Iraqi Journal of Desert Studies 2024, 14 (1): 50-57 **Original Article**

Variability, Heritability, Correlation and Path Coefficient Analysis in Maize Crosses (*Zea mays* L.)

Ahmed Shehab Abd-allah Ramadan
University of Anbar- College of Agriculture – Department of Field Crops

Abstract

A study in the field was conducted in the Saqlawiya area, west of Baghdad, in latitude- 33.3962011, longitude- 43.7046653, in the spring and fall seasons 2021. In this study, there were 6 inbred of maize (*Zea mays* L.) were employed; these inbred lines were included in half diallel crosses using model 1 (fixed) and the fourth approach, in the 2021 spring for producing fifteen F1 single crosses. In fall, R.C.B.D. was used to plant cross grains, and three duplicates were used, The statistical analysis's results displayed the mean squares of the genotypes varied significantly for all the traits under study except for the 250 grain weight trait, Variations, heritability for each trait, and coefficients of variation for genotype and phenotype, The correlations between genotype and phenotype between characteristic pairs were calculated to separate the genetic correlation coefficient among effects that are direct and indirect, Studying the path coefficients was utilized. For the most, the traits under investigation, the findings indicated that the genotype variance values were greater than the environmental variance values, grain yield had a highly substantial positive genotype, phenotype link with rows number per ear and grains number per row, as was the greatest heritability of average yield of grains (96%). The grains number per row had the most direct impact on yield of grains, according to Studying the path coefficients, However, the highest rows number per ear was total sum the impact of both direct and indirect factors on maize grain production.

Key word: diallel, Path Coefficient, Correlation, Heritability, maize.

التباينات والتوريث والارتباطات وتحليل معامل المسار لهجن الذرة الصفراء (*Zea mays* L.)

احمد شهاب عبد الله رمضان
جامعة الانبار - كلية الزراعة -قسم المحاصيل الحقلية

الملخص

نفذت تجربة حقلية في منطقة الصقلاوية غرب مدينة بغداد في خط العرض- 33.3962011، خط الطول- 43.7046653 في الموسمين الربيعي والخريفي 2021، استعملت في هذه الدراسة ست سلالات من الذرة الصفراء (*Zea mays* L.) ادخلت هذه السلالات في تضريب تبادلي نصفي وفقاً لطريقة Griffing الرابعة والانموذج الثابت في الموسم الربيعي 2021 لإنتاج 15 هجين فردي، زرعت بذور الهجن في الموسم الخريفي باستخدام تصميم القطاعات العشوائية الكاملة وبثلاث مكررات، اظهرت نتائج التحليل الاحصائي وجود فروق عالية المعنوية بين التضريبات النصف لتبادلية لجميع الصفات المدروسة عدا صفة وزن 250 حبة التي كانت معنوية، قدرت التباينات ومعاملات الاختلاف الوراثية والمظهرية ونسبة التوريث بالمعنى الواسع لكل صفة والارتباطات الوراثية والمظهرية بين ازواج الصفات، تم تجزئة معامل الارتباط الوراثي الى تأثيرات مباشرة وغير مباشرة باستخدام معامل المسار، حيث اظهرت النتائج ان قيم التباين الوراثي اكبر من قيم التباين البيئي في اغلب الصفات المدروسة، كما كانت اعلى نسبة توريث بالمعنى الواسع لمتوسط حاصل النبات الواحد (96%)، اظهر حاصل النبات الواحد ارتباطاً وراثياً ومظهرياً موجباً عالي المعنوية مع عدد الصفوف بالعرنوص وعدد الحبوب بالصف. اوضح تحليل معامل المسار ان عدد الحبوب بالصف حققت اعلى تأثير مباشر في حاصل النبات الواحد، بينما اعطى عدد الصفوف بالعرنوص اعلى مجموع كلي للتأثيرات المباشرة وغير المباشرة في حاصل النبات الواحد، نستنتج من الدراسة اعتماد صفتي عدد الصفوف بالعرنوص وعدد حبوب الصف كمعيار لأدخالها في برامج مستقبلية لتطوير حاصل النبات في الذرة الصفراء.

الكلمات المفتاحية: التضريب، معامل المسار، الارتباط، Zea *mays* L.، نسبة التوريث.

