Contents

5. SUMMARY

The present work was conducted to study the soil water table depth in its relation to soil and water management and to soil productivity under different drainage conditions.

This work aimed to:

1- evaluate the relationship between the drainage conditions, i.e. adequate and inadequate subsurface drainage and the soil water table depth.
2- evaluate the effect of soil water table depth on some soil hydrophysical properties such as the drainage intensity factor, saturated hydraulic conductivity, drainable porosity and the pore size distribution.
3- studying the relationship between ground water table depth and soil moisture content as an attempt to monitor the irrigation time and as an approach for soil workability using the simple measure of the water table depth.
4- quantify the effect of the soil water table depth, through the distance from the drain, on the crop yield and water use efficiency, under different drainage conditions.

To achieve the aim of this study, two sites were selected to represent the different drainage conditions, i.e. adequate (site 1) and inadequate (site 2) subsurface drainage system. The selected two sites located at Ebiar village in Kafr El-Zayat district, El-Gharbia Governorate. At each site, observation wells were installed along a line perpendicular of three laterals. Observation wells were located at a distance of 1/8, 1/4 and 1/2 the drain spacing (40 m). The two sites were cultivated, in agricultural cycle, with wheat and corn crops during the two successive growing seasons of 1998/1999 and 1999/2000. The experiment was arranged in split split plot design

with three replicates. The main plot was assigned as the drainage status; adequate and inadequate drainage. The subplot was the distance from drain (lateral) which were 5, 10 and 20 m. The sub-subplot was assigned as the plant growth stages. Each plot was 2m×2m ($4m^2$).

In each site disturbed and undisturbed soil samples were collected from soil profiles every 30 cm depth until 60 cm. Each site was represented by two profiles. One profile above the drain pipe and the other in the midway between each two laterals for comparison. The soil samples were used to determine the main physical and chemical soil properties.

Water table depth was recorded daily between every two irrigation cycles during the growing seasons of wheat and corn crops. Rate of water table drawdown, the frequency distribution of water table and the relative ground water depth were calculated to evaluate the ground water table and the performance of the drainage system. Also drain discharge was measured during all irrigation cycles and some hydrological parameters such as drainage intensity factor and the effective porosity were calculated. The hydraulic conductivity and the pore size distribution were also determined.

The measurements of the soil water table depth (WTD) were made simultaneously with the soil moisture content (MC) at 5, 10 and 20 m distance from drain during the growing seasons of wheat and corn for each study site. Also the soil moisture content at the lower plastic limit (LPL) for the surface soil layer (0-30 cm depth) was determined.

Finally, some vegetative growth parameters, yield and yield components, water consumptive use (Cu) and water use efficiency

(WUE) of wheat and corn crops were determined for the two sites along the two years study period.

The obtained results can be summarized in the following:

1- **Soil water table and its relation to the different drainage condition:-**

(a) Fluctuation of the water table depth (WTD):

The WTD is mainly depended on the drainage status as well as the distance from the tiles and the growing seasons. The overall average of WTD under the adequate drainage conditions ranged from 85.1 to 120.3 cm and from 106.7 to 132.3 cm, respectively, during the wheat crop seasons 98/99 and 99/2000. Under corn crop, the obtained value ranged from 72.3 to 93.6 cm and from 70.4 to 90.8 cm, respectively, for the same two seasons. Under the inadequate drainage conditions, the overall average of WTD varied from 45.4 to 65.3 cm and from 60.7 to 73.8 cm, respectively, for the wheat growing seasons 98/99 and 99/2000. Under corn crops the obtained values varied from 42.5 to 57.1 cm and from 48.8 to 62.1 cm, respectively, for the same two seasons. Whatever the drainage conditions, the WTD decreased as the distance from pipe drain increased to the mid point between them. It was more deeper in the vicinity of the pipe drains than that at the mid distance between them.

The amplitude of the WTD fluctuation, at mid distance between tiles, was higher under the adequate drainage conditions than that under the inadequate one. It was 1.55 and 1.97 times more greater under the adequate drainage conditions than that of the inadequate one, respectively, for areas cultivated with wheat and corn crops.

