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EFFECT OF RIDGE SPACING AND IRRIGATION PATTERNS ON GROWTH, GRAIN YIELD, YIELD COMPONENTS, AND WATER PRODUCTIVITY FOR MAIZE CROP

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ABSTRACT

A Field trial was conducted in Gemmeiza Agricultural Research Station (Middle Nile Delta, Egypt) in 2011and 2012 to study the effect of four irrigation patterns under two ridge spacing on maize growth, grain yield, yield components, saving of applied irrigation water, and water productivity(WP). The assessed irrigation patterns were: 1) Control where all of furrows were irrigated (ALL), 2) irrigating via every other furrow starting at the 3rd irrigation (EOF3), 3) irrigation via every other furrow technique starting from the 4th irrigation (EOF4), and 4) irrigating with every other furrow starting from the 5th irrigation (EOF5). Irrigation patterns were evaluated under two ridge spacing (70 and 80 cm). The experimental design was randomized complete block arranged in incomplete block design, where replications were nested within ridge spacing and irrigation pattern treatments were randomly arranged within ridge spacing treatments.

The most important findings could be as follows:-

*Under 80-cm ridge spacing both days to 50% tasseling and 50% silking were significantly decreased, but 70-cm ridge spacing reduced ear height, and ear position (%).

* Ridge spacing did not significantly affect plant height, grain yield, number of kernels per row, ear length, ear diameter, kernel depth, and 100-kernel weight. However, 80-cm ridge spacing was associated with higher ear length, ear diameter, kernel depth, and 100-kernel weight.

*Irrigation pattern (EOF3) had significantly higher days to 50% tasseling than the control (ALL). Treatment EOF4 had the highest plant height. The lowest plant height was linked to EOF5 treatment but the highest ear height and ear position resulted from application of EOF3.

*Grain yield was not significantly affected by irrigation patterns. Irrigation patterns EOF4 and EOF5 were associated with the lowest number of kernels per row.

* Effect of ridge spacing x irrigation pattern Interaction was significant for plant height, ear height and kernel depth.

*Applied irrigation water decreased, while water productivity increased under 80-cm comparing with 70-cm ridge spacing. The highest value of applied water was recorded for (ALL) irrigation pattern treatment with 70-cm ridge spacing. Application of EOF3, EOF4, and EOF5 patterns reduced applied irrigation water and improved water productivity.

*The highest WP was recorded under the interaction of planting maize crop in 80-cm ridge spacing with EOF3 and EOF4 irrigation patterns. Saving irrigation water was higher at EOF3 followed by EOF4, then EOF5. This study strongly suggest applying every other furrow irrigation technique starting from the 3rd irrigation

(EOF3) with planting maize crop on 80-cm ridge spacing to save more irrigation water without concomitant reduction in grain yield.

Keywords: maize, grain yield, yield components, ridge spacing, every other furrow irrigation, water productivity.

INTRODUCTION

In Egypt, under furrow irrigation, maize crop normaly needs to apply seven to eight or more irrigations throughout the growing season, depending on duration of genotype maturity, location, prevailing weather conditions, and soil texture…….etc. Water losses under surface irrigation is mainly due to deep percolation, particularly in the upper part of the field that comprise not less than 45 %, causing several acute problems i.e. nutrient leaching and raising groundwater, which consequently negatively affected grain yield and reduce fertilizer and water use efficiencies. Therefore, improving performance of the surface irrigation method is must, particularly under limited irrigation water resources. Abdel-Maksoud and Khater (1997) reported that irrigation of every other furrow was linked to reduction in both maize yield by 7.22 % and water applied by 21.1 %, comparable with the traditional furrow irrigation. Furthermore, Mahgoub *et al.* (2009) stated that every other furrow irrigation saved 8.43 and 9.36% of applied irrigation water for maize plants grown on 70 and 80-cm ridges, respectively, comparable with the control. In connection, Shayannejad and Moharrery (2009) stated that every other furrow irrigation reduced the volume of irrigation water and improved water use efficiency. Rafiee and Shakarami (2010) found that fixed every other furrow irrigation decreased irrigated water at the rate of 26.2 % and then yield at the rate of 11% and exhibited the highest water use efficiency for biological and grain yields comparing with control. In connection, Kashiani *et al.* (2011) reported that semi-alternate furrow irrigation was associated with higher fresh weight of sweet corn compared with all furrow irrigation with no significant differences between semi-alternate furrow irrigation and Every Other Furrow irrigation with 30% less water supplied.

