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GENOTYPIC AND PHENOTYPIC VARIANCE, CORRELATION, AND PATH COEFFICIENT ANALYSIS IN MAIZE

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Abstract

A half-diallel crossing was carried out between six Inbreeds of maize according to the second Griffing method. The genotypes (parents and the hybrids resulting from them) were planted during the spring and fall seasons of 2022 using a randomized complete block design (RCBD) with three replicates to study genetic and phenotypic correlations and their variations and the path coefficient for traits (number of silking days, plant height, leaf area, number of ears, number of rows per ear, number of grains per row, weight of 500 grains, and grain yield per plant). Analysis of Variance showed highly significant differences between the genotypes for all the studied traits for the fall and spring seasons of 2020. The results indicated that the values of the phenotypic variation coefficient were close to the values of the genetic variation coefficient for most traits. Accordingly, the genotype can be studied by taking phenotypic data, and such traits can be considered a selection index for improving this crop. The broad-sense heritability values were high for all traits and were highest for the number of grains per row and plant yield for the two seasons, reaching 91.95% and 90.21% for the spring season, respectively, and 95.52%, 86.08% for the fall season, respectively. The number of rows per ear and the number of grains per row showed a highly significant positive genetic correlation with the grain yield of the plant in the spring season, reaching 0.819 and 0.915 respectively. The highest genetic correlation for the autumn season for the traits of the number of ears and the number of rows per ear with the plant yield was 0.874 and 0.604. There was a highly significant phenotypic correlation with the grain yield of the plant for the traits of the number of ears, the number of rows per ear, and the number of grains per row. For both seasons, it reached 0.568, 0.707, and 0.748 for the spring season, respectively, and 0.825, 0.603, and 0.809 for the fall season, respectively. Furthermore, the highest direct effects on yield in the spring and fall seasons were through silking, the number of ears, and the number of rows per ear, as they reached 0.691, 0.498, and 0.671 for the spring season, respectively, and 0.701, 0.516, and 0.689 for the fall season and the above traits, respectively. Consequently, path coefficient analysis revealed that it is possible to benefit from direct selection for silking traits, number of ears, and number of rows per ear in breeding programs to increase yields in yellow maize.

Keywords: Pathway, GCV, PCV, Corn, Inbreed.

الارتباطات والتباينات الوراثية والمظهرية وتحليل معامل المسار في الذرة الصفراء

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الخلاصة

نفذ التهجين نصف التبادلي بين ست سلالات من الذرة الصفراء وفق طريقة Griffing الثانية زرعت التراكيب الوراثية (الآباء والهجن الناتجة منها) خلال موسمي الربيعي والخريفي 2022 باستخدام تصميم القطاعات العشوائية الكاملة (R.C.B.D) وبثلاثة مكررات بهدف دراسة الارتباطات الوراثية والمظهرية وتبايناتهما ومعامل المسار لصفات (عدد الأيام للتزهير الأنثوي وارتفاع النبات والمساحة الورقية وعدد العرانيص وعدد الصفوف

