Maize Performance under Different Levels of Plant Population Density and Time of Defoliation

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ABSTRACT

Two field experiments were carried out, in the summer seasons of 2021 and 2022 at Agriculture Research Station, Alexandria University, Alexandria, Egypt, to study the response of some growth and productivity traits of maize (Giza 168 cultivar) to three plant densities (46.6, 57.0 and 71.4 thousand plants/ ha) and four defoliation treatments of D_0= no defoliation besides D_1, D_2 and D_3 defoliation times applied, at 60, 75 and 90 days after sowing (DAS). Forage production by defoliation was found to be closely related to time of defoliation and plant density, where the maximum leaves yield was obtained from the highest plant density and defoliation at 90 days (3.66 and 3.60 t/ ha in 2021 and 2022 seasons, respectively), whereas the respective lowest leaves yield of 2.53 and 2.70 t/ ha, were obtained from the lowest plant density and defoliation at 60 DAS. Grain yield production was found to be a function for defoliation time and plant density, where the lowest grain yield was obtained with the lowest plant density and defoliation at 60 DAS (3.92 and 3.87 t/ ha in 2021 and 2022 seasons, respectively), while the respective highest grain yield was produced by no defoliation and highest plant density (5.72 and 5.54 t/ ha) and it was statistically similar to defoliation at 90 DAS for the same plant density. Quadratic response indicated that the optimal plant density for grain yield was lower than the maximum applied density. However the highest grain yield was obtained with the maximum plant density. That implies the necessity to determine the increase of grain yield above the optimal density in relation to economic return per unit area.

In conclusion, both proper time of defoliated leaves at maximum plant density, without significant reduction in grain yield, encourages maize cultivation as a dual purpose crop (food for humans and fodder for animals).

Keywords: Maize, plant density, defoliation, grain yield, fodder yield.

INTRODUCTION

Maize (*Zea mays* L.) ranked the third, as a cereal crop, after wheat and rice (FAO, 2019). It is a multipurpose crop for production of food (for humans) and feed (for animals) in addition to being used in different industrial products.

Modification of morphological and physiological plant traits to favor plant growth will enhance plant growth performance. Such modifications can be through changes in maize microenvironment which can be altered with the use of different population densities and practices applied to the crop (as manual defoliation of maize leaves). Maize plant density more than optimum may expose maize plants to crowding severity, mutual shading and reduction in light interception as well as photosynthesis and photoassimilates production that are responsible for yield (Sinclair and Gardner, 1998). Hashemi *et al.* (2005); Gomaa *et al*. (2019) and Duan *et al*. (2023) stated that increasing plant density above the optimum population decreased number of grains per ear and grain weight. Moreover, plant density over the optimum may lead to increase in barren plants number which will reduce the grain yield per unit land area (Imran *et al.*, 2015; Absy & Abdel-Latif, 2020 and Djaman *et al*., 2022). In addition, Edmeades & Lafitte (1993); Assefa *et al.* (2016); Battaglia *et al.* (2018); LiChao *et al.* (2018) and Thomason & Battaglia (2020) reported that improving crop productivity through higher plant density requires understanding of how plants respond to increased intraplant competition. They also added that population more than optimum increased plant height and decreased leaf area index (LAI).

In Egypt, where green fodder is insufficient in summer season and the inability of small farmers to plant a sole fodder crop, farmers tend to defoliate maize plants by removal of maize leaves as a fodder source for live stock. Degree of defoliation severity on maize growth performance, as reported by Fasae *et al.* (2009), is related to the allocation of leaves on the stem and to defoliation time.

Allison and Watson (1966) stated that the middle five leaves (the ear leaf in addition to two above and the two below the ear) contributed, approximately, to 50 % of the yield. Barzegari (1996) and Lauer *et al.* (2004) showed that the five leaves below the ear moved greater amount of assimilates to the ear grains. Proper time of defoliation without reduction in grain yield is necessary for maize to provide enough fodder yield. As for leaves

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allocation, there is an important role of leaves below the ear in enhancement of maize traits (Jahan *et al*., 2022). Barimavandi *et al.* (2010), Khaliliaqdam *et al.* (2012) and Testa *et al.* (2016) reported that the leaves below the ear move greater part from photosynthesis products to roots leading to a feed back that increases the uptake of growth resources, photosynthesis, crop growth rate and yield potentiality.

This study aimed at the investigation of maize response to plant population density and to determine the proper time of defoliation of below- ear leaves that produces sufficient fodder yield with insignificant grain yield reduction.

