Barley Productivity and Soil Quality in Response to Sowing Methods and Two Agricultural Buried Drain Tile Network Designs in Salt-Affected Soils

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ABSTRACT

The productivity of barley crops is significantly constrained globally by salt stress. Agriculture in salt-affected soils requires managing salinity to reduce its risks. Sowing practices and a sufficient drainage system are crucial mitigation measures for such risks. Soils that have been impacted by salt are typical of the Al-Tina Plan area in North Sinai, Egypt. The main purpose was to select an appropriate and efficient drainage system and sowing method to overcome salinity hazards and obtain superior and sustainable barley productivity. The current study included field experiments carried out for two winter seasons, 2019/2020 and 2020/2021 at Al-Tina plan area. The experiments included two sowing methods broadcast sowing (BS), ridge sowing (RS), and three types of drainage (two types of buried drainage Tiles Limited drains (LD), Intense drains (ID), and traditional open drainage as a control (TD).

Broadcasting sowing method and ridge sowing performed a significant increase in barley grains, straw and biological yield and its components parameters i.e., germination %, plant height, spike length, No. of spikes /m^2, No. of grains /spike, grain weight kg / m^2, harvest index %, as well as carbohydrates %, and protein % of barley as compared with the broadcast method. These results were similar for both seasons. Moreover, ridge sowing caused a significant increase in all chemical compositions of barley grains. The highest values of barley yield and their component parameters were obtained at intense drains as compared to control (traditional open drains) in both seasons. Intense drains had a significant effect on the chemical composition of grains as compared to control treatment for both growing seasons. The interaction between sowing methods and designs of agricultural buried drains tile networks was significant in barley yield types and their components, these were true for both growing seasons.

Results showed that the highest values of studied parameters of yield and its components were achieved through using ridge method and intense drains as compared to control in both seasons. Application of agriculture buried drain decreased the soil water table salinity in the two growing season, as a result to improving the soil quality.

Keywords: barley yield, sowing methods, chemical contents, agricultural buried drains tile networks, salt-affected soil.

INTRODUCTION

In Egypt, one of the most significant minor grain crops is barley (*Hordeum vulgare* L.). The grains grown for human consumption and utilized as animal feed which has 65–68% carbohydrate, 10–17% protein, 4-9% ß-glucan, 2-3% free lipids, and 1.5–2.5% minerals (Carcea *et al.*, 2015). It has the benefit of growing in marginal areas that are unfavorable for other cereal crops and is one of the principal winter cereals in the Mediterranean region (Newman and Newman, 2006). In terms of total cereal production and acreage, it is in fourth place behind rice, wheat, and maize (AQUASTAT-FAO, 2019). It is a good crop because it can withstand numerous abiotic factors that negatively impact crop growth and output by lowering photosynthesis and partitioning of biomass to harvestable portions of the plant, such as drought and salt stress on the soil and the likelihood that it is sown on marginal soils (Jones *et al.*, 2015). Nonetheless, it is especially susceptible to waterlogging, among others, Miricescu *et al.* (2021) the greatest method for reclamation in salt-affected soil is to use species that can tolerate salinity through the use of adequate varietal selections (Ali *et al.,* 2017), according to AQUASTAT-FAO (2019). Around 1187.2 thousand hectares of barley are planted, Egypt also leads the Arab world in terms of barley production, with a yield of roughly 244 kg per hectare (Ouda *et al.*, 2021 and Shaaban *et al.*, 2022).

Despite substantial recent fluctuations, Egypt's barley production has generally increased from 1971 to 2020, reaching 108,000 tons in 2020 (Ouda *et al.*, 2016). Salinity has an impact on large agricultural areas in the Mediterranean region (AQUASTAT-FAO, 2019).

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In particular in arid and semi-arid locations, salinity is one of the most significant abiotic stressors that negatively impacts crop yield (Isayenkov & Maathuis, 2019 and Awaad *et al.,* 2020). Especially on poorly drained soils and in situations where there is persistent waterlogging, farming can increase crop yields and land productivity (Yannopoulos *et al.,* 2020).

Due to salt buildup in the surface layers as a result of higher soil evaporation rates, the current climate change is characterized by decreasing precipitation and increasing warmth, which leads to greater aridity (Chen and Mueller, 2018). According to previous research, agricultural buried drain tile networks are designed to help crops combat the detrimental impacts of salinity (Liu *et al.,* 2021). In Egypt's original desert regions as well as certain recently reclaimed ones, drainage is regarded one of the most crucial agricultural operations.

Also, Abd-Elaty *et al.* (2017) founded that the effects of drainage on the environment have caused a lot of worry, therefore subsurface drainage system design and operation in the future should meet agricultural and environmental goals. Furthermore, an Environmental Impact Assessment (EIA) should be conducted for subsurface drainage projects due to their significant significance and size in the national water strategy. Visual drainage assessment (VDA) design is a method for designing land drainage systems visually that was created by Tuohy *et al.* (2016). It is based on data from a soil profile assessment along with previous knowledge of the site and outfall circumstances. This might be improved to provide an approximation of the permeability of different soil horizons in actual field settings. This knowledge could then be preserved and made more accessible to a wider range of practitioners by serving as the foundation for a site-specific drainage system design that is understandable to all stakeholders and does not require laboratory or field measurements of soil physical or hydrological properties. According to Moukhtar *et al.* (2012), effective mole drainage on a particular soil type may assist lessen issues with salt and waterlogging.

The aim of the current study was to select an appropriate and efficient drainage system and sowing method to overcome salinity hazards and obtain superior and sustainable barley yield. The experiments included two sowing methods as broadcast sowing (BS), ridge sowing (RS) as well as two type of buried drainage Tiles beside traditional open drainage.

MATERIALS AND METHODS

1. Field experiments sites

A set of two field experiments were carried out along two winter seasons in Al-Tina plan area, North Sinai Governorate, Egypt, during the 2019/2020 and 2020/2021 seasons, to study the effect of two sowing methods broadcast sowing (BS), ridge sowing (RS) and designs of agricultural buried drain tile networks traditional open drainage (TOD), Light drains (LD) and Intense drains (ID) under salt affected soil conditions. The experiment included 6 treatments which were the combinations between the two sowing methods and three designs of agricultural buried drains tile networks.

The site of the experiment located was determined in the following table (1), and the following contouring map in Fig. (1) illustrated the surface topographic of the experimental site.

1.1. Agricultural buried drains tile

1.1.1. Laboratory, field devices and field equipment

Chemical and physical analyses devices, leveling surveying devices, piezometer tubes, sounder devices, observation wells, double ring device and GPS were used before and during experiment. Soil samples were taken by auger, soil EC was determined by EC meters (Black and Power (1965), cations and anions were measured, soil mechanical analyses determined by dry, and wet sieves (Jackson *et al.,* 1973), and soil hydraulic conductivity measured under saturated condition (pumped borehole method) (Wolf, 1982). Precipitation are measured by rain gauge in the field (Al_quntra weather station).

1. Coordinates of the four corners	2. The four borders
3. 32°:27:22.3N 33:02:46.0"E	1. West borders: private watering can first degree (I)
4. 31°:02:44.9"N 33:27:29.9'E	2. East borders: private drains collector first degree (I)
5. 31°:02:36.2'N 33:27:22.7'E	3. North borders: public canal third degree (III)
6. 31°:02:36.6'N 33:27:30.2'E	4. South borders: neighbor farm

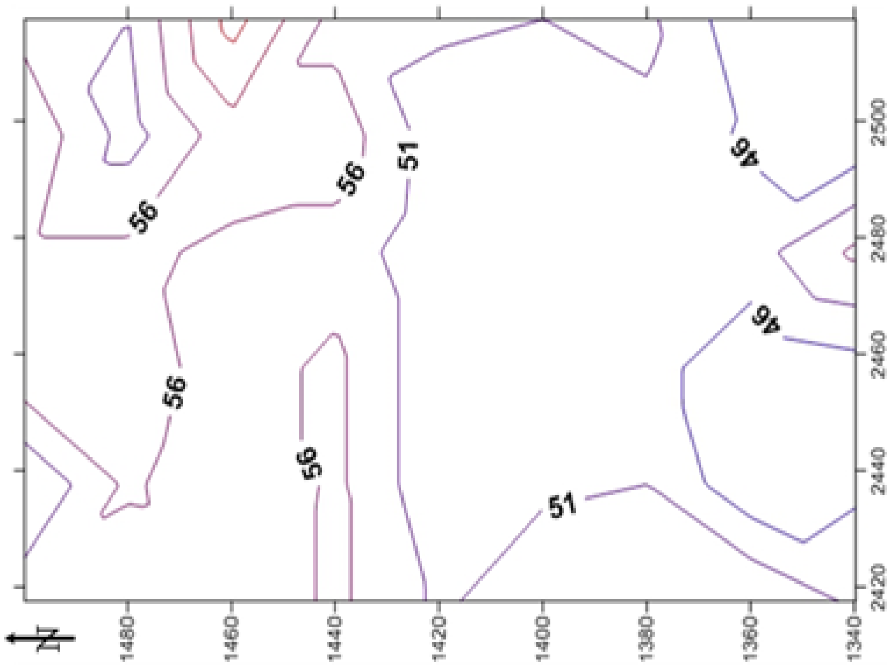

Fig. 1. Topographic of Experimental site.

