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EFFECT OF SOIL MOISTURE DEPLETION LEVELS AND PLANTING METHODS ON WHEAT YIELD AND IRRIGATION EFFICIENCY

Metwally. M. A.
Agricultural Engineering Res. Inst. Giza, Egypt.

ABSTRACT

The present study was conducted to improve the managing of the irrigation regime to develop agriculture to be more efficient and sustainable. As the main scope of the study was to investigate the overall effect of deficit irrigation and planting methods on wheat yield and some water relations in North Nile Delta. Wheat was grown in an experimental field at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate(31° 05' N latitude and 30° 56' E longitude), Egypt. The treatments were arranged in a split-split plot design with four replicates. The main treatments were three planting methods of basin, furrow and bed. The sub-treatments were four levels of N fertilizer i. e. 60, 75, 90 and 105 kg nitrogen fed.$^{-1}$. The sub-sub treatments were assigned by three levels of soil moisture depletion namely: 45, 60 and 75 % depletion of available water(AW). **The main results in this study can be summarized as follows:**

1- The highest and lowest average values of the wheat grain yield(2791 and 2698 kg fed.$^{-1}$), water productivity WP (2.12 and 1.95 kg m^{-3}) and irrigation water productivity IWP(1.45 and 1.17 kg m^{-3}) were achieved with the bed and flat planting methods, respectively during the 1st growing season. The bed planting method increased water productivity(WP) and irrigation water productivity (IWP) by 8.71 and 23.9%, respectively compared to the basin planting method for the soil moisture depletion of 45% during the1st growing season. The 2nd growing season had the same previous trend

2- The bed planting method accomplished the lowest average values of irrigation water applied(1973 and 1983 m^3 fed.$^{-1}$) and water consumptive use (1332 and 1335 m^3 fed.$^{-1}$) while, the highest average values of irrigation water applied(2395 and 2409 m^3 fed.$^{-1}$) and water consumptive use (1437 and 1442 m^3 fed.$^{-1}$) were given with the basin planting method for soil moisture depletion of 45% in the two growing seasons. Using the bed planting method saved about 17.6% of irrigation water applied compared to the basin planting method.

3- The soil moisture depletion of 45% recorded the highest average values of wheat grain yield(2942 and 2969 kg fed.$^{-1}$), WP (2.13 and 2.14 kg m^{-3}) and IWP(1.36 and 1.36 kg m^{-3}) while, the soil moisture depletion of 75% attained the lowest average values of wheat grain yield(2551 and 2574 kg fed.$^{-1}$), WP (1.93 and 1.94 kg m^{-3}) and IWP(1.25 and 1.28 kg m^{-3}) during the 1st and 2nd growing seasons, respectively. However, deficit irrigation (irrigating the wheat crop at depletion 45% of available water) increased wheat grain yield, water productivity and irrigation water productivity by 15.3, 10.4 and 8.8% compared to irrigating the wheat crop at depletion 75% of available water.

4- Application of 90 kg N fed.$^{-1}$ for wheat crop achieved the highest average values of wheat grain yield(3136 kg fed.$^{-1}$), WP (2.28 kg m^{-3}) and IWP(1.46 kg m^{-3}) for 1st growing season. Application of 90 kg N fed.$^{-1}$ for wheat crop achieved the highest average values of wheat grain yield(3136 kg fed.$^{-1}$), WP (2.28 kg m^{-3}) and IWP(1.46 kg m^{-3}) for 1st growing season, whereas the minimum average values of wheat grain yield in the two growing seasons were obtained with the lower applications of N fertilizer level (60 and 75 kg fed.$^{-1}$).

5- It is recommended to use the bed planting method and application of 90 kg N $fed.^{-1}$ in addition to irrigation of the wheat crop at depletion 45% of available water to obtain the highest values of wheat grain yield, water productivity (WP) and irrigation water productivity (IWP) in addition to save about 16.9 % of irrigation water applied.

Keywords: Wheat, Deficit irrigation, Available water , Water stress, Water productivity.

INTRODUCTION

Bread Wheat (Triticum aestivum L.) is the most important grain crop in the world. It covers most of cultivated areas all over the world. The wheat production in Egypt reaches around eight million tons obtained from2.9 million feddan (ARC., 2010). One of the main problems of crop cultivation and production is the lack of water resources, especially during periods of low rainfall which affect the vegetative growth rate and the amount of yield. Scarce water resources frequently limit crop production in semi-arid lands.

In the past, water resources of Egypt have been adequate to meet the existing and emerging demand for water by the various sectors. Gradually, Egypt has passed from a state of water abundance to a state of water scarcity. However, agriculture remains the backbone of Egypt's economy and the largest consumer of fresh water where it consumes more than 80% of Egypt's water resources. Egypt has plans to use its limited water resources efficiently and overcome the gap between supply and demand. Management of irrigation water is one of the most important factors which influence the yield and quality of crops. It is very useful for high yield and saving both of irrigation water and fertilizer, Knany et al., 2005.

Improving water productivity (WP is an important strategy for addressing future water scarcity which is driven particularly by population growth and potential changes in climate and land use. Improving WP in agriculture will reduce competition for scarce water resources, mitigate environmental degradation and enhance food security simply because by producing more food with less water rewards the saved water to other natural and human uses (Rijsberman, 2001 and Molden *et al.,* 2001).

