Alex.J.Agric.Res Vol.54,No.3,pp.17-27,2009

Effect of Row Orientation, Row Spacing and Plant Population Density on Grain Yield and Other Agronomic Traits in Maize (*Zea mays L.*)

El-Mekser, Hoda Kh. A.; H. E. Mosa; Maha, G. Balbaa and M.A.M. El-Ghonemy

Maize Res. Dept., Field Crops Res. Inst., ARC, Giza, Egypt

Received on : 4/6/2009 ***Accepted : 2/8/2009***

ABSTRACT

The present investigation was conducted at three locations, i.e., Sakha, Gemmeiza and Nubaria Agric. Res. Stns., Field Crops Res. Inst., Agric. Res. Center, during the two growing seasons of 2007 and 2008 to study the effect of rows orientation, rows spacing and plant density on maize growth and yield. Single cross hybrid (SC 10) was used in this study. Two field trials were conducted at each location, one for row orientation of East-West (E-W), and the other for North-South (N-S). Number of treatments in each trial was nine treatments which were the combinations of: 1. Three row spaces; i.e., 60, 70 and 80 cm, and 2. Three plant population densities; i.e., 20,000, 25,000 and 30,000 plants fad^{-1}. Each row orientation treatment was planted in a separate experiment, arranged according to a split-plot design, with four replications, where row spacing was arranged in the main plots, while, plant population density treatments was arranged in the sub- plots. Combined analysis was performed among row orientation experiments, where replications were nested within row orientation for each year. The previous crop was wheat for all trials. Soil type was clay loam at Sakha and Gemmeiza, whereas, it was calcarious at Nubaria. Results indicated that planting maize on rows oriented from East to West (E-W) led to a significant reduction in number of days from planting to 50% tasseling and silking, at Gemmeiza and Nubaria in 2007 season, and at Nubaria in 2008 season. This treatment led, also, to a significant increase in plant and ear height at all locations in the two years, except for Sakha in 2008 season, for plant height, and Gemmeiza in 2007 for ear height. The same treatment significantly increased grain yield at all locations in the two years, except at Sakha and Gemmeiza in the second season. Planting maize on rows, spaced 80 cm, significantly reduced the number of days from planting to 50% tasseling and silking at both locations in 2007 and 2008 growing seasons. Maize plants became tall with high ear placement when planted on rows spaced of 80 cm. Planting maize on 80 cm rows led to a significant increase in plant and ear height, as well as grain yield per plant and per faddan, compared with 60 and 70 cm row-spacing's. The effect of plant population density on plant height differed with locations and seasons (environments). Increasing plant population density up to 30,000 plants fad^{-1} led to a significant reduction in plant height at Gemmeiza, while, increasing plant population density up to 30,000 plants, at Nubaria, resulted in a significant increase in plant height in both growing seasons. For ear height, the effect of plant population density was significant only at Nubaria in 2007 growing season, while, it was significant at all locations in 2008 growing season. Increasing plant population density was associated with a significant reduction in grain yield per plant at all locations in both growing seasons. Grain yield (in ardab per faddan) significantly increased as plant population density increased up to 30,000 plants fad^{-1}

Key words: maize, rour orientationt, plant density, location

INTRODUCTION

Corn producers continually search for new practical procedures to increase productivity and to reduce production costs. Plant density, distribution and row orientation (direction) may play an important role on maize growth and grain yield. It is well known that good distribution of maize plants permits canopy to intercept more light energy and, hence, increases vegetative growth and grain yield. On the other hand, controlling plant population density can be achieved through controlling hill spacing, row width and row direction. Also, controlling inter- and intra-plant competitions would help maize plants to intercept more light, absorb more water and improve nutrient uptake from soil. At low population density, grain yield is limited by number of plants per unit area.

Concerning row direction (orientation), Robinson (1975) and Seif *et al* (1988), in grain sorghum, showed that north-south row direction recorded a significant higher seed index, grain weight $head^{-1}$, grain yield $plant^{-1}$ and stover yield, as compared with east-west row direction. Talentino (1982) reported that row direction significantly influenced the interception and transmission of solar radiation through the plant canopy. They, also, found that the daily intercepted solar radiation was higher at north-south row direction at 53 days after sowing. El-Murshedy (1991) reported no advantages in grain yield due to sowing maize on east-west or north-south rows direction. However, north-south direction outyielded east-west direction in stover yield. On the contrary, Abdrabou (1996) found that maize plants, grown from east-west direction, significantly increased grain yield $faddan^{-1}$ than those grown from north-south. Ismail (1997) found that north-south row direction recorded a significant higher plant height, grain and stover yields faddan^{-1}, compared to east-west row direction. Abd El-Maksoud (2008) showed that row direction at east-west was superior to the other row direction of north-south for plant height and grain yield faddan^{-1}.

