Journal of Plant Production

Journal home page: www.jpp.mans.edu.eg
Available online at: www. jpp.journals.ekb.eg

Effect of Deficit Irrigation and Planting Method on Maize Plants under Middle Delta Conditions of Egypt

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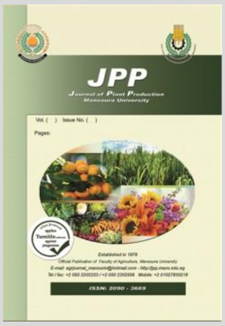

ABSTRACT

Two field experiments were conducted at El-Gemmeiza Agricultural Research Station Farm, Egypt, during 2017 and 2018 summer seasons to study the effect of deficit irrigation and the planting method on maize plants under Middle Delta conditions of Egypt. Irrigation at 65% available soil moisture depletion (AVSMD) did not significantly decrease chlorophyll content, dry matter (DM), leaf area index (LAI), crop growth rate (CGR), relative water content (RWC), osmotic potential (OP), ear length, ear diameter, rows per ear, kernels per row,100-kernel weight and grain yield. 50% irrigation treatment (control) decreased crop water productivity (CWP) by 9.93% compared to irrigation at 80% AVSMD, which increased drought sensitivity (YR/ SD) and the drought susceptibility index (S). The reduction in water consumptive use (WCU) due to irrigation at 65 % of AVSMD reached 19.34 to 20.30% and the improvement in CWP was 15.42 to 14.37% compared to the irrigation at 50% (AVSMD). Sowing maize plants on beds140 cm apart on both sides of beds and the distance between hills 25 cm resulted in the highest chlorophyll content, DM, LAI, CGR, RWC, ear height, ear length, 100-kernel weight and grain yield. This treatment decreased YR/SD, S and increased CWP. It can be recommend with sowing maize plants on beds140 cm apart on both sides of beds and the distance between hills 25 cm and irrigation at 65% of AVSMD which decreased WCU and improved CWP, in addition this treatment did not significantly decrease yield and its components and attained the lowest YR/S and S values.

Keywords: Maize, Available soil moisture depletion, leaf area index, crop growth rate, water relations and planting methods.

INTRODUCTION

Surface irrigation is the traditional method applied in about 80% of the irrigated areas in Egypt (Abd El-Halim and Abd El-Razik, 2013). These authors mentioned that the double ridge- furrow planting technique used as practical way to reduce the applied water quantities saved more water than the conventional ridge furrow irrigation method. This technique was also used by Meshreghi *et al*. (2014) on maize grown for fodder purpose. In this respect, Bakht *et al.* (2011) reported that planting methods had a significant effect on days to tasseling, days to silking, plant height, thousand grain weight, grain and biological yields.

In Egypt, river Nile is the major renewable water source and the most of the summer supplies of the river Nile comes from Ethiopian areas and because of the building the Ethiopian High Dam the supplies of water to Egypt will be affected. Also, for the traditional patterns of surface irrigation prevailing in most irrigated land in Egypt, we must save every water drop for the newly reclaimed lands to meet the highly growing population. So controlling and improving irrigation management must be followed. Some investigators in this respect studied the irrigation intervals (Abd El-Halim and Abd El-Razik, 2013). They reported that double ridge- furrow with irrigation at 7- day intervals proved superior to increase the grain yield and water productivity compared to 14-days interval and the convention treatment. Abu-Grab *et al.* (2015) on wheat reported that application of available water at a rate of 65% increased chlorophyll content. Irrigation at 80% available soil moisture depletion (AVSMD) decreased dry matter, leaf area index (LAI), crop growth rate (CGR), relative water content (RWC), osmotic potential (OP), water consumptive use (WCU), and grain yield. They added that grain yield reduction comprised 14.35% corresponding to 28.26% decrease in WCU and improved crop water productivity (CWP) by 19.09%. Nassiri*et al*. (2016) studied the effect of water at amounts of 60, 80 and 100% of crop evapotranspiraton (ETc), and two planting methods on-bed and in-bottom of furrow. Their results revealed that the irrigation regimes and planting methods had significant effects on grain yield and total dry matter of maize. The irrigation regime of 80% of ETc with planting in-bottom resulted in the highest grain yield (8193 kg ha^{-1}) and crop water productivity (1.05 kg m^{-3}). Maize response to deficit water and planting methods was studied assessing phenological development and yield under Punjab conditions (Singh *et al.* 2016). They used three levels of Cumulative Pan Evaporation (CPE), i.e. Drip Irrigation (DI) to replenish 60, 80, and 100% of base (30 mm) CPE and three planting method i.e. 1Row/Ridge,1Row/Bed and 1Row (zigzag) / Bed. The additional two treatments, i.e. flat and ridge sown were kept as control. Each increase from DI_{60} to DI_{100} caused significant earliness in visibility of tasseling and silking and significant delay in dough stage and physiological maturity.

This work aims to save water consumptive use and improve crop water productivity using water deficit regime and planting method in plants maize under Middle Delta conditions of Egypt.

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DOI: /10.21608jpp.2019.62278

MATERIALS AND METHODS

Two field experiments were laid out at El-Gemmeiza Agricultural Research Station Farm, Egypt during 2017 and 2018 summer seasons to study the effect of soil water deficit irrigation and methods of planting maize plants under Middle Delta of Egypt. The soil of the experimental sites was clay in texture, and some of its characteristics are shown in Table (1).

Table 1. Some soil- water constant properties and bulk density of the experimental sites in 2017 and 2018 seasons.