The most appropriate spacing is one, which enables the plants to make the best use of the conditions at their disposal (Lawson and Topham 1985 and Malik *et al*. 1993). Reducing row width with a more equidistant planting pattern has the potential to increase maize grain yield especially when highly productive single-cross early hybrids are grown in soils with high fertility and under irrigation (Sangoi *et al*. 1998). In this sense, Farnham (2001) averaged across years, locations, and plant densities, corn grown on 76-cm row spacing produced higher yields than that grown on 38-cm rows. Maqbool et al.(2006) In Pakistan, found that row spacing (75, 65 and 55cm) insignificantly affected maize grain yield. Nevertheless, Paszkiewicz,1998 and Roth, 1997 reported maize yield increases of up to 9.9% by growing maize in rows narrower than 76 cm. In addition, Ahmad (2010) found that narrowing the ridge spacing from 75 to 60 or 45cm increased grain yield by 11-18 and 17- 24%, respectively. On saving irrigation water issue, quicker shading of soil surface during early part of the season results in less water being lost by evaporation (Karlen and Camp, 1985). This is especially important under favorable soil surface moisture conditions because it allows maize plants to maximize photosynthesis and the proportion of water that is used in growth processes rather than evaporated from the soil. Tsegaye et al.(1993) found that a given amount of water produced about a 10% higher yield of grain sorghum when applied as wide spaced furrow irrigation (WSFI) than as Every Furrow Irrigation(EFI). The water use efficiency of plants was found to be 24% higher for WSFI than for EFI and Evaporation from the soil surface was 30 mm greater for EFI than WSFI. In Egypt, EL-Marsafawy *et al. (*1998), found that irrigation with 140 cm apart furrows, compared with 70 cm apart ones, resulted in 8% reduction in evapotranspiration and improved root environment, which increased absorption media and encouraged growth characteristics for maize crop.

The objectives of the present study are to find out the extent to which growth, grain yield, yield components, quantities of applied water and water productivity for maize crop were affected due to applying different irrigation patterns under the every other furrow irrigation scheme along with 70 and 80 cm ridge spacing systems.

MATERIALS AND METHODS

A Field experiment was conducted at Gemmeiza Agricultural Research Station (Middle Nile Delta, Egypt) in 2011 and 2012 to study the effect of different four irrigation patterns under two ridge spacing treatments and their interaction on maize growth, grain yield, yield components, quantity of applied irrigation water and water productivity(WP). Some chemical soil and soil-water characteristics of the experimental site as determined according to klute (1986) and Page *et al*. (1982) are recorded in Tables 1and 2. The assessed irrigation patterns were: 1) irrigating all of furrows (control) 2) irrigating via every other furrow technique starting at the 3^{rd} irrigation 3) irrigation via every other furrow technique starting at 4^{th} irrigation 4) irrigating with every other furrow technique starting at 5^{th} irrigation. These irrigation patterns were evaluated under two ridge spacing (70 and 80 cm). The experimental design was randomized complete block arranged in incomplete block design, where replications were nested within ridge spacing and irrigation pattern treatments were randomly arranged within ridge spacing treatments. Single Cross10 maize hybrid was used and the preceding crop was wheat in both seasons. Planting was done on June 6^{th} and 8^{th} in 2011 and 2012 seasons, respectively. Plot size was 6 ridges with 6.8 m in length for 70-cm ridges spacing with a plot area of 28.6 m^2. Meanwhile, it was 6 ridges with 6.0 m in length for 80-cm ridges spacing giving rise to a plot area of 28.8 m^2. Phosphorus and potassium fertilizers at the rate of 15.5 kg P_2O_5 and 24 kg K_2O fad^{-1}, respectively, were applied during soil preparation. The experimental field was ploughed twice and properly leveled before sowing to ensure uniform application of water.