Concerning plant populations and row spacing, Fulton (1970) reported that, under the conditions of adequate soil moisture, higher plant densities (54,362 plants ha^{-1}) produced higher yields than the lower densities (39,536 plants ha^{-1}). On the other hand, rows, spaced 50 cm, produced higher grain yield than rows spaced 100 cm apart. In addition, he reported that density x row spacing interaction was significant in one out of four experimental years, indicating that the effect of narrow row spacing was greater at high plant densities than low plant densities. Lutz *et al* (1971) obtained a 5% yield increase for 76 cm row spacing, compared to 102-cm row spacing and an additional 2.7% yield advantaged for 38-cm row spacing. Beech and Basinski (1975) investigate the effect of three row spacings (50 cm, 75 cm and 100 cm) and three plant populations (44,500, 59,300 and 89,000 plants ha^{-1}) on two maize cultivars (short, early XL 45 and tall, late Q 692). They found that none of the crop measurements were significantly affected by row spacing. Tasselling, sliking and maturity occurred 10, 12 and 16 days later in Q 692 than in XL 45, respectively. Their time of occurrence was not affected by plant density. Grain yield of XL 45 significantly increased, when plant density increased up to 59,300 plants ha^{-1} but, leveled off. On the other hand, grain yield of Q 692 significantly fell with each population increase. Choudhary (1981) found that a maize population of 61,700 plants ha^{-1} was associated with higher grain yield than the conventional 36,000 plants ha^{-1}. There was no difference in yields with inter-row spacings of 45, 60 and 90 cm, regardless of population levels. Cardwell (1982) obtained a significant yield increase by 175 kg ha^{-1} due to decreasing row spacing from 107 to 90 cm. In addition, Bullock *et al* (1988), Nielsen (1988) and Widdicombe and Thelen (2002) found that grain yield significantly increased with reducing row spacing from 76 to 38 cm.

Teasdale (1995) mentioned that maize, grown at a constant plant density, intercepted a higher proportion of incident radiation in narrow rows, because of an increase in leaf area index (LAI) and in the efficiency of light interception per unit of leaf area. Liu *et al* (2004) reported that the uniformity of plant distribution within the row, along with plant density and row spacing, played an important role in corn production. In this regard, Duncan (1984) and Farnham (2001) proposed a theoretical basis for plant competition effects on grain yield of maize.

Intra-spacing and competition for water, as well as light and nutrients, determine optimum plant densities for each environmental factor. Tetio-Kagho and Gardnar (1988) and Khalil *et al* (1999) demonstrated that planting maize in equidistance distribution increased the efficiency of light utilization and, hence, encouraged the accumulation and translocation of metabolites to the developing plant organs. Ragheb *et al* (1993) found that planting maize at the rate of 24000 plants fad^{-1} (60 x 30 or 70 x 25 cm) produced the highest grain yield. In this respect, Sarhan (1994) reported that the highest grain yield faddan^{-1} was recorded by planting arrangement of 75 x 30 cm. Abdel-Aal *et al* (1997) found that growing maize plants in 40 x 60 cm system gave the highest grain yield plant^{-1}. In contrast, the highest significant value for grain yield faddan^{-1} was achieved by planting maize plants in quadratic distribution of 40 x 40 system, compared to the other systems, 60 x 40 and 60 x 30. El-Murshedy and Abuldahab (2002) reported that increasing hill spacing from 20 to 30 cm, with row width 70 cm, increased yield component of maize yield, but grain yield faddan^{-1} was decreased. Oraby and Sarhan 2002, Oraby *et al* 2003a and Oraby *et al* 2005b found that maize varieties differed in their yield potential, depending on their genetic makeup and its interaction with the environmental conditions.

The main objectives of this study was to investigate the effect of two row orientations; *i.e.*, East-west (E-W) and North-South (N-S), three row spacings (60, 70 and 80 cm) and three plant densities (20,000, 25,000 and 30,000 plants fad^{-1}) on grain yield and other agronomic traits of maize.

MATERIALS AND METHODS

A field experiment was conducted at Sakha, Nubaria and Gemmeiza Res. Stns., Field Crops Res. Inst., ARC, Egypt, in 2007 and 2008 growing seasons to study the effect of row orientation (direction), row spacing and plant population density on maize grain yield and other agronomic traits.

Experimental treatments:

I. Rows orientations (D):

1. East to West (E-W).
2. North to South (N-S).

II. Three row spacings, *i.e.*, 60, 70 and 80 cm

III. Three plant population densities; *i.e.*, 20,000, 25,000 and 30,000 plants fad^{-1}.

For row width 60 cm, equivalent distance among hills (35 cm, 28 cm 23 cm), for row width 70 cm(30 cm, 25 cm 20 cm), and for row width 80 cm(26 cm, 21 cm 17.5 cm).

Two field trials were conducted at each location, one for row orientation of East-West (E-W), and the other for North-South (N-S). Number of treatments in each trial was nine treatments which were the combinations of: 1. Three row spaces; i.e., 60, 70 and 80 cm; and 2. Three plant population densities; i.e., 20,000, 25,000 and 30,000 plants fad^{-1}. Each row orientation treatment was planted in a separate experiment, arranged according to a split-plot design, with four replications, where row spacing was arranged in the main plots, while, plant population density was arranged in sub-plots. Combined analysis was performed among row orientation experiments, where replications were nested within row orientation for each year.

Soil type was clay loam at Sakha and Gemmeiza, whereas, it was calcarious at Nubaria. The previous crop was wheat at each location in both growing seasons. Recommended doses of super- phosphate and potassium fertilizers (30 kg P_2O_5 and 24 kg K_2O fad^{-1}) were applied for all plots during land preparation, whereas, nitrogen fertilizer (as urea) was applied at the rate of 120 kg N fad^{-1}, as side dressing in two equal doses. Each plot consists of four rows, the distances among hills were 35, 28 and 23 cm for 60 cm row spacing; 30, 25 and 20 cm for 70 cm and 26, 21 and 17.5 cm for 80 cm, which were equivalent to plant density of 20000, 25000 and 30000 plant $faddan^{-1}$, respectively. Two to three maize grains $hill^{-1}$ of SC 10 hybrid were planted in the normal seasons and thinned to one plant $hill^{-1}$ after 18-21 days from planting. The two outer rows were left as a border, while, the middle two rows were assigned to determine grain yield and other studied traits.

