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EVALUATION OF INTRODUCED EGYPTIAN MAIZE *(ZEA MAYS* L.) VARIETIES FOR GRAIN YIELD AND YIELD COMPONENTS UNDER DIFFERENT PLANT DENSITIES IN MIDDLE AND WESTERN REGIONS OF IRAQ

Elaf Mustafa Hamood[1], Banan Hassan Hadi[2]

[1,2] Crops Sciences Department, College of Agriculture Engineering Sciences, University of Baghdad, Baghdad, Iraq
[2]Email: b.h.hadi@coagri.uobaghdad.edu.iq

ABSTRACT
Two field experiments were conducted during the FALL season of 2024 at the Baghdad and Anbar locations to evaluate the response of four introduced Egyptian varieties of maize (TW-78E, TW-345E, IY-355E, and IY-207E) compared to two local varieties (Baghdad 3 and Al Maha) at three plant densities of 60.000, 70.000, and 80.000 plants ha^{-1}. The experiments were conducted according to a randomized complete block design (RCBD) with a split-plot arrangement with three replications, where plant densities were distributed in the main plots and varieties in the subplots, and a combined analysis was performed for the two locations. The results showed significant differences between the two locations and most of the study factors and their interactions, as the Baghdad location was significantly superior in most of the studied traits, recording the highest average length of the ear (18.58 cm), ear diameter (4.11 cm), number of rows (14.88 rows), number of grains per row (38.18 grains row^{-1}), number of grains per ear (569.7 grains per ear^{-1}), and yield per plant (187.10 g), compared to the Anbar location , which recorded 16.97 cm, 3.80 cm, 13.64 rows, 34.89 grains per row^{-1}, 473.1 grains per ear^{-1}, and 124.95 g, respectively. Plant density significantly affected most traits, with a density of 70.000 plants/ha achieving the best performance, recording the highest average ear length (18.28 cm), number of kernels per row (38.12 grains row^{-1}), number of grains ear^{-1}(540.0 grains ear^{-1}), and yield plant^{-1}(163.33 g). Ear diameter and number of rows were not significantly affected by plant density. Varieties showed clear variation in performance. The Egyptian variety IY-355E excelled in ear length (18.14 cm), while the Iraqi variety Al Maha recorded the highest number of rows (15.01 rows), and the Egyptian variety TW-345E achieved the highest number of grains row^{-1} (39.93 grains row^{-1}). While the IY-207E variety excelled in the number of grains per ear (542.7 grains $^{-1}$) and yield per plant (162.08 g), the two- and three-way interactions showed a clear difference in the response of the varieties depending on the location and plant density. The TW-345E variety at the Baghdad location recorded the highest number of grains, reaching 646.3 grains $^{-1}$, while the Iraqi variety Baghdad 3, at a density of 70.000 plants ha^{-1} at the Baghdad site, achieved the highest yield plant^{-1}, reaching 230.41 g. The results confirm the existence of a significant interaction between genotypes, environment and plant density, and that a density of 70.000 plants hectare^{-1} represents the optimal level for most yield traits. The Egyptian varieties, especially IY-207E, TW-345E and IY-355E, showed high productive efficiency and good ability to adapt to Iraqi environmental conditions, which qualifies them for adoption in maize improvement and production programs.

KEYWORDS: Maize (Zea mays L.); Plant densities; Combined analysis; Genotype × Evironment interaction

INTRODUCTION
Agriculture is one of the most important economic and productive sectors in the world, playing a fundamental role in achieving food security and addressing the continuous increase in population, particularly in developing countries, including Iraq, which suffers from a widening gap between food production and population growth. This necessitates improving the productivity of strategic crops and increasing the efficiency of agricultural resource utilization (1). Maize (Zea mays L.) is one of the most important cereal crops in the world due to its nutritional, feed, and industrial importance, as well as its high yield and adaptability to different environmental conditions. It is an annual herbaceous plant with monoecious growth. The female flowers(silks) are borne in the leaf axils near the centre of the plant, while the male flowers are clustered in the terminal inflorescence (tassel). Maize is also characterized

by its great genetic diversity and widespread cultivation in diverse agricultural environments, which gives it high flexibility in responding to different environmental conditions. The productivity of Maize is determined by the interaction of three main factors: genotypes, environmental conditions, and agricultural management. This interaction leads to the determination of growth level, yield, and its components. The variation in agricultural locations is one of the most important environmental factors affecting crop productivity, due to differences in soil properties, climatic conditions, and levels of moisture and fertility, all of which directly impact growth characteristics, yield, and its components. The varying responses of genotypes when grown in different environments are known as genotype × environment interaction (G×E), which is one of the most significant challenges facing plant breeding programs. This is because it affects the accurate assessment of genotype performance and complicates the selection of superior and productively stable varieties across different environments (2). Therefore, evaluating varieties across multiple locations and growing environments has become a crucial step in selecting highly efficient and productively stable genotypes. Numerous studies have confirmed the importance of evaluating varieties across different environments. For example, (3) demonstrated highly significant differences between varieties and locations, as well as significant interactions between them, for most of the studied traits, including plant yield, number of grains per row, number of rows per ear, 1000-grain weight, and the number of days for tassling and silking. However, the interaction effect was not significant for ear length. As (4) demonstrated when evaluating the performance of individual hybrids and their parents at the Baghdad and Wasit locations, the Baghdad location excelled in average dry matter weight, number of ears, 300-grains weight, and grain yield, reaching 223 g, 1.24 ears per plant^{-1}, 63 g, and 6.52 tons ha^{-1}, respectively. However, no significant difference was found between the two locations in the number of grains ear^{-1}. (5) indicated significant differences between the Baghdad and Diyala locations. The Baghdad site excelled in ear length, 100-grain weight, and plant dry weight, and reached physiological maturity earlier. The Diyala location, on the other hand, excelled in the number of grains row^{-1} and the number of grains ear^{-1}. No significant differences were found between the two locations in the number of ears plant^{-1}, the number of rows ear^{-1}, plant yield, or total yield. In a recent study,(6) demonstrated the superiority of the Wasit location in the number of row grains and the number of ear grains, while the Baghdad location recorded the highest average ear diameter, while the Wasit location achieved the highest weight of 100 grains and the highest dry weight of the plant. The locations did not show significant differences in the yield of the individual plant or the total yield. Improving maize productivity depends not only on selecting the right variety but also on implementing appropriate agricultural practices, most importantly determining the optimal plant density. This directly affects the degree of competition between plants for light, water, and nutrients, which in turn impacts growth characteristics and yield. In this regard, (7) indicated that a plant density of 53.330 plants ha^{-1} resulted in the highest number of grains row^{-1} and a 500-grain weight, while lower density resulted in a higher number of ears per plant, fewer rows ear^{-1}, and a lower yield per plant.(8) also demonstrated that increasing plant density led to a significant decrease in ear length and the number of ears plant^{-1}, while it did not significantly affect the number of rows ear^{-1} or grain weight. Therefore, evaluating the performance of local and introduced varieties under different environmental conditions and at various plant density levels is a cornerstone of breeding and genetic improvement programs, as it provides accurate information about the varieties' adaptability, stability, and productivity. Therefore, this study aimed to evaluate the performance of six varieties of maize (four Egyptian varieties and two local Iraqi varieties) under the influence of two agricultural locations representing the middle and western regions of Iraq, and three different plant densities, with the aim of identifying the best, most stable and productive varieties under different environmental conditions.