Nitrogen fertilizer (120 kg N fad^{-1} as urea 46.5% N was split into two equal doses and applied before the first and second irrigations. All plants on the 2nd, 3rd and 4th ridges were harvested and grain yield was adjusted to 15.5 % moisture and expressed in ardab per feddan (ard fed^{-1}). Plants of the fifth ridge were use for sampling, whereas plants of the first and sixth ridges were considered as borders.

Table 1: Some soil chemical properties of the experimental site in 2011 and 2012 seasons.

Soil property	2011 season	2012 season
Available phosphorus, ppm	8.5	7.8
Available potassium, ppm	120	110
Available nitrogen, ppm	45.5	39.5
Organic matter, %	2.37	2.50
pH (1:2.5)	7.0	7.0
Ec, dSm^{-1}	2.2	2.4

Table 2: Some soil – water characteristics of the experimental site

Soil depth (cm)	**Field capacity (%,wt/wt)**	**Wilting Point (%,wt/wt)**	**Bulk density (kgm^{-3})**
	2011 season		
00 - 15	43.20	23.40	1.11
15 - 30	41.00	22.24	1.26
30 - 45	39.60	21.52	1.31
45 - 60	36.00	19.57	1.35
	2012 season		
00 - 15	45.60	24.30	0.82
15 - 30	42.30	22.10	1.20
30 - 45	39.50	21.00	1.31
45 - 60	36.90	18.60	1.38

Growth parameters under study were number of days to 50 % tasseling, number of days to 50 % silking, plant height (cm), ear height (cm), and ear position (%). Plant height and ear height were measured from the ground surface to the base of the tassel and the base of the upper ear, respectively. Ear position was estimated by dividing ear height by plant height and expressed as percentage.

Grain yield was expressed in ardab per feddan (ard fed^{-1}). One ardab = 140 kg grains(15.5% moisture content). One feddan = 4200 m^2. Tested yield components were ear length (cm), ear diameter (cm), kernel depth (cm), number of kernels per row and 100–kernel weight (g) . Data were statistically analyzed according to Steel and Torrie (1980**).**

Crop–water relationships

1. Applied irrigation water

Irrigation water was applied to the experimental unit through 4'' plastic tube and the delivered water was determined according to the following formula:

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

Q = discharge rate (cm^3 sec^{-1}),

C = discharge coefficient of the spile (which was estimated empirically to be 0.61)

g = gravity acceleration (980 cm sec^{-2})

A = spile cross sectional area (cm^2) and

h = effective water head above the spile (cm)

The effective water head above the spile was measured several times during irrigation. Irrigation water was applied to the plot until the propagating wave of in-flowing water reaches the end of the plot. The time required to irrigate the plot was recorded to estimate the amount of water applied.

2. Water Productivity

Water productivity (WP), as kg grains per the cubic meter of applied water was estimated as out lined by Molden *et al.*(2001) as follows:

WP, kg grain yield m^{-3} = grain yield, kg fad^{-1}/applied water, m^3 fad^{-1}.

RESULTS AND DISCUSSION

1. Growth , grain yield and yield components

1.1 Ridge spacing Effect

Results revealed that 80-cm ridge spacing significantly decreased both days to 50% tasseling and 50% silking in the 1st season, but this effect was not significant for days to 50% silking in 2nd season (Table 3). Plant height was not affected by ridge spacing in both years. Ear height, and ear position (%) were not significantly affected by ridge spacing in 2011, but 70 cm ridge spacing reduced ear height, and ear position (%) in the 2nd season. In this respect, Zeidan et al. (2006) stated that row spacing exhibited significant effects on number of days from planting to silking. But the present results are contradicted with Ahmad (2010) who reported that plant height was significantly affected by ridge spacing and was higher under 45 cm ridges spacing than 60 and 75 cm ones. Such differed trends may be attributed to different experimental situations.

