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Estimation of the genetic indicators of the yield and its components of sorghum(Sorghum bicolor L. Moench) genotypes with spraying boron at different stages of growth

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ABSTRACT
A field experiment was conducted in the autumn season of (2024) in Diyala Governorate to estimate the genetic parameters and analyze the path coefficient when spraying boron at a concentration of 150 mg/L¹ according to the plant growth stages, which are (the five-leaf stage S:2, the growth point differentiation stage S:3, Boot stage S:5, and Half bloom stage S:6). For seven varieties of sorghum, namely (Rabih, Buhuth, Enqaz, Giza, Lilo, G, and Khair), according to the split-plot system with a complete randomized block design RCBD and three replicates, the main plots contained the boron spraying stages, while the secondary plots included the varieties. The study showed values of genetic variance and phenotypic variance were higher values of environmental variance in most of the studied traits and at all stages of boron spraying, the coefficients of genetic variation were between medium and low for all stages of boron spraying, while the phenotypic variation coefficients were high for the trait of number of head seeds, head weight and biomass yield in the fourth stage of boron spraying, which were (31.139, 34.887, 33.563) respectively. As for the heritability in the broad sense, it was high for each of the traits of number of head seeds, head diameter, biomass yield, and grain yield, and they reached (70.132, 60.835, 61.665, 61.422) respectively. the expected genetic advance as a percentage, it was high for the trait of number of head seeds and biomass yield (40.529, 35.189) respectively. While the path coefficient analysis showed high direct effects for number of head seeds, head weight, head diameter, 1000-grain weight, biomass yield and harvest index at different stages of boron application, the indirect effects were high for plant height, number of head seeds, head weight, head diameter, 1000-grain weight and biomass yield at different stages of boron application.

***Keywords*:** sorghum, boron, genetic parameters, path coefficient analysis.

INTRODUCTION
Sorghum is one of the most important agricultural crops that plays a significant and major role in food security and the agricultural economy in many countries around the world, especially in arid and semi-arid regions. Sorghum is considered one of the food grain crops that is characterized by its tolerance to harsh climatic conditions. Sorghum is used for many purposes, whether as human food or animal feed[1]. It is a rich source of carbohydrates, fiber, and proteins. It is also gluten-free, making it a suitable food for people with gluten sensitivity [2].Sorghum is also considered one of the important solutions to confront food shortages in the world due to its high nutritional value and its good proportions of proteins, carbohydrates, and fiber[3]. In 2024, the global production of sorghum was approximately 61.3 million tons, which represents a 4.3% increase from 2023's production of around 58.8 million tons. Global cultivated area for sorghum is estimated to be between 40-45 million hectares.[4]. In Iraq, sorghum is widely cultivated in the central and southern regions as green fodder. In 2021, the planted area was approximately 33,741.25 hectares, with a production of 226,119 tons.[5].The importance of estimating genetic parameters comes from determining the appropriate breeding and selection method based on the genetic variations present in that community, and that the phenotypic variations in any environment can be measured and represent environmental variations as well as the interaction between them[6]. Since sorghum yield improvement is determined by the nature and degree of genetic variation, heritability, and expected genetic improvement present among varieties, path

coefficient analysis. The study aims to identify the genetic parameters, variances and coefficients of variation of the varieties at each growth stage of boron spraying. Also, the effects of the association are divided into direct and indirect effects at each growth stage of spraying with boron.