Recorded data:

1. Number of days to 50% tasseling and silking.
2. Plant and ear height (cm): It was measured from the ground surface to the end node of the tassel and the highest ear-bearing node, respectively.
3. Grain yield (in ardab fad^{-1}): Ears of the two inner rows were harvested at recommended harvest date (110 days after planting) at each location. Ears were weighed and a random sample of 5 kg was taken from each plot to measure shelling percentage and moisture content in grains. Grain yield was adjusted to 15.5% moisture content. to

Recorded data were statistically analyzed, according Steel and Torrie (1980)

RESULTS AND DISCUSSION

A. Row orientation:

Number of days to 50% tasseling and silking were significantly affected by row orientation (direction). Planting maize on rows, directed from east to west (E-W), led to a significant reduction in number of days from planting to 50% tasseling, at Gemmeiza and Nubaria in 2007 growing season, and Nubaria in 2008 growing season (Table 1). Also, row orientation of east-west was linked with a significant reduction in number of days to 50% silking, at Gemmeiza and Nubaria in 2007 growing season, and at Gemmeiza and Nubaria in 2008 growing season.

Data in Table 1 revealed that planting maize on rows directed from east to west (E-W), was associated with a significant increase in plant height and grain yield per plant, as well as per faddan at all locations, in 2007, and at Nubaria in 2008 growing seasons. This might indicate that east-west direction (E-W) allowed more lights to penetrate maize canopy than north-south (N-S). Moreover, e-w direction permitted plants to capture more light energy and got better plant growth, compared with N-S direction. The same trend was observed for ear height. East-west row direction had a significant effect on ear height at all locations in the two growing seasons, except for Gemmeiza in 2007 growing season. Ear height significantly increased by planting maize on row directed from east-to-west.

It is worth noting that planting maize in E-W rows direction led to a significant increase in grain yield (in Ardab $faddan^{-1}$) at all locations, in 2007, and at Nubaria in 2008 growing seasons (Table 1). This was clear, since the E-W rows direction allowed more light to penetrate through plant canopy which resulted in a better growth and was coupled with higher grain yield per unit area. These results are in agreement with those obtained by El-Murshedy (1991), Abdrabou (1996), Mahgoub and El-Shenawy (2006) and Abd El-Maksoud (2008) who found that planting maize on rows directed E-W, led to a significant increase in plant growth and, hence, increased grain yield, compared with N-S row direction.

B. Row spacing:

The effect of row spacing on flowering dates, plant and ear heights, as well as grain yield at Sakha, Gemmeiza and Nubaria, in 2007 and 2008 growing seasons, are presented in Table 2. Planting maize on rows, spaced at 80 cm, significantly reduced the number of days from planting to 50% tasseling and silking at all locations in 2007 and 2008 growing seasons, except for tasseling date at Gemmeiza in 2008 growing season. Both plant and ear heights were significantly affected by row spacing.

Maize plants became taller with higher ear placement when planted on rows spaced of 80 cm. This was true since the wider rows (80 cm) brought about improving light interception through plant canopies, which, in turn enhanced maize growth through inducing flowering and increasing number and/or length of the internodes.

Data in Table 2 showed clearly that row spacing had a significant effect on grain yield per plant and per faddan at all locations in the two gr seasons, except for grain yield at Sakha in 2008 season. Planting maize on 80-cm rows was associated with increasing grain yield per plant, as well as per faddan, compared with 60 and 70 cm row spacings. These results clearly indicated that 80-cm row spacing improved light penetration

Table1:Effect of row orientation on flowering date, grain yield and other agronomic traits at Sakha (SK), Gemmeiza (Gm) and Nubaria (Nub) in 2007 and 2008 growing seasons

Row direction (cm)	2007 growing season			2008 growing season		
	SK	Gm	Nub	SK	Gm	Nub
			Days to 50% tasseling			
East-West	64.9	63.4	61.6	60.4	60.4	61.9
North-South	64.8	64.4	64.8	61.1	60.2	64.5
LSD (0.05)	NS	0.9	0.4	NS	NS	0.9
			Days to 50% silking			
East-West	65.2	63.4	63.4	60.8	61.3	63.7
North-South	65.1	64.3	66.8	61.2	60.9	66.6
LSD (0.05)	NS	0.9	0.5	NS	0.3	0.7
			Plant height (cm)			
East-West	285	276	271	339	277	256
North-South	273	265	237	335	261	233
LSD (0.05)	14.3	5.3	2.4	NS	10.4	4.9
			Ear height (cm)			
East-West	163	153	159	199	156	146
North-South	158	151	131	193	144	128
LSD (0.05)	5.7	Ns	4.2	5.7	8.7	3.6
			Grain yield plant^{-1} (g)			
East-West	177	164	215	204	167	202
North-South	169	151	188	188	156	175
LSD 0.05	8.3	5.4	8.5	NS	NS	7.7
			Grain yield (ard fad^{-1})			
East-West	29.89	28.12	36.25	31.16	28.58	32.71
North-South	28.36	25.27	31.42	29.11	26.42	28.23
LSD (0.05)	1.50	1.15	1.42	NS	NS	1.88

within plant canopies, which, in turn, reduced the competition among plants and, hence, enhanced maize growth. These results were in agreement with those reported by Fulton (1970) and Lutz *et al* (1971). However, contradicted results were obtained by Brown *et al* (1970), Nielsen (1988) and Younis *et al* (1989). They reported that row spacing had little or no effects on grain yield per unit area.