1.1.2. Description of drainage treatment components

Traditional open drainage and two buried experimental buried drain Tiles type with its equipment were described as the following:

Open drain system was applied at study area, main or first-degree drains and sub main (collector or second degree) were implemented and designed by Egyptian Public Authority for Drainage Project (EPADP), but the designing of third degree or tiles drains were left to done by the farm owners and through the farmers themselves or by untechnical workers. Farm owners may be establishing drain tiles or not. Tiles (open or buried) that were installed by farm owners were created randomly and on non-geometric or scientific basis. In the experiment site, main and sub main drains were applied and randomized traditional open drain tiles as a control treatment (OD) (Hassan *et al.,* 2017).

The earliest kind of tile drains were called intensive drains (ID), which were made of perforated Ultra-Poly Vinyl Chloride (U.P.V.C.) hoses with an 80mm diameter coated in a layer of gravel with a 0.3m thick layer. The ID's longitudinal and preference distances were 100m and 14m, respectively. Further trencher drainage nets were conducted above perpendicular and intersecting on the hose net in other levels with 0.80m depth; half of this depth (0.4m) was filled with gravels. It was also buried and installed at 1.25m average depth. The gravel layers' junction and connection, with longitudinal and preferences distances of 10 and 100 meters, respectively, were used to connect it to the network of hoses. The second type of drains were light (LD) and smaller (ID), and the preferred trencher drains net distance was 20 meters. All of these drains were connected and collected with collectors at an average depth of 1.50 meters.

The kind of gravel was selected from seven-degree sieves with 5mm-diameter holes that matched (Karpoff, 1955). 60 kW excavator, 90 kW loader, and 90 kW tractor; two flow meters, one with a 6-inch diameter for measuring irrigation water amounts; El Salam Canal, which delivers water mixed with agricultural drainage water and fresh water from the Nile River's Damietta branch, was the source of the irrigation water. Winter crop seeds were the only ones being raised.

Methods: During the agricultural seasons of 2019-2020 and 2020-2021, it was carved out what the drainage water salinity, water table level, physical and chemical qualities of the soil, and productivity of barely (Karpoff 1955). Fig. (2), schematic illustration shows how the experimental treatments were created.

1.2. Estimating soil hydraulic conductivity (K) above water table under unsaturated condition

According to Sakla (2003) the inverted auger-hole method was used to measure soil conductivity for the experimental soil site from the soil surface to 50 cm of depth and from that depth to the surface of the water table. The following relationship and the form in Fig.

(3) that demonstrate the method's parameters were used to compute K using the unsaturated approach.

$$K=\frac{1.15r\left[\log_{10}\left(h_1+\frac{r}{2}\right)-\log_{10}\left(h_2+\frac{r}{2}\right)\right]}{(t_2-t_1)} \text{ or}$$

$$K=1.5r\tan\alpha \quad \frac{\left[\log_{10}\left(h_1+\frac{r}{2}\right)-\log_{10}\left(h_2+\frac{r}{2}\right)\right]}{(t_2-t_1)}$$

Where: K-soil conductivity above water table (unsaturated case) m/day; r, radius of hole, cm. $h_{1,}$ water high inside the hole at moment stop pumping/cm. h_2, water high inside the hole at the moment before next pumping/cm. t_1, time at the moment when water level high inside hole reached h1/min. t_2, time at the moment when water level high inside hole reached h_2/min. tan α (or) Inclination the straight line that resulted from the relation between log10 (h + r/2) and time.

1.3. Identifying soil hydraulic conductivity under saturated conditions, zone which planned to establish subsurface drainage-(K)

The hydraulic conductivity or coefficient of permeability was computed using the Zangar (1953), relationship, and the value (K), the most significant parameter of the drainage design equations, was identified using the pumped borehole method test.

$$K=\frac{Q}{C.L.r}\ ,\ L=\left(\frac{H^2-h^2}{H}\right)$$

Where: K–hydraulic conductivity (m/day); r–radius of the hole/cm; Q–constant flow of pump (cubic cm/min.); H, h-dimensions by meter as shown above in Figs (3, 4); C– coefficient depend on the dimensions of the hole and identified form the following carves (Fig 5), coefficient depend on the dimensions of the hole and determined from the shown carves at Fig (6).

1.4. Measurements of soil and drained water

1.4.1. Salinity of the soil prior to and throughout the experiment; Water or drained water prior to and throughout the experiment; water table vitality or erratic levels; Crop measurements and chemical and physical characteristics (Kilmer & Alexander, 1949 and Seilsepour et al., 2009). Agricultural Practices

1.4.1.1. Sowing methods

The traditional sowing technique, spread sowing, and the ridge sowing technique were both examined (30 cm between ridge). The 2019–2020 and 2020–2021 growing seasons' barley seeds were planted on the middle of both ridge sides on November 6 and 10, respectively. 42 m^2 was the size of the experimental unit (10.5m in length and 4m in width). The productivity and quality of the barley crop, as well as the interplay between the type of drain and the sowing techniques, were all considered in the evaluation. About the application of ammonium nitrate (33.5% N) at a rate of 20 kg fed^{-1} in three doses as a nitrogen fertilizer (at sowing, tillering stage, elongation stage). During both growth seasons, all additional cultural techniques were carried out as advised for barley crops.

1.4.1.2. Barley Agro-physio-biochemical traits

All barley plants were harvested in 21st, and 23rd April in 2019/2020 and 2020/2021 seasons respectively, to determine yield and yield components i.e. germination %, plant height (cm), spike length (cm), no. of spikes /m^2, no. of grains /spike, grain weight/m^2 (g), grain yield (kg/fed.), straw yield (kg/fed.), biological yield (kg/fed.), harvest index %, whereas harvest index (%) was computed by HI (%)= grain yield/ biological yield x 100. Contents of grains from some chemical parameters i.e., carbohydrates % and protein %. Total nitrogen was determined using the modified micro-Kjeldahl method as described by Peach and Tracey (1956). The crude protein content was calculated by multiplying by 6.25 to obtain the crude protein percentage, total carbohydrates were extracted according to Smith et al. (1964). All data were subjected to statistical analysis according to the procedure outlined by Snedecor and Cochran (1990). The means of the different treatments were compared using the least significant difference (LSD) test at $P<0.05$.

1.4.2. Soil sampling analysis

By using a soil auger, soil samples were taken in triplicate between 0 and 40 cm deep. These disturbed soil samples were crushed, air dried passed through a 2 mm sieve, in order to prepare them for soil analysis. Using the pipette method as described by Klute (1986) samples of undisturbed soil were collected to analyze their chemical and physical characteristics, such as particle size distribution, (Kilmer and Alexander, 1949) employed sodium hexameter phosphate as a dispersion agent. The soil paste was made. According to Black and Power (1965) description, the extracted was tested for electrical conductivity (EC) in dS/m using a conductivity meter. Soil (pH) was determined in soil suspensions using a Beckman bench type pH meter (Seilsepour *et al.*, 2009). Soluble cations and anions in meq/L were determined according to the methods as described by Jackson *et al.* (1973). As shown in Table (1).

Table 1. Some physical properties, particle size distribution (%) of soil surface (0-40 cm), as well as soluble cations and anions of irrigation water at the studied area.

Some physical properties, particle size distribution (%) of soil surface											
Soil depth (cm)	Sand %		Silt %		Clay %			Texture class	EC (dS/m)		
0-40	23.3		30.5		46.2			Clay	14.0625		
Soluble cations and anions of irrigation water											
			Cations (meq/L)					Anions (meq/L)			
Treatment	pH	EC (dS/m)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	SAR
Irrigation water	6.84	1.4	2.40	1.03	2.97	0.62	0.00	2.02	2.98	2.08	2.26

1.4.3. Water sampling analysis

Water for irrigation was trickling from the El Salam Canal, which conveys mixed water with a 1:1 mixing ratio (fresh water from the Damietta branch of the Nile River and agricultural drainage water). Winter crop seeds were the only ones being raised. As shown in Table (1).

1.5. Statically analysis

The sowing experiment design was laid out in strip plot design where, the main plots were occupied by drainage while, sowing method treatment were allocated in sub plots in four replicates. The experimental design for the treatments is shown in Figure (2), where the drained water was collected in a master manhole and disposed of by pump at low water table levels but by gravity flow on collector open drain at high water table levels.