MATERIALS AND METHODS

A two-year field study was conducted during 2021 and 2022 summer seasons at the Agricultural Research Station, Alexandria University, Egypt. That investigation aimed at the examination of maize growth performance under the effect of three plant densities and four defoliation dates. Soil physical and chemical analysis (as an average of the two seasons) are shown in Table (1). A split-plot design with three replicates was used during the two seasons. Plant densities occupied the main plots, whereas, the subplots were assigned to the time of defoliation. Each experimental unit was of area 10.8 m^2 including six ridges, each 3 m long and 0.7 m wide. Plant population densities were 48000 (P_1), 57600 (P_2) and 72000 (P_3) plants/ ha., as maize was, respectively, grown at 20.0, 25.0 and 30.0 cm between hills and thinned to one plant per hill after 21 days from sowing (21 DAS).

Defoliation of all the leaves below the ear-leaf was performed after 60 (D_1), 75 (D_2) and 90 (D_3) days after sowing in comparison with non defoliation (D_0) treatment. Defoliated leaves were weighed (on plot basis) and transformed into ton/ ha green fodder. Sowing date was May 10^{th} during the two successive seasons. All other agricultural practices were uniformly applied according to the region recommendations.

At harvest, guarded plants of the inner four ridges of each plot were taken to determine the studied characters which included maize plant height (cm), ear leaf area (cm^2), ear weight (g),100-grain weight (g) and grain yield (ton/ ha), in addition to forage yield.

All statistical procedures (comparison of means and regression analysis) were conducted according to Gomez and Gomez (1984). Comparison of means were carried out at the 0.05 level of probability.

RESULTS AND DISCUSSION

Results for the analysis of variance (Table 2) indicated that all studied traits were significantly, or highly significantly affected by maize population density (P) and defoliation time (D) in both seasons. Moreover, the interaction between studied factors (P*D) was significant for all studied traits except plant height, 100-grain weight and leaves yield per ha in the two season and grain yield/ha in the first season.

Data in Table (3) indicated that with the increase in density, there was an increase in plant height over the two seasons. The mean values for plant height were 292.08, 298.25 and 303.0 cm in the first season, corresponding to 280.8, 296.3 and 308.8 cm in the second season, for P_1, P_2 and P_3, respectively.

Table 1. Soil physical and chemical properties as an average of the two seasons.

Physical properties		**Chemical properties**	
Sand %	56.25	pH	8.13
Silt %	10.75	EC (dS/m)	1.55
Clay %	33	Ca^{2+} (meq/ L)	4.43
Texture	Sandy clay loam	Mg^{2+} (meq/ L)	3.39
Nutritional properties		Na^+ (meq/ L)	9.96
Av. N (ppm)	307.00	K^+ (meq/ L)	0.58
Av.P (ppm)	16.20	Cl^- (meq/ L)	6.44
Av. K (ppm)	470.50	CO_3^{2-} (meq/ L)	1.28
Organic matter (%)	2.12	HCO_3^- (meq/ L)	2.42
Micro nutrients		SO_4^{2-} (meq/ L)	8.22
Av. Cu (ppm)	3.53	$CaCO_3$ (%)	8.55
Av. Fe (ppm)	4.79	SAR	5.38
Av. Mn (ppm)	4.62		
Av. Zn (ppm)	1.86		

Increases in maize plant density increased between plants both mutual shading and intracompetition for light which led to stems internodes and plant height increases (Gardner *et al*., 1985, Echarte *et al.*, 2006 and Song *et al*., 2016). These results were in agreement with those reported, with regard to the effect of plant density, by Greveniotis *et al.* (2019) and Absy and Abdel-Latif (2020).

Data in Table (3) further showed that there were significant variations between plant densities for ear leaf area in both seasons. The P_1 density gave the largest value for such trait (724.6 cm^2) followed by P_2 (708.95 cm^2) that was 16.66 cm^2 greater than the P_3 density, as an average of both seasons. LiChao *et al*. (2018) and Duan *et al.* (2023) reported that the extension of maize leaves (length and width) responded to the changes of maize density where the increase in plant population decreases the ear leaf area and vice versa. Increases in plant density was associated with a decrease in leaves light interception due to increase in among plants crowding density along with the plants intracompetition for light and hence a reduction in photosynthesis and photoassimilates production and translocation to the ears (Sinclair & Gardner, 1998 and Fageria *et al*., 2006).

Responses of 100-grain weight to the different densities were significant and were found to be greater for P_1 (32.99) than either P_2 (31.58) and P_3 (30.33) as an average of the two seasons.

These results were agreement with Subedi *et al.* (2006); Zamski & Schaffer (2017) and Duan *et al*. (2023), who reported that the more the plant density, the lesser 100-grain weight was obtained. As shown in Table (3), there was a reciprocal relationship between the plant density and 100-grain weight. That can be due to decreases in light and growth resources uptake by the individual plants (as plant density increased), leading not only to a decline in photoassimilates production and translocation to the ear, but also to a decrease grain weight (Fageria *et al*., 2006).