Results revealed that the assessed ridge spacing did not significantly affect grain yield and number of kernels per ear row in both years, and ear length, ear diameter, kernel depth, and 100-kernel weight in 2011 (Table 4). In 2012, however, 80-cm ridge spacing was associated with significantly higher ear length, ear diameter, kernel depth, and 100-kernel weight. Such findings are in parallel with those reported by Maqbool et al. (2006) and Ahmad (2010). Farnham (2001) averaged across years, locations, and plant densities, stated that maize grown in 76-cm row spacing produced higher yields than that grown in 38-cm rows (10.5 vs. 10.3 Mg ha^{-1}), respectively . In addition, Tsegaye et al.(1993) reported that a given amount of water produced about a 10% higher yield of grain sorghum when applied as Wide Spaced Furrow Irrigation than as Every Furrow Irrigation

Table 3: Effect of ridge spacing and irrigation pattern on days to 50% tasseling, days to 50% sillking, plant height ,ear height and ear position (%) at Gemmeiza in 2011 and 2012

	Days to 50% tasseling	Days to 50% sillking	Plant height (cm)	Ear height (cm)	Ear position (%)
	2011				
Ridge spacing:					
70 cm	62.5 a	63.5 a	288 a	177 a	61.4 a
80 cm	61.9 b	62.8 b	286 a	174 a	60.8 a
Irrigation pattern:					
ALL	62.1 b	63.0 a	283 b	170 a	60.1 a
EOF3	62.6 a	63.4 a	284 b	175 a	61.5 a
EOF4	62.3 ab	63.4 a	291 a	180 a	61.7 a
EOF5	61.9 b	62.9 a	289 ab	177 a	61.2 a
CV%	0.8	0.9	2.0	4.1	4.0
	2012				
Ridge spacing					
70 cm	60.9 a	61.8 a	220 a	122 b	55.3 b
80 cm	60.4 b	61.5 a	222 a	134 a	60.4 a
Irrigation pattern:					
ALL	60.6 a	61.8 ab	221 a	123 b	55.5 b
EOF3	60.9 a	61.9 a	225 a	134 a	59.5 a
EOF4	60.6 a	61.5 b	227 a	130 ab	57.4 ab
EOF5	60.5 a	61.5 b	211 b	125 b	59.1 a
CV%	0.7	0.5	4.2	6.2	4.4

† Vertical means with the same letter(s) are not significantly different at 0.05 level.
*** ALL, EOF3, EOF4 and EOF5 are referred to irrigation all of furrows (control, irrigating via every other furrow technique starting from the 3rd, 4th and 5th irrigation, respectively.**

On the other hand, Alford et al. (2004); Maqbool *et al.* (2006) and Strieder et al.(2008) found that maize grain yield insignificantly affected due to row spacing. Moreover, Widdicombe and Thelen, 2002; Fanadzo et al. (2010) and Ahmad (2010) found a different trend where narrower ridge spacing out yielded the wider one. Ahmad (2010) found that number of grains per row, cob length and grain weight/ear were significantly affected by ridge spacing. In connection, Maqbool et al. (2006) reported that grain weight/cob was not affected due to 55, 65 and 75cm row spacing.

1.2 Irrigation pattern Effect

Irrigation pattern significantly affected days to 50% tasseling and plant height in 2011, days to 50% silking, plant height, ear height, and ear position in 2012 (Table 3). Irrigation pattern (EOF3) had significantly higher days to 50% tasseling than the control (ALL) with no significant difference between EOF3 and EOF4 in 2011.

Treatment EOF4 had the highest plant height in 2011 season. In 2012, EOF3 had significantly higher days to 50% silking compared with EOF4 and EOF5 but the difference between EOF3 and ALL was not significant. The lowest plant height was linked to EOF5 treatment but the highest ear height and ear position resulted from application of EOF3 compared with the control (ALL) in 2012.

Table 4: Effect of ridge spacing and irrigation patterns on grain yield, ear length, ear diameter, kernel depth, kernels № per row, and 100– kernel weight at Gemmeiza in 2011 and 2012