Soil layer depth (cm)	Field capacity (w/w,%)		Wilting point (w/w,%)		Available water (mm)		Bulk density (gcm^{-3})	
	2017	2018	2017	2018	2017	2018	2017	2018
00 - 20	44.56	43.87	23.45	23.25	51.09	49.07	1.21	1.19
20 - 40	40.85	40.03	21.50	21.11	49.54	48.81	1.28	1.29
40 - 60	37.54	36.93	19.73	19.52	46.66	45.96	1.31	1.32

Water deficit treatments:

1- Irrigation when 50 % of the available water was depleted (I_1, as control)

2 - Irrigation when 65 % of the available water was depleted (I_2).

3- Irrigation when 80 % of the available water was depleted (I_3).

Methods of planting: in all planting methods the plant density was 24000 plants per feddan (4200 m^2)

1-Maize grains were sown on ridges 70 cm apart and the distance between hills 25 cm (M_1).

2- Maize grains were sown on beds 140 cm apart on both sides of the beds and the distance between hills 25 cm (M_2).

3-Maize grains were sown on beds 140 cm apart on three lines on both sides and middle of the beds (140 cm) and the distance between hills 37.5 cm (M_3).

4-Maize grains were sown on beds (140 cm) a part and four lines were applied on the beds (140 cm) and the distance between hills 50 cm (M_4).

Water stress was created by irrigating maize plants when available soil moisture depletion (AVSMD) reached to the adopted available soil moisture depletion in the root zone (60 cm depth). The available soil moisture in each soil layer was computed as follows:-

AVSMD (mm) = (FC – WP)/100 X BD X D

(Israelson and Hansen (1962)

Where, FC, WP, and BD are field capacity(w/w %), wilting point (w/w %) and bulk density (gcm^{-3}) of the soil layer, respectively and D is the effective root zone (600 mm).

On determining the irrigation time, under the adopted irrigation treatments, cumulative Pan Evaporation norms were calculated as follows:-

Total available soil moisture (mm) per 60 cm of soil profile x assessed % AVSMD = cumulative Pan Evaporation norms.

Irrigation was practiced, for a particular irrigation treatment, as the two sides of the above formula were equal.

A split plot design with four replications was adopted where irrigation treatments were in the main plots, whereas the tested methods of sowing occupied the sub ones.The experimental unitarea was 21 m^2 (4.2 x 5 m), i.e. 1/ 200 fed. Seeds of the tested maize treatments (single cross 168) were supplied from Maize Department, Field Crops Research Institute, Agricultural Research Center (ARC) Egypt. Planting date on 28th May in the first season and on 2nd June in the second season respectively, as conventional practice in the area.

Table 2. Monthlymeans of agroclimatological data for GharbiaGovernorate last ten years.*

Month	Maximum Temp. (C°)	Minimum Temp. (C°)	Wind Speed ($m\ sec^{-1}$)	Relative Humidity (%)	E pan ($mm\ day^{-1}$)
May	34.3	17.2	4.2	34.8	8.9
June	38.0	20.1	4.3	36.0	9.8
July	38.6	21.5	4.2	41.5	9.3
August	38.6	22.1	3.9	43.2	8.8
September	35.6	20.9	4.0	46.8	7.6
October	30.9	17.8	3.8	48.8	6.0

***Source: Water Requirements and field Irrigation Research Dpt., Soil Water and Environment Research Institute (SWERI), Agric. Res. Center. Egypt.**

At 60 and 80 days after sowing (DAS), five plants of each plot were gathered, fresh weighed and the following data were recorded:

Dry matter DM (g $plant^{-1}$). A sample of five plants was fresh weighed then one plant was oven dried at 70 C° to constant weight then re-weighed and the mean dry weight per plant was computed.

Crop growth rate CGR (g m^{-2} day^{-1}) (Watson, 1952). Crop growth rate (CGR) is the rate of dry matter accumulation per unit of occupied ground per day.

$$CGR = (W_2 - W_1) / (T_2 - T_1) = g\ m^{-2}\ day^{-1}$$

Where, W_1 and W_2 refer to dry weight of maize plant at 60 and 80 days after plants whereas T_1 and T_2 refer to the time between 60 and 80 days.

Leaf area index (LAI)

To determine leaf area per plant, 20 disks area equal [20*3.14*$(1.5)^2$] = 141.3 cm^2 according to Hunt (1990) by the following formula:

Leaf area per plant =141.3*dry weight of leaves per plant / dry weight of leaves disks

LAI= leaf area per plant divided by ground area occupied by plant.

Chlorophyll content (mg dm^{-2}) was measured spectrophotometrecally at 80 DAS only (Moran, 1982). Chlorophyll a and b were calculated using the following formula:

$$Chl.a = 12.64 \times A664 - 2.99 \times A647\ (\mu g.\ ml^{-1})$$

$$Chl.b = 23.26 \times A647 - 5.6 \times A664\ (\mu g.\ ml^{-1})$$

$$Chl.a+b = 7.04 \times A664 + 20.27 \times A647 = (\mu g.\ ml^{-1}),$$

Where: A664 is the absorbance reading at 664nm, A 647 is the reading at 647nm.

Leaf relative water content (RWC,%) (Barris and Weatherley, 1962)

$$RWC = (Fw - Dw)/ (Tw - Dw) \times 100$$

Where Fw, Tw and Dw are fresh weight, turgid weight and dry weight, respectively.

Flag leaf osmotic potential (OP, bar) (Gusev, 1960).

Water consumptive use (WCU) mm was determined gravimetrically according to Israelson and Hansen (1962) as follows:

$$WCU\ (mm) = \theta_2 - \theta_1 / 100 \times BD \times D$$

Where, θ_1 and θ_2 are soil moisture % by weight just before and 48 hrs after irrigation, BD is the soil bulk density and D is the effective root zone, 600 mm.