Materials and methods

A field experiment was in Governorate of Diyala, Baladruz District, on the demonstration farm located at latitude 33.69 north and longitude 45.12 east during the autumn season of 2024 to study the effect of boron spraying on seven sorghum genotypes (Rabih, Buhuth, Enqaz, Giza, Lilo, G, and Khair). Using boric acid (B17%) with 99.9% purity from AVONCHEM International Company, using a concentration of 150 mg/L^1 [7]. at different growth stages of the plant according to the sorghum growth scale , which are: 1- Spraying the plant (five-leaf stage S:2), 2- Spraying the plant at the stage (the growth point differentiation stage S:3), 3- Spraying the plant at (Boot stage S:5), 4- Spraying the plant at (Half bloom stage S:6) [8]. Each main plot was divided into seven sub-plots representing different genotypes of sorghum, and each replication included 28 experimental units. The area of the experimental unit was (4×2.10 = 8.4 m^2). Each experimental unit was divided into three rows, the distance between each line and the next was 0.7 m and 0.25 m between plants[9]. the experiment was planted on 1 august 2024. 3-4 seeds were placed in each hole and Thinned to one plant at the five-leaf stage. Chemical phosphate fertilizer P2O5 was added at a rate of (120 kg ha-1) during soil preparation, and nitrogen fertilizer was added at a rate of (240 kg. ha-1) at urea (46%) in two doses: when the plant emerges and after 30 days of planting [10].Boron was sprayed early in the morning using a 16-litre backpack sprayer according to the amount required by the crop to achieve full wetness for the stage. A split-plot system was used in a randomized complete block design [11], which included three replicates, each of which had four main plots representing the stages of boron spraying. Preventive control of corn stem worm was carried out using 10% diazinon granules, which were sprayed on the heart of the plant in two doses: the first one month after planting and the second 14 days after the first dose[12]. Five plants were randomly selected and the traits of height of plant, No. grains head, head weight, head diameter, weight of 1000 grains, grain plant yield, biomass yield and harvest index were studied. Genetic parameters were estimated and path coefficient was analyzed according to what was calculated Genetic, environmental and phenotypic variation coefficients were estimated according to what was mentioned and they are as follows: less than (10) % low, between (10-30) % medium and then (30) % high. as the equations: , , + , , , , H2.B.S= / , , . The degree of heritability was calculated in the broad sense as mentioned, and the expected ranges of expected genetic advance according [13],were adopted by [14], which are as follows: less than (10) % low, between (10-30) % medium, and more than (30) % high. The standard error of each of the above components was estimated to find out their content by the [13] and by the following equations: $V(\sigma 2G) = 2/r\text{^}2\ [\ [\![(MSG)]\!]\ \text{^}2/(K+2)\ +\ [\![(MSE)]\!]\ \text{^}2/(K+2)]$, $V(\sigma 2E) = (2\ [\![(MSE)]\!]\ \text{^}2)/(K+2)$, As for the calculation of the variance of the phenotypic variation (σ2P)V, it was calculated as in the equation studied and presented by [14], $V(\sigma 2P)\ =\ [\![2(\sigma\text{^}2\ P)]\!]\ \text{^}2/N$, Since K = degrees of freedom for each source of heterogeneity, N= degrees of freedom for varieties + degrees of freedom for Experimental Error and taking the square root of the mentioned variations we obtain the standard error standard Error(SE) for each variation about [17]. And The path coefficient analysis established by [18] was used to break down the correlation coefficient (r) between two variables into direct effects (Direct effect) of the cause (Cause) of the effect (Effect), and indirect effects (Indirect effect) of the cause of the effect through the path (path) i.e. through other causes in the way explained by [19], As for the indirect effects, they were estimated by the following equation: Indirect Effect = PY (R), the residual effect was estimated by the following equation√(1-∑ (Piy riy))=PR The characterization given by [20] was adopted for the values of direct and indirect effects, which are from(0-0.09) negligible, from(0.1-0.19) little or low, from(0.29-0.2) medium, from(0.99-0.3) high and more than 1 very high. These results were estimated using the Obstat program.

Results and Discussion

Table (1) Analysis of variance table

SOV	d.f	Plant length (cm	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %	Grain yield (g)
Replicate	2	4872.858	8040867.75	17099.640	16.781	271.14	169.74	945.31	13247.433
Spray stage	3	569.67 *	3384896.77**	2914.232*	2.581**	12.75n.s	21.33*	198.30*	2377.187*

Replicate (Spray stage)	6	84.704	264518.74	320.406	0.090	6.28	2.71	26.86	331.129
Varieties	6	1063.428 **	5623375.51**	3071.46**	6.683 **	94.41**	59.76**	136.29**	1615.830**
Spray stage ×Varieties	18	549.623 **	777060.53**	782.644**	0.466n.s	7.24n.s	14.50**	48.02**	589.941**
Error	48	83.961	200115.77	220.800	0.297	4.97	2.00	15.13	163.845

At the 0.05 and 0.01 levels, respectively, significant (*) (**) and highly significant

Table (1) shows values of some genetic parameters at the first spraying stage using phenotypic correlation, show genetic variation, phenotypic variation and environmental variation were significant for all studied traits, it becomes clear to genetic and phenotypic variations of some traits are higher than the values of environmental variation, which means that the high phenotypic and genetic variation of the trait gives a great opportunity for plant breeders to increase the efficiency of the breeding process, improve and select the superior traits and elect the best of them directly because they are less affected by environmental factors, unlike the traits that showed that environmental variation is higher than genetic or phenotypic variation, which indicates that this trait is more related to environmental conditions, which means that improving it is better when improving environmental conditions[23] They got similar results . but the values of the coefficient of genetic correlation was between medium and low, and the highest values for the number of head seeds was 20.108 and the lowest for the harvest index was 6.59, as for the coefficient of phenotypic difference, they were all average and the highest values for the trait biomass yield was 24.984 and the lowest values in the weight of 1000 grains was 12.605, As for the environmental variance coefficient, it was high for the plant height trait, reaching 33.96, while the average for the other traits was, note that the results of the values of the coefficients of phenotypic and genetic variation and this is mainly due to the values of both phenotypic and genetic variation differed, and these values were between low and medium for all traits, and this gives confidence to plant breeders by relying heavily on the phenotypic form of selection for superior compositions, as the gene expression is clear on the performance of genotypes, unlike the low values of the coefficients of variation, as for heritability in the broad sense it was high for the number of head seeds, which reached 62,112, and the highest for the harvest index, which reached 23,397, and the average for the rest of the traits ‹The high heritability values indicate the importance of genetic variation as one of the main components of the phenotypic variation of these traits, which are indicators of the possibility of inferring the genotype with the desired genes by the phenotypic form of the trait, so the plant breeder can choose the superior genotype of its phenotypic form and rely on the total selection in improving these traits without resorting to controlled environmental, but medium heritability values, due to the convergence of the values of genetic and environmental variability, this trait can be improved by interaction a breeding program with improved environmental conditions such as fertilization, irrigation and other controlled environmental factors. [24] reached similar results in the trait of the number of head seeds, as for the expected genetic advance as a percentage was high for the number of head seeds, reaching 32.646, and the highest for the harvest index, reaching 6.237, and the average for the rest of the traits, these results correspond to [23] in the number of head seeds. We conclude from this the values of the response to the selection (expected genetic advance) were low to high for most traits, including the traits of the yield and its components ,and this indicates the importance of the selection in improving these traits, as it is expected that the improvement in these traits is significant as a result of the selection, which shows the importance of the genetic aspect in improving these traits and that the expected improvement in the grain yield is by causing an increase in one or more of its main components because it is the result of the product of these components [24].

