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Effect of Irrigation Water Management on Wheat Yield

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ABSTRACT

Two field experiments were conducted at El Karda experimental research station, kafr El Sheikh governorate, Water Management and Irrigation System Research Institute, National Water Research Center, Egypt during two seasons of 2012/2013 and 2013/2014 to study the effect of planting methods and irrigation treatments on yield of wheat and irrigation water management. Experiment laid out in strip plot design with three replicates. Main plots devoted to planting methods as assigned to six planting methods; Flat broadcasting (FB), Flat Drill (FD), Flat Hill (FH), Bed broadcasting (BB), Bed Drill (BD), and Bed Hill (BH), the sub plots were three levels of irrigation water applied; Calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity (I_1), Calculation of water applied according to soil depth 0-40 cm as root length to reach soil moisture before irrigation to field capacity (I_2), and Calculation of water applied according to soil depth 0-60 cm as root length to reach soil moisture before irrigation to field capacity (I_3). The important results that obtained from present work were as follows:- Planting methods had non-significant effect on grain yield in the first season and a highly significant effect in the second season. Also, irrigation levels had non-significant effect and interaction between both Planting methods and irrigation levels in both seasons.- Planting methods had a significant effect on straw yield in first season, and a highly significant effect in second season, and irrigation levels had non-significant effect, and the interaction between planting method and Irrigation levels in both seasons.-Flat broadcasting with calculation of water applied according to soil depth 0-60 cm as root length to reach soil moisture before irrigation to field capacity had the highest value of seasonal water applied in the first and second season. While, the lowest value of seasonal water applied recorded with bed drill with calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity.-The highest average value of water saving was obtained with bed drill and bed hill with calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity, and the lowest value was obtained with flat drill and flat hill with calculation of water applied according to soil depth 0-60 cm as root length to reach soil moisture before irrigation to field capacity.-The highest value of water consumptive use was recorded under flat broadcasting with calculation of water applied according to soil depth 0-60 cm as root length to reach soil moisture before irrigation to field capacity, while the lowest value was recorded under flat broadcasting with calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity.-Bed drill and bed hill under calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity recorded the highest mean values of irrigation water productivity in the two growing seasons.-Bed hill with calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity recorded the maximum value of water productivity in the first and second seasons, while the minimum value of water productivity was obtained with Flat broadcasting under calculation of water applied according to soil depth 0-60 cm as root length to reach soil moisture before irrigation to field capacity in the first and second seasons.

INTRODUCTION

Wheat is the most important winter cereal crop in Egypt, and its national production is not sufficient to supply the annual demand of the increasing population, this caused a gap between production and consumption. On the other hand, water is becoming a limiting factor for crop production in many parts of the world, especially developing countries as Egypt. So, wheat production in Egypt, with rapid increasing in population, competitive demands of water for domestic, industrial and recreational uses reduces its availability to agriculture sector. In addition, production of major crops especially staple food like wheat needs to be increased in the country to fulfill food needs.

Hossain *et al* (2006), reported that methods of planting were found significantly on yield and yield contributing characters of wheat. Bed planting produced more number of plants and spikes per square meter, longer spike length and maximum grain weight than conventional methods. Maximum grain yield (3.60 t/ha) was obtained from bed planting due to higher yield attributes. Similar trend was followed in case of straw yield. Alam *et al*. (2007) indicated that planting method had a significant positive effect on yield and contributing characters. The highest grain yield (2.93 t/ha) was obtained from bed planting method, while the lowest (2.41 t/ha) was recorded in conventional method. This similarly, straw yield (3.80 t ha^{-1}), biological yield (6.77 t/ha), grain $spike^{-1}$(44.45) were the highest in the bed planting method. Khan *et al* (2007), indicated that line planted wheat 30cm apart produced significantly higher number of spikes m^{-2} (164), thousand grain weight (39.85g) and grain yield (5164 kg ha^{-1}), while broadcast method produced least number of spike m^{-2} (104), number of grains $spike^{-1}$(57), thousand grain weight (32.09 g) and grain yield (4088 kg ha^{-1}). This study showed that line planting 30 cm apart gave better results for grain yield of wheat than broadcast and other planting methods studied. Hossain *et al* (2009) stated that significant differences between bed planting and conventional method of sowing was detected for grain yield, spike length, grains/spike. The bed method allowed plants to uptake more nutrients and moisture that contributed to higher yield through partitioning of photosynthesis to the grains. Moreover, higher spike length, and grains/spike contributed towards higher grain yield in bed planting. Soomro *et al* (2009)

revealed that plant height, number of spikes/plant, number of kernel/spike, 1000-grain weight as well as grain and straw yields were significantly increased by using drilling method as compared with other methods. Waraich *et al* (2010) stated that the water use efficiency (WUE) was maximum under the treatment where crop was sown on beds with 68 cm, bed width having six rows, as compared to conventional flat sowing. Ali *et al* (2012) revealed that significant increases in all parameters were noted in raised beds planting system compared to all other planting methods. The obtained increases were (24.46 % by beds planting), (20.26 % by ridge sowing) and (17.33 % by drill sowing) over conventional method of broadcasting. Mushtaq *et al* (2012) revealed that raised bed and ridge sowing methods of wheat plantation saved 22.47 and 13.26 % irrigation water, respectively over flat sowing either by drilling or broadcasting. Genedy (2014) revealed that bed sowing method significantly increased all traits, except (plant height, number of tillers/m^2, and 1000 grains weight). Fahong *et al* (2004) indicated that grain yields for the two varieties were increased by bed planting as compared with flat planting, some yield components were also affected, grains per spike and grain weight increased but there was no effect of planting method on spikes per square meter and harvest index. Changing from flat planting with flood irrigation to raised bed planting with furrow irrigation improved water use efficiency by 25.5 % combined with an approximate 17% savings in applied irrigation water. El-Hag (2015) indicated that, bed sowing method was better for growing wheat plants than flat due to saving the amount of irrigation water from 8 to 12 % under this investigation. As well as bed sowing method markedly increased grain yield by 7.7 % in the second season.