(b) The rate of water table drawdown under the adequate drainage conditions was 1.5 and 1.6 times higher than that under the inadequate one during the growing seasons of wheat and corn, respectively. The overall average rate of water table drawdown was 51.12 and 33.77 mm/day, respectively, under the adequate and inadequate drainage conditions during wheat growing season. The corresponding values during corn growing season, were 64.17 and 39.44 mm/day, respectively, under adequate and inadequate drainage conditions. The rate of water table drawdown increased as the distance from pipe drain decreased.

(c) Whatever the growing season, occurrence percentages of water table deeper than 80 cm from soil surface were higher under the adequate drainage conditions than that under the inadequate one. The cumulative occurrence percentage of water table >80 cm, during wheat growing season, ranged from 62.1 to 76.7% and from 6.1 to 27.3%, respectively, under adequate and inadequate drainage conditions. The corresponding values, during corn growing season, ranged from 54.3 to 57.9% and from 0.0 to 1.4%, respectively under adequate and inadequate drainage conditions.

(d) The relative ground water depth (RGWD) is about 1.6-1.8 times more greater under the adequate drainage conditions than that under the inadequate one. The RGWD decreased with increasing the distance from the pipe drain. The lowest value was at the midpoint between tiles and the highest one was always near the tiles.

2- **Effect of soil water table on some hydrophysical properties of the soil under different drainage conditions:**

a) The drainage intensity factor "*a*" under the adequate drainage system at site (1) is almost 2.2 and 2.0 times higher than that obtained for site (2) (inadequate drainage system) during wheat and corn growing seasons, respectively. Average values of "*a*" during the wheat season were 0.105 and 0.047, respectively, under adequate and inadequate drainage conditions. The corresponding values during corn growing seasons were 0.104 for the adequate drainage conditions and 0.052 for the inadequate one.

b) Average values of K were higher under the adequate drainage site; 23.37 and 18.5 cm/day than that under the inadequate one; 14.7 and 10.26 cm/day, respectively for the above and between the pipe drains.

c) The soil provided with adequate drainage system has almost the double effective porosity (*f*) than that obtained in inadequate drainage system. The overall average of the "*f*" values were 4.13% and 1.96% respectively for the adequate and inadequate drainage.

d) The values of quickly and slowly drainable pores were relatively low in site (2) compared with that of site (1) and decrease with increasing distance from pipe drains in both two sites. Average values of QDP were 4.16% and 3.03%, respectively, in site (1) and (2). The corresponding values for SDP were 9.11% and 5.67%, respectively for the same two sites. On the other hand, the values of water holding and fine capillary pores were relatively high in the soil of site (2) and decreased with improving drainage system in site (1). Average values of the WHP were 21.98% and 23.85% respectively for site (1) and (2). The corresponding values for the F.C.P were 21.97% and 25.18%, respectively for the same two sites.

3- Soil water table depth (WTD) in its relation to soil and water management:

The relationship study of the measured WTD simultaneously with the soil moisture content (MC) in the root zone depth, 0-60 cm, showed that a good correlation exists between the soil WTD and MC. The determination coefficient (R^2) was highly significant, which confirms the suitability of using soil MC for predicting the soil WTD. The predicted WTD at MC which meets the irrigation time could be used as an approach fast and easy to schedule irrigation for wheat and corn crop. The obtained regression equations of the relation between MC and WTD measured at mid-distance between drains are:

MC = 44.72-0.1407 WTD (at site 1 under, wheat crop)

MC = 47.892-0.2118 WTD (at site 2 under, wheat crop)

MC = 49.97 – 0.222 WTD (at site 1 under corn crop)

MC = 51.136 – 0.3296 WTD (at site 2 under corn crop)

Where MC is the mean values of soil MC of the 0-60 cm depth.

Data showed the possibility of using these equations as an approach fast and easy to schedule irrigation for wheat and corn. Also, prediction of WTD at convient MC for field operation will be used as a simple means for soil workability.

(a) **Soil WTD as an approach for irrigation timing:**

The concept of this approach is that irrigation can be applied when WTD reached a predetermined certain value. This value could be obtained from the empirical equation, which represents the regression equation between the soil WTD and the soil MC in the root zone depth (0-60 cm) for the considered crop. Solving the regression equation, of the considered crops, at MC which meets the irrigation time give the required WTD.

