and 40 cm at the end of the growing season



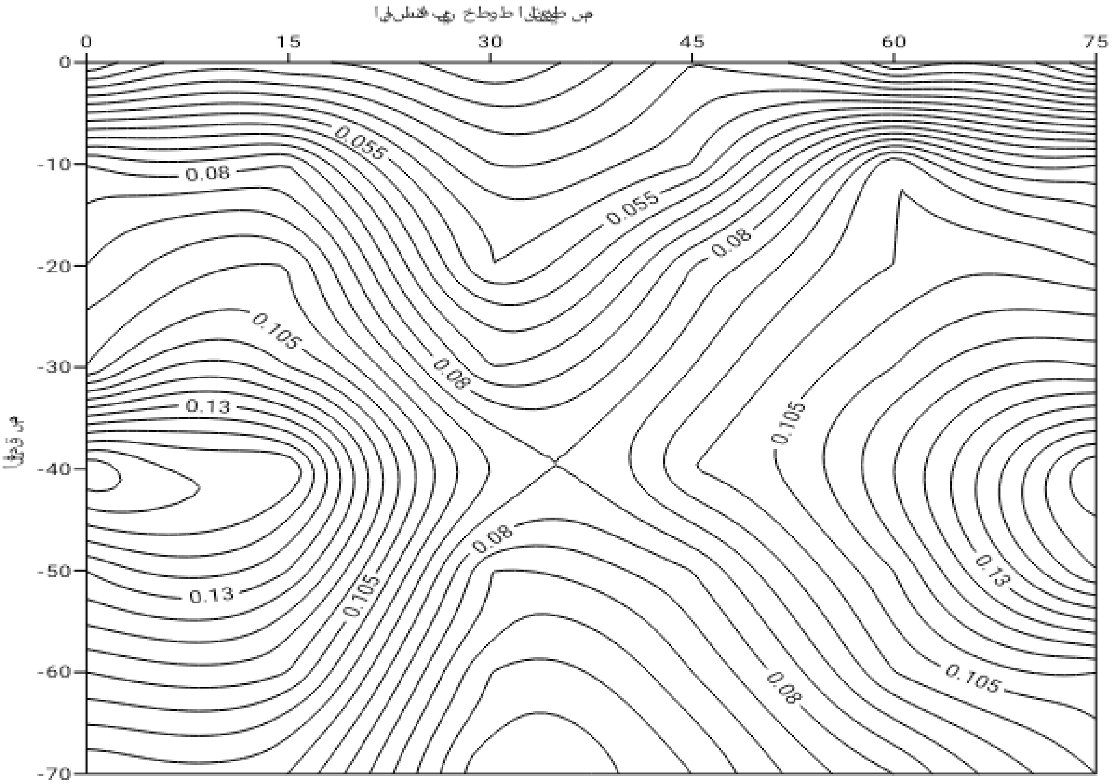
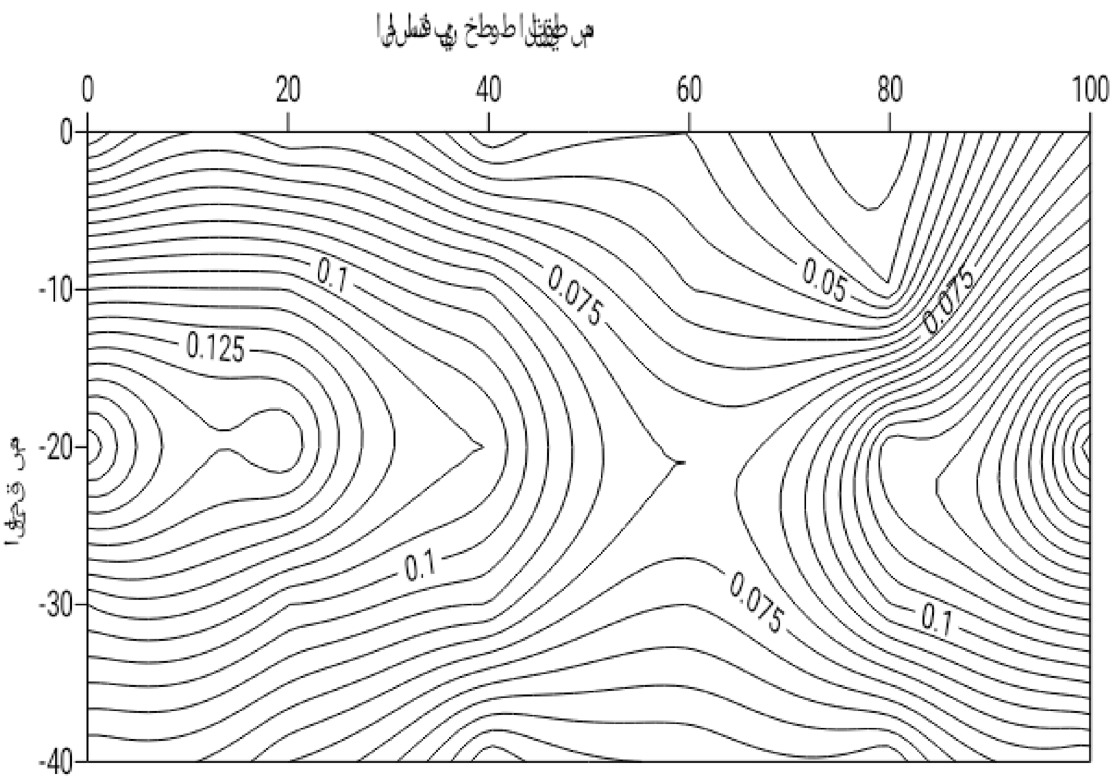


