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Analysis of Path Coefficient, Correlations, Variances and Heritability of Genotypes of Maize (*Zea mays* L.)

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Abstract: Studies are being carried out at Karmat Ali, University of Basra's Agricultural Research Station, College of Agriculture which is at 47.80° longitude and 30.57° north latitude, a field experiment was done. In silty loam soil during the spring agricultural season2022, to study the path coefficient analysis, correlations, variances, and the degree of heritability for three genotypes (Al-Maha, IPA-5018, Bhooth-106) of corn crop *Zea mays* L. The experiment was applied according to the method of factorial experiments using randomized complete block design (RCBD) with three replications. The trait of 300 grains weight had the strongest direct positive genetic and phenotypic effect on grain yield, according to the analysis of genetic and phenotypic path coefficients amounted to 0.806 and 0.582, respectively, followed by the characteristic of grains number in corn cob, which had a direct positive genetic and phenotypic effect on grain yield, amounted to 0.164 and 0.308, respectively. The grain yield showed a positive and highly significant genetic and phenotypic correlation with the characteristics of the weight of 300 grains, the number of cobs in plant, and grains number in cob reached (0.912** and 0.934**) (0.479** and 0.815**) (0.846** and 0.897**) for attributes in succession. Variations in grain yield caused by genetic, environmental, and phenotypic factors recorded a variation of 0.1554, 0.00736, and 0.1627, respectively, with a broad-sense heritability average of 95.51%. The heritability average in the broad sense varied according to the different studied traits, and the plant height trait recorded a highest heritability average of 98.74 percent, while protein in grains trait recorded the lowest heritability average in the broad sense, amounting to 68.55%.

Key words:

Introduction

Yellow corn, *Zea mays* L., is regarded as one of the main grain crops. With all of its vegetable and fruit sections, yellow corn serves a variety of purposes as food and fodder for animals, which highlights its significance. Its leaves serve as a foundational component in the paper industry. The best kinds of oils and starch are taken from its grains. It is classified as concentrated fodder because it contains several vitamins, including as B2, B1, and F, as well as 81% carbs, 10.6% protein, 4.6% oil, and 2% ash (Al-Nasrawi,2015). With an average yield of 4.632 tons per hectare, Iraq's farmland will cover 90.522 thousand hectares in 2020 (Directorate of Agricultural Statistics, 2020). A correct understanding of the mechanism of inheritance of crop traits is essential for the management and preparation of systematic breeding programs, especially when dealing with a trait such as grain yield. Therefore, it is necessary to study other traits such as growth traits and yield components by studying some important genetic parameters, including the analysis of path coefficient, variations, and heritability in the broad sense and the genetic and phenotypic correlations through which the possibility of actual planning of breeding and improvement programs for this crop can be achieved (Al-Zubaidy *et al.*, 2018). The information obtained on the direct and indirect effects is based on fragmentation of the correlations between yield and, its components under the influence of agricultural distances. The difference between injustice and the path coefficient, which is an advanced step that determines the minimum characteristics that can be used as an electoral criterion (Muaalla and Hasban, 2011; Waheed *et al.*, 2016),

The selection of genotypes and the evaluation of their performance played a significant role in increasing crop yields of many crops, including the yellow corn crop, and their responses differ depending on the genetic ability of each genotype in the transfer of manufactured foodstuffs from source to downstream. As a result, one trend is the selection of genotypes with high productivity, while the other is after serving the soil and crop to achieve the best possible production. The process of continuous provision of genotypes is accompanied by the adoption of the method of distributing plants in the field, which is one of the important applications for exploiting the various environmental factors (light, water, soil, fertilization, etc.) and benefiting from them to increase the quantity and quality of the crop per unit area. The variation of planting distances between plants leads to different plant densities that work. It reduces the seeding rate per unit area without any negative effect on the final yield, and the plant density is one of the important factors in controlling the ratio and efficiency of intercepting effective rays in the photosynthesis process, which in turn affects growth and crop productivity (Jaddoa *et al.*, 1998; Rafiq *et al.*, 2010). Because there have been no previous studies on the study of some genetic parameters of genotypes of yellow maize crops cultivated at different agricultural distances between crops under the conditions of Basra Governorate, this study was carried out with the goal of calculating some genetic parameters and determining the most important trait in increasing yellow maize yield by path coefficient analysis.