So, this investigation to study the effects of different planting methods and irrigation levels on the productivity of grain and straw yields and wheat water characteristics.

MATERIALS AND METHODS

Site and experimental design

Field experiments were conducted at El-Karada Experimental Research Station, Kafr El-sheikh Governorate, (Latitude: 31°6'N/ Longitude: 30°56'E) Water Management and Irrigation System Research Institute, National Water Research Center, Egypt during two seasons (2012/2013 and 2013/2014) to study the effect of irrigation water management on wheat yield.

Experiment was laid out in strip plot design with three replicates, main plots devoted to planting methods as assigned to six planting methods; Flat broadcasting (FB), Flat Drill (FD), Flat by Hills (FH), Bed broadcasting (BB), Bed Drill (BD), and Bed by Hills (BH), the sub plots were three levels of irrigation water applied; Calculation of water applied according to soil depth 0-20 cm as root length to reach soil moisture before irrigation to field capacity (I_1), Calculation of water applied according to soil depth 0-40 cm as root length to reach soil moisture before irrigation to field capacity (I_2), and Calculation of water applied according to soil depth 0-60 cm as root length to reach soil moisture before irrigation to field capacity (I_3). Physical and chemical properties of the experimental soil were determined according to Black *et al* (1965) and Klute (1986) and are presented in Table (1).

Table (1): Soil physical and chemical properties of the experimental soil during 2012-2013 and 2013-2014 seasons.

Physical properties								
Depth (cm)	Particle size distribution (%) Sand	Silt	Clay	Soil texture class	Field capacity(%)	Wilting point (%)	Bulk density (g/cm^3)	Water table level (cm)
2012/2013								
0-20	18.00	26.00	56.00	Clayey	44.54	24.21	1.12	
20-40	22.30	26.70	51.00	Clayey	38.12	20.70	1.15	78
40-60	19.80	33.00	47.20	Clayey	36.74	19.59	1.25	
2013/2014								
0-20	18.00	26.00	56.00	Clayey	44.54	24.21	1.12	
20-40	22.30	26.70	51.00	Clayey	38.12	20.70	1.15	79
40-60	19.80	33.00	47.20	Clayey	36.74	19.59	1.25	

Chemical properties										
Depth (cm)	EC (dS/m^{-1})	pH (1:2.5 soil water suspension)	Soluble cations (meq/l) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Soluble anions (meq/l) CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
2012/2013										
0-20	0.72	7.55	1.42	3.15	3.90	0.12	0.0	2.35	3.69	2.55
20-40	0.81	7.50	2.10	1.42	7.20	0.13	0.0	2.72	5.00	3.13
40-60	0.95	7.44	1.92	1.70	8.00	0.14	0.0	2.90	5.31	3.55
2013/2014										
0-20	0.52	7.80	1.42	3.15	3.90	0.12	0.0	2.35	3.69	2.35
20-40	0.71	7.70	2.00	1.30	6.00	0.13	0.0	2.60	3.83	3.00
40-60	0.85	7.50	1.80	1.60	7.00	0.14	0.0	2.50	4.84	3.20

Note. EC = Electrical conductivity

Wheat (*Triticum aestivum* L.) Masr 1 variety was planted in 18 and 22 November 2011 and 2012. All cultural practices in the experimental field were the same as implemented in the area except planting methods and irrigation treatments.

Measurements

1-Grain and straw Yields

Grain and straw yields (ton/Feddan) were recorded from the central area of 1 m^2 and determination were at harvest to obtain grain and straw yields per plot and adjusted to 14 % moisture basis.

Then grain and straw yields were transformed to kilogram, and ton per fed.

2-Irrigation water measurements:

In the two growing seasons irrigation water applied (IWA) was measured by using rectangular sharp crested weir. The discharge was calculated using the following formula of Massoud (1967):

$$Q = CL\ H^{3/2}$$

Where: Q = the discharge in cubic meters per second, L = the length of the crest in meters, H = the head in meters, and C = an empirical coefficient that must be determined from discharge measurements, (1.84).

3-Water saving

Water saving was calculated by subtracting the amount of water applied (m^3/fed.) for all treatments from amount of water applied (control) and dividing on control as percentage.

4-Water consumptive use (WCU)

The amount of water consumptive use (WCU) is assumed to be equal to the difference between both moisture contents after each irrigation and before the next one. In fact, this amount is consumed by plants through the transpiration in addition to the quantity which was lost from the soil surface by evaporation. The quantities of water consumptive use were calculated for the 60 cm soil depth which was assumed to be the depth of the root zone as reported by many investigators for an area of 4200 m^2 (one fed.), calculation of water consumptive use reported for all irrigations until harvesting date using the following equation of Israelsen and Hansen (1962), Water consumptive use (cm) as a depth of water will convert to m^3/fed.