Figure 5. Distribution of the volumetric moisture content (cm3 cm-3) for the treatment of the distance between drip lines 75 cm at depths 20 and 40 cm at the end of the growing season



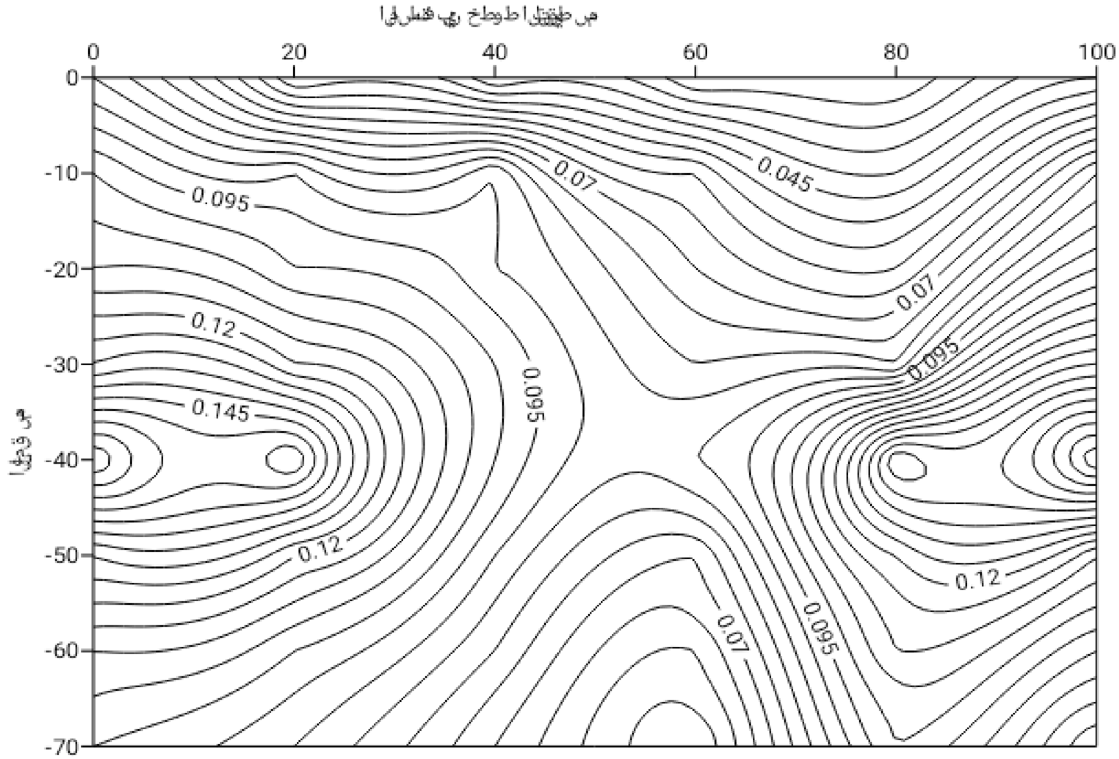


Figure 6. Distribution of the volumetric moisture content (cm 3 cm-3) for the treatment of the distance between the drip lines 100 cm at the depths of 20 and 40 cm at the end of the growing season

Salt distribution under subsurface drip irrigation system:

Figures 7, 8 and 9 show the horizontal and vertical distribution of soil salinity at the beginning of the barley growing season and for all subsurface drip irrigation treatments. In general, it becomes clear that the soil salinity increases when horizontally and vertically away from the drip line. This is attributed to the displacement of salts as a result of the movement of the wetting front. With an increase in the distance between the drip lines. Figure 7 shows the salt distribution for the distance treatment of 50 cm and the depths of 20 and 40 cm. It is noted that the highest salt accumulation at the surface layer is 0-10 cm and decreases at the drip source, as the electrical conductivity values for the depth treatment 20 cm reached 2.01, 2.22, 2.54, 2.47, 2.18 and 2.18 dS.m^{-1} for horizontal distances 0, 10 and 20 and 30, 40 and 50 cm between the two drip lines, respectively, with a standard deviation coefficient of 0.19. While the electrical conductivity values for the depth treatment of 40 cm were 1.87, 1.83, 1.90, 2.22, 1.94 and 1.85 dSm m^{-1} for the horizontal distances above, respectively, with a standard deviation coefficient of 0.14.Figure 7 shows the salt distribution for the distance treatment of 50 cm and the depths of 20 and 40 cm. It is noted that the highest salt accumulation at the surface layer is 0-10 cm and decreases at the drip source, where the electrical conductivity values for the depth treatment 20 cm reached 2.01, 2.22, 2.54, 2.47, 2.18 and 2.18 dS. m^{-1} for horizontal distances 0, 10 and 20 and 30, 40 and 50 cm between the two drip lines, respectively, with a standard deviation coefficient of 0.19.While the electrical conductivity values for the depth treatment of 40 cm were 1.87, 1.83, 1.90, 2.22, 1.94 and 1.85 dS.m^{-1} for the horizontal distances above, respectively, with a standard deviation coefficient of 0.14.It is noticed from the results that the lowest values of electrical conductivity were at the drip source, and the values were taken to increase as we moved away from the drip source to the middle of the horizontal distance between the drip lines, with an increase of 19.6 and 10.7% for the depth treatments 20 and 40 cm, respectively.The reason for the decrease in soil salinity at the drip source is due to the high moisture content, as the hydration front displaces the salts by capillary action and the salts accumulate above and below the drip line, and this is what was indicated (5).Figure 8 shows the salt distribution of the soil volume for the treatment of the distance of 75 cm between the drip lines and for the depth of 20 and 40 cm. Soil salinity was 2.31, 3.29, 4.67, 4.04, 3.54, and 2.80 ds m^{-1} for the horizontal distances 0, 15, 30, 45, 60 and 75 cm, respectively, with a standard deviation coefficient of 0.84.It is noticed that the electrical conductivity decreases at the emitters source, then it increases at the middle of the distance between the drip lines, and then decreases in the direction of the line corresponding to the previous one, as the percentage of increase in salinity at the middle of the distance amounted to 70.5% compared to the position of the emitters(Fig. 8a).The decrease in soil salinity at the drip source is due to the high moisture content, which works to wash the salts to the lower depths. While the electrical conductivity values were 2.30, 2.40, 3.40, 4.84, 2.21 and 2.80 dS m^{-1} for the same horizontal distances above, respectively, for the depth treatment of 40 cm and with a standard deviation coefficient of 1.00. It is noted that the highest salt accumulation was at the surface layer 0-10 cm and decreases at the drip source and for depths of 20 and 40 cm, respectively.The reason for the high values of soil salinity at the surface layer is due to the increase in evaporation from the soil surface and the accumulation of salts, as well as the displacement of salts as a result of the movement of the hydration front. Figure 9 shows the salt distribution for the distance treatment of 100 cm and for the depth of 20 and 40 cm.The results showed an increase in the accumulation of salts with an increase in the distance between the drip lines, in addition to the accumulation of salts above and below the drip line. Soil salinity reached 3.17, 3.30, 3.77, 4.90, 3.20 and 2.22 Ds. m^{-1} for the horizontal distances 0, 20 and 40 and 60, 80 and 100 cm, respectively, for the depth treatment of 20 cm, and with a standard deviation coefficient of 0.88.While the electrical conductivity was 3.10, 3.92, 4.10, 6.36, 4.00, and 2.77 dS.m^{-1} for the same horizontal distances above, respectively, for a treatment of 40 cm, with a standard deviation coefficient of 1.25.The results indicated that the lowest values of soil salinity were at the drip source and increased when moving away from it up to the middle of the horizontal distance between the drip lines, where the percentage increase was 60.9 and 78.4% for the depth treatments 20 and 40 cm, respectively.

