Assessment of on-farm water management for sustainable agricultural development in Nile delta

Abou El Hassan W.H., El Gamal F., Kitamura Y.

in

Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.).
Water saving in Mediterranean agriculture and future research needs [Vol. 3]

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.III

2007
pages 197-208

Abou El Hassan W.H., El Gamal F., Kitamura Y. **Assessment of on-farm water management for sustainable agricultural development in Nile delta.** In : Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.). *Water saving in Mediterranean agriculture and future research needs [Vol. 3].* Bari : CIHEAM, 2007. p. 197-208 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.III)

ASSESSMENT OF ON-FARM WATER MANAGEMENT FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN NILE DELTA

W. H. Abou El Hassan[*], F. El Gamal[*] and Y. Kitamura[**]
[*] National Water Research Center, WMRI, Delta Barrage NWRC Building, 13621/5, Egypt
[**] Tottori Univ., Faculty of Agric., 4-101, Koyama-cho Minami, Tottori 680-8553, Japan

SUMMARY- In Egypt, the major challenge facing the sustainable requirements for agricultural development is limited water resources. The study area is located in the Nile Delta region. The Nile is the main source of water for irrigation in Egypt. Surface irrigation methods account for more than 85% of the total volume of water used for irrigation. These generally have a low level of performance. Improvement in On-farm water management requires careful review of water allocations in order to raise irrigation efficiencies in Nile Delta. This paper describes pervious studies which have demonstrated the potential use of On-farm water management and associated limitations in Nile Delta. Also, a brief background on the water resources, agriculture and crop rotation patterns in Nile Delta is provided.

In Egypt, research projects and studies provide an ample evidence of the urgent need to improve On-farm water management such as: implementation of integrated management of irrigation and drainage water management, limitations of drainage water reuse for irrigation under normal and saline soils, ground water contributions for crop water requirements, optimization of the irrigation time to suit the soil and plant conditions, design and management of surface irrigation system, as well as improvement of the irrigation delivery system and development of tertiary system (meska). This data will be developed to assist the management decisions regarding water delivery and drainage for the Nile Delta. Finally, this study could be used to make recommendations on the adoption of improved irrigation practices in crop production and use of viable solutions that may be defused throughout the country on large scale basis for water saving and then sustainable agriculture development in Nile Delta.

Key words: On-farm water management, Drainage, Nile Delta.

INTRODUCTION

Arid lands have a lot of problems in the field of water management. The Nile including Lake Nasser is considered the only supply source for surface water. At present, this system constitutes 98% of Egypt's total water resources. The amount of water allocated to Egypt is 55.5 billion m^3 as agreed in the 1959 treaty with Sudan (Abu-Zeid and Rady, 1991). The population of Egypt was estimated at 74.7 million capita in July 2004. The agricultural land base is 7.5 million feddans (1 feddan = 4200 m^2) and annual consumption of fresh water is 891.2 m^3/ capita. With only 3.5 % of land area being arable, an average land holding of less than 0.8 ha makes the country one of the lowest in the world. In Egypt, high groundwater levels and salinity have negative impacts on environment and sustainable agriculture. Thus, the main target for subsurface drainage system is to control water level for upland crops. In the early 1970s, a total area of 2.7 million ha was in need of providing subsurface drainage system. Of that area, 60 % had been completed in the period of 1973 to 1993. To date, new subsurface drains were installed and old drains were renewed in 2.924 million ha. In order to reach the overall target of 3.26 million ha, about 0.336 million ha remain to be serviced. Drainage is generally performed to dispose of excess water from rice fields and to reclaim land and maintain reclaimed land (Abd El-Dayem, 2000). In Egypt, water shortage has become more frequent and farmers often face deficiencies in water deliveries resulting into reduced yields and incomes. Furthermore, rice normally requires a water application of about 1900 mm; an amount much higher than other crops. Cotton, for example, requires an application of about 1380 mm and maize requires about 1000 mm. The cultivation of rice in the summer season has significantly expanded from about 420×10^3 ha in 1987 to about 654.4×10^3 ha in 1999 with an average annual increase of 3.76% (RRTC, 2000). Water for rice irrigation in summer is provided to farmers through irrigation canals on the basis of a rotation, which consists of 4 days "on" and 6 days "off" (4/6 rotation). The normal duration of the rice water rotation is from May 1 to October 15. The irrigation rotation for non–rice cultivated areas (winter crops) is 5 days “on” and 10 days “off” (5/10 rotation). The normal duration for the non–rice rotation is from October 16 to April 30 (Oad and Azim, 2002). Less amount of irrigation water was consumed when an irrigation interval of every 12 days was practiced for rice. Regarding water use efficiency, it decreased significantly as irrigation intervals increased and varied among different varieties (Abou El-Hassan, 1997). Almost fifty percent of the amount of water diverted to rice fields is consumed through evapotranspiration and the rest is lost due to percolation (EWUP, 1983). Regarding to the importance of drainage, Hefny and Shata (1995) reported that the northern strip of the Delta is also characterized by highly saline groundwater due to the subsurface intrusion of seawater and/or marine ingress attributed to continuous submergence of this part of the Delta under seawater. In case of rice planting, some of the most important parameters in design of subsurface drainage are land use and hydrological parameters (Hamilton, 1982). In arid and semi-arid areas, drainage coefficient is calculated on the basis of irrigation management and leaching requirement for salinity control (Willardson, 1982). Raising water dilutes salts in the field water, countering the increased salinity resulting from evapo–concentration. This is important as it helps to moderate and control early season salinity problems (Scardaci *et al.*, 2002). Surveying drainage water in Egypt allowed identifying the following four classes and their particular usage: 1) drainage with salt concentration < 700 mg L^{-1} can be used directly for irrigation; 2) drainage with salt concentration 700 to 1500 mg L^{-1} can be mixed with fresh water in proportion of 1:1; 3) drainage with salt concentration 1500 to 3000 mg L^{-1} can be mixed with fresh water in proportion of 1:2; and 4) drainage water with salt concentration > 3000 mg L^{-1} can not be used without chemical treatments as mentioned by Gad *et al.* (1994) and Gad (1997). Therefore, the aim of this research was to evaluate the impact of construction of subsurface drainage on rice cultivation in Nile Delta, taking into consideration that the grain yield should satisfy the needs of the local consumption and soil chemical improvement.