Irrigation timing is accomplished with the soil WTD approach by:

- determining the soil moisture constants F.C. and PWP and calculating the available soil water (AW).
- Knowing the maximum allowable depletion (MAD) which is usually available in the specialized references to calculate the readily available water; RAW = MAD×AW
- Calculate the moisture content percent which meets the irrigation time, $(MC)_i$ = F.C. – RAW
- Use the recommended regression equation for the considered crop, under adequate or inadequate drainage conditions, to calculate the value of the $(WTD)_i$ at $(MC)_i$ which metes the irrigation time.
- Follow the daily measurement of WTD in mid-distance between tiles after irrigation. The day that the predetermined $(WTD)_i$ reached is the day of the next irrigation.

According to this approach, the results showed that the predicted water table depth (WTD) for irrigation timing, were 137.3 and 93.3 cm for wheat crop respectively, under adequate (site 1) and inadequate drainage (site 2). The corresponding values for corn crop were, 110.7 and 69.8 cm, respectively, for the same two sites. The calculated irrigation intervals values were about 23 and 27 days for wheat crop under adequate drainage (site 1) and the inadequate one site (2) respectively. The corresponding values for corn crop were about 16 and 17 days, respectively, for the same two sites. The obtained irrigation intervals values of this approach is comparable with the conventional irrigation intervals for corn (two weeks approx.) and for wheat (3 weeks approx.) under the condition of the studied area, which indicate the validity of the soil WTD as a new-approach for irrigation timing.

b- **Soil water table depth in its relation to soil management** :

In this study the soil WTD was used as an approach fast and easy for predicting soil workability. The concept of this approach depends on the relationship between the WTD, measured at the mid-distance between the drains, and the MC determined at the tillage soil depth (0-30 cm). The suitable time for workability is determined when WTD reached a certain value, called critical water table depth limit $(WTD)_c$ for workability. This value of the $(WTD)_c$ is obtainable from the simple regression equation between WTD and MC at the tillage depth. Solving the regression equation for the considered soil and crop, at the moisture content of the lower plastic limit (LPL) gives the required $(WTD)_c$.

The suitable time for soil workability is predicted with the soil WTD approach by:

- determining the MC at the LPL for the tillage depth of the soil (0-30 cm).
- use the recommended regression equation for the considered crop, under adequate or inadequate drainage conditions to calculate the $(WTD)_c$, which correspond the WTD at LPL.

- follow the daily measurement of WTD at mid distance between drains after irrigation. The day that the predetermined $(WTD)_c$ reached is the suitable time for workability.

The recommended regression equations of the relationship between soil WTD measured at mid-distance between drains and the MC determined for the tillage depth (0-30 cm) are:-

MC = 62.609 – 0.278 WTD (at site 1 under wheat crop)

MC = 57.34 – 0.303 WTD (at site 2 under wheat crop)

MC = 59.854 – 0.301 WTD (at site 1 under corn crop)

MC = 61.26 – 0.406 WTD (at site 2 under corn crop)

Accordingly, the critical limit of the water table depth $(WTD)_c$ at which higher than this limit the soil is suitable for field operation were about 113 and 72 cm under wheat crop, respectively for the adequate drainage conditions (site 1) and the inadequate one (site 2). The corresponding values of the $(WTD)_c$ under corn crop were about 95 and 63 cm, respectively, for the same two sites.

The average workability timing duration, after an irrigation event, varied between about 13 and 18 days, respectively, for corn and wheat in site (1) cultivated under adequate drainage. While it varied between about 15 and 20 days, respectively, for corn and wheat cultivated under inadequate drainage conditions in site (2).

The calculated consistency index (IC) using the obtained $(WTD)_c$ from the relationship between MC and WTD confirmed the reliability of the WTD as an approach to predict the suitable time for soil workability particularly in soils with adequate drainage conditions.