MATERIALS AND METHODS

Two experiments were carried out at two locations: the first, the middle Region (Baghdad), in the fields belonging to the College of Agricultural Engineering Sciences - University of Baghdad, and the second, the Western Region (Anbar) in Karma, for the fall season of 2024, to evaluate the performance of Egyptian varieties under different plant densities in different locations in Iraqi environment .

Table 1: Names and symbols of maize varieties used in the study and their source.

Variety number	Variety	Pedigree
1	Baghdad 3 I	Ministry of Agriculture – Department of Agricultural Research(Abu Ghraib -Iraq)
2	Al-Maha I	
3	TW-78E	Egyptian Ministry of Agriculture – Agricultural Research Center – Crops Research Institute – Maize Research Department(Cairo -Egypt)
4	TW-345E	
5	IY-355E	
6	IY-207E	

Experiment Factors, Design and Arrangement

The study included two factors: the first was three plant densities (60, 70 and 80 thousand plants ha^{-1}), and the second was six varieties of maize, four of which were introduced (TW-78E, TW-345E, IY-355E, IY-207E) and two local varieties (Baghdad 3 I and Al-Maha I). The experiment was designed using a Complete Block Design (RCBD) with a split-plots arrangement in three replications, where the main plots included plant densities and the secondary plots included varieties.

Soil analysis and Weather forecast (temperature and relative humidity)

A soil sample was taken before planting at a depth of 30 cm for both locations and was analyzed at the Central Laboratory for Soil, Water and Plant Analysis – Consulting Office of the College of Agricultural Engineering Sciences – University of Baghdad. The results were as shown in Table 1. The climatic conditions for the period from 1/7 to 1/12, during which the experimental plants passed, were also obtained from the General Authority for Meteorology and Seismic Monitoring (table 3).

Table 2: Some chemical and physical properties of the experimental soil before planting.

<table>
<tr><th colspan="4">Baghdad</th><th colspan="2">Anbar</th></tr>
<tr><th colspan="2">The measured attribute</th><th>Value</th><th>unit of measurement</th><th>Value</th><th>unit of measurement</th></tr>
<tr><td colspan="2">Electrical conductivityEC</td><td>1.3</td><td>ds m^{-1}</td><td>1.6</td><td>ds m^{-1}</td></tr>
<tr><td colspan="2">PH 1:1</td><td>7.12</td><td>-----</td><td>7.26</td><td>-----</td></tr>
<tr><td colspan="2">Available nitrogen(N)</td><td>15</td><td rowspan="3">mg/kg^{-1} soil</td><td>13</td><td rowspan="3">mg/kg^{-1} soil</td></tr>
<tr><td colspan="2">Available phosphorus P</td><td>5.17</td><td>6.18</td></tr>
<tr><td colspan="2">Available potassium K</td><td>117.89</td><td>137.02</td></tr>
<tr><td colspan="2">organic soil material</td><td>4.5</td><td rowspan="2">gm kg^{-1}</td><td>3.2</td><td rowspan="2">gm kg^{-1}</td></tr>
<tr><td colspan="2">Carbonate minerals</td><td>235</td><td>312</td></tr>
<tr><td colspan="2">Dissolved calciumCa $^{+2}$</td><td>6.14</td><td rowspan="8">milliequivalent to $^{-1}$ liter</td><td>6.31</td><td rowspan="8">milliequivalent to $^{-1}$ liter</td></tr>
<tr><td colspan="2">Dissolved magnesium(Mg</td><td>3.12</td><td>5.00</td></tr>
<tr><td colspan="2">Dissolved sodium(Na $^{+)}$</td><td>2.21</td><td>3.42</td></tr>
<tr><td colspan="2">Soluble potassiumK</td><td>0.82</td><td>0.90</td></tr>
<tr><td colspan="2">Soluble bicarbonateHCO3</td><td>1.2</td><td>1.5</td></tr>
<tr><td colspan="2">Dissolved chlorine(Cl- $^{)}$</td><td>9.00</td><td>10.15</td></tr>
<tr><td colspan="2">Soluble sulfatesSO4-2</td><td>2.8</td><td>4.35</td></tr>
<tr><td colspan="2">CarbonatesCO3</td><td>Nill</td><td>Nill</td></tr>
<tr><td colspan="2">Soil texture</td><td>Sandy</td><td></td><td>Silt loam</td><td>-----</td></tr>
<tr><td rowspan="3">Soil separators</td><td>sand</td><td>572</td><td rowspan="3">gm kg^{-1} soil</td><td>472</td><td rowspan="3">gm kg^{-1} soil</td></tr>
<tr><td>clay</td><td>88</td><td>28</td></tr>
<tr><td>silt</td><td>340</td><td>500</td></tr>
</table>

