THE GENOTYPE-ENVIRONMENTAL INTERACTION ON YIELD AND ITS MAIN COMPONENTS OF BREAD WHEAT (*Triticum aestivum* L.)"

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ABSTRACT

In order to evaluate the performance of ten wheat genotypes under low nitrogen conditions and to determine their ability to determine the optimal genotype for the appropriate environment. Three experiments were conducted during the winter season of 2021-2022 in three locations: Baghdad, Wasit, and Diwaniyah. The experiments were conducted according to the randomized complete block design with split plots arrangement, where nitrogen levels (0, 50, 100 kg N ha^{-1}) represented the main plots, while the genotypes(T2,T3,S1,S2,S148,IPA99, Adna99, Rasheed, Buhooth 10 and Buhooth22) represented the sub-plots with three replicates at each location. Aggregation analysis of the locations was performed. The results showed a genotype by environmental interaction between the genotypes and nitrogen fertilization levels. The S2(IPA95 X IPA99) genotype outperformed with the highest grain yield per unit area (5.38 t ha^{-1}) and did not differ significantly from Bahooth22 and IPA99 (5.37 and 5.26 t ha^{-1}, respectively) at the high nitrogen level (100 kg N ha^{-1}). These genotypes also outperformed at the low nitrogen level (50 kg N ha^{-1}). There was a significant interaction between genotypes and locations, as S2 had the highest grain yield (4.82 t ha^{-1}) in Baghdad. It is concluded that some genotypes performed well under low nitrogen stress conditions (50 kg N ha^{-1}), indicating that increasing nitrogen levels may not always result in a significant increase in yield. Furthermore, high-yielding genotypes showed adaptability to certain environments, suggesting that their qualitative traits should be studied to determine their response to environmental genetic interaction. Genotypes with baking quality may perform well in several environments and are not limited to a specific environment or lack baking quality.

Keywords: Genotype x environment interaction, stability, yield and its components.

INTRODUCTION

The issue of food security and declining crop productivity coincides with climate change, which is unpredictable and expected to worsen in the near future. Despite many policies that have been initiated to address food security [1], one of the most challenging proposals is to achieve higher crop productivity under environmental stress conditions, by taking advantage of genetic-environmental interaction in wheat genotypes. This indicates that different genotypes respond differently to various environmental conditions, and the ideal variety should have the highest yield and the least variation in productivity when grown in diverse environments. Agriculture as a profession relies on the ability to cultivate suitable crops for a specific climate in a given region, as well as genotypes with high genetic productivity [2]. The problems of mineral nutrition in wheat have a regional character, where the efficiency of added amounts and their ratios depend on the properties of diverse soils, specific climatic conditions, as well as the characteristics of the variety in terms of its response to environmental conditions, mineral absorption, transportation, and accumulation [3]. The heritability potential may differ depending on the environment in which it grows, and the genetic variance depends on the extent of environmental changes [4]. Wheat is a unique grain crop because wheat flour contains a complex protein called gluten that provides the elastic properties of dough used in bread making [5].

Nitrogen plays a vital role in plant life and is considered an essential element for many vital functions. At the same time, it has a negative impact on the environment and may be costly, affecting the final production yield. Therefore, management in this field has a significant impact on production by diagnosing genotypes or genotypes that respond to low levels of nitrogen. One of the most significant problems related to wheat crops is related to the variety and its suitability for a certain environment, crop servicing operations, soil and climate problems. Therefore, the introduction or derivation of new genotypes suitable for soil and climate conditions in any environment and with high productivity and genetic stability is required [6]. The instability of quantitative traits for genotypes from one environment to another may arise as a result of gene expression of a group of genes or variation in their response and interaction with those environments. Therefore, studies on gene-environment interaction are important in identifying genotypes that have high productivity and stability in a wide range of environments [7]. Al-Hasan [8] noted a significant difference in grain yield with varying levels of nitrogen, with the 200 kg N/ha level giving the highest average yield of 6.254 tons ha^{-1}, which was not significantly different from the 150 kg N/ha level that recorded a yield of 6.204 tons ha^{-1}compared to other levels. Moreover, there was a significant difference in the weight of 1,000 grains between genotypes, with the Iraq variety performing best, recording the highest weight of 41.967 g. While, the Abu Ghraib-3 variety recorded the lowest average for the trait at 33.508 g, and this may be due to genetic variation between the genotypes. Al-Majdi et. al., [9] mentioned the existence of significant differences between genotypes when evaluating twenty genotypes of durum wheat under the conditions of the central region of Iraq. Hadi et. al., [10] found significant differences in the number of tillers per square meter, number of grains per spike, 1000-grain weight, and total yield for nine genotypes of bread wheat grown in two locations (Wasit and Diwaniyah). Bektash and Naes [11] found that when evaluating 21 genotypes, that the strain S97 and S148 were significantly superior to the rest of the genotypes except for A4.10 and Abu Ghraib variety, and the grain yield of the two strains was 6.09 and 6.35 tons ha^{-1}, respectively. Al-Naqeeb et. al.,[12] found significant differences in the number of grains per spike among three genotypes of wheat, with the IPA 99 variety giving the highest number of grains per spike at 43.9 and 46.4 grains per spike for two consecutive seasons, while the Buhooth 22 variety recorded the lowest number of grains at 43.0 and 45.6 grains per spike for the two seasons, respectively. Iraq has a large collection of wheat genotypes and genotypes. This study was conducted to determine the stability and possibility of identifying the optimal genotype for a specific environment or a group of environments under low nitrogen conditions.