Mean values in Table (3), also, showed a significant response of the ear grain weight to maize population densities in both seasons. The increase in ear grain weight was disproportion to the densities increase along with the statistical equality for such trait among P_1 and P_2 densities in the second season. Maize plants grown at P_1 density were 3.5 and 0.83 g greater than those grown under P_2 and P_3 treatments in 2021 season, and were 2.84 and 7.0 g greater in the second season, respectively. Greater photoassimilates supply to ears of P_1 plants, compared to P_2 and P_3, during grain filling stage increased grain weight with corresponding increase in ear grain weight as a total (Ransom and Endres, 2013). Testa *et al*. (2016) reported a close relationship between plant density and photoassimilates harvested portion in grains of the ear, and concluded that the more plant population produced lower ear grain weight, compared to lower densities. It could be concluded that increase in ear leaf area might have been associated with increase in photo assimilates production that increased ear grain weight (Nawar, 2004).

Grain yield/ ha (Table 3) revealed an inverse trend to that of ear grain weight and 100-grain weight over the two seasons. That means that maize grain yield was directly related to the rate of plant density applied; the maximum grain yield value of 5.26 ton/ ha. was obtained from P_3 in the first season, however the minimum yield (4.27 ton/ ha), was obtained from P_1 population in the second season. This finding indicated that, despite decline in maize yield attributes (100-grain weight and ear grain weight), there were increase in grain yield/ ha, with the increase in plant density. Such direct response of maize plants to increases in maize density assumed the compensation effect of increased plant stand for the reductions in yield attributes. Results were in agreement with those reported by Testa *et al*. (2016) who found that with the increase in plant population density, there was an increase in the crop yield. Maddonni & Otegui (2006) and LiChao *et al.* (2018) declared that intraspecific competition is closely related to increased plant density for below ground resources (e.g., water and nutrients), above ground resources (e.g., light), or both.

They also added when plant density increased, the resource availability for individual plants decreased and population competitive density increased resulting in decreases in plant grain yield. They attributed such decreases to a decrease, in 1000-kernel weight with a decline in ear grain weight.

The P_2 and P_3 treatments are statistically equal and superior to P_1 in the weight of below ear fresh defoliates over the two seasons. Maximum stand of P_3 had greater increase in leaves fresh fodder by 0.10 and 0.39 ton/ ha., compared to P_2 and P_1, respectively, as an average of the two seasons. Increasing maize stand (number of plants/ ha) along with weeds suppression (due to higher shade of the ground area) increased plants growth resources uptake and photoassimilates translocation into the plants leaves, leading to the increase of P_3, compared to P_1 and P_2, in such traits, along with a higher number of leaves harvested from the higher density (Fasae *et al.*, 2009). Andrews and Kassam (1976) showed that increase in plant density increased leaves number per unit area with an increase in fresh fodder yield.

Table 2. Analysis of variance for studied maize characters in 2021 and 2022 summer seasons

S.O.V.	d.f	Plant height (cm)		Ear leaf area (cm^2)		Ear grain weight (g)		100-grain weight (g)		Grain yield (ton/ ha)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Rep	2	280.44	629.36	2706.25	3117.36	80.52	46.36	34.56	0.194	1.58	1.47
P	2	359.52**	2346.52**	3664.58**	2744.44**	103.44**	76.77**	5.33**	63.86*	19.33**	18.30**
Error (a)	4	5.08	8.73	27.08	2.77	1.44	2.86	0.270	4.81	0.022	0.025
D	3	1491.11**	1237.96**	4546.99**	3863.65**	208.39**	95.77**	109.83**	72.32**	8.48**	6.25**
P*D	6	6.97	31.33	555.32**	699.07**	13.25**	3.44*	1.83	0.490	0.223 n.s	0.235*
Error (b)	18	21.85	16.35	38.65	48.37	3.25	1.25	0.923	0.240	0.101	0.092

S.O.V.	d.f	Leaves yield (ton/ ha)	
		2021	2022
Rep	2	0.045	0.125
P	2	0.501**	0.148*
Error (a)	4	0.005	0.013
D	2	0.780**	0.952**
P*D	4	0.024 n.s	0.055 n.s
Error (b)	26	0.0101	0.024

*, **: significant at 0.05 and 0.01 probability levels, respectively.

n.s.: not significant

Table 3. Means of the studied characters of maize as affected by plant density and below ear leaves times of defoliation in 2021 and 2022 seasons