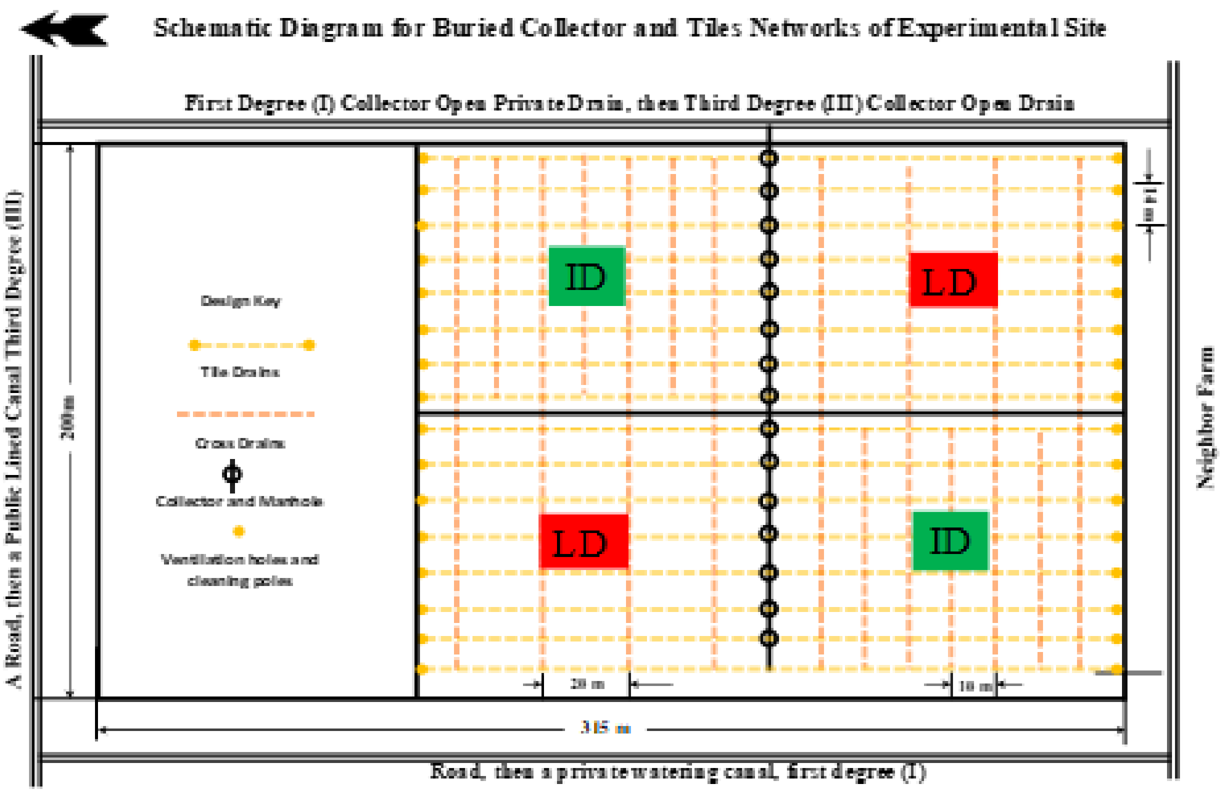

Fig. 2. Drains design of experimental treatments.

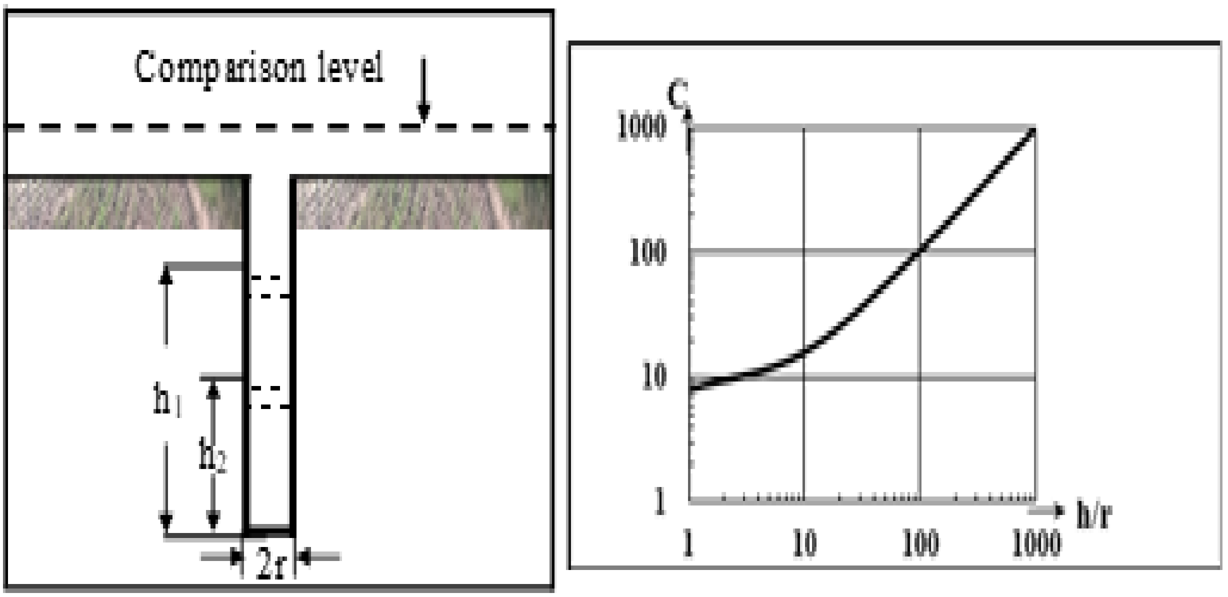

Fig 3. Estimating soil hydraulic conductivity above water table.

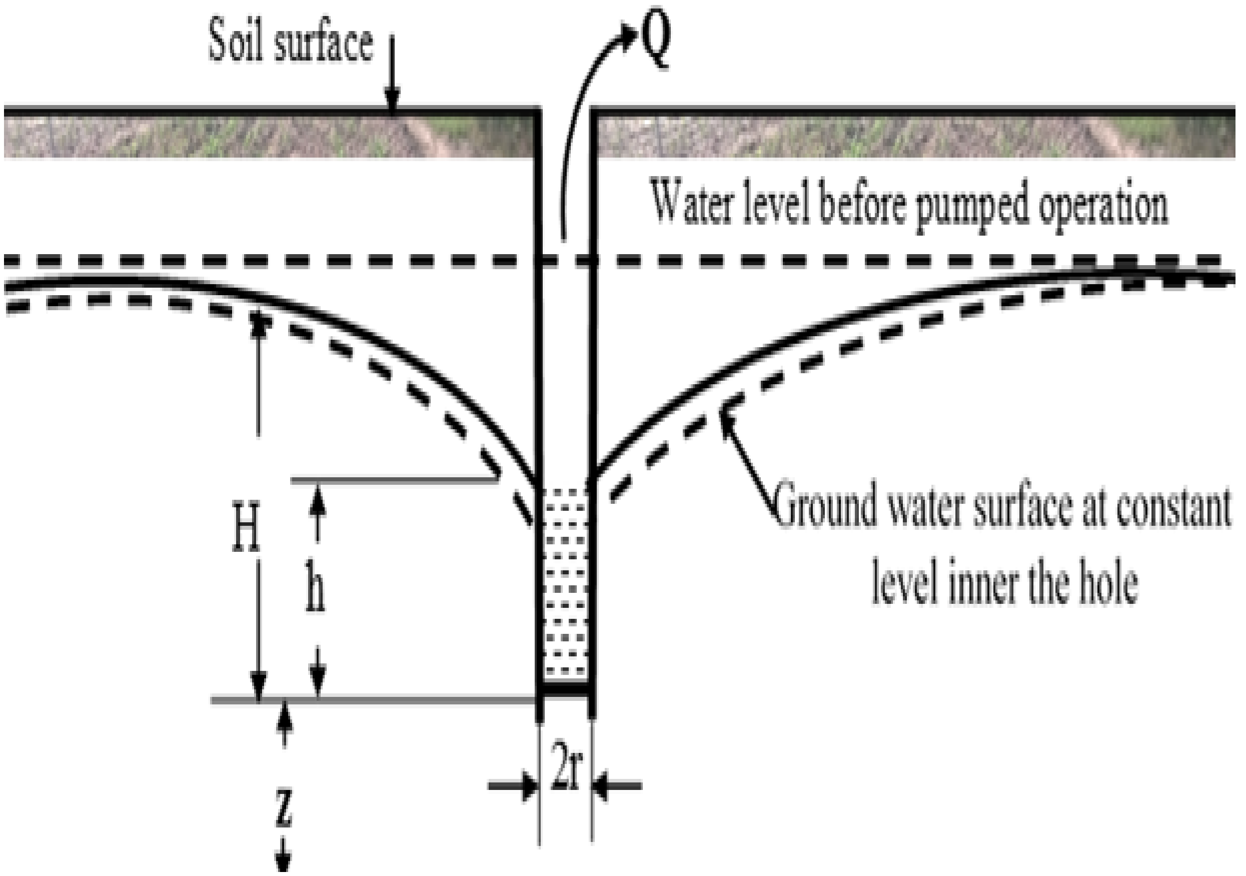

Fig 4. Schematic diagrams illustrate the pumped borehole method for measured the soil conductivity (K) under saturated conditions.

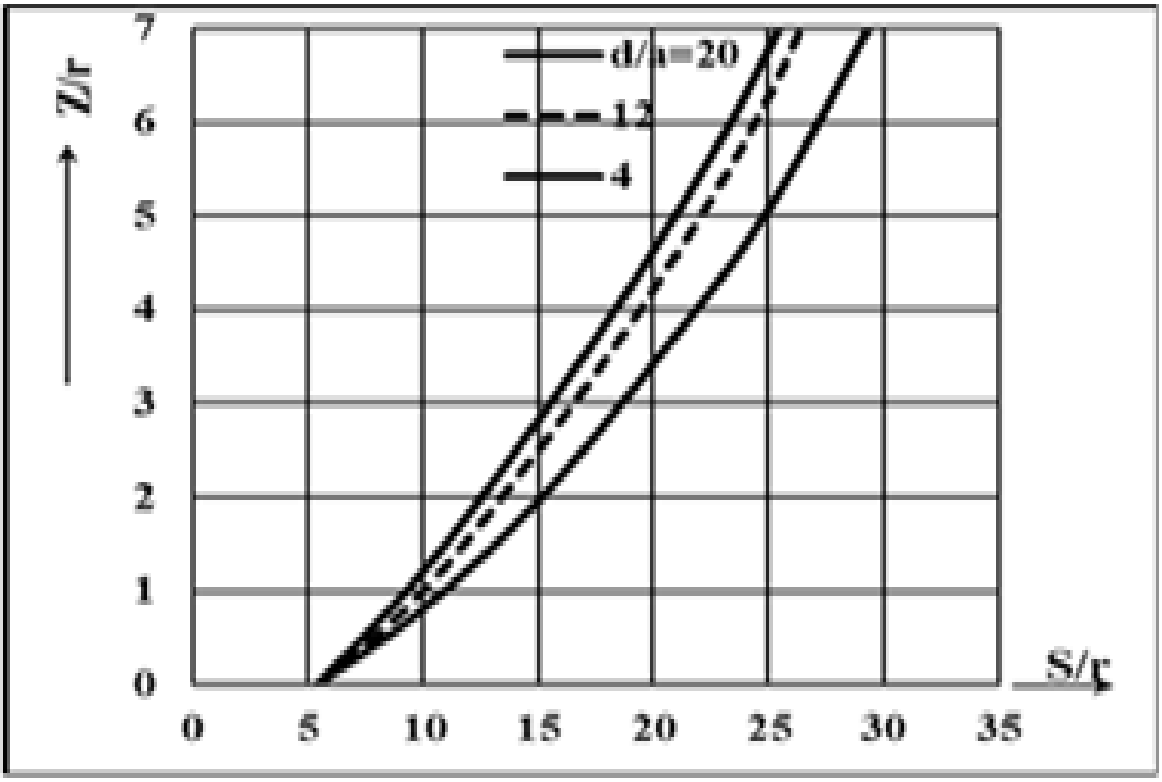

Fig 5. Value of function S.