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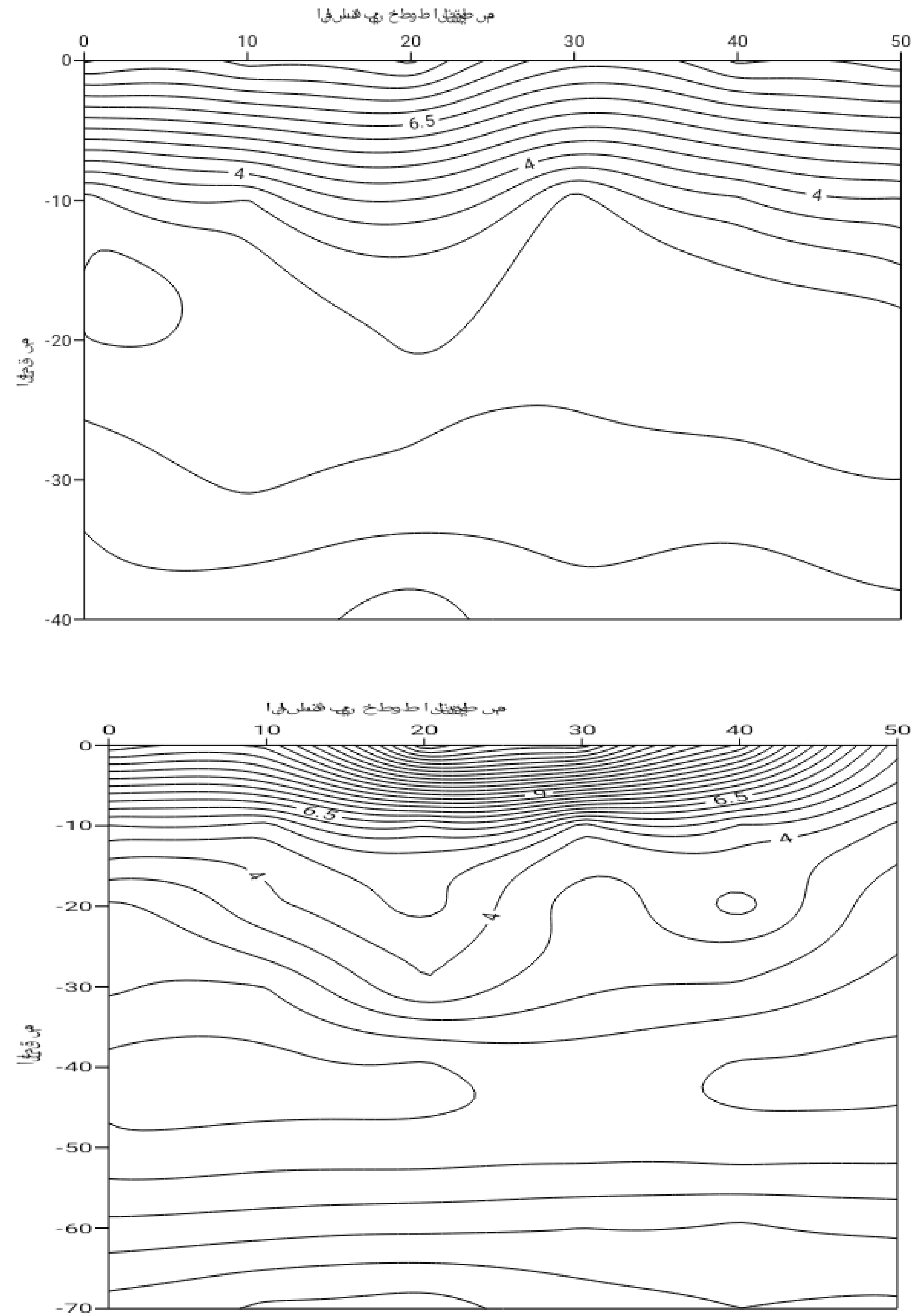