Materials And Methods

At the Agricultural Research Station of the College of Agriculture, University of Basrah, Karma location, a field experiment was conducted at 47.80° West longitude and 30.57° North latitude in spring agricultural season year 2022. With the aim of estimating some genetic parameters of the genotypes of the yellow corn crops planted at different agricultural distances. Samples were taken for the purpose of conducting an analysis of chemical and physical characteristics of soil field before planting, and the samples were examined in the main laboratory at the College of Agriculture, University of Basrah, with the outcomes displayed in Table 1. The experiment included two factors: first factor included 3 approved genotypes that were obtained from the General Authority for Agricultural Research, Baghdad (Al-Maha, IPA-5018, Bhooth-106).

The experiment was carried out utilizing the randomized complete block design (RCBD) with three replicates in accordance with the factorial experimentation methodology.Because the various treatments were planted at random within each sector, the number of experimental units increased to (12) units for each replicate, for a total of 36 experimental units. The soil was prepared for cultivation by plowing it with two orthogonal plows, moldboard plows, and disc harrows, then leveling it with a leveling machine, and finally dividing the land into three sectors according to the design used. Each plot contains 12 experimental units, thus a total of 36 experimental units with dimensions (3 m x 4 m = 12 m^2), and six lines were included in each experimental unit of 3 m length, a distance of 70 cm between lines . A distance of 1.5 m was left between experimental units and between a repeaters, and a distance of 2 m between the main treatments.

Yellow corn seeds were sown in the spring season on 26.03.2022, 2-3 seeds were placed in a hole, and then the process of thinning into one plant was carried out three weeks after sowing. Then the experimental land was watered immediately after planting, while the other irrigations were given one irrigation every week and according to the plant's needs. Urea fertilizer was 240 kg N/ha as a source of nitrogen fertilizer (Mohsen, 2007), Moreover, it was added in three equal batches, the first one coming after emergence, the second one coming after one month from planting, and the third one coming at the start of flowering. When planting, 200 kg hectare-1 of triple superphosphate fertilizer (P_2O_5) was applied in one batch. Irrigation and weeding operations were also carried out during the season according to the crop's needs, and the plants were harvested on 24.07.2022.

Table (1) the physical and chemical field's properties.

Characteristics	**Values**	**Units**
pH	7.38	
E.Ce.	8.65	Desimines m^{-1}
Organic matter	10.5	g kg-1
Nitrogen	53.0	mg kg $^{-1}$ soil
Phosphorus	4.86	
Potassium	125	
Sand	369	g kg $^{-1}$ soil
Silt	536	
Clay	95	
Texture	Silty loam	