It is worthy to mention that water table measurements showed that it was not shared in water consumed by maize plants.

Crop water productivity (CWP) was computed by dividing the weight in kg of grain yield per fed by water consumptive use per fed in m^3(kg/m^3).

Days to tasseling (DTT) from planting.

Days to silking (DTS) from planting.

At harvest time (1st of October), the following data on yield and yield components were recorded:

1-Grain yield (GY) ardabfeddan^{-1}, as the four inner rows of the plot were harvested and used for grain yield determination.
2-Plant height (cm) 3-Ear height (cm)
4-Ear length (cm) 5-Ear diameter (cm)
6-Number of rows per ear (mean of 10 cops per plot).
7-Number of kernels / row (mean of 10 cops per plot)
8-100- kernel weight (g)

Drought sensitivity (YR/SD) was estimated according to Hiller and Clark (1971) equations where YR is relative yield reduction and SD are stressed days.

$$YR = 1 - Yd / Yc$$

Where Yd and Yc are yield of stressed and control treatments, respectively.

$$SD = (1 - Ed / Ec)\, N$$

Where, Ed and Ec are evapotranspirations from stressed and fully irrigated control respectively and N is the entire growth period of maize.

The drought susceptibility index (S) was calculated for the yield data according to Fisher and Maurer (1978).

$$S = [1 - (YD/YC)] / D$$

Where, D= drought intensity = 1-(mean Yd for all stressed treatments/mean of YC of full irrigated (control) treatments.

The collected data, except WCU, were statistically analyzed (Steel and Torrie1980). Means of the studied traits were compared using LSD at 5% probability level.

RESULTS AND DISCUSSION

Chlorophyll contents:

Irrigation at 50% of AVSMD resulted in increasing chlorophyll (Chl) contents (Table 3). In this respect, the data of Chl.a, Chl.b, and Chl.(a+b) was significant in both studied seasons, except those of Chl.a+b in the first season only, which were highly significant. In this respect, irrigation at 65 % of AVSMD did not decrease all chlorophyll parameters in both seasons. This may be due to that this treatment gave the adequate water enough to absorb nitrogen and other nutrients from the soil where nitrogen is considered the main component of chlorophyll molecule. El Sabagh *et al.* (2017) reported that plants under drought condition exhibited reduced rate of photosynthesis as a result of reduction in stomatal aperture and stomatal conductance which could be a major determinant for high grain yield in maize under stress condition. However, Abu-Grab *et al.* (2015) on wheat reported that, application of available water at a rate of 65 % (AVSMD) increased chlorophyll content.

Methods of planting also, had highly significant effect on Chl.a, Chl. (a+b) in the first seasons, whereas, Chl.b data showed highly significant differences in both seasons (Table, 3). In this connection, sowing maize grains on beds 140 cm apart on both sides of beds and the distance between hills 25 cm (M_2) induced the highest chlorophyll content in maize leaves in both seasons. Whereas the lowest content was obtained with sowing on beds (140 cm) apart, and four lines on beds, distance between hills were 50 cm (M_4). This is mainly due to exist once of four lines on beds, which may induce disturbance in the plant canopy geometry, hence retard the penetration of sun light to arrive the leaf plant surface in the best way.

The interaction effect of planting methods and irrigation treatments had no significant effect on chlorophyll content in both seasons (Table3).

Table 3. Chlorophyll a, chlorophyll b and chlorophyll (a+ b) as affected by irrigation treatments (AVSMD), planting methods and their interactions in 2017 and 2018 seasons.

Treatments		Chl.a (mg/dm²)		Chl.b (mg/dm²)		Chl.(a+b) (mg/dm²)	
		2017	2018	2017	2018	2017	2018
Irrigation treatments							
50% AVSMD (I_1)		18.03	19.06	5.36	5.58	23.39	24.64
65% AVSMD (I_2)		17.41	17.63	5.11	4.97	22.52	22.60
80% AVSMD (I_3)		12.79	13.19	4.20	4.29	17.00	17.48
F. test		*	*	*	*	**	*
LSD 0.05		0.85	1.53	0.47	0.62	1.27	2.21
Planting methods							
M_1		16.70	17.98	5.01	5.53	21.70	23.50
M_2		17.56	17.57	5.51	5.11	23.06	22.68
M_3		15.26	15.87	4.61	4.82	19.87	20.69
M_4		14.79	15.08	4.44	4.32	19.24	19.41
F. test		**	*	**	**	**	*
LSD 0.05		0.95	1.64	0.43	0.83	1.34	2.57
Irrigation treatments X Planting methods							
I_1	M_1	18.65	20.42	5.63	6.05	24.28	26.46
	M_2	19.38	19.96	5.90	5.74	25.28	25.70
	M_3	17.30	18.20	5.07	5.43	22.37	23.63
	M_4	16.80	17.66	4.84	5.10	21.64	22.76
I_2	M_1	18.09	18.89	5.16	5.74	23.25	24.63
	M_2	19.10	18.51	5.97	5.14	25.06	23.65
	M_3	16.29	17.30	4.71	4.90	21.00	22.19
	M_4	16.15	15.82	4.60	4.10	20.76	19.92
I_3	M_1	13.36	14.63	4.23	4.80	17.59	19.42
	M_2	14.20	14.24	4.65	4.47	18.86	18.71
	M_3	12.18	12.11	4.06	4.13	16.24	16.24
	M_4	11.43	11.77	3.88	3.77	15.31	15.54
F. test		NS	NS	NS	NS	NS	NS
LSD 0.05		NS	NS	NS	NS	NS	NS

AVSMD =Available soil moisture depletion

Growth parameters:

Data listed in Table(4) revealed that irrigation at 65 %did not differ significantly with irrigation at 50 % of AVSMD, so we prefer irrigation treatment at 65 % as this treatment saved more water than irrigation at 50 % treatment. In this respect, irrigation at 50 % treatment increased all studied parameters, i. e. dry matter (DM) and leaf area index (LAI) at both sampling intervals for the two studied seasons. Irrigation at 80 % AVSMD decreased dry matter by 35.63 and 44.05 % in the first and second sampling periods in the first season, respectively. These values reached 20.84 and 33.82 % in the second season in the same order. As for LAI, the decreased values of 80% AVSMD by 28.06% and 44.42%.These values were 30.34 and 43.25% at60 and80 DAS, respectively in the second season. The crop growth rate (CGR) reductions values were54.42% and 50.60% for I_3 treatment in the first and second season, respectively (Table 4). The obtained results are in agreement with those of Meena *et al.* (2015) on maize crop who reported that irrigation at 60 mm CPE increased DM and LAI. In the same trend Kuan-Hung *et al.* (2019) reported that DM and LAI were significant declined under regulated deficit irrigation (RDI) compared with full irrigation (FI)

Table 4. Growth parameters i.e dry matter (DM), leaf area index (LAI) and crop growth rate (CGR) as affected by irrigation treatments (AVSMD), planting methods and their interactions in 2017 and 2018 seasons.

Treatments		DM (g plant^{-1}) (60 DAS)		DM (g plant^{-1}) (80 DAS)		LAI (60 DAS)		LAI (80 DAS)		CGR (g m^{-2} day^{-1}) (60-80 days)	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatments											
50% AVSMD (I_1)		205.7	236.1	373.2	418.7	7.27	8.14	9.77	10.52	47.85	52.13
65% AVSMD (I_2)		178.7	218.6	327.7	382.1	6.72	7.65	8.82	9.83	42.54	46.71
80% AVSMD (I_3)		132.4	186.9	208.8	277.1	5.23	5.67	5.43	5.97	21.81	25.75
F. test		*	**	*	**	**	**	**	**	*	*
LSD 0.05		28.5	20.38	48.68	40.62	0.86	1.51	1.05	0.71	5.80	5.60
planting methods											
M_1		182.5	225.6	346.0	401.1	6.77	7.54	8.59	9.34	46.71	50.13
M_2		192.3	244.5	356.2	417.6	7.11	7.82	9.27	10.05	46.82	49.39
M_3		161.1	195.2	268.4	326.1	6.01	6.77	7.29	7.97	30.61	37.34
M_4		153.1	190.1	242.2	292.5	5.74	6.49	6.87	7.74	25.47	29.24
F. test		**	**	**	**	**	**	**	**	*	*
LSD 0.05		23.88	18.67	43.83	44.34	0.71	1.36	1.03	0.49	7.63	8.08
Irrigation treatments X Planting methods											
I_1	M_1	218.9	262.6	434.2	494.3	7.71	8.83	10.87	11.48	61.50	66.18
	M_2	225.0	268.5	437.5	482.6	8.02	9.04	11.34	11.85	60.70	61.10
	M_3	192.5	208.8	327.9	370.5	6.84	7.58	8.75	9.61	38.66	46.14
	M_4	186.5	204.4	293.1	327.5	6.50	7.11	8.11	9.15	30.43	35.12
I_2	M_1	188.9	229.2	374.7	424.7	7.30	8.30	9.78	10.84	53.10	55.84
	M_2	194.3	251.0	384.2	443.7	7.69	8.25	9.94	11.10	54.25	54.99
	M_3	170.2	197.7	288.7	346.9	6.08	7.13	8.08	8.86	33.86	42.60
	M_4	161.5	196.3	263.2	313.0	5.83	6.93	7.48	8.53	29.06	33.29
I_3	M_1	139.6	184.9	229.0	284.3	5.29	5.47	5.11	5.69	25.52	28.38
	M_2	157.6	214.0	246.9	326.5	5.62	6.18	6.52	7.20	25.52	32.15
	M_3	120.8	179.0	188.5	260.8	5.11	5.60	5.04	5.44	19.36	23.35
	M_4	111.4	169.5	170.7	236.9	4.91	5.43	5.04	5.56	16.96	19.24
F. test		NS	*	**	**	NS	*	*	*	**	**
LSD 0.05		NS	20.49	45.95	40.84	NS	0.98	0.92	0.85	4.51	5.31

AVSMD =Available soil moisture depletion

As shown from the data in Table (4), it can be seen that planting methods induced significant effects on each of dry matter, leaf area index and CGR. It can be detected that beds140 cm apart and on both sides treatment (M2) method resulted in the highest DM, LAI and CGR in both seasons, whereas beds 140 cm apart, and four lines on (M4) attained the lowest DM, LAI and CGR in both seasons. The main reductions in DM (60 DAS) due to the application of (M4) were 20.38 and 22.25% in the first and second seasons, respectively. As for DM (80 DAS), these values were 32.00 and 29.96%, respectively in the same order. The main reductions in LAI were 22.58 and 20.00 %. Whereas, the main reduction in CGR comprised 45.60 and 41.67% in the two studied seasons, respectively. In this respect, Khan *et al.* (2012) found that ridge sowing resulted in better root system which affect nutrient and water uptake resulting in high LAI. LAI indicates the size of assimilatory system of crop, which captures solar radiation for C assimilation; higher LAI thus provides more area for photo-assimilation resulting in higher CGR. Moreover, Nassiri *et al.* (2016) reported that planting methods had significant effects on total dry matter of maize. As we said previously the application of (M4) planting method decreased planting growth. This is mainly due to exist once of four lines on the beds which disturb the plant geometry, hence retard the penetration of sun light to arrive the plant surface and may resulted in decreasing photosynthesis rate.