Introduction

Like other crops, maize depends on the components of yield and some other characteristics. Due to its low yield and low production rate, many research agencies working in breeding programs seek to develop a breeding program for it to advance the current reality and develop high-yielding varieties and improve its quality and be more appropriate to environmental conditions by identifying selective evidence of traits that are genetically related to the crop and directly or indirectly affecting it. Plant breeders can rely on conducting a precise selection process to increase and improve grain yield, because yield is an intricate trait whose inheritance is controlled by a great number of genetic factors. It is characterized by having a certain type of gene action (Elsahookie,1990), and breeders seek to improve this trait through their programs, trying to shorten the time, effort and costs to reach the desired results (Baktash and Jallow, 2001). Therefore, it is important to identify the changes that affect the yield of maize, whether the effects are direct. or indirect, the information obtained about the heritability of the different traits, as well as the information about the relationship of these traits with the amount of yield, is very important in knowing how to practice methods of effective selection to obtain the best possible genetic improvement, heritability of maize yield and other traits have been studied by many researchers such as (Mukhlif et al., 2021; Reddy et al., 2013; Vijay et al., 2015; Ramadan et al., 2020; Ramadan et al., 2021; Mukhlif et al., 2021), and we can conclude from these studies that most traits have a higher heritability than the trait of the quantity of the yield, and that the trait of the yield is the result of many

*Corresponding author.
Email: ag.ahmed.shehab@uoanbar.edu.iq
https://10.36531/ijds.2024.148013.1067
Received 20-02-2024; Received in revised form 01-06-2024; Accepted 01-06-2024

other traits that make up it and its broad linkage, it does not respond to selection easily, so it is necessary to improve it by selecting one or more alternative traits, from through the search for the traits affecting the yield by following Methods of statistical analysis like the coefficient of correlation, Which measures the correlational relationships between them and the characteristics that make them up, which are necessary when using selection, and since, in addition to the shared impacts of other traits on the yield, the correlations do not specify the proportion that each trait contributes to both indirect and direct effects, Consequently, plant breeders turn to using other statistical techniques like path coefficient analyzing. that was founded by Wright, (1934) and developed by (Li, 1956 and used Dewey & Lu 1959; Singh & Chaudhary 1985), It provides extra information as it is a crucial genetic statistical analysis that several scientists in the field of the breeding of plants utilize about what the correlation coefficient gives. it uses organizing and finding relative relationships between the dependent variable and the independent variable through a system of paths and divides the phenotypic or genotypic correlation coefficient indicating both the indirect and direct effects of the yield's other components to determine the most influential traits and count it as electoral guides that educators can benefit from in producing hybrids and synthetic varieties. The path coefficient has been used by many researchers (Reddy et al., 2013; Wuhaib, 2018; Gayathri & Padmalatha, 2018; Mhoswa et al., 2016; Yahaya et al., 2021; Alabd et al., 2013; Shikha et al., 2020; Al Najjar et al., 2020; Ahmed & Abbas, 2010; Wuhaib, 2018), their results showed that some traits have a direct effect and some have a greater indirect effect on grain yield.