MATERIALS AND METHODS

The research was conducted in three locations; the first in the fields of the College of Agricultural Engineering Sciences at the University of Baghdad- Jadiriya, the second location was at the research station in Wasit, while the third location was at the research station in Diwaniyah. Both the second and third locations are affiliated with the Agricultural Research Department - Ministry of Agriculture, during the winter season 2021-2022, with the aim of evaluating the performance of several genotypes of wheat under nitrogen deficiency, and to determine the stability and possibility of diagnosing the optimal genotype for the suitable environment or adapting to several environments. This experiment was applied according to the Randomized Complete Block Design (RCBD) with a split plot arrangement with three replicates, then the aggregation analysis was performed for the three locations. The main plots included nitrogen fertilizer levels (0, 50, 100 kg N ha^{-1}) and the sub-plots included 10 genotypes (Table 1). Statistical analysis was performed at the 0.05 significance level [13]. Soil samples were taken from different locations to a depth of (0, 30) cm before planting and analyzed in the laboratory for physical and chemical soil properties, as shown in Table (2). The experimental unit included four lines with a length of 3 m and a distance of 20 cm between each line. Soil preparation operations were carried out, including plowing, smoothing, leveling, then the field was planned as per the design of the experiment. Triple superphosphate fertilizer (P_2O_5%45) was added at a rate of 100 kg P_2O_5 ha^{-1} in one dose during soil preparation [14]. Urea fertilizer (N%46) was used according to the treatments (0, 100, 200 kg N ha^{-1}), where the fertilizer was added supplementally according to soil analysis (Table 2) to reach the desired level in three batches (at planting, elongation, and booting stages). The first irrigation was on November 23, 2021, at all locations. The characteristics studied included the number of spikes per unit area, the number of grains per spike, the weight of 1000 grains (g), and the grain yield per unit area (ton ha^{-1}).

Table 1. The genetic pedigree of the genotypes included in the research.

ID	Genotype	Pedigree	Origin
1	T2	PFAU/MILAN/FUNG MAI 24/3/ACHTAR/INRA 1754	ICARDA
2	T3	HOOSAM-8/2FLAG-4	ICARDA
3	S1	IPA95 X Abu-Ghraib 3	مستنبطة محليا
4	S2	IPA95 X IPA99	مستنبطة محليا
5	S148	A4.10 × A3103	مستنبطة محليا
6	IPA99	Ures/Bows/3/Jup/B/2S1//Ures	CIMMYT
7	Adna99	PFAU/SERI-M-82/BOBWHITE	Turkey
8	Rasheed	Irradiation of purified maxipak strains with 10 kb gamma	مستنبطة محليا
9	Buhooth 10	IPA99 X IPA95	مستنبطة محليا
10	Buhooth 22	CMSS96YO3236M-050M-040M-020M-050sy-020sy-IM-	CIMMYT

Table 2. Analysis of the chemical and physical properties of the soil of the experimental locations.