5-Water productivity (WP)

Water productivity (WP) as a measurement used to clarify variations in yield due to irrigation water applied as it calculated according to Michael (1978) as follows:

WP = Yield (kg/feddan) / Water consumptive use (m^3/feddan)

6-Productivity of irrigation water (PIW):

Productivity of irrigation water (kg/m^3) is considered an evaluation parameter of yield per unit of applied water.

PIW = Yield (kg/feddan) / Applied water (m^3/feddan)

RESULTS AND DISCUSSION

Yield

1- Grain yield:

Data in Table (2) show the grain yield as affected by planting methods, irrigation levels and their interaction during 2012-2013 and 2013-2014 seasons.

Grain yield highly significantly affected by the six tested planting methods in first season and second season. Bed Hill planting method had the highest values among the other planting methods in the two growing seasons, and the lowest significant value was recorded by Flat broadcasting. On the other hand, grain yield had not affected significantly by the three tested irrigation levels in both seasons.

Table (2): Grain and straw yields as affected by planting methods, irrigation levels and their interaction during 2012-2013 and 2013-2014 seasons.

Planting Method	Irrigation levels	Grain Yield (ton/Fed)		Straw Yield (ton/Fed)	
		1st season	2nd season	1st season	2nd season
Flat broadcasting		3.077 c	2.939 b	4.366 a	4.187 a
Flat Drill		3.408 b	3.288 a	4.238 ab	4.113 ab
Flat Hill		3.415 b	3.228 a	4.232 ab	3.869 bc
Bed broadcasting		3.262 b	3.231 a	4.200 b	3.958 abc
Bed Drill		3.580 a	3.389 a	4.041 c	3.909 bc
Bed Hill		3.597 a	3.394 a	4.030 c	3.811 c
F Test		**	**	**	*
	0-20 cm	3.369	3.214	4.116 b	3.836 b
	0-40 cm	3.395	3.244	4.201 ab	3.974 ab
	0-60 cm	3.405	3.277	4.238 a	4.114 a
F Test		NS	NS	*	*
Flat broadcast	0-20 cm	3.069 h	2.916 e	4.315 ab	4.046 cd
	0-40 cm	3.083 h	2.925 e	4.388 ab	4.103 c
	0-60 cm	3.080 h	;82.975 e	4.394 a	4.413 a
Flat Drill	0-20 cm	3.387 defg	3.265 bcd	4.215 abcd	4.017 cd
	0-40 cm	3.414 bcde	3.272 bcd	4.232 abcd	4.045 cd
	0-60 cm	3.423 bcd	3.329 abc	4.267 abc	4.277 b
Flat Hill	0-20 cm	3.414 bcde	3.185 d	4.214 abcd	3.693 g
	0-40 cm	3.405 cdef	3.248 cd	4.231 abcd	3.948 de
	0-60 cm	3.425 bcd	3.252 cd	4.252 abcd	3.966 d
Bed broadcast	0-20 cm	3.252 g	3.206 d	4.125 cd	3.841 ef
	0-40 cm	3.272 efg	3.239 cd	4.207 bcd	3.996 cd
	0-60 cm	3.263 fg	3.249 cd	4.269 abc	4.038 cd
Bed Drill	0-20 cm	3.539 abc	3.344 abc	3.918 e	3.750 fg
	0-40 cm	3.590 a	3.408 a	4.077 de	3.976 cd
	0-60 cm	3.611 a	3.416 a	4.128 cd	4.002 cd
Bed Hill	0-20 cm	3.554 ab	3.369 ab	3.906 e	3.670 g
	0-40 cm	3.608 a	3.371 ab	4.071 de	3.776 fg
	0-60 cm	3.629 a	3.441 a	4.115 cd	3.988 cd
F Test		**	**	**	*

***, ** and NS indicate p < 0.05, < 0.01 and not significant, respectively. Means of each treatment followed by the same letter are not significantly different at 5 % level, according to Duncan s multiple range test.**

2-Straw yield:

Data in Table (2) show the straw yield as affected by planting methods, irrigation levels and their interaction during 2012-2013 and 2013-2014 seasons.

Straw yield highly significantly affected by the six tested planting methods in first season and significantly affected in the second season. Flat broadcasting planting method showed the highest values while the lowest significant values were obtained with Bed Hill in first and second seasons. On the other hand, straw yield significantly affected by the three tested irrigation levels in both seasons.

Interaction effect:

From data presented in Table (2), it can be concluded that the interaction between planting methods and irrigation levels on grain and straw yield of wheat had a significant effect in both seasons. Bed Hill planting method recorded the highest grain yield under I_3 irrigation level in both seasons. While, straw yield, flat broadcasting planting method under I_3 irrigation level recorded the highest straw yield value, and the lowest straw yield value was obtained with Bed Hill planting method under I_1 irrigation level.

Water measurements:

1-Seasonal amount of water applied:

Presented data in Table (3) illustrated that mean values of seasonal water applied through two growing seasons were affected by planting methods and irrigation levels treatments.

Seasonal water applied consists of the two main components; irrigation water delivered to the field plot and effective rainfall. The total amounts of the effective rainfall during the two growing seasons were (226.4 and 190.0 m^3/fed.) in the first and second growing seasons respectively.

Table (3): Amount of irrigation water (m^3/fed.), rainfall (m^3/fed.) and seasonal water applied for wheat crop during 2012-2013 and 2013-2014 seasons.