Table 3. Percentage of relative humidity, maximum and minimum temperatures, and their averages monthly for Baghdad and Anbar locations for the fall season 2024

Period	Site	Relative Humidity	Minimum Temperature	Maximum Temperature	Average Temperature
1-31/July	Baghdad	18.3	20.5	45.86	33.18
	Anbar	19.74	31.04	44.71	37.87
1-31/August	Baghdad	23	27.73	44.94	36.34
	Anbar	20.24	30.84	44.74	37.79
1-30/September	Baghdad	26.88	24.39	41.11	32.75
	Anbar	26.64	26.84	39.92	33.38
1-31/October	Baghdad	29.18	17.22	33.27	25.25
	Anbar	27.51	18.71	32.05	25.38
1-30/November	Baghdad	64.103	11.214	23.67	17.44
	Anbar	61.53	13.20	22.72	17.96
1-31/December	Baghdad	58.96	4.487	18.66	11.57
	Anbar	56.12	7.22	17.88	12.55

Land preparation and soil and crop management operations .

The land was prepared for cultivation at the two experimental locations (Baghdad and Anbar) by carrying out all necessary agricultural operations, including plowing, harrowing, and leveling. Fertilization was then performed with a single application of 240 kg hectare-1 of NPK compound fertilizer before planting. Additionally, 360 kg hectare-1 of urea (46% nitrogen) was applied in two applications: the first during the elongation stage and the second at the beginning of the flowering stage(9). The land was divided int 54 plots, each representing an experimental unit. Each plot measured (2 × 3) m² and contained four rows of maize .. The spacing between rows was 75 cm, and the spacing between plants was 16 cm for a plant density of 80,000 plants hectare-1, 19 cm for a plant density of 70.000 plants hectare-1 and 22 cm for a plant density of 60,000 plants hectare-1 . Planting date for the Baghdad location: 25-7- 2024, and for the Anbar location: 26-7-2024.The seeds were sown at a rate of 2-3 seeds per hole, and the plants were thinned Weeding was carried out manually several times during the growing season, and irrigation was done whenever needed..Preventive control was carried out against the stem borer insect using granular diazinon with a concentration of 10% at a rate of 4 kg/h in two applications, the first when the plant was about 25 cm high and the second 15 days after the first application.

Traits studied

1. Ear length (cm): The lengths of the main ears of the five plants per experimental unit at both locations were measured using a tape measure.
2. Ear diameter (mm): The diameter of the five main ears per experimental unit at both locations was measured using a vernier calliper.
3. Number of rows ear^{-1}: The number of rows per ear for the five plants at both experimental units and locations was calculated.
4. Number of grains row^{-1}: The number of grains per row for the five plants at both experimental units and locations was calculated.
5. Number of grains ear^{-1}: Calculated using the following equation: Number of grains ear $^{-1}$= Number of grains row × Number of rows ear^{-1}.
6. Plant yield (g plant^{-1}): Five plants were randomly harvested from the central rows of each experimental unit at each location. Their seeds were threshed and weighed using a sensitive balance after correcting the weight for a moisture content of 15.5%. (10).

Statistical Analysis

Statistical analysis was performed on all studied traits using Excel and Genstat software according to the RCBD design within the arrangement of the split plots for the Baghdad and Anbar locations. Then the combined analysis of the locations was performed and the means were compared according to the least significant difference (LSD) at a probability level of 0.05 **(11)**.

RESULTS AND DISCUSSION

Ear length (cm)