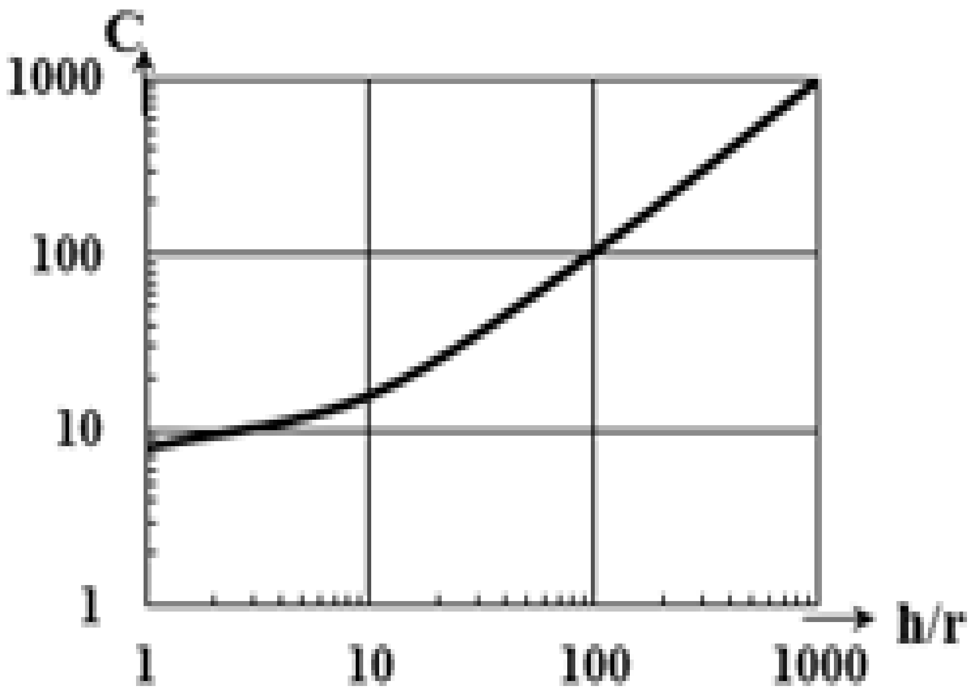

Fig 6. Value of coefficient C.

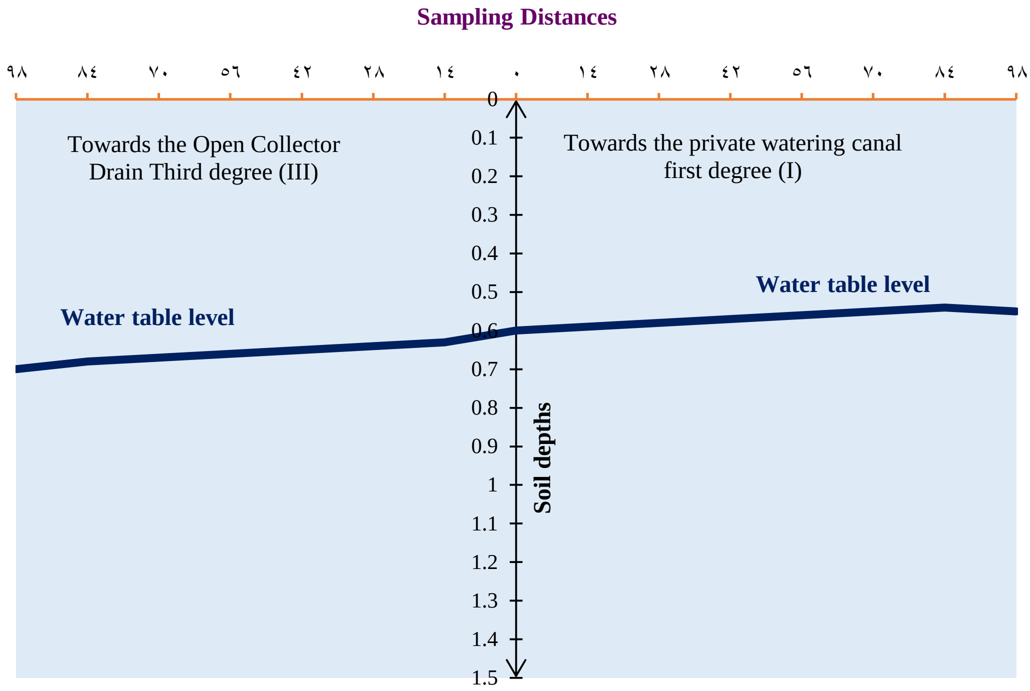

Fig 7. Water level fluctuating upon receiving the experiment site.

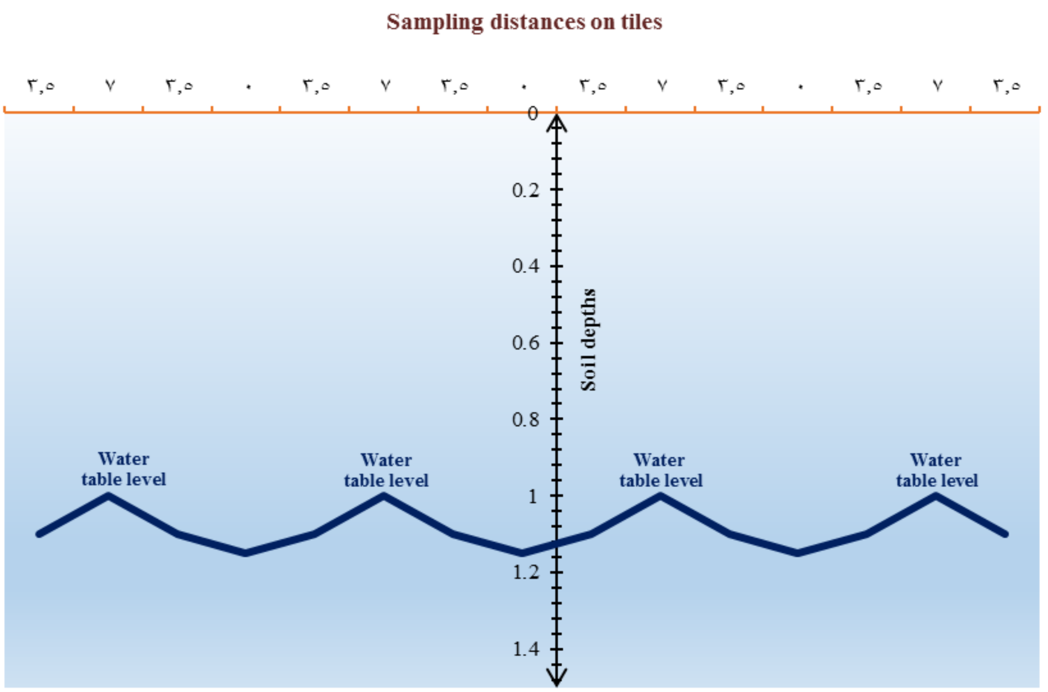

Fig 8. Periodic monitoring water table fluctuating on intensive drains (ID).

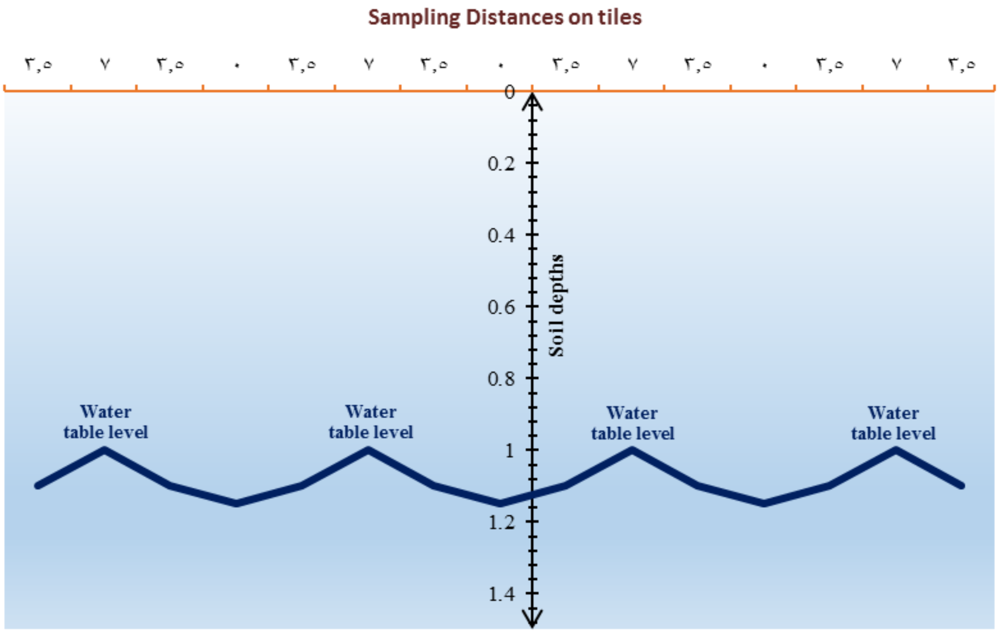

Fig 9. Periodic monitoring water table fluctuating on light drains (LD).