Planting Method	Irrigation levels	2012-2013			2013-2014			Mean
		Amounts of applied irrigation water (m^3/fed)	Effective rainfall (m^3/fed)	Seasonal water applied (m^3/fed)	Amounts of applied irrigation water (m^3/fed)	Effective rainfall (m^3/fed)	Seasonal water applied (m^3/fed)	
Flat broadcasting		1913.00		2139.40	1908.81		2098.81	2119.11
Flat Drill		1881.00		2107.40	1857.67		2047.67	2077.53
Flat Hill		1875.00	226.40	2101.40	1848.67	190.00	2038.67	2070.03
Bed broadcasting		1652.00		1878.40	1644.12		1834.12	1856.26
Bed Drill		1623.00		1849.40	1611.33		1801.33	1825.37
Bed (hill)		1613.67		1840.07	1615.86		1805.86	1822.96
	0-20 cm	1326.50		1552.90	1319.91		1509.91	1531.40
	0-40 cm	1793.00	226.40	2019.40	1775.05	190.00	1965.05	1992.22
	0-60 cm	2159.33		2385.73	2148.28		2338.28	2362.00
Flat broadcasting	0-20 cm	1421.00		1647.40	1409.02		1599.02	1623.21
	0-40 cm	1956.00	226.40	2182.40	1950.69	190.00	2140.69	2161.55
	0-60 cm	2362.00		2588.40	2366.72		2556.72	2572.56
Flat Drill	0-20 cm	1390.00		1616.40	1378.00		1568.00	1592.20
	0-40 cm	1924.00	226.40	2150.40	1895.00	190.00	2085.00	2117.70
	0-60 cm	2329.00		2555.40	2300.00		2490.00	2522.70
Flat Hill	0-20 cm	1385.00		1611.40	1365.00		1555.00	1583.20
	0-40 cm	1920.00	226.40	2146.40	1890.00	190.00	2080.00	2113.20
	0-60 cm	2320.00		2546.40	2291.00		2481.00	2513.70
Bed broadcasting	0-20 cm	1271.00		1497.40	1274.74		1464.74	1481.07
	0-40 cm	1679.00	226.40	1905.40	1656.24	190.00	1846.24	1875.82
	0-60 cm	2006.00		2232.40	2001.38		2191.38	2211.89
Bed Drill	0-20 cm	1242.00		1468.40	1235.00		1425.00	1446.70
	0-40 cm	1650.00	226.40	1876.40	1627.00	190.00	1817.00	1846.70
	0-60 cm	1977.00		2203.40	1972.00		2162.00	2182.70
Bed (hill)	0-20 cm	1250.00		1476.40	1257.69		1447.69	1462.05
	0-40 cm	1629.00	226.40	1855.40	1631.34	190.00	1821.34	1838.37
	0-60 cm	1962.00		2188.40	1958.55		2148.55	2168.48

Concerning the effect of planting methods under all irrigation treatments, the highest value was recorded under Flat broadcasting method comparing with the other treatments where the mean values were (2139.4 and 2098.81 m^3/fed.) in the two growing seasons, respectively. Meanwhile, the lowest seasonal values were recorded under Bed Hill planting method which average values were (1840.07 and 1805.86 m^3/fed.) in the first and second growing seasons, respectively. Increasing the mean values of irrigation water applied under normal method (flat) comparing with raised beds method might be attributed to increasing irrigation area, time of irrigation, amount of water percolation, seepage and evaporation. These results are in a great harmony with those obtained by Fahong, *et al* (2004).

Regarding the effect of irrigation treatments on the mean values of seasonal amount of water applied through the two growing seasons, the highest mean values were recorded under irrigation level I_3 in comparison with other treatments. The mean values were (2385.72 and 2338.28 m^3/fed.) in the first and second growing seasons, respectively. Meanwhile, the lowest seasonal values were recorded under irrigation level I_1 which mean values were (1552.90 and 1509.91 m^3/fed.) in the first and second growing seasons, respectively. Generally the seasonal values of water applied can be descended in order $I_3>I_2>I_1$. Increasing

the seasonal values of water applied under irrigation treatment I_3 in comparison with other irrigation treatments I_2 and I_1 might be attributed to increasing time of irrigation and hence increasing the amount of water applied. The difference in seasonal water applied between the first and second seasons due to the variation precipitation.

Interaction effect:

Data indicated that Flat broadcasting planting method with I_3 irrigation level had the highest value of seasonal water applied in the first and second seasons (2588.40 and 2556.72 m^3/fed). While, the lowest value was (1468.40 and 1425.00 m^3/fed) which recorded with Bed Drill planting method with I_1 irrigation tratment.

2-Water consumptive use:

Water consumptive use or which so-called evapotranspiration for any crop means the summation of two components; evaporation (E) from the soil surface and transpiration (T) from plant.

Tabulated data in Table (4) clearly indicated that the overall mean values for water consumptive use were greatly affected by both planting methods and irrigation treatments.

Table (4): Seasonal water consumptive use of different treatments during 2012-2013 and 2013-2014 seasons.