The Baghdad site significantly outperformed the Anbar location, yielding an average ear length of 18.580 cm, a 9.50% increase over the Anbar location, where plants yielded an average ear length of 16.967 cm (Table4). This superior ear length in Baghdad is attributed to favourable environmental conditions, specifically the soil environment (Table 2) and suitable atmospheric conditions such as radiation, temperature, and humidity (table 3). These factors led to increased efficiency of carbon assimilation and the accumulation of chromosomes, positively impacting the growth of female reproductive organs and resulting in increased ear elongation. Similar results were obtained by (4) and (5), who indicated in their research that the Baghdad location was superior in ear length compared to the other locations they studied. As shown in the table (3), there were significant differences in plant densities. Ear length increased with increasing density from 60.000 to 70.000 plants hectare^{-1}, and then decreased at a density of 80.000 plants hectare^{-1}. The highest average ear length was recorded at the second plant density (70.000 plants hectare^{-1}), reaching 18.281 cm, and the lowest average at the third density, which did not differ significantly from the first density. Thus, the relationship between plant density and ear length did not follow a linear pattern. The response was optimal at medium densities, then decreased at high and low densities, exhibiting a quadratic curve as a result of the effects of competition and the resulting stresses. The results of most researchers showed a linear response to ear length with increasing plant density, including (8), (12), (13), and (14). The trait showed a significant difference with regard to plant density among several researchers, including (15). The same table indicates the differences between the varieties, with the Egyptian variety IY-355E exhibiting the longest ear length at 18.144 cm. This length was not significantly different from the Egyptian varieties TW-345E and IY-207E, nor from the Iraqi varieties Baghdad 3 and Al-Maha. The Egyptian variety TW-78E recorded the lowest average ear length at 16.839 cm. These differences reflect variations in genetic factors and gene expression, which in turn affect phenotypic traits such as ear length. This confirms the findings of (16), (13), (17), and (15), who observed variations in ear length based on genotypes. The table 4 shows a significant interaction effect between locations and plant densities. Ear length increased with increasing plant density from 60.000 to 70000.plant hectare^{-1}. The Baghdad location significantly outperformed Anbar, recording the highest average ear length at the second density of 19.061 cm, while Anbar had the lowest average length at the first density of 16.578 cm. Data in table 3 indicates that the response of the varieties varied according to location. The response was linear, with an increase in ear length for all varieties at the Baghdad location. The best response was for the TW-345E variety at the Baghdad location, which gave the highest average ear length of 19.411 cm. This did not differ significantly from the Maha and IY-355E varieties. While the TW-78E variety in Anbar gave the lowest average length for this trait at 16.167 cm, some varieties, such as TW-345, exhibited greater adaptability to the Baghdad environment, enabling them to make optimal use of available conditions with greater efficiency. This was reflected in increased ear length. Table 3 shows the variation in the response of varieties with different plant density. Ear length decreased for the Iraqi varieties Baghdad 3 and Al-Maha, as well as the Egyptian variety TW-345, with increasing plant density. In contrast, ear length increased for the Egyptian varieties IY-355E and TW78E with a density of 70,000 plants ha^{-1}, then decreased at the third density. The performance of the IY-207 variety remained relatively stable and was not significantly affected by plant density variations. The Baghdad 3 and Al Maha varieties showed the best response at the first and second planting densities, as did the Egyptian variety TW-345 at the second and third densities. Conversely, the TW-78E variety showed the lowest response at a density of 80,000 plants per hectare, with an ear length of 16.067 cm. The interaction between varieties and plant densities is an important indicator of the efficiency of genetic combinations in exploiting different environmental conditions and tolerating biotic stresses resulting from interplant competition. The response of the varieties varied according to plant density and planting locations. The response varied, either decreasing or increasing, according to the location, plant density, and variety. The best response was for the Iraqi variety Al Maha at the second density in the Baghdad location, where the ear length reached 20.333 cm and did not differ significantly from the same variety at the first density. It also did not differ significantly from the Egyptian variety TW-345E at the first and second densities. In contrast, the lowest response was for the Egyptian variety IY-207E at the Anbar location at the first density of 60.000 plants per hectare, where it reached 15.663 cm and did not differ significantly from the Egyptian varieties IY-355E and TW-78E at the first and third densities respectively.

Table 4: Combined analysis of ear length (cm) of introduced varieties of Maize at three plant densities in Baghdad and Anbar locations for the fall season of 2024.

Locations	Plant population 1000 P. h^{-1}	Varieties						Locations ×plant densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad	60	17.967	19.233	17.300	19.267	19.067	19.133	18.661
	70	19.133	20.333	18.933	18.700	18.833	18.433	19.061
	80	17.333	17.133	16.300	20.267	18.667	18.400	18.017
Anbar	60	18.500	17.267	15.667	16.033	16.333	15.663	16.578
	70	16.767	16.933	17.000	17.967	18.933	17.400	17.500
	80	17.133	17.100	15.833	16.600	17.033	17.233	16.822
L.S.D (0.05)		location × plant densities × Varieties=						0.5141
Locations		Varieties						Mean Location
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad		18.144	18.900	17.511	19.411	18.865	18.656	18.580
Anbar		17.467	17.100	16.167	16.876	17.433	16.767	16.967
LSD		0.6972 location ×Varieties =						0.4333
Plant densities		Varieties						Mean densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
60		18.233	18.250	16.483	17.650	17.700	17.400	17.619
70		17.950	18.633	17.967	18.333	18.883	17.917	18.281
80		17.233	17.117	16.067	18.433	17.850	17.817	17.419
L.S.D (0.05)		Plant densities = 0.6972 × Varieties						0.3497
Mean varieties		17.806	18.000	16.839	18.139	18.144	17.711	
L.S.D (0.05)		0.4797						

Ear diameter (cm)

Table 5 shows significant differences between the Baghdad and Anbar locations. The Baghdad location had the highest average ear diameter, reaching 4.107 cm, a 7.99% increase compared to the Anbar location, where plants averaged 3.803 cm. The superiority of the Anbar location may be attributed to its superior plant height, number and area of leaves, and their index, this increased the efficiency of the source and the transport of carbon dioxide to the sink, resulting in a balanced source-sink relationship. This balance led to an increase in the (19) indicated: that ear diameter is clearly affected by different environments (locations) due to the interaction between genetic and environmental factors. Changes in environmental conditions lead to variations in ear growth and development. The same table shows that neither plant density nor variety were significant. The interaction between locations and plant density was significant, with the best response for ear diameter at the Baghdad site (70.000 plants hectare^{-1}), reaching 4.176 cm. Conversely, the lowest response for ear diameter at the same density was observed at the Anbar location. It reached 3.781 cm. Favourable conditions at the Baghdad location at the second density improved carbon metabolism and nutrient accumulation, leading to an increase in ear diameter.

The same table shows no significant differences between the other two-way interactions and the three-way interaction.

Table 5. Combined analysis of ear diameter (cm) of introduced varieties of maize at three plant densities in Baghdad and Anbar locations for the fall season of 2024.
Number of rows ear^{-1}

Locations	Plant population 1000 P. h^{-1}	Varieties						Locations ×plant densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad	60	4.213	3.913	4.027	4.193	4.100	4.240	4.114
	70	4.087	4.153	4.233	4.160	4.167	4.253	4.176
	80	3.873	4.027	4.073	4.053	4.120	4.040	4.031
Anbar	60	3.847	3.673	3.927	3.720	3.813	3.813	3.799
	70	3.553	3.813	3.713	3.807	3.693	4.107	3.781
	80	3.840	3.847	3.887	3.653	3.853	3.893	3.829
L.S.D (0.05)		location × plant densities × Varieties= N.S						0.1282
Locations		Varieties						Mean Location
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad		4.058	4.031	4.111	4.136	4.129	4.178	4.107
Anbar		3.747	3.778	3.842	3.727	3.787	3.938	3.803
LSD		location ×Varieties = N.S						0.1273
Plant densities		Varieties						Mean densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
60		4.030	3.793	3.977	3.957	3.957	4.027	3.957
70		3.820	3.983	3.973	3.983	3.937	4.180	3.978
80		3.857	3.937	3.980	3.853	3.987	3.967	3.930
L.S.D (0.05)		Plant densities × Varieties = N.S						N.S
Mean varieties		3.002	3.904	3.977	3.931	3.958	4.058	
L.S.D (0.05)		N.S						