Treatment	Grain yield (ard fed^{-1})	Ear length (cm)	Ear diameter (cm)	Kernel depth (cm)	Kernels No per row	100– kernel weight (g)
	2011 season					
Ridge spacing:						
70 cm	36.6 a	21.0 a	4.8 a	0.91 a	45.7 a	44.6 a
80 cm	37.8 a	21.0 a	4.8 a	0.91 a	46.0 a	44.9 a
Irrigation pattern*						
ALL	37.8 a	21.0 a	4.73 a	0.93 a	46.9 a	44.9 a
EOF3	34.5 a	21.0 a	4.84 a	0.93 a	45.8 ab	44.8 a
EOF4	38.1 a	21.1 a	4.78 a	0.89 a	45.0 b	44.6 a
EOF5	38.1 a	20.9 a	4.75 a	0.90 a	45.6 b	44.8 a
CV%	8.0	1.1	5.1	14.8	2.6	1.1
	2012 season					
Ridge spacing						
70 cm	31.2 a	20.4 b	4.44 b	1.05 b	44.1 a	40.8 b
80 cm	31.5 a	21.7 a	4.90 a	1.22 a	43.1 a	43.2 a
Irrigation pattern*						
ALL	31.5 a	21.3 a	4.75 a	1.13 a	44.9 a	42.3 a
EOF3	29.7 a	21.4 a	4.63 a	1.15 a	42.4 a	42.0 a
EOF4	31.5 a	20.8 a	4.60 a	1.10 a	41.7 a	40.8 a
EOF5	31.8 a	20.8 a	4.70 a	1.16 a	45.5 a	42.9 a
CV%	7.3	4.2	4.4	10.8	13.2	5.4

† Vertical means with the same letter(s) are not significantly different at 0.05 level.
*** ALL, EOF3, EOF4 and EOF5 are referred to irrigation all of furrows (control, irrigating via every other furrow technique starting from the 3rd, 4th and 5th irrigation, respectively.**

Grain yield was not significantly affected by irrigation patterns in the 1st and 2nd seasons (Table 4). In this sense, Rafiee and Shakarami (2010) found that fixed every other furrow irrigation decreased maize grain yield by 11%. Such differed trends may be attributed to different experimental conditions such as timing of treatment application, soil type, maize hybrid, etc. Results in Table 4 revealed that the yield components under study were not significantly influenced by the adopted irrigation patterns, except for kernels per row in 2011. Irrigation patterns EOF4 and EOF5 were associated with the lowest number of kernels per row in 2011.

1.3 Interaction Effect

Effect of ridge spacing x irrigation pattern Interaction on ear height was significant in 2011 (Table 5). But this interaction effect was not significant for all other tested traits in 2011 season. In contrast, the effect of ridge spacing x irrigation pattern interaction was significant for plant height, ear height, and kernel depth in 2012. All other studied traits were not affected by ridge spacing x irrigation pattern Interaction in 2012.

The highest plant height was associated with application of EOF4 under 70-cm ridge spacing, while the lowest plant height was recorded for EOF5 and ALL in 2012. Under 80-cm ridge spacing, irrigation patterns of EOF3, EOF4, and EOF5 had significantly shorter plant height compared with the control (ALL) in 2012 season. The lowest ear height was achieved when maize plants were planted in 70-cm ridge spacing and irrigation pattern (ALL) was followed, and when maize is planted in 80-cm ridge spacing and EOF3 was followed in 2011. In 2012, the lowest ear height was associated with planting in 70-cm ridge spacing when ALL pattern was followed. The longest kernel depth was recorded for maize planting in 80-cm ridge spacing and either EOF4 or EOF3 irrigation regimes were followed in 2012 (Table 5).

Table 5. Effect of ridge spacing (RS) x irrigation pattern (IP) Interaction on plant height, ear height, and kernel depth in 2011 and 2012 seasons.

Treatments		Plant height (cm)		Ear height (cm)		Kernel depth (cm)	
RS	IP	2011	2012	2011	2012	2011	2012
70 cm	ALL	284	209	169	109	0.93	1.08
	EOF3	288	229	183	133	0.89	1.08
	EOF4	290	235	178	127	0.95	0.90
	EOF5	290	206	178	118	0.88	1.15
Mean		288	220	177	122	0.91	1.05
80 cm	ALL	282	234	172	138	0.93	1.18
	EOF3	281	222	167	135	0.98	1.23
	EOF4	292	219	182	133	0.83	1.30
	EOF5	288	215	175	131	0.93	1.18
Mean		286	223	174	134	0.92	1.22
$LSD_{0.05}$ for RS x IP		NS	7	5	6	NS	0.09