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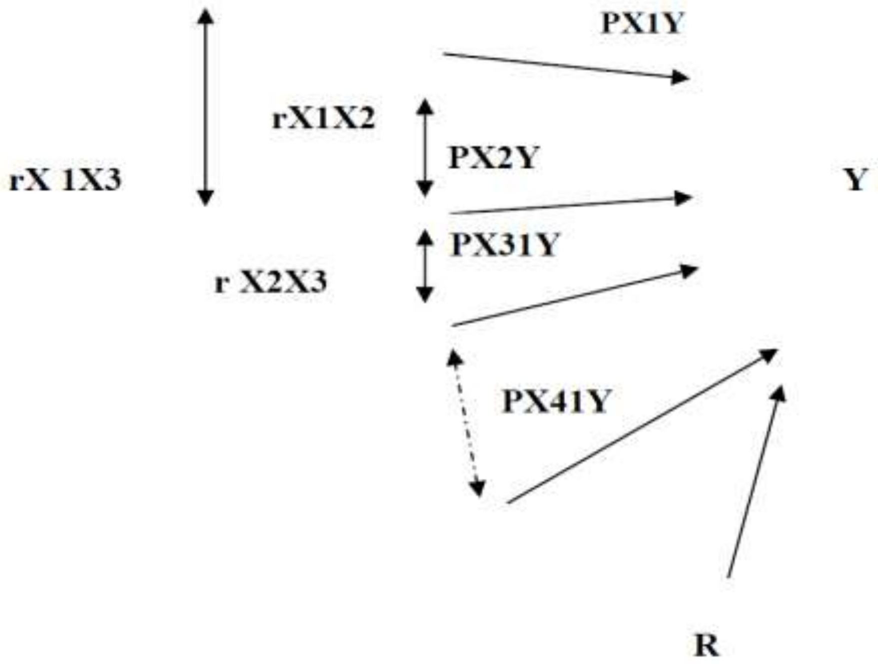
Path Coefficient Analysis: The path coefficient analysis was studied, as well as to determine the trait or traits most influencing of yield, this Planned by (AL-Rawi, 1987):



As:
Xi: Factors that Contribute to (Three studied traits)
Y: Responsive factor (grain yield)
R: The remaining factors

← : The path parameter from Causative to the effector is represented by a vector.

↕ : A vector representing the coefficient of correlation between the two traits rxixi

From the above chart, grain yield y was a result causative factors x1, x2, x3, and x4

$rx1y=px1y+px2yr12+ \ldots + px4yr14$

$rx2y=px1yr21+px2y+ \ldots + px4yr24$

$rx4y=px1yr14+px2yr24 + \ldots + px4y$

$rRy=PRY= (1-\sum PxiYrxiy)1/2$

Putting these simultaneous equations into a matrix yields the following:

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$$\begin{pmatrix} rx1y \\ rx2y \\ \cdot \\ rx4y \end{pmatrix} = \begin{pmatrix} rx1x1 & rx1x2 \ldots\ldots\ldots rx1x4 \\ rx2x1 & rx2x2 \ldots\ldots\ldots rx2x4 \\ & \\ rx4x1 & rx4x2 \ldots\ldots\ldots rx4x4 \end{pmatrix} \times \begin{pmatrix} rx1y \\ rx2y \\ \\ rx4y \end{pmatrix}$$

A B C

To calculate the values of matrix C (the values of the path coefficient), we compute the inverse of matrix B.

$$\begin{pmatrix} Px1y \\ Px2y \\ \cdot \\ Px4y \end{pmatrix} = \cdot \begin{pmatrix} 1 & rx1x2 \ldots\ldots\ldots rx1x4 \\ rx2x1 & 1 \ldots\ldots\ldots rx2x4 \\ & \\ Rx4x1 & rx4x2 \ldots\ldots\ldots 1 \end{pmatrix} \times \begin{pmatrix} rx1y \\ rx2y \\ \cdot \\ rx4y \end{pmatrix}$$

C = B^{-1} × A

Calculate the phenotypic and genetic correlation coefficient according to the following equations:

Phenotypic correlation rpij= $\frac{\delta pipj}{\sqrt{\delta^2 pi \delta^2 pj}}$

Genetic correlation $rgij = \frac{\delta gigj}{\sqrt{\delta^2 gi \delta^2 gj}}$

Whereas:

$\delta pipj$ = The common phenotypic variation between the two traits
$\delta^2 pi$ = Phenotypic variance of the first trait
$\delta^2 pj$ = Phenotypic variance of the second trait
$\delta gigj$ = The Genetic correlation variation between the two trait
$\delta^2 gi$ = Genetic variance of the first trait
$\delta^2 gj$ = Genetic variance of the second trait