Levels	Plant height (cm)		Ear leaf area (cm^2)		Ear grain weight (g)		100-grain weight (g)		Grain yield (ton/ ha)		Leaves yield (ton/ ha)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Plant density (plant/ ha)												
P1= 47600	292.08	280.8	729.58	719.58	270.58	269.5	31.83	34.15	4.35	4.27	2.86	2.88
P2= 57000	298.25	296.93	716.66	701.25	267.08	266.66	31.16	32.00	4.89	4.75	3.21	3.11
P3= 71400	303.00	308.08	695.00	689.58	269.75	262.50	30.50	30.16	5.26	5.16	3.31	3.21
$L.S.D._{0.05}$	4.40	3.35	5.89	6.88	1.36	1.91	0.59	2.48	0.17	0.18	0.10	0.15
Defoliations:												
D0 = No defoliation	312.33	311.11	728.88	718.66	273.77	270.77	35.00	35.44	5.20	5.04	-	-
D1= 60 DAS	284.11	286.11	681.11	673.88	263.44	263.44	26.94	27.66	4.42	4.28	2.83	2.77
D2 = 75 DAS	298.33	297.22	716.66	704.44	264.00	269.00	29.94	30.63	4.88	4.68	3.13	3.02
D3 = 90 DAS	304.33	302.22	728.33	716.88	272.33	271.33	32.77	33.22	5.03	4.91	3.42	3.41
$L.S.D._{0.05}$	15.63	13.91	4.00	3.14	1.92	1.29	2.95	2.49	0.31	0.30	0.103	0.16

Table 4. Means of maize traits as affected by the plant density * defoliation time interaction in 2021 and 2022 summer seasons.

Levels		Plant height (cm)		Ear leaf area (cm^2)		Ear grain weight (g)		100-grain weight (g)		Grain yield (ton/ ha)		Leaves yield (ton/ ha)	
Plant density	Defoliations times	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
P_1	D_o	307.66	293.33	761.66	753.33	276.66	272.66	35.00	38.00	4.72	4.62	--	--
	D_1	278.66	275.00	698.33	680.00	265.33	263.00	27.17	31.00	3.92	3.87	3.02	2.88
	D_2	285.33	273.33	720.00	711.66	269.00	268.33	31.50	34.00	4.17	4.10	3.26	3.17
	D_3	296.66	281.66	738.33	733.33	271.33	270.00	33.66	36.00	4.58	4.47	3.66	3.60
P_2	D_o	312.00	310.00	711.66	701.66	274.66	270.00	35.33	35.33	5.18	4.96	--	--
	D_1	283.33	290.00	688.33	685.00	262.33	263.33	26.66	28.00	4.60	4.56	2.95	2.73
	D_2	290.66	285.00	726.66	695.00	261.00	264.66	29.33	31.66	4.76	4.62	3.20	2.95
	D_3	307.00	300.00	740.00	723.33	270.33	268.66	33.33	33.00	5.02	4.87	3.47	3.35
P_3	D_o	317.33	330.00	713.33	695.00	270.00	266.66	34.66	33.00	5.72	5.54	--	--
	D_1	290.33	295.00	656.66	656.66	262.00	260.00	27.00	27.00	4.74	4.71	2.53	2.70
	D_2	295.00	300.00	703.33	706.66	262.00	263.33	29.00	30.00	5.10	5.02	2.93	2.95
	D_3	309.33	310.00	706.66	700.00	264.33	264.00	31.33	30.66	5.49	5.36	3.13	3.30
$L.S.D._{0.05}$		n.s.	n.s.	10.66	11.93	3.09	1.92	n.s.	n.s.	n.s	0.52	n.s	n.s

n.s.: not significant

In addition to all above mentioned studies regarding the response of maize traits to plant density, Irmak *et al.* (2015); Sher *et al.* (2017) as well as Li *et al.* (2019) and Duan *et al.* (2023) reported that there was a decrease in thousand and ear grain weights, and increase in stem height and grain yield/ ha with the highest plant densities.

The response equation of grain yield to plant density and also that of leaves fodder yield to the time of defoliation can be described as shown in Figures (1 to 8) in 2021 and 2022 seasons. The figures showed that the quadratic response was indicative of the response of grain yield to the studied factors levels. The computed r^2 values for the response of yield to plant density were nearly 1.0 indicating that 100 % of the total variation in the mean yields was explained by the plant density.

The negative quadratic coefficient indicated that increase in plant density level above 57000 plants/ ha, would cause a progressive decrease in the rate of yield increase until arrival at the optimum population density (66667 in the first season and 58823 plants/ ha., in the second season). Irmak & Djaman (2016) and Djaman *et al.* (2022) showed a strong quadratic relationship between maize grain yield and plant density where r^2 reached 100 % during the two seasons of their study. Assefa *et al.* (2016); Qian *et al.* (2016); LiChao *et al.* (2018) and Dajaman *et al.* (2022) reported that grain yield showed a curvilinear response to plant density producing higher values at the optimum density which had lower intraspecific competition compared to the highest population density.

With regard to defoliation times, means of the studied characters, i.e., plant height, ear leaf area, ear and 100-grain weights as well as grain yield/ ha, of maize crop are presented in Table (3).