Planting Methods	Irrigation levels	2012-2013 Water Consumptive use (m^3/fed)	2012-2013 Water Consumptive use (cm)	2013-2014 Water Consumptive use (m^3/fed)	2013-2014 Water Consumptive use (cm)	Overall mean values of two seasons (m^3/fed)	Overall mean values of two seasons (cm)
Flat broadcasting		1196.20	28.48	1114.64	26.54	1155.42	27.51
Flat Drill		1171.17	27.88	973.30	25.92	1129.90	26.90
Flat Hill		1165.17	27.74	1085.97	25.80	1124.40	26.77
Bed broadcasting		1090.35	25.96	1017.30	23.43	1037.16	24.69
Bed Drill		1063.17	25.31	980.30	23.28	1020.57	24.30
Bed Hill		1046.64	24.92	974.76	22.76	1001.28	23.84
	0-20 cm	912.12	21.72	799.22	19.03	855.67	20.37
	0-40 cm	1144.13	27.24	856.99	24.90	1095.04	26.07
	0-60 cm	1310.09	31.19	1074.73	29.93	1283.66	30.56
Flat broadcasting	0-20 cm	973.50	23.18	826.02	19.67	899.76	21.42
	0-40 cm	1236.98	29.45	1172.60	27.92	1204.79	28.69
	0-60 cm	1378.12	32.81	1345.30	32.03	1361.71	32.42
Flat Drill	0-20 cm	948.50	22.58	800.30	19.05	874.40	20.82
	0-40 cm	1211.50	28.85	1146.30	27.29	1178.90	28.07
	0-60 cm	1353.50	32.23	1319.30	31.41	1336.40	31.82
Flat Hill	0-20 cm	942.50	22.44	798.30	19.01	870.40	20.72
	0-40 cm	1204.50	28.68	1140.30	27.15	1172.40	27.91
	0-60 cm	1348.50	32.11	1312.30	31.25	1330.40	31.68
Bed broadcasting	0-20 cm	890.16	21.19	794.30	18.91	842.23	20.05
	0-40 cm	1096.27	26.10	945.30	22.51	1020.79	24.30
	0-60 cm	1284.63	30.59	1212.30	28.86	1248.47	29.73
Bed Drill	0-20 cm	863.50	20.56	789.30	18.79	826.40	19.68
	0-40 cm	1070.50	25.49	939.30	22.36	1004.90	23.93
	0-60 cm	1255.50	29.89	1205.30	28.70	1230.40	29.30
Bed Hill	0-20 cm	854.57	20.35	787.12	18.74	820.85	19.54
	0-40 cm	1045.04	24.88	931.85	22.19	988.45	23.53
	0-60 cm	1240.30	29.53	1148.82	27.35	1194.56	28.44

Concerning the effect of planting methods treatments under all irrigation levels, the highest overall mean values were recorded under Flat broadcasting planting method and the value is 1155.42 m^3/fed. (27.51 cm). Meanwhile the lowest overall mean value was recorded under raised beds technique (Bed Hill) with all irrigation levels treatments 1001.28 m^3/fed. (23.84 cm). Generally the overall mean values for water consumptive use can be descended in order; Flat broadcasting> Flat Drill > Flat Hill >Bed broadcasting > Bed Drill > Bed Hill. Increasing values of water consumptive use under Flat broadcasting planting methods in comparison with other treatments might be attributed to increasing the amount of water applied under the conditions of this treatment.

Concerning the effect of irrigation levels treatments on the values of water consumptive use for wheat, overall mean values for water consumptive use can be descended in order; (I_3>I_2>I_1) in the two growing seasons in which mean values in two growing seasons were (1283.66, 1095.04 and 855.67 m^3/fed.) respectively. Increasing the value of water consumptive use under irrigation levels I_3 in comparison with other treatments might be attributed to increasing the amount of water applied under the conditions of this treatment and hence forming strong plants with a huge vegetative growth, therefore increasing transpiration from plant leaves which considers one of the main components of water consumptive use a long with evaporation from both soil and plants.

Interaction effect:

The highest value of water consumptive use was recorded under (I_3) irrigation treatment, where the mean values are (1361.71, 1336.40, 1330.40, 1248.47, 1230.40 and 1194.56 m^3/fed.) with Flat broadcasting, Flat Drill, Flat Hill, Bed broadcasting, Bed Drill and Bed Hill respectively, while the lowest value was recorded under (I_1) irrigation treatment, and the mean values are (899.76, 874.40, 870.40, 842.23, 826.40 and 820.85 m^3/fed.) under the previous planting methods, respectively.

3-Water saving

Data presented in Table (5) show that, overall average of water saving in the two growing seasons as

affected by planting methods were (296.14, 293.74 and 262.85 m^3/fed.) with Bed hill, Bed Drill, and Bed broadcasting, respectively in comparison with Flat broadcasting method.

Overall average of water saving in the two growing as affected by irrigation treatments were (830.60 and 369.78 m^3/fed.) with I_1 irrigation treatment and I_2 irrigation treatment, respectively in comparison with I_3 irrigation treatment.

Interaction effect:

Data presented in Table (5) show that the average of water saving as affected by interaction between Planting methods and irrigation treatments. Average of the highest value of two growing seasons was obtained with Bed Drill and Bed Hill planting methods with I_1 irrigation level (1125.86 and 1110.52 m3/fed.) respectively, and the lowest value (49.86 and 58.86 m3/fed.) was obtained with Flat Drill planting method with I_3 irrigation level and Flat Hill planting method with I_3 irrigation level respectively.

Table (5): Average of water applied (m^3/fed.) and water saving (m^3/fed.) and (%) as affected by planting methods and irrigation treatments during 2012-2013 and 2013-2014 seasons.