Parameter	Unit	Growing season 2021 -2022		
		Baghdad	Al-saouara (Wasit)	Diwaniyah
pH	-	7.4	7.2	7.2
EC	**ds.m^{-1}**	2.40	4.20	4.35
N	PPM	18	16	14
P	PPM	6.00	4.21	4.20
K	PPM	190	150	160
OM%	%	0.73	0.59	0.44
Sand	%	36.00	14.8	21.00
Clay	%	16.90	50.0	45.5
Silt	%	47.10	35.2	33.5

RESULTS AND DISCUSSION

Number of spikes m^{-2}

The results indicate that the locations differed significantly in the number of wheat spikes per unit area (Table 3). The highest spike rate was recorded in Baghdad, with 314.49 spikes m^{-2}, while the lowest rate was recorded in Diwaniyah at 271.56 spikes m^{-2}. This indicates the differences in environmental conditions between the locations, especially in soil salinity, texture, and organic matter. The lowest level of salinity was found in Baghdad, while the soil texture was sandy loam in Baghdad, and clay loam in Al-saouara (Wasit) and Diwaniyah. Moreover, Baghdad had the highest percentage of organic matter (Table 2). There was a significant difference in the nitrogen levels for this trait, where the highest rate was recorded at a nitrogen level of 100 kg N ha^{-1}, reaching 350.80 spikes m^{-2}, while the lowest rate was at a control level, reaching 229.48 spikes m^{-2}. The increase in nitrogen fertilization caused a general increase in vegetative growth at different crop stages, resulting in high efficiency in utilizing light energy, especially in the early stages, which increased the availability of nutritional compounds that support the growth and formation of tillers. Nitrogen also had an effect on the growth and development of some inactive tillers into spike-bearing tillers. The genotypes differed significantly, where the Adna 99 genotype recorded the highest average number of spikes per unit area, reaching 334.11 spikes m^{-2}, while the Rasheed genotype recorded the lowest average of 257.67 spikes m^{-2}. The dwarf genes had an effect on reducing plant height, thus increasing the number of spikes per unit area. The Adna 99 genotype gave the lowest average plant height and the highest average number of spikes, unlike the Rasheed genotype, which gave the highest average plant height with the lowest average number of spikes. The amount of response of genotype to increasing nitrogen fertilization levels varied.

The results indicate that the highest average for the trait was recorded for the genotype Adna99 for the nitrogen fertilization level of 100 kg N ha^{-1}at 395.00 spikes m^{-2}. On the other hand, the genotype Rasheed recorded the lowest average for the trait at the control N level at 201.78 spikes m^{-2}. This result reflects the nutritional requirement for each genotype of nitrogen, which is usually related to the genetic nature and physiological ability of the genotype to achieve the maximum possible benefit from the added nitrogen, as genotype differ in their abundance growth and tillering. The genotypes responded quantitatively differently with different locations, as genotype S2 gave the highest rate at the Baghdad location at 354.78 spikes m^{-2}, and did not differ significantly from the genotype Adna99, which recorded a number of spikes of 347.89 spikes m^{-2} at the same location, while the genotype Rasheed recorded the lowest rate at 239.22 spikes m^{-2} in the Diwaniyah location. This indicates a change in the response of genetic compositions in different locations. The effect of nitrogen levels differed with different locations, and it was observed that the second level of nitrogen (N2) at the Baghdad location was significantly superior by giving the highest number of spikes per unit area, reaching 374.67 spikes m^{-2}, while the Diwaniyah location recorded the lowest average for the trait at the control level at 216.63 spikes m^{-2}, while no significant differences were recorded in the three-way interaction.

Table 3. | Aggregation analysis of locations, nitrogen fertilization, and genotypes of the number of spikes per unit area for the season 2021-2022.