MATERIALS AND METHODS

Two field experiments were carried out during the summer season in 2002 at Kafr El-Sheikh Governorate, located in northern Nile Delta, Egypt, as shown in Fig.1. The first experiment site that includes subsurface drainage is located at 4 km south of Kafr El-Sheikh (El-Karada Experimental Research Station). The layout of drainage system in the study area is shown in Fig.2.

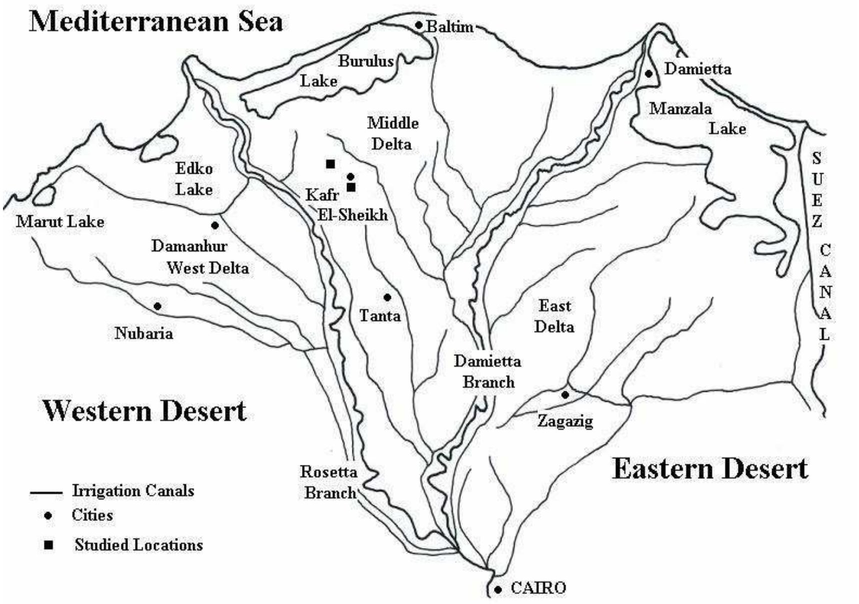

Fig.1. Map of Egypt showing the location of the study area

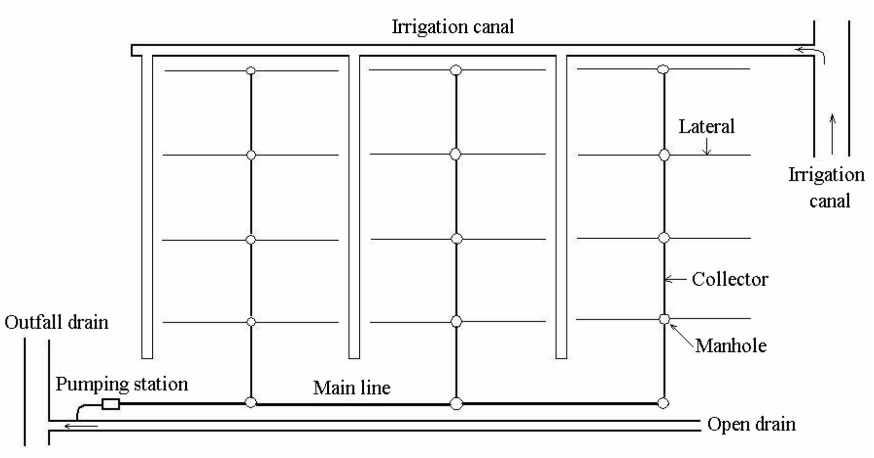

Fig.2. Layout of the subsurface drainage system

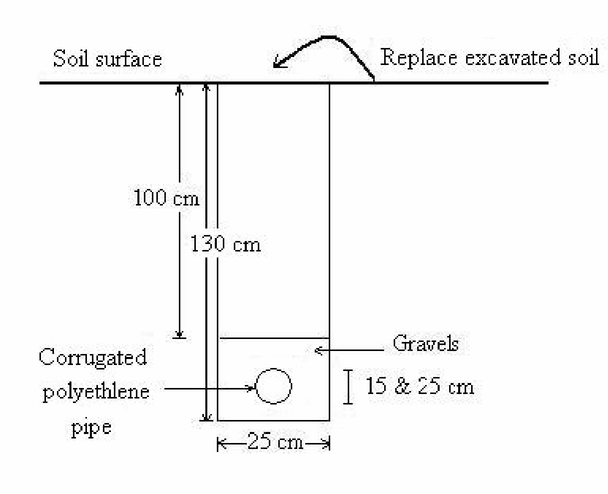

Fig.3. Cross-sectional plane of subsurface lateral drain

The length of lateral drain is 50 m mand the lateral spacing is 20 m. The gradient of laterals is 10 cm per 100 m and 5 cm per 100 m for main lines. As shown in Fig. 3, the depth of lateral drains is around 1.2 m. The inner diameter of lateral drains is 15 cm and 25 cm for main line pipes. The material of the lateral drainpipes is corrugated polyethylene. Concrete manholes with 1 m diameter are installed at the intersection of lateral and collector drains, and main lines for stilling of flow, watching and maintaining drain pipes, as shown in Fig. 2. The other experiment site, without subsurface drainage, is located at 12 km northwest of Kafr El-Sheikh (farmer owned field).

The experiments were arranged in split plot design for each variety with four replicates. The data were statistically analyzed using the Stat-View software (SAS, 2002). The main treatments are: irrigation with continuous flooding of zero cm depth, irrigation with continuous flooding of 3 cm depth and irrigation with continuous flooding of 5 cm depth. Two rice crop varieties (short duration), namely Sakha 102 (125 days) and Giza 178 (135 days) were selected for each experiment as a sub treatment. The natural conditions of both experiment sites are almost same. The density of field irrigation canals and main drainage canals of both sites is also same. The soil in both experiment sites is clayey in texture. All agricultural operations were the same for all treatments. The size of each field experiment was 70.5×171 m with precise land leveling.

The following parameters were studied:

- Amounts of water applied (mm) were measured and recorded using parshall flume (20×90 cm). After measuring the water discharge and the required time, the amount of water applied per unit area was calculated. The metrological data for the studied location is presented in *Table 1*. The electrical conductivity (*EC*) of irrigation water was 0.35 dS m^{-1}, while the measured sodium adsorption ratio (*SAR*) was 2.81.
- Crop grain yield (kg ha^{-1}) was identified through crop cutting experiment in a 10 m^2 test plot in each plot. After harvest plants were air dried for about 3 days and then threshed separately. The total weight of grains from all plants in the test-plot (10 m^2) was recorded in kg and calibrated on a 14 % moisture content basis, and then adjusted into kg ha^{-1}.