Number of rows ear^{-1}

The Baghdad location showed the highest average number of rows, reaching 14.878 rows, a 9.116% increase compared to the Anbar location, which recorded the lowest average number of rows per ear of maize at 13 635 row(Table, 6). This may be attributed to the Baghdad location superior ear diameter (Table 5), which positively impacted the number of rows. These results are consistent with those of several researchers, including (4) and (5). Table 6 indicates that plant density was not statistically significant. The same table shows that the Iraqi variety, Al-Maha, exhibited the highest number of rows at 15 .011row, differing from all other studied varieties. The Egyptian variety, TW-345E, recorded the lowest average row size at 13,106 rows per ear of maize. The variation in the number of ear rows among different varieties may be attributed to the genotypic differences among varieties. The superiority of the Maha variety in the number of ear rows is attributed to its higher genetic capacity to regulate the number of flower clusters on the ear, a trait controlled by genes related to flower formation and distribution. This confirms the findings of (20), (16), and (21), whose results showed significant differences in the number of ear rows based on different genotypes. From the combined analysis table (6), we observe no significant differences in the two-way interaction (locations × densities). The same table indicates the significance of the two-way interaction (locations × varieties), with the Baghdad location outperforming the Anbar location in all varieties. The Iraqi varieties Baghdad 3 and Al-Maha at the Baghdad location showed the highest response, reaching 15.244 rows, while the Egyptian varieties IY-355E and IY-207E at the Anbar location showed the lowest response for the trait, at 13,133 rows. The same table indicates that there are no significant differences in the binary interaction (densities × varieties), while (Table 5) shows a significant response of varieties with a difference in plant density by increase or decrease or a non-linear response (second order, quadrate) in the Baghdad and Anbar locations, as the Iraqi variety Al Maha gave the best response for the number of rows trait in the Baghdad site at a density of 60.000 plants ha^{-1}, reaching 15.400 rows, and it did not differ significantly from the Baghdad 3 variety at a density of 70.000 plants ha^{-1} for the Baghdad location, nor did it differ significantly from the two Iraqi varieties Baghdad 3 and Al Maha and the Egyptian variety IY-207E at a plant density of 80.000 plants ha^{-1} for the same location, while the Egyptian variety IY-207E at a density of 60.000 plants ha^{-1} in the Anbar location recorded the lowest response, reaching 12.533 rows in the ear.

Table 6: Combined analysis of number of rows ear $^{-1}$ of introduced varieties of maize at three plant densities in Baghdad and Anbar locations for the fall season of 2024.

Locations	Plant population 1000 P. h^{-1}	Varieties						Locations ×plant densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad	60	14.933	15 400	14.733	14.133	14.133	14.867	14.867
	70	15.533	15.267	14.533	14.933	14.600	14.533	14.900
	80	15.267	15.067	14.733	14.533	14.467	15.133	14.867
Anbar	60	14544	14.600	13.933	13.267	13.533	12.533	13.733
	70	13.667	15.267	12.733	13.300	12.733	13.667	13.561
	80	13933	14.467	13.200	13.467	13.400	13.200	13.611
L.S.D (0.05)		location × plant densities × Varieties= 0.7764						N.S
Locations		Varieties						Mean Location
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad		15.244	15.244	14.667	14.400	14.844	14.844	14.878
Anbar		14.044	14.778	13.289	13.222	13.133	13.133	13.635
LSD		location ×Varieties =0.4504						0.2768
Plant densities		Varieties						Mean densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
60		14.733	15.000	14.333	14..200	13.833	13.700	14.300
70		14.600	15.267	13.633	14.117	13.667	14.100	14.231
80		14.600	14.767	13.967	14.000	13.933	14.167	14.239
L.S.D (0.05)		Plant densities × Varieties= N.S						N.S
Mean varieties		14.644	15.011	13.978	13.106	13.811	13.989	
L.S.D (0.05)		0.3109						