بالعرنوص وعدد الحبوب بالصف ووزن 500 حبة وحاصل الحبوب بالنبات). أظهر تحليل التباين وجود اختلافات معنوية عالية بين التراكيب الوراثية ولجميع الصفات المدروسة وللموسمين الخريفي والربيعي 2020. أشارت النتائج إلى ان قيم معامل الاختلاف المظهري كانت مقاربة من قيم معامل الاختلاف الوراثي لمعظم الصفات، وعليه يمكن استقراء التركيب الوراثي من خلال اخذ بيانات مظهرية وبالإمكان اعتبار مثل هذه الصفات كدليل انتخابي في تحسين هذا المحصول. كانت نسبة التوريث بالمعنى الواسع مرتفعة لجميع الصفات وكان أعلاها لصفتي عدد الحبوب بالصف وحاصل النبات للموسمين بلغت 91.95% و90.21% للموسم الربيعي بالتتابع و95.52% و86.08% للموسم الخريفي بالتتابع. أبدى عدد الصفوف بالعرنوص وعدد الحبوب بالصف ارتباطاً وراثياً موجباً عالي المعنوية مع حاصل الحبوب بالنبات في الموسم الربيعي بلغ 0.819 و0.915 بالتتابع وبلغ أعلى ارتباط وراثي للموسم الخريفي لصفتي عدد العرانيص وعدد الصفوف بالعرنوص مع حاصل النبات بلغ 0.874 و0.604 وكان هناك ارتباطاً مظهرياً عالي المعنوية مع حاصل الحبوب بالنبات لصفات عدد العرانيص وعدد الصفوف بالعرنوص وعدد الحبوب بالصف ولكلا الموسمين بلغ 0.568 و0.707 و0.748 للموسم الربيعي بالتتابع و0.825 و0.603 و0.809 للموسم الخريفي بالتتابع. أعلى التأثيرات المباشرة على الحاصل في الموسمين الربيعي والخريفي كان من خلال التزهير الأنثوي وعدد العرانيص وعدد الصفوف بالعرنوص إذ بلغت 0.691 و0.498 و0.671 للموسم الربيعي بالتتابع و0.701 و0.516 و0.689 للموسم الخريفي وللصفات أعلاه بالتتابع وعليه كشف تحليل معامل المسار انه بالإمكان الاستفادة من الانتخاب المباشر لصفة التزهير الأنثوي وعدد العرانيص وعدد الصفوف بالعرنوص في برامج التربية لرفع الحاصل في الذرة الصفراء.

كلمات مفتاحية: معامل المسار، معامل الاختلاف الوراثي، معامل الاختلاف المظهري، الذرة الصفراء، السلالة.

Introduction

The maize yield (Zea mays L.) is a quantitative trait with complex inheritance because many genes control it. Therefore, direct selection for it is an ineffective way to improve this trait. However, indirect selection through traits related to yield, which have a high degree of heritability, is an effective way to improve this trait, as it depends on the phenotypic correlation and additional genetic variation, in addition to the degree of heritability of the traits correlated with the yield (1 and 2). The correlation coefficient is useful in selecting many of the main components that affect yield (3). The correlation coefficient provides plant breeders with important information, as this information can indicate the most important traits studied (4). The genetic correlation coefficient measures the degree of relationship between the genetic variations of two quantitative traits in a population, and the genetic correlation coefficient is calculated in the inheritance of quantitative traits and in breeding research (19). The genetic correlation is calculated from the components of the covariance of the two traits when analyzing the covariance. Genetic correlation values are often higher than phenotypic correlation values, which indicates that the genotype determines the phenotypic correlation (5). Genetic Variance is the difference between plants with a dissimilar genotype, grown under the same or controlled environmental conditions. While Environmental Variance is defined as the difference between plants with an identical genotype, cultured under different environmental conditions, whereas Phenotypic Variance is the sum of genetic variation and environmental variation, and depends on the randomness of environmental variation (location and time) (8). Genetic variation is important for plant breeders, as it gives the breeder a wide range in selecting genetic variation, which represents the raw material from which it can select the best genetic genotypes. The environment was found to be an “important” element in demonstrating the characteristics of living organisms. Simple correlation between traits is not the ideal way to aid in selection, since a high correlation between multiple traits may have a negative impact on some other traits. Therefore, the path coefficient is used as an advanced step that determines the minimum number of traits that can be used as a criterion in selection for the yield trait (21). The scientist Swell Wright published the path coefficient analysis method for the first time in 1921 as a general calculation of the method and the relationship between the correlation and the path coefficient together. The benefit of path analysis is that it allows the correlation coefficient to be decomposed into its components. The path coefficient is used in agricultural experiments by plant breeders to help them identify useful traits, as selection criteria for increasing yields (17).

Materials and Methods

This study relied on data from cultivating 21 genotypes, including six Inbreeds of maize, as shown in Table 1, with fifteen individual hybrids between them. The fifteen single-cross hybrids were obtained by crossing the six Inbreeds according to the second method of the scientist (10), the fixed model. The number of crosses will be according to the following equation: $\left(1 - p\left(\frac{p}{2}\right)\right)$

Table 1: of Inbreed names and numbers.

