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Determine Independent Population Density for Each Maize Hybrid (*ZEA MAYS* L.)

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Abstract. To evaluate the performance of three modern maize hybrids under the different plant population densities, to determine the benefits from using population density and the suitable plant density for hybrid maize, this work was undertaken. Therefore, two field experiments were carried out in the farm of the Faculty of Agriculture (Saba Basha), Alexandria University, during the summer growing seasons of 20012 and 2013. The experimental design was split plot with three replicates. Three plant spacing (population densities) were, 30 cm = (53332 plants/ha.), 25 cm = (64000 plants/ha.), and 20 cm = (80000 plants/ha.) were tested with four yellow hybrids of maize, i.e., Three way cross 352 (T.W.C.352), Single cross 168 (S.C.168), Single cross 173 (S.C.173), and Single cross 166 (S.C.166) which were occupied in the subplot units. However, four hybrids exhibited such variations in their plant height (cm), the yield and its components, namely; Ear length (cm), number of row/ear, number of kernels/row, 100- kernel weight (g), Stover yield Mg/ha., grain yield Mg/ha., and protein %. However, plant population 64000 plant/ha., gave the highest mean values for most studied characters and protein %. , and reduced weeds spread. Also, hybrid "TWC 352" recorded the highest values of most studied parameters under Alexandria conditions.

Keywords*:* plant spacing; plant density; maize; hybrid; yellow; yield; yield components; weeds.

1. Introduction

Maize (*Zea mays* L.) is the world's widely grown highland cereal and primary staple food crop and animal feed in many developing countries. It is the third most important staple food crop both in terms of area and production after wheat and rice in Egypt. Total area under cultivation of maize in Egypt is 888329 ha, which is about 25.17 % of the total cultivated agricultural land. It is about 21.9 % of the total cereal production [1]. The rapidly increasing demand of maize is driven by increased in demand for direct human consumption in the hills as a staple food crop [2]. Where increasing grain yield per unit area and increasing the corn are the best solution to decrease the gap between consumption and production from feed and forage. Among the good agricultural practice to achieve this goal is to define the best plant density area^{-1}.

Increasing plant density (40 plant m^{-2}) decreased the number of inflorescence per plant, leaf area, shoot dry weight and grain yield per plant but increased plant height. Early sowing dates with low density and high irrigation levels increased growth period and reduced competition, so increased production potential of Amaranth [3]. Plant density of 66666 plants ha^{-1}produced the higher grain yield (11.19 tons/ha.) compared to that of 55555 plants/ha (9.52 tons ha^{-1}). However, grain yield at 66666 plants/ha., did not show a significant difference with that of 83333 plants ha^{-1} (10.5 tons/ha). Increasing plant density from 55555 plants ha^{-1} to 83333 plants ha^{-1} had increased the stover yield, whereas harvest index and grain stover ratio were not significantly influenced by plant densities [4]. Ear length, ear weight, number of grains row^{-1} and 1000- grain weight were, significantly, varied among maize hybrids. The hybrid "YH-1898" had, significantly, greater ear length (22.3 cm) and 1000- grain weight (460.8 g) while the hybrid "FH-793" had higher ear weight

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(290.5 g) and “Yusafwala” hybrid excelled in number of grains per row (43.5) as compared to other hybrids. Different plant spacing also, significantly, affected plant height, ear length, ear weight, number of grains per row, number of grains ear^{-1}, 1000- grain weight and grain yield. Plant spacing of 17.5 cm gave significantly longest ear (23.5 cm), higher ear weight (295.3 g), number of grains per row (44.5), number of grains ear^{-1} (717.0), and 1000 - grain weight (443.3 g) while plant spacing of 12.5 cm excelled in grain yield (8.37 tons ha^{-1}) as compared to other plant spacing [5]. Reference [6] reported that hybrid “Pioneer” had significantly higher grain yield (3275.0 kg ha^{-1}) as compared with other hybrids. Spacing of 15 cm had significantly highest mean values of most of studied characters. Interaction of hybrid Pioneer and 25 cm gave highest grain yield. Also, Reference [7] conducted that narrow rows reduced weed biomass by 58 %. Growing maize at 40000 plants ha^{-1} resulted in similar green ear weight regardless of inter-row spacing. Ear length decreased with increase in plant population and with wider rows. Similar grain yield was obtained regardless of inter-row spacing when maize was grown at 40000 plants ha^{-1}, but at 60000 plants ha^{-1} resulted in 11 % higher grain yield. Increasing plant population from 40000 to 60000 plants ha^{-1} resulted in a 30% grain yield increase.