2. Crop–water relationships

2.1 Applied water

2.1.1 Ridge spacing effect

Results in Table 6 indicate that, regardless of irrigation patterns, applied water decreased under 80 cm ridge spacing by 7.56 and 7.37 %, compared with 70 cm one in 1st and 2nd seasons, respectively. In connection, Abd El-Halim and Abd El-Razek (2013) stated that, regardless of irrigation intervals, smaller depth of applied water for maize crop was observed with double ridge-furrow planting technique (140cm width) compared to conventional ridged-furrow planting one (70cm width). Moreover, Barbieri et al. (2012) stated that narrow rows consistently increased (8%) maize crop ET during the initial stages of growth, however, seasonal crop ET was not influenced due to row spacing .

2.1.2 Irrigation pattern effect

Regardless ridge spacing, applied irrigation water was reduced under every other furrow irrigation schemes compared with the control (ALL). Application of EOF3, EOF4, and EOF5 irrigation patterns reduced the applied irrigation water by 16.59, 12.46 and 8.22 % in 2011 season and by 16.05, 11.39 and 6.48 % in 2012 season, respectively (Table 6). Several literatures had been cited and confirmed the potency of the other – row irrigation system in reducing the applied irrigation water for maize crop (Abdel-Maksoud and Khater, 1997; Shayannejad and Moharrery, 2009, Mahgoub *et al.* 2009 and Rafiee and Shakarami, 2010; Kashiani *et al.* 2011).

2.1.3 Interaction Effect

Interaction effect of ridge spacing × irrigation pattern revealed that the highest value of applied water was recorded for 70-cm ridge spacing with (ALL) irrigation pattern (control), whereas the lowest value resulted from EOF3 irrigation pattern with 80-cm ridge spacing (Table 6). Such trend was true in 1st and 2nd seasons.

Table 6: Applied water at each irrigation event and seasonal (m^3 fad^{-1}) under 70 and 80-cm ridge spacing and different irrigation patterns in 2011 and 2012

Ridge spacing	70 cm				80 cm			
Irrigation pattern*	ALL	EOF3	EOF4	EOF5	ALL	EOF3	EOF4	EOF5
	2011 season							
Planting	588.8	5888	588.8	588.8	556.9	556.9	556.9	556.9
The first	436.0	436.0	436.0	436.0	385.6	385.6	385.6	385.6
The second	372.1	372.1	372.1	372.1	351.5	351.5	351.5	351.5
The third	346.5	230.2	346.5	346.5	317.9	231.0	317.9	317.9
The fourth	436.0	302.8	290.2	436.0	417.1	270.5	266.3	417.1
The fifth	455.3	330.1	320.0	275.9	441.0	298.6	320.0	281.0
The sixth	346.9	280.1	290.6	286.9	336.8	198.2	226.8	260.0
Total, seasonal	2981.6	2540.1	2644.2	2742.2	2806.8	2292.3	2425.0	2570.0
Saving, m^3fad^{-1}		441.5	337.4	239.4		514.5	381.8	236.8
Saving, %	-	14.81	11.32	8.03	-	18.33	13.60	8.44
	2012 season							
Planting	560.3	560.3	560.3	560.3	541.0	541.0	541.0	541.0
The first	410.8	410.8	410.8	410.8	365.4	365.4	365.4	365.4
The second	365.4	365.4	365.4	365.4	340.2	340.2	340.2	340.2
The third	331.0	225.1	336.0	335.6	301.6	221.3	299.9	302.8
The fourth	401.9	298.6	285.6	420.0	402.8	261.2	254.9	399.0
The fifth	436.0	318.8	301.6	266.7	430.1	320.0	301.9	275.1
The sixth	336.0	275.1	285.2	276.8	325.9	191.1	202.4	252.0
Total, seasonal	2728.4	2341.1	2431.9	2522.6	2617.0	2202.4	2305.7	2475.5
Saving, m^3fad^{-1}	-	443.3	296. 5	205.8	-	414.6	311.3	141.5
Saving, %	-	16.25	10.87	7.54	-	15.84	11.90	5.41

*** ALL , EOF3, EOF4 and EOF5 are referred to irrigation all of furrows (control) , irrigating via every other furrow technique starting at the 3rd, 4th and 5th irrigation, respectively.**