Table (1) Genetic parameters at the first spraying stage using the phenotypic correlation

Genetic parameter	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %	Grain yield (g)
σ^2_G	264.61 ±170.87	692813.12 ±420227.41	369.73 ±278.68	0.377 ±0.29	7.87 ±4.87	6.16 ±4.36	8.61 ±9.68	233.49 ±175.58
σ^2_P	482.65 ±160.88	1115418.38 ±371806.13	886.37 ±160.88	0.977 ±0.32	13.25 ±4.41	13.31 ±4.43	36.83 ±12.27	557.64 ±185.88
σ^2_E	218.04 ±82.40	422605.25 ±159729.77	516.63 ±195.27	0.600 ±0.22	5.38 ±2.03	7.14 ±2.70	28.21 ±10.66	324.15 ±122.51

C.V.G	10.803	20.108	13.875	8.034	9.714	17.003	6.259	13.023
C.V.P	14.590	25.514	21.483	12.938	12.605	24.984	12.940	20.126
C.V.E	33.96	15.70	16.40	10.14	8.03	18.29	11.32	15.34
H^2.b.s	54.826	62.112	41.713	38.559	59.390	46.318	23.397	41.871
E.G.A	24.813	1,351.339	25.583	0.785	4.454	3.482	2.925	20.369
E.G.A %	16.478	32.646	18.460	10.277	15.422	23.838	6.237	17.360

The results of Table (2) show the values of some genetic parameters at the second spraying stage, the values of genetic variation are significant for each weight 1000 grains, the harvest index and the yield of the grain plant yield, while the values of phenotypic variation and environmental variation were significant for all the studied traits, it becomes clear to us that the values of the genetic and phenotypic variations of some traits are higher than the values of environmental variation, which means that the high phenotypic and genetic variation of the trait gives a great opportunity for plant breeders to increase the efficiency of the breeding process, improve and select the superior traits and elect the best of them directly because they are less affected by environmental factors, unlike the traits that showed that environmental variation is higher than genetic or phenotypic variation, which indicates that this trait is more related to environmental conditions, which means that improving it is better when improving environmental conditions, but the coefficient of genetic difference was low for all traits, the coefficient of phenotypic difference was low for the plant height trait and amounted to 7.345 and the medium for the rest of the traits, as the highest value for the number of grains in the head was 23.342, As for the environmental variance coefficient, it was between average and low for all traits. note that the results of the values of the coefficients of phenotypic and genetic variation and this is mainly due to the values of both phenotypic and genetic variation differed, and these values were between low and medium for all traits, and this gives confidence to plant breeders by relying heavily on the phenotypic form of selection for superior compositions, as the gene expression is clear on the performance of genotypes, unlike the low values of the coefficients of variation. these results correspond to [25]who found the coefficient of phenotypic difference it was high only in the class of the grain plant yield reached 61.422 and low for the rest of the traits, as it was the lowest value in the class of head weight reached 2.865 these results correspond to[26], as for the expected genetic advance the average in the grain plant yield class was 15.276 and low for the rest of the traits and the lowest values in the head weight class was 1.057 .these results correspond to [27] in the grain plant yield. We conclude from this the values of the response to the selection (expected genetic advance) were low too high for most traits, including the traits of the yield and its components ,and this indicates the importance of the selection in improving these traits, as it is expected that the improvement in these traits is significant as a result of the selection, which shows the importance of the genetic aspect in improving these traits and that the expected improvement in the grain yield is by causing an increase in one or more of its main components because it is the result of the product of these components [24; 28].