English et al. (1990) defined deficit irrigation as "an optimizing strategy under which crops are deliberately allowed to sustain some degrees of water deficit and yield reduction." They also reported that deficit irrigation strategies aim to increase water use efficiency, either by reducing irrigation adequacy or by eliminating the least productive irrigations. Increasing profits and maximizing or stabilizing regional crop production can be achieved by using a deficit irrigation strategy. Melvin and payero(2007) and Guttieri et al. (2001) reported that water stress during tillering until physiological maturity causes significant reduction of wheat grain yield cultivars. Also, this reduction results from both grain weight reduction and number of grain per spike. In a controlled research, Ramezanpoor and Dastfal (2004) reported that the 25 and 50 percents reduction of water consumption may decrease grain wheat yield by 21.8 % and 40.7% respectively. Abd-El Mawgoud et al. (2004) indicated that increasing the applied water to 80% of soil moisture depletion increased the grain and straw yields and harvest index comparing to treatments which received 60 and 70% of soil moisture depletion. Bayoumi (2005) illustrated that water stress decreased plant height, number of grains / spike and 1000- grain weight of wheat. Tawfelis and Tammam (2005) showed that irrigation stress significantly decreased plant height, number of spikes m^{-2}, number of kernels/ m^2 weight and grain yield of wheat. Salemi et al. (2006) reported that the 19.3 % decrease of grain yield was due to 40% decrease of water use in another related experiment. Thus, this water saving leaded to 34.5% water use efficiency, and the quality characteristics were increased in this water treatment. In another report by Ahmadi et al. (2006) it was found that there was a significant reduction in grain yield and 1000-grain weight under drought stress treatment condition. Hassan et al. (2000) investigated the impact of deficit irrigation strategies on wheat yield and water savings. They reported from a 1year study that a two-stage deficit at yield formation and ripening stage produced the highest yield, and saved 34% of irrigation water, compared to normal watering (4 frequency). However, they did not investigate the effects of alternate deficit on yield and water productivity. The authors also did not evaluate net returns under various deficit conditions. Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield (Ghinassi and Trucchi, 2001;Kirda, 2002; Mao et al., 2003; and Zhang et al.,2004). The basic information needed to adopt this technique is the response of water deficit for various stages of the crop. It is also important to determine the relative monetary gains or economic advantage under well-irrigated and deficit conditions. Mugabe and Nyakatawa(2000) observed that applying 75% and 50% of crop water requirements resulted in yield decreases of 12% and 20% in 2 years, respectively. Ali et al.(2007)concluded that the highest water productivity and productivity of irrigation water were obtained in the alternate deficit treatment, where deceits were imposed at maximum tillering (jointing to shooting) and flowering to soft dough stages of growth period, followed by single irrigation at crown root initiation stage. El-Shamy(2009) studied the effect of water stress and normal conditions on some bread wheat genotypes. The results revealed that water stress decreased days to heading, days to maturity, plant height, 100 kernel, number of kernels / spike, grain yield and its components and flag leaf area. Moayedi et al. (2010) reported that water deficit decreased the number of spikes m^{-2}, number of kernels/ spike, 1000-kernel weight, plant height, day to maturity duration, harvest index and grain yield. Jazy et al. (2012) indicated that wheat may be irrigated after 90 mm cumulative pan evaporation not only may save about 22% in irrigation water with no significant loss in yield under conditions similar to this experiment, but also grain protein percent increase 1.7%. The irrigation number, amount and uniformity of water applications are used mainly to determine the efficiency of irrigation scheduling. Excessive doses of infrequently applied water will lead to high percolation losses. There is stiff competition for water by the agricultural, domestic and industrial users during the dry season, hence there is the need for farmers to conserve and make judicious use of the available water, (Adekalu and Okunade, 2006 and Ancuta et al. 2007). Kayombo et al. (2002) indicated that the crop water use efficiency has been shown to depend on irrigation amount and frequency, also, the type of irrigation system and tillage practices can influence the water use efficiency for a given irrigation frequency.

Fertilizer application is one of the most important, quickest and easiest factor of increasing yield per unit area. The application of fertilizers is usually by hand with low efficiency, resulting in higher costs and environmental problems, Abou Kheira, 2005. Nitrogen is considered as one of major nutrients required by the plants for growth, development and yield (Singh *et al*., 2003, Watcharasak and Thammasak, 2005 and Jilani *et al*., 2009). Nitrogen fertilizer applied at rates higher than the optimum requirement for crop production may cause an increase in nitrate accumulation below the grain zone and leaching. (Norwood 2000) reported that irrigation, fertilizer, and plant density management systems substantially increased yields.

It would be very useful to have adequate information on the probabilities of the various yield outcome that would aid in determine a fertilization program. This would then enable researchers to calculate the economical optimum rate of fertilizer application. The expected yield when this optimum rate is applied, and the obtainable yield at specified rate of fertilizer application can also be predicted (Balba, 1987). Many investigators have used the quantitative approach to evaluate and quantitatively express the response of crops yield to nitrogen fertilizer, Thabet and Balba (1994), El-Shebiny and Badr (1998), Atia (2005), Atia *et al*. (2009).

The main aim of the present investigation was to study the overall effect of deficit irrigation and planting method on wheat yield and some water relations in North Nile Delta.