The interaction effect of the AVSMD irrigation treatments and maize planting methods is shown in Table (4). It can be seen that applying irrigation at 50 % AVSMD and sowing maize plants in the (M2) method attained the highest DM, LAI, and CGR in all studied times. Although the data in some times were not significant, Nassiri *et al.* (2016) studied the effect of water at amounts of 60, 80 and 100% of crop evapotranspiraton (ETc), and two planting methods on-bed and in-bottom of furrow and revealed that the irrigation regimes and planting methods had significant effects on total dry matter of maize.

Water relations:

Water consumptive use (WCU) data, relative water content (RWC), osmotic pressure (OP), and crop water productivity (CWP) data are presented in Table (5). From the data in such Table it can be seen that irrigation at 65% AVSMD decreased WCU by 19.34 to 20.30% and improved CWP by 15.42 and 14.37 % compared with irrigation at 50 % treatment. Increasing WCU by irrigation at 50% AVSMD led to increasing RWC by 14.23 and 13.26% compared to irrigation at 80 % AVSMD in the first and second season, respectively. On the other hand, it increased OP by 32.94 and 31.90 % in the same order. This treatment decreased CWP by 10.44 and 9.42 % in the two studied seasons in the same order. The obtained results go along with those of Meena *et al.* (2015) on maize crop who reported that irrigation at 80 mm CPE recorded highest value of CPW but irrigation at 100 mm CPE recorded lowest value of WCU. Also, Farouk *et al.* (2018) on maize had similar results and reported that irrigation every 25 days decreased the relative water content in leaves and OP was increased compared with irrigation every 15 and 20 days.

Table 5. Water relations (water consumptive use, leaf relative water content , flag leaf osmotic potential and crop water productivity) as affected by irrigation treatments (AVSMD) , planting methods and their interactions in 2017 and 2018 seasons.

Treatments		RWC %		CU (mm)		OP (bar)		CWP economic yield (kg m^{-3})	
		2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatments									
50% AVSMD (I_1)		72.65	74.72	2783	2831	-12.23	-11.53	1.48	1.55
65% AVSMD (I_2)		69.56	72.06	2245	2257	-13.90	-12.71	1.75	1.81
80% AVSMD (I_3)		62.31	64.81	1755	1830	-18.24	-16.93	1.66	1.71
F. test		**	*	—	—	**	**	*	**
LSD 0.05		2.4	2.99	—	—	1.83	1.53	0.09	0.11
Planting methods									
M_1		65.72	67.93	2443	2596	-16.36	-15.05	1.64	1.64
M_2		67.83	70.15	2305	2371	-15.45	-14.27	1.88	1.90
M_3		68.94	71.23	2201	2198	-14.06	-13.26	1.59	1.67
M_4		70.20	72.81	2094	2059	-13.30	-12.30	1.41	1.55
F. test		*	**	—	—	**	**	**	**
LSD 0.05		2.57	1.63	—	—	1.78	1.74	0.10	0.12
Irrigation treatments X Planting methods									
I 1	M_1	69.79	71.00	2955	3217	-13.45	-12.63	1.51	1.47
	M_2	72.42	74.97	2803	2863	-12.87	-11.92	1.69	1.71
	M_3	73.73	75.69	2722	2681	-11.80	-11.23	1.44	1.55
	M_4	74.66	77.22	2652	2564	-10.81	-10.35	1.29	1.47
I 2	M_1	66.82	69.23	2471	2497	-15.51	-13.83	1.71	1.78
	M_2	69.16	71.47	2295	2368	-14.09	-12.94	2.00	1.98
	M_3	70.57	73.11	2163	2158	-13.11	-12.25	1.72	1.75
	M_4	71.69	74.44	2050	2003	-12.91	-11.81	1.56	1.72
I 3	M_1	60.54	63.56	1902	2073	-20.13	-18.71	1.70	1.67
	M_2	61.93	64.02	1816	1881	-19.37	-17.96	1.94	2.02
	M_3	62.51	64.89	1719	1755	-17.26	-16.30	1.61	1.69
	M_4	64.24	66.78	1581	1610	-16.20	-14.75	1.38	1.46
F. test		**	NS	—	—	NS	NS	NS	NS
LSD 0.05		5.31	NS	—	—	NS	NS	NS	NS

AVSMD =Available soil moisture depletion

Planting methods induced highly significant differences on waterrelation parameters, except RWC data in the first season where the data were significant (Table 5). In this respect, when maize grains were sown on beds 140 cm apart, and four lines were applied on beds, distance between hills were 50 cm(M4) increased RWC and decreased CWP, WCU and OP. Planting maize on beds140 cm apart on both sides of beds and the distance between the hills was 25 cm (M2) led to decreasing WCU, and increased CWP.These results are in accordance with those of Khan *et al.* (2012) who found that this method increased CWP with direct result of grain yield improvement. However, Abd El-Halim and Abd El-Razik (2013) mentioned that the double ridge- furrow planting technique used as practical way to reduce the applied water quantities, saved more water than the conventional ridge-furrow irrigation method. Also Meena *et al.* (2015) on maize crop found that furrow irrigated raised bed recorded significant highest CPW and lowest WCU compared with other planting method (flat bed and ridge and furrow).

Respecting the interaction effect of the irrigation treatments and the planting methods, all the data exerted no significant, except of RWC which showed significance in the first season (Table 5). In this respect, I_1 (50 % irrigation treatment) and planting method (M4) attained the highest RWC in both studied seasons.