Data showed significant or highly significant responses of maize traits to defoliation over the two seasons. The D_0 and D_3 treatments were statistically equal for such traits over the two seasons. Meanwhile, differences of those traits between D_0 with each of D_1 and D_2 were also significant in 2021 and 2022 seasons. Variations among those traits were affected by the lag time between defoliation date after sowing and maize physiological maturity, since the greater lag time was associated with a greater decline in values of the above mentioned traits over the two seasons. Barimavandi *et al.* (2010); da Silva & Dalchiavon (2020) and Thomason & Battaglia (2020) reached the previously mentioned findings for maize plant height response to the defoliation time of leaves below the ear. Emam *et al.* (2013) and Battaglia *et al.* (2018) concluded that removal of maize leaves below the ear was accompanied with a redistribution of photoassimilates stored in the leaves and stem leading to a decrease in their weights as well as a decrease in ear leaf area and maize stem height. da Silva & Dalchiavon (2020); Yan *et al.* (2021) and Jahan *et al.* (2022) reported that maize plants of full number of leaves, under suitable growth conditions, produced more photoassimilates than maize plants stressed by below ear leaves removal. That was associated by assimilates movement to the ear which increased the 100-grain and ear grain weights which were followed by the increase of maize yield.

Heidari (2012) and Jahan *et al.* (2022) showed a negative response of ear and grain yield to maize defoliation indicating that defoliation resulted in a decrease in photoassimilates products and translocation to ear attributes with a decrease in grain yield and yield components. They also added that the degree of severity defoliation of increased with the proximity of the time of defoliation to maize maturity date.

Defoliating maize below the ear leaves at 60 DAS produced lower forage yield over that two seasons, compared to 75 and 90 DAS forage yield. That might be attributed to the removal of the leaves at early vegetative growth. This was in agreement with Crookston and Hicks (1988) who reported that early defoliation of maize led to a fodder reduction. The increases in time of defoliation at D_2 gave higher fodder yield than the yield of D_1, but was lower than D_3 yield in both seasons. These results show that the shorter the period from sowing to defoliation the lower yield obtained from fresh forage. These results were in agreement those obtained by Fasae *et al.* (2009). According to the data, it may be suggested that the defoliation period from 60 DAS to physiological maturity (105 DAS) could be classified into 3 categories:

I- 90-105 DAS period: There was no effect an grain yield and yield components since the maize plants reached the phase of complete grain formation and the beginning of ear drying.

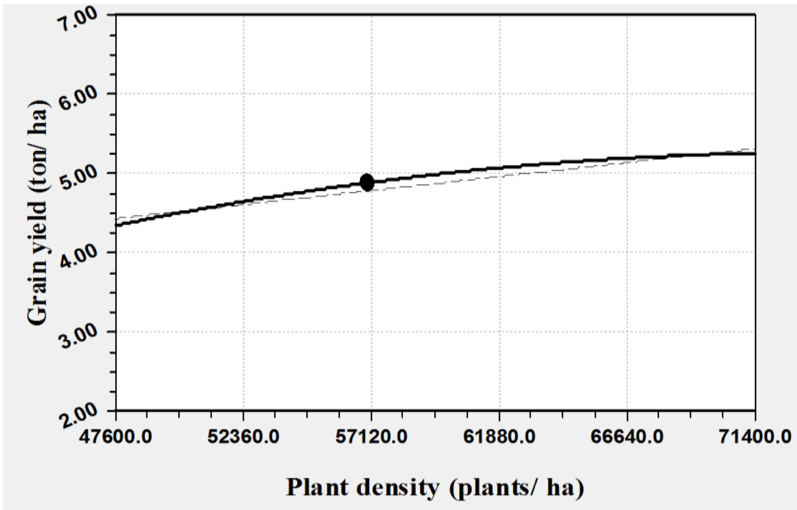
II- 75-105 DAS period: In this period, grain yield will be reduced significantly due to reduction in grain weight resulting from lower transport of assimilates to the grain.

III- 60-105 DAS period: During this period, grain yield will be significantly reduced due to smaller ear formation and lower grain weight as a result of leaves removal prior to the reproductive stage and ear formation.

Fasae *et al.* (2009) reported significant effects on grain and leaves yield with maize defoliation before 84 DAS, while delaying defoliation after that date had insignificant effect on grain yield. Mutetikka & Kyarisiima (1997) and Fasae *et al.* (2009) reported significant reductions in the leaf and grain yields with early defoliation.

Differences in the ear leaf area below defoliation of maize plants * plant density interaction were significant in both seasons (Table 4). The least value for this trait was obtained from the D_1P_3 level in comparison with the maximum record value of such trait with application of D_3P_2 combination.

Also, data in Table (3) showed that there were significant differences between P_2 and P_1 in grain yield/ ha., while the differences were insignificant between P_2 and P_3, as an average of time of defoliation in both seasons. Over the two seasons, the maximum and minimum grain yields/ ha., were, respectively, obtained from P_3D_0 and P_1D_1 interaction levels. The increase in leaf area index of the P_3 zero defoliation treatment increased photoassimilates production and translocation to grains of ear leading to an increase in the ear weight and finally in the grain yield/ ha (Sinclair and Gardner, 1998). Furthermore, data revealed that, under all plant densities, the longer time of defoliation, the higher amount of fresh leaves yield in both seasons, though differences were not statistically significant P_1 interacted with D_3, maize fodder yield reached the maximum, corresponding to the minimum of P_3 and D_1 combination over the two seasons.