Figure 7. Salinity distribution (dS m^{-1}) for the treatment of the distance between drip lines 50 cm at depths 20 and 40 cm at the beginning of the growing season

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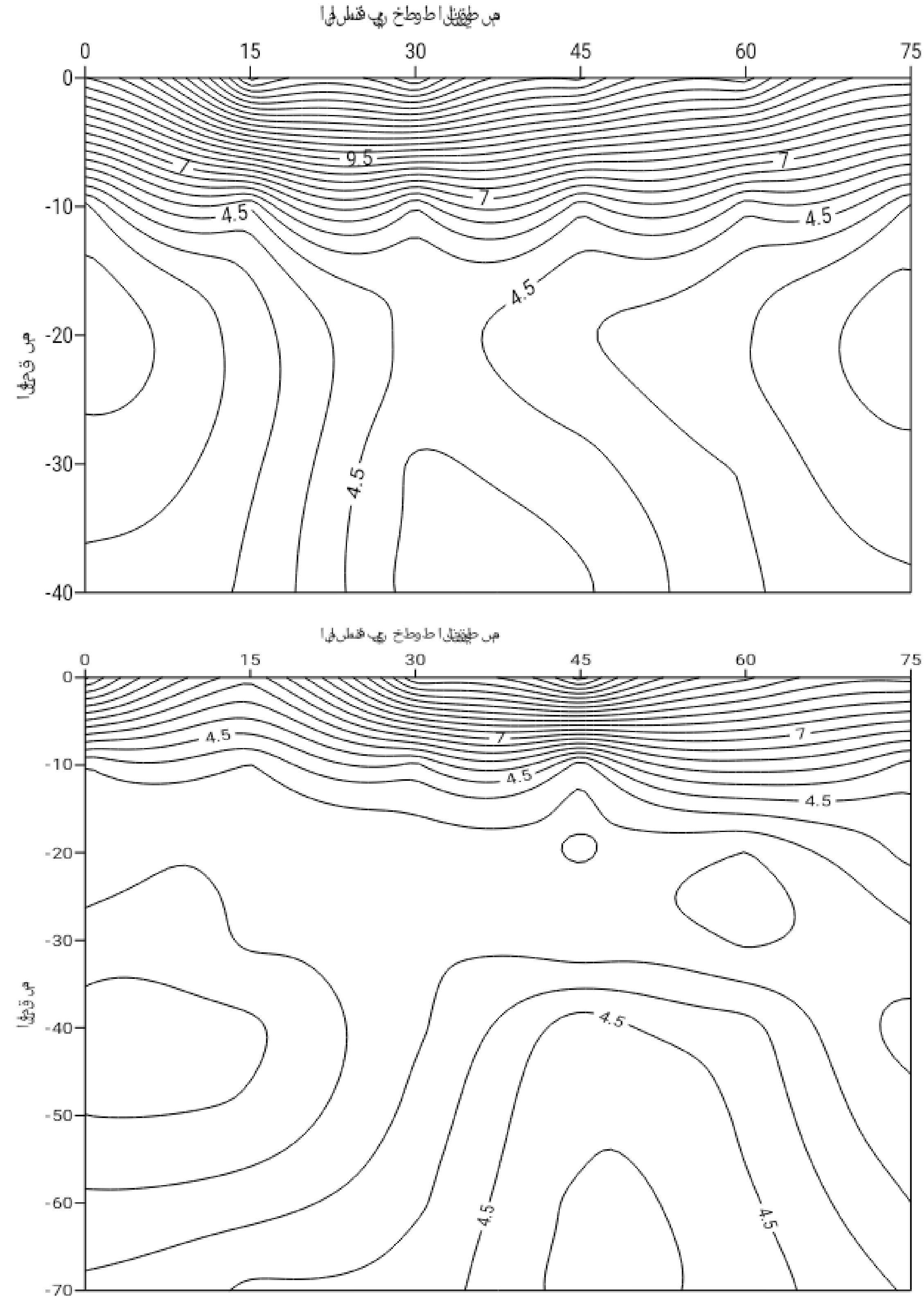

Figure 8. Salinity distribution (ds m^{-1}) for the treatment of the distance between drip lines 75 cm at depths 20 and 40 cm at the beginning of the growing season