Number of Grains Row^{-1}

As shown in Table 7, the Baghdad location significantly outperformed the Anbar location, giving the highest average number of grains row^{-1}, reaching 38.18 grains row^{-1}, while the Anbar location recorded the lowest average for the trait, at 34.89 grains row, $^{-1}$ representing an increase of 9.25%. The reason for the superiority of the Baghdad location is attributed to its superiority in the ear length trait (Table,4). The same table shows significant differences between the different plant densities. The number of grains row $^{-1}$ increased with increasing plant density from 60.000 to 70.000 plants hectare^{-1}, then decreased at a density of 80.000 plants hectare^{-1}. The second density recorded the highest average for the trait, at 38.12 grains per row. The response of the number of grains row^{-1} was similar to that of the ear length across different plant densities, exhibiting a non-linear, quadratic response pattern (as indicated in Table 3). This is a likely consequence of the positive correlation between the number of grains row^{-1} and ear length ,In contrast, the response of the number of grains row^{-1} with increasing plant density was linear in the studies of (22), (16), (13), and (15). Study by (14) did not show significant differences between the two plant densities (70.000 and 90.000 plants ha^{-1}) for the number of grains row $^{-1}$. Table 7 indicates differences in the genotypic differences among the varieties, with the Egyptian variety TW-345E exhibiting the highest average number of grains row^{-1}, reaching 39.93 grains row^{-1}, followed by the Egyptian variety IY-355E, exhibited superior results. The superiority of these two varieties is attributed to their superior ear length, as shown in Table 4. The Egyptian variety TW-1278E showed the lowest average number of grains row^{-1}, at 34.51 grains row -^{1} and did not differ significantly from the Iraqi variety Baghdad 3. Several researchers have reached similar conclusions, including (23) (20), (13), (17), and (14). The same table also indicates no significant differences in the two-way interaction (locations × plant densities). The varieties responded significantly to different locations. Specifically, the Baghdad location showed a significant increase in the number of grain row^{-1} compared to the Anbar location, with the Egyptian variety IY-355E exhibiting the best results at the Baghdad LOCATION. The response was 40.31 grains row^{-1}, which did not differ significantly from the Egyptian varieties TW-345E and IY-207E. Meanwhile, the Egyptian variety TW_78E, at the Anbar location, recorded the lowest response for the trait at 32.47 grains row^{-1}, which did not differ significantly from the Egyptian varieties IY_207E and IY_355E at the same location. Table 7 indicates that the response of the varieties differed significantly with varying plant densities. The number of grains per row increased for the varieties with increasing plant density up to 70.000 plants hectare^{-1}, and then, the yield decreased at a density of 80.000 plants hectare^{-1}, and the best response for the Egyptian variety TW-345E at the second density was 42.83 grains row $^{-1}$. The lowest response was for the variety TW-78E at the first two densities... The third density was not significantly different from that of the Baghdad 3 variety and the Egyptian IY-207 variety at the first density. Table 6 shows the significance of the three-way interaction (location × density × variety). The Iraqi Al-Maha variety at a density of 60.000 plants hectare^{-1} in the Baghdad location showed the best response for the number of grains row^{-1}trait, reaching 45.20 grains row $^{-1}$. This did not differ significantly from the Egyptian TW-345E variety at the third density in the same location, nor from the same variety at the second density in the Anbar location. Meanwhile, the Egyptian IY-207E variety at a density of 60.000 plants hectare^{-1} in the Anbar location recorded the lowest average for the trait, at 29.40 grains row $^{-1}$, and did not differ significantly from the TW-78E variety at the same density and location.

Table 7. Combined analysis of number of grain row^{-1} of introduced varieties of maize at three plant densities in Baghdad and Anbar locations for the fall season of 2024.

Locations	Plant population 1000 P. h^{-1}	Varieties						Locations ×plant densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad	60	35.13	45.20	36.80	39.47	40.07	38.07	37.46
	70	37.40	40.13	39.47	36.67	41.13	41.73	39.42
	80	33.80	36.07	33.40	44.60	39.74	38.33	37.66
Anbar	60	36.07	37..07	31.13	33.13	33.13	29.40	33.32
	70	34.60	32.73	33.67	44.00	36.47	34.47	36.82
	80	33.53	35.33	32.60	36.73	33.07	35.87	34.52
L.S.D (0.05)		location × plant densities × Varieties= 2.677						N.S
Locations		Varieties						Mean Location
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad		35.44	37.13	36.56	40.24	40.31	39.38	38.18
Anbar		34.73	35.04	32.47	39.62	34.22	33.24	34.89
LSD		location ×Varieties =1.751						1.481
Plant densities		Varieties						Mean densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
60		35..60	36.13	33.97	36.30	36.60	33.73	35,39
70		36.00	36.43	36.57	42.83	38.80	38.10	38.12
80		33.67	35.70	33.00	40.67	36.40	37.10	36.09
L.S.D (0.05)		Plant densities × Varieties = 1.797						0.943
Mean varieties		35.09	36.09	34.51	39.93	37.27	36.31	
L.S.D (0.05)		1.013						

Grain number ear^{-1}

The results presented in Table 8 revealed significant effects of locations, plant densities, varieties , and their two-way and three-way interactions on the number of grains ear $^{-1}$The Baghdad location significantly outperformed the Anbar location, yielding an average total grain number 569.7 grains ear^{-1} compared to the Anbar location, whose plants yielded an average of 473.1 grains ear^{-1}, representing an increase of 20.42%. The reason for the superiority of the Baghdad location in grains number is attributed to its superior ear length and diameter (Tables 4 and 5), which resulted in a greater number of rows and kernels per row (Tables 6 and 7). The results of (5) and (4) showed a similar response in this trait at the Baghdad location compared to the Diyala and Wasit locations, respectively. Table 7 of the cumulative analysis shows a significant difference between plant densities. The total number of grains increased with increasing plant density from 60.000 to 70 000 plants hectare^{-1}, reaching 540.0 grains ear^{-1} at the second density. It then decreased at the third density of 80 .000 plants hectare^{-1}, recording an average of 513.3 grains per ear. This response is consistent with the response of the two traits of ear length (Table 4) and number of grains per row (Table 7). These two traits are secondary components of the yield, which results in the main component, the number of grains ear^{-1}. Therefore, the plants at the second density had a higher number of grains per ear as an inevitable consequence of their superiority in the secondary components. (13) obtained similar results. The same table indicates the difference between the varieties, as the Egyptian variety IY-207E recorded the highest average for the total number of grains, which reached 542.7 grains ear^{-1}, and it did not differ significantly from the Iraqi variety Al Maha and the Egyptian variety TW-345E, which reached 539.8 and 534.9 grains ear^{-1}. The superiority of the three varieties is attributed to their superiority in the number of rows at times, or the number of grains row^{-1} at other times, or both together (Tables 6 and 7), which directly contributed to increasing the number of grains ear^{-1} (Table 8). These results are consistent with what was obtained by, (20 (16), (13), and (17).
Table 8 shows the significant interaction between locations and plant densities. The response direction was quadratic and not linear, as the number of grains ear $^{-1}$ increased at the second density and then decreased at the third density in both locations. The best response for the number of grains ear $^{-1}$ was recorded at the Baghdad location at a density of 70.000 plants hectare-^{1}, reaching 591.3 grains ear $^{-1}$. The lowest response for the trait was recorded at the Anbar location at the first density, with an average of 464.0 grains ear $^{-1}$. The varieties responded significantly across both locations. The varieties were characterized by a higher number of grains ear $^{-1}$ at the Baghdad location and a lower number at the Anbar location. The best response was for the Egyptian variety IY-207E at the Baghdad location, reaching 615.2 grains ear $^{-1}$, and it did not differ significantly from the Egyptian variety TW-345E. The