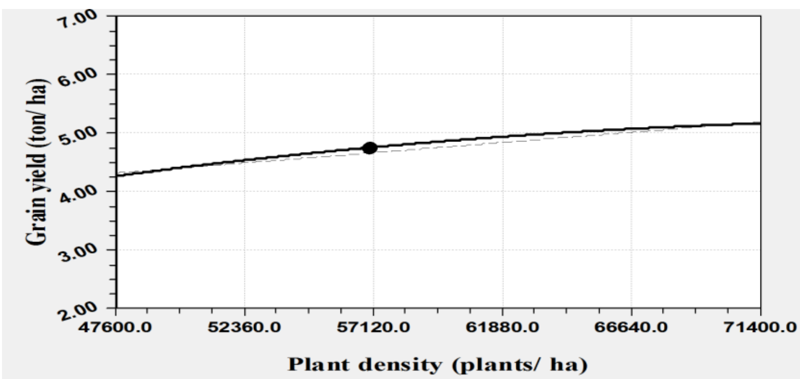


Linear: $\hat{Y} = 2.65 + 3.7 * 10^{-5}$ $r^2 = 0.94$

Quadratic: $\hat{Y} = -2.004 + 0.000019\ X - 1.33*10^{-9}$ $r^2 = 1$

Optimal level : 52631 plants/ ha

Fig. 1. Linear and quadratic responses of grain yield to plant density in 2021 season

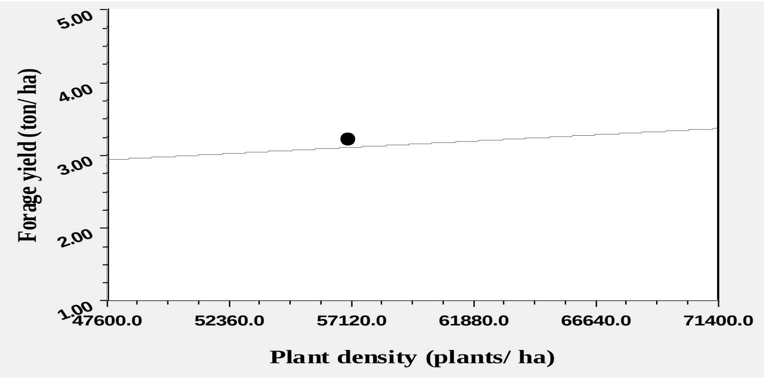


Linear: $\hat{Y} = 2.57 + 3.66*10\text{-}5$ $r^2 = 0.96$

Quadratic: $\hat{Y} = -0.73 + 0.000015\ X - 9.49*10^{-10}$ $r^2 = 1$

Optimal level: 66667 plants/ ha

Fig. 2. Linear and quadratic responses of grain yield to plant density in 2022 season