Inbreed names	Inbreed numbers
1	B73
2	IK
3	A132
4	NA30
5	S7
6	DR-B1

The genotypes were planted in the spring and fall of 2022 growing seasons in lines according to the RCBD design, with three replicates and four lines for each genotype, with a distance of 0.25 m between holes and 0.75 m between lines. The field was fertilized with 320 kg.ha^{-1} of dab fertilizer added to the soil during land preparation, and 100 kg.ha^{-1} of urea was added in two batches, half the amount when the plant reached an average height of 25 cm and the other half at the beginning of flowering. The weeds were controlled using the herbicide atrazine at a concentration of 80% active ingredient at a rate of 1 kg.ha^{-1} after planting and before germination, while continuing the weeding process whenever necessary. An analysis of Variance and covariance was conducted to find estimates of genetic Variance $(\delta^2 g)$, phenotypic Variance $(\delta^2 P)$, and environmental Variance $(\delta^2 e)$, the genotypic coefficients of variation (% G.C.V.), phenotypic coefficients of variation (%PCV), and broad-sense heritability (H2b.s) between these traits. The genetic correlation (rgij) and phenotypic correlation (rpij) between the pairs of studied traits was also calculated according to the following equations (9):

$$Genotypic\ variance, \sigma^2 \text{g} = \frac{GMS - EMS}{r}$$

σ^2g = genetic variance, EMS = Error mean square

$$\%\ GCV = \frac{\delta\ \ g}{\overline{X}} \times 100, \qquad \%\ PCV = \frac{\delta\ p}{\overline{X}} \times 100$$

Based on the variance components of the general and specific unity potential for parents in diallel crosses and the variance of the experimental error, which represents environmental variance, the broad-sense heritability rate was estimated as stated by (22):

$$h^2_{bs} = \frac{\sigma^2 G}{\sigma^2 P} = \frac{\sigma^2 A + \sigma^2 D}{\sigma^2 A + \sigma^2 D + \sigma^2 e} = \frac{2\sigma^2 gca + \sigma^2 sca}{2\sigma^2 gca + \sigma^2 sca + \sigma^2 e}$$

h^2_{bs} = Broad-sense heritability rate

$\sigma^2 A$ = Additional genetic variation

$\sigma^2 D$ =Dominant genetic variation

$\sigma^2 G$ =Total genetic Variance (additive Variance + non-additive Variance).

$\sigma^2 P$ =Phenotypic variation (genetic variation + environmental variation)

The genetic and phenotypic correlation was estimated after calculating the variance for each trait and then calculating the covariance between the traits in pairs, as follows:

$$r_{pij} = \frac{\sigma p_i\, p_j}{\sqrt{\sigma^2 p_i \sigma^2 p_j}}$$

$$r_{gij} = \frac{\sigma g_i\, g_j}{\sqrt{\sigma^2 g_i \sigma^2 g_j}}$$

r_{gij} = Genetic correlation

r_{pij} = phenotypic correlation

$\sigma g_i g_j$: covariance. $\sigma p_i p_j$: phenotypic Variance. σ^2 : the trait variance.

After confirming the existence of a genetic link between the traits, path coefficient analyses were applied according to the method used by (22 and 23) for agricultural applications, from which the direct and indirect effects of each trait on seed yield were determined and organized in a table consisting of a matrix with the main diagonal that represents the path coefficients (direct effects) and both sides of the matrix represent the indirect effects.