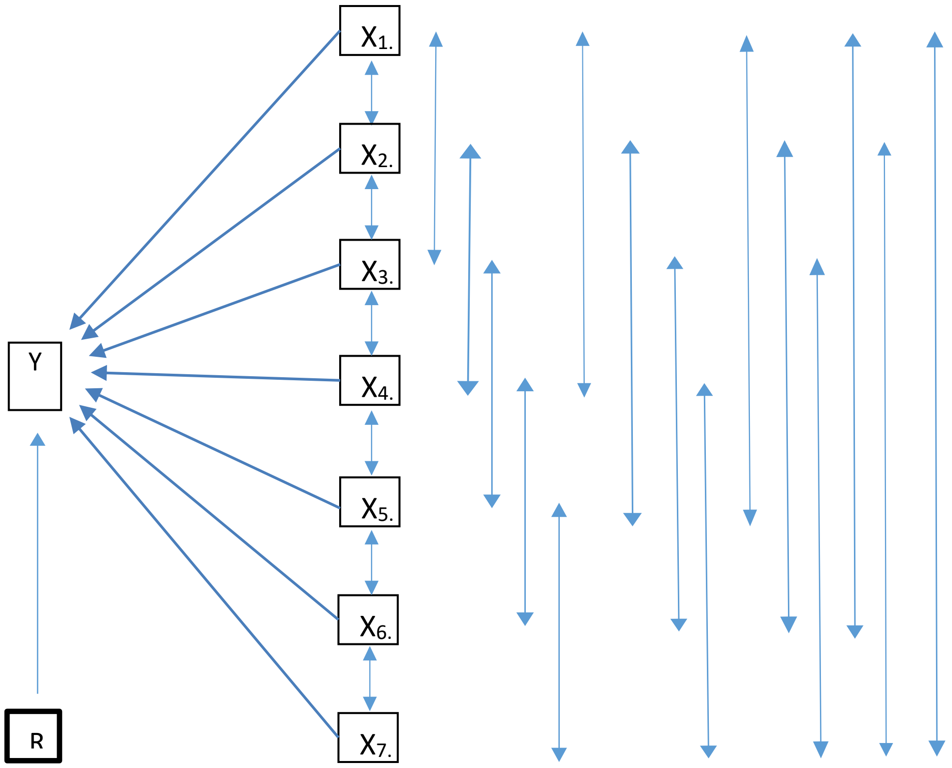
The objective of the current study is to estimate a few genetic factors related to yields of maize and other traits. The genetic correlation coefficient among the yield and its constituents and other variables was split into both indirect and direct effects using path coefficient analysis to identify the extent to which each trait contributes to increasing and improving the grain yield and adopting them as electoral evidence.

Materials and Methods

A field study was carried out in the Saqlawiya region, west of Baghdad, in latitude- 33.3962011, longitude- 43.7046653, in the seasons of fall and spring, 2021, using six inbred maize lines, namely: (1) Sxn.2, (2) zm-9, (3) Am-65, (4) ART-A.2, (5) ART-C-19, (6) syn-35. Soil services were carried out, after that, 400 kg/ha-1 of N:P compound fertilizer (10:18) was added, the inbred lines' grains were sowed on March 15, 2021, during the spring season. Each inbred had two lines, each measuring 7 meters in length and with a 0.75-meter spacing between lines and plants, and in an alternating manner with other Inbred lines within the required single crosses combinations. Two batches of 400% Kg/ha^{-1} urea fertilizer (46%N) were given, one at the beginning of male flowering and the other thirty days after the plant first appeared. Atrazine was sprayed at a dosage of 3.2 kg/ha-1 to control weeds at an 80% concentration following the initial watering but before to germination. Crop services, were performed during the growing season. Granular diazinon insecticide, applied topically twice to the plant's developing top, accounted for 10% of the control of the maize stalk borer (Sesamia criteca), for the first edition, the plant must reach the six-leaf stage; for the second, it requires for twenty days. These additions were carried out in both seasons. All diallel cross were conducted between the parental Inbred lines according to the fourth method and model 1 (fixed) of (Griffing, 1956), to produce Single crosses without parents, after bagging the female inflorescences at the emergence and male inflorescences one day before pollination, The process of hybridization persisted until all necessary crossings were made. the ears were harvested at the final stage of this season, and the grains of each one was sown separately for planting in the fall season. The grains of 15 Single Cross were sown in the comparison experiment in the form of lines, Using RCBD design, with a width of (0.75) a length of 7 meters, both inside lines and (0.25) between the plants and at the rate of 2 lines for each single cross. Data were collected on 10 plants that were guarded for every experimental unit for every characteristic under study, days to 50% silking, (DTS), plant height, (PLH), ear height, (EH), ear length, (EL), number of rows per ear, (NRPE), number of grains per row, (NGPR), 250 grain weight, (250 GW), and grains yield per plant, (GYPP).

The covariance data was analyzed after calculating the average results of individual plants for each cross for eight traits according to the experimental design used for each trait separately, after that, the difference that was least significant at a probability level of 5% and 1% was used to compare the differences that were significant between the averages. Next, the genetic variance ($\delta^2 g$), environmental variance ($\delta^2 E$), and phenotypic variation ($\delta^2 P$) were calculated, genetic variation coefficient (CVg%), phenotypic (CVP%), and broad sense heritability ($h^2 b.s.$). Genetic covariances ($\delta gigj$) were also calculated and phenotypic ($\delta pipj$) and the genetic correlation (rgij) and phenotypic (rpij) between the pairs of traits studied according to the following equations: which were used by (Singh & Chaudhary, 1985).