MATERIALS AND METHODS

Experimental Site:

Two field experiments were conducted at the experimental farm, Sakha Agricultural Research Station, Kafr El-Sheikh Governorate(31° 05’ N latitude and 30° 56’ E longitude), Egypt in two successive growing seasons of 2010/2011 and 2011/2012 to study the effect of deficit irrigation, N fertilizer levels and planting methods on wheat yield and some water relations in North Nile Delta. Soil samples were randomly taken from the experimental sites and prepared for analysis of both physical and chemical properties. The soil texture is clay loam with water field capacity of 37.63%, wilting point of 18.94% and soil bulk density of 1275 Mg $m.^{-3}$. Field capacity, permanent wilting point and bulk density were measured according to Black (1983), Klute (1986) and Westerman (1990). Particle size distribution of soil was determined by using pipette method according Black(1983). Ec of irrigation water was determined by using conduct meter according to Black (1983). PH value was determined by using PH meter according to Black (1983). Available soil moisture was calculated as the difference between the field capacity and permanent wilting point. Another characteristics were presented in Tables 1 and 2. The irrigation water source was surface water from open Canal.

Table 1: Some physical and chemical properties of the experimental soil

Soil depth (cm)	Sand %	Silt %	Clay %	Texture class	EC dSm^{-1} (1:5 Soil : Water extract)	pH 1: 2.5 Soil: Water suspension	Available nutrients g kg^{-1} soil		
							N	P	K
0-15	33.0	28.6	38.4	Clay loam	3.32	7.80			
15-30	33.4	28.4	38.2	Clay loam	3.58	7.60			
30-45	33.2	28.5	38.3	Clay loam	3.45	7.70	22	1.6	18
45-60	33.0	28.6	38.4	Clay loam	3.49	7.75			

Table 2: Values of some soil moisture contents, irrigation water and bulk density.

Soil depth, cm	Bulk density ($Mg\ m^{-3}$)	Field capacity %	Per-wilting point %	Available water %	EC of irrigation water
0-15	1120	40.50	20.64	19.86	
15-30	1260	38.02	19.04	18.98	0.64
30-45	1340	36.25	18.22	18.03	dSm^{-1}
45-60	1380	35.75	17.91	17.84	

Experimental layout:

The experimental design was laid out in split-split plot design with four replicates in both growing seasons. The main -treatments were basin, furrow and bed planting methods The sub- treatments were four levels of N fertilizer i.e. 60, 75, 90 and 105 units of nitrogen per feddan. The sub-sub treatments were three soil moisture depletion of 45, 60 and 75% of available water..

The experimental land was ploughed, disked, leveled and cultivated mechanically with wheat seeds (Sakha 68 variety) by a planter at a seed rate of 100 kg/ha(40 kg $fed.^{-1}$). in Sakha Agricultural Research Station on November 15. The furrows and beds were installed at spacing 0.60 and 0.90 m respectively. The total experimental area was 0.63 ha (1.5 feddan), both the planting methods plots occupied 2100 m^2 (70 m x 30m for all the planting plots). Each main experimental plot was divided into four sub-plots and arranged to levels of N fertilizer. The area of sub-plot was 525 m^2 (30m x 17.5 m for all fertilization plots). Each sub experimental plot was partitioned to three sub-sub plots and soil moisture depletion was followed with area 175. m^2 $plot.^{-1}$ (10m x 17.5m). All agricultural practices for wheat were done as recommended by the Egyptian Ministry of Agricultural and Land Reclamation, except the factors under study. Irrigation season of wheat was ended two weeks before harvest. Wheat was harvested mechanically in the first of April. Yield attributing data were collected from ten randomly selected plants from each plot.

Crop-water Relation Parameters:

-Irrigation water applied (IWA):

The amount of irrigation water applied was calculated by the summation of the daily records of class A pan evaporation. Submerged flow orifice with fixed dimension was used to convey and measure the irrigation water applied, as the following equation (James,1988).

$$Q = CA \sqrt{2gh}$$

Where:

Q = Discharge through orifice, (cm^3 sec^{-1}).
C = Coefficient of discharges (0. 61).
A = Cross sectional area of orifice, cm^2.
g = Acceleration due to gravity, cm/sec^2 (980cm/sec).
h = Pressure head, over the orifice center, cm.

-Water Consumptive Use (CU):

Soil moisture content was determined before and after each irrigation to calculate water consumptive use according to the following equation (Hansen et al., 1979).

$$SMD = Cu = \sum_{i=1}^{1=4} D_1 \text{ x } D_{b1} \text{ x } \frac{PW_2 - PW_1}{100}$$

Where:

SMD = Soil moisture depletion in the effective root zone, cm.
CU = Water consumptive use, cm.
D_1 = Soil layer depth, (15 cm each).
D_{b1} = Soil bulk density, $g.cm^{-3}$ for this depth.
PW_1 = Soil moisture percentage before the next irrigation (%, d.b.).
PW_1 = Soil moisture percentage, 48 hours after irrigation ((%, d.b.).
I = Number of soil layers.

-Water productivity (WP):

Water productivity (or water use efficiency) was calculated according to Ali et al., (2007) as follows:

$$WP= Gy\ ET.^{-1}$$

Where:

Gy = grain yield, kg $fed.^{-1}$.
ET = Total water consumptive use of the growing season, m^3 $fed.^{-1}$.