C. Plant population density:

Effect of plant population density on grain yield and other agronomic traits at sakha, Gemmeiza and Nubaria Res. Stns., in 2007 and 2008 growing seasons, are presented in Table 3. It is worth noting that plant density of 20,000 plants fad^{-1} significantly reduced number of days to 50% tasseling at Gemmeiza and Nubaria, in 2007 growing season, and at Sakha and Nubaria in 2008 growing season. However, increasing plant population density did not significantly affect number of days to 50% tasseling at Sakha and Gemmeiza in 2007 and 2008 growing seasons, respectively. On the other hand, planting maize by the rate of 20,000 plants fad^{-1} was associated with a significant reduction in number of days from planting to 50% silking at all locations, in 2007 season, and at Sakha and Nubaria in 2008 season. Soliman *et al* (2005) reported that increasing plant density delayed pollen shedding and silk appearance due to competition within the adjacent plants and, hence, reduced plant growth. Several investigators found similar results (Jollife *et al*, 1990, Ragheb *et al*, 1993, and Soliman *et al*, 2005). They reported that increasing plant population density increased number of days to 50% tasseling and silking.

Concerning plant height, data in Table 3 revealed clearly that plant population density had a significant effect on plant height at all locations in the two growing seasons, except for the experiments at Sakha in both growing seasons. The effect of plant population density on plant height differed among locations (environments) in both growing seasons. At Gemmeiza, increasing plant population density up to 30,000 plants fad^{-1} led to a little, but a significant reduction in plant height. On the other hand, increasing plant population density up to 30,000 plants, at Nubaria, resulted in a significant increase in plant height in both growing seasons. For ear height (Table 3), the effect of plant population density was significant at Nubaria in 2007 growing season, while, it was significant at all locations in 2008 growing season.

Increasing plant population density was associated with a significant reduction in grain yield per plant at all locations in both growing seasons. The rate of decrease in grain yield per plant (5.5% at

Table 2: Effect of row spacing (cm) on flowering dates, grain yield and other agronomic traits at Sakha (Sk), Gemmeiza (Gm) and Nubaria (Nub) in 2007 and 2008 growing seasons

Row spacing (cm)	2007 season			2008 season		
	SK	Gm	Nub	SK	Gm	Nub
Days to 50% tasseling						
60	65.5	64.0	63.8	60.8	60.4	63.4
70	65.0	64.6	63.5	61.0	60.4	63.3
80	63.9	63.2	62.3	60.4	60.2	62.9
LSD $_{(0.05)}$	1.0	0.4	0.4	0.7	NS	0.4
Days to 50% silking						
60	65.9	63.4	65.7	61.1	61.3	65.3
70	65.3	64.5	65.4	61.2	61.0	65.3
80	64.3	63.2	64.1	60.5	60.9	64.8
LSD $_{(0.05)}$	1.0	0.3	0.4	0.7	0.3	0.5
Plant height (cm)						
60	277	267	237	333	267	225
70	279	265	251	337	268	245
80	282	280	274	340	272	262
LSD $_{(0.05)}$	NS	7.2	2.0	6.9	2.8	4.2
Ear height (cm)						
60	161	151	130	195	150	123
70	158	147	145	195	149	137
80	163	157	159	197	151	150
LSD $_{(0.05)}$	5.8	4.7	2.2	NS	NS	5.4
Grain yield plant^{-1} (g)						
60	166	155	191	172	165	160
70	169	155	202	194	152	187
80	183	163	211	222	168	218
LSD $_{(0.05)}$	13.0	5.0	8.9	13.5	11.7	5.5
Grain yield (ard fad^{-1})						
60	28.25	26.60	32.16	29.88	27.62	26.43
70	28.68	25.73	33.56	30.06	26.16	30.50
80	30.43	27.76	35.80	30.47	28.72	34.48
LSD $_{(0.05)}$	2.40	0.97	1.02	NS	1.74	0.97

Nubaria, in 2007 growing season, and 16.2% at Sakha in 2008 growing season) was associated with increasing number of plants from 20000 to 25,000 plants fad^{-1}. In contrast, the rate of decrease in grain yield per plant, due to increasing number of plants per faddan from 25000 to 30,000 plants, ranged from 3.6% at Nubaria, in 2007 growing season, to 23.8% at Sakha in 2008 growing season. The reduction in grain yield per plant, due to increasing plant population density, might be due mainly to the competition and mutual shading among adjacent plants, which reduced the amount of solar radiation and light energy intercepted by plants. Jollife *et al* (1990) and Hassan *et al* (2008) obtained similar results and found that the yield reduction per plant was due to the effects of inter-plant competition for light, water, nutrients and other potentially yield-limiting environmental factors.