Path coefficient analysis, which laid the foundations Wright, (1934), is used to separate the genetic connection into its indirect and direct components according to how it was designed Li, (1956) and applied Singh & Chaudhary, (1985), for determining the indirect and direct impacts of various characteristics on yield of maize. and testing the model that includes seven independent variables as shown. In Figure No. (1).



Figure, (1) Pathological relationship between the variables

X1. = (DTS), X2. = (PLH), X3. = (EH), X4. = (EL), X5. = (NRPE), X6. = (NGPR), X7. = (250 GW), Y.= (GYPP). R= Residual

$\longleftrightarrow$ correlation coefficient

$\longleftarrow$ A vector path coefficient using the following matrices of correlation:

$[rij]^{-1}[R]$ $[P]=$

[P] = direct effect value

$[R]^{-1}$= The inverse of the matrix

[rij] = The value of the correlation coefficients

Then the above equations are placed in a matrix and the solution of this matrix using the computer calculates the path coefficients, including determining the effects of all traits, both indirect and direct, on plant yield (Singh & Chaudhary, 1985).

Results and Discussion

Variance, coefficient of variation, and heritability, Table 1's findings demonstrated that, except for the 250-grain weight trait, there were highly differences variations among the mean squares for the genotypes for every trait under study. which was significant, there were also difference in the components of genotype, phenotype and environmental variance for most of the characteristics studied in Table 2, because for the majority of the characteristics under study, the values of genotype variance exceeded the values of environmental variance (Kinfe & Tsehaye, 2015). As for the values of phenotype variation, its values ranged between 704.98 for grain yield and 0.97 for the rows number per ear. The values of genetic variation coefficient varied between traits, as they ranged between 0.67 for 250 grain weight and 14.66 for yield of one plant Roy et al., (2018), where grain yield was distinguished in giving it the highest value of the phenotype variation coefficient which reached 14.96, while the 250 grain weight gave the lowest value for phenotype variation coefficient which reached 2.74, This shows that the yield of a single plant was highest for the phenotypic variation coefficient, these results agree with (Chaudhary et al., 2016; Reddy et al., 2013). For the variables in Table 2, the heritability percentages varied in a broad sense, as it ranged between 0.06 in the trait of 250 grain weight and 0.96 in the yield of one plant, as the high value of this value in most traits gives the opportunity to improve these traits by direct selection(Reddy et al., 2013; Kinfe & Tsehaye 2015; Roy et al., 2018; Chaudhary et al., 2016).

Table 1 Analysis of variance half diallel crosses (SCA) according to Griffing's fourth method for the studied traits in maize

S.O. V	d.f	DTS	PH	EH	EL	NRPE	NGPR	250 GW	GYPP
R.	2	0.267	23.822	12.422	0.267	0.067	1.689	5.089	70.956
T.	14	31.705**	271.022**	312.984**	3.819**	1.771**	56.222**	4.032*	2057.698**
E.	28	1.100	8.846	28.684	0.814	0.567	1.975	3.351	28.622

(*) at the 5% and (**) at the 1% levels

Table 2 Estimates of genotype, environmental and phenotype variation, phenotype and genotype variation coefficient, and heritability of studied traits in maize

studied traits	Genotype variation	environmental variation	phenotype variation	C.V.P%	C.V.G%	heritability
DTS	10.20	1.10	11.30	5.56	5.28	0.90
PH	87.39	8.85	96.24	5.09	4.85	0.91
EH	94.77	28.68	123.45	11.60	10.16	0.77
EL	1.00	0.81	1.82	6.99	5.19	0.55
NRPE	0.40	0.57	0.97	5.93	3.82	0.41
NGPR	18.08	1.97	20.06	11.55	10.97	0.90
250 GW	0.23	3.35	3.58	2.74	0.67	0.06
GYPP	676.36	28.62	704.98	14.96	14.66	0.96