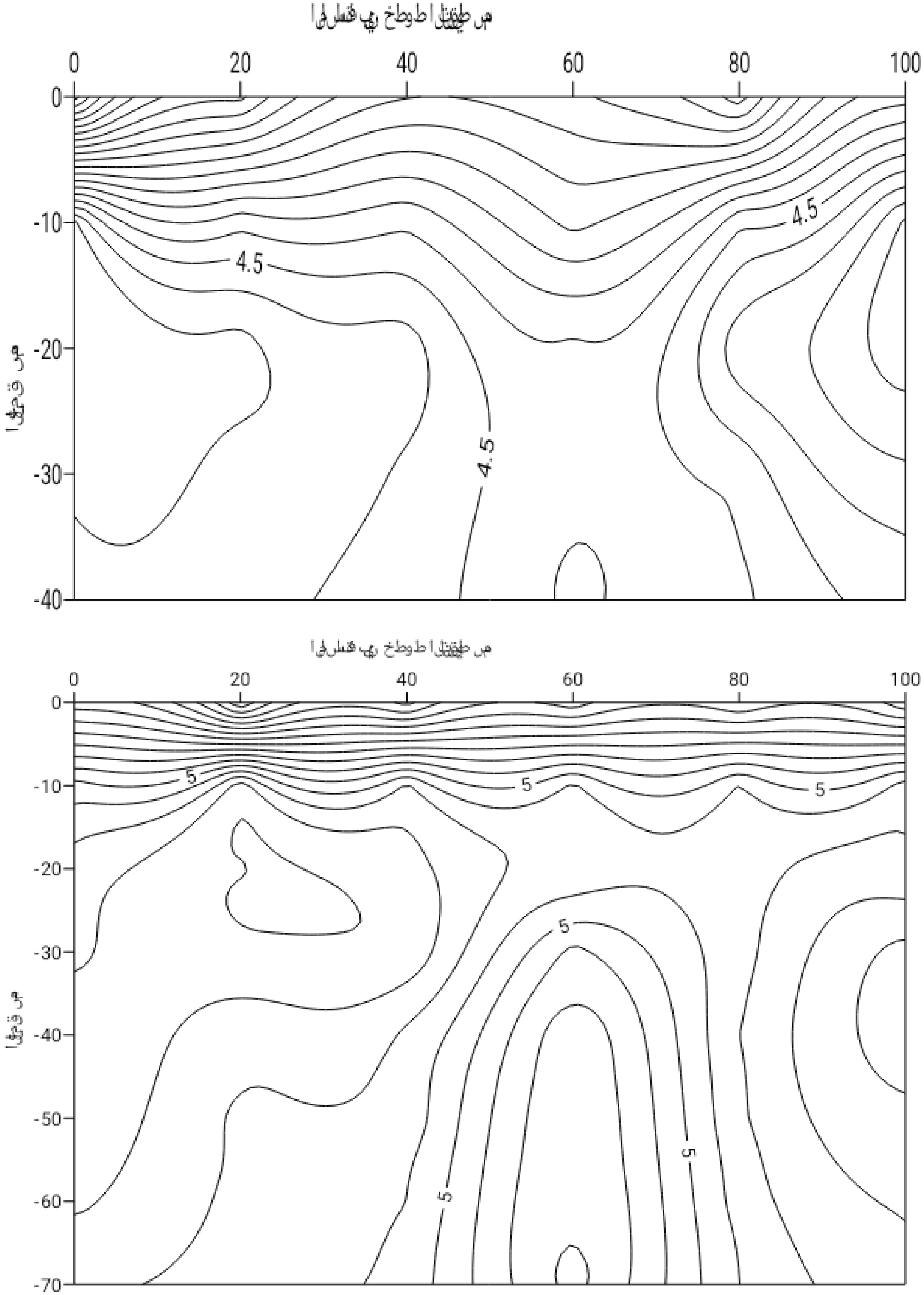

Figure 9. Salinity distribution (dS.m^{-1}) for the treatment of the distance between drip lines 100 cm at depths 20 and 40 cm at the beginning of the growing season

Figures 10, 11 and 12 show the horizontal and vertical distribution of soil salinity at the end of the barley growing season and for all study parameters. In general, it is clear that there is an accumulation of salt at the end of the growing season compared to the beginning of the season.Figure 10 shows the salt distribution for the treatment of distance 50 cm and depth of 20 and 40 cm, respectively. The results showed that the least accumulation of salt was below the drip line and increased by increasing the horizontal and vertical distance from the drip until it reaches the highest salt accumulation at the surface layer and at a depth of 0-10 cm and at the edges of the wet area and this is what was indicated by (22).The electrical conductivity values for the drip line depth of 20 cm were 2.58, 2.90, 3.18, 3.50, 2.30 and 2.62 ds m^{-1} for the horizontal distances of 0, 10, 20, 30, 40 and 50 cm between the two drip lines, respectively, with a standard deviation coefficient of 0.43 . While the electrical conductivity values for the 40 cm treatment were 3.20, 3.22, 3.85, 3.49, 2.60 and 2.70 ds m^{-1} for the above horizontal distances, respectively, with a standard deviation coefficient of 0.47.It is noted from the results that the lowest values of electrical conductivity were at the drip source and increased at the middle of the horizontal distance with an increase of 28.4 and 24.4% compared to the position of the emitter for treatment and for treatments 20 and 40 cm, respectively. Figure 11 shows the salt distribution of the soil volume for the treatment distance of 75 cm and depth of 20 and 40 cm. Soil salinity was 2.82, 3.81, 4.10, 3.75, 3.15 and 2.91 ds m^{-1} for the horizontal distances 0, 15, 30, 45, 60 and 75 cm, respectively, and with a coefficient standard deviation of 0.53,It is noted that the salt accumulation increased at the midpoint between the drip lines, with an increase of 37% compared to the position of the emitters. Soil salinity at a depth of 40 cm was 2.03, 2.98, 4.10, 4.00, 2.40 and 2.28 dS. m^{-1} for the above horizontal distances, with an increase of 90.6% compared to the emitters position, with a standard deviation coefficient of 0.89. Figure 12 shows the distribution of the salinity of the soil volume for the treatment of distance 100 cm and depth of 20 and 40 cm. It is noticed that the salt accumulation increases with the increase of the horizontal distance between the drip lines, especially at the middle of the horizontal distance, where the salinity reached 2.98, 2.49, 5.47, 4.34, 4.07 and 2. 37 dS. m^{-1} for the horizontal distances 0, 20, 40, 60, 80 and 100 cm, respectively, for the depth treatment of 20 cm. For the aforementioned horizontal distance, respectively, the percentage increase at the middle of the horizontal distance was 83.5 and 56.9%, compared to the position of the emitters and for the depth of 20 and 40 cm, respectively.