- Water use efficiency (g m^{-3}) is the weight of marketable crops produced (g) per volume unit of applied water (m^3) **(**Michael, 1978).
- Soil samples were taken from soil layers of 0-20, 20-40 and 40-60 cm and analyzed to obtain soluble cations and anions and electric conductivity (*EC*). *EC* was determined in the field using portable EC-meter. The analytical methods employed for chemical analyses were as follows: (1) determination of Na^+ and K^+ in a 1:5 soil-water solution by flame photometer (Jackson, 1967); (2) determination of Ca^{+2} and Mg^{+2} using atomic absorption spectrophotometer; (3) determination of SO_4^{-2} using visible spectrophotometer and Cl^- using titration method (Jackson, 1967). The soil chemical properties in the two locations before planting are presented in *Table 2*.
- Sodium adsorption ratio (*SAR*) is computed using equation (1) to get sodification in the soil solutions.

$$SAR = [Na^+]/\sqrt{([Ca^{2+}] + [Mg^{2+}])/2} \qquad (1)$$

Where, Na^+, Ca^{2+} and Mg^{2+} are expressed in meq L^{-1} of Na^+, Ca^{2+} and Mg^{2+} in the soil solution. When the sodium adsorption ratio (SAR_e) of saturated soil extract rises above 12 to 15, serious physical soil problems arise and plants have difficulty in absorbing water. This will limit aeration and soil permeability leading to reduced crop growth.

- Consumptive use of water for rice crop had been determined using a tank with 60 cm diameter and 110 cm length. The tank had been placed in an experimental field in each site in order to be surrounded by buffer area of paddy, representing the actual microclimate.

Table 1. Monthly temperature (°C), relative humidity (%), wind velocity (km d^{-1}) an rainfall (mm d^{-1}) at Kafr El-Sheikh

Month	Summer 2002							
	Air temperature (°C)			Relative humidity (%)			Wind velocity (km d^{-1})	Rain (mm d^{-1})
	Max.	Min.	Mean	Max.	Min.	Mean		
June	30.0	20.8	25.4	75.0	51.0	63.0	68.0	0.0
July	32.5	22.9	27.7	80.0	56.0	68.0	51.0	0.0
Aug.	33.6	20.2	26.9	80.7	49.3	65.0	52.0	0.0
Sept.	32.5	19.7	26.1	77.0	45.0	61.0	87.0	0.0

Table 2. Salinity characteristics of the soil before planting in the experimental sites

Location status	Soil depth (cm)	$EC_{1:5}$ (dS m^{-1})	Cation (meq L^{-1})				Anion (meq L^{-1})			$SAR_{1:5}$
			Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO^{-1}	Cl^-	SO_4^{-2}	
With subsurface drainage	0-20	2.65	13.75	0.50	3.65	7.75	6.85	5.75	13.05	5.759
	20-40	2.85	17.15	0.55	5.05	6.70	6.90	9.00	13.55	7.075
	40-60	3.15	20.55	0.60	5.35	4.55	8.35	9.25	13.65	9.236
Without subsurface drainage	0-20	3.00	16.90	0.60	4.50	7.20	7.30	6.40	15.50	6.988
	20-40	3.20	18.30	0.65	5.10	8.30	8.60	9.45	14.30	7.071
	40-60	3.60	25.55	0.65	5.45	4.65	10.85	10.85	14.60	11.37