Genetic and phenotypic corrolations

Table 3 shows the variation of the genotype correlation coefficients among traits. It is shown that the rows number per ear and grain yield have a highly significant favorable genetic correlation 1.02, grain number per row 0.98, and 250 grain weight 0.50. This agrees with (Batool et al., 2012; Adesoji et al., 2015; Al-Fahadi, 2011; Gazal et al., 2018; Yahaya et al., 2021; Jakhar et al., 2017; Chaudhary et al., 2016; Roy et al., 2018; Yahaya & Unguwanrimi, 2021), while grain yield was genetically highly significant negatively associated with ear length of -0.44, and this agrees with (Vijay et al., 2015), that is, selection for ear length works to reduce the amount of grain yield, because the multiple genes in it work antagonistically in its effect on two traits, The genetic significance of the 250 weight grain was positively correlated with ear height 0.61 and rows number per ear 0.67. The 250 grain weight was also associated with days to 50% silking had a positive of significant genetic correlation of 0.35, while the grain number per row was genetically highly positively of significant associated with the rows number per ear 0.99 and highly significant negatively with the ear length -0.45, while the rows number was associated with a highly significant negative genetic correlation with ear length was -0.63, while the ear length was genetically correlated negatively with the height of the cob -0.30. Genetically, ear height was correlated positively with plant height, very significant (0.59), and positive of significant with days to 50% silking (0.31).

The same table also showed that trait of grain yield was associated with a positive, highly significant phenotype association between the rows' number of ears 0.70 and the grain number per row 0.93, and this agrees with (Kumar et al., 2014; Batool et al., 2012; Gazal et al., 2018; Alabd Alhadi et al., 2013; Yahaya et al., 2021; Vijay et al., 2015; Reddy et al., 2013), grain yield was also negatively significant with 0.47 ear length, while the rows number per ear was highly significant negatively associated with ear length -0.39, there was a strong positive association between plant height and ear height 0.48, This is consistent with (Singh et al., 2020; Alam et al., 2022; Izzam et al., 2017; Gazal et al., 2018; Chaudhary et al., 2016; Roy et al., 2018; Kinfe & Tsehaye, 2015) in that they obtain positive and negative correlations.

The positive correlation between any two traits, no matter how intangible, guarantees the selection of the influencing trait an increase in the responsive trait, which encourages its inclusion in the selection programs, especially those that are stable in the direction of its relationship. As for the negative correlation between any two traits, no matter how insignificant it is, it leads to a decrease in the responsive trait, and therefore it must be removed for selection programs and agrees with (Al-Rawi, 2011).

Table 3 correlation coefficients between genotype and phenotype of the traits of the maize under study

S.T.	GYPP	250- GW	NGPR	NRPE	EL	EH	PH	DTS
(DTS)	0.07	0.35*	0.07	-0.05	-0.22	0.31*	0.117	
(PH)	0.13	-0.16	0.14	0.06	0.18	0.59**		0.08
(EH)	0.11	0.61**	0.05	0.17	-0.30*		0.48**	0.26
(EL)	-0.44**	0.25	-0.45**	-0.63**		-0.12	0.13	-0.20
(NRPE)	1.02**	0.67**	0.99**		-0.39**	0.17	0.01	-0.06
(NGPR)	0.98**	0.29		0.47**	-0.28	0.01	0.14	0.06
(250 GW)	0.50**		-0.01	-0.10	-0.08	0.14	-0.07	0.19
(GYPP)		0.14	0.93**	0.70**	-0.35*	0.08	0.10	0.06

(*) at the 5% and (**) at the 1% levels

Path coefficient analysis

To give further details regarding the kind, extent, and significance of the association between grain yield trait and other traits, the genetic correlation coefficients were segmented using path analysis and according to the path relationship shown in Figure 1 and the overall effects were divided into effects of the traits, both direct and indirect influencing to determine the traits most influential on the yield of one plant as a criterion for his election and as shown in Table 4.

It is observed that the days to 50% silking trait showed a direct negative effect on grain yield, amounting to -0.5597 and agrees with (Mhoswa et al., 2016; Gayathri & Padmalatha, 2018; Reddy et al., 2013) It has medium positive indirect effects through the height of the head 0.83 and negative and moderate through the of 250 grain weight -0.2689, while the rest of the indirect effects were few and not significant, the total effect of it on grain yield had a low positive value of 0.06.