Two hybrids 30 Y 87 and 31 R 88 having density levels 15 cm, 20 cm, 25 cm and 30 cm were sown at row spacing of 60 cm. The hybrid “30 Y 87” was early in maturity, produced more, more number of grain rows, less number of grains per row and less ear length than the hybrid 31 R 88. Similarly 1000- grain weight, grain yield and straw yield of hybrid “30 Y 87” was significantly greater than the hybrid “31 R 88”. Although narrow plant spacing (15 and 20 cm) caused substantial reduction in yield components such as 1000- grain weight compared to the wide plant spacing (30 cm) yet it gave the maximum yield (7.69 tons ha^{-1}) against the minimum of (5.01 tons ha^{-1}) in the latter. The interactive effect of plant population density and hybrids was found to be non-significant in all the parameters under study [8]. Maize and weed biomass and composition were evaluated at 3 weeks pre- silking, silking, 3 weeks post silking, and at physiological maturity. Maize leaf area index, leaf chlorophyll content, and photosynthetic photon flux density transmittance with and without weeds were also measured. Increasing maize plant density from 4 to 10 plants m^{-2} reduced weed biomass by up to 50 %. The impact of high weed-pressure treatments on maize dry matter accumulation remained in a narrow range of 18 to 21 % throughout the growing season. The grain yield reductions attributable to high weed pressure were 26, 17, and 13 % for the maize plant densities of 4, 7, and 10 plants m^{-2}, respectively. Results showed that the competitiveness of maize with weeds can be enhanced by increasing plant density [9].There was a significant reduction in number and dry weight of broadleaved, grass and total weeds at 10 weeks after sowing with the increase of plant population. Narrowing the spacing between maize plants from 30 cm to 17 cm caused a significant reduction (21%) in the total weed dry weight [10].

The objectives of the experiments were to evaluate performance of four modern yellow hybrids of maize under the different plant population densities to determine the benefits from using population density for each maize hybrid.

2. Materials and Methods

Two field experiments were conducted at the farm, Faculty of Agriculture (Saba Basha), Alexandria University, during the summer growing seasons of 2012 and 2013 to study benefits from determine and using maize population density- independent hybrid. Soil samples were taken before maize planting from the experimental site. The soil samples were air dried, passed through a 2 mm sieve, and then analyzed according to reference [11]. The soil type of experimental site was clay loamy. Mechanical and chemical analysis of the experimental site is presented in Table 1.

The preceding crop was Egyptian clover (*Trifolium alexanderinum,* L.) during both seasons of the study. The experimental design was split plot with three replicates and the treatments were distributed at random as follow: Three plant spacing or population densities, i.e., 30 cm = (53332 plants/ha.), 25 cm = (64000 plants/ha.), and 20 cm between plants = (80000 plants/ha.) were located in main plots. While, four yellow hybrids of maize, i.e., Three way cross 352 (T.W.C.352), Single cross 168 (S.C.168), Single cross 173 (S.C.173), and Single cross 166 (S.C.166) were distributed randomly in the sub-plot units in the experimental design. The two planting dates was (30^{th} and 25^{th}) of May for 2012 and 2013 seasons, respectively. Application of mineral fertilization was nitrogen fertilizer; 240 kg N ha^{-1} in the form of urea (46.5 % N) was applied in an equal two doses with the first and second irrigation, and phosphorus fertilizer; 480 kg ha^{-1} from calcium super phosphate fertilizer (15.5% P_2O) was applied in one dose.