Fig 10. Periodic monitoring water table salinity index for light drain types (LD).

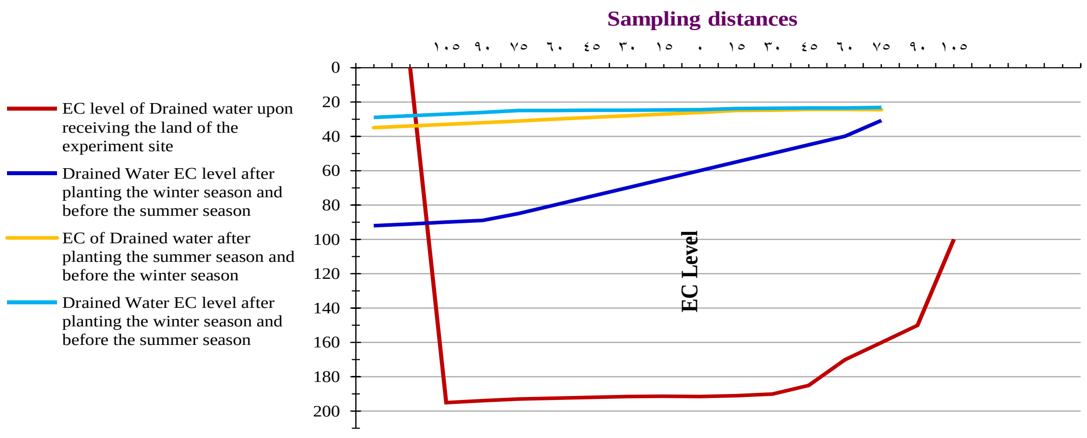

Fig 11. Periodic monitoring water table salinity index for intensive drain types (ID).

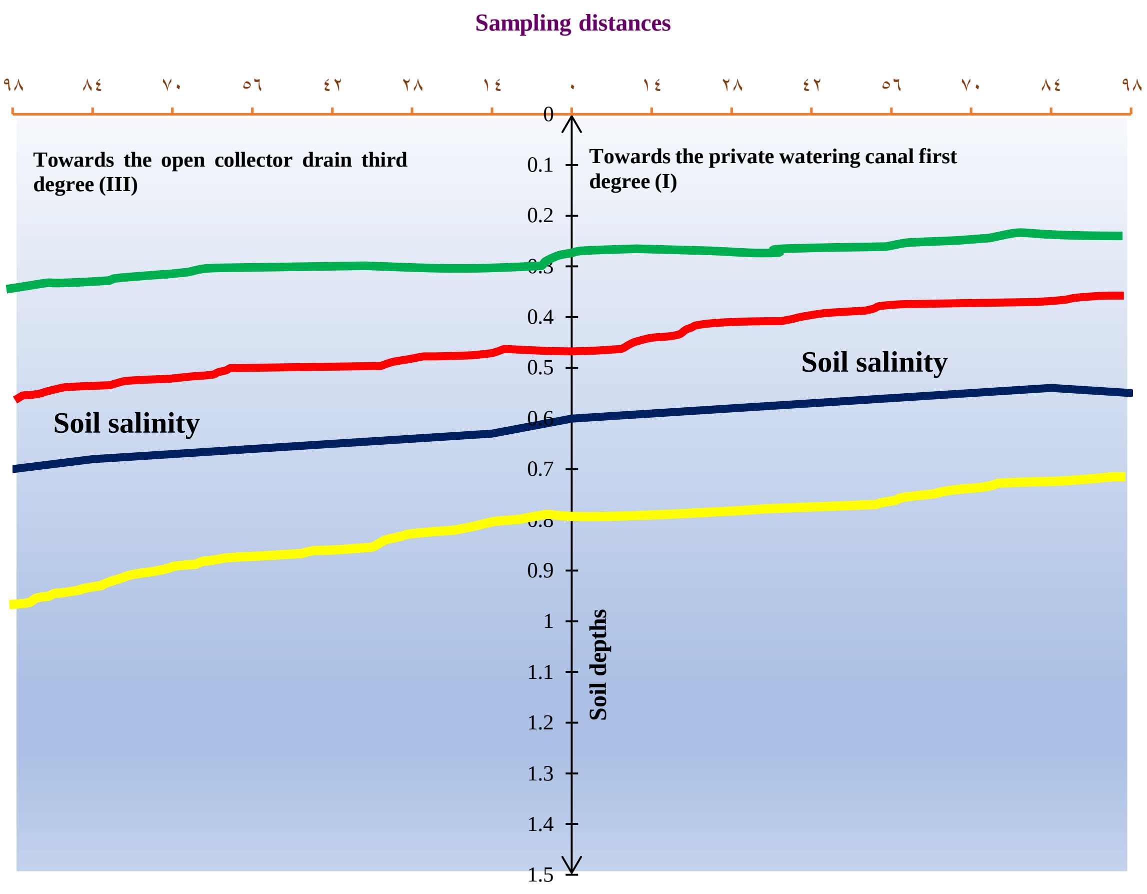

Fig 12. Initial soil salinity level at four depths and four sits of two type drains (ID – LD).

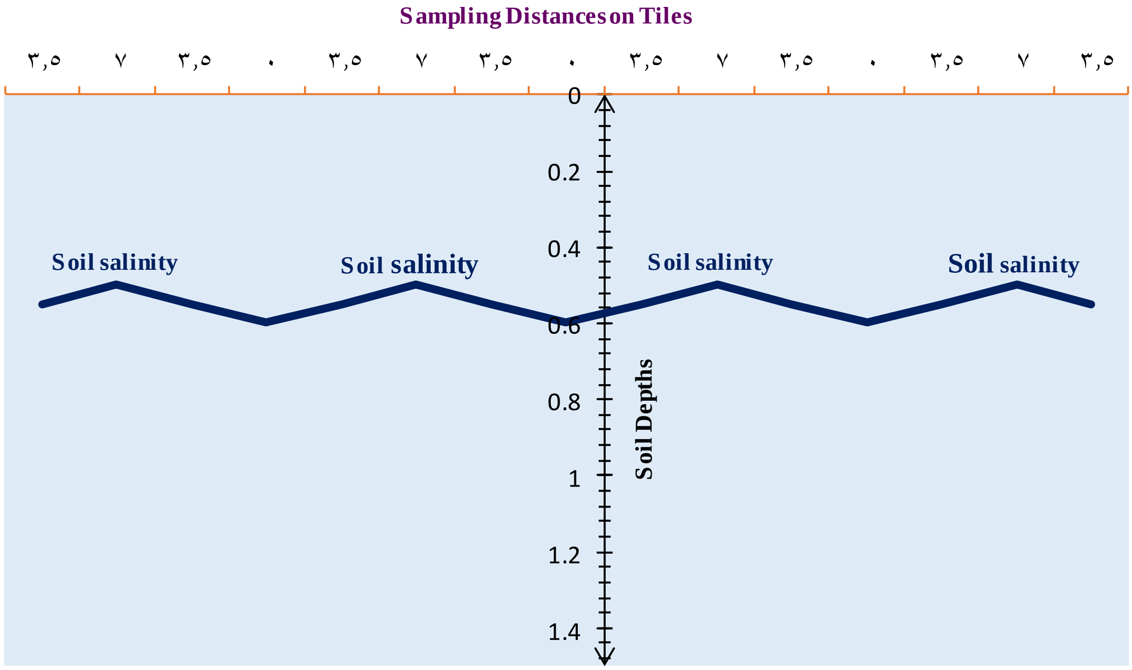

Fig 13. Periodic monitoring soil salinity index for light and intensive drain types (LD - ID).

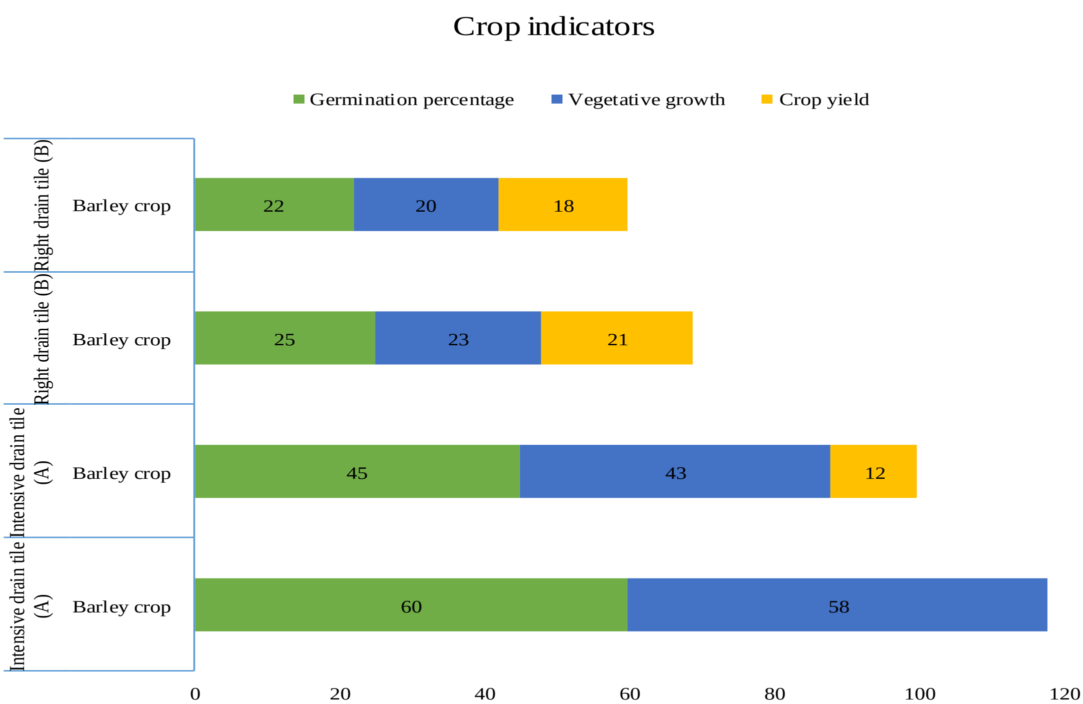

Fig 14. Impact of agricultural drain tile types and sowing method on crop indicators.