Results and Discussion

Genetic, environmental, and phenotypic variations and coefficient of variation: From the results shown in Table 2, it is clear that the coefficient of variation (CV) values, which did not exceed 16%, indicates good homogeneity in the data. The results of the ratio of genetic to environmental variation (VG/VE) in the number of grains per row and plant yield amounted to 11.42 and 9.21 in the spring season, respectively, and in the fall season 21.31 and 6.18, respectively, indicating the possibility of adopting different selection methods to improve these traits, and that these two traits were influenced genetically more than by the environment, as the values of genetic variation were higher than environmental variation. There is a difference in the values of genetic, phenotypic, and environmental Variance in the two growing seasons. The variance components differed for most of the studied traits. The genetic variance values were more significant than the environmental variance values for all traits, which indicates the significant contribution of non-additive (dominant) genetic action in controlling the studied traits. When observing the values of the (G.C.V.) for silking characteristics, plant height, number of ears, number of rows per ear, number of grains per row, weight of 500 grains, and plant yield, they were close to the values of the (PCV) for both seasons. This indicates that the plants were identical genetically and phenotypically; in other words, genetic variation is the ruling factor in the variations of these traits, indicating that these traits are more genetically stable and not affected by environmental factors. From the above, it can be found that the plants were highly homogeneous phenotypically and genetically, and genetic variation played a significant role in the phenotypic variation of these traits. This indicates the possibility of studying the genotype by taking phenotypic data, and such traits can be considered a selection index for improving maize yield. The results are consistent with the findings of each of the researchers (15). The broad-sense heritability values were high for all traits, as in (Table 2). The highest was for the number of grains per ear and plant yield, which reached 91.95% and 90.21% for the spring season, respectively. For the fall season, they reached 95.52% and 86.08%, respectively, due to the high values of genetic variation relative to the environmental variation, where the heritability rate can be considered a selection criterion in improving the trait. This was found by (16).

Table 2: Genetic and phenotypic variations and degree of heritability for the spring and fall seasons 2022 for the studied traits in maize.

Characteristics	Mean	CV%	SE	V_G	V_E	V_G/V_E	V_P	P.C.V	G.C.V	h²b.s%
Silking	62.3	4.49	0.61	5.81	1.21	4.8	7.02	4.25	3.87	82.76
	59.2	2.90	0.38	4.03	0.97	4.15	5.00	3.77	3.39	80.60
Plant height	164.3	4.63	1.70	133.66	32.51	4.11	166.17	7.85	7.04	80.43
	168.9	8.05	2.96	161.37	37.16	4.34	198.53	8.34	3.61	81.28
Leaf area	0.423	15.60	0.014	0.006	0.004	1.5	0.01	23.64	18.31	60.00
	0.457	8.53	0.008	0.004	0.002	2.0	0.006	16.95	13.84	66.66
Number of ears	1.14	4.82	0.12	0.009	0.005	1.800	0.014	9.741	7.873	64.29
	1.19	5.04	0.01	0.006	0.003	2.0	0.009	7.97	6.51	66.65
Number of rows	15.1	5.23	0.17	1.432	0.625	2.29	2.057	9.50	7.92	69.61
	15.5	6.19	0.21	1.709	0.443	3.86	2.152	9.46	8.43	79.41
Number of grains	29.6	9.79	0.63	71.05	6.22	11.42	77.27	29.69	28.47	91.95
	31.2	5.73	0.39	64.13	3.01	21.31	67.14	26.26	25.66	95.52
Weight of 500 grains	85.8	8.75	1.64	109.87	40.769	2.694	150.64	14.451	12.342	72.93
	83.2	11.21	2.03	177.23	64.32	2.75	241.55	18.68	16.0	73.37
Plant yield	129.8	8.09	2.20	1048.8	113.86	9.21	1162.66	26.27	24.92	90.21
	143.4	5.92	1.85	937.2	151.6	6.18	1088.8	23.01	21.35	86.08

Genetic, phenotypic, and environmental correlations: Silking: The results in Table 3 showed that the genetic correlation coefficient (rG) for this trait was significant in the negative direction in the spring season with all traits except the number of ears and grain weight, where the genetic correlation with them was in the negative direction and was non-significant, amounting to -0.011 and -0.99. This negative correlation confirms that the behavior of genotypes is unstable under all environmental conditions due to the influence of yield components. In the fall season, the genetic correlation coefficient was positive and highly significant with the two characteristics of the number of rows per ear and plant yield 0.278 and 0.366. These results indicate that the yield increases whenever the flowering period is shorter. That is, the varieties that gave the shortest duration for Silking led to an increase in yield compared to the varieties with an increased number of Silking days. The phenotypic correlation coefficient for Silking was associated with a positive, significant phenotypic correlation with the plant yield trait, reaching 0.301 and 0.256 for both seasons, respectively. At the same time, there was a significant, negative correlation with the plant height trait in the fall season and no significant correlation with the rest of the traits. As for the environmental correlation coefficient for silking, it was significantly positively correlated with plant height in the fall season, amounting to 0.277, and there was a non-significant environmental correlation with the rest of the traits; the results are consistent with (6).