Three tanks were used for the measurement of consumptive use of water for each variety of rice crops. The first tank has a bottom wall, and rice plants were grown on soils in the tank to measure evapotranspiration. The second tank also has a bottom wall but no plants were grown on soils in the tank to measure evaporation from water surface. The third one has no bottom and rice plants were grown in it to measure both evapotranspiration and percolation. At the beginning of observation, water level in each tank was set at 10 cm deep above the soil surface. Water level in each tank was measured daily to determine water losses, which was being compensated to maintain the desired level. Rice plants were transplanted from the nursery bed to the two tanks on the same day of transplanting in the experimental field.

- Potential evapotranspiration (*ETp*) was calculated using: Modified Penman, Blaney-Criddle, Radiation and Pan-evaporation (Class-A Pan) methods (Doorenbos and Pruitt, 1977). The description of each method is presented as follows (All variables in the following equations are explained in notation):

a) Modified Penman method:

$$ETp = C\left[W \times Rn + (1 - W) \times f(u) \times (ea - ed)\right] \quad (2)$$

b) Blaney-Criddle method:

$$ETp = a + b\left[p(0.46T + 8.13)\right] \quad (3)$$

c) Radiation method

$$ETp = a + b\left[W \times Rs\right] \quad (4)$$

d) Pan evaporation (Class-A Pan) method:

$$ETp = \left[Kp \times Epan\right] \quad (5)$$

- Crop Coefficient (*Kc*), defined as the ratio between actual crop evapotranspiration (*ETa*) and potential evapotranspiration (*ETp*) when both are in a large field under optimum growing conditions (Doorenbos and Pruitt, 1977):

$$Kc = \left[{ETa}/{ETp}\right] \quad (6)$$

RESULTS AND DISCUSSION

Data presented in Fig. 4 shows the history of rice planting areas. The area increased from 420×10^3 ha in 1987 to 633.4×10^3 ha in 2003 (about 1.5 times; an average annual increase of 2.6 %). The increment is because of the importance of rice for Egyptian farmers and increased population. Concerning the grain yield, it was recorded 5714 kg ha^{-1} in 1987, and 9738 kg ha^{-1} in 2003 (RRTC, 2003). In 1998 and 2001 the total area drastically decreased because of the substantial increase of cultivated areas in the previous years of 1997, 1999 and 2000 that led to decrease of rice prices and cultivated areas.

In Egypt, the farmers prefer to keep deep standing water in the rice basins. Moreover, the high rates of completion of the on-going subsurface drainage projects (69×10^3 to 72×10^3 ha y^{-1}) accelerate the increase of percolation losses.

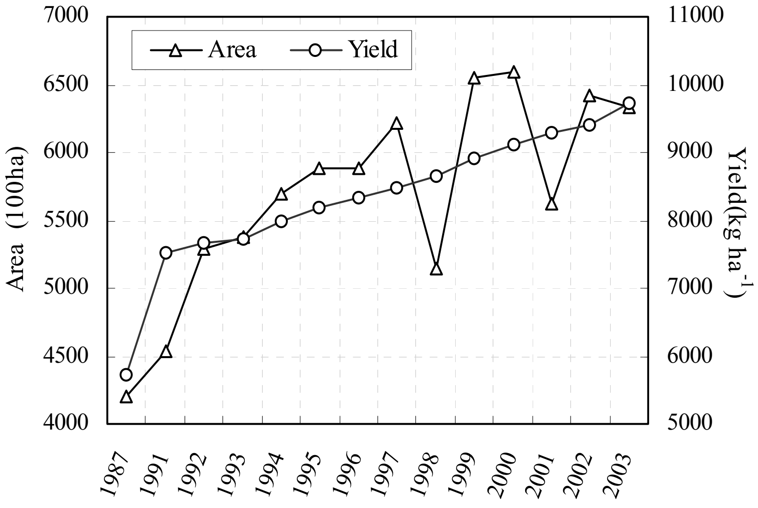

Fig. 4. Change in rice planted area and grain yield from 1987 to 2003 in Egypt

Actual and potential evapotranspiration and crop coefficient

The potential evapotranspiration (*ETp*) was calculated based on meteorological data. Crop coefficient (*Kc*) is presented in *Table 3* to account the effect of crop characteristics on crop water requirement. Factors affecting the values of *Kc* are mainly crop characteristics such as sowing date, rate of crop germination, length of growing period, climatic conditions and irrigation frequency (El Sabagh, 1993). The values were calculated based on the actual evapotranspiration (*ETa*) of rice crop. Daily *ETa* showed that the plant consumed the lowest amounts of water at the first growth stage and increased to the maximum consumption in maximum tillering stage then decreased in maturity stage. The result of *ETp* showed that the Modified Penman was suitable to predict the water consumption under North Delta condition, having the highest correlation coefficient (R^2 = 0.914) between *ETa* and *ETp* estimated by Modified Penman. The average values of seasonal *Kc* for rice calculated based on Modified Penman, Blaney-Criddle, Radiation and Class-A Pan methods, were 1.13, 1.30, 1.17 and 1.56, respectively. The closest average value of *ETp* (6.69 mm d^{-1}) to *ETa* (7.55 mm d^{-1}) as well as the lowest average value of *Kc* (1.13) obtained by Modified Penman method also supports its suitability to be applied in this region. Results indicated that the value of *Kc* was lowest at early stages of growth and increased gradually and reached its maximum in the mid season (grain yield filling) and then declined at maturity stage (*Table 3*).