3- Accounting for genetic, environmental, and phenotypic variances:

Genetic and phenotypic variations are estimated according to the method explained by (Walter, 1975) by calculating each of the following:

$\sigma^2_G = \frac{Msv - Mse}{r \times a}$

$$\sigma^2 E = Mse$$

$$\sigma^2 P = \sigma^2 G + \sigma^2 E$$

Whereas:
$G^2\sigma$ = Genetic Variance
$E^2\sigma$ =Environmental Variance
$P^2\sigma$ =Phenotypic Variance
*Ms*v =Mean squares cultivars
Mse =Mean squares of experimental error
r = The number of replicates
a = levels of factor a
4- Degree of heritability: It includes heritability in the broad sense ($h^2_{b.s.}$).
As it was estimated by the method explained by (Hanson *et al.*, 1956) and as follows:

$$h^2_{b.s} = \frac{\delta^2 G}{\delta^2 p} \times 100$$

$h^2_{b.s.}$ it represents heredity in the broadest sense
$\delta^2 G$ Genetic variation of the trait
$\delta^2 P$ Appcobance variance

Results And Discussion
Genetic and phenotypic pathway coefficient analysis:
Table 2 shows the findings of an examination of the genetic and phenotypic pathway coefficients, which showed a statistically significant relationship between the qualities under study due to the overlap between their genetic and environmental bases and the correlation between the traits with direct and indirect influences give the plant its phenotypic shape, Furthermore, correlation analysis just provides information on the relationship between two variables, rather than the full picture. Path coefficient analysis, which examines the direct and indirect effect of a cause on grain production, was preferred in more complex scenarios because it provided more essential and accurate results than other attributes in describing the nature of the association between these traits and grain yield. Three characteristics of the components of the grain yield were studied, and the results show in Table (2) that the weight of 300 grains had a direct positive effect on the genetic path coefficient of 0.806 on grain yield and a direct positive effect on the phenotypic path coefficient, which amounted to 0.582 on grain yield. As for indirect effect through other traits, the results indicate that the indirect genetic effect through the number of cobs in the plant amounted to -0.014, and there is an indirect genetic effect through number of grains per cob, which reached 0.142, the results also indicated that there was an indirect phenotypic effect of this trait through the number of ears and the number of grains per ear, which amounted to 0.103 and 0.248, respectively, on grain yield and the results indicated that there is an indirect phenotypic effect of this. As for the direct effect of the number of cobs per plant, the results indicated that direct genetic effect of the number of cobs in plant amounted to -0.029, while there was a direct positive phenotypic effect. It reached 0.145 grain production, or the harvest. The genetic path coefficient measured the indirect effect of this feature on grain yield, and found that 300-grain weight and number of grains per cob were both positive predictors (0.402 and 0.105) respectively.
The phenotypic path coefficient on the number of cobs in the plant had a positive indirect effect through the weight of 300 grains, and grains number in cob reached 0.416 and 0.253 on the grain yield, respectively. In the grain yield, there was also a positive effect of this trait, for the coefficient of the phenotypic pathway amounted to 0.308 in the yield of grain, and the coefficient of the genetic path had an indirect positive effect for this trait through the weight of 300 grains, which amounted to 0.701 in yield of grain, while indirect effect of grains number in cob by means of the number of cobs per plant amounted to -0.018, while an indirect positive effect of the coefficient of the phenotypic path of the characteristic of grains number in cob by means of grain weight and the number of cobs per plant amounted to 0.469 and 0.119, respectively, on

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grain yield. Total effect of the coefficient of the genetic pathway for the weight of 300 grains, cobs number in plant, and the number of grains per cob in grain yield was 0.934, 0.478, and 0.847, respectively, while the total effect of the coefficient of the phenotypic path for the weight of 300 grains, number of cobs per plant, and number of grains per cob in grain yield (0.933, 0.814 and 0.896) respectively, and according to these results, the weight of 300 grains can be counted as a selective guide in the subsequent breeding programs for these genotypes in order to improve their performance, , then the quantity of grains per cob. All of this fits with what has been found by Al-Rawi (2011).