Plant height: The results in Table 3 indicate that the genetic correlation coefficient for plant height in the spring season was significant in the positive direction with all traits, and in the fall season, the genetic correlation was highly significant in the positive direction with the traits of leaf area and plant yield, reaching 0.511 and 0.311 for two traits, respectively. There was a significant genetic correlation with the trait of the number of ears, amounting to 0.276. The phenotypic correlation in the spring season was highly positive and significant with the traits of leaf area and the number of grains, reaching 0.414 and 0.626 for the two traits, respectively. The plant height trait was significantly correlated with the number of ears and plant yield only phenotypically, amounting to 0.299 and 0.289. At the same time, there was no significant environmental correlation of plant height with other traits. In the fall season, the plant height trait had a positive and highly significant phenotypic correlation with the characteristics of leaf area, amounting to 0.577, and a positive and significant correlation with the characteristics of the number of ears, the number of grains per row, grain weight, and plant yield, amounting to 0.301, 0.255, 0.308, and 0.233, similar results were obtained by (7 and 11).

Leaf area: The results in Table 3 showed that the genetic correlation coefficient for the leaf area trait in the spring season was highly significant and positive with the traits of the number of rows per ear and plant yield, amounting to 0.417 and 0.463, a significant genetic correlation with the grain weight of 0.310. In the fall season, the leaf area trait was positively genetically correlated to the traits of the number of rows per ear, grain weight, and plant yield, reaching 0.345, 0.511, and 0.489 for the above traits, respectively. While the phenotypic correlation of the leaf area trait was highly significant with the two traits of grain number and plant yield for both seasons, it reached 0.369 and 0.356 for the spring season and 0.388 and 0.456 for the fall season, respectively. While the environmental correlation of the leaf area trait in the spring season was non-significant with other traits, in the fall season, the environmental correlation was highly significant with the two traits of the number of grains per row and grain weight, reaching 0.401 and 0.511. A significant environmental correlation between the two traits of the number of rows per ear and plant yield reached 0.255 and 0.259. This was found by (12).

Number of ears: The results in Table 3 show that the number of ears in the spring season was highly significantly genetically correlated to the number of grains per row and plant yield 0.485 and 0.548. It was also negatively significantly genetically correlated to grain weight -0.366. In the fall season, the number of ears was highly genetically correlated with plant yield, amounting to 0.874, and a significant genetic correlation with the number of grains per row, amounting to 0.287. The phenotypic correlation of this trait with the traits of grain number and plant yield was highly significant and positive for both seasons, reaching 0.322 and 0.568 for the spring season, respectively, and 0.408, 0.825 for the fall season, respectively, and a negative, significant correlation with grain weight, reaching -0.297 and -0.255 for two seasons respectively. As for the environmental correlation for the trait of the number of ears, it was highly significant with the characteristic of the number of grains per row, amounting to 0.369, and a non-significant environmental correlation with the rest of the traits, as shown in Table 3. In the fall season, it was found that the environmental correlation for the number of ears was highly significant with the two traits of the number of grains per row and plant yield, reaching 0.426 and 0.332; similar results were obtained by (14).

Number of rows per ear: The results of Table 3 indicated that the trait of the number of rows per ear was correlated with a positive and significant genetic correlation with the two characteristics of the number of grains per row and the plant yield, reaching 0.404 and 0.819 for the spring season, respectively, and 0.266 and

0.604. While the genetic correlation was non-significant in the negative direction with grain weight, reaching -0.036 and -0.256. The phenotypic correlation of the number of rows per ear was highly significant with plant yield, reaching 0.707 and 0.603 for both seasons, respectively. No environmental correlation was mentioned for the number of rows per ear with the other traits in Table 3. This is what was obtained (11).