Tasseling and silking time, plant and ear heights:

Irrigation at either 65 or 80 %AVSMD decreased days to tasseling and silking, plant height and ear height compared to control irrigation treatment (I_1) which increased the teaseling and silking date, plant height and ear height. The data were either significant or highly significant in both seasons (Table 6). An exception was found where the data of plant height in the first season did not reach the significance level (Table 6). This is mainly due to increased plant growth period. Singh*et al.*(2016) reported that maize response to deficit water and planting method was studied for assessing phenological development and yield under Punjab conditions. They used three levels of Cumulative Pan Evaporation (CPE) i.e. Drip Irrigation (DI) to replenish 60, 80 and 100% of base (30 mm) CPE and three planting methods, i.e. 1Row/Ridge, 1Row/Bed and1Row (zigzag) /Bed. They reported that each increasefrom$D1_{60}$ to $D1_{100}$ caused significant earliness in visibility of tasseling and silking, which mean decreasing time to tasseling and silking. Kuan-Hung *et al.* (2019) reported that plant height was significant declined under regulated deficit irrigation (RDI) compared with full irrigation (FI)

Planting maize on beds 140 cm apart and four lines on beds and distance between hills of 50 cm (M_4) exerted the latest tasseling and silking dates, highest plant and ear heights. This trend was true in both seasons of study (Table 6). This increased the growth maize season on one hand and the exerted four lines on the ridge may affect the canopy geometry on the other. In this respect, Singh *et al.* (2016) reported that previous studied planting methods resulted in insignificant earliness in visibility of tasseling and silking, which mean decreasing time to tasseling and silking dates.

The interaction effect of deficit irrigation treatments and maize planting methods showed no significant differences between the studied parameters in both seasons, except that of plant height in the first season (Table 6).

Table 6. Days to tasseling & silking, plant and ear heights as affected by irrigation treatments (AVSMD), planting methods and their interactions in 2017 and 2018 seasons

Treatments		Tasseling date (day)		Silking date (day)		Plant height (cm)		Ear height (cm)	
		2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatments									
50% AVSMD (I_1)		61.56	61.94	63.69	63.44	233.6	230.9	141.3	133.1
65% AVSMD (I_2)		60.88	61.31	62.81	62.81	228.2	218.5	132.2	129.4
80% AVSMD (I_3)		59.25	59.56	61.44	61.50	228.5	210.4	122.5	114.7
F. test		**	*	**	*	NS	*	*	**
LSD 0.05		0.72	1.16	0.65	0.95	NS	8.00	8.94	5.57
Planting methods									
M_1		60.58	60.83	62.50	62.42	228.5	221.7	127.5	126.3
M_2		60.00	60.42	62.25	62.08	227.1	215.4	131.7	122.5
M_3		60.75	61.33	62.75	63.00	231.3	224.2	126.3	128.3
M_4		60.92	61.17	63.08	62.83	233.4	218.4	142.5	125.9
F. test		*	*	*	NS	NS	*	**	NS
LSD 0.05		0.57	0.61	0.48	NS	NS	6.31	7.39	NS
Irrigation treatments X Planting methods									
I_1	M_1	61.50	61.25	63.50	62.75	239.3	235.0	138.8	132.5
	M_2	60.50	62.00	63.00	63.50	231.3	226.3	145.0	127.5
	M_3	61.75	62.50	63.75	64.00	240.0	236.3	136.3	140.0
	M_4	62.50	62.00	64.5	63.50	223.8	226.3	145.0	132.5
I_2	M_1	61.00	61.50	63.00	63.00	225.0	220.0	127.5	130.0
	M_2	60.50	60.00	62.50	61.50	230.0	216.3	136.3	128.8
	M_3	61.25	61.75	63.00	63.25	226.3	217.5	123.8	125.0
	M_4	60.75	62.00	62.75	63.50	231.3	220.0	141.3	133.8
I_3	M_1	59.25	59.75	61.00	61.50	221.3	210.0	116.3	116.3
	M_2	59.00	59.25	61.25	61.25	220.0	203.8	113.8	111.3
	M_3	59.25	59.75	61.50	61.75	227.5	218.8	118.8	120.0
	M_4	59.50	59.50	62.00	61.50	245.0	208.8	141.3	111.3
F. test		NS	NS	NS	NS	**	NS	NS	NS
LSD 0.05		NS	NS	NS	NS	11.76	NS	NS	NS

AVSMD =Available soil moisture depletion

Yield and yield components:

The yield and yield components data are presented in (Table 7). From such data it can be seen that irrigation at65% of AVASMD (I_2) did not significantly decrease no. of kernels per row, 100-kernel weight and grain yield per feddan in both seasons compared with the 50% AVSMD (I_1) treatment (control), which resulted in the highest grain yield. Increases in grain yield due to 50 % AVSMD treatment were 29.32 and 28.16 % for the first and second seasons respectively, compared with 80% AVSMD (I_3) treatment. It could be attributed to that treatment saved the adequate water enough to grow plants well (Tables, 4 and 5). Moreover, Nassiri *et al.* (2016) studied the effect of water at amounts of 60, 80 and 100% of crop evapotranspiraton (ETc), and two planting methods on-bed and in-bottom of furrow and revealed that the irrigation regimes and planting methods had significant effects on grain yield and dry matter of maize. In this respect, irrigation at 65 % treatment did not significantly decrease yield and its components in both seasons.