-Productivity of irrigation water (IWP):

Productivity of irrigation water was calculated according to (Ali et al., 2007).

$$IWP= Gy\ IW.^{-1}$$

Where:

Gy = grain yield, kg $fed.^{-1}$.
IW = irrigation water applied, m^3 $fed.^{-1}$.

2-4 Statistical analysis:

The obtained data were statistically analyzed by analysis of variance. The data of the two seasons showed nearly the same trend, Thus, combined analysis was done according to Gomez and Gomez (1984) .Means of the treatment were compared by the least significant difference (LSD) at 5% level of significance which developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

1-Grain yield of wheat crop:

The grain yield of wheat crop was significantly affected by planting methods, N fertilizer levels and soil moisture depletion during two growing seasons of 2010/2011 and 2011/2012 as shown. in Table 3. The bed planting method achieved the highest average values of grain yield (2791 and 2810 kg fed.$^{-1}$) in the 1st and 2nd growing seasons, respectively while, the lowest average values of grain yield (2698 and 2725 kg fed.$^{-1}$) had been obtained with the basin planting method during two growing seasons of 2010/2011 and 2011/2012 , respectively.

Data also indicated that the obtained average values of wheat grain yield were 2942, 2729 and 2551 kg fed.$^{-1}$ for treatments which were irrigated at soil moisture depletions of 45, 60 and 75 % of AW respectively, during the 1st growing season. While, the corresponding values were 2969, 2751 and 2574 kg fed.$^{-1}$ during the 2nd growing season. It is clear that deficit irrigation (irrigating wheat crop at higher rate of soil moisture depletion) tends to decrease the wheat grain yield for all planting methods and N fertilizer levels. The grain yield of wheat were increased by 15.33 and 15.35 % as a result of irrigating wheat crop at lower rate of soil moisture depletion (45% of AW) compared to the soil moisture depletion of 75 % in the 1st and 2nd seasons, respectively. These results could be attributed to decrease kernel weight, kernel spike.$^{-1}$, plant height, days to maturity and grain yield. These results were in agreement with those of El-Shamy (2009) and Moayedi et al. (2010).

Table 3 : Effect of planting methods, N fertilizer levels and soil moisture depletion on wheat grain yield during 2010-2011 and 2011-2012 growing seasons.

Planting methods	N-fertilizer levels, Kg N fed^{-1}	Grain yield of wheat crop, kg fed.$^{-1}$					
		2010/2011			2011/2012		
		Soil m. depletion,%			Soil m. depletion,%		
		45%	60%	75%	45%	60%	75%
Basin	60	2305	2203	2063	2335	2221	2080
	75	2872	2645	2372	2895	2678	2405
	90	3322	3052	2892	3342	3085	2911
	105	3125	2854	2673	3160	2876	2716
Furrow	60	2338	2230	2088	2369	2236	2100
	75	2909	2684	2418	2934	2716	2446
	90	3358	3078	2932	3365	3120	2940
	105	3167	2880	2710	3196	2894	2762
Bed	60	2357	2233	2102	2385	2242	2126
	75	2925	2711	2472	2938	2726	2506
	90	3386	3180	3022	3407	3190	3024
	105	3244	3000	2860	3282	3022	2872
Mean of soil m. depletion, %		2942	2729	2551	2969	2751	2574
Mean of planting methods	basin		2698			2725	
	furrow		2733			2756	
	bed		2791			2810	
L.S.D at 0.05			18.4			17.6	
Mean of N-fertilizer levels	60		2213			2233	
	75		2668			2694	
	90		3136			3154	
	105		2946			2976	
L.S.D at 0.05			176.2			169.5	

Concerning the effect of N fertilizer levels on the wheat grain yield, as shown in Table 3, the obtained average values of wheat grain yield were 2213, 2668, 3136 and 2946 kg $fed.^{-1}$ in the 1^{st} growing season and 2233, 2694, 3156 and 2976 kg $fed.^{-1}$ during the 2^{nd} growing season at N fertilizer levels of 60, 75, 90 and 120 units of N $fed.^{-1}$,respectively. However, results revealed that the application of 90 kg N $fed.^{-1}$ for wheat crop accomplished the maximum average values of wheat grain yield, whereas the minimum average values of wheat grain yield in the two growing seasons were obtained with the lower application of N fertilizer level (60 and 75 kg $fed.^{-1}$).

So, the obtained values of wheat grain yield were higher in case of furrow and bed planting methods compared with the basin planting method for all the soil moisture depletion and N fertilizer levels. This is due to increasing the cultivated area in case of the furrow and bed planting methods compared with the flat planting method.

a- Irrigation Water applied (IWA):

Data in Table 4 illustrated that the amounts of irrigation water applied (m^3 $fed.^{-1}$) were significantly affected by planting methods, N fertilizer levels and soil moisture depletion during two growing seasons of 2010/2011 and 2011/2012.

The basin, furrow and bed planting methods recorded average amounts of irrigation water applied of 2310, 2111 and 1920 m^3 $fed.^{-1}$ in the 1^{st} growing season, whereas, it were 2318, 2120 and 1923 m^3 $fed.^{-1}$ in the 2^{nd} growing season. It can be concluded that the lowest values of irrigation water were applied at using the bed planting method followed by the furrow planting method but, the highest average amounts of irrigation water were applied with the basin planting method for all the fertilizing levels and soil water depletions during two growing seasons. The bed and furrow planting methods saved 16.9 and 9.05 % of irrigation water applied (m^3 $fed.^{-1}$) compared to the flat planting method in the 1^{st} growing season.