lowest response for the trait was for the Egyptian variety TW-78E at the Anbar location, reaching 433.2 grains ear $^{-1}$. The varieties exhibited significantly different responses to different plant density. The Egyptian variety TW-345E showed a positive linear response, with the number of grains ear $^{-1}$ increasing as plant density increased, whereas the variety IY-207E exhibited the opposite trend, with grains number decreasing as plant density increased. In contrast, the remaining varieties displayed a quadratic response, characterized by an increase in the number of grains ear $^{-1}$ at 70.000 plants ha $^{-1}$ followed by a decline at 80.000 plants ha $^{-1}$. The highest mean number of grains ear $^{-1}$ (596.5) was recorded by the variety IY-207E at a plant density of 60.000 plants ha $^{-1}$, whereas the Egyptian variety TW-78E produced the lowest value 460.7 grains ear $^{-1}$. Table 8 indicates the significance of the three way interaction (locations × plant densities × varieties), as the response varied according to the three factors. It was a linear response for locations and a non-linear response for plant densities, according to the varieties. The best response was for the Egyptian variety TW-345E at a density of 80 000 plants ha $^{-1}$ at the Baghdad site, where the ear yielded 646.3 grains. It did not differ significantly from the same variety at the first density at the Baghdad location, nor from the Egyptian variety IY-355E at the second density at the Baghdad location, nor from the Egyptian variety IY-207E at all its densities at the Baghdad location. It also did not differ significantly from the Maha variety at the Baghdad location at a density of 70.000 plants ha $^{-1}$. The Egyptian variety IY-207E at the Anbar location at a density of 60 .000 plants ha $^{-1}$ recorded the lowest average for the trait in the total number of grains, which amounted to 393.7 grains ear $^{-1}$. The superiority of the Egyptian variety TW-345E in the number of ear grains at the third density of 80.000 plants ha $^{-1}$ at the Baghdad location is an indication of the variety's high genetic potential to withstand the competition resulting from the increase in the number of plants and the efficient exploitation of resources, as the suitable environmental conditions at the Baghdad location helped to maintain the efficiency of carbon assimilation and the accumulation of metabolites despite the biological stress (high plant densities), which was reflected positively on the formation of a larger number of ear grains.

Table 8. Combined analysis of number of grain ear $^{-1}$ of introduced varieties of maize at three plant densities in Baghdad and Anbar locations for the fall season of 2024.

Locations	Plant population 1000 P. h $^{-1}$	Varieties						Locations ×plant densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad	60	521.3	541.5	519.1	594.7	569.1	599.4	557.5
	70	577.4	610.3	573.7	544.4	600.4	641.5	591.3
	80	516.5	535.8	490.9	646.3	566.8	604.7	560.2
Anbar	60	526.4	538.8	435.0	434.8	455.5	393.7	464.0
	70	469.7	504.1	434.1	523.6	467.4	533.1	488.7
	80	475.5	508.3	430.5	465.5	435.1	483.7	466.4
L.S.D (0.05)		location × plant densities × Varieties= 54.84						N.S
Locations		Varieties						Mean Location
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad		538.4	562.5	527.9	595.1	578.8	615.2	569.7
Anbar		490.6	517.1	433.2	474.6	452.7	470.2	473.1
LSD		Locations ×Varieties = 31.77						17.24
Plant densities		Varieties						Mean densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
60		523.9	540.1	477.0	514.8	512.3	596.5	510.8
70		523.6	557.2	503.9	534.0	533.9	587.3	540.0
80		496.0	522.1	460.7	555.9	501.0	544.2	513.3
L.S.D (0.05)		plant densities ×Varieties 38.85 =						17.76
Mean varieties		514.5	539.8	480.5	534.9	515.7	542.7	
L.S.D (0.05)		22.61						

Individual Plant Yield (gm plant $^{-1}$)

The Baghdad location gave the highest average individual plant yield of 187.10 g, while the Anbar location recorded the lowest average of 124.95 g, a decrease of 33.22% compared to the Baghdad location (Table 9). Baghdad's superiority in individual plant yield is attributed to the suitability of environmental conditions, particularly soil fertility (Table 1), the availability of relative moisture (table,2), and nutrients. This positively impacted vegetative growth efficiency, leading to increased plant height, stem diameter, number of leaves, leaf area, and improved carbon metabolism efficiency. This, in turn, led to greater dry matter accumulation and its subsequent translocation to the sink organs, thereby enhancing yield components., thus increasing the secondary yield components (Tables 4, 5, 6, and 7), which in turn increased the overall components. which is the result of this integrated series of physiological processes. These results are consistent with those obtained by (24), (4) and (5). Their studies indicated that the variation in individual plant yield in maize is attributed to the environment and the genetic ×

environmental interaction (G×E).It is clear from the same table that increasing the number of plants from 6 to 7 plants per square meter led to an increase in the yield of the individual plant, as the second density gave the highest average yield of 163.33 g, then the yield decreased again at the third plant density (80,000 plants ha^{-1}) to reach 152.85 g. This is attributed to the fact that moderate density provided a suitable balance between the number of plants and the efficiency of nutrient, water, and light consumption. Here, the yield response to plant density did not follow a linear pattern, but rather a quadratic one. This is an inevitable consequence of the non-linear response of the primary and secondary components of yield (4,6,7), which was reflected in the yield of the individual plant (Table 8). (26) obtained similar results, confirming that the relationship between maize yield and plant density does not follow a linear pattern but rather a quadratic curve. Yield increases with increasing density up to an optimal level and then begins to decline. The researchers also demonstrated that the highest yield per plant was at a density of 72.000 plants ha^{-1}, and then the yield decreased at higher densities.

