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Evaluating the Performance of the Lines and Their Half Diallel Cross in Maize (Zea mays L.) Under Plant Density

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Abstract. Two field experiments were conducted during spring and autumn season of 2020, which were carried out at the Research Station of the College of Agriculture, Anbar University, in the first season The lines were introduced into the Half Diallel cross-program according to the second method proposed by [24]. the second season the experiment was applied during the autumn season of 2020 in a split-block arrangement according to a randomized completely -block design with three replications. The main block included the plant density, which was expressed through the distance between the holes. While the secondary block occupied the genotypes (lines + crosses). The results of the analysis showed that there were significant differences between densities and genotypes.The cross 3 × 5 was distinguished by giving the least number of days to tasseling. It also gave the highest plant height 188.60 cm, number of rows / heads 15.5, and the highest yield 19.54 tons / hectare. The cross 1× 5 showed the highest leaf area 5925 cm, while the cross 4×5 and 3×4 showed the highest average number of kernels / row 39.33 and 38.97. The cross 1×4 also distinguished with the highest weight of 300 grains. Cultivated plants with a density 62,500 plants / hectare were distinguished by giving them the fewest days to flower, the highest plant height, leaf area, number of rows, number of grains / row and weight of 300 grains. While the yield was low at 14.93 compared to the plants that cultivated at a density of 125,500 plants / hectare, the reason for this is that the increase in the number of plants per unit area was replaced by the decrease in the yield components.

1. Introduction

The plant density has a great influence on the growth and yield of corn, the difference in the competitiveness of plants at higher densities [**1**]. Plant growth and increase it needs ideal plant densities that enable it to make optimal use of nutrients and water in the soil and intercept the best light in addition to the availability of other growth factors affecting the growth of plants. *Duvick* [**2**] Suggested that the best way to affect future gains in yielding ability may be to make further improvements in tolerance to high plant densities, in combination with improvements and potential yield per plant under low stress environments. *Fasoula &Fasoula* [**3**] emphasized the importance of low stress conditions example (very low plant density, so that competition among plants is avoided) in optimizing the effectiveness of selection foreign approved potential yield per plant tolerance to stresses and responsiveness and inputs. Maize yield increases across different plant density conditions were associated with greater ear sink strength (kernel weight and number) during reproductive development [**4**]. The kernel weight component has been found to be more related to the yield increases than to kernel number, and was associated with a longer grain-filling period, improved biomass remobilization during reproductive development, enhanced stress tolerance to N loss, and higher plant densities [**5**]. Researchers recently suggested that per-plant yield potential remains unchanged while performance of maize hybrids in high plant density improves, even if these two traits (per-plant yield and density tolerance) are not antagonistic. *Duvick* [**6**] suggested that half of the yield improvement is due to improved management and the other half to crop breeding. Recently, *Tollenaar et al,*[**7**] discussed the corn yield improvement factors as technological (genetics and management) versus nontechnological (weather-based changes), concluding that solar brightening contributed about 27% of corn yield trend from 1984 to 2013.

Planting at the agronomic optimum plant density AOPD is among one of the most critical management decisions for maize production because modern hybrids on average have one productive ear per plant and hardly tiller even with an occasional abundance of resource [**8, 9**]. Plant density directly limits the crop yield for a given environment when all the other conditions for crop growth are met [**10**]. Maximum yield can be achieved with appropriate management when the plant density allows rapid development of the leaf canopy to attain maximum leaf area index (LAI) [**11, 12**]. Increasing planting density is required to increase grain yield production in maize. The average density of intense maize cultivation in the USA is 97,500 plants.ha^{1} [13]. The recommended planting density in Iraq is 66.666 plants. H., which is low the amount used in the USA. The use of lower plant densities decreases light interception, leading to high grain production per plant but low grain production per unit area [**14**]. The impact of plant density on yield is dependent on complex interactions between genotype (G), environment (E), and management (M) factors (G × E × M). [**15**] evaluated five management factors that contributed to decreases in the maize yield gap (attainable minus actual yield) and concluded that plant density increased yield only when other management factors (e.g., transgenic insect resistance, fungicides containing strobilurin, N-P–S–Zn fertility) were jointly applied. Previous studies also suggested that the AOPD varied relative to water supply [**16**], soil type [17] and hybrid [**18**]. Following this rationale, it is essential to isolate the plant density contribution to yield gain, while acknowledging that changes in plant density itself is part of the complex G × E × M interactions. Thus, any investigation geared to identify the sole contribution of plant density over time needs to consider comparison of events at similar environments or yield changes at similar plant density levels.