Table (2) Analysis of the genetic and phenotypic path coefficient of grain yield and its components.

Effect type		path coefficient	
		Genetic	phenotypic
1- Effect 300 grains weight			
a- direct effect	P1Y	0.806	0.582
A- Indirect effect			
By the number of cobs per plant	r12p2y	-0.014	0.103
By the number of grains per cob	r13p3y	0.142	0.248
Total adjective effect		0.934	0.933
2-Effect of cobs number plant			
a- direct effect	P2Y	-0.029	0.145
B- Indirect effect			
By weight of 300 grains	r12p1y	0.402	0.416
By the number of grains per cob	r23p3y	0.105	0.253
Total adjective effect		0.478	0.814
3 -Effect of grains number per cob			
a- direct effect	P3Y	0.164	0.308
B- Indirect effect			
By weight of 300 grains	r13p1y	0.701	0.469
By the number of cobs per plant	r23p2y	-0.018	0.119
Total adjective effect		0.847	0.896

Genetic and phenotypic correlates:

Grain yield in cereal crops is affected productively by a number of traits of economic importance, so selection is necessary and important not only because of its influence on the trait to which the selection is directed but also because of its effects on other traits. The two traits and environmental influences were studied, and the genetic and phenotypic correlations were studied with four traits of yield characteristics and their components included in the study. According to Table 3, there is a positive and extremely significant genetic association between the number of grains per cob and the number of cobs per plant, the weight of 300 grains, and the grain production.

The average genetic correlation between the number of earwigs per plant and the weight of 300 grains was 0.499, and the average genetic correlation between the weight of 300 grains and the grain yield was 0.479. Similarly, the average genetic correlation between the weight of 300 grains and the grain yield was 0.912. These results are presented in Table 4. There was a positive and statistically significant relationship between

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the number of grains per cob and the other two phenotypic measures of plant performance: the number of cobs per plant and the weight of 300 grains, and the yield of grains. Weight per 300 grains had a positive and extremely significant phenotypic correlation with grain yield; the average was 0.934. These findings are in line with those of other studies (Al-Najjar, 2016; Wuhaib *et al*., 2018), and in light of these findings, we find that the genetic and phenotypic association between grain yield and the weight of 300 grains and the number of grains per cob is positive and very significant (2017).

Whereas:

P1Y: 300 grains weight, P2Y: cobs number in plant, P3Y: grains number in cob.

Table (3) values of coefficient of genetic correlations

0.846	0.870	0.646	grains number/ cob
0.479	0.499	Cobs number/ plant	
0.912	300 grains weight		
Grain yield Y			

Scheme (1) coefficient of genetic pathway between the yield and the studied traits**:**

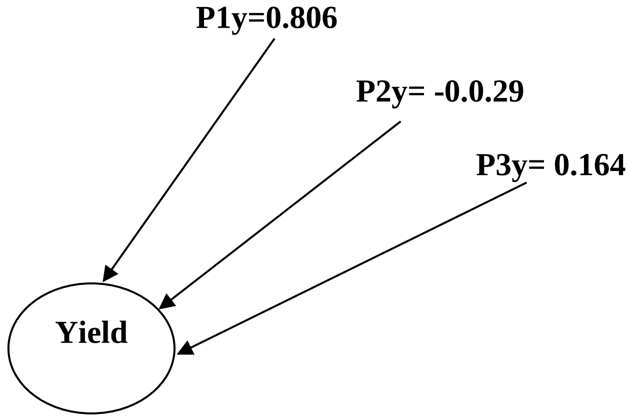
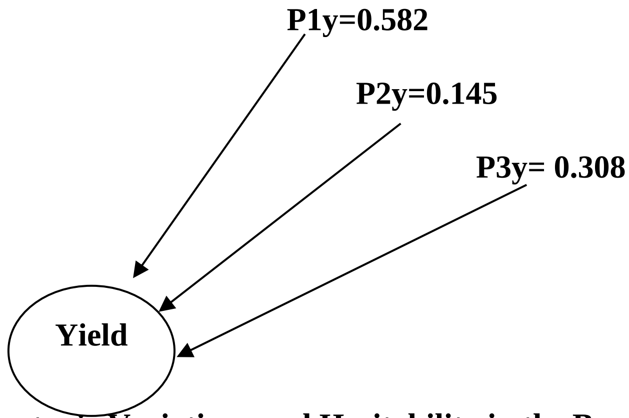