Table 3. Monthly actual evapotranspiration (*ETa*), potential evapotranspiration (*ETp*) and crop coefficient (*Kc*) during the studied growing season

Month	Duration (Day)	Actual water consumptive use		Modified Penman		Blaney-Criddle		Radiation		Class-A Pan	
		ETa mm d^{-1}	*ETa* (mm/duration)	*ETp* mm d^{-1}	*Kc*	*ETp* mm d^{-1}	*Kc*	*ETp* mm d^{-1}	*Kc*	*ETp* mm d^{-1}	*Kc*
June	26	7.03	182.78	6.63	1.06	5.5	0.78	7.2	1.02	5.60	1.26
July	31	8.80	272.80	6.90	1.28	5.7	1.54	7.5	1.17	5.04	1.75
August	31	8.15	252.65	7.02	1.16	5.2	1.57	6.2	1.42	4.69	1.74
September A*	11	6.21	68.31	6.22	1.00	4.7	1.32	5.8	1.07	4.13	1.50
September B*	21	6.21	130.41								
Average		7.55	A* 776.54 B* 838.64	6.69	1.13	5.28	1.30	6.68	1.17	4.87	1.56
Correlation (R^2)				0.914		0.758		0.591		0.336	

A: Sakha 102=124 days (from seedling to harvest) and B: Giza 178 =134 days (from seedling to harvest)

The effect of drainage status and ponded water depth

Experiments using Sakha 102 rice variety

Data presented in *Table 4* shows a summary of the analysis of variance for the effect of drainage, irrigation and varieties on the grain yield, water applied and *WUE*. It can be observed that the irrigation treatments and varieties have a highly significant effect on amount of applied water in experimental fields with and without subsurface drainage. The interaction between both of them has no significant effect in the case with subsurface drainage, while it has a significant effect in the case without subsurface drainage. Drainage status, ponded water depth and rice varieties and their interaction have a significant and highly significant effect on grain yield and *WUE,* respectively. Results showed that the mean values of amounts of applied water (mm) for both cases of with subsurface drainage and without subsurface drainage statuses increased with increasing ponded water depth (Figs.5 and 6). The lowest mean values of amounts of applied water were 1013.2 and 901.1 mm recorded for zero cm water depth in experimental fields with subsurface drainage and those without subsurface drainage status, respectively. This could be attributed to greater water losses due to percolation.

Table 4. Summary of the analysis of variance for the effect of drainage, irrigation and varieties on the affected grain yield, water applied and *WUE*.

Source of Variation		F-Value		
		Water applied mm	Grain yield kg ha^{-1}	*WUE* g m^{-3}
With subsurface drainage	Irrigation (I)	19.6 **	154.4 **	4.0 *
	Varieties (V)	33.5 **	1768.2 **	196.4 **
	I × V	3.0 ^{ns}	20.4 **	18.0 **
Without subsurface drainage	Irrigation (I)	9.9 **	5.8 *	46.5 **
	Varieties (V)	150.4 **	869.4 **	41.3 **
	I × V	6.6 *	36.0 **	7.5 *

$^{**}p<0.01$, $^{*}p< 0.05$ and ns = not significant

The reduction of the amounts of applied water was more pronounced in the case without subsurface drainage status as compared with that of with subsurface drainage status. As rice is the only crop with standing water on the subsurface drainage system, consequently, high irrigation losses occurred in the drained rice fields. To save water losses, farmers block the collector drainpipes at nearest manhole with whatever available, i.e. mud and straw, within the rice fields to reduce the losses (El Atfy, 1999).

Regarding the effect of the studied treatments on grain yield of rice crop (kg ha^{-1}), the data illustrated in Figs. 5 and 6 indicate that the case with subsurface drainage status treatment remarkably reduced the yield as compared with that of without subsurface drainage status under all ponded water depth treatments. Those could be attributed to the characteristics of rice crop, which was more sensitive for ponded water than soil salinity. Because the little difference in soil salinity was not effective on rice grain yield. An exception is the treatment at 5 cm water depth in experimental fields under subsurface drainage status that the rice grain yield was higher than that of without drainage status.

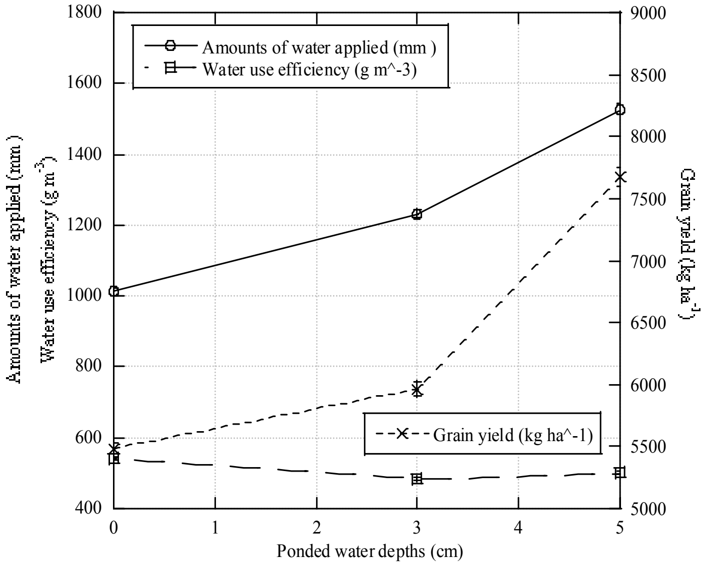

Fig. 5. The effect of ponded water depth on amounts of applied water , water use efficiency and yield in experimental fields with subsurface drainage status for sakha 102 rice crop variety