Table (2) Genetic parameters at the second spraying stage using the phenotypic correlation

Genetic parameter	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %	Grain yield (g)
σ^2_G	30.399 ±31.95	135898.15 ±201745.42	17.046 ±127.63	0.247 ±0.30	6.204 ±5.58	0.879 ±1.61	8.900 ±8.29	116.595 ±71.10
σ^2_P	118.846 ±39.62	821953.39 ±273984.46	594.931 ±198.31	1.180 ±0.39	19.554 ±6.52	6.810 ±2.27	29.470 ±29.47	189.828 ±63.27
σ^2_E	88.447 ±33.43	686055.24 ±259304.51	577.885 ±218.42	0.933 ±0.35	13.350 ±5.04	5.931 ±2.24	20.570 ±7.77	73.233 ±27.67
C.V.G	3.715	9.491	3.031	6.057	8.325	5.946	7.149	9.462
C.V.P	7.345	23.342	17.909	13.233	14.780	16.552	13.009	12.073
C.V.E	6.33	21.32	17.64	11.77	12.21	15.41	10.87	7.50
H^2.b.s	25.579	16.534	2.865	20.947	31.728	12.906	30.200	61.422
E.G.A	5.744	308.786	1.440	0.469	2.890	0.694	3.377	17.433
E.G.A %	3.870	7.950	1.057	5.710	9.660	4.401	8.093	15.276

Table (3) shows the values of some genetic parameters at the third spraying stage using the phenotypic correlation, the values of genetic variation were significant for both the plant height, the number of head seeds, the biomass yield and the grain plant yield, while the values of phenotypic variation and environmental variation were significant for all the studied traits. It becomes clear to us that the values of the genetic and phenotypic variations of some traits are higher than the values of environmental variation, which means that the high phenotypic and genetic variation of the trait gives a great opportunity for plant breeders to increase the efficiency of the breeding process, improve and select the superior traits and elect the best of them directly because they are less affected by environmental factors, unlike the traits that showed that environmental variation is higher than genetic or phenotypic variation, which indicates that this trait is more related to environmental conditions, which means that improving it is better when improving environmental conditions. but the coefficient of genetic difference was between the medium and the low, as the number of head seeds gave the highest value of 23.493,and the lowest value for the head diameter was 4.195 ,while the coefficient of phenotypic difference was the medium for all traits and the highest value for the number of head seeds was 28.053 and the lowest value for the plant height was 13.608 [29] obtained similar results for the coefficient of genetic and phenotypic differences in plant height, head weight, weight of 1000 grains, grain plant yield and harvest index note that the results of the values of the coefficients of phenotypic and genetic variation and this is mainly due to the values of both phenotypic and genetic variation differed, and these values were between low and medium for all traits, and this gives confidence to plant breeders by relying heavily on the phenotypic form of selection for superior compositions, as the gene expression is clear on the performance of genotypes, unlike the low values of the coefficients of variation, As for the environmental variance coefficient, it was low for the plant height trait and average for the other traits, as for heritability in the broad sense , it was high for the number of head seeds and the harvest index, and amounted to 70.132, 81.665 ,respectively , and between the medium and low for the rest of the traits, if the lowest for the head diameter was 8.572, The high heritability values indicate the importance of genetic variation as one of the main components of the phenotypic variation of these traits, which are indicators of the possibility of inferring the genotype with the desired genes by the phenotypic form of the trait, so the plant breeder can choose the superior genotype of its phenotypic form and rely on the total selection in improving these traits without resorting to controlled environmental, but medium heritability values, due to the convergence of the values of genetic and environmental variability, this trait can be improved by interaction a breeding program with improved environmental conditions such as fertilization, irrigation and other controlled environmental factors. [30; 31] obtained results similar to the plant height, while the expected genetic advance as a percentage was the highest in the number of head seeds was 40.529 and the lowest for the head diameter was 2.53 and between medium and low for the rest of the traits. We conclude from this the values of the response to the selection (expected genetic advance) were low too high for most traits, including the traits of the yield and its components ,and this indicates the importance of the selection in improving these traits, as it is expected that the improvement in these traits is significant as a result of the selection, which shows the importance of the genetic aspect in improving these traits and that the expected improvement in the grain yield is by causing an increase in one or more of its main components because it is the result of the product of these components [24; 32].

Table (3) Genetic parameters at the third spraying stage using the phenotypic correlation

Genetic parameter	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %	Grain yield (g)
σ^2_G	211.051 ±141.39	778448.66 ±446438.5	296.463 ±286.91	0.099 ±0.26	2.088 ±4.01	8.872 ±5.39	28.272 ±19.50	178.606 ±199.58
σ^2_P	412.465 ±137.48	1109983.77 ±369994.6	1035.440 ±345.14	1.150 ±0.38	17.067 ±5.68	14.387 ±4.79	58.256 ±19.41	757.496 ±252.49
σ^2_E	201.414 ±76.12	331535.11 125308.5	738.977 ±279.30	1.051 ±0.39	14.979 ±5.66	5.515 ±2.08	29.984 ±11.33	578.890 ±218.79
C.V.G	9.734	23.493	13.941	4.195	5.149	21.751	12.051	12.848
C.V.P	13.608	28.053	26.054	14.329	14.720	27.699	17.298	26.460
C.V.E	9.50	15.33	22.01	13.70	13.78	17.14	12.41	23.13
H^2.b.s	51.168	70.132	28.632	8.572	12.235	61.665	48.530	23.578
E.G.A	21.407	1522.085	18.979	0.189	1.041	4.818	7.630	13.368
E.G.A %	14.343	40.529	15.367	2.530	3.710	35.186	17.293	12.852