Locations	N Levels	Genotypes										Locations x N
		T2	T3	S1	S2	S148	IPA99	Adna99	Rasheed	Buhooth 10	Buhooth 22	
Baghdad	N0	252.3	241.0	243.0	269.3	220.3	250.7	262.3	217.3	208.3	244.3	240.9
	N1	331.0	324.0	318.3	378.0	330.0	325.7	369.3	277.7	264.3	360.7	327.9
	N2	354.0	384.0	387.0	417.0	380.0	377.7	412.0	325.3	331.7	378.0	374.7
Wasit	N0	241.0	229.0	236.0	226.0	219.0	241.3	247.0	210.7	199.7	259.3	230.9
	N1	297.7	295.7	328.7	344.7	296.0	334.7	373.7	264.7	262.0	339.7	313.7
	N2	323.3	328.7	371.3	363.3	330.3	361.0	406.3	305.7	326.3	370.0	348.6
Diwaniyah	N0	230.0	195.3	223.7	208.7	202.3	231.0	247.0	190.3	197.3	240.7	216.6
	N1	263.0	231.7	289.7	278.0	268.0	266.0	322.7	233.3	226.0	312.0	269.0
	N2	314.7	294.7	339.3	326.7	317.0	349.0	366.7	294.0	324.3	364.7	329.1
LSD 0.05	N.S											11.65
												N means
Genotype x N	N0	241.1	221.8	234.2	234.7	213.9	241.0	252.1	206.1	201.8	248.1	229.5
	N1	297.2	283.8	312.2	333.6	298.0	308.8	355.2	258.6	250.8	337.4	303.6
	N2	330.7	335.8	365.9	369.0	342.4	362.6	395.0	308.3	327.4	370.9	350.8
LSD 0.05	13.71											8.11
												Location means
Genotype x Locations	Baghdad	312.4	316.3	316.1	354.8	310.1	318.0	347.9	273.4	268.1	327.7	314.5
	Wasit	287.3	284.4	312.0	311.3	281.8	312.3	342.3	260.3	262.7	323.0	297.8
	Diwaniyah	269.2	240.6	284.2	271.1	262.4	282.0	312.1	239.2	249.2	305.8	271.6
LSD 0.05	11.74											2.99
Genotypes means		289.7	280.4	304.1	312.4	284.8	304.1	334.1	257.7	260.0	318.8	
LSD 0.05	6.99											

Number of grains spike^{-1}

The results indicate a significant difference between locations (Table 4). The locations of Baghdad and Diwaniyah recorded the highest trait rate at 49.37 and 49.32 grains spike^{-1}, respectively, while the Wasit location recorded the lowest rate at 46.51 grains spike^{-1}. This indicates the difference in environmental conditions between the locations during the flowering and fruit setting period, with temperature and photoperiod being the most influential factors. A significant difference was also found for the trait at a high nitrogen level N2, with the highest rate of 53.82 grains spike^{-1} and the lowest for control level at 41.81 grains spike^{-1}. This was due to the availability of nitrogen during the growth and development stages of the crop, contributing to an increase in the number of spikelets and their synthesis, which consists of the grains and the subsequent increase in the number of grains per spike. This result is consistent with AL-Hassan [15]. The genotypes differed in the number of grains per spike, with the genotype of IPA99 recording the highest rate of 58.36 grains spike^{-1}, while the genotype T3 recorded the lowest number of grains spike^{-1} at 40.60 grains spike^{-1}. This indicates the difference in genotypes between them, especially in the number of spikelets and the ability of the genotype to form a high number of grains. The amount of response of the genotypes differed with the increase in nitrogen levels, and it can be seen from Table (5) that all genotypes outperformed at the N2 level. This is due to the ability of the genotypes to respond to high nitrogen and form a high number of grains, as the genotype IPA99 recorded the highest rate at the nitrogen level of N2, at 65.09 grains spike^{-1}, while the genotype T3 recorded the lowest rate at 37.52 grains spike^{-1}. The response of the genotypes differed with the different locations, with the genotype of IPA99 recording the highest rate in all three locations, reaching 58.80, 58.21, and 58.07 grains spike^{-1} in Wasit, Baghdad, and Diwaniyah, respectively, this indicates the adaptability of this genotype to environmental conditions in all locations, while the genotype T3 recorded the lowest rate in Wasit location, reaching 39.81 grains spike^{-1}. The effect of nitrogen levels varied between locations, and it is noted from the table that the N2 level in Diwaniyah and Baghdad locations significantly exceeded the Wasit location, which gave rates of 54.84 and 54.08 grains spike^{-1}, respectively, while the Wasit location recorded the lowest rate at the control level, which reached 39.22 grains spike^{-1}. The superiority of the Diwaniyah location may be due to environmental conditions, while the superiority of the Baghdad location may be due to the organic matter content in the soil (Table 2). There is a difference in the response of genotypes in different locations with varying nitrogen levels, as the genotype IPA 99 recorded the highest rate in Wasit and Diwaniyah locations, reaching 67.53 and 65.53 grains spike^{-1}, respectively, at the N2 level. The reason for this may be the suitability of environmental conditions with a high nitrogen level, which led to the superiority of these two treatments, while the genotypeT3 recorded the lowest rate in Wasit at the control level, reaching 36.33 grains spike^{-1}.