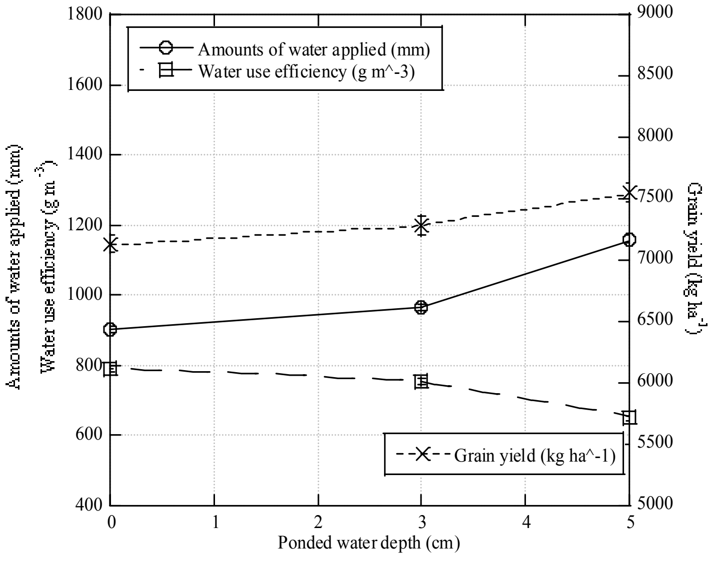

Fig. 6. The effect of ponded water depth on amounts of applied water , water use efficiency and yield in experimental fields without subsurface drainage status for sakha 102 rice crop variety.

The treatments without subsurface drainage status had higher values of water utilization efficiency (*WUE*) than those with subsurface drainage status. *WUE* values were higher under zero cm ponded.

Water depth than those under 3 or 5 cm water depth. The explanation of these results are that the treatment without subsurface drainage system especially under zero cm water depth leads to less water losses through deep percolation and less amount of applied water during the irrigation. The treatments under zero cm water depth recorded the highest mean values of *WUE* of 540.5 and 791.5 g m^{-3} under with and without subsurface drainage, respectively.

Experiments using Giza 178 rice variety

Total amounts of applied water for Giza 178 variety were recorded and shown in Figs.7 and 8. It has been noticed that experimental fields with subsurface drainage status received higher amount of irrigation water, while those without subsurface drainage status received lower amount of irrigation water delivered to the field under the different treatments. Treatments under ponded water depth of 5 cm showed the highest amount of irrigation water, then followed by these under 3 cm depth and the minimum amount of irrigation water was recorded under zero cm water depth.

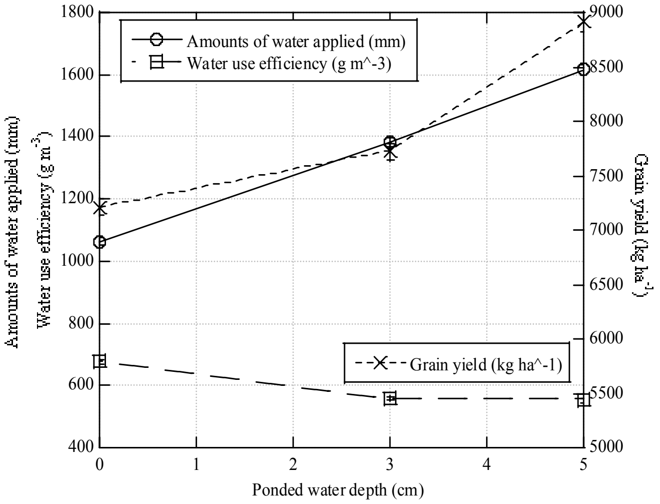

Fig. 7. The effect of ponded water depth on amounts of applied water , water use efficiency and yield in experimental fields with subsurface drainage status for Giza 178 rice crop variety.

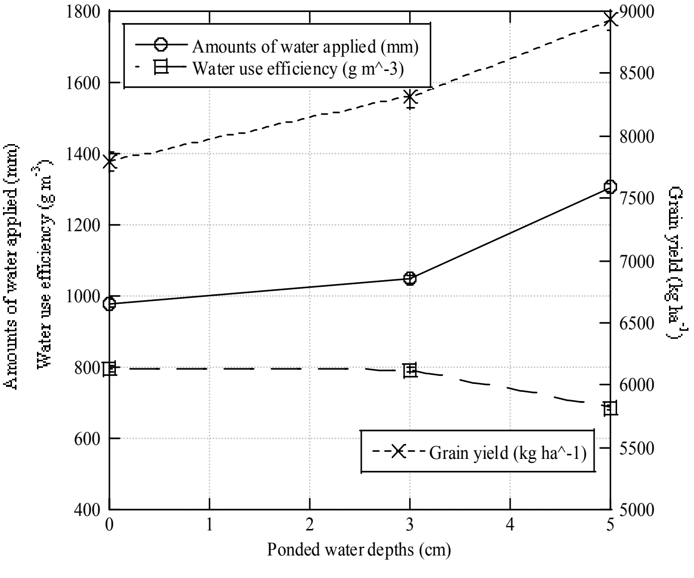

Fig. 8. The effect of ponded water depth on amounts of applied water, water use efficiency and yield in experimental fields without subsurface drainage status for Giza 178 rice crop variety.