Table 1: Physical and Chemical Properties of the Experimental Soil Sites during the Two Cropping Seasons

Seasons	Soil properties											
	Physical properties				Chemical properties				Available cations meq/100 g soil			
	Clay	Silt	Sand	Soil texture	PH	E.C_e (dS/m)	Total C %	Total N %	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
2012	41.5	48.9	14.3	Clay loam	8.24	2.54	4.39	0.20	26.25	16.33	3.98	1.48
2013	42.5	49.5	14.1	Clay loam	8.56	2.58	4.66	0.39	25.35	15.73	3.98	1.57

- Studied characters: plant height at harvest , Ear length (cm), Number of ears $plant^{-1}$, number of rows ear^{-1}, number of kernels row^{-1}, 100 kernels weight (g), Stover yield, Grain yield per hectare, Harvest index (H.I. %), Protein percentage (Association of Official Agricultural Chemicts [12]), and Number of weeds/m^2.
- Data were statistically analyzed as split-split plot design experiments according to reference [13], using the split- split model as obtained by reference [14] as statistical program. Treatment means were compared according to reference [15] to estimate the significant differences among treatments.

3. Results and Discussions

The present work was carried out to explore response of four yellow hybrids of maize to three plant population densities on growth attributes, yield, and its components under Alexandria governorate conditions during 2012 and 2013 seasons.

The attained results will be present in following part:

The results indicated that those plant spacing had significant effects on most of growth attributes. The tallest maize plants (198.2 and 194.2 cm) were obtained when the space between the plant was 20 cm compare to plant spacing of 25 cm, maize hybrid “S.C. 166” gave the tallest plants (204.7 and 203.1 cm) followed by “TWC352” (195.0 and 191.0 cm), “S.C. 173” (186.7 and 186.6 cm) and “S.C. 168” (184.2 and 180.2 cm) each season, respectively.

Data as shown in Table 2 detected that both plant density and maize hybrid affected significantly most of yield and its components. Whereas, plant spacing 25 cm among plants led to the highest mean values of most yield and its components parameters namely, ear length (18.9 and 19.4 cm), number of row/ear (13.8 and 13.6), number of kernels/row (39.9 and 40.1), 100- kernel weight (g), and grain yield Mg/ha., in both season, respectively. Meanwhile, plant spacing 20 cm distance among plants recorded the lowest ear length (17.3 and 17.4 cm), number of kernels/row, number of kernels/ear, 100- kernel weight (g), and grain yield Mg/ha., during both seasons. On the other hand, plant spacing 30 cm brought about the highest stover (Mg/ha.) without significant difference with plant spacing 25 cm. while, plant spacing 20 cm recorded the lowest stover yield Mg/ha., in both seasons of the study. Furthermore, results, also, showed significant interaction effect of plant spacing and maize hybrid on some characters of yield and its components. The hybrid “TWC352” with plant density 30 cm recorded the highest mean values of ear length (cm), number of kernels/row, 100- kernel weight (g), stover and grain yields Mg/ha., in the first season. In second season, the hybrid “TWC 352” with 25 cm achieved the highest mean values ear length, number of kernels/row, 100- kernel weight, stover yield. Meanwhile, high grain yield Mg/ha., recorded from the hybrid “TWC352” with 30 cm as plant spacing in the second season. Similar results, more or less, were obtained by references [4]-[7]. Exceeding beyond a certain limit of plant density, yield is lost due to missing of plants, increase in plant to plant unevenness and increase in plant infertility as high plant density above the certain level elongate the duration between pollen shedding and silking resulting in more unproductive plants. Modern maize hybrids are more efficient as compared to old ones because of better tolerance to crowding stress, lower lodging frequencies and improved tolerance to low-input and harsher growing conditions. It is, therefore, suggested that modern maize hybrids should be preferably grown at higher plant density because of their tolerance to high plant density, to get maximum grain yield, but not above a given certain level where their yield sharply decline [16].