Many researchers studied the response of varieties or genotypes when cultivating them under different plant densities [**19, 20, 21, 22, 23**]. This research aims to determine the best genotypes for a number of phenotypic traits resulting from crossing of a number of lines under a plant density.

2. Materials and methods

2.1. Season 1

A field experiment was conducted during the spring season of 2020, which carried out at the Research Station of the College of Agriculture, Anbar University, Hamziya region. The experiment soil was plowed, leveled, and divided into rows of 5 m in length and 0.75 m in width, with two rows for each line. The seeds of the lines were planted manually on 1/3/2017 inside a hole in the row. Hybridization was performed between the lines, which were derived locally, the following symbols were given (L1= **BK 116** , L2= **Zm 6**, L3= **ABS 6**, L4= **BK 104**, and L5= **Inb-27**). The lines were introduced into the Half Diallel cross-program according to the second method proposed by [**24**]. At the end of the season, the heads of the genotypes were harvested and then dried and discarded the seeds of each separately for planting for the next season. Urea fertilizer N46% was added by 400 kg. h^{-1}was given in two doses, The irrigation process was carried out according to the condition of the plant and soil moisture.

2.2. Season 2

The experiment was applied were conducted during the autumn season of 2020 in a split-block arrangement according to a randomized completely -block design with three replications. The main block included the plant density, which was expressed through the distance between the holes. Two distances were used, the first 10 cm between one hole and another, and the second 20 cm, a symbol of D1, D2, with the distance between one row and another with a distance of 80 cm between the row to give a plant density of 125,500 and 62,500 plants per hectare While the secondary block occupied the genotypes (lines + crosses). Soil service was performed from plowing and leveling, and it was divided into rows of 4 m length, and the distance between rows was 80 cm by two rows for each genotype. The seeds of the lines and their hybrids obtained from the previous season were planting manually on 07/30/2020. Urea fertilizer N46% was added by 400 kg. H^{-1} was given in two doses, and the field was irrigated according to the needs of the plants. Weeding was carried out as needed.

2.3. Studied traits

Five guarded plants were taken randomly for each experimental unit to study the following traits: The number of days from planting up to 50% tasseling (day), Plant height (cm), Leaf area (cm^{2}), Number of grains in a row (grain. Row $^{-1}$), Number of rows / header (row. Head), Average weight of 300 grains (gm) and Plant yield tan.h^{-1}.

2.4. statistical analysis

The data were analyzed statistically according to the experimental design using the analysis of variance to design (RCBD) in the arrangement of the split block, using the statistical program (Genstat) and using the lowest significant difference (LSD) at a probability level of 5% for comparison between the arithmetic means of the studied characteristics [25].

3. Results and Discussion

3.1. Number of days from planting to 50% tasseling

The results of the analysis of variance table (8) showed that there are significant differences between the arithmetic averages, the number of days from planting to 50% tasseling, as a result of the effect of the interactions between (plant density + genotypes). The results of a table (1) showed that the plants that cultivated at a distance of 62,500 plants per hectare were significantly superior if they needed fewer days, 47,689 days to reach tasseling flowering than the plants that cultivated 125,500 plants per hectare. The reason for this is that plants planted in narrow spaces require more days to reach flowering, that this distance leads to giving a dense vegetative growth in the unit area and thus reduces the transmission light during vegetative growth, which leads to an increase in the production of the hormone oxen, which slows the induction of flowering, which leads to increase the time required for flowering and ripening. Also, this work will reduce the temperature of the soil as a result of the deception that it causes, and then the temperature accumulated in the soil in the narrow distances between the holes will be less than it is in the spaced distances between the holes, which leads to a delay in flowering and ripening [**26, 27**] . The genotype H 4×5 took the fewest days to reach the stage of flowering, outperforming the rest of the genotypes.