The effects of subsurface drainage status and ponded water depth on the amount of applied water, water use efficiency and grain yield for Giza 178 variety are presented in Figs. 7 and 8. The data clearly show that the treatments without subsurface drainage status gave higher grain yield. The treatment under 5 cm ponded water depths recorded the highest mean values of yield of 8914.5 and 8943.3 kg ha^{-1} in experimental fields with and without subsurface drainage, respectively. It's clear that the rice grain yield increased with increasing ponded water depth. With regard to *WUE*, data clearly show that treatments without subsurface drainage status achieved higher values of *WUE* (753.3 g m^{-3}) under different ponded water depths.

Regarding to ponded water depths, it is clearly evidenced from the data that treatments under ponded water depth of zero cm achieved the highest values of *WUE* of 677.7 and 795.7 g m^{-3} with and without subsurface drainage statues, respectively. Then it was followed by those under ponded water depth of 3 cm (558.6 and 793.2 g m^{-3}), while the lowest values were obtained in treatments under ponded water depth of 5 cm (551.3 and 685.4 g m^{-3}).

Soil chemical characteristics

From the obtained data, *Tables 2, 5, 6* and *7* show the change of soil salinity characteristics before planting and after harvesting under different treatments. They show that the soil salinity characteristics were improved under subsurface drainage condition, by reducing $EC_{1:5}$, and total anions and cations in the analyzed soil layers. The significant increase in $EC_{1:5}$, $SAR_{1:5}$, and anions and cations except Mg^{+2} are consistent with the increase of soil depth in all the treatments with and without subsurface drainage statuses. The data presented in *Tables 5, 6* and *7* show the effect of subsurface drainage status on the soil chemical characteristics and ponded water depth controlled at zero, 3 and 5 cm. The data clearly showed that treatments without subsurface drainage status achieved higher values of $EC_{1:5}$ and anions and cations under the three studied water depths. At the same time the difference was non-effective on rice grain yield because the rice grain yield under treatments of without subsurface drainage was higher than that of with subsurface drainage. The higher mean values of $SAR_{1:5}$ occurred under treatments of without subsurface drainage status.

It can be concluded that $SAR_{1:5}$ values also increased with increasing soil depth. Based on the values of $SAR_{1:5}$ after harvesting presented in *Tables 5, 6* and *7*, it can be noticed that $SAR_{1:5}$ values decreased with increasing irrigation water depth. The same trend was observed that the $SAR_{1:5}$ values in the cases without subsurface drainage status were higher than those with subsurface drainage status.

Table 5. Salinity characteristics of the soil after harvesting in the experimental sites treated under zero cm water depth

Location Status	Soil depth(cm)	$EC_{1:5}$ (dS m^{-1})	Cation (meq L^{-1})				Anion (meq L^{-1})			$SAR_{1:5}$
			Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO^-	Cl^-	SO_4^{-2}	
With subsurface drainage	0-20	2.50	12.80	0.45	6.40	6.50	12.30	10.05	3.80	5.039
	20-40	2.45	15.15	0.15	3.40	6.80	6.30	7.15	12.2	6.709
	40-60	2.65	17.75	0.30	3.80	5.10	11.30	10.15	5.50	8.412
Without subsurface drainage	0-20	2.75	16.60	0.85	5.30	5.70	12.35	9.95	6.15	7.079
	20-40	3.30	19.05	0.50	3.40	12.0	11.65	18.30	5.00	6.865
	40-60	3.60	24.35	0.65	5.20	5.75	16.60	13.15	6.20	10.41

Table 6. Salinity characteristics of the soil after harvesting in the experimental sites treated under 3 cm water depth.

Location Status	Soil depth(cm)	$EC_{1:5}$ (dS m^{-1})	Cation (meq L^{-1})				Anion (meq L^{-1})			$SAR_{1:5}$
			Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO^-	Cl^-	SO_4^{-2}	
With subsurface drainage	0-20	1.85	10.10	0.35	3.35	4.25	6.25	4.05	7.80	5.182
	20-40	1.90	10.60	0.40	4.20	4.30	6.70	4.40	8.40	5.141
	40-60	2.10	13.30	0.30	2.95	3.50	10.80	4.25	5.00	7.405
Without subsurface drainage	0-20	2.15	11.25	0.55	4.70	4.15	7.10	7.40	6.15	5.347
	20-40	3.00	17.05	0.60	7.15	6.30	10.05	13.30	7.75	6.575
	40-60	3.20	19.20	0.65	6.75	6.35	10.15	13.60	9.20	7.503

Table 7. Salinity characteristics of the soil after harvesting in the experimental sites treated under 5 cm water depths.