2.2 Water productivity (WP)

2.2.1 Ridge spacing effect

Water productivity is an efficiency term quantified as a ratio of product output (goods and services) over water input. The output could be biological goods such as crop grain, fodder….etc. Data in Table 7 indicated that, regardless the adopted irrigation patterns, water productivity for maize crop, was increased under 80cm spacing by 11.70 and 10.24% in comparison with 70cm one, respectively, in 1st and 2nd seasons. In this respect, Tsegaye *et al*. (1993) found that WUE of sorghum plants was found to be 24% higher for Wide Spacing Furrow Irrigation than for Every Furrow Irrigation. In addition, Jones (2007) reported that Twin-row spacing as an alternative planting practice for corn silage production in the Shenandoah

Valley leads to greater corn silage yields through greater water use efficiency and faster canopy development. On the contrary, Barbieri *et al.*(2012) found that reduced row spacing increased water use efficiency for maize grain production up to 17%.

Table 7: Applied water and water productivity for maize as affected by ridge spacing and Irrigation pattern at Gemmeiza in 2011 and 2012 seasons

Treatment		Grain yield (ard fad^{-1})	Applied Water ($m^3 fad^{-1}$)	Water Productivity (kg m^{-3})	Grain yield (ard fad^{-1})	Applied Water ($m^3 fad^{-1}$)	Water Productivity (kg m^{-3})
		2011 season			2012 season		
Ridge spacing:							
70 cm		36.6	2727.3	1.88	31.1	2615.1	1.66
80 cm		37.8	2521.2	2.10	31.6	2422.3	1.83
Irrigation pattern*							
ALL (Control)		37.8	2894.0	1.83	31.5	2767.0	1.59
EOF3		34.5	2416.3	2.00	29.6	2328.1	1.79
EOF4		38.1	2530.5	2.10	31.7	2424.7	1.82
EOF5		38.1	2656.1	2.01	32.7	2555.1	1.79
Interaction							
70 cm	ALL	36.8	2981.6	1.73	31.5	2827.4	1.56
	EOF3	33.1	2540.6	1.83	29.5	2454.1	1.68
	EOF4	38.3	2644.7	2.03	30.4	2543.9	1.67
	EOF5	38.0	2742.2	1.94	33.1	2635.1	1.76
80 cm	ALL	38.7	2806.4	1.93	31.5	2706.5	1.63
	EOF3	36.1	2291.9	2.21	29.7	2202.1	1.89
	EOF4	38.0	2416.3	2.19	32.9	2305.4	2.00
	EOF5	38.2	2570.0	2.08	32.2	2475.1	1.82

*** ALL, EOF3, EOF4 and EOF5 are referred to irrigation all of furrows (control), irrigating via every other furrow technique starting at 3rd, 4th and 5th irrigation, respectively**

2.2.2 Irrigation pattern effect

Applied irrigation water was efficiently utilized where EOF irrigation patterns were applied, compared with the control (Table 7). Application of irrigation patterns EOF3, EOF4, and EOF5 improved water productivity (WP) by 9.29, 14.75 and 9.84% in the 1st season and 12.58, 14.47, 12.58 % in 2nd season compared with the control (ALL), respectively. Results of the 2nd year followed similar pattern to the first year, which confirmed the potency of EOF technique in improving WP. The role of EOF irrigation scheme in enhancing water use efficiency for maize crop was previously reported by Shayannejad and Moharrery (2009) and Rafiee and Shakarami (2010). In connection, Kang et al. (2000a and 2000b) stated that controlled alternate partial root-zone irrigation (part of the root system being exposed to drying soil while the remaining part being irrigated normally) are also ways to increase WUE of maize.

2.2.3 Interaction Effect

The interaction data in Table 7 indicated that higher WP figures were recorded under EOF3 and EOF4 irrigation patterns as interacted with 80cm ridge spacing and such findings were true in 1st and 2nd seasons.