The same table shows a significant interaction between plant density and genotypes in this trait, as there was a significant increase in the number of flowering days when the number of plants per unit area increased, and it was more evident in Line 1 than in the other genotypes under the influence of plant density of 125,500 plants. Ha, gave the highest rate of 51.00 days.

Table1. mean of the number of days from planting up to 50% tasseling

	Genotypes	D 125500	D 62500	MEAN
1	L1	51.00	48.33	49.67
2	L2	50.00	47.33	48.67
3	L3	50.67	47.33	49.00
4	L4	49.67	48.33	49.00
5	L5	50.67	48.67	49.67
6	H 1×2	48.67	46.67	47.67
7	H 1×3	48.67	47.33	48.00
8	H 1×4	48.33	47.67	48.00
9	H 1×5	50.00	47.67	48.83
10	H 2×3	49.00	47.33	48.17
11	H 2×4	47.67	47.67	47.67
12	H 2×5	49.33	48.00	48.67
13	H 3×4	48.67	47.67	48.17
14	H 3×5	48.00	47.00	47.50
15	H 4×5	48.67	48.33	48.500
	Mean	49.267	47.689	
LSD 5%		Plant Density	Genotypes	Interaction
		0.1912	0.9588	1.356

3.2. Plant height (cm)

The height of a plant in limited growth crops such as maize is determined by the emergence of inflorescence, which is affected by the nature of the genotype and the surrounding environmental factors that have a major influence in causing a change in the amount, intensity and distribution of light on the different vegetative parts, which is clearly reflected in the process of carbonic representation.[1]

The results of the statistical analysis table (8) indicate the presence of significant differences between the genotypes in the characteristic of plant height. The table (2) shows the superiority of the genotype H 3×4 by giving it the highest rate of the trait 188.60 cm compared to other genotypes in which the plants of the genotype L5 gave the lowest plant height 162.51 cm, and this may be due to The genetic differences between them, which were reflected in the difference in their response to the environmental factors (plant density) were reflected in their difference in plant height, as well as the increase in growth period from germination to flowering, as corn is a limited growth crop whose length ends when flowering is complete.

The table shows that the plants with a plant density of 62,500 plants per hectare significantly outperformed them, giving the highest plant height 187.52 than the plants planted with a density of

125,500 plants per hectare (10 cm between a hole), which gave the lowest average of 165.43 cm. The reason for this is attributed to the intensity of competition between plants for light and nutrients as a result of deception, which leads to restricting the action of auxin in elongation, and thus the decrease in plant height, while cultivation at separate distances allowed for the penetration of a large amount of light into the vegetative cover of the plant, which caused an increase in the action of auxins and thus increases the elongation of the product It increases plant height.

The same table shows the existence of a significant interaction between plant density and genotypes in this trait, and the results show that there was a significant increase in plant height when the number of plants per unit area decreased. It was more pronounced in the genotype H 1 × 4, outperforming the other genotypes at plant density of 62,500 plants. Ha, gave the highest average for a characteristic of 202.20 cm.

Table. 2 mean of the Plant height cm^2

	Genotypes	D 125500	D 62500	MEAN
1	L1	152.24	191.53	171.89
2	L2	157.51	185.14	171.33
3	L3	164.79	174.09	169.44
4	L4	172.40	177.69	175.05
5	L5	161.06	163.96	162.51
6	H 1×2	141.18	198.88	170.03
7	H 1×3	142.80	188.03	165.42
8	H 1×4	167.47	202.20	184.84
9	H 1×5	182.78	190.43	186.61
10	H 2×3	180.05	177.45	178.75
11	H 2×4	179.07	181.18	180.13
12	H 2×5	171.67	188.69	180.18
13	H 3×4	177.64	199.56	188.60
14	H 3×5	166.66	199.29	182.97
15	H 4×5	164.11	194.70	179.41
	Mean	165.43	187.52	
	LSD 5%	Plant Density 3.070	Genotypes 3.002	Interaction 4.246

3.3. leaf area (cm^2)