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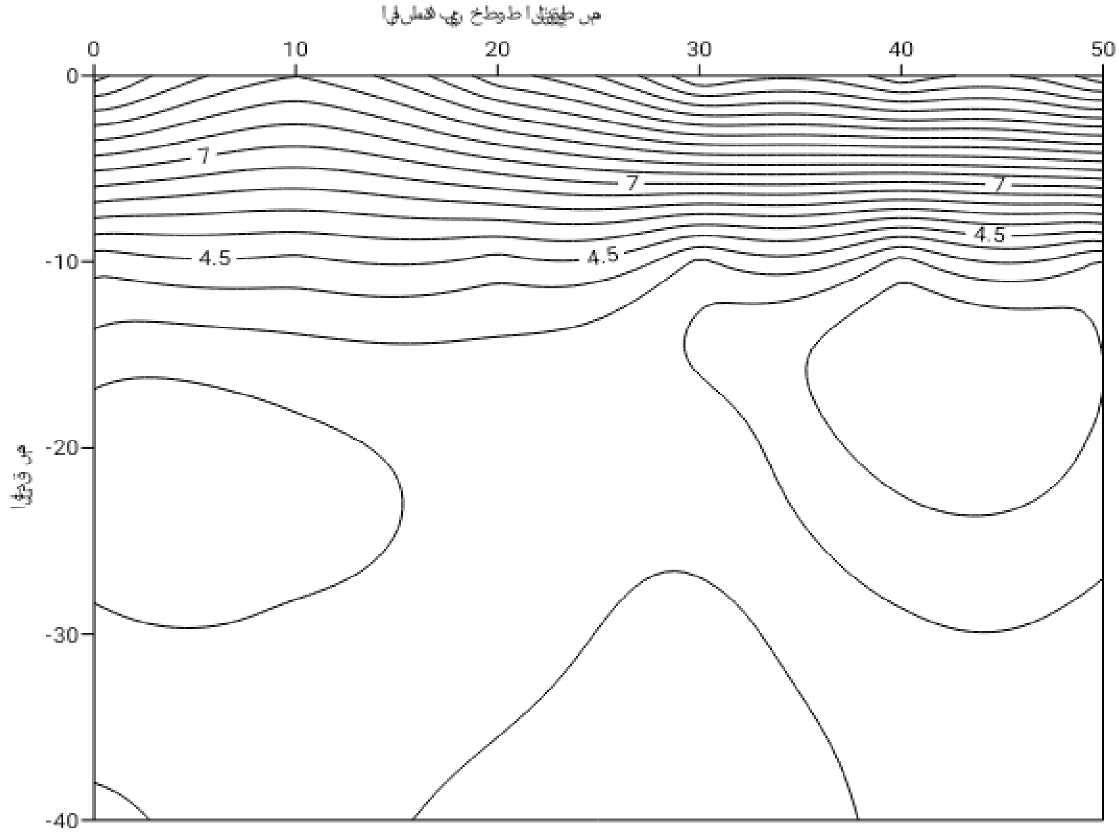