Number of grains per row: The results presented in Table 3 showed that this trait has positive and highly significant genetic correlations with plant yield, amounting to 0.915 and 0.502 for both seasons, respectively, and significant genetic correlations in the negative direction with grain weight, amounting to -0.265 and -0.622. There was a highly significant and positive phenotypic correlation with plant yield of 0.748 and 0.809 for the spring and fall seasons, respectively, and a negative, significant phenotypic correlation with grain weight of -0.346 and -0.307 for both seasons, respectively. At the same time, there was no significant environmental correlation for this trait with other traits in Table 3. This is confirmed by (13).

Weight of 500 grains: In the weight of the grain, it was shown from Table 3 that there was a positive, significant genetic correlation in the fall season with the plant yield, amounting to 0.264, and a non-significant positive genetic correlation in the spring season, with the yield, amounting to 0.123. While the phenotypic correlation was positive, a highly significant correlation with plant yield in the fall season reached 0.318, and a positive, non-significant phenotypic correlation with plant yield in the spring season amounted to 0.105. Regarding the environmental correlation with plant yield, it was positive and non-significant. The highest values of the genetic and phenotypic correlation coefficient were between the number of rows per ear and plant yield, reaching 0.833 and 0.716, respectively. Similar results were obtained by (20). These correlations indicate that the multiple genes involved in quantitative traits cooperate by affecting each of the two traits that are synergistically linked (18). Therefore, selecting one trait will affect the other in the same direction. From the previous, it can be concluded that the number of rows, the number of grains per row, and the number of ears can be used as a selection index to improve grain yield in maize, where the genetic correlation values reached 0.819 and 0.915 and 0.548 for the spring season and 0.604, 0.502 and 0.874 for the fall season. The phenotypic correlation values for these traits are 0.707, 0.748, and 0.568 for the spring season and 0.603, 0.809, and 0.825 for the fall season, respectively.

Table 3: Genetic correlation, direct effects, phenotypic correlation, and indirect effects for the spring and fall seasons of 2022 in maize.

Characteristics	Silking	Plant height	Leaf area	Number of ears	Number of rows	Number of grains	Weight of 500 grains	Plant yield
Silking	1.00	-0.269	-0.503	-0.011	-0.332	-0.303	-0.199	-0.461
		0.166	0.207	-0.102	0.278	0.097	-0.206	0.548
Plant height	-0.202	1.00	0.414	0.494	0.691	0.811	0.422	0.502
	-0.314		0.511	0.276	0.117	0.208	0.118	0.311
Leaf area	-0.104	0.414	1.00	0.233	0.417	0.184	0.310	0.463
	0.099	0.577		0.112	0.354	0.261	0.511	0.489
Number of ears	0.106	0.299	0.109	1.00	0.044	0.485	-0.366	0.604
	0.096	0.301	0.253		0.222	0.287*	0.165	0.874
Number of rows	-0.227	0.098	0.256	0.185	1.00	0.404	-0.036	0.819
	-0.116	-0.243	0.194	0.208		0.266	-0.265	0.366
Number of grains	-0.202	0.626	0.263	0.322	0.205	1.00	-0.572	0.915
	0.133	0.255	0.388	0.408	0.277		-0.622	0.277
Weight of 500 grains	-0.207	-0.292	0.369	-0.297	-0.039	-0.346	1.00	0.123
	0.122	0.308	0.278	-0.255	-0.112	-0.307		0.264
Plant yield	0.301	0.289	0.356	0.568	0.707	0.748	0.105	1.00
	0.256	0.223	0.456	0.825	0.603	0.809	0.318	

Values: 0.325 = (1%) r Values: 0.250 = (5%) r * and ** Significant at the 5% and 1% levels.