The results of the analysis of variance table (8) showed the presence of significant differences for the study factors. The table (3) showed that the cultivated plants at a plant density of 62,500 plants per hectare, which was distinguished from the cultivated plants, with a density of 125,500 plants per hectare (10 cm between the hole). The reason for the superiority of cultivated plants by a long distance between one plant and another in the leaf area is the decrease in competition between plants for the different growth requirements, which leads to a balance in what is available of these requirements for one plant, which was positively reflected on the size of the leaf area. Some researchers mentioned that the increase in plant density negatively affected the average leaf area of maize plants. The table also shows that there are significant differences between the genotypes in this trait. Genotype H 1×5 surpasses the other genotypes in giving it the highest average leaf area 5925. The reason for this is attributed to the nature of the genes that each genotype carries, which is reflected in its difference in the average length and width of the leaf and the number of leaves in addition to the length of the vegetative growth period. Perhaps the reason for this is that there are differences in leaf area between the different genotypes, which differ in their ability to maintain the carbon representation during its growth period. [**26, 27**]

The same table shows that there is a significant interaction between plant density and genotypes in this trait, the results show that there is a significant increase in leaf area when the number of plants per unit area decreases. It was more pronounced in the genotype H 1 × 2, outperforming the other genotypes, under the influence of plant density of 62,500 plants. Ha, gave the highest average for the characteristic 6382 cm.

Table. 3 mean of the leaf area cm^2

	Genotypes	D 125500	D 62500	MEAN
1	L1	4335	4985	4670
2	L2	4576	5022	4799
3	L3	4607	5490	5048

4	L4	4658	6301	5479
5	L5	4782	5524	5153
6	H 1×2	4921	6382	5652
7	H 1×3	4614	5812	5213
8	H 1×4	4817	6163	5490
9	H 1×5	5662	6188	5925
10	H 2×3	5366	5474	5420
11	H 2×4	4310	6003	5157
12	H 2×5	5543	6032	5787
13	H 3×4	5807	5480	5644
14	H 3×5	5756	5100	5428
15	H 4×5	5058	4569	4814
	Mean	4989	5635	
LSD 5%		Plant Density 330.9	Genotypes 385.4	Interaction 545.0

3.4. The number of rows

The number of rows of the maize crop is one of the important yield components that are determined at the beginning of the formation of the head, and it is one of the genetic traits that are affected by environmental factors, which affects the vegetative growth.

Results in Table (8) and (4) show that there are significant differences between genotypes in the characteristic of the number of rows/ head. The genotype H 3×4 outperformed by giving it the highest rate for this trait, which was 15.5, and it did not differ significantly from genotypes H 3×5 which gave 15.48, surpassing the rest of the genotypes, while L1 genotype gave the lowest rate for this trait 13.33. This may be attributed to the genetic nature of the genotypes and the degree of Affected by different environmental factors (plant density).

The table 4. shows that the cultivated plants with a density of 62,500 plants per hectare (20 cm between the hole) were significantly superior, if they gave 16.062. When the flowers are formed in high plant density and the number of flowering plants formed, it decreases and the amount of this decrease is due to the plant's ability to compete with other plants and the fact that the plants are cultivated with high density suffer from both competition within the same plant and between plants for growth requirements. The same table shows the existence of a significant interaction between plant density and genotypes in this trait, and the results show that there is a significant increase in the number of rows when the number of plants per unit area decreases [1]. It was more pronounced in the H 2 × 4 genotype, outperforming the other genotypes, when the plant density was 62,500 plant/ H., the highest average for the characteristic is 17.16.