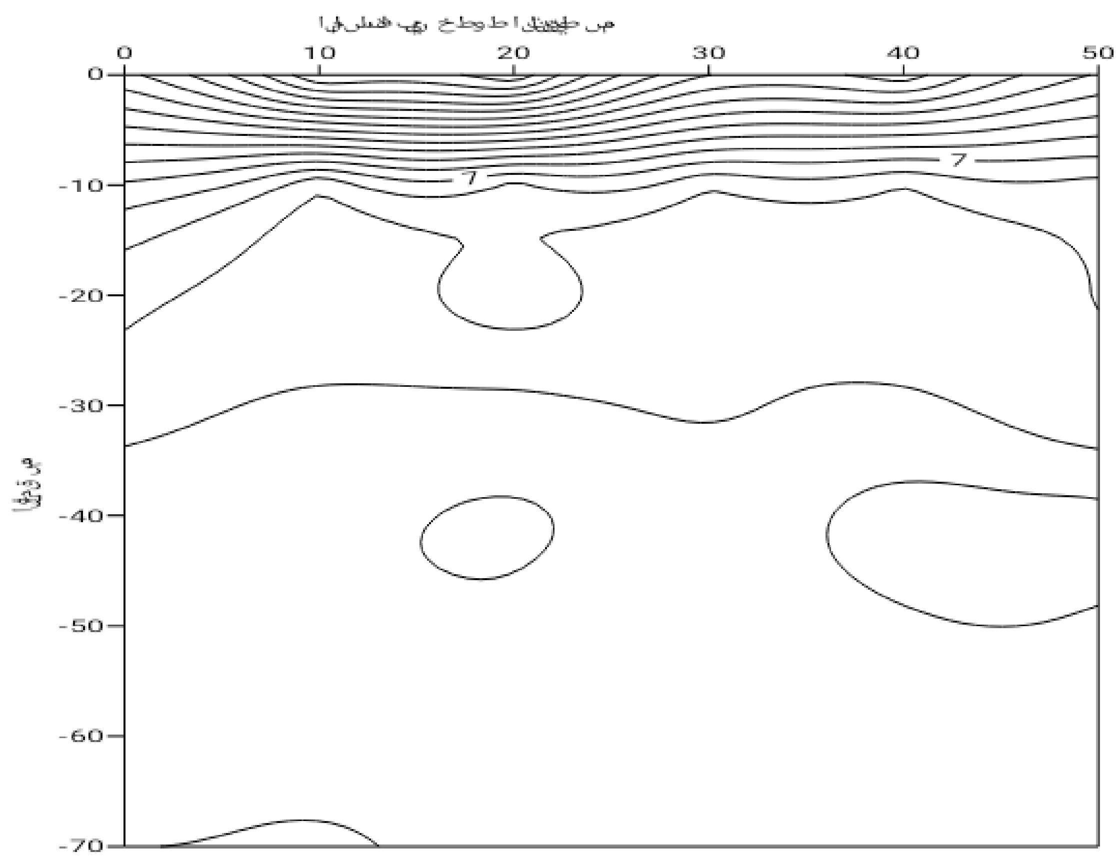

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Figure 10. Salinity distribution (ds.m-1) for the treatment of distance between drip lines 50 cm at depth 20 and 40 cm at the end of the growing season

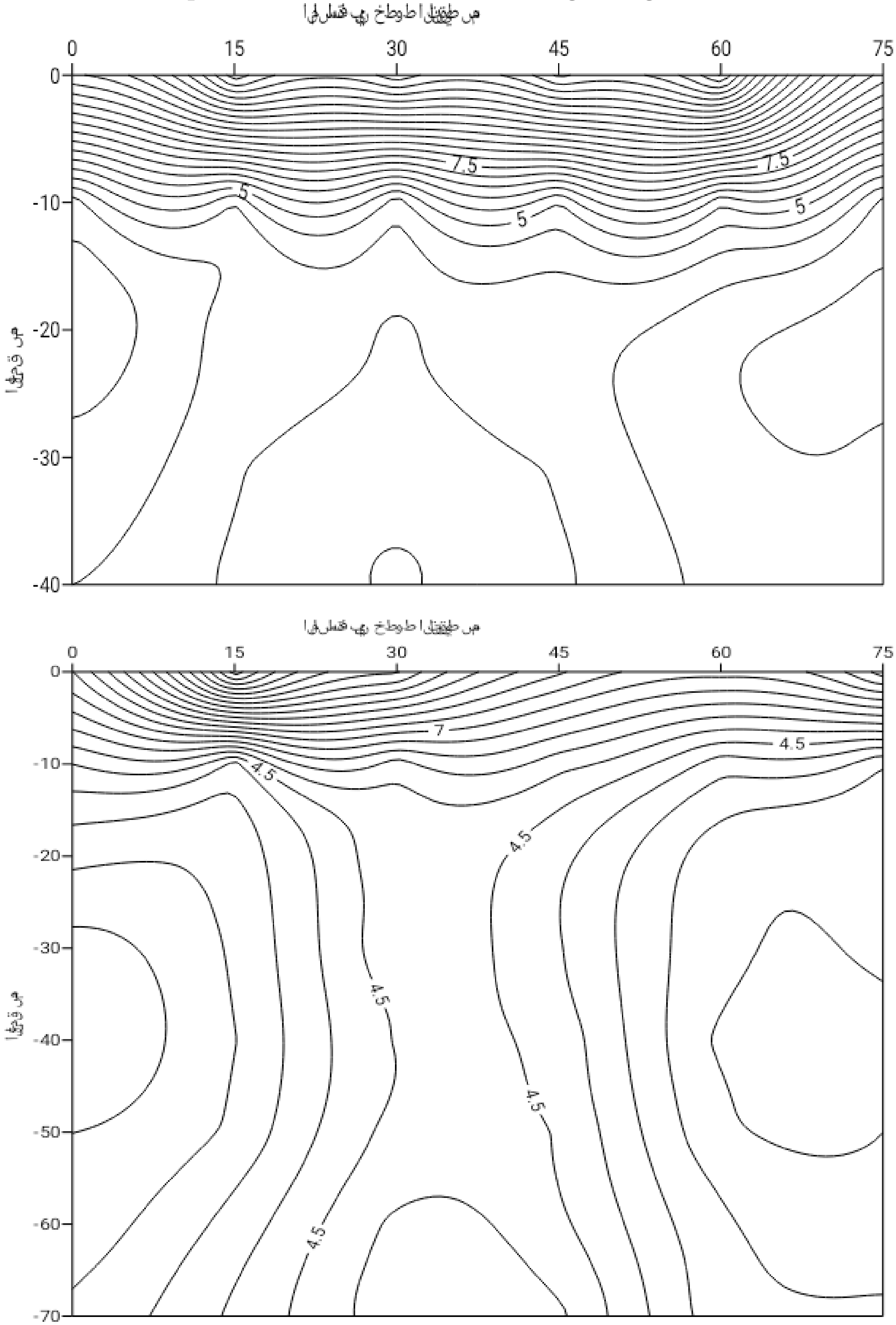
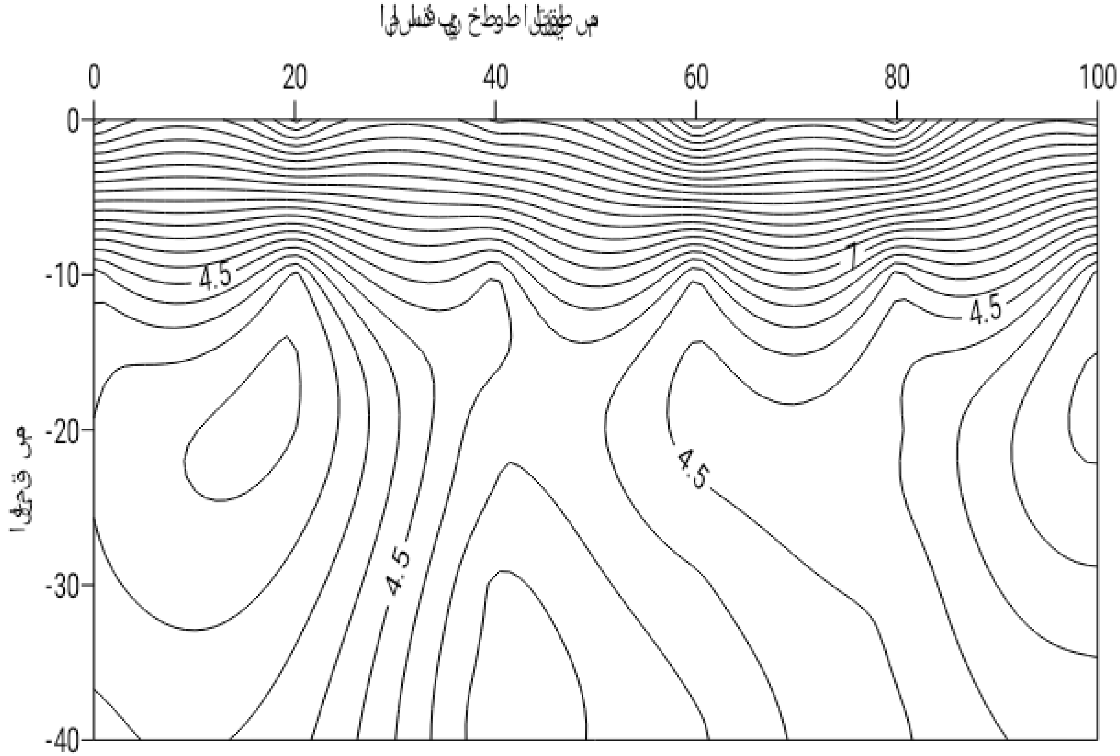