4- Soil productivity as affected by ground water table depth under the different drainage conditions:

Effect of the WTD on the productivity of the cultivated crops was studied through the distance from the pipe drains, where the deep WTD is always above the drain pipes and the shallow depth is at the mid distance between the drain pipes. The obtained results showed that:

I- Wheat Crop:

(a) The vegetative growth parameters:

All the studied growth characters for wheat crop; plant height, dry matter weight and growth rate were significantly affected by the drainage conditions, distance from drain pipes and the growing stage. The highest plant height was 114.5 cm and 113.7 cm at the yield formation stage, respectively under adequate drainage condition and 5 m distance from the drain pipes. The highest dry weight of 5.6 g/plant was recorded under the adequate drainage and under 5 m distance from drains at the yield formation stage. The highest crop growths rate 0.779 and 0.671 g/week were obtained under the adequate drainage conditions at the flowering stage, respectively for 1st and 2nd seasons.

(b) Yield and yield components:

Both of grain yield and 1000 grain weight of wheat are significantly affected by drainage conditions and distance from drains. The highest grain yield of 2.74 and 2.43 ton/fed. was obtained under the condition of adequate drainage, respectively for the 1st and 2nd seasons. With respect to the effect of distance from drain, the highest grain yield were 2.66 and 2.35 ton/fed at 5m distance from the drain, respectively, for the 1st and 2nd seasons.

The interaction between drainage status and distance from drain pipes was not significant.

(c) Water consumption use (Cu) and water use efficiency (WUE):

Average values of the water consumptive use generally higher under the conditions of the adequate drainage (site 1) compared with that under the inadequate one (site 2), as well as at the vicinity of drain in comparison with at the mid distance between drains. The overall averages were 1670.9 m^3/fed and 1444.8 m^3/fed, respectively under the adequate drainage conditions of site (1) and the inadequate one of site (2).

Data also showed that the WUE values were higher under the adequate drainage conditions than that under the inadequate one, as well as at vicinity of the drain than at mid-distance between drains. The higher WUE values were 1.64 and 1.47 kg/m^3 in the vicinity of the drain pipes, respectively, under the adequate drainage conditions of site (1) and the inadequate one of site (2). The lower values 1.56 and 0.87 kg/m^3 were obtained at mid-distance between drains under the same two sites, respectively.

II - Corn crop

(a) Vegetative growth parameters :

The obtained results showed that plant height was not significantly affected by the drainage conditions. However the average highest plant height was about 326 cm under the adequate drainage conditions at the end of the yield formation stage, while the lowest one was about 319 cm under the inadequate drainage conditions.

Data also showed that plant height decreased significantly with increasing the distance from the drains, where maximum values of plant height 343.7 cm was obtained at 5 m distance in the end of yield formation stage. The lowest value 57.6 cm was obtained at 20 m distance in the end of the establishment stage.

With respect to the dry weight of corn plant, data showed that it was affected significantly by drainage conditions, distance from drains and growth stages. In general higher values of dry weight were found under the adequate drainage conditions and in vicinity of the drain at 5 m distance from drains. The interaction between the drainage condition and both of distance from drain and growth stage was not significant as well as the interaction among the three parameters under study. Only interaction between distance from drain and growth stages which was significant. The highest dry matter weight of 2.09 g/plant was obtained at 5 m distance from the drain for the yield formation stage. The lowest value of 4.38 g/plant was found at 20 distance from drains for the establishment stage.

(b) Yield and Yield components:

Data showed that both grain yield and 100 grain weight of corn are significantly affected by drainage conditions and distance from drains. The highest grain yield of about 3.49 ton/fed, as an average for the two seasons, was obtained under the adequate drainage conditions. The average values of the lowest grain yield about 1.98 ton/fed, was obtained under the inadequate drainage conditions. With respect to the effect of distance from drains, data showed that the highest values was obtained in vicinity of the drain at 5 m distance with an average of 3.14 ton/fed. The lowest values were obtained at the mid distance between drains at 20 m distance with an average of 2.3 ton/fed. The interaction between drainage conditions and distance from drains on grain yield was not significant except for the 2^{nd} season. The highest grain yield of 3.79 ton/fed was under the adequate drainage conditions in the vicinity of the drain, at 5 m distance from the drains, while the lowest one 1.4 ton/fed was obtained under the inadequate drainage conditions at 20 m distance from the drains.