Table. 4 mean of the number of rows

	Genotypes	D 125500	D 62500	MEAN
1	L1	12.50	14.17	13.33
2	L2	12.83	15.23	14.03
3	L3	12.44	16.17	14.30
4	L4	12.33	15.50	13.92
5	L5	12.61	14.33	13.47
6	H 1×2	13.97	16.17	15.07
7	H 1×3	14.30	17.00	15.65
8	H 1×4	12.08	16.17	14.12
9	H 1×5	13.00	16.20	14.58
10	H 2×3	14.13	16.03	15.08
11	H 2×4	13.47	17.16	15.32
12	H 2×5	14.13	16.33	15.23
13	H 3×4	14.17	16.83	15.50
14	H 3×5	14.13	16.83	15.48
15	H 4×5	13.33	16.83	15.08
	Mean	13.296	16.062	
LSD 5%		Plant Density 0.2088	Genotypes 0.6156	Interaction 0.8710

3.5. The number of grains / Row

The table (8) analysis of variance shows the presence of significant differences between the genotypes, plant density and interaction between them, and table (5) shows that cultivated plants with a density of 62,500 plants per hectare (20 cm between the hole) significantly outperformed, showing the highest rate of 40.83. This may be attributed to the genetic nature of the genotypes and the degree of affected by different environmental factors (plant density).

The table 5. indicates that there are significant differences between the genotypes in the study for the number of grains in row. Note that the genotype H 4×5 exceeded the number of grains 39.33 and did not differ significantly from the genotypes H 2×5 , H 3×4 and H 3×5 , due to the genetic variation between the genotypes in this study and differences in the number of The flowering inflorescences that formed seeds in the future, and this is due to the influence of the genetic factor and may be due to environmental factors(plant density) during the growing season and its interaction with genetic factors. When the flowers are formed in high plant density and the number of flowering plants formed, it decreases and the amount of this decrease is due to the plant's ability to compete with other plants and the fact that the plants are cultivated with high density suffer from both competition within the same plant and between plants for growth requirements [10,26 and 27]. The same table shows the existence of a significant interaction between plant density and genotypes in this trait, and the results show that there is a significant increase in the number of rows when the number of plants per unit area decreases. It was more pronounced in the H 2×4 genotype, outperforming the other genotypes at density 62,500 plants. H., the highest average for the characteristic is 42.08.

Table. 5 mean of the number of grains / Row

Genotypes		D 125500	D 62500	MEAN
1	L1	31.25	39.08	35.17
2	L2	29.82	41.42	35.52
3	L3	29.92	40.83	35.38
4	L4	31.33	39.58	35.46
5	L5	32.75	40.67	36.71
6	H 1×2	32.25	39.37	35.81
7	H 1×3	31.92	40.83	36.38
8	H 1×4	33.83	41.75	37.79
9	H 1×5	31.83	40.50	36.17
10	H 2×3	34.23	41.42	37.83
11	H 2×4	32.92	42.08	37.50
12	H 2×5	35.92	40.25	38.08
13	H 3×4	36.43	41.50	38.97
14	H 3×5	35.45	41.58	38.52
15	H 4×5	37.08	41.58	39.33
	Mean	33.13	40.83	
LSD 5%		Plant Density 1.557	Genotypes 1.844	Interaction 2.623

3.6. Weight of 300 grains

The results of the analysis of variance indicated that there were significant differences between the arithmetic mean of seed weight. It appeared that the plants that were planted at a distance of 20 cm between the hole (62500 plants ha) exceeded significantly in the weight of 300 seeds and gave 108 grams on the cultivated plants with a distance of 10 cm between the hole table 6 . The reason for this is that the cultivation of plants at close distances, the flowers are in large numbers in each plant, and this leads to competition between inflorescences within the same plant, which leads to a decrease in the efficiency of seed production per flower and the loss in efficiency is large and clear than it is in the spaced distances by producing A high number of seeds and an increase in seed size compared to cultivated plants with higher density. The same table shows the presence of significant differences between the genotypes, as the genotype H 1×4 exceeds in the weight of the grain [27]. The reason for this is due to the genetic nature of its effect on this trait, as well as due to the early flowering and the long period of seed fullness. The same table shows the presence of a significant interaction between plant density and genotypes in this trait, and the results show that there was a significant increase in the weight of grains when the number of plants per unit area decreased. When the crosse. Hectare gave the highest rate of 126.50 gm.