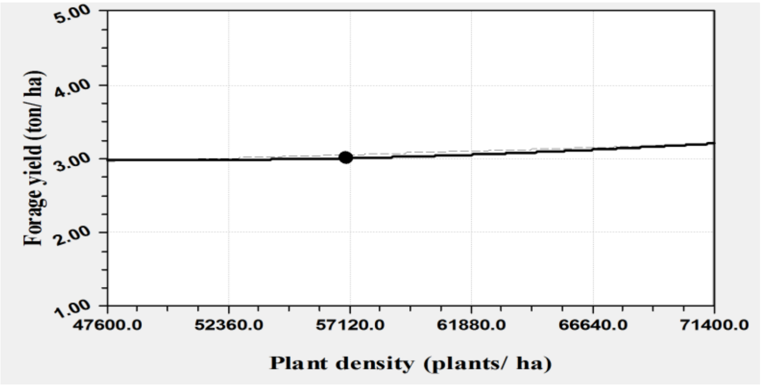


Linear: $\hat{Y} = 2.07 + 1.79*10\text{-}5\ X$ $r^2 = 0.81$

Quadratic: $\hat{Y} = -2.36 + 0.000017\ X – 1.27*10^{-9}\ X^2$ $r^2 = 1$

Optimal level: 58823 plants/ ha

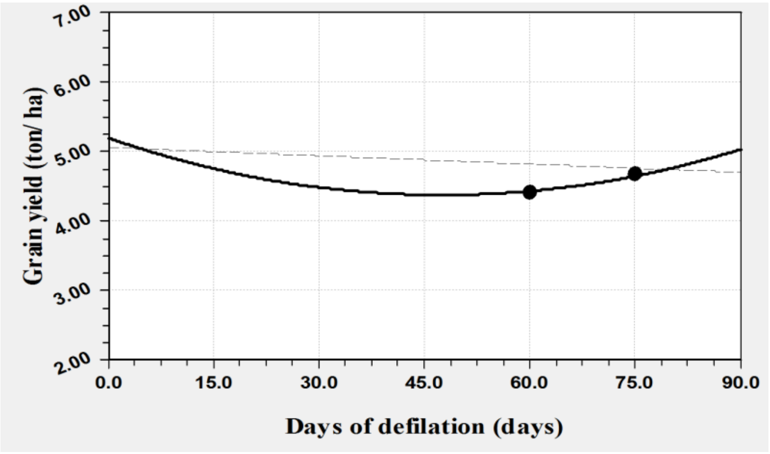
Fig. 3. Linear and quadratic responses of forage yield to plant density in 2021 season



Linear: $\hat{Y} = 2.47 + 1.00*10^{-5}\ X$ $r^2= 0.92$

Quadratic: $\hat{Y} = 4.04 – 4.38*10^{-5}\ X + 4.49*10^{-10}X^2$ $r^2 = 1$

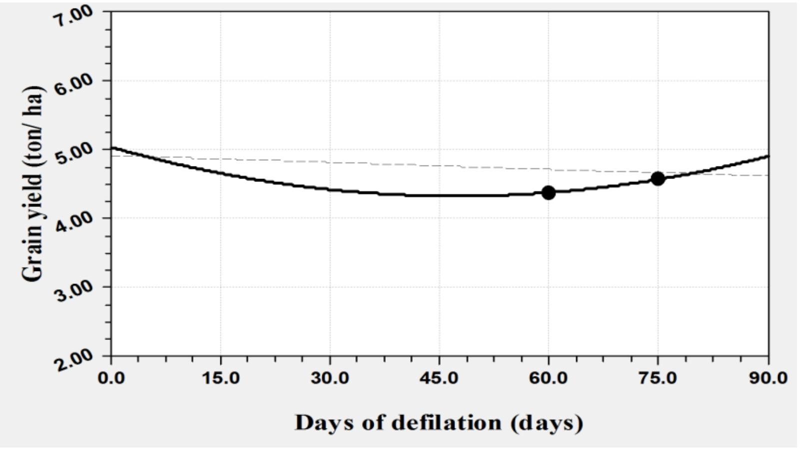
Fig. 4. Linear and quadratic responses of forage yield to plant density in 2022 season



Linear: $\hat{Y} = 5.05 – 0.0039\ X$ $r^2 = 0.19$

Quadratic: $\hat{Y} = 5.19 -0.03\ X + 0.0003$ $r^2 = 0.98$

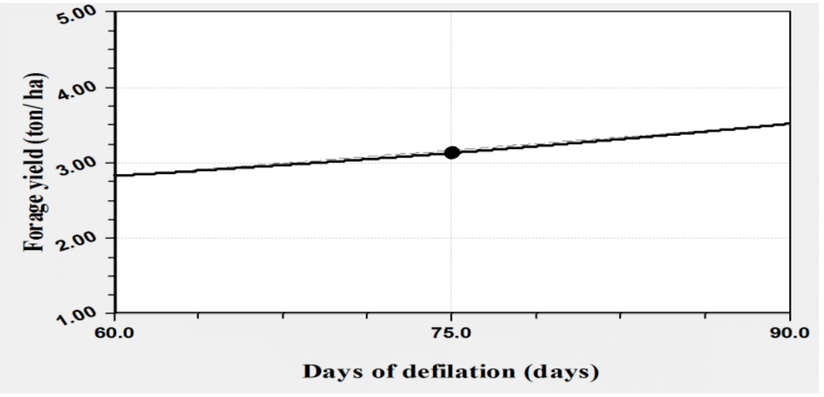
Fig. 5. Linear and quadratic responses of grain yield to time of defoliation in 2021 season



Linear: $\hat{Y} = 4.91 - 0.0003\ X$ $r^2 = 0.18$

Quadratic: $\hat{Y} = 5.03 - 0.003\ X + 0.0003X^2$ $r^2 = 0.98$

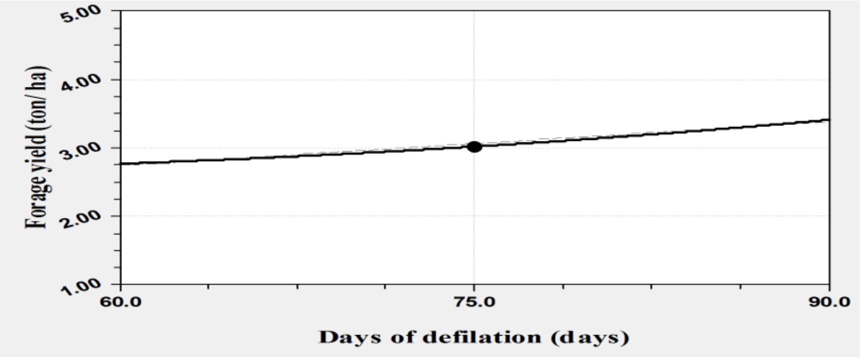
Fig. 6. Linear and quadratic responses of grain yield to time of defoliation in 2022 season