Figure 11. Salinity distribution (dS. m-1) for the treatment of the distance between drip lines 75 cm at depth 20 and 40 cm at the end of the growing season



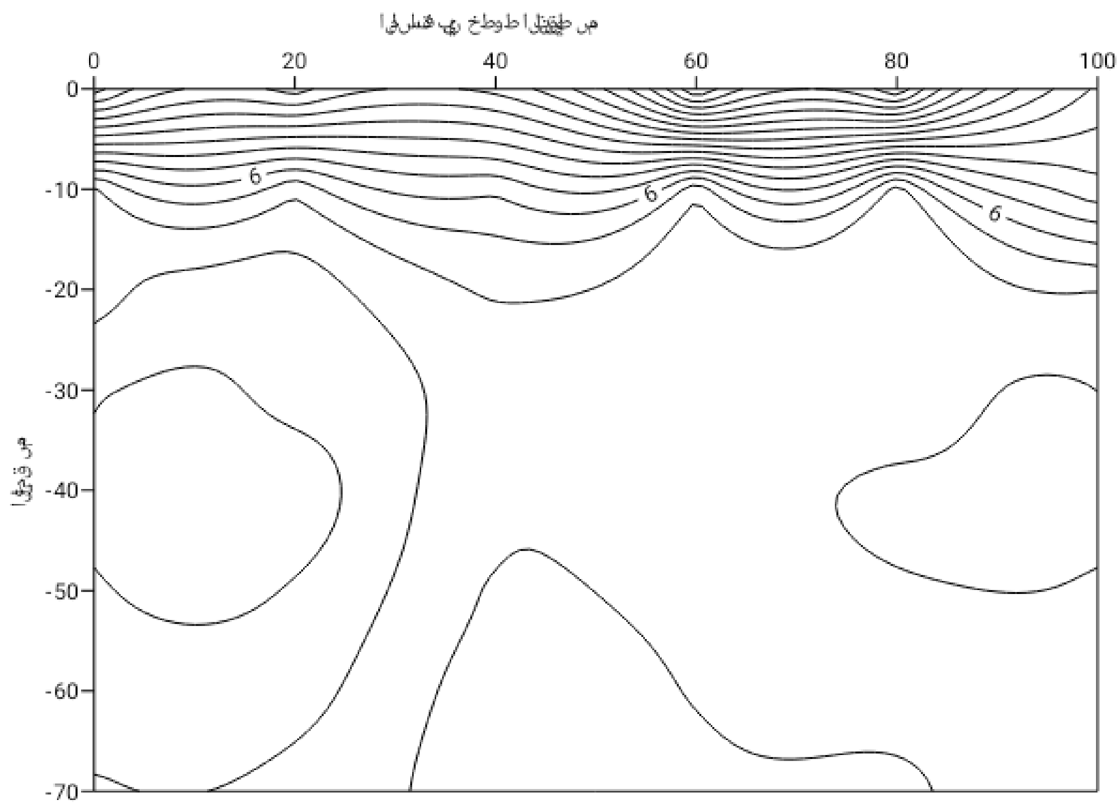


Figure 12. Salinity distribution (ds.m-1) for the treatment of the distance between drip lines 100 cm at 20 and 40 cm depth at the end of the growing season

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Through the results obtained from this study, it became clear that reducing the distance between drip lines maintained a distribution of moisture and salt content suitable for plant growth and a good spread of the root system, in comparison with an increase in the distance between drip lines, which resulted in a decrease in moisture content at the middle of the horizontal distance between drip lines, in addition to the best moisture and salt distribution in the soil bed was when treating the distance of 50 cm for the drip lines and for the depths of 20 and 40 cm, and increasing the distance leads to the heterogeneity of the salt and moisture distribution.

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