The IY-207E variety outperformed others by yielding the highest average per plant at 162.08 g, not significantly different from the Iraqi Maha variety, while the TW-345E variety recorded the lowest average at 148.08 g (Table 9). The superiority of the IY-207E variety is attributed to its early physiological maturity, which allowed it to make optimal use of the growing season and rapidly accumulate dry matter and convert it into grain. The IY-207 variety was distinguished by a grain filling period of 45.7 days and produced a relatively high grain weight (0.303 g). It also excelled in the number of grains per ear (Table 7), meaning it combined a large number of grains with a high grain weight, which directly contributed to increasing the yield per plant. These results are consistent with the studies of several researchers who indicated that early-maturing varieties with a high number of grains and a relatively large grain weight often give the highest yield per plant due to vegetative growth (source efficiency), increased carbon assimilation, and conversion of products to estuaries, which increases the yield (27)

The table 9 shows the significant interaction between locations and plant densities for individual plant yield. The response to densities did not follow a linear pattern; yield was highest at the second density and then decreased at the third density for both study locations. The best response for individual plant yield was observed at the second density in Baghdad, reaching 201.09 g, while the lowest response was at the 60 .000 plant ha^{-1} density in Anbar, reaching 122.92 g. The second and third densities did not differ significantly for the same location.

The same table shows that the response of varieties varies according to location. Variety IY-355E in Baghdad showed the best response, yielding 197.52 g plant^{-1}, and did not differ significantly from the Egyptian variety IY_207E in the same location. In contrast, the Egyptian variety TW-345E in Anbar showed the lowest yield response, at 113.59 g. This variation is attributed to the different genetic-environmental interactions between varieties and environments (locations). Some varieties showed higher efficiency in utilizing resources under the conditions of the Baghdad location, while the efficiency of other varieties in Anbar decreased due to environmental stress, which was reflected in a lower individual plant yield. The response of the varieties varied according to the three plant densities (Table 9). The best response was observed for variety IY-207E at a plant density of 70.000 plants ha^{-1}, yielding the highest value per plant at 186.42 g, followed by the Iraqi varieties Baghdad and Al-Maha at the same density. However, its response was the opposite at a plant density of 60.000 plants ha^{-1}, yielding 134.37 g plant^{-1}, which did not differ significantly from the Baghdad 3 variety at the third density. The reduced performance of IY-207 at the low density indicates that this variety requires a certain level of competition to stimulate its productive efficiency. At the low density, the products of carbon metabolism may be directed towards vegetative growth rather than crop yield, leading to a decrease in yield. The same table indicated the significance of the three-way interaction (locations × plant densities × varieties), as the best response for individual plant yield was 230.41 g for the Baghdad 3 variety at the Baghdad location at a plant density of 70.000 plants ha^{-1}, followed by the Iraqi Al Maha variety at the same density. Meanwhile, the TW-345E variety showed the lowest response for individual plant yield, reaching 108.37 g at the Anbar location at a plant density of 60.000 plants ha^{-1}. We note from the three -way interaction that the Egyptian varieties gave a high yield per plant at the third density at the Baghdad location, outperforming the Iraqi varieties, which are considered adapted to their environment. This supports the success of acclimatizing these varieties under increasing densities at the Baghdad location. However, at the Anbar location, the response differed, as we note that the Iraqi Al Maha variety was the highest performer at the third density and did not differ significantly from the Egyptian variety IY-207E.

Table 9: Combined analysis of of grain yield (gm) of introduced varieties of maize at three plant densities in Baghdad and Anbar locations for the fall season of 2024.

Locations	Plant population 1000 P. h^{-1}	Varieties						Locations ×plant densities
		Baghdad 3	Al-Maha	TW-78	TW -345	IY-355	IY-207	
Baghdad	60	157.81	177.92	184.34	180.30	214.25	167.54	180.86
	70	230.41	220.26	186.68	175.84	176.37	217.00	201.09
	80	144.84	160.38	178.62	191.60	201.94	198.61	179.33
Anbar	60	148.70	132.51	133.66	108.37	113.09	151.19	122.92

	70	119.79	126.80	119.44	119.39	112.15	155.84	125.57
	80	124.43	137.72	122.21	113.00	128.58	132.31	126.38
L.S.D (0.05)		**location × plant densities × Varieties= 9.611**						**4.267**
Locations		**Varieties**						**Mean Location**
		Baghdad 3	**Al-Maha**	**TW-78**	**TW -345**	**IY-355**	**IY-207**	
Baghdad		177.69	186.19	184.21	182.58	197.52	194.38	187.10
Anbar		130.97	132.34	125.10	113.59	117.94	129.78	124.95
LSD		**Locations ×Varieties = 5.426**						**2.608**
Plant densities		**Varieties**						**Mean densities**
		Baghdad 3	**Al-Maha**	**TW-78**	**TW -345**	**IY-355**	**IY-207**	
60		153.26	155.21	160.50	144.34	163.67	134.37	151.89
70		175.10	173.53	153.06	147.62	144.26	186.42	163.33
80		134.63	149.05	150.42	152.30	165.26	165.46	152.85
L.S.D (0.05)		**Plant density× Varieties = 6.890**						**3.409**
Mean varieties		154.33	159.26	154.66	148.08	157.73	162.08	
L.S.D (0.05)		**3.944**						

CONCLUSION

The results showed that the Baghdad location outperformed the Anbar location in most yield components and individual plant yield, confirming the importance of environmental conditions in improving the productive performance of maize. A plant density of 70.000 plants ha^{-1} achieved the best response for most of the studied traits, while the response of the varieties varied according to their genotypic differences and their interaction with the location and plant density. The IY-207E variety exhibited the highest individual plant yield, while the TW-345E variety demonstrated a high ability to maintain yield components at high densities, making them promising varieties for cultivation in Iraqi environments and for improving maize productivity.

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