Results also indicated that the obtained average amounts of irrigation water applied were 2177, 2112 and 2051 $m^3 fed.^{-1}$ in 2010/2011growing season in addition to 2197, 2114 and 2053 m^3 $fed.^{-1}$ in 2011/2012 growing season for soil moisture depletion of 45, 60 and 75%, respectively. Meanwhile, the amounts of irrigation water applied (m^3 $fed.^{-1}$) relatively increased with the treatments which were irrigated at 45% of soil moisture depletion for all the planting methods and N fertilizer levels during two growing seasons. However, increasing the soil moisture depletion tended to decrease the irrigation water applied for all the studied treatments. On the other hand, the treatments which were fertilized by 90 kg N $fed.^{-1}$ received the highest values of irrigation water applied for all the planting methods and soil moisture depletion during two growing seasons. The obtained average values of irrigation water applied were 2062, 2106, 2176 and 2140 m^3 $fed.^{-1}$ with application of 60, 75, 90 and 105 kg N $fed.^{-1}$,respectively for the 2^{nd} growing season. It is clear that increasing or decreasing the N fertilizer level than 90 kg N $fed.^{-1}$ tended to decrease the irrigation water applied.

b- Water consumptive use "CU" in m^3 $fed.^{-1}$:

The obtained average values of water consumptive use of wheat crop in 2010/2011and 2011/2012 growing seasons were significantly affected by planting methods, N fertilizer levels and soil moisture depletion as shown in Table 5. It is clear that the obtained average values of CU were 1384, 1342 and 1321 m^3 $fed.^{-1}$ in the 1st growing season but, it were 1390, 1353 and 1324 m^3 $fed.^{-1}$ in the 2nd growing season for basin, furrow and bed planting methods, respectively. The lowest average values of CU were recorded with the bed planting method followed by the furrow planting method while, the highest average values of CU were given with the basin planting method in the two growing seasons.

Table 4 : Effect of planting methods, N fertilizer levels and soil moisture depletion on Water applied during 2010-2011 and 2011-2012 growing seasons.

Planting methods	N-fertilizer levels, Kg N fed^{-1}	Water applied, m^3 $fed.^{-1}$					
		2010/2011			2011/2012		
		Soil m. depletion,%			Soil m. depletion,%		
		45%	60%	75%	45%	60%	75%
Basin	60	2320	2260	2188	2330	2226	2195
	75	2390	2280	2220	2398	2282	2236
	90	2460	2360	2280	2480	2380	2274
	105	2410	2310	2245	2426	2324	2260
Furrow	60	2110	2068	1994	2122	2054	2002
	75	2160	2076	2028	2182	2084	2038
	90	2230	2148	2098	2284	2176	2096
	105	2174	2150	2094	2206	2138	2088
Bed	60	1920	1886	1834	1930	1882	1822
	75	1966	1890	1845	1984	1896	1854
	90	2028	1954	1892	2030	1980	1886
	105	1978	1956	1890	1986	1946	1882
Mean of soil m. depletion, %		2177	2112	2051	2197	2114	2053
Mean of planting methods	basin		2310			2318	
	furrow		2111			2120	
	bed		1920			1923	
L.S.D at 0.05			86.4			81.9	
Mean of N-fertilizer levels	60		2064			2062	
	75		2095			2106	
	90		2161			2176	
	105		2131			2140	
L.S.D at 0.05			24.3			22.8	

It was observed that the treatments which were irrigated at soil moisture depletions of 45, 60 and 75% gave average values of water consumptive use of 1379, 1346 and 1321 m^3 $fed.^{-1}$ in the 2010/2011 growing season while, the CU values were 1386, 1351 and 1330 m^3 $fed.^{-1}$,respectively in the 2011/2012 growing season. It is concluded that the CU values decreased with the treatments which were irrigated at soil moisture depletion of 75% for all the planting methods and N fertilizer levels. Decreasing the soil moisture depletion tends to increase the CU values for all the other factors. On the other hand, the treatments which received 60, 75, 90 and 105 kg N $fed.^{-1}$ consumed CU values of 1326, 1352, 1381 and 1363 m^3 $fed.^{-1}$, respectively in the 1st growing season. It is concluded that the highest values of water consumptive use were recorded with the N fertilizer level of 90 kg $fed.^{-1}$ for all the planting methods and soil moisture depletion during the two growing seasons. Increasing or decreasing the N fertilizer level than 90 kg N fed.$^{-1}$ tended to decrease the water consumptive use.

Table 5 : Effect of planting methods, N fertilizer levels and soil moisture depletion on Water consumptive use during 2010-2011 and 2011-2012 growing seasons.