The results of table (4) show the values of some genetic parameters at the fourth spraying stage, the values of genetic variation are significant for the plant height, the number of head seeds, the head diameter and the biomass yield, while the values of phenotypic variation and environmental variation were significant for all the studied traits, it becomes clear to us that the values of the genetic and phenotypic variations of some traits are higher than the values of environmental variation, which means that the high phenotypic and genetic variation of the trait gives a great opportunity for plant breeders to increase the efficiency of the breeding process, improve and select the superior traits and elect the best of them directly because they are less affected by environmental factors, unlike the traits that showed that environmental variation is higher than genetic or phenotypic variation, which indicates that this trait is more related to environmental conditions, which means that improving it is better when improving environmental conditions, the coefficient of genetic difference was between the medium and low and the highest values in the biomass yield was 20.864 and the lowest in the head weight was 3.859, while the coefficient of phenotypic difference was high in the number of head seeds, head weight, biomass yield and the highest values for head weight was 34.887 and the lowest in plant height was 13.886 [33] based on similar results in the head weight trait, note that the results of the values of the coefficients of phenotypic and genetic variation and this is mainly due to the values of both phenotypic and genetic variation differed, and these values were between low and medium for all traits, and this gives confidence to plant breeders by relying heavily on the phenotypic form of selection for superior compositions, as the gene expression is clear on the performance of genotypes, unlike the low values of the coefficients of variation, As for the environmental variance, it was low for the head diameter trait and high for the head weight trait, reaching 34.67, while the average for the other traits was moderate , while the heritability in the broad sense was high for the head diameter reached 60.835, the lowest for the harvest index reached 9.547, and the rest is between medium and low, these results correspond to This is due to the heritability low value of genetic variation compared to environmental variation and that low heritability values indicate that this trait is highly influenced by environmental conditions and makes selection for this trait difficult. [34]for the head diameter, as for the expected genetic advance as a percentage, it was between medium and low, reaching values for the number of head seeds of 22.971 and the lowest for the head weight of 0.88. [35; 36]obtained similar results for the plant height, the number of head seeds and the grain plant yield. We conclude from this the values of the response to the selection (expected genetic advance) were low too high for most traits, including the traits of the yield and its components ,and this indicates the importance of the selection in improving these traits, as it is expected that the improvement in these traits is significant as a result of the selection, which shows the importance of the genetic aspect in improving these traits and that the expected improvement in the grain yield is by causing an increase in one or more of its main components because it is the result of the product of these components[24].

Table (4) Genetic parameters at the fourth spraying stage using the phenotypic correlation

Genetic parameter	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %	Grain yield (g)
σ^2_G	156.408 ±117.58	353238.55 ±293205.1	19.35 ±334.21	0.914 ±0.56	3.181 ±6.44	8.048 ±6.36	5.147 ±12.33	123.042 ±148.67
σ^2_P	373.382 ±124.46	986394.33 ±328798.1	1581.83 ±527.27	1.503 ±0.50	27.603 ±9.20	20.826 ±6.94	53.912 ±17.97	577.221 ±192.40
σ^2_E	216.974 ±82.00	633155.77 ±239310.4	1562.48 ±590.56	0.589 ±0.22	24.422 ±9.23	12.778 ±4.82	48.765 ±18.43	454.179 ±171.66
C.V.G	8.988	18.634	3.859	11.810	6.086	20.864	5.701	11.823
C.V.P	13.886	31.139	34.887	15.141	17.925	33.563	18.452	25.607
C.V.E	10.58	24.94	34.67	9.47	16.85	26.28	17.54	22.71
H^2.b.s	41.890	35.811	1.224	60.835	11.526	38.643	9.547	21.316
E.G.A	16.674	732.673	1.003	1.536	1.247	3.633	1.444	10.550
E.G.A %	11.983	22.971	0.880	18.975	4.256	26.718	3.629	11.244