Data in Table 3 showed that the effect of plant population density on grain yields (in ard fad^{-1}) was significant at all locations and in both growing seasons, except for Sakha in 2008 growing season. It is worth noting that grain yield (in arddab faddan^{-1}) significantly increased as plant population density increased up to 30,000 plants fad^{-1} at Gemmeiza and Nubaria, in 2007 growing season, and at Nubaria in 2008 growing season. Significant increase in grain yield per faddan was associated with an increase in plant population density up to 25,000 plants faddan^{-1} at Sakha and Nubaria in 2007 growing season and

Table 3: Effect of plant population densities on flowering dates, grain yield and other agronomic traits at Sakha (Sk), Gemmeiza (Gm) and Nubaria (Nub) in 2007 and 2008 growing seasons

Plant densities (1000 plants fad^{-1})	2007 growing season			2008 growing season		
	SK	Gm	Nub	SK	Gm	Nub
	Days to 50% tasseling					
20	64.8	63.8	62.5	60.6	60.3	62.3
25	64.7	64.0	63.2	60.6	60.5	63.1
30	64.9	64.2	63.8	61.1	60.2	64.2
$LSD_{(0.05)}$	NS	0.3	0.4	0.4	NS	0.3
	Days to 50% silking					
20	65.0	63.7	64.3	60.5	60.9	64.2
25	65.0	63.7	65.1	60.9	61.3	65.1
30	65.5	64.1	65.8	61.5	61.1	66.1
$LSD_{(0.05)}$	0.4	0.3	0.4	0.5	NS	0.3
	Plant height (cm)					
20	278	273	246	335	267	235
25	282	272	255	337	274	245
30	278	267	262	338	265	253
$LSD_{(0.05)}$	NS	3.7	2.7	NS	2.9	2.6
	Ear height (cm)					
20	159	152	139	192	148	130
25	162	154	146	198	152	138
30	161	151	149	198	149	142
$LSD_{(0.05)}$	NS	NS	2.9	4.4	2.7	2.7
	Grain yield $plant^{-1}$ (g)					
20	194	182	211	230	198	190
25	175	166	200	198	166	192
30	150	125	193	160	122	183
LSD 0.05	8.3	4.4	5.9	9.5	10.9	6.8
	Grain yield (ard fad^{-1})					
20	27.56	25.82	29.36	29.43	25.67	26.33
25	29.40	26.08	33.51	30.95	28.10	31.65
30	30.40	28.19	38.65	30.03	28.73	33.43
$LSD_{(0.05)}$	1.15	0.82	0.93	NS	1.79	1.14

Gemmeiza, as well as Nubaria in 2008 growing season. On the other hand, grain yield significantly increased as plant population density was increased from 20,000 up to 30,000 plant fad^{-1} at Nubaria in 2007 growing season. These results were in a good agreement with those reported by El-Deep (1990), and Hassan *et al* (2008) who found that plant population density had a significant effect on grain yield $faddan^{-1}$. They obtained the highest grain yield by planting maize hybrids at the rate of 25,0000 pants fad^{-1}.

D. Row direction x row spacing interaction:

The effect of first-order interaction of rows orientation and rows spacing was significant for number of days to 50% tasseling, plant height, ear height and grain yield (in arddab $faddan^{-1}$) (Table 4). Planting maize on rows, directed from east to west (E-W) and rows spacing of 80 cm apart, was linked for earlier tasseling date (60.9 and 62.7 days, at Nubaria and Gemmeiza in 2007, and 60.1 and 60.2 at Sakha and Gemmeiza in 2008 growing seasons), respectively. The same trend was achieved at Sakha and Gemmeiza in 2008 by planting maize on rows directed from north to south (N-S) and rows spacing 80 cm apart. The effect of the first-order interaction of rows orientation and rows spacing on plant height was significant. The shortest plants were obtained at Nubaria in both growing seasons and associated with planting maize on rows spaced at 60 cm and directed from E-W or N-S.. The same trend was observed with respect to ear height at Nubaria. It was observed that the lower ear placement was linked with planting maize in both row directions and spaced 60 cm apart. The highest grain yield was obtained when maize was planted on rows directed east-west and spaced at 80 cm at all locations in the two growing seasons.

E. Plant population density x row spacing interaction:

Row spacing and plant density interaction was significant for number of days to 50% tasseling, plant height, ear height and grain yield (Table 5). The lowest number of days to 50% tasseling and silking was obtained in both growing seasons by

Table 4: Effect of row directions and row spacing interaction on number of days to 50% tasseling, plant height, ear height and grain yield at Sakha (Sk), Gemmeiza (Gm) and Nubaria (Nub) in 2007 and 2008 growing seasons