Planting methods	N-fertilizer levels, Kg N fed^{-1}	Water consumptive use, m^3 fed.$^{-1}$					
		2010/2011			2011/2012		
		Soil m. depletion,%			Soil m. depletion,%		
		45%	60%	75%	45%	60%	75%
Basin	60	1392	1346	1312	1396	1334	1324
	75	1434	1368	1332	1438	1372	1340
	90	1476	1416	1356	1485	1428	1362
	105	1446	1386	1347	1450	1396	1350
Furrow	60	1330	1315	1296	1338	1314	1304
	75	1360	1338	1318	1380	1346	1326
	90	1406	1354	1338	1418	1366	1348
	105	1370	1354	1328	1386	1362	1340
Bed	60	1318	1300	1278	1321	1305	1300
	75	1330	1313	1311	1334	1318	1314
	90	1348	1335	1323	1350	1340	1327
	105	1332	1322	1316	1335	1325	1323
Mean of soil m. depletion, %		1379	1346	1321	1386	1351	1330
Mean of planting methods	basin		1384			1390	
	furrow		1343			1353	
	bed		1321			1324	
L.S.D at 0.05			23.4			20.7	
Mean of N-fertilizer levels	60		1321			1326	
	75		1345			1352	
	90		1372			1381	
	105		1356			1363	
L.S.D at 0.05			19.8			15.7	

c- Water productivity (WP):

Water productivity (WP) expressed in kg of wheat grains m^{-3} of water consumptive use of wheat crop. The obtained values of water productivity (kg m^{-3}) were significantly affected by planting methods, N fertilizer levels and soil moisture depletion during two growing seasons of 2010/2011 and 2011/2012 as presented in Table 6. The obtained results show that the bed planting method gave the highest average values of WP (2.12 and 2.12 kg grains m^{-3} water consumed) followed by the furrow planting method (2.03and 2.04 kg grains m^{-3} water consumed) while, the lowest average values of WP (1.95 and 1. 96 kg grains m^{-3} water consumed) were recorded with the basin planting method during 2010/2011and 2011/2012 growing seasons, respectively. The WP values increased by 8.72 % when the bed planting method was used instead of the basin planting method during the 1st growing season.

Data in Table 6 indicated that the obtained average values of WP were 2.13, 2.03 and 1.93 kg grains m^{-3} water consumed for soil moisture depletion of 45, 60 and 75 % of AW during the 1st growing season. While, they were 2.14, 2.03 and 1.94 kg grains m^{-3} water consumed for soil moisture depletions of 45, 60 and 75 % of AW during the 2nd growing season. The highest average values of WP were achieved with the soil moisture depletion of 45% followed by 60% but, the lowest average values of WP were accomplished with the soil moisture depletion of 75% for all the planting methods and N fertilizer levels during two growing seasons.

Table 6 : Effect of planting methods, N fertilizer levels and soil moisture depletion on Water productivity during 2010-2011 and 2011-2012 growing seasons.

Planting methods	N-fertilizer levels, Kg N fed^{-1}	Water productivity, kg m^{-3}					
		2010/2011			2011/2012		
		Soil m. depletion,%			Soil m. depletion,%		
		45%	60%	75%	45%	60%	75%
Basin	60	1.66	1.64	1.57	1.67	1.66	1.57
	75	2.00	1.93	1.78	2.01	1.95	1.79
	90	2.25	2.16	2.13	2.25	2.16	2.14
	105	2.16	2.06	1.98	2.18	2.06	2.01
Furrow	60	1.76	1.70	1.61	1.77	1.70	1.61
	75	2.14	2.01	1.83	2.13	2.02	1.84
	90	2.39	2.27	2.19	2.37	2.28	2.19
	105	2.31	2.13	2.04	2.31	2.12	2.06
Bed	60	1.79	1.72	1.64	1.81	1.72	1.64
	75	2.20	2.06	1.89	2.20	2.07	1.91
	90	2.51	2.38	2.28	2.52	2.38	2.28
	105	2.44	2.27	2.17	2.46	2.28	2.17
Mean of soil m. depletion, %		2.13	2.03	1.93	2.14	2.03	1.94
Mean of planting methods	basin		1.95			1.96	
	furrow		2.03			2.04	
	bed		2.12			2.12	
L.S.D at 0.05			0.018			0.022	
Mean of N-fertilizer levels	60		1.68			1.68	
	75		1.98			1.99	
	90		2.28			2.28	
	105		2.17			2.18	
L.S.D at 0.05			0.102			0.076	

On the other hand, the treatments which were fertilized by 60, 75, 90 and 105 kg N fed.$^{-1}$ gave average WP values of 1.68, 1.98, 2.28 and 2.17 kg grains m^{-3} water consumed, respectively during the 1st growing season in addition to 1.68, 1.99, 2.28 and 2.18 kg grains m^{-3} water consumed during the 2nd growing season. It could be concluded that the water productivity of wheat crop significantly affected by the N fertilizers level for all the planting methods and soil moisture depletion levels during the two growing seasons. It is also clear that the treatments which were fertilized by 90 kg N fed.$^{-1}$ recorded the highest average values of WP for all the planting methods and soil moisture depletion during the two growing seasons. Increasing or decreasing the N fertilizer level than 90 kg N fed.$^{-1}$ tended to decrease the water productivity of wheat crop. The water productivity of wheat crop decreased by 12.7 and 26.3% when the N fertilizer level decreased from 90 kg N fed.$^{-1}$ to 75 and 60 kg N fed.$^{-1}$, respectively.

d- Productivity of irrigation water (IWP):

Productivity of irrigation water (IWP) expressed in kg of wheat grains m^{-3} of irrigation water applied. Data presented in Table 7 indicated that the obtained values of irrigation water productivity (kg m^{-3}) were significantly affected by planting methods, N fertilizer levels and soil moisture depletion during two growing seasons of 2010/2011 and 2011/2012. The obtained average values of IWP 1.17, 1.29 and 1.45 kg grains m^{-3} of irrigation water applied were given with using the basin, furrow and bed planting methods, respectively in the 1st growing seasons. While, the other ones, 1.17, 1.30 and 1.45 kg grains m^{-3} of irrigation water applied were attained during the 2nd growing season. The highest average value of irrigation water productivity(IWP) was recorded by using the bed planting method followed by the furrow planting method. While, lowest average value of irrigation water productivity(IWP) was recorded by using the basin planting method for all the soil moisture depletion and N fertilizer levels during two growing seasons. These results could be attributed to the significant differences among wheat yield, evapotranspiration and water applied values.