Path coefficient: Estimating the correlation only indicates the extent and nature of the relationship between yield and its traits but does not show the direct and indirect effects of different crops on yield itself. Grain yield depends on several traits and is mutually linked. This, in turn, will weaken the relationship between the component and grain yield. A change in any one component is likely to change the outcome. Thus, each component has two paths of action, i.e., a direct effect on grain yield and an indirect effect through components that are not revealed from correlation studies. Path analysis allows partitioning of the direct and indirect effects of the correlation. Table 4 showed that the direct effects on grain yield of other traits were directly beneficial to crop development. However, the indirect effects of some traits showed that they indirectly affected grains. Moreover, path coefficient analysis showed that the Silking characteristic 0.691 had the highest direct effect on plant yield for the spring season of 2020, followed by the number of rows per ear 0.671. The number of ears 0.498, the number of grains per row 0.308, and the weight of 500 grains 0.299. Whereas in the fall season, the highest direct effect on plant yield was the Silking trait 0.701, followed by the number of rows per ear 0.689, the number of ears 0.516, the weight of 500 seeds 0.316, and the number of grains per row 0.274. Plant height showed a direct effect in the negative direction, amounting to -0.214 -0.199 for the spring and fall seasons, respectively. As for the indirect effect, it was through the number of ears, the number of rows, and the number of grains per row. The overall effect of plant height was positive, reaching 0.886 and 0.605 for the spring and fall seasons, respectively. The leaf area showed a direct effect in the negative direction, amounting to -0.459 -0.412 for the two seasons, respectively. As for the indirect effect, it was through the number of ears, the number of rows, and the number of grains, despite the presence of a significant positive genetic and phenotypic correlation for the rest of the traits. It was found that the total effect of leaf area was positive, amounting to 0.454 and 0.464 for the spring and fall seasons, respectively. The results are consistent with what was obtained by (3) for the number of ears per plant and the number of rows per ear, (1) for Silking and grain weight, (17) for the number of grains per row, plant height, and grain weight, and (9) for the number of grains per row and grain weight, (8) for the number of grains per row.

Table 4: Path coefficient analysis of the direct effects and indirect effects for the spring and fall seasons of 2022 for the studied traits on maize yield.

Characteristics	Silking	Plant height	Leaf area	Number of ears	Number of rows	Number of grains	Weight of 500 grains
Silking	0.691	-0.219	-0.323	-0.014	-0.239	-0.222	-0.148
	0.701	-0.118	-0.329	-0.106	-0.250	-0.199	-0.161
Plant height	0.058	-0.214	-0.080	-0.090	-0.151	-0.161	0.089
	-0.033	-0.199	-0.102	-0.066	-0.179	-0.094	0.105
Leaf area	0.218	-0.193	-0.459	-0.121	-0.178	-0.102	0.023
	0.307	-0.205	-0.412	-0.084	-0.192	-0.097	0.068
Number of ears	-0.214	0.261	0.153	0.498	0.101	0.071	-0.204
	0.106	-0.281	0.149	0.516	0.150	0.036	-0.216
Number of rows	-0.414	0.433	0.266	0.124	0.671	0.562	-0.066
	-0.422	0.401	0.304	0.119	0.689	0.591	-0.107
Number of grains	-0.066	0.192	0.035	0.133	0.226	0.308	-0.129
	0.009	0.204	0.011	0.013	0.275	0.274	-0.099
Weight of 500 grains	-0.148	-0.131	-0.015	-0.115	-0.105	-0.201	0.299
	-0.099	-0.144	-0.021	0.152	-0.098	-0.197	0.316
Total effect	0.967	0.886	0.454	0.755	0.998	0.941	0.411
	1.123	0.605	0.464	0.800	1.114	0.901	0.489
Residual Effect	0.0593						
	0.0634						

Conclusions

Plant yield was associated by significant statistical significance with each of the characteristics of the number of ears, the number of rows per ear, and the number of grains per row. This indicates the possibility of using these traits as selection criteria in breeding programs aimed at indirectly obtaining high maize production. It is expected that traits with high positive correlation, along with high direct effects, will be useful as selection criteria in an improvement program, as the results obtained from this research on trait correlation and path coefficient analysis showed the contribution of each of the traits: number of ears, number of rows per ear, and number of grains per row in the positive direction has a significant impact on the grain yield per plant in maize. Therefore, selecting these traits can be considered essential selection criteria for improving maize grain yield.

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