Row Direction	Row spacing (cm)	2007 season			2008 season		
		SK	Gm	Nub	SK	Gm	Nub
		Days to 50% tasseling					
East-West	60	65.5	64.2	62.3	60.8	60.6	62.7
	70	64.9	63.4	61.5	60.3	60.6	61.5
	80	64.3	62.7	60.9	60.1	60.2	61.4
North-South	60	66.2	65.0	65.4	61.6	60.6	65.2
	70	64.5	64.5	65.3	61.3	60.3	64.3
	80	63.6	63.7	63.6	60.5	59.8	64.1
LSD $_{(0.05)}$		1.35	0.55	0.62	1.01	0.59	0.58
		Plant height (cm)					
East-West	60	278	253	**251**	328	273	**233**
	70	286	260	267	335	276	258
	80	291	282	294	340	282	277
North-South	60	267	274	**222**	335	261	**218**
	70	272	276	235	337	259	233
	80	280	278	255	345	262	247
LSD $_{(0.05)}$		13.8	10.2	2.9	10.0	4.0	5.9
		Ear height (cm)					
East-West	60	168	149	**142**	192	154	**131**
	70	158	143	160	196	155	146
	80	162	162	174	190	159	160
North-South	60	157	154	**118**	198	146	**115**
	70	159	151	130	198	143	128
	80	160	153	143	201	142	140
LSD $_{(0.05)}$		8.2	6.6	3.1	8.7	4.1	7.7
		Grain yield (ard fad^{-1})					
East-West	60	28.53	27.14	34.33	29.08	27.94	28.69
	70	30.09	27.55	35.92	29.20	28.35	32.29
	80	31.04	29.68	**38.51**	29.06	29.44	**37.14**
North-South	60	26.42	23.90	29.99	30.68	24.37	24.16
	70	28.83	25.85	31.20	30.93	25.80	28.71
	80	29.82	26.05	**33.09**	31.88	29.09	**31.82**
LSD $_{(0.05)}$		3.40	1.37	1.44	2.52	2.46	1.37

Table 5 : Effect of row distances and plant population densities interaction on number of days to 50% tasseling, 50% silking and grain yield at Sakha (Sk), Gemmeiza (Gm) and Nubaria (Nub) in 2007 and 2008 growing seasons

Row distance	Densities (1000 plants fad^{-1})	2007 season			2008 season		
		SK	Gm	Nub	SK	Gm	Nub
		Days to 50% tasseling					
60 cm	20	65.4	62.8	62.9	60.8	60.5	63.1
	25	65.6	63.0	64.1	60.4	60.9	63.3
	30	65.6	63.8	64.3	61.4	59.9	63.8
70 cm	20	65.1	64.9	63.0	60.6	60.6	62.3
	25	64.8	64.3	62.8	60.4	60.0	63.1
	30	65.1	64.6	64.6	60.1	60.5	64.6
80 cm	20	64.0	63.6	61.5	60.4	59.9	61.4
	25	63.8	64.1	62.8	61.0	60.5	63.0
	30	64.1	64.1	62.5	61.8	60.3	64.3
$LSD_{(0.05)}$		0.8	0.5	0.7	0.7	0.8	0.5
		Days to 50% silking					
60 cm	20	65.5	62.8	64.8	60.9	61.0	65.0
	25	65.9	63.0	66.0	60.6	62.0	65.4
	30	66.4	63.8	66.4	61.8	61.1	65.6
70 cm	20	65.4	64.9	65.0	60.4	61.3	64.3
	25	65.0	64.1	64.6	60.8	60.6	65.3
	30	65.6	64.0	66.6	60.6	60.9	66.4
80 cm	20	64.1	63.5	63.3	60.4	60.4	63.3
	25	64.3	64.0	64.6	61.3	61.3	64.8
	30	64.5	64.0	64.5	62.0	61.3	66.3
$LSD_{(0.05)}$		0.8	0.5	0.7	0.8	0.6	0.6
		Grain yield (ard fad^{-1})					
60 cm	20	24.85	24.85	27.64	29.3	26.17	22.71
	25	28.46	27.69	31.35	29.4	27.86	26.52
	30	29.72	25.41	37.49	29.6	24.25	30.04
70 cm	20	27.46	25.49	30.05	29.12	28.92	26.82
	25	29.57	27.98	33.16	31.51	28.64	31.45
	30	30.11	24.64	37.46	29.56	24.44	33.24
80 cm	20	30.37	27.90	30.37	29.87	29.22	29.47
	25	30.18	28.89	36.01	31.93	29.69	36.98
	30	31.37	27.42	**41.01**	30.93	28.31	37.00
$LSD_{(0.05)}$		0.25	1.41	1.60	2.43	3.10	1.98

planting maize on rows 80 cm apart and 30 cm among plants (20,000 plants fad^{-1}). The highest grain yield was recorded in 2007 growing season at Sakha and Nubaria (31.37 and 41.01 ard fad^{-1}) by planting maize, using 80 cm among rows and 30000 plants fad^{-1}. At Gemmeiza, the highest grain yield (28.89 ard fad^{-1}) was obtained by planting maize on rows spaced at 80 cm with 25,000 plants fad^{-1} . In 2008 growing season, it was observed that the highest grain yield (37.00 ard fad^{-1}) was obtained at Nubaria by planting maize on rows 80 cm apart and 30,000 plants fad^{-1}. Many investigators found that the wider row spacing encouraged plants to intercept more light and, hence, produced high dry matter accumulation and, hence, high grain yield (Choudhary, 1981, El-Murshedi, 1991, Abdel-Aal, 1997 and Oraby *et al*, 2003a). However, Ragheb *et al* (1993) and Abd El-Maksound (2008) found that planting maize at the rate of 24,000 plants fad^{-1} (60 x 30 or 70 x 25 cm), produced the highest grain yield.

CONCLUSIONS

This investigation could recommend planting maize on 80-cm-row spacing, which should be oriented toward east-west direction with a plant density of 20-25 thousand plants fad

REFERENCES

Abdel-Aal, S. M., M. E. Ibrahim, A. A. Ali and Kh. S. Sarhan. **1997**. Studies on some maize varieties sown at different plant distribution systems. II. Flowering, grain filling and yield and its components. Monofya J. Agric. Res. **22**(3): 755-780.