Planting Methods	Irrigation levels	2012-2013 irrigation water applied (m3/fed)	2012-2013 Water Saving (m3/fed)	2012-2013 Water Saving %	2013-2014 irrigation water applied (m3/fed)	2013-2014 Water Saving (m3/fed)	2013-2014 Water Saving %	Overall mean values of two seasons (m3/fed)	Overall mean values of two seasons %
Flat broadcasting		1913.00	-	-	1908.81	-	-	-	-
Flat Drill		1881.00	32.00	1.67	1857.67	51.14	2.68	41.57	2.18
Flat Hill		1875.00	38.00	1.99	1848.67	60.14	3.15	49.07	2.57
Bed broadcasting		1652.00	261.00	13.64	1644.12	264.69	13.87	262.85	13.76
Bed Drill		1623.00	290.00	15.16	1611.33	297.48	15.58	293.74	15.37
Bed (hill)		1613.67	299.33	15.65	1615.86	292.95	15.35	296.14	15.50
	0-60 cm	2159.33	-	-	2148.28	-	-	-	-
	0-20 cm	1326.50	832.83	38.57	1319.91	828.37	38.56	830.60	38.56
	0-40 cm	1793.00	366.33	16.97	1775.05	373.23	17.37	369.78	17.17
	0-20 cm	2362.00	-	-	2366.72	-	-	-	-
Flat broadcasting	0-40 cm	1421.00	941.00	39.84	1409.02	957.70	40.47	949.35	40.15
	0-60 cm	1956.00	406.00	17.19	1950.69	416.03	17.58	411.02	17.38
	0-20 cm	1390.00	972.00	41.15	1378.00	988.72	41.78	980.36	41.46
Flat Drill	0-40 cm	1924.00	438.00	18.54	1895.00	471.72	19.93	454.86	19.24
	0-60 cm	2329.00	33.00	1.40	2300.00	66.72	2.82	49.86	2.11
	0-20 cm	1385.00	977.00	41.36	1365.00	1001.72	42.33	989.36	41.84
Flat Hill	0-40 cm	1920.00	442.00	18.71	1890.00	476.72	20.14	459.36	19.43
	0-60 cm	2320.00	42.00	1.78	2291.00	75.72	3.20	58.86	2.49
	0-20 cm	1271.00	1091.00	46.19	1274.74	1091.98	46.14	1091.49	46.16
Bed broadcasting	0-40 cm	1679.00	683.00	28.92	1656.24	710.48	30.02	696.74	29.47
	0-60 cm	2006.00	356.00	15.07	2001.38	365.34	15.44	360.67	15.25
	0-20 cm	1242.00	1120.00	47.42	1235.00	1131.72	47.82	1125.86	47.62
Bed Drill	0-40 cm	1650.00	712.00	30.14	1627.00	739.72	31.26	725.86	30.70
	0-60 cm	1977.00	385.00	16.30	1972.00	394.72	16.68	389.86	16.49
	0-20 cm	1250.00	1112.00	47.08	1257.69	1109.03	46.86	1110.52	46.97
Bed (hill)	0-40 cm	1629.00	733.00	31.03	1631.34	735.38	31.07	734.19	31.05
	0-60 cm	1962.00	400.00	16.93	1958.55	408.17	17.25	404.09	17.09

4-Productivity of irrigation water (PIW) (Kg/m3):

Productivity of irrigation water (kg/m^3) is considered an evaluation parameter of yield per unit of applied water.

Concerning to the effect of planting methods on productivity of irrigation water, data presented in Table (6) illustrated that the highest mean values of the two growing seasons were obtained with Bed Drill and Bed Hill planting methods (1.96 kg grain/m^3 water) followed by Bed broadcasting method (1.80 kg grain/m^3 water) and Flat Drill (1.67 kg grain/m^3 water) and Flat Hill (1.66 kg grain/m^3 water) and the lowest mean value was recorded with Flat broadcasting (1.47 kg grain/m^3 water). The bed methods had realized to optimum conditions. It noticed that the highest values due to the lowest amount of water requirements which allowed relative to the flat method. Similar results were obtained by Genedy (2014) and El Hag (2015).

On the other side, the effect of irrigation treatments on Productivity of irrigation water, data indicated that irrigation treatment I_1 had the highest mean value of the two growing seasons (2.16 kg grain/m^3 water) followed by I_2 (1.68 kg grain/m^3 water) and I_3 (1.43 kg grain/m^3 water), as showed in Table (6).

Interaction Effect:

Data presented in Table (6) illustrated that Bed Drill and Bed Hill planting methods under I_1 irrigation level recorded the highest mean value for productivity of irrigation water (2.38 Kg grain/m^3 water) in the two growing seasons, while the lowest mean value for productivity of irrigation water (1.47 Kg grain/m^3 water) was obtained with Flat broadcasting planting methods with I_3 irrigation level in the two growing seasons.

5-Water Productivity:

Concerning the effect of Planting methods on water productivity, data presented in Table (7) indicated that the highest mean value for water productivity in the two growing seasons was recorded by Bed Hill planting method (3.57 kg grain/m^3 water) followed by Bed Drill method (3.50kg grain/m^3 water) and Bed broadcasting method (3.22 kg grain/m^3 water) and Flat Drill method

(3.06 kg grain/m^3 water) followed by Flat Hill method (3.05 kg grain/m^3 water) while the lowest mean value in the two growing seasons (2.69 kg grain/m^3 water) was with Flat broadcasting planting method. It means that bed method is more efficiently for water utilization than flat method, similar results were obtained by Genedy (2014) and El-Hag (2015).

Table (6): Productivity of irrigation water of different treatments during 2012-2013 and 2013-2014 seasons.