As for plant height, it had a strong, direct negative impact on grain yield (-2.2076) and this agrees with (Roy et al., 2018). Grain yield is positively and significantly impacted by it through the ear height 1.5481, while the rest of the indirect effects were small and insignificant, and there was a little positive general effect on grain yield, ear height had a positive and significant direct impact on grain yield 2.6434, and this agrees with (Reddy et al., 2013), and through plant height, it displayed a significant negative indirect effect (-1.2928), while the rest of the indirect effects were negative and average for most of the traits, while the total effect of it on grain yield was of a positive and average value of 0.1083.

It is also clear from Table 3 that there is a direct and significant effect of ear length on grain yield, with a value of 1.0259, and this is consistent with (Singh et al., 2020; Batool et al., 2012; Adesoji et al., 2015; Roy et al., 2018; Kinfe & Tsehaye, 2015; Shikha et al., 2020; Reddy et al., 2013), There were positive and high indirect effects of the rows number per ear on grain yield 2.1297, and negative and high through the grains number per row -2.3326 Batool et al., (2020), whereas the rest of the indirect effects for the rest of the traits were few and not significant, the total effect of ear length on yield of grain has a negative and medium value of -0.4404.

There is also a direct negative effect of the rows number per ear on yield of grain of -3.3834, this agrees with (Kinfe& Tsehaye, 2015; Shikha et al., 2020; Roy et al., 2018) the indirect effects were positive and high through grain number per row 5.2179 as well as average, negative, and grain yield through ear length -0.6458, while the rest of the indirect effects were negative and moderate for most of the traits and not significant, and the total effect of this trait was in the score is high and positive.

As for the traits of grains number per row, It has a favorable effect on grain yield, reaching 5.2401 as a high, that is, by increasing the grains number per row as a component of yield, the grain yield increases, as well as for the other components of the yield, this agrees with (Zarie et al., 2012; Singh et al., 2020; Kumar et al., 2014; Adesoji et al., 2015; Gazal et al., 2018; Roy et al., 2018; Kinfe& Tsehaye, 2015; Vijay et al., 2015) There was a positive and moderate indirect effect of ear height on yield of grain of 0.1417 and negative and high through the rows number per ear -3.3691, as for the rest of the indirect effects were negative, small and insignificant, and the total effect of this trait on grain yield had a positive and very small value 0.9842, the 250 grain weight's direct impact on yield of grain was negative with an mean of -0.7695, this does not agree with (Kinfe& Tsehaye, 2015), while the indirect effect was positive and highly significant through ear height 1.6113 and through grain number per row 1.5006, negative and highly significant. During rows number per ear was-2.2502, the total effect was positive on yield, amounting to 0.5028, As for other indirect effects were few and not significant.

Table 4 Path coefficient analysis of the traits affecting the yield of maize

	DTS	PH	EH	EL	NRPE	NGPR	250 GW	ET
DTS		-0.2573	0.8287	-0.2206	0.1804	0.3619	-0.2689	0.0646
PH	-0.0652		1.5481	0.1844	-0.199	0.7425	0.122	0.1252
EH	-0.1754	-1.2928		-0.3085	-0.5702	0.2809	-0.4691	0.1083
EL	0.1203	-0.3968	-0.7948		2.1297	-2.3326	-0.1921	-0.4404
NRPE	0.0298	-0.1298	0.4455	-0.6458		5.2179	-0.5118	1.0224
NGPR	-0.0387	-0.3128	0.1417	-0.4567	-3.3691		-0.2204	0.9842
250 GW	-0.1956	0.3501	1.6113	0.2562	-2.2502	1.5006		0.5028
DE	-0.5597	-2.2076	2.6434	1.0259	-3.3834	5.2401	-0.7695	

IE= Indirect effect, DE= Direct effect, ET= Effect Total

Conclusions

It is clear from the above study that grains number in a row had the most direct impact on grain output and the greatest indirect impact for both attributes through it for the two traits (rows number per ear and 250- grain weight), and the rows number in ear achieved the biggest overall impact, both direct and indirect on yield of grain. We conclude that adopting the previous traits that have a direct effect on yield and creating a selection program for them increases the plant's yield, and that introducing hybrids with high yields in the production of double and triple hybrids is considered an important matter, and it is also possible to introduce strains that were used in the production of synthetic varieties.