Linear: $\hat{Y} = 1.43 + 0.023\ X$ $r^2 = 0.98$

Quadratic: $\hat{Y} = 2.53 - 0.007\ X + 0.0002\ X^2$ $r^2 = 1$

Fig. 7. Linear and quadratic responses of forage yield to time of defoliation in 2021 season



Linear: $\hat{Y} = 1.46 + 0.02\ X$ $r^2 = 0.98$

Quadratic: $\hat{Y} = 3.17 - 0.025\ X + 0.0003\ X^2$ $r^2 = 1$

Fig. 8. Linear and quadratic responses of forage yield to time of defoliation in 2022 season

That may be due to a decrease in plant leaves green area with D_1 defoliating level and with an increased mutual shading of P_3 density which increased maize plants intracompetition for light and nutrients and that was associated with a decrease in fodder yield/ ha (Fasae *et al*., 2009).

The r^2 values for the maize fodder yield response to the below ear leaf defoliation time were, also, nearly one in the two seasons showing that total variations in fodder yield are attributed to the quadratic response to the time of defoliation. The computed r^2 values for the response of fodder yield to time of defoliation for the leaves below the ear were aground one in both seasons indicating that the total variations in the mean fodder yields was explained by the time of defoliation. The positive quadratic coefficient indicated that the arrival at defoliation time 90 DAS produced the maximum fodder yield potentiality and the increase in time of defoliation would cause a progressive increase in the rate of fodder yield until the arrival of maize to maturity during the two seasons.

In conclusion, the results obtained from the present study indicated that determination of proper time for leaf defilation of maize at higher plant density, that may cause insignificant redaction in grain yield, may encourage farmers to use maize as dual purpose crop for human food and animal feed.

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الملخص العربي

سلوك الذرة الشامية تحت مستويات مختلفة من الكثافة النباتية وميعاد التوريق

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أجريت تجربتان حقليتان فى الموسم الصيفى لعامى ٢٠٢١، ٢٠٢٢ فى محطة البحوث الزراعية، جامعة الإسكندرية، جمهورية مصر العربية، لدراسة استجابة بعض صفات النمو والإنتاجية للذرة الشامية (صنف جيزة ١٦٨) لثلاث كثافات نباتية (٤٦٦٠٠، ٥٧٠٠٠، ٧١٤٠٠ نبات/ هكتار) وأربعة مواعيد لإزالة الأوراق (D_0= بدون إزالة الأوراق، D_1, D_2, D_3= إزالة الأوراق بعد ٦٠، ٧٥، ٩٠ يوم من الزراعة). وقد أوضحت النتائج أن إنتاج العلف الأخضر من الأوراق التى تم توريقها كان مرتبطاً بموعد التوريق والكثافة النباتية حيث أن أعلى محصول للأوراق تم الحصول عليه من أعلى كثافة نباتية والتوريق على ٩٠ يوم (٣,٦٦ و ٣,٦٠ طن/ هكتار فى موسمى ٢٠٢١ و٢٠٢٢ على التوالى) بينما نتج أقل محصول للأوراق (٢,٥٣ و٢,٧ طن/ هكتار) من أقل كثافة نباتية عندما كان التوريق عند ٦٠ يوم. كما أوضحت الدراسة أن محصول الحبوب كان دالة لكل من ميعاد التوريق والكثافة النباتية حيث نتج أقل محصول من أقل كثافة نباتية والتوريق عند ٦٠ يوم (٣,٩٢ و٣,٨٧ طن/ هكتار) بينما تم الحصول على أعلى محصول حبوب من عدم التوريق فى حالة أعلى كثافة نباتية (٥,٧٢ و٥,٥٤ طن/ هكتار) فى موسمى ٢٠٢١ و٢٠٢٢ على التوالى، وهذا المحصول كان إحصائياً مساوياً لمعاملة التوريق عند ٩٠ يوم لنفس الكثافة النباتية. وقد أوضح تحليل الارتداد من الدرجة الثانية (غير خطية) أن الكثافة المثلى أعطت محصول حبوب يقل عن الناتج من أعلى كثافة نباتية مستخدمة، وهذا يوضح أهمية تقدير الزيادة فى المحصول فوق الكثافة النباتية المثلى وعلاقتها بالعائد الاقتصادى من وحده المساحة.

تشير نتائج هذه الدراسة إلى أن الميعاد المناسب لتوريق الذرة الشامية عند الكثافة النباتية العالية، بدون نقص معنوى فى محصول الحبوب، يشجع على زراعة الذرة الشامية كمحصول ثنائى الغرض كغذاء للإنسان وعلف للحيوان.