Location Status	Soil depth(cm)	$EC_{1:5}$ (dS m^{-1})	Cation (meq L^{-1})				Anion (meq L^{-1})			$SAR_{1:5}$
			Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO^-	Cl^-	SO_4^{-2}	
With subsurface drainage	0-20	1.65	8.05	0.35	4.50	4.05	6.05	4.70	6.20	3.893
	20-40	1.60	8.00	0.50	4.15	3.25	7.15	4.05	4.70	4.159
	40-60	1.85	11.50	0.55	4.00	3.50	10.30	6.20	3.05	5.939
Without subsurface drainage	0-20	2.10	11.20	0.40	3.00	5.35	7.65	6.50	5.80	5.482
	20-40	2.50	15.10	0.55	4.45	6.55	12.70	9.30	4.65	6.439
	40-60	2.75	15.40	0.60	4.10	6.40	12.00	7.85	6.65	6.722

CONCLUSIONS

1. It has been noticed that the treatments with subsurface drainage status received higher amount of irrigation water as compared to without subsurface drainage status. The rice yield remarkably reduced in treatments with subsurface drainage status as compared to without subsurface drainage status under all controlled ponded water depths. *WUE* values were higher under zero cm irrigation water depths than 3 or 5 cm water depths.

2. The result of potential evapotranspiration (*ETp*) showed that the Modified Penman was the most suitable method to predict water consumption of rice under north Delta condition in comparison with other methods. The computed average values of seasonal *Kc* for rice using Modified Penman, Blaney-Criddle, Radiation and Class-A Pan were 1.13, 1.30, 1.17 and 1.56, respectively.

3. Subsurface drainage system and planting rice crop led to improved soil chemical characteristics related to soil salinity. The increment of irrigation rates in rice fields also led to the decrease of $EC_{1:5}$ and Na^+ values, and thus, led to improvement of soil chemical properties related to soil salinity. Improvement of soil salinity was more effective in areas with subsurface drainage as compared with areas without subsurface drainage.

4. Rice cropping led to decreased $SAR_{1:5}$ values. It means that appropriate rice cultivation may protect soils from sodification.

5. Based on a series of results, it is recommended to modify the constructed subsurface drainage system as well as to develop the management technology to reduce water losses through the system in rice fields. At the same time, the total area for rice crop satisfying the local consumption should be recommended.

REFERENCES

Abd El-Dayem, S. (2000): Drainage experiences in arid and semi-arid regions, *Proceedings of the 8th ICID International Drainage Workshop, 31st January - 4th February 2000, New Delhi, India,* International Commission on Irrigation and Drainage (ICID).

Abu-Zeid, M. A. and Rady, M. A. (1991): Egypt's water resources management policies, *Policy Workshop on Comprehensive Water Resources Management,* Washington, the World Bank.

Abou El Hassan, W. H. M. (1997): Effect of different methods of seedbed preparation and irrigation treatments on productivity of rice crop, *M.Sc. Thesis Faculty of Agric., Kafr El Sheikh, Tanta University,* Egypt.

Doorenbos, J. and Pruitt, W. O., (1977): Crop water requirements. *Irrigation and drainage paper* 24, FAO, Rome, Italy.

El Atfy, H. (1999): Water resources and irrigation, Egypt. Modified drainage system for rice growing areas: a tool for water saving Watsave award, Innovative water management award winning paper (ICID).

El Sabagh, A. A. (1993): Effect of soil moisture stress and foliar application of zinc on some maize varieties, *Ph.D. Agronomy Dept., Faculty of Agriculture,* Zagazig University, Egypt

EWUP (1983): Irrigation and production of rice in Abu Raya, Kafr El Sheikh Governorate, *Technical report* No. 9, NWRC, Delta Barrage, Cairo.

Gad , A., Younes H.A. and Abd el-Rahman, M. A. (1994): Effect of irrigation practices on water quality in the Serry command area, El Menia, Egypt, "XXVI" Congress of IAH solutions'95- Managing the effect of man's activity on ground water", Edmonton, Alberta, Canada, 4-10.

Gad A. (1999): The effect of irrigation practices on the ground water table of some alluvial soils, El Menia Governorate, Egypt. *Egyptian Journal of Soil Since,* 39, 1

Hamilton, D. J. (1982): Drainage coefficient, *Proc. 1st National Land Drainage Seminar,* Massey University, New Zealand: 159-166.

Hefny, K. and Shata, A. (1995): Strategies for planning and management of ground water in the Nile valley and Delta in Egypt*, SRP Working paper series* No. 31-1, MIWR, Cairo.

Jackson, M. L. (1967): Soil chemical analysis, *Prentice Hall, Englewood Cliffs:* 227–261.

Michael, M. L. (1978): Irrigation theory and practice, *Vikas publication house,* New Delhi.

Oad, R. and Azim, R. (2002): Irrigation policy reforms for rice cultivation in Egypt, *Irrigation and Drainage Systems* 16:15-31.

Rice Research and Training Center (RRTC) (2000): RRTC annual report, *Agric. Research Center, Ministry of Agric.,* Sakha, Kafr El-Sheikh, Egypt.

Rice Research and Training Center (RRTC) (2003): RRTC annual report, *Agric. Research Center, Ministry of Agric.,* Sakha, Kafr El-Sheikh, Egypt.

SAS Institute (2002): StatView software, Version 5, *SAS Institute Inc.,* Cary, NC, USA.

Scardaci, S. C., Shannon, M., Grattan, S. R., Eke, A. U., Roberts, S. R. , Smith, S. G. and Hill, J. E. (2002): Water management practices can affect salinity in rice fields, *California Agric.,* 56 (6): 184-188.

Willardson, L. S. (1982): Drainage Coefficients, *The American Society of Agric. Eng., Trans. ASAE* 25 (5): 1251-1253.