Abd El-Maksoud, M. F. **2008**. Effect of row direction and plant arrangement on growth, yield and yield components of two maize cultivars. J. Appl. Sci. Res., **4**(10): 1182-1190.

Abdrabou, R. Th. **1996**. Response of maize yield to etheophon treatment and nitrogen fertilizer rates under two directions. Annals Agric. Sci., **41** (2): 683-695, Ain. Shams Univ. Cairo, Egypt,.

Beech, D. F. and J. J. Basinski, **1975**. Effect of plant populations and row spacings on early and late maize hybrids in the Ord Valley. Australian J. Exp. Agric. and Animal Husbandry **15** (74): 406-413.

Brown, R. H., E. R. Beaty, W. J. Ethredge and D. D. Hayes. **1970**. Influence of row width and plant population on yield of two varieties of corn (*Zea mays* L.). Agron. J. **62**: 767-770.

Bullock, D. G., R.L. Nielsen and W. F. Nyquist. **1988**. A growth analysis comparison of corn grown in conventional and equidistant spacing. Crop Sci. **28**:254-257.

Cardwell, V. **1982**. Fifty years of Minnesota corn production. Source of yield increase. Agron. J. **74**: 984-990.

Choudhary, A. H. **1981**. Effects of Population and Inter-Row Spacing on Yields of Maize and Control of Weeds with herbicides in the irrigated savanna. Experimental Agriculture **17**:389-397.

Duncan, W. G. **1984**. A theory to explain the relationship between corn populations and grain yield. Crop Sci. **24**: 1141-1145.

El-Deep, A. A. 1990. Effect of plant density and nitrogen level on the yield models of certain maize cultivars. Proc. 4th Conf. Agron., Cairo, 15-16 Sept., **1**: 419-434. El-Murshedi, W. A. **1991**. Crop canopy and crop distribution pattern in the field and its influence on biological and economical yields in Maize. M.Sc. Thesis, Fac. Agric., Cairo Univ., Egypt.

El-Murshedy, W. A. and A. A. Abuldahab. **2002**. Response of some maize hybrids and synthetic cultivars to planting density. Egyptian J. Appl. Sci. **17** (7): 546-562.

Farnham, D. **2001**. Row spacing, plant density, and hybrid effects on corn grain yield and moisture. Agron. J. **93**: 1049-1053.

Fulton, J. M. **1970**. Relationship among soil moisture stress, plant population, row spacing and yield of corn. Can J. Plant Sci. **50**:31-38.

Hassan, M.M.M.,M.A.M.El-Ghonemy and R.S.H.Aly. **2008**. Response of some maize single cross hybrids to plant density under different Egyptian environmental condition. Minufiya J. Agric.Res. 33 No.**2**: 427-443.

Ismail, M. A. **1997**. Effect of some agronomic practices on maize. M.Sc. Thesis Zagazig University, Zagazig, Egypt.

Jollife, P. A., A. J. P. Tarimo and G. W. Eaton. **1990**. Plant growth analysis: Growth and yield component responses to population density in forage maize. Annals of Botany, **65**:139-147.

Khalil, A. N. M., Sh. A. El-Shamarka, M. W. Ibrahim and E. A. El-Absawy.(**1999**. Effect of plant densities on growth and yield of sixteen maize genotypes differed in their leaves angles. Minufiya J. Agric. Res. **24** (1): 85-106.

Liu, W., M. Tollenaar, G. Stewart and W. Deen. **2004**. Within-row plant spacing variability does not affect corn yield. Agron. J. **96**: 275-280.

Lutz, J.A. Jr., H. M. Camper and G. D. Gones **1971**. Row spacing and population effects on corn yields. Agron. J., **63**:12-14.

Mahgoub, G. M. A. and A. A. El-Shenawy. **2006**. Response of some maize hybrids to row spacing and plant density. First Field Crops Conference Proceedings, 22-24 August, 2006. Giza Egypt: pp. 285-293.

Nielsen, R. L. 1988. Influence of hybrids and plant density on grain yield and stalk breakage in corn grown in 38 cm row width. J. Prod. Agric. 1:190-195.

Oraby, F. T. and A. A. Sarhan. 2002. Proper agronmic practices required to maximize productivity of some maize varieties in old and reclaimed soils: II- Response of some maize varieties to NPK fertilization in the reclaimed sandy soil. Egyptian J. Appl. Sci. 17(11): 520-542.

Oraby, F. T., A. A. Sarhan, M. F. Abd El-Maksoud and A. H. Bassiouny. 2003a. Proper agronomic practices required to maximize productivity of some maize varieties in old and reclaimed soils: III. Effect of sowing dates on response of two maize hybrids to nitrogen fertilization. Egyptian J. Appl. Sci. 18(5B): 597-618.

Oraby, F. T., M. F. Abd El-Maksoud and A. A. Sarhan. 2005b. Proper agronmic practices required to maximize productivity of some maize varieties in old and reclaimed soils: v- Response of ten maize hybrids to N fertilization under two locations. J. Prodct. & Dev. 10 (1): 55-73.

Robinson, R. G. 1975. Effect of row direction on sunflower. Agron. J. 67: 93-94.