Weight of 1000 grain (gm)

The results indicated significant differences between locations in the weight of grains (Table 5). Baghdad had the highest average weight of grains at 39.750 grams, while Diwaniyah recorded the lowest average weight of 1000 grains at 34.619 grams. The difference in maturity period and the duration of grain filling in Baghdad compared to the other two locations caused this variation in this trait. Increasing nitrogen fertilizer levels led to an increase in grain weight. The highest weight was recorded at level N2 with an average of 39.276 grams, while the lowest value was recorded at the control level with 34.146 grams. The reason for the increase in grain weight with increasing nitrogen level is that nitrogen is the key to the growth and development of grains in the spikes, through its effect on vegetative growth, it increases the efficiency source (leaves) of nutrient production. This result is in agreement with Ullah et al. [2]. The results showed significant differences between genotypes in the weight of 1000 grains (Table 5). Genotype T3 had the highest average weight at 40.355 grams, while genotype IPA 99 had the lowest average weight of 32.156 grams. This affects the rate of the share of each grain or the share of the grain of the manufactured materials from photosynthesis Also, the limited number of effective tillers (number of spikes) allows the opportunity for the representation of carbon assimilation transfer towards the spikes to fill the grains, contributing to an increase in the weight of the single grain (Table 5). This genotype had a low average value for the number of spikes per unit area. This result is in agreement with Hassan [16].

The amount of response of genotypes to increasing nitrogen varied, as genotype S2 showed the highest response to nitrogen fertilization, recording the highest average grain weight at 42.51 grams at level N2, while IPA 99 had the lowest response, recording the lowest weight of grains at 30.42 grams at the control level. The amount of response of genotypes also differed between locations. Genotypes S2 and S148 had the highest trait values and did not differ significantly, recording an average weight of 43.31 and 42.05 grams, respectively in Baghdad. While IPA 99 recorded the lowest rate in the Diwaniyah location at 29.35 gm.

Table 4. | Aggregation analysis of locations, nitrogen fertilization, and genotypes of the number of number of grains spike^{-1} for the season 2021-2022.

Locatio ns	N Levels	Genotypes										Locatio ns x N
		T2	T3	S1	S2	S14 8	IPA 99	Ad na 99	Rashe ed	Buhoo 10 th	Buhoo 22 th	
Baghda d	N0	44.	37.	43.	44.	44.	52.	38.4	42.68	43.25	46.75	43.89
	N1	52.	40.	52.	51.	50.	59.	42.7	48.98	46.87	56.65	50.15
	N2	59.	42.	58.	57.	51.	62.	43.0	52.52	51.80	60.53	54.08
Wasit	N0	37.	36.	37.	36.	38.	48.	35.7	41.43	39.17	41.60	39.22
	N1	48.	38.	50.	43.	48.	60.	40.8	47.30	48.40	51.33	47.77
	N2	54.	44.	56.	49.	50.	67.	43.5	52.33	50.00	57.17	52.54
Diwaniy ah	N0	43.	38.	43.	41.	42.	48.	39.6	40.00	41.77	44.73	42.34
	N1	48.	41.	54.	48.	52.	60.	44.1	50.15	50.67	56.72	50.77
	N2	55.	45.	56.	52.	59.	65.	46.6	51.77	52.33	62.00	54.84
LSD 0.05	3.091											1.315
												N
Genoty pe x N	N0	41.	37.	41.	40.	41.	49.	37.9	41.37	41.39	44.36	41.81
	N1	49.	39.	52.	47.	50.	60.	42.5	48.81	48.64	54.90	49.56
	N2	56.	44.	57.	53.	53.	65.	44.4	52.21	51.38	59.90	53.82
LSD	1.774											0.754
												Locatio
Genoty pe x Locatio	Baghda	52.	40.	51.	51.	48.	58.	41.4	48.06	47.31	54.64	49.37
	Wasit	46.	39.	47.	43.	45.	58.	40.0	47.02	45.86	50.03	46.51
	Diwaniy	49.	41.	51.	47.	51.	58.	43.4	47.31	48.26	54.48	49.32
LSD	1.816											0.951
Genotypes means		49.	40.	50.	47.	48.	58.	41.6	47.46	47.14	53.05	
LSD	0.996											

Table 5. | Aggregation analysis of locations, nitrogen fertilization, and genotypes of the weight of 1000 grain (gm) for the season 2021-2022.