Table. 6 mean of the Weight of 300 grains

	Genotypes	D 125500	D 62500	MEAN
1	L1	81.71	92.03	86.87
2	L2	88.60	95.14	91.87
3	L3	84.40	81.50	82.95
4	L4	84.53	94.95	89.74
5	L5	85.24	93.02	89.13
6	H 1×2	97.16	122.72	109.95
7	H 1×3	102.15	123.39	112.77
8	H 1×4	113.94	125.01	119.48
9	H 1×5	95.74	115.73	105.74
10	H 2×3	87.65	118.83	103.24
11	H 2×4	95.10	100.45	97.77
12	H 2×5	88.00	115.98	101.99
13	H 3×4	95.94	126.50	111.22
14	H 3×5	95.54	117.57	106.56
15	H 4×5	99.26	107.54	103.40
	Mean	93.00	108.69	
LSD 5%		Plant Density 0.826	Genotypes 3.217	Interaction 4.549

3.7. The grain yield tan /H.

The results of the analysis of variance table (8) showed that there were significant differences between the arithmetic means of the grain yield due to the influence of the study factors, the distance between holes and genotypes and the interaction between them. The table 7 shows that the cultivated plants at 125,500 plants per hectare significantly outperformed the yield 17.21 tons per hectare over the cultivated plants at a density of 62,500 plants. Hectare. The reason for the superiority of the cultivated plants by close distances in the yield of the grain is due to the increase in the number of plants per unit area, which compensated for the decrease in the individual plant yield and the yield components for the cultivated plants at low density. The same table showed that there were significant differences between the genotypes of the grain yield, as the genotype 3 × 4 outperformed the other genotypes [26]. The reason for this is due to its superiority in one or more of the yield components (the number of rows and the number of grains / row) despite the fact that the weight of the grain is less than the rest of the other genotypes, in addition to the difference in the nature of the genotype. Significant differences were found for the interaction between the two study factors. The genotype 3 × 4 was cultivated, with a density of 125,500 plants ha, gave a higher grain yield 20.67 tons. Hectare

Table .7 mean of the grain yield /H.

	Genotypes	D 125500	D 62500	MEAN
1	L1	13.35	10.62	11.98
2	L2	14.18	12.51	13.35
3	L3	13.12	11.21	12.16
4	L4	13.68	12.17	12.92
5	L5	14.75	11.31	13.03
6	H 1×2	18.29	16.27	17.28
7	H 1×3	19.48	17.84	18.66
8	H 1×4	19.40	17.57	18.48
9	H 1×5	16.55	15.80	16.17
10	H 2×3	17.76	16.43	17.10
11	H 2×4	17.70	15.13	16.42
12	H 2×5	18.67	15.88	17.28
13	H 3×4	20.67	18.41	19.54
14	H 3×5	20.02	17.13	18.54
15	H 4×5	20.53	15.68	18.11
	Mean	17.21	14.93	

LSD 5%	Plant Density	Genotypes	Interaction
	0.516	1.148	NS

Table. 8 Analysis of variance for yield, yield Components and growth parameters

S.O.V	DF	N.D.T	P.H	L.A	N.G.R	N.R.H.	W300 G.	G.Y
BLOCK	2	5.38	61.29	2613582	6.33	0.327	74.04	274
Plant Density	1	56.01*	10980.8*	9394994.*	1728.0*	172.3*	5543.4*	232955*
ERROR	2	0.44	11.45	133101.	0.18	0.053	0.828	9.6
Genotypes	14	2.78*	368.7*	841880.*	9.52*	3.51*	692.5*	5965.*
INTERACTION	14	1.29*	485.5*	847485.*	9.52*	0.882*	164.1*	818.7*
ERROR	56	0.687	6.74	111012.	5.14	0.284	7.74	126.5

number of days from planting to 50% tasseling (N.D.T), plant height (P.H), leaf area (L.A) , The number of rows(N.R.H.) , The number of grains / Row(N.G.R) , Weight of 300 grains(W300 G.) and The grain yield tan /H. (G.Y)

4. Conclusion

Cultivated plants with a density 62,500 plants / hectare were distinguished by giving them the fewest days to flower, the highest plant height, leaf area, number of rows, number of grains / row and weight of 300 grains. While the yield was low at 14.93 compared to the plants that cultivated at a density of 125,500 plants / hectare, the reason for this is that the increase in the number of plants per unit area was replaced by the decrease in the yield components.

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