Planting Method	Irrigation levels	2012-2013 Yield (Kg/fed)	2012-2013 Seasonal water applied (m^3/fed)	2012-2013 Productivity of irrigation water (PIW) (Kg/m^3)	2013-2014 Yield (Kg/fed)	2013-2014 Seasonal water applied (m^3/fed)	2013-2014 Productivity of irrigation water (PIW) (Kg/m^3)	mean of two growing seasons
Flat broadcasting		3076.79	2139.40	1.49	2938.57	2098.81	1.45	1.47
Flat Drill		3408.21	2107.40	1.67	3288.21	2047.67	1.66	1.67
Flat (hill)		3414.29	2101.40	1.68	3227.86	2038.67	1.64	1.66
Bed broadcasting		3261.79	1878.40	1.78	3231.07	1834.12	1.81	1.80
Bed Drill		3580.00	1849.40	1.99	3389.29	1801.33	1.93	1.96
Bed (hill)		3596.79	1840.07	2.00	3393.57	1805.86	1.93	1.96
	0-20 cm	3369.11	1552.90	2.18	3213.93	1509.91	2.14	2.16
	0-40 cm	3395.00	2019.40	1.69	3243.57	1965.05	1.66	1.68
	0-60 cm	3404.82	2385.73	1.44	3276.79	2338.28	1.41	1.43
Flat broadcasting	0-20 cm	3068.57	1647.40	1.86	2916.43	1599.02	1.82	1.84
	0-40 cm	3082.50	2182.40	1.41	2925.00	2140.69	1.37	1.39
	0-60 cm	3079.29	2588.40	1.19	2974.29	2556.72	1.16	1.18
Flat Drill	0-20 cm	3387.86	1616.40	2.10	3264.64	1568.00	2.08	2.09
	0-40 cm	3413.57	2150.40	1.59	3271.07	2085.00	1.57	1.58
	0-60 cm	3423.21	2555.40	1.34	3328.93	2490.00	1.34	1.34
Flat (hill)	0-20 cm	3413.57	1611.40	2.12	3184.29	1555.00	2.05	2.08
	0-40 cm	3405.00	2146.40	1.59	3247.50	2080.00	1.56	1.57
	0-60 cm	3424.29	2546.40	1.34	3251.79	2481.00	1.31	1.33
Bed broadcasting	0-20 cm	3251.79	1497.40	2.17	3205.71	1464.74	2.19	2.18
	0-40 cm	3271.07	1905.40	1.72	3238.93	1846.24	1.75	1.74
	0-60 cm	3262.50	2232.40	1.46	3248.57	2191.38	1.48	1.47
Bed Drill	0-20 cm	3538.93	1468.40	2.41	3343.93	1425.00	2.35	2.38
	0-40 cm	3590.36	1876.40	1.91	3408.21	1817.00	1.88	1.89
	0-60 cm	3610.71	2203.40	1.64	3415.71	2162.00	1.58	1.61
Bed (hill)	0-20 cm	3553.93	1476.40	2.41	3368.57	1447.69	2.33	2.37
	0-40 cm	3607.50	1855.40	1.94	3370.71	1821.34	1.85	1.90
	0-60 cm	3628.93	2188.40	1.66	3441.43	2148.55	1.60	1.63

Table (7): Water productivity index of different treatments during 2012-2013 and 2013-2014 seasons.

Planting Methods	Irrigation levels	2012-2013 Yield (Kg/fed)	2012-2013 Cu	2012-2013 WP	2013-2014 Yield (Kg/fed)	2013-2014 Cu	2013-2014 WP	mean
Flat broadcasting		3076.79	1196.20	2.63	2938.57	1114.64	2.75	2.69
Flat Drill		3408.21	1171.17	2.97	3288.21	1088.63	3.15	3.06
Flat Hill		3414.29	1165.17	3.00	3227.86	1083.63	3.10	3.05
Bed broadcasting		3261.79	1090.35	3.06	3231.07	983.97	3.38	3.22
Bed Drill		3580.00	1063.17	3.44	3389.28	977.97	3.57	3.50
Bed Hill		3596.79	1046.64	3.51	3393.57	955.93	3.63	3.57
	0-20 cm	3369.11	912.12	3.71	3213.93	799.22	4.03	3.87
	0-40 cm	3395.00	1144.13	2.99	3243.57	1045.94	3.14	3.07
	0-60 cm	3404.82	1310.09	2.61	3276.79	1257.22	2.62	2.61
Flat broadcasting	0-20 cm	3068.57	973.50	3.15	2916.43	826.02	3.53	3.34
	0-40 cm	3082.50	1236.98	2.49	2925.00	1172.60	2.49	2.49
	0-60 cm	3079.29	1378.12	2.23	2974.29	1345.30	2.21	2.22
Flat Drill	0-20 cm	3387.86	948.50	3.57	3264.64	800.30	4.08	3.83
	0-40 cm	3413.57	1211.50	2.82	3271.07	1146.30	2.85	2.84
	0-60 cm	3423.21	1353.50	2.53	3328.93	1319.30	2.52	2.53
Flat Hill	0-20 cm	3413.57	942.50	3.62	3184.29	798.30	3.99	3.81
	0-40 cm	3405.00	1204.50	2.83	3247.50	1140.30	2.85	2.84
	0-60 cm	3424.29	1348.50	2.54	3251.79	1312.30	2.48	2.51
Bed broadcasting	0-20 cm	3251.79	890.16	3.65	3205.71	794.30	4.04	3.84
	0-40 cm	3271.07	1096.27	2.98	3238.93	945.30	3.43	3.21
	0-60 cm	3262.50	1284.63	2.54	3248.57	1212.30	2.68	2.61
Bed Drill	0-20 cm	3538.93	863.50	4.10	3343.93	789.30	4.24	4.17
	0-40 cm	3590.36	1070.50	3.35	3408.21	939.30	3.63	3.49
	0-60 cm	3610.71	1255.50	2.88	3415.71	1205.30	2.83	2.85
Bed Hill	0-20 cm	3553.93	854.57	4.16	3368.57	787.12	4.28	4.22
	0-40 cm	3607.50	1045.04	3.45	3370.71	931.85	3.62	3.53
	0-60 cm	3628.93	1240.30	2.93	3441.43	1148.82	3.00	2.96