Ragheb, M. M. A., A. A. Bedeer, and A. Sh. A. Gouda, 1993. Effect of row spacing and plant population density on grain yield of some maize hybrids. Zagazig J. Agric. Res. 20(2): 581-594.

Sarhan, A. A. 1994. Agroforestry system and plant arrangement effects on yield and its components of some maize hybrids. Egypt. J. Appl. Sci. 12: 728-746.

Seif, S. A., M. I. Bashir and M. H. El-Bakry. 1988. Effect of sowing directions, inter and intra row spacing on growth and yield of two grain sorghum cultivars. (*Sorghum bioclor L.*). Egyptian J. Appl. Sci. 3: 181-191.

Soliman, F. H. S., A. A. Ahmed and M. E. Abd El-Azeem. 2005. Maize productivity under different plant densities in Toshka region, South Valley of Egypt. Egypt. J. Appl. Sci. 20 (5b): 671-695.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics. 2[nd] Edit. McGraw-Hill Book Company, U.S.A.

Talentino, N. M. 1982. Solar radiation interception on sorghum (*Sorghum bioclar L.*) grown at different plant densities. Sorghum and Millets information Center (SMIC) Newsletter, 19, April, 1986).

Teasdale, J. R. 1995. Influence of narrow row/high population corn (*Zea mays* L.) on weed control and light transition. Weed Technol. 9: 113-118.

Tetio, F. Kagho and F. P. Gardnar. 1988. Response of maize to plant population density. 1 Canopy development, light relationship and vegetative growth. Agron. J., 80: 430-435.

Widdicombe W. D. and K. D. Thelan. 2002 Row width and plant density effects on corn grain production in the Northern Corn Belt. Agron. J. 94:1020-1023.

. Younis, M. A., S. M. M. Amer, A. A. Awad and Sh. F. Aboul-Saad. 1989 Effect of row spacing and plant population on maize grain yield. Egypt. J. Appl. Sci. 4 (3): 359-365.

الملخص العربى

تأثير إتجاه التخطيط والمسافة بين الخطوط والكثافة النباتية على محصول الحبوب وبعض الصفات المحصولية الأخرى فى الذرة الشامية

هدى خيرى عبد المنعم المقصر ــ حاتم الحمادى موسى
مهــا جلال بلبــع محمد ــ أحمد محمد الغنيمى
قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – الجيزة – مصر

أقيمت تجربة حقلية واحدة فى ثلاث محطات للبحوث الزراعية هى: سخا (محافظة كفر الشيخ) والجميزة (محافظة الغربية) والنوبارية التابعة لمركز البحوث الزراعية خلال موسمى ٢٠٠٧ و٢٠٠٨ لدراسة تأثير إتجاه التخطيط والمسافة بين الخطوط وكثافة النباتات على نمو ومحصول الذرة الشامية . كان المحصول السابق فى جميع المواقع هو القمح بينما كان الصنف المنزرع هو هجين فردى ١٠ (هــ.ف.١٠). أشتملت التجربة على ثلاث معاملات هى: اتجاهان للتخطيط من الشرق الى الغرب ومن الشمال الى الجنوب ، وثلاث مسافات بين الخطوط هى ٦٠ و٧٠ و٨٠ سم ، وثلاث كثافات نباتية هى: ٢٠ و٢٥ و٣٠ الف نبات للفدان. كان التصميم الإحصائى المستخدم فى التجربة هو القطاعات المنشقة مرة واحدة بحيث وضعت كل معامله من معاملتى أتجاه الخطوط فى تجربه مستقله وفى كل تجربة وضعت معاملة عرض الخط فى القطع الرئيسية ، بينما وضعت كثافة النباتات فى القطع المنشقة وعند إجراء التحليل الإحصائى تم إجراء تحليل الضم لتجربتى إتجاه التخطيط معا. وقد أوضحت النتائج ان زراعة الذرة على خطوط من الشرق الى الغرب مع عرض ٨٠ سم للخطوط قد ادى الى نقص معنوى فى عدد الأيام من الزراعة حتى طرد ٥٠% من النباتات للنورات المذكرة والمؤنثة ، كما أدت نفس المعاملتين الى زيادة معنوية فى كل من إرتفاع النبات وارتفاع الكوز ومحصول الحبوب للنبات وللفدان. هذا وقد كان تأثير كثافة النباتات على كل من صفات التزهير وارتفاع النبات والكوز مختلفا بين المحطات وبين مواسم النمو ، الا ان زيادة كثافة النباتات حتى ٣٠ الف نبات للفدان قد ادى الى نقص معنوى فى ارتفاع النباتات فى الجميزة ، بينما أدى الى زيادة معنوية فى النوبارية وفى موسمى النمو ، وكان تأثير الكثافة النباتية على ارتفاع الكوز معنويا فى النوبارية فى موسم ٢٠٠٧ فقط ، بينما كان التأثير معنويا فى ســخا والجميزة موسم ٢٠٠٨ ، وفى جميع الحالات أدت زيادة الكثافة النباتية الى نقص معنوى فى محصول الحبوب للنبات وزيادة معنوية فى محصول الحبوب للفدان. وبصفة عامة يمكن القول ان زراعة الذرة الشامية على خطوط من الشرق الى الغرب وعرض الخط ٨٠ سم والكثافة النباتية ٢٥ الف نبات للفدان قد أدت الى تحسن نمو النباتات وزيادة كمية المحصول.