Path coefficient analysis

Table (5) shows the path coefficient analysis based on the phenotypic correlation of the grain yield at the first stage, that the direct effect of plant height was neglected, as for the indirect effect, the average number of head seeds was 0.28612 and a low for the biomass yield was 0.17177 and neglected and negative for the rest of the traits, and thus the total effects in the grain yield became 0.27034. As for the number of head seeds, the direct effect was high and amounted to 0.86026, and the indirect effect was low for both the weight of the head and the biomass yield amounted to (0.14976, 0.18679), respectively, and negative for the rest of the traits, so the total effects in the grain yield became 0.90376, as for the head weight, the direct effect was low and amounted to 0.16871. while the indirect effect was medium for both the number of head seeds and the biomass yield (0.76367, 0.21473) respectively, negative and neglected for the rest of the traits, and thus the total effects in the grain yield 0.9795 , As for the head diameter, the direct effect was negative, and the indirect effect was high for the number of head seeds amounted to 0.51918 and the average for the biomass yield amounted to 0.2200 and a low for the head weight amounted to 0.12487 and neglected and negative for the rest of the traits, so the total effects in the grain yield 0.68735, and for the weight of 1000 grains, the direct effect was high, reaching 0.39510, while the indirect effect was neglected and negative, and thus the total effects in the grain yield -0.28119 , the biomass yield was an medium direct effect of 0.25681. As for the indirect effect ,it was high for the number of head seeds, it reached 0.62571, and low for the head weight, it reached 0.14106, and neglected and negative for the rest of the traits, and thus the total effects in the grain yield 0.79318, while in the harvest index, if the direct effect was small, it reached 0.16123, the indirect effect was neglected and negative, and thus the total effects in the grain yield -0.06525 the 0.00212 . These results are in line with the findings of [37; 38].

Table (5) analysis of the path coefficient at the first spraying stage based on the phenotypic correlation (diagonal values) direct effect and (values above and below the diagonal) indirect effect of traits in the grain yield

Traits	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %
Plant length (cm)	**0.00157**	0.00052	0.00054	0.00102	-0.00038	0.00105	-0.00121
Number of head seeds	0.28612	**0.86026**	0.76367	0.51918	-0.56879	0.62571	-0.04215
Head weight (g)	0.05774	0.14976	**0.16871**	0.12487	-0.04786	0.14106	-0.02793
Head diameter (cm)	-0.02624	-0.02418	-0.02965	**-0.04006**	0.00500	-0.03432	0.02197
Weight of 1000 grain (g)	-0.09661	-0.26123	-0.11210	-0.04931	**0.39510**	-0.09248	-0.00994
Biomass yield (g)	0.17177	0.18679	0.21473	0.22000	-0.06011	**0.25681**	-0.16699
Harvest index (%)	-0.12444	-0.00790	-0.02669	-0.08841	-0.00405	-0.10484	**0.16123**
Total effects	0.27034	0.90376	0.9795	0.68735	-0.28119	0.79318	-0.06525
Residuals	0.00212						

Table (6) shows the path coefficient analysis based of the phenotypic correlation of the grain yield at the second stage, that the direct effect of a rise is negative, while the indirect effect was negative and neglected, and thus the total effects in the grain yield became 0.05680- As for the number of head seeds , the direct effect was average ,reaching 0.27224 , and the indirect effect was high for both the biomass quotient and the harvest guide , reaching(0.41115 ,0.27757), respectively, and negligible and negative for the rest of the qualities, and thus the Total Effects in the grain quotient became 0.69047, as for the weight of the head, the direct effect was negative, while the indirect effect was high for both the biomass quotient and the harvest guide, reaching (0.60570, 0.32031), respectively, and the average number of head seeds is 0.21413, and negligible and negative for the rest of the qualities, so the Total Effects in the grain yield became 0.83477 , While for the diameter of the head, as the direct effect was small, 0.13320, the indirect effect was high for the biomass quotient was 0.59639, and a small number of head seeds, 0.13465, and negative for the rest of the qualities, and so the Total Effects in the grain quotient became 0.38386, as for the weight of 1000 grains, the direct effect was negligible, and the indirect effect was negligible and negative, and so the Total Effects in the grain quotient became 0.06077- While in the biomass quotient , the direct effect was high and amounted to 0.82753 , while the indirect effect was low for the number of head seeds amounted to 0.13526, neglected and negative for the rest of the qualities, and thus the Total Effects in the grain quotient became 0.58296, as for the harvest guide, the direct effect was high, reaching 0.75334, while the indirect effect was low for the number of head seeds amounted to 0.10031, the rest of the qualities are neglected and negative, and thus the total effects in the grain quotient 0.4378 . While the rest that were not studied, their value reached 0.25238. [39; 40] obtained similar results.

Table (6) analysis of the path coefficient at the second spraying stage based on the phenotypic correlation (diagonal values) direct effect and (values above and below the diagonal) indirect effect of traits in the grain yield

Traits	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %
Plant length (cm)	**-0.11195**	0.00670	-0.00264	-0.04111	-0.02113	-0.00437	0.00266
Number of head seeds	-0.01630	**0.27224**	0.21413	0.13465	-0.17128	0.13526	0.10031
Head weight (g)	-0.00860	-0.28696	**-0.36483**	-0.18444	0.02084	-0.26703	-0.15512
Head diameter (cm)	0.04891	0.06588	0.06734	**0.13320**	-0.03586	0.09599	-0.04079
Weight of 1000 grain (g)	0.01676	-0.05587	-0.00507	-0.02391	**0.08881**	0.00181	0.00480
Biomass yield (g)	0.03232	0.41115	0.60570	0.59639	0.01691	**0.82753**	-0.22706
Harvest index (%)	-0.01789	0.27757	0.32031	-0.23072	0.04075	-0.20670	**0.75334**
Total effects	-0.0568	0.69047	0.83477	0.38386	-0.06077	0.58296	0.4378
Residuals	0.25238						