References

1. Adesoji, A.G., Abubakar, I.U. & Labe, D.A. (2015). Character Association and Path Coefficient Analysis of Maize (*Zea mays* L.) Grown under Incorporated Legumes and Nitrogen. *Journal of Agronomy*, 14(3), 158-163.
2. Ahmed, A.A., Abbas, S.H. (2010). Path coefficient analysis and expected genetic advance from Several Genotypes in the Durum Wheat. Kufa Journal of Agricultural Sciences, 2(1), 109-121.
3. Al Najjar, R., Shehab, S. & Ali, M.A. (2020). Correlation and Path Coefficient Analysis of Phonological, Morphological and Yield Components Traits in Maize (Zea mays L.). Syrian Journal of Agricultural Research, 7(5), 229-242.
4. Alabd Alhadi, R.A., Hadid, M.L. & Al-Ahmad, S.A. (2013). Potence Ratio and Path Analysis for Yield and Quality Traits in Single Crosses of Maize (Zea mays L.) Produced in Syria. Jordan Journal of Agricultural Sciences, 173(805), 1-18.
5. Alam, M.A., Rahman, M., Ahmed, S., Jahan, N., Khan, M.A.A., Islam, M.R. & Hossain, A. (2022) Genetic variation and genotype by environment interaction for agronomic traits in maize (Zea mays L.) hybrids. Plants, 11(11), 1522.
6. Al-Fahadi, M.Y.H. (2011). Genotypic, phenotypic correlations and selection index for yield and its components in single and triple maize hybrids (Zea mays L.) introduced from CIMMYT. The Jordanian Journal of Agricultural Sciences, MG. 7(1), 149-163.
7. Al-Rawi, R.S.S. (2011). Path Coefficient Analysis in Maize as Affected by Planting Date- Al-Qaim/ Al-Anbar. Iraqi Journal of Desert Studies, 3(1), 42-50.
8. Baktash, F.Y. & Jallow, R.A.J. (2001). Estimation of Number of Genes Controlling Several Characters of Maize and Some Genetic Parameters. Iraqi J. Agric, 6(2), 20-30.
9. Batool, Z., Kahrizi, D., Aboughadareh, A.P. & Sadeghi, F. (2012). Correlation and path coefficient analysis for determining interrelationships among grain yield and related characters in corn hybrids (Zea mays L.). Intl. J. Agri. Crop Sci, 4(20), 1519-1522.
10. Chaudhary, A., Srivastava, K., Agrawal, V. & Kumar, S. (2016). Elucidation of variability, interrelationships and path-coefficient in maize (Zea mays L.). Nature Environment and Pollution Technology, 15(2), 653.