Planting methods also increased ear length, no. of kernels per row and 100-kernel weight which reflected on increasing grain yield per feddan (Table, 7). In this respect, sowing maize on beds 140 cm apart in both sides of beds and the distance between hills 25 cm (M_2) resulted in best maize grain yield and its components in both seasons. This may be due to the fact that ridge planting provide good soil conditions for proper root development and root growth as reported by Bakht *et al*., (2006), Liu and Young (2008) and Belachew and Abera (2010). The obtained results are in agreed with those of Abd El-Halim and Abd El-Razik, (2013) in Egypt. They mentioned that beds planting technique used as practical way to reduce the applied water quantities saved more water than the conventional ridge furrow irrigation method. This technique was also used by Meshreghi *et al*. (2014) on maize grown for fodder purpose. In this respect, Bakht *et al.* (2011) reported that planting methods had a significant effect on days to tasseling, days to silking, plant height, thousand grains weight, grain and biological yields.

The interactive effect of irrigation treatments and planting methods is presented in Table (7). From such data, it can be seen that sowing maize on beds 140 cm apart on both sides of beds and the distance between hills 25 cm (M_2) with irrigation at 50 % AVSMD attained the best grain yield and yield components in both seasons. All interaction data were not significant, except ear length and ear diameter in the second season, no. of kernels in both seasons which showed significant difference only in (Table 7).

Drought sensitivity (YR / SD) and susceptibility index (S):

Data of drought sensitivity and susceptibility index are presented in Table (8). Such data clearly show that decreasing irrigation rate from 50% to 65 % AVSMD resulted in decreasing grain yield by 4.89 and 6.84 % in the first and second seasons, respectively. These values reached 29.80 and 28.80 % when irrigation was carried out at 80 % AVSMD in the same order. The (YR/ SD) was 0.287 and 0.390 for the two seasons, respectively. The obtained results are in accordance with those of Abu-Grab *et al.* (2015), Abu-Grab and Elsharawy (2013) and Abu-Grab and Murad (2010). S-values followed the same trend of YR /SD. In the same trend Abo-Marzoka *et al.* (2016) on maize illustrated that the yield was reduced by 28.85 and 38.83% when it was irrigated every 20 or 25 days, respectively it may be attributed to depression growth parameters and yield component.

Table 7. Yield and yield components as affected by irrigation treatments (AVSMD), planting methods and their interactions in 2017 and 2018 seasons.

Treatments		Ear length (cm)		Ear diameter (cm)		No of rows /ear		No. of Kernels/row		100- kernel weight (g)		Grain Yield (Ard/fed)	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatments													
50%AVSMD (I_1)		23.14	23.04	4.90	5.25	15.59	15.70	45.12	45.58	38.37	37.63	29.55	31.33
65%AVSMD (I_2)		22.18	22.49	4.42	4.52	14.57	13.99	43.91	43.91	36.42	36.01	28.14	29.24
80%AVSMD (I_3)		20.25	19.39	4.08	4.39	14.31	14.22	40.57	39.29	32.48	33.85	20.89	22.47
F. test		*	**	*	*	*	*	*	**	**	*	**	**
LSD 0.05		1.14	0.94	0.50	0.82	0.75	0.59	1.68	1.73	2.04	1.65	2.13	2.21
Planting methods													
M_1		21.80	21.90	4.46	4.77	14.47	14.56	43.93	43.	36.63	36.92	28.39	30.09
M_2		22.09	21.49	4.45	4.78	14.90	14.83	43.23	44.45	38.80	39.22	30.61	31.90
M_3		21.19	20.82	4.39	4.68	14.96	14.57	41.56	42.53	34.15	34.61	24.82	25.98
M_4		21.31	20.38	4.58	4.65	14.97	14.59	42.54	40.91	33.43	32.58	20.94	22.75
F. test		NS	**	NS	NS	NS	NS	*	**	**	**	**	**
LSD 0.05		NS	0.62	NS	NS	NS	NS	1.39	1.09	1.97	1.59	2.00	1.79
Irrigation treatments X Planting methods													
I_1	M_1	23.85	23.48	4.95	5.30	14.65	15.60	46.20	45.35	40.65	40.48	31.89	33.78
	M_2	23.58	23.90	4.90	5.50	15.80	16.00	47.78	48.45	41.68	42.12	33.84	35.02
	M_3	22.38	22.40	4.73	5.10	16.15	15.60	43.50	46.75	35.05	35.73	28.08	29.69
	M_4	22.78	22.38	5.03	5.10	15.75	15.60	43.00	41.75	36.08	32.18	24.38	26.84
I_2	M_1	21.35	22.15	4.38	4.53	14.50	13.78	43.95	44.25	37.18	36.78	30.15	31.74
	M_2	22.60	22.55	4.55	4.70	14.75	14.18	43.03	44.55	39.43	38.08	32.86	33.53
	M_3	20.78	21.18	4.28	4.38	14.28	13.90	41.50	41.68	34.98	34.80	26.65	27.04
	M_4	20.85	20.18	4.48	4.45	14.75	14.10	42.53	42.35	34.08	34.40	22.89	24.65
I_3	M_1	20.20	20.08	4.05	4.48	14.25	14.30	41.63	41.05	32.08	33.50	23.13	24.76
	M_2	20.08	20.03	3.90	4.13	14.15	14.30	38.88	40.35	35.28	37.45	25.12	27.14
	M_3	20.40	19.88	4.16	4.56	14.45	14.20	39.68	40.15	32.43	33.30	19.74	21.22
	M_4	20.30	18.58	4.23	4.40	14.40	14.08	42.10	38.63	30.13	31.15	15.55	16.77
F. test		NS	*	NS	*	NS	NS	*	**	NS	NS	NS	NS
LSD.05		NS	1.08	NS	1.09	NS	NS	2.40	1.89	NS	NS	NS	NS

Table 8. Relative yield reduction (YR), stressed days (SD), Drought sensitivity (Y R/SD) and susceptibility index (S) as affected by irrigation treatments (AVSMD), planting methods and their interactions in 2017 and 2018 seasons.