On conclusion, as well known that under limited irrigation water resources, it's recommended to point out how much water, based on either consumed or applied, required to produce the unity of final crop yield which is defined as water productivity. On this basis and according to data in Table 7, it is advisable to cultivate maize crop on 80cm ridge space and irrigating according to EOF3 or EOF4 irrigation regimes where such interactions exhibited acceptable values of water saving, WP and grain yield under the experimental circumstances. Further researches are needed to confirm the achieved results.

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تأثير المسافة بين الخطوط ونماذج الري على نمو ومحصول الحبوب ومكونات المحصول وإنتاجية مياة الري لمحصول الذرة الشامية

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أقيمت تجربة حقلية في محطة بحوث الجميزة (وسط دلتا النيل، مصر) في ٢٠١١ و ٢٠١٢ لدراسة تأثير أربعة نماذج ري تحت مسافتين بين الخطوط على نمو ومحصول الحبوب ومكونات المحصول وتوفير ماء الري وإنتاجية الماء. كانت نماذج الري المختبرة: ١- المقارنة وتم فيها ري كل الخطوط (كل الخطوط)، ٢- الري من خلال أسلوب ري خط وترك خط ابتداء من الربة الثالثة (ري خط وترك خط (٣) ، ٣- الري من خلال أسلوب ري خط وترك خط ابتداء من الربة الرابعة (ري خط وترك خط (٤)) ، ٤- الري من خلال أسلوب ري خط وترك خط ابتداء من الرية الخامسة (ري خط وترك خط (٥)) . تم تقييم نماذج الري تحت مسافتين بين الخطوط (٧٠ و ٨٠ سم). كان تصميم التجربة قطاعات كاملة العشوائية مرتبة في قطاعات غير كاملة حيث رتبت المكررات داخل معاملات المسافة بين الخطوط كما تم توزيع نماذج الري عشوائيا داخل معاملات المسافة بين الخطوط.

- اظهرت النتائج أن ٨٠سم بين الخطوط أدت الي نقص عدد الأيام حتي ٥٠% لقاح و ٥٠% حريرة ، لكن ٧٠سم بين الخطوط أدت الي نقص في ارتفاع الكوز و وضع الكوز %.
- لم تؤثر المسافة بين الخطوط معنويا علي ارتفاع الكوز و محصول الحبوب و عدد الحبوب بالصف و طول و قطر الكوز و عمق الحبة و وزن ال ١٠٠ حبة ، بالرغم من ذلك فان ٨٠سم بين الخطوط أظهر زيادة في عمق الحبة و وزن ال١٠٠ حبة و عدد الحبوب في السطر مقارنة مع ٧٠سم بين الخطوط .
- أدت معاملة ري خط وترك خط ٣ إلى زيادة معنوية في عدد الأيام حتى ٥٠ % لقاح عن المقارنة (كل الخطوط). أدت المعاملة ري خط وترك خط (٤) إلى الحصول على أعلى إرتفاع نبات. أقترن ري خط وترك خط (٥) مع أقل إرتفاع للنبات بينما نتج أعلى إرتفاع كوز ووضع الكوز من تطبيق ري خط وترك خط (٣).
- لم تؤثر نماذج الري معنويا على محصول الحبوب. إرتبطت نماذج الري ري خط وترك خط (٤) و ري خط وترك خط (٥) مع أقل عدد للحبوب في السطر.
- تفاعل المسافة بين الخطوط و نماذج الري المختبرة معنويا لارتفاع النبات و ارتفاع الكوز و عمق الحبة .
- نقصت كمية مياه الري المضافة بينما زادت إنتاجية مياه الري مع ٨٠سم بين الخطوط مقارنة مع ٧٠سم بين الخطوط. كانت أعلي مياه مضافة مع نموذج ري كل الخطوط مع الزراعة علي

٧٠سم بين الخطوط.

- أعلي إنتاجية لمياه الري كانت مع نموذجي ري الخط الآخر ٣ و ٤.
- كان التوفير في مياه الري مع نموذج ري الخط الآخر ٣ يلية ٤ ثم ٥، وتقترح الدراسة بإتباع نموذج ري الخط الآخر ابتدءا من الرية الثالثة مع زراعة ألاذرة الشامية علي خطوط المسافة بينها ٨٠ سم نظرا لتوفير مياة الري دون نقص في محصول الحبوب.

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