Table 7 : Effect of soil planting methods, N fertilizer levels and soil moisture depletion on Irrigation water Productivity during 2010-2011 and 2011-2012 growing seasons.

Planting methods	N-fertilizer levels, Kg N fed^{-1}	Irrigation water Productivity, kg m^{-3} of water applied.					
		2010/2011			2011/2012		
		Soil m. depletion,%			Soil m. depletion,%		
		45%	60%	75%	45%	60%	75%
Basin	60	0.99	0.97	0.94	1.00	0.97	0.95
	75	1.20	1.16	1.07	1.21	1.17	1.08
	90	1.35	1.29	1.27	1.35	1.30	1.27
	105	1.30	1.24	1.19	1.30	1.24	1.20
Furrow	60	1.11	1.08	1.05	1.12	1.09	1.05
	75	1.35	1.29	1.19	1.34	1.30	1.20
	90	1.51	1.43	1.40	1.49	1.43	1.41
	105	1.46	1.34	1.29	1.45	1.35	1.32
Bed	60	1.23	1.18	1.15	1.24	1.19	1.17
	75	1.49	1.43	1.34	1.48	1.44	1.35
	90	1.67	1.63	1.60	1.68	1.61	1.60
	105	1.64	1.53	1.51	1.65	1.55	1.53
Mean of soil m. depletion, %		1.36	1.30	1.25	1.36	1.30	1.28
Mean of planting methods	basin t		1.17			1.17	
	furrow		1.29			1.30	
	bed		1.45			1.45	
L.S.D at 0.05			0.033			0.042	
Mean of N-fertilizer levels	60		1.08			1.10	
	75		1.28			1.28	
	90		1.46			1.46	
	105		1.39			1.40	
L.S.D at 0.05			0.045			0.031	

Data also illustrated that the average values of IWP were 1.36, 1.30 and 1.25 kg grains m^{-3} of irrigation water applied with soil moisture depletion of 45, 60 and 75%, respectively during the 1st growing season. The 2nd growing season had the same trend. The treatments which were irrigated at soil moisture depletion until 45% of available water fulfilled the highest average values of irrigation water productivity(IWP) compared with the soil moisture depletion of 60 and 75% for all the planting methods and N fertilizer levels.Therefore, values of IWP were higher under the moisture depletion of 45% than the other soil moisture depletions of 60 and 75% for the two growing seasons.

Concerning the effect of N fertilizer levels on the IWP, as shown in Table 7, results reveal that the obtained average values of IWP were 1.08, 1.28, 1.46 and 1.39 kg grains m^{-3} of irrigation water applied for the treatments which received 60, 75, 90 and 105 kg N $fed.^{-1}$, respectively during the 1^{st} growing season. While, they were 1.10, 1.28, 1.46 and 1.40 kg grains m^{-3} water applied during the 2^{nd} growing season. It could be concluded that the highest average values of IWP of wheat crop realized with the treatments which were fertilized by 90 kg N $fed.^{-1}$ for all the planting methods and soil moisture depletion levels during the two growing seasons. It is also clear that the treatments which were fertilized by 60 kg N $fed.^{-1}$ recorded the lowest average values of IWP for all the planting methods and soil moisture depletion levels during two growing seasons. Increasing or decreasing the N fertilizer level than 90 kg N $fed.^{-1}$ tended to decrease the water productivity of wheat crop. The irrigation water productivity of wheat crop decreased by 12.3 and 26.03% when the N fertilizer level decreased from 90 kg N $fed.^{-1}$ to 75 and 60 kg N $fed.^{-1}$, respectively

CONCLUSION

It is recommended to use the bed planting method and application of 90 kg N $fed.^{-1}$ in addition to irrigating the wheat crop at depletion 45% of available water to obtain the highest values of wheat grain yield, water productivity (WP) and irrigation water productivity (IWP) in addition to save about 16.9% of irrigation water applied.