11. Dewey, D.R. & Lu, K.H. (1959). Correlation and path-coefficient analysis of crested wheat grass seed production. Agro. J., 51: 515-518.
12. Elsahookie, M.M. (1990). Maize Production and Breeding, Mosul Press, Univ. of Baghdad, Iraq, pp:400.
13. Gayathri, N.K. & Padmalatha, Y. (2018). Correlation and path analysis studies in medium duration rice varieties of Andhra Pradesh. J. Nutr. Health, Sci, 5(3), 304.
14. Gazal, A., Dar, Z.A., Lone, A.A., Yousuf, N. & Gulzar, S. (2018). Studies on maize yield under drought using correlation and path coefficient analysis. Int. J. Curr. Microbiol. Appl. Sci, 7, 516-521.
15. Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. of Biol. Sci., 9, 463-493.
16. Izzam, A., Sohail, H.R.A., Shahzad, A.M. & Hussain, Q. (2017) Genetic variability and correlation studies for morphological and yield traits in maize (Zea mays L.). Pure and Applied Biology (PAB), 6(4), 1234-1243.
17. Jakhar, D.S., Singh, R. & Kumar, A. (2017). Studies on path coefficient analysis in maize (Zea mays L.) for grain yield and its attributes. International Journal of Current Microbiology and Applied Sciences, 6(4), 2851-2856.
18. Kinfe, H. & Tsehaye, Y. (2015). Studies of heritability, genetic parameters, correlation and path coefficient in elite maize hybrids. Academic research journal of agricultural science and research, 3(10), 296-303.
19. Kumar, P., Prashanth, Y., Reddy, V.N., Kumar, S.S. & Rao, P.V. (2014) Character association and path coefficient analysis in maize (Zea mays L.) International. J. of Applied Biol. and Phar. Tech, 5(1), 257-260.
20. Li, C.C. (1956). The Concept of path coefficient and its impact on population genetics. Biometrics, 12: 191-209.
21. Mhoswa, L., Derera, J., Qwabe, F.N. & Musimwa, T.R. (2016). Diversity and path coefficient analysis of Southern African maize hybrids. Chilean journal of agricultural research, 76(2), 143-151.
22. Mukhlif, F.H., Abdullah, A.S. & Hammody, D.T. (2021). Study of Combining Ability and Hybrid Vigor in Many Maize lines Zea mays L. In IOP Conference Series: Earth and Environmental Science, 904(1), p. 012017.
23. Mukhlif, F.H., Ramadan, A.S.A.A. & Alkasisy, A.M.A. (2021). Heterosis, Genetic Parameters of Maize (Zea Mays L.) Using the Half Diallel Cross Method. Annals of the Romanian Society for Cell Biology, 25(5),1257-1269.
24. Ramadan, A.S.A.A., Muhammad, M.A.G., Abbas., A.A. (2020). Estimation of combining ability and gene action of maize (Zea Mays L.) Lines using line×tester crosses. Biochemical and Cellular Archives, 20(1):1769-1775
25. Ramadan, A.S.A.A., Mukhlif, F.H., Najm, B.F. (2021). Genetic Analysis of Combining Ability and Gene Action of Yield and Its Components in Maize (Zea Mays L.) Using Full Diallel Cross. Annals of the Romanian Society for Cell Biology, 25(5),1241-1256.
26. Reddy, V.R., Jabeen, F., Sudarshan, M.R. & Rao, A.S. (2013). Studies on genetic variability, heritability, correlation and path analysis in maize (Zea mays L.) over locations. Int. J. Appl. Bio. Pharma Tech, 1: 195—199.
27. Roy, P.R., Haque, M.A., Ferdausi, A. & Al Bari, M.A. (2018). Genetic variability, correlation and path co-efficients analyses of selected maize (Zea mays L.) genotypes. Fundamental and Applied Agriculture, 3(1), 382-389.
28. Shikha, K., Shahi, J.P. & Singh, S. (2020). Path coefficient analysis in maize (Zea mays L.) hybrids. Journal of Pharmacognosy and Photochemistry, 9(2), 278-282.
29. Singh, D., Kumar, A., Kumar, R., Singh, S.K., Kushwaha, N. & Mohanty, T.A. (2020) Correlation and Path Coefficient Analysis for 'Yield Contributing' Traits in Quality Protein Maize (Zea mays L.). Current Journal of Applied Science and Technology, 39(25), 91-99 https://journalcjast.com/index.php/CJAST/article/view/2862
30. Singh, R.K. & Chaudhary, B.D. (1985). Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publisher Lundhiana. New Delhi, pp: 299.

31. Vijay, K., Singh, S.K., Bhati, P.K., Sharma, A. Sharma, S.K., Mahajan, V. (2015). Correlation, path andgenetic diversity analysis in Maize (Zea mays L.). Environment & Ecology, 33 (2A), 971-975.
32. Wright, S. (1934). The method of path coefficient. Ann. Math. Stat, 5:161-215.
33. Wuhaib, K.M. (2018) Genotypic and phenotypic correlation in maize and path coefficient I-Agronomic traits. Iraqi Journal of Agricultural Sciences, 49(2).
34. Yahaya, M.S., Bello, I. & Unguwanrimi, A.Y. (2021). Correlation and path-coefficient analysis for grain yield and agronomic traits of maize (Zea mays L.). Science World Journal, 16 (1), 10-13.
35. Zarie, B., Kahrizi, D., Aboughadareh, A.P. & Sadeghi, F. (2012). Correlation and path analysis for determining interrelationships among grain yield and related characters in corn hybrids (Zea mays L.). Inter. J. of Agric. *and Crop Sci*, 4(20), 1519-1522.