Grain protein of the three maize hybrids had significant differences as affected by plant spacing at during growing seasons 2012 and 2013 (Table 2). Plant spacing 25 cm each, gave the highest protein content in grains with 20 cm as plant spacing. Meanwhile the lowest content of protein obtained from 30 cm distance between plants in both seasons. "S.C.166" recorded to the highest protein content in grain (11.4 and 11.3), while the lowest protein % (10.5 and 10.7) recorded with the hybrid "S.C.168" during two cropping seasons. There was no interaction effect between plant spacing x maize hybrid on protein %.

Data presented in Table 2 indicated that there is a significant effect of plant spacing, maize hybrids and their interaction on number of weeds/m^2. Whereas, number of weeds/m^2 (33.00) decreased with the maize hybrid "TWC352", meanwhile number of weeds/m^2 (52.56) increased with maize hybrid "S.C.166" during both seasons. Maize cultivation at decreased plant spacing to 20 cm was found to reduce number of weeds/m^2 with in par plant spacing 25 cm between maize plants in both growing seasons, while increased plant spacing to 30 cm increased number of weeds/m^2. These results were explained by reference [17] who reported that plant competition in its basic sense can be defined as competition for resources such as light, water and nutrients. The intensity of crop competition, especially competition of row crops such as maize, mostly depends on population density and plant arrangement. A better use of maize plant density and row spacing may be one way of developing crops that would be more competitive against weeds. Likewise, results outlined in Table 2 showed significant interaction effect of plant spacing and maize hybrid on some characters as number of weeds/m^2.The maize hybrid "TWC352" with plant density 20 cm recorded the lowest number in both seasons. On the other hand, the hybrid "S.C. 173" with 30 cm gave the highest number in the second season.

In Conclusion using plant population as 64000 plant/ha. (25 cm between plants) gave highest value of most of growth attributes, yield, it components and protein %, also, the maize hybrid "TWC352" recorded the highest mean values of most of studied characters and reduced weeds spread under Alexandria conditions**.**

Table 2: Means of leaf area index (lai), chlorophyll (mg/m^2), ear length (cm), number of row/ear, number of kernels/row of 100- kernel weight (g), stover, grain yields mg/ha. Protein % and number of weeds/m^2 four new yellow hybrids of maize under three plant population density during 2011 and 2012 seasons

Attributes	**Season**														
		2012							**2013**						
		Plant spacing (S)							**Plant spacing (S)**						
	Maize hybrids (H)	30 cm	25 cm	20 cm	**Mean (H)**	L.S.D. (H) at 0.05	L.S.D. (S) at 0.05	L.S.D. (H x S) at 0.05	30 cm	25 cm	20 cm	**Mean (H)**	L.S.D. (H) at 0.05	L.S.D. (S) at 0.05	L.S.D. (H x S) at 0.05
Plant height at harvest (cm)	S.C.168	175.33	185.67	191.67	**184.22**	13.355	4.645	N.S.	171.33	181.67	187.67	**180.22**	11.552	6.062	N.S.
	TWC 352	184.33	204.00	196.67	**195.00**				180.33	200.00	192.67	**191.00**			
	S.C. 173	188.33	196.67	186.67	**190.56**				184.33	192.67	182.67	**186.56**			
	S.C. 166	200.33	195.67	217.67	**204.56**				196.33	199.33	213.67	**203.11**			
Mean (S)		187.08	195.50	198.17					183.08	193.42	194.17				
Ear length (cm)	S.C.168	16.07	19.07	17.60	**17.58**	0.497	0.805	0.860	16.73	19.13	17.33	**17.73**	0.919	0.976	1.592
	TWC 352	19.80	18.53	17.27	**18.53**				20.20	21.20	20.20	**20.53**			
	S.C. 173	17.67	18.47	17.13	**17.76**				18.40	18.73	14.73	**17.29**			
	S.C. 166	18.27	19.40	17.00	**18.22**				19.40	18.40	17.20	**18.33**			
Mean (S)		17.95	18.87	17.25					18.68	19.37	17.37				
Number	S.C.1	12.0	13.7	12.8	**12.8**	0.56	0.34	N.S.	14.1	13.6	12.1	**13.2**	0.39	0.48	1.96