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تأثير مستويات استنفاذ الرطوبة الأرضية وطريقة الزراعة علي إنتاجية محصول القمح وكفاءة الري

محمد علي متولي

معهد بحوث الهندسة الزراعية ـ مركز البحوث الزراعية ـ الجيزة ـ مصر

أجري هذا البحث بالمزرعة البحثية بمحطة البحوث الزراعية بسخا – بمحافظة كفر الشيخ خلال الموسم الزراعي ٢٠١٠ / ٢٠١١ و ٢٠١١ / ٢٠١٢ م لدراسة تأثير طرق الزراعة المختلفة، ومعدلات استنفاذ رطوبة التربة المختلفة ومعدلات التسميد النتروجيني على إنتاجية محصول القمح وكفاءات الري وقد صممت التجربة بنظام القطع المنشقة مرتين في أربع مكررات حيث مثلت القطع الرئيسية ثلاث طرق مختلفة للزراعة وهي (الزراعة التقليدية ، الزراعة علي خطوط ، الزراعة علي مصاطب) بينما شغلت القطع المنشقة مرة واحدة معدلات استنفاذ رطوبة التربة المختلفة ممثلة في (٤٥، ٦٠،٧٥ % من الماء الميسر للنبات) وشغلت معدلات التسميد النتروجيني ممثلة في (٦٠، ٧٥، ٩٠، ١٠٥ كج/فدان) القطع المنشقة الثانية ، وكانت أهم نتائج الدراسة كما يلي:-

١ - أوضحت النتائج أن أقصي وأقل قيمة متوسطة لكل من إنتاج حبوب القمح (٢٠٩١ ، ٢٦٦٨كج / فدان) ، كفاءة الاستهلاك المائي (٢.١٢ ، ١.٩٥ كج لكل متر مكعب ماء مستهلك) و الكفاءة الإنتاجية لمياه الري المضافة (١.٤٥ ، ١.١٧ كج لكل متر مكعب ماء مضاف) قد تم الحصول عليها باستخدام طريقتي الزراعة علي مصاطب والزراعة التقليدية علي الترتيب ، كما أن كلا من كفاءة الاستهلاك المائي و الكفاءة الإنتاجية لمياه الري المضافة زادت بنسبة ٨.٧١ ، ٢٣.٩% علي الترتيب باستخدام طريقتي الزراعة علي مصاطب مقارنة بالزراعة التقليدية مع الري عند استنفاذ ٤٥ % من الرطوبة الأرضية الميسرة للنبات خلال موسم الزراعة ٢٠١٠/ ٢٠١١م.

٢ - أقل كمية مياه مضافة لري محصول القمح (١٩٧٣ ، ١٩٨٣ مترمكعب/ فدان) وأقل قيمة متوسطة من كمية الماء المستهلك(١٣٣٢ ، ١٣٣٥ متر مكعب/ فدان) سجلت مع معاملة الزراعة علي مصاطب بينما أقصي كمية مياه مضافة(٢٣٩٥ ، ٢٤٠٩مترمكعب/ فدان) وكمية مياه مستهلكة (١٤٣٧ ، ١٤٤٢مترمكعب/ فدان) أعطيت مع طريقة الزراعة التقليدية خلال الموسمين الزراعيين ٢٠١٠/٢٠١١ ، ٢٠١١/٢٠١٢م علي الترتيب ، كما أن طريقة الزراعة علي مصاطب وفرت حوالي ١٧.٦ % من كمية المياه المضافة للنبات.

٣ - حقق ري محصول القمح عند استنفاذ ٤٥ % من الماء الميسر أعلي قيمة لكل من إنتاج حبوب القمح (٢٩٤٢ ، ٢٩٦٩كج / فدان) ، كفاءة الاستهلاك المائي (٢.١٣ ، ٢.١٤ كج لكل متر مكعب ماء مستهلك) و الكفاءة الإنتاجية لمياه الري المضافة (١.٣٦ ، ١.٣٦ كج لكل متر مكعب ماء مضاف) ، بينما أعطت معاملة الري عند استنفاذ ٧٥% من الماء الميسر أقل القيم من إنتاجية محصول القمح (٢٥٥١ ، ٢٥٧٤كج / فدان) ، كفاءة الاستهلاك المائي (١.٩٣ ، ١.٩٤ كج لكل متر مكعب ماء مستهلك) و الكفاءة الإنتاجية لمياه الري المضافة (١.٢٥ ، ١.٢٨ كج لكل متر مكعب ماء مضاف) خلال الموسمين الزراعيين ٢٠١٠/ ٢٠١١ ، ٢٠١١/٢٠١٢م علي الترتيب ، كما حقق الري عند استنفاذ ٤٥ % من الماء الميسر للنبات زيادة في الإنتاجية و كفاءة الاستهلاك المائي و الكفاءة الإنتاجية لمياه الري المضافة مقدارها ١٥.٣ ، ١٠.٤ ، ٨.٨% علي الترتيب مقارنة بالري عند استنفاذ ٤٥ % من الماء الميسر .

٤ - أشارت النتائج أن إضافة ٩٠ كج سماد نتروجين / فدان أعطي أعلي القيم المتوسطة من إنتاجية الحبوب (٣١٣٦ كج / فدان) ، كفاءة الاستهلاك المائي (٢.٢٨ كج لكل متر مكعب ماء مستهلك) و الكفاءة الإنتاجية لمياه الري المضافة (١.٤٦ كج لكل متر مكعب ماء مضاف) مقارنة بمعدلات التسميد الأخرى ٦٠ ، ٧٥ ، ١٠٥كج .

٥ - توصي الدراسة باستخدام طريقة الزراعة علي مصاطب و إضافة ٩٠ كج سماد نتروجين / فدان مع ري محصول القمح عند استنفاذ ٤٥ % من الماء الميسر للحصول علي أعلي إنتاجية للمحصول وأقصي كفاءة للري وتوفير ١٦.٩ % من كمية المياه المضافة لري محصول القمح.