Note: CU =Water Consumptive use (m3/fed), WP= Water Productivity index (Kg/m^3)

with regard to the effect of irrigation treatments on water Productivity, the highest mean value of the two growing seasons was recorded by I_1 irrigation treatment (3.87 kg grain/m^3 water) followed by I_2 irrigation treatment (3.07 kg grain/m^3 water) and I_3 irrigation treatment (2.61 kg grain/m^3 water). It can be concluded

that water productivity was decreased with increasing depth of applying irrigation water from 0-20 to 0-60 soil depth.

Interaction Effect:

Data presented in Table (7) reveal that bed hill planting method with I_1 irrigation treatment recorded the maximum value of water productivity (4.16 and 4.28 kg grain/m^3 water) in the first and second seasons, respectively, while minimum value of water productivity (2.23 and 2.21 kg grain/m^3 water) was obtained with Flat broadcasting planting method under I_3 irrigation treatment in the first and second seasons, respectively.

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تأثير إدارة مياه الري علي محصول القمح

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أجريت تجربتان حقليتان في محطة بحوث المقننات المائية بالقرضا محافظة كفر الشيخ – معهد بحوث إدارة المياه – المركز القومي لبحوث المياه لموسمين زراعيين ٢٠١٢-٢٠١٣ و٢٠١٣-٢٠١٤ لدراسة أثر طرق الزراعة المختلفه ومستويات الري علي انتاجية محصول القمح وإدارة مياه الري لمحصول القمح. أجريت التجربة في شرائح متعامدة بثلاثة مكررات ، وكانت المعاملات الرئيسية هي معاملات طرق الزراعة التي يمكن تقسيمها الي : البدار في أحواض، التسطير في أحواض، الجور في أحواض، مصاطب بدار، مصاطب تسطير و مصاطب في جور ، أما المعاملات الشقية فكانت مستويات الري ويمكن تقسيمها الي : الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٢٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية، الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٤٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية، الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٦٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية. وقد أوضحت أهم النتائج أنه:- توجد فروق معنوية بين معاملات طرق الزراعة علي إنتاجية محصول حبوب القمح في الموسم الزراعي الأول، وفروق عالية المعنوية في الموسم الزراعي الثاني. أما بالنسبة لمعاملات الري فقد وجد انه لا يوجد فروق معنوية خلال الموسمين وكذلك لا توجد فروق معنوية بين التفاعل بين معاملات طرق الزراعة ومعاملات الري أيضاً خلال الموسمين الزراعين.- توجد فروق معنوية بين معاملات طرق الزراعة علي إنتاجية محصول القش في الموسم الزراعي الأول، وفروق عالية المعنوية في الموسم الزراعي الثاني. أما بالنسبة لمعاملات الري فقد وجد انه لا يوجد فروق معنوية في الموسمين وكذلك لا توجد فروق معنوية بين التفاعل بين معاملات طرق الزراعة ومعاملات الري أيضاً في الموسمين الزراعين.- بالنسبة لكميات مياه الري المضافة الموسمية، حققت طريقة الزراعة بدار في أحواض مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٦٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية أعلي معدلاً وذلك بين باقي المعاملات الأخري خلال الموسمين الزراعين الأول والثاني، بينما كانت طريقة زراعة المصاطب تسطير مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٢٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية أقل معدلاً بين باقي المعاملات الأخري أيضاً خلال موسمي الزارعة.- حققت طريقة الزراعة بدار في أحواض مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٦٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية أعلي معدلاً في قيم الإستهلاك المائي وذلك بين باقي المعاملات الأخري خلال الموسمين الزراعين الأول والثاني، بينما كانت طريقة زراعة بدار في أحواض مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٢٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية أقل معدلاً في قيم الإستهلاك المائي بين باقي المعاملات الأخري أيضاً خلال موسمي الزارعة.- كانت أعلي قيم توفير مياه الري مع طريقة الزراعة مصاطب تسطير ومصاطب في جور مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٢٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية، وكانت أقل القيم مع طريقة الزراعة تسطير في أحواض وجور في أحواض مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٦٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية.- حققت طريقة الزراعة مصاطب تسطير و مصاطب في جور مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٢٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية أعلي معدلاً في قيم إنتاجية مياه الري خلال موسمي الزراعة.- حققت طريقة الزراعة مصاطب في جور مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٢٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية أعلي معدلات لقيم انتاجية محصول المياه خلال موسمي الزراعة. بينما كانت اقل القيم مع طريقة الزراعة بدار في أحواض مع الري حسب كميات المياه المضافة طبقاً لنسبة رطوبة التربة قبل الري للعمق ٠-٦٠ سم (طول الجذر) حتي الوصول الي السعة الحقلية.