Locations	N Levels	Genotypes										Locations x N
		T2	T3	S1	S2	S148	IPA 99	Adn 99 a	Rasheed	Buhooth 10	Buhooth 22	
Baghdad	N0	36.2	37.1	38.2	39.8	38.8	34.3	34.9	37.50	37.13	35.00	36.924
	N1	40.4	45.4	41.4	43.7	42.1	36.3	36.5	40.31	39.46	37.65	40.350
	N2	41.8	43.4	41.2	46.3	45.0	38.1	39.2	42.85	42.41	39.20	41.975
Wasit	N0	34.0	34.6	33.0	36.9	35.3	29.0	30.9	35.28	35.33	33.52	33.812
	N1	36.7	36.3	34.4	39.5	39.3	30.6	34.5	38.86	38.61	37.30	36.624
	N2	39.0	41.6	36.3	43.0	42.3	32.8	34.9	40.13	40.40	37.15	38.793
Diwaniyah	N0	32.1	36.6	32.2	33.0	29.0	27.8	29.0	30.83	34.16	32.08	31.703
	N1	35.1	43.2	33.4	36.0	33.8	29.8	32.7	33.61	37.26	35.96	35.095
	N2	37.5	44.8	35.8	38.1	35.0	30.4	33.1	36.70	40.20	38.80	37.060
LSD 0.05	N.S											N.S
												N
Genotype x N	N0	34.1	36.1	34.4	36.6	34.4	30.4	31.6	34.53	35.54	33.53	34.146
	N1	37.4	41.6	36.4	39.7	38.4	32.2	34.5	37.60	38.45	36.97	37.356
	N2	39.4	43.2	37.8	42.5	40.8	33.8	35.7	39.89	41.00	38.38	39.276
LSD	1.241											0.472
												Locations
Genotype x Location	Baghdad	39.4	41.9	40.2	43.3	42.0	36.2	36.9	40.22	39.67	37.28	39.750
	Wasit	36.6	37.5	34.5	39.8	39.0	30.8	33.4	38.09	38.11	35.99	36.410
	Diwani	34.9	41.5	33.8	35.7	32.6	29.3	31.6	33.71	37.21	35.61	34.619
LSD	1.425											0.968
Genotypes means		37.0	40.3	36.2	39.6	37.9	32.1	34.0	37.34	34.33	36.29	
LSD	0.709											

Grain yield (ton ha^{-1})

The results indicate that the grain yield varies across different locations (Table 6). The highest grain yield was recorded at the Baghdad location, reaching 3.877 tons ha^{-1}, while the lowest yield was recorded at the Diwaniya location, reaching 3.272 tons ha^{-1}. The good soil texture, low salinity, and high organic matter content of the Baghdad location (Table 2) contributed to its superior yield. Increasing the level of nitrogen fertilizer resulted in higher yield. The highest yield was obtained with the N2 fertilizer level, reaching 4.556 tons ha^{-1}, while the lowest yield was obtained with the control level at 2.139 tons ha^{-1}. The N1 level produced a good grain yield of 3.916 tons ha^{-1}. The increase in nitrogen level contributed to an increase in the main components of the grain yield, namely, the number of spikes m^{-2}, number of grains spike^{-1}, and 1000-grain weight. The results also showed a significant difference between the genotypes in the grain yield, S2 genotype recorded the highest yield and did not differ significantly from the Buhooth 22 that recorded yields of 4.097 and 4.197 tons ha^{-1}, respectively, as well as the IPA 99 variety, which did not differ significantly from the genotype S2 and produced a yield of 3.989 tons ha^{-1}. The superiority of these genotypes was due to their ability to produce a good number of spikes per unit area (Table 3), as well as the higher grain weight produced by S2 (Table 5), the Buhooth 22 genotype, which had a high average number of grains per spike (Table 4), and the IPA 99 genotype, which recorded the highest number of grains per spike (Table 4). While, the genotype T3 recorded the lowest grain yield of 3.102 tons ha^{-1} due to its lower number of grains per spike, a similar finding was reported by [17]. From Table (6), it can be observed that there is a significant interaction between genotype sand nitrogen fertilization levels, as the yields of the genotypes differed across the fertilization levels, gradually decreasing with decreasing nitrogen levels. The genotype S2 gave the highest average grain yield of 5.38 tons ha^{-1}, which did not differ significantly from the genotypes Buhooth 22 and IPPA 99, which recorded average yields of 5.37 and 5.26 tons ha^{-1}, respectively. On the other hand, the lowest grain yield was recorded for the Adna 99 variety under control treatment (without fertilization), which was 1.82 tons ha^{-1}. Although the yields of the genotypes S2, Buhooth 22, and IPA 99 decreased significantly when the nitrogen level decreased from 100 to 50 kg ha^{-1}, their yields were still higher compared to the other genotypes. This indicates that the high grain yield of these genotypes under low nitrogen conditions reflects their increased stress tolerance and higher nitrogen use efficiency compared to the other genotypes. The genotypes differed in quantity and direction across different locations. The genotype S2 gave the highest grain yield in Baghdad, reaching 4.823 tons ha^{-1}, due to having the highest seed weight and number of spikes per unit area. On the other hand, the lowest yield was recorded for the Adna 99 genotype (2.920 ton ha^{-1}), this is because it has the least flag leaf area, which has a major role in accumulating the nutrients in the grain in Diwaniya. The effect of nitrogen levels varied across different locations. N2 significantly outperformed the other nitrogen levels in Baghdad, with a yield of 4.920 tons ha^{-1} due to recording the highest number of spikes per unit area. However, the control treatment in Diwaniya recorded the lowest yield of 1.874 tons ha^{-1}, as it had the lowest number of spikes per unit area.