Table (7) shows the analysis of the path coefficient based on the phenotypic correlation of the grain yield at the third stage ,that the direct effect of a neglected height , while the indirect effect is high for the head weight amounted to 0.34301 and the average for the biomass yield 0.22879 and a small number of head seeds amounted to 0.10332 and negative and neglected for the rest of the traits, and thus the total effects in the grain yield became 0.49599, as for the number of head seeds, the direct effect was small and amounted to 0.16079 while the indirect effect was high for the head weight of 0.53624 and the medium biomass yield was 0.234117 and neglected and negative for the rest of the traits, so the total effects in the grain yield became 0.84227 , for the head weight the direct effect was high at 0.61536 ,while the indirect effect was medium for the biomass yield was 0.23640, a small number of head seeds was 0.14011, neglected and negative for the rest of the traits, and thus the total effects in the grain yield became 0.98774, as for the head diameter the direct effect was negative, while the indirect effect was high for the weight of the head was 0.38534 and a little for the biomass yield was 0.16036, negative and neglected for the rest of the traits, and thus the total effects in the grain yield became 0.56048, while for the weight of 1000 grains ,the direct effect was neglected, and the indirect effect was only a little for the harvest index amounted to 0.15273 and neglected and negative for the rest of the traits, so the total effects in the grain yield became 0.11666. As for the biomass yield ,the direct effect medium 0.28766, while the indirect effect was high for the head weight amounted to 0.50570 and low for the number of head seeds amounted to 0.12921, neglected and negative for the rest of the traits, and so the total effects in the grain yield became 0.7544, or in the harvest index, the direct effect medium 0.25657, neglected and negative for the rest of the traits, and so the total effects in the grain yield became 0.24106, while the total number of unexplored residues was 0.00418 [23; 41]to similar results

Table (7) analysis of the path coefficient at the third spraying stage based on the phenotypic correlation (diagonal values) direct effect and (values above and below the diagonal) indirect effect of traits in the grain yield

Traits	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %
Plant length (cm)	**0.01778**	0.01143	0.00991	0.00646	-0.00695	0.01414	-0.00901
Number of head seeds	0.10332	**0.16079**	0.14011	0.07624	-0.06835	0.12921	-0.01145
Head weight (g)	0.34301	0.53624	**0.61536**	0.38534	0.02649	0.50570	0.07819
Head diameter (cm)	-0.02926	-0.03820	-0.05044	**-0.08056**	-0.00786	-0.04491	-0.00114
Weight of 1000 grain (g)	-0.03781	-0.04110	0.00416	0.00944	**0.09668**	-0.02568	0.05755
Biomass yield (g)	0.22879	0.23117	0.23640	0.16036	-0.07640	**0.28766**	-0.13008
Harvest index (%)	-0.13006	-0.01827	0.03260	0.00364	0.15273	-0.11602	**0.25657**
Total effects	0.49599	0.84227	0.98774	0.56048	0.11666	0.75044	0.24106
Residuals	0.00418						

Table (8) shows the analysis of the path coefficient based on the phenotypic correlation of the grain yield at the fourth stage ,that the direct effect of plant height medium 0.22752 ,while the indirect effect was high for the number of head seeds and the biomass yield reached (0.54300 ,0.79495), respectively, and the average head diameter reached 0.26913, negative and neglected for the rest of the traits, and thus the total effects in the grain yield became 0.49906, the number of head seeds the direct effect was high, reaching 0.77440, while the indirect effect was high for the head diameter and the biomass yield reached (0.31437, 0.78340), respectively, and low for both the plant height and the harvest index, reaching (0.15953 ,0.11750) respectively, as for the rest of the traits, it was negative and neglected, and thus the total effects in the grain yield became 0.67087. As for the head weight, the direct effect was negative, while the indirect effect was high for both the number of head seeds and the biomass yield, reaching (0.71831 , 0.82249), respectively, and the medium head diameter was 0.28463 and a little for the plant height and the harvest index, reaching (0.17394 ,0.16401), respectively, and neglected for the rest of the traits, and thus the total effects in the grain yield became 0.60088 , As for the head diameter ,the direct effect was high and amounted to 0.42453 ,while the indirect effect was high for the number of head seeds and the biomass yield (0.57344, 0.74549), respectively, and low for the plant height reached 0.14423 and negative for the rest of the traits, so the total effects in the grain yield became 0.64204, as for the weight of 1000 grains, the direct effect was neglected, while the indirect effect was high for the harvest index, reaching 0.31221 the medium biomass yield is 0.2466, and the remaining traits are neglected and negative, so the total effects in the grain yield became 0.06759 , As for the biomass yield , the direct effect was high and amounted to 0.93127 ,while the indirect effect was high for the number of head seeds and the head diameter (0.65144 ,0.33984), respectively, and low for the plant height reached 0.19421, neglected and negative for the rest of the traits, and thus the total effects in the grain yield became 0.5638, as for the harvest index, the direct effect was high, reaching 0.72014, while the indirect effect was low for the number of head seeds 0.12636 is neglected and negative for the rest of the traits, so the total effects in the grain yield became 0.17437. As for the rest that were not studied, their value was 0.40168.[42; 43], obtained similar results. We conclude from this that the values of direct genetic influences are greater than the values of the phenotypic effects of all the studied traits, that is, environmental influences had a negative impact and that genetic influences are more important than phenotypic in breeding programs to improve the grain yield because it expresses the common genetic components between the yield and the qualities in question that are inherited from parents to progeny.