Treatments		YR		SD		YR/SD		S	
		2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatments									
65%AVSMD (I_2)		0.049	0.068	23.32	24.32	0.0021	0.0028	0.287	0.392
80%AVSMD (I_3)		0.298	0.288	44.42	42.48	0.0067	0.0068	1.748	1.649
planting methods									
M_1		0.165	0.164	31.21	34.77	0.0046	0.0043	0.966	0.937
M_2		0.143	0.134	32.00	30.95	0.0037	0.0038	0.841	0.765
M_3		0.174	0.187	34.43	32.43	0.0044	0.0053	1.021	1.072
M_4		0.212	0.228	37.85	35.45	0.0049	0.0058	1.242	1.307
Irrigation treatments X planting methods									
I_2	M_1	0.055	0.060	19.65	26.86	0.0028	0.0022	0.320	0.346
	M_2	0.029	0.043	21.75	20.75	0.0013	0.0021	0.170	0.243
	M_3	0.051	0.089	24.64	23.41	0.0021	0.0038	0.299	0.511
	M_4	0.061	0.082	27.24	26.26	0.0022	0.0031	0.359	0.467
I_3	M_1	0.275	0.267	42.76	42.67	0.0064	0.0063	1.612	1.528
	M_2	0.258	0.225	42.25	41.16	0.0061	0.0055	1.512	1.287
	M_3	0.297	0.285	44.22	41.45	0.0067	0.0069	1.743	1.632
	M_4	0.362	0.375	48.46	44.65	0.0075	0.0084	2.125	2.147

AVSMD =Available soil moisture depletion

The least decrease in grain yield due to decreasing AVSMD from 50 to 65 %, i.e (YR) was recorded when maize crop were sown on beds140 cm apart on both sides of beds and the distance between hills 25 cm (M_2).The yield reduction was 14.30 and 13.40% for the first and second seasons, respectively, compared with 21.2 and 22.8% for (M_4) in the same order.

The interactive effect of irrigation treatment and planting methods is presented in Table (8). Maize plants grown in M_2 plots and irrigated at 65 % AVSMD attained the lowest (YR /SD) and S in both seasons. Whereas, those grown in M_4 plots and irrigated at 80 % AVSMD recorded the highest (YR /SD) and S in both seasons.

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تأثيرنقص الرى وطرق الزراعة على نباتات الذرة الشامية تحت ظروف وسط الدلتا – مصر

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تم اجراء تجربتين حقليتين فى مزرعة محطة البحوث الزراعية بالجميزة خلال الموسمين الصيفيين 2017 و 2018 لدراسة تأثير نقص ماء الرى وطرق زراعة محصول الذرة الشامية فى منطقة وسط الدلتا بجمهورية مصر العربية وكانت أهم النتائج مايلى : لم يؤدى رى نباتات الذرة عند فقد 65 % من الماء الميسرالى نقص معنوى فى تركيز الكلوروفيل بأوراق النباتات كما لم تؤدى الى نقص معنوى فى كل من الوزن الجاف, دليل مساحة الاوراق, معدل النمو النسبى للمحصول, محتوى الماء بالأوراق, الجهد الأسموزي لها, قطرالكوز, عدد السطور فى الكوز,عدد الحبوب بالكوز,عدد الحبوب فى السطر, وزن الـ 100 حبة,محصول الحبوب بالفدان وأدى رى النباتات عند فقد50 % من ماء الرى الى زيادة فى محصول الحبوب بالفدان بنسبة 29,32 و28,28 % فى موسمى الدراسة على التوالى . كما أدت تلك المعاملة الى زيادة الآستهلاك المائى ومحتوى الأوراق من الماء. وكان متوسط مقدار النقص فى كفاءة استخدم ماء الرى 9,93 % بالمقارنة بالرى عند فقد 80 % من الماء الميسر وقد أدت معاملة الرى عند فقد 80 % من الماء الميسر الى زيادة الحساسية للعطش.وفى هذا السياق أدى رى نباتات الذره الشاميه عند فقد 65 % الى نقص الآستهلاك المائى بمقدار 19,34 و 20,30% وتحسين كفاءه استخدام ماء الرى بمقدار15,42و14,37% مع عدم نقص المحصول ومكوناته معنويا"فى الموسمين على التوالى مع أقل قدر من الحساسيه للعطش والقابليه للإصابه بالعطش ولهذا السبب تفضل هذه المعاملة. أدت زراعة نباتات الذرة الشامية على الريشتين عرض المصطبة الواحدة 140 سم والزراعة على جانبى الريشتين والمسافة بين النباتات 25سم الى زيادة الكلوروفيل والمادة الجافة ودليل مساحة اللأوراق ومعدل النمو النسبي للمحصول ومحتوي الماء بالأوراق وطول الكوز ووزن 100 حبة مما أدى الى زيادة محصول الحبوب فى الموسمين. وقد أدت هذه المعاملة الى نقص الحساسية للعطش وكان زيادة الحساسية للعطش مصحوبة بزيادة كفاءة استخدام ماء الرى فى الموسمين. يوصى هذا البحث بزراعة نباتات الذرة على الريشتين (عرض المصطبة 140سم) والمسافة بين النباتات 25 سم (24000 نبات للفدان) والرى عند فقد 65% من الماء الميسر مع تقبل انخفاض فى محصول الحبوب قدره 4,89 % و 6,84 % فى كلا الموسيمين على التوالى مع أقل قدر من الحساسيه للعطش والقابليه للإصابه بالعطش مع توفير ماء الرى بمقدار19,34 و 20,30% وتحسين كفاءة استخدام ماء الرى بمقدار15,42و14,37% مع عدم نقص المحصول ومكوناته معنويا فى الموسمين على التوالى.