Based on the foregoing, it can be inferred that some genotypes gave good yield under nitrogen stress conditions (at a level of 50 kg ha^{-1}), as there was no significant increase in yield with an increase in nitrogen level. Additionally, high-yielding genotypes have shown adaptability in a particular environment, meaning that they adapted to a specific environment and respond to growth inputs. Therefore, we propose studying the qualitative traits of these genotypes to determine their response to environmental x genotype interaction. Genotypes possessing the trait of bread-making may be preferred in several environments and are not limited to cultivating a good variety for a specific environment and poor quality.

Table 6. | Aggregation analysis of locations, nitrogen fertilization, and genotypes of the total grain yield (ton ha^{-1}) for the season 2021-2022.

Locations	N Levels	Genotypes										Locations x N
		T2	T3	S1	S2	S148	IPA 99	Adna 99	Rasheed	Buho 10 oth	Buho 22 oth	
Baghdad	N0	2.7	2.3	2.6	2.9	2.4	2.82	2.467	2.480	2.397	2.873	2.615
	N1	4.3	3.3	3.9	5.2	3.7	4.48	4.003	3.587	3.730	4.570	4.096
	N2	5.0	4.2	5.0	6.2	4.4	5.30	4.660	4.457	4.187	5.420	4.920
Wasit	N0	1.9	1.7	2.0	1.9	1.8	1.97	1.473	1.813	2.067	2.460	1.927
	N1	3.4	3.4	4.0	4.8	3.4	4.81	3.503	3.733	3.490	4.790	3.951
	N2	4.0	3.8	4.5	5.2	4.0	5.70	4.060	4.097	4.153	5.360	4.507
Diwaniyah	N0	1.8	1.6	1.9	1.8	1.8	2.04	1.507	1.657	1.980	2.370	1.874
	N1	3.4	3.2	3.9	4.0	3.6	3.96	3.267	3.397	3.583	4.587	3.701
	N2	3.8	3.9	3.9	4.6	4.0	4.77	3.987	3.800	4.70	5.343	4.241
LSD 0.05	N.S											4.241
												N
Genotype x N	N0	2.1	1.9	2.2	2.2	2.0	2.28	1.816	1.983	2.148	2.568	2.139
	N1	3.7	3.3	3.9	4.6	3.5	4.42	3.591	3.572	3.601	4.649	3.916
	N2	4.3	4.0	4.5	5.3	4.1	5.26	4.236	4.118	4.137	5.374	4.556
LSD	0.137											0.301
												Locati
Genotype x Location	Baghda	4.0	3.3	3.8	4.8	3.5	4.20	3.710	3.508	3.438	4.288	3.877
	Wasit	3.1	3.0	3.5	3.9	3.0	4.16	3.012	3.214	3.237	4.203	3.462
	Diwani	3.0	2.9	3.2	3.4	3.1	3.59	2.920	2.951	3.211	4.100	3.272
LSD	0.210											0.328
Genotypes means		3.4	3.1	3.5	4.0	3.2	3.98	3.214	3.224	3.295	4.197	
LSD	0.168											

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