Table (8) analysis of the path coefficient at the fourth spraying stage based on the phenotypic correlation (diagonal values) direct effect and (values above and below the diagonal) indirect effect of traits in the grain yield

Traits	Plant length (cm)	Number of head seeds	Head weight (g)	Head diameter (cm)	Weight of 1000 grain (g)	Biomass yield (g)	Harvest index %
Plant length (cm)	0.22752	0.15953	0.17394	0.14423	0.06843	0.19421	-0.04364
Number of head seeds	0.54300	0.77440	0.71831	0.57344	0.08471	0.65144	0.12636
Head weight (g)	-1.22674	-1.48842	-1.60464	-1.07586	-0.71081	-1.41720	-0.36544
Head diameter (cm)	0.26913	0.31437	0.28463	0.42453	-0.02963	0.33984	-0.09642
Weight of 1000 grain (g)	0.02886	0.01049	0.04250	-0.00670	0.09594	0.02541	0.04159
Biomass yield (g)	0.79495	0.78340	0.82249	0.74549	0.24668	0.93127	-0.20808
Harvest index (%)	-0.13814	0.11750	0.16401	-0.16356	0.31221	-0.16090	0.72014
Total effects	0.49906	0.67087	0.60088	0.64204	0.06759	0.5638	0.17437
Residuals	0.40168						

Conclusion:

We conclude the genetic and phenotypic variance were higher than the environmental variance, while the first spraying stage was the most significant. The phenotypic variance components showed high values in the fourth spraying stage. Path coefficient values showed that the fourth spraying stage had the highest direct effect on grain yield.

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تقدير المعالم الوراثية للحاصل ومكوناته في تراكيب وراثية من الذرة البيضاء (Sorghum bicolor L. Moench) تحت رش عنصر البورون في مراحل نمو مختلفة

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الخلاصة

أجريت تجربة حقلية في الموسم الخريفي (2024) في محافظة ديالى لتقدير المعالم الوراثية وتحليل معامل المسار عند رش البورون بتركيز 150 ملغم/لتر¹ وفقاً لمراحل نمو النبات وهي (مرحلة الخمس أوراق ***S:2***، مرحلة تمايز نقطة النمو ***S:3***، مرحلة التجهيز ***S:5***، ومرحلة الإزهار ***S:6***). ولسبعة أصناف من الذرة الرفيعة وهي (رابح، بحوث، إنقاذ، جيزة، ليلو، ***J***، وخير)، وفقاً لنظام القطع المنشقة بتصميم القطاعات العشوائية الكاملة وبثلاثة مكررات، احتوت القطع الرئيسية على مراحل رش البورون، بينما احتوت القطع الثانوية على الأصناف. أظهرت الدراسة ارتفاع قيم التباين الوراثي والتباين المظهري عن قيم التباين البيئي في معظم الصفات المدروسة وفي جميع مراحل رش البورون، حيث تراوحت معاملات التباين الوراثي بين المتوسطة والمنخفضة في جميع مراحل رش البورون، بينما كانت معاملات التباين المظهري مرتفعة لصفة عدد الرؤوس ووزن الرؤوس وإنتاجية الكتلة الحيوية في المرحلة الرابعة من رش البورون، حيث بلغت (31.139، 34.887، 33.563) على التوالي. أما بالنسبة لمعدل التوريث بالمعنى الواسع، فقد كان مرتفعًا لكل من صفة عدد الرؤوس وقطر الرؤوس وإنتاجية الكتلة الحيوية وإنتاجية الحبوب، حيث بلغت (70.132، 60.835، 61.665، 61.422) على التوالي. كان التحسين الوراثي المتوقع كنسبة مئوية مرتفعًا لصفة عدد الرؤوس وإنتاجية الكتلة الحيوية (40.529، 35.189) على التوالي. بينما أظهر تحليل معامل المسار تأثيرات مباشرة عالية على عدد الرؤوس، ووزن الرأس، وقطر الرأس، ووزن حبة، والحاصل البايلوجي ، ومؤشر الحصاد في مراحل مختلفة من إضافة البورون، كانت التأثيرات غير المباشرة عالية على ارتفاع النبات، وعدد الرؤوس، ووزن الرأس، وقطر الرأس، ووزن 1000 حبة، والحاصل البايلوجي في مراحل مختلفة من إضافة البورون.

الكلمات المفتاحية: الذرة البيضاء، البورون، المعالم الوراثية، تحليل معامل المسار .