RESULTS

1. Effect of agricultural Buried Drains

Data presented in Table (2) show that using agricultural design buried drains i.e., non-drains (ND), Limited drains (LD) and Intense drains (ID) under salt-affected soil tile networks significantly increased all yield and its components parameters compared with non-drains in the two growing seasons. The highest values of all yield and its components parameters were obtained with Intense drains (ID) as compared to control in both seasons. The increasing percentages of these parameters by Intense drains treatment as compared with non-drains treatment were plant height (cm); were 16.45 and 18.74; spike length (cm) was 27.03 and 26.17; No. of spikes /m^2; were 36.84 and 30.66; No. of grains /spike; were 10.64 and 11.68; grain weight (gm m^2; were 50.23 and 52.17; grain yield (kg/fed.) ; were 50.05 and 52.04; straw yield (kg/fed.) ; were 39.50 and 44.60; biological Yield (kg/fed.); were 43.11 and 47.05; harvest index %; were 12.15 and 13.73; carbohydrates ; were 10.39 and 13.02% and protein; were 22.53 and 21.45%; in 2019/ 2020 and 2020/ 2021 growing seasons, respectively.

Regarding, effect of designs of agricultural buried drains tile networks (DABDN) on saline water drainage during under growing seasons at salt-affected soil conditions, the mechanical analyzes of experimental soil site samples were carried out for four sites with four depths along the soil profile, from 0-0.20, 0.20-0.40, 0.40-0.60, 0.60-0.80 m, respectively, the texture was clay from zero level to 0.40 m depth, and from 0.40-0.80 m swamp clay. Average soil hydraulic conductivity along the soil profile at three depths reached less than 3 m/day (24 hours). Periodic chemical analysis of the soil extract solution was carried out for each treatment because the change of chemical analysis is another indicator of removal of excess water and consequently salinity of wastewater, (Table 3).

An increase in soil salinity was found along the soil profile (before starting the experiment) for all treatments, and the range was 2-12 dS/m. After the start of the experiment, the soil salinity decreased along the length of the soil profile, and the range was 1.5-8 dS/m, (Figure 12). Also, the ground water level and its salinity level, as well as the salinity of the soil when the land was received at the site of the experiment and the change that occurred after the installation of the network of light and dense drains fields and the correlation of the drop in the ground water level with the decrease in soil and ground water salts from 120,000 parts per million to 28000 parts per million. (Figures 7-13). The increase in yield indicators such as the percentage of germination, vegetative growing and yield was associated with a decrease in the level of ground water, which resulted in a reduction of salts in the ground water removed in the fields of heavy and light drains, and consequently a decrease in salinity in the soil profile, where the percentages reached 15, 30, 45 and 60%, respectively, for barley crops. The frequency of light and heavy drainage and sowing method compared to the percentages of germination, vegetative growing and yield in areas where both types of light and dense field drains were not established, and this is illustrated by Figure (14).

1.6. Effect of the sowing method (Yield and its components):

Data in Table (4) illustrated that using the ridge sowing method performed a significant increase in all quantitative yield characteristics of barley i.e. germination %, plant height (cm), spike length (cm), no. of spikes /m^2, no. of grains /spike, grain weight/ m^2 (g), grain yield (kg/fed.), straw yield (kg/fed.), biological yield (kg/fed.), harvest index %, carbohydrates %, and protein % as compared with the control treatment in both seasons. The increasing percentages of these attributes by using the ridge sowing method as compared with broadcast sowing method treatment i.e. plant height (cm) were 3.37 and 5.74; spike length (cm) was 17.72 and 12.51; No. of spikes /m^2 were 13.86 and 5.18; no. of grains /spike were 2.77 and 5.12; grain weight/ m^2 (g) were 2.97 and 9.46; grain yield (kg/fed.) were 3.26 and 26.40 ; straw yield (kg/fed.) were 6.91 and 19.96; biological yield (kg/fed.) were 5.77 and 22.12; harvest index% were 2.73 and 4.20; carbohydrates% were 1.18 and 2.06 and protein% were 2.91 and 6.17 in 2019/2020 and 2020/2021 growing seasons respectively, (Table 4).

1.7. Effect of the interaction between the sowing method and agricultural Buried Drains:

Data illustrated in Table (5) indicated that the effect of the interaction between the sowing method and agricultural Buried Drains was significant on all yield and its components in both growing seasons. Data showed that the highest values of studied parameters of yield and its components were achieved through the ridge sowing method and intense drains treatments as compared to control in both seasons. It could be concluded that using the ridge sowing method and intense drains was sufficient to obtain the best effect on all studied parameters of barley plants (Giza 126 cultivar) under salt-affected soil conditions.

Table 2. Two designs of agricultural buried drains tile networks (DABDN) affected yield and its components and chemical composition of barley during 2018/ 2019 and 2019/ 2020 following seasons under salt-affected soil conditions.

SM \ Char.	Plant height (cm)	Spike length (cm)	No. of spikes /m^2	No. of grains /spike	Grain weight/ m^2(g)	Grain yield (kg/fed.)	Straw yield (kg/fed.)	Biological Yield (kg/fed.)	Harvest index %	Charbo-hydrats %	Protein %
2019/2020											
Traditional open drainage	64.41	5.91	108.79	33.41	108.97	435.88	1006.76	1442.64	30.21	58.79	8.25
Limited drains	71.82	7.13	132.42	35.73	171.01	683.56	1393.62	2077.18	32.92	61.63	9.39
Intense drains	77.10	8.10	171.92	37.39	217.96	871.84	1663.68	2535.52	34.39	65.61	10.69
LSD at 5%	3.43	1.13	5.91	0.92	7.13	10.61	13.83	22.16	0.64	0.53	0.12
2020/2021											
Traditional open drainage	61.15	5.36	104.69	33.71	99.92	399.71	929.42	1329.13	30.75	56.63	7.54
Few drains	66.68	6.26	120.245	34.41	158.28	633.14	1111.57	1744.93	33.41	61.31	8.78
Intense drains	75.26	7.26	150.38	38.17	207.70	832.82	1677.65	2510.47	35.64	65.11	9.60
LSD at 5%	4.22	0.83	4.18	0.55	5.22	9.51	11.37	15.64	0.72	0.34	0.16

Table 3. Two designs of agricultural buried drains tile networks (DABDN) affected on saline water drainage during two growing seasons under salt-affected soil conditions.

Treatments	pH	EC (dS/m)	Cations (meq/L)				Anions (meq/L)				SAR
			Ca^{++} (meq/L)	Mg^{++} (meq/L)	Na^{+} (meq/L)	K^{+} (meq/L)	CO_3^{--} (meq/L)	HCO_3^{-} (meq/L)	Cl^{-} (meq/L)	SO_4^{--} (meq/L)	
2019/2020											
Traditional open drainage	7.8	92	324.51	299.29	720.03	62.24	0.00	378.03	420.73	606.84	49.89
Barely broadcast sowing with limited drainage	7.85	126.3	305.98	273.68	1269.29	83.98	0.00	572.84	1275.18	87.37	86.34
Barely broadcast sowing with intense drainage	7.84	117.20	329.66	254.96	1135.77	72.68	0.00	330.83	1063.42	398.84	75.98
Barely ridge sowing with limited drainage	7.70	104.20	321.70	260.10	931.00	81.58	0.00	556.91	908.36	128.99	63.80
Barely ridge sowing with intense drainage	7.56	102.30	236.89	188.04	1055.52	85.45	0.00	92.52	1232.27	240.30	72.41
2020/2021											
Traditional open drainage	7.74	90	392.44	216.87	705.13	61.57	0.00	81.68	825.91	469.35	48.13
Barely broadcast sowing with limited drainage	7.68	112.5	386.87	257.44	1000.03	76.66	0.00	91.68	955.97	673.45	55.72
Barely broadcast sowing with intense drainage	7.63	86.3	230.00	149.96	885.37	54.96	0.00	80.78	838.59	400.83	64.23
Barely ridge sowing with limited drainage	7.58	84.1	238.91	130.83	860.89	55.36	0.00	82.10	880.44	323.76	63.32
Barely ridge sowing with intense drainage	7.5	62.3	140.32	120.66	584.37	52.96	0.00	49.08	658.49	190.83	51.16

Table 4. Effect of sowing methods (SM) on yield and its components and chemical composition of barley during two growing seasons under salt affected soil conditions.