(c) Water consumptive use (Cu) and water use efficiency (WUE):

Data showed that the trend of Cu and that of the WUE were the same as that observed with the wheat crop. I.e. the highest values of Cu and WUE were obtained under the adequate drainage conditions as well as in the vicinity of the drains. The overall average of the Cu were 2095 m^3/fed and 1795.8 m^3/fed, respectively under the adequate and inadequate drainage conditions.

Average values of WUE were 1.67 kg/m^3 and 1.1 kg/m^3, respectively, for the adequate and inadequate drainage conditions. With respect to the distance from drains; the higher values of 1.73 and 1.3 kg/m^3 were obtained at 5 m distance, under the adequate and inadequate drainage, with an average of 1.5 kg/m^3. The lower values 1.62 and 0.9 kg/m^3 with an average of 1.26 kg/m^3 were obtained at mid-distance between drains under the same two sites.

CONCLUSION

From the abovementioned results, it could be conclude that:

1. Evaluation parameters of the WTD; fluctuation, rate of drawdown, relative depth and the frequency distribution of the WTD, depend mainly on the drainage conditions and the distance from the drains. Consequently, these parameters are good indicator to evaluate the efficiency of the subsurface drainage (tile drainage). Average values of each of the studied parameters of the WTD were greater under the adequate drainage conditions than that under the inadequate one.
2. Higher WTD due to the inadequate drainage conditions, resulted in low values of the studied hydrophysical properties of the soil. Average values of drainage intensity factor "*a*", saturated hydraulic conductivity "K", effective porosity "*f* ", quickly drainable pore "QDP" and slowly drainable pore "SDP" were about 2.1, 1.67, 2.1, 1.4 and 1.6 times greater under the adequate drainage conditions than that under the inadequate one. Whereas average value of WHP and FCP were, respectively, 0.92 and 0.87 times lower under adequate drainage conditions than the inadequate one. Average values of these soil properties were, also, found to be decrease with increasing the distance from drains to the mid-distance between them.
3. The poor conditions for plant growth resulting from the inadequate drainage conditions are responsible for average crop production losses equal to 31.6 and 43.2% of the production under the adequate drainage conditions, respectively, for grain yield of wheat and corn crop. The average grain yield for the two seasons of study was 2.59 and 3.49 ton/fed., respectively, for wheat and corn crops under the adequate drainage

conditions. While it were 1.77 and 1.98 ton/fed., respectively, for the same two crops, under the inadequate drainage conditions.

Also the undesirable soil properties due to the higher WTD obtained at 20 m distance from the drains, are responsible for grain yield losses equal to 29.1 and 26.7% of the yield obtained at 5 m distance from drains where WTD is always more deeper relative to that at mid-distance from drains, respectively, for grain yield of wheat and corn. The average grain yield of the two seasons was 2.51 and 3.14 ton/fed., respectively, for wheat and corn at 5 m distance from drains. While it was 1.78 and 2.3 ton/fed., respectively, for the same two crops at 20 m distance from the drains.

4- The seasonal water Cu of wheat and corn under the adequate conditions was about 15.6 and 16.7% more than that under the inadequate one. Values of the Cu decreases as WTD decrease as well as that of the WUE. The WUE of wheat and corn grains were, respectively, 1.42 and 1.5 times more under adequate drainage conditions than that under the inadequate one.

5- The predicted W.T.D at the soil MC, in the root zone depth, which meets the irrigation time could be used as a new approach fast and easy for irrigation timing of wheat and corn crops under the conditions of the studied area. According to this approach, irrigation interval was about 23 and 27 days for wheat crop under adequate and inadequate drainage conditions. The corresponding values for corn crop were about 16 and 17 days, respectively for the same two sites.

Also, the prediction of the WTD at the moisture content (MC) of the lower plastic limit (LPL), in the tillage soil depth

(0-30 cm), could be used as an approach for soil workability using the simple measure of the WTD. According to this approach the suitable time for field operations is the time at which WTD reach 113 cm under wheat and 95 cm under corn, for the adequate drainage conditions. And at which WTD reach 72 and 63 cm, respectively, for wheat and corn under the inadequate drainage conditions.

The average workability timing duration, after an irrigation event varied between about 13 and 18 days, respectively, for corn and wheat in site (1) cultivated under adequate drainage. While it varied between about 15 and 20 days, respectively, for corn and wheat cultivated under inadequate drainage conditions in site (2).