of row/Ear	68	0	3	0	**4**	5	2		3	0	3	**9**	6	7	4
	TWC 352	14.00	14.27	12.53	**13.60**				13.87	13.87	14.00	**13.91**			
	S.C. 173	12.13	13.73	12.13	**12.67**				12.53	13.73	12.40	**12.89**			
	S.C. 166	12.97	13.47	12.53	**12.99**				12.40	13.20	13.07	**12.89**			
Mean (S)		12.78	13.80	12.50					13.23	13.60	12.90				
Number of kernels/row	S.C.168	34.93	40.27	36.00	**37.07**	1.307	1.930	2.263	38.73	37.97	30.87	**35.86**	1.495	2.110	2.589
	TWC 352	42.00	40.13	35.87	**39.33**				40.00	43.20	42.73	**41.98**			
	S.C. 173	38.07	40.80	36.33	**38.40**				33.93	39.47	35.13	**36.18**			
	S.C. 166	38.00	38.33	36.73	**37.69**				36.13	39.67	35.43	**37.08**			
Mean (S)		38.25	39.88	36.23					37.20	40.08	36.04				
100-kernel weight (g)	S.C.168	30.33	41.17	30.30	**33.93**	2.061	3.353	3.852	37.83	41.33	36.67	**38.61**	2.462	2.161	4.265
	TWC 352	42.67	39.00	30.33	**37.33**				48.17	50.50	38.00	**45.56**			
	S.C. 173	35.07	38.33	32.00	**35.13**				38.00	44.17	38.33	**40.17**			
	S.C. 166	36.33	33.83	34.17	**34.78**				41.00	41.83	35.67	**39.50**			
Mean (S)			36.10	38.08	**31.70**				41.25	44.46	37.17				
Stover yield Mg/ha.	S.C.168	9.05	10.82	8.78	**9.55**	0.712	1.061	0.628	9.59	10.15	8.34	**9.36**	1.058	1.140	N.S.
	TWC 352	12.68	10.81	8.85	**10.78**				11.55	11.90	9.31	**10.92**			
	S.C. 173	10.19	9.54	9.06	**9.60**				7.97	10.85	7.56	**8.79**			
	S.C. 166	10.49	9.53	9.15	**9.73**				8.82	8.89	7.81	**8.51**			
Mean (S)	10.60	10.17	8.96					9.48	10.45	8.26					
Grain yield Mg/ha.	S.C.168	4.23	5.92	5.31	**5.16**	0.362	0.237	1.233	3.77	5.01	4.55	**4.45**	0.338	0.432	0.586
	TWC 352	6.31	5.08	5.41	**5.60**				6.12	5.60	5.59	**5.77**			
	S.C. 173	4.86	5.49	4.77	**5.04**				4.40	5.27	4.21	**4.63**			
	S.C. 166	5.22	5.92	4.32	**5.15**				4.73	5.36	4.41	**4.84**			
Mean (S)		5.15	5.60	4.95					4.76	5.31	4.69				
Protein %	S.C.168	9.43	11.53	10.57	**10.51**	0.635	0.850	N.S.	9.97	11.50	10.63	**10.70**	0.538	0.365	N.S.
	TWC 352	10.53	11.33	11.20	**11.02**				10.70	11.60	11.07	**11.12**			
	S.C. 173	10.33	12.37	11.23	**11.31**				10.60	12.17	11.03	**11.27**			
	S.C. 166	11.63	11.37	11.25	**11.42**				11.43	11.20	11.22	**11.28**			
Mean (S)		10.48	11.65	11.06					10.68	11.62	10.99				
Number of weeds/m^2	S.C.168	64.00	38.00	26.67	42.89	14.574	6.190	10.722	67.67	37.00	29.67	44.78	12.040	5.902	10.222
	TWC 352	54.33	27.00	17.67	33.00				58.67	29.67	19.33	35.89			
	S.C. 173	85.00	37.00	29.00	50.33				85.67	40.00	30.67	52.11			
	S.C. 166	78.00	35.67	44.00	52.56				80.33	38.67	45.67	54.89			
		70.33	34.42	29.33					73.08	36.33	31.33				

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