Char. / SM	Plant height (cm)	Spike length (cm)	No. of spikes /m2	No. of grains /spike	grain weight/ m^2(g)	Grain yield (kg/fed.)	Straw yield (kg/fed.)	Biological Yield (kg/fed.)	Harvest index %	Charbo-hydrats %	Protein %
2019/2020											
Broadcast sowing	69.89	6.36	127.46	35.12	163.21	652.53	1306.06	1958.60	32.05	61.64	9.31
Ridge sowing	72.33	7.73	147.96	36.02	168.74	674.98	1403.30	2078.29	32.95	62.38	9.59
LSD at 5%	2.55	0.12	3.52	0.73	4.32	8.92	11.12	18.34	0.43	0.53	0.17
2020/2021											
Broadcast sowing	70.54	5.87	128.71	37.13	153.91	616.97	1287.28	1904.26	32.55	60.38	8.36
Ridge sowing	74.84	6.71	135.33	39.22	169.25	837.01	1608.02	2445.03	33.98	61.65	8.91
LSD at 5%	3.16	0.23	3.26	0.53	6.18	12.56	17.61	19.94	0.91	0.62	0.11

Table 5. Effect of interaction between sowing methods and designs of agricultural buried drains tile networks (DABDN) on yield and its components and chemical composition of barley during two growing seasons under salt affected soil conditions.

SM X DABDN	Char.	Plant height (cm)	Spike length (cm)	No. of spikes /m^2	No. of grains /spike	grain weight/ m^2(g)	Grain yield (kg/fed.)	Straw yield (kg/fed.)	Biological Yield (kg/fed.)	Harvest index %	Charbo hydrats %	Protein %
						2019/2020						
Broadcast sowing	Traditional open drains	62.92	5.51	95.24	33.21	107.52	430.08	960.16	1390.24	30.93	58.24	8.15
	few drains	71.11	6.33	125.92	35.23	166.52	665.08	1333.16	1998.24	33.28	61.35	9.22
	intense drains	75.66	7.25	161.24	36.56	215.61	862.44	1624.88	2487.32	34.66	65.34	10.53
Ridge sowing	Traditional open drains	65.91	6.31	122.35	33.62	110.42	441.68	1053.36	1495.04	29.49	59.34	835
	few drains	72.53	7.93	138.92	36.23	175.51	702.04	1454.08	2156.12	32.56	61.92	9.56
	intense drains	78.55	8.95	182.61	38.23	220.31	881.24	1702.48	2583.72	34.12	6589	10.86
LSD at 5%		0.85	0.06	1.17	0.36	1.44	2.97	3.70	7.33	0.19	0.25	0.11
						2020/2021						
Broadcast sowing	Traditional open drains	61.12	5.11	104.15	33.51	98.32	393.28	946.56	1339.84	29.35	56.62	7.13
	few drains	72.24	5.61	135.25	34.22	157.25	629.01	1168.02	1797.03	33.01	60.18	8.55
	intense drains	78.28	6.91	145.64	37.13	206.16	828.64	1747.28	2575.92	35.31	64.34	9.42
Ridge sowing	Traditional open drains	61.98	5.61	105.24	33.92	101.53	406.12	912.24	1318.36	32.15	56.64	7.95
	few drains	71.12	6.91	135.25	34.61	159.32	637.28	1055.12	1692.84	33.81	62.44	9.01
	intense drains	72.24	7.62	165.52	39.22	209.25	837.01	1608.02	2445.03	35.98	65.88	9.79
LSD at 5%		1.12	0.10	1.12	0.35	2.47	5.23	7.04	7.38	0.37	0.36	0.08

Table 6. The effect of interaction between sowing methods and agricultural buried drainage system on some salt affected soil properties.

Treatments	Depth (cm)	pH	EC (dS/m)	Cations (meq/L)				Anions (meq/L)				SAR
				Ca^{++} (meq/L)	Mg^{++} (meq/L)	Na^{+} (meq/L)	K^{+} (meq/L)	CO_3^{--} (meq/L)	HCO_3^{-} (meq/L)	Cl^{-} (meq/L)	SO_4^{--} (meq/L)	
Control	0-20	7.62	81.9	231.79	195.90	801.61	23.70	0.00	70.82	791.46	390.72	54.82
(Traditional	20-40	7.5	90.6	316.87	212.64	790.13	67.56	0.00	81.68	856.97	448.35	48.56
open	40-60	7.84	99.4	341.88	293.51	832.33	55.29	0.00	92.24	840.73	590.03	46.70
drains)	60-80	8.21	123.8	551.05	295.98	963.29	83.68	0.00	98.98	995.18	799.84	46.81
2019/2020												
Barely	0-20	7.82	51.6	51.79	45.90	601.61	23.70	0.00	40.82	591.46	90.72	86.08
broadcast	20-40	7.87	60.3	116.87	102.44	595.13	54.56	0.00	21.68	556.97	290.35	56.83
sowing with	40-60	7.92	59.2	141.88	93.51	562.33	55.29	0.00	52.24	420.73	380.03	51.83
limited drainage	60-80	8	117.6	251.05	195.98	1268.29	83.68	0.00	83.98	1165.18	549.84	84.83
Barely	0-20	7.93	46.5	95.98	80.82	437.43	36.77	0.00	32.80	383.36	198.84	46.52
broadcast	20-40	7.85	53.4	108.72	83.00	524.70	31.58	0.00	60.10	558.91	128.99	53.59
sowing with	40-60	7.88	59.2	131.88	83.51	582.33	55.29	0.00	52.24	420.73	380.03	56.11
intense drainage	60-80	7.71	95.6	235.89	187.14	955.52	83.45	0.00	92.52	833.37	536.11	65.70
Barely	0-20	7.88	36.6	63.74	52.14	358.50	25.63	0.00	23.08	319.87	157.06	47.10
ridge	20-40	7.87	44.9	86.87	75.75	442.25	24.13	0.00	11.96	477.42	139.62	49.04
sowing with	40-60	7.77	59.3	145.69	89.85	585.17	34.29	0.00	52.38	522.26	280.36	53.92
limited drainage	60-80	7.82	60.3	192.44	116.87	505.13	54.56	0.00	21.68	456.97	390.35	40.62
Barely	0-20	7.85	24.3	26.88	21.60	250.05	15.47	0.00	23.82	267.07	23.11	50.79
ridge	20-40	7.82	29.8	26.11	24.78	318.49	29.62	0.00	31.12	339.12	29.64	63.14
sowing with	40-60	7.88	35.1	38.85	35.63	390.12	15.39	0.00	20.96	305.02	154.02	63.93
intense drainage	60-80	7.77	36.5	41.91	34.83	396.89	25.36	0.00	22.10	380.44	96.46	64.07

Cont. Table 6. The effect of interaction between sowing methods and agricultural buried drainage system on some salt affected soil properties.

Treatments	Depth (cm)	pH	EC (dS/m)	Cations (meq/L) Ca^{++} (meq/L)	Mg^{++} (meq/L)	Na^{+} (meq/L)	K^{+} (meq/L)	Anions (meq/L) CO_3^{--} (meq/L)	HCO_3^{-} (meq/L)	Cl^{-} (meq/L)	SO_4^{--} (meq/L)	SAR
						2020/2021						
Barely broadcast sowing with limited drainage	0-20	7.89	45	89.66	70.73	444.86	24.75	0.00	22.10	453.08	154.82	49.68
	20-40	7.86	57.5	111.77	95.58	576.66	44.99	0.00	11.82	588.15	229.03	56.63
	40-60	7.71	53.4	108.72	83.00	524.70	31.58	0.00	60.10	558.91	128.99	53.59
	60-80	7.82	84.5	232.00	109.66	905.37	44.96	0.00	77.68	898.49	315.83	69.27
Barely broadcast sowing with intense drainage	0-20	7.91	35	59.66	50.73	342.86	24.75	0.00	22.10	313.08	142.82	46.15
	20-40	7.92	47.5	87.77	75.58	466.66	34.99	0.00	11.82	488.15	165.03	51.64
	40-60	7.91	53.4	108.72	83.00	524.70	31.58	0.00	60.10	558.91	128.99	53.59
	60-80	8.01	74.5	140.00	118.66	835.37	44.96	0.00	40.68	858.49	239.83	73.46
Barely ridge sowing with limited drainage	0-20	7.89	30.3	65.62	54.44	263.41	22.53	0.00	13.36	258.10	134.54	34.00
	20-40	7.86	39.7	75.70	57.86	384.40	25.03	0.00	23.80	384.06	135.14	47.04
	40-60	7.71	48.7	144.57	99.88	423.64	13.90	0.00	44.08	389.84	248.09	38.32
	60-80	7.82	55	92.58	77.83	560.97	39.62	0.00	22.52	498.48	250.00	60.77
Barely ridge sowing with limited drainage	0-20	7.91	22.3	55.62	46.44	163.41	22.53	0.00	13.36	158.10	116.54	22.87
	20-40	7.92	29.7	45.70	37.86	289.40	25.03	0.00	23.80	284.06	90.14	44.77
	40-60	7.91	28.7	44.57	39.88	285.64	13.90	0.00	14.08	289.84	80.09	43.96
	60-80	8.01	35	62.58	47.83	342.97	24.62	0.00	22.52	312.48	143.00	46.16

The aim of this study was achieved using two field experiments during the 2019/2020 and 2020/2021 seasons at the Desert Research Center, Sahli Alttinah, North Sinai Governorate, Egypt (Table 5).

The effect of the interaction between the sowing method and agricultural Buried Drains on some salt affected soil properties shown in table (6). The results indicated that soil was a poorly medium dense sand, have an electrical conductivity (EC) more than 4 dS/m. The results show that there was a change in the salinity rate of cultivation in the first season (2019-2020) compared to the second season (2019-2020). This shows that the average salinity was lower in the soil treated with different types of drainage (limit drainage and intense drainage) and the two types of crop sowing (broadcast sowing and ridge sowing) than the control average of 29%. On the other hand, the soil salinity of the soils treated with intensive drainage decreased by 22% and 23% compared to the salinity of the soils treated with limit drainage in the same season 2019-2020 and 2019-2020, respectively. In addition, the salinity rate decreased in the soils treated with intensive drainage at a rate of 49% in the second season (2019-2020) when compared to the first season (2019-2020). From the abovementioned the best treatment was Barely ridge sowing with intensive drainage. Furthermore, intense drainage was high efficiency for sustainable cultivation for salt affected soil to decrease soil saline and improved barley yield, (Table 6).

DISCUSSIONS

In Egypt's original desert regions as well as certain recently reclaimed ones, drainage is regarded as one of the most crucial agricultural operations, (Bedair *et al.*, 2023 and Gabr, 2023). Visual drainage assessment design is based on data from a soil profile assessment along with previous knowledge of the site and outfall circumstances (Jato-Espino *et al.*, 2022 and Dukiya *et al.*, 2023). This might be improved to provide an approximation of the permeability of different soil horizons in actual field settings. Effective mole drainage on a particular soil type may assist in lessening issues with salt and waterlogging (Miricescu *et al.*, 2021).

The aim of the current study was to determine an efficient drainage system and sowing method to overcome salinity hazards and obtain superior and sustainable barley yield. Our treatments included two sowing methods as broadcast sowing (BS), ridge sowing (RS) as well as two type of buried drainage Tiles beside traditional open drainage. In our study, the highest values of yield and its components parameters were obtained with Intense drains (ID) as compared to control, this may be due to controlling salinity stress, which triggers the impact of other abiotic stresses which is represented in higher salt aggravates the essential nutrient supply to the plants throughout their growth cycle resulting in devastating yield losses by sowing barley with non-drains under salt-affected soil conditions (Hussain *et al.*, 2022). Much of the research on this trend such as Fraser *et al.* (2001); Blann *et al.* (2009) and Hassan *et al.* (2017). Also, such an enhancing effect of Intense drains (ID) might be due to drain activities promoting salt migration in the upper soil layer downwards, (Aragüés *et al.*, 2011 and El-Shahat, 2023).

In our study, average soil hydraulic conductivity along the soil profile at three depths reached less than 3 m/day (24 hours). Also, increases in soil salinity were found along the soil profile before starting the experiment for all treatments, due to the accumulated soil water and its content of salts, as there is no way to dispose this water. After the start of the experiment, the soil salinity decreased along the length of the soil profile (ranged 1.5-8 dS/m), due to the efficiency of the drainage treatments in removing excess water (Mielcarek *et al.*, 2022; Sabliy and Zhukowa, 2022).The increase yield indicators such as the percentage of germination, vegetative growing and yield which was associated with a decrease in the level of ground water, which resulted in a reduction of salts in the ground water removed in the fields of heavy and light drains, and consequently a decrease in salinity in the soil profile, for the frequency of light and heavy drainage and sowing method compared to the percentages of germination, vegetative growing and yield in areas where both types of light and dense field drains were not established (Wang *et al.*, 2022; Mariey *et al.*, 2023; Masrahi *et al.*, 2023 and Sabra *et al.*, 2023).

In our study, using the ridge sowing method performed a significant increase in all quantitative yield characteristics of barley and its grain components as compared with the controls in both seasons, this may be due to their ability to maintain biomass, germination, early root growth, and other indicators, under the ridge method in salt-affected soil conditions, (Kristensen *et al.*, 2006; Olsen *et al.*, 2012 and Pour-Aboughadareh et al., 2021), and others decided that too. Many researchers have pointed to the importance and role of the ridges sowing method compare with broadcast under salt-affected soil conditions of yield were ideal for cover crop germination, distribution of cover barley crop seedlings under salt-affected soil, and cover crop stands with a distinctive pattern on the bed consistent across replications and experiments, (Collins & Fowler,1992; Bartholomew *et al.*, 2011 and Jeon *et al.*, 2011).

In our study, the highest yield and its components were achieved using ridge sowing method and intense drains treatments (ID) as compared to control. However, salinity of soils treated with ID decreased by 22% and 23% compared those treated with limit drainage (LD) in both seasons, respectively. In addition, the salinity rate decreased in soils treated with ID at rate of 49% in 2019-2020 compared to 2019-2020. From the abovementioned the best treatment was barely ridging sowing with ID. Furthermore, ID was high efficiency for sustainable cultivation for salt affected soil to decrease soil saline and improved barley yield. This agreement with Gaber (2018). It could be concluded that using the ridge sowing method and intense drains was sufficient to obtain the best effect on all studied parameters of barley plants (Giza 126 cultivar) under salt-affected soil conditions.

CONCLUSIONS

The role of the ridge sowing method compare with broadcast under salt-affected soil conditions of yield were ideal for cover crop germination, Distribution of cover barley crop seedlings under salt-affected soil, and cover crop stands with a distinctive pattern on the bed consistent across replications and experiments.

The increase in yield indicators such as the percentage of germination, vegetative growing, and yield was associated with a decrease in the level of groundwater, which resulted in a reduction of salts in the groundwater removed in the fields of heavy and light drains, and consequently a decrease in salinity in the soil profile. The highest values of all yield and its components parameters were obtained with intense drains as compared to control in both seasons.

The effect of the intensive drainage treatment led to increased soil leaching and reduced soil salinity. The effect of the interaction between the sowing method and agricultural Buried Drain Tiles was significant on all yield and its components in both growing seasons. Using the ridge sowing method and intense drains was sufficient to obtain the best effect on all studied parameters of barley plants (Giza 126 cultivar) under salt-affected soil conditions.

Soil intensive drainage was high efficiency for sustainable cultivation for salt affected soil to decrease soil saline and improved crop yield. it is recommended that (1) applying buried drainage system to improve washing of soil salts (2) changing the cropping system at the scheme to meet soil salinity levels (3) periodic monitoring for the irrigation water, drainage water, soil salinity, and the groundwater are important issue to manage crop pattern and drainage water.

Availability of data and materials

All data generated or analyzed as part of this study are included in this published article.

Abbreviations

BS: Broadcast sowing

DABDN**:** designs of agricultural buried drains tile networks

EC**:** electrical conductivity

ID: Intense drains

LD: Limited drains

LSD**:** least significant difference

ND**:** non-drains

OD**:** control treatment

RS: Ridge sowing

TOD: Traditional open drainage

VDA**:** Visual drainage assessment

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الملخص العربي

إنتاجية الشعير وجودة التربة إستجابة لطريقة الزراعة وتصميمين لحقليات المصارف الزراعية المغطاة فى التربة المتأثرة بالملوحة

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تضمنت الدراسة الحالية تجارب ميدانية أجريت لموسمي ٢٠١٩/٢٠٢٠ و٢٠٢٠/٢٠٢١ في منطقة سهل الطينة. تضمنت التجارب طريقتين للزراعة، طريقة البذار (BS)، والزراعة فى السطور (RS) ، وثلاثة أنواع من الصرف المغطى (المصارف المحدودة (LD) ، والمصارف المكثفة (ID)، والصرف المفتوح التقليدي كعنصر تحكم كنترول.(TD)

أدت طرق الزراعة فى سطور إلى زيادة معنوية في حبوب الشعير والقش والمحصول البيولوجي ومكونات المحصول مثل، نسبة الإنبات، ارتفاع النبات، طول السنبلة، عدد السنابل/ م٢، عدد الحبوب/ السنبلة، وزن الحبوب(كجم/م٢)، دليل الحصاد٪، وكذلك نسبة الكربوهيدرات ٪، والبروتين٪ من الشعير مقارنة بطريقة البذار كانت هذه النتائج متشابهة لكلا الموسمين. علاوة على ذلك، تسبب طريقة الزراعة فى سطور في زيادة معنوية في جميع الصفات الكيميائية لحبوب الشعير. كما تم الحصول على أعلى قيم لإنتاجية محصول الحبوب الشعير ومكوناتها في المصارف المغطاة المكثفة مقارنة بالمصارف التقليدية المفتوحة في كلا الموسمين. كان للمصارف المكثفة تأثير معنوي على التركيب الكيميائي للحبوب مقارنة بالمعاملة المقارنة لموسمي النمو. أيضا أثر التفاعل بين طرق البذر الزراعة فى سطور وتصميمات شبكات المصارف الزراعية المغطاة المكثفة معنويا في إنتاجية محصول الشعير ومكوناتها، وكانت هذه النتائج في موسمي النمو.

أوضحت النتائج أن أعلى قيم للمعاملات تحت الدراسة لمحصول الشعير ومكوناته قد تحققت من خلال استخدام طريقة الزراعة فى سطور والمصارف المغطاة المكثفة مقارنة بالمصارف التقليدية المفتوحة الكنترول في كلا الموسمين. كما أن تطبيق نظم المصارف الزراعية المغطاة أدى إلى تخفيض ملوحة مياة التربة الناتجة عن نظم الصرف المغطى وبالتالى يحسن من جودة التربة.

الكلمات المفتاحية: محصول الشعير، طرق الزراعة، التركيب الكيميائي، شبكات المصارف الزراعية المغطاة، التربة المتأثرة بالملوحة.