Table (4) values of coefficient of phenotypic correlations

0.897	0.807	0.824	grains number/ cob
0.815	0.715	Cobs number/ plant	
0.934	300 grains weight		
Grain yield Y			

Scheme (2) Coefficient of phenotypic path between the yield and the studied traits**:**



Genetic, Environmental, Phenotypic Variations and Heritability in the Broad Sense:

Table (5) displays the heritability in a broad sense of the characteristics evaluated as well as genetic, environmental, and phenotypic variability. The average number of days from planting to 50% male blooming varies by genetic background, environmental conditions, and phenotype (with values of 4.5424, 0.436, and 4.9793, respectively). According to these numbers, the observed level of genetic variation is larger than previously thought. The degree of heritability for this trait was calculated to be 91.22%, and it was found that the value of the phenotypic variance resulting from the overlap of genetic and environmental variance increased as a result of the value of environmental variance, indicating the stability of the genetic factor. According to Table 5, the average degree of heritability for the trait "number of days from sowing up to 50% female blooming" is 91.87 percent, whereas the genetic, environmental, and phenotypic variances for this trait are 4.369, 0.386, and 4.7560 days, respectively. Heritability was calculated to be 98.74% and the results showed that the genetic, environmental, and phenotypic differences in plant height amounted to 84.149, 1.072, and 85.221, respectively (Table 5). The table shows that the heritability of the trait paper area index is 96.58% and that the genetic, environmental, and phenotypic variability of this trait amount to 0.0226, 0.00078, and 0.0234, respectively. The degree of heritability was calculated to be 96.58%, and the table showed that the genetic, environmental, and phenotypic differences in stem diameter amounted to 5.1190, 0.1808, and 5.2998, respectively.

The average heritability was 88.30%, whereas the genetic, environmental, and phenotypic variances in the number of cobs per plant were 0.0040, 0.00049, and 0.00453, respectively (see Table 5). The average degree of heritability was found to be 77.83%, with the minimum and maximum values being 1254.17, 357.1 and 1611.27. According to the data in the table, the heritability for the trait of 300-grain weight was calculated at 96.62%, with genetic, environmental, and phenotypic variances all totaling 25.603, 0.8930 , 26.4966 , A total of 0.1554, 0.00736 and 0.1627 were found to be the genetic, environmental, and phenotypic variations of the grain yield trait, whereas the average heritability was 95.51 percent with average values of 76.88% and 0.6153, 0.1850,0.8003 for heritability in the broadest sense. The table's results showed that the genetic, environmental, and phenotypic variations of protein in grains amounted to 1.688, 0.7739, and 2.4624, respectively, when the degree of heritability in the broad sense reached 76.80%; these numbers are in line with the findings that heritability increases from 0% to 70% across multiple levels of analysis (Idan, 2021).

Table (5) Estimates of genetic, environmental, and phenotypic differences in characteristics of yellow corn and their heritability in a wide sense are shown

Studied traits	δ^2G Genetic variance	δ^2E Environmental **variance**	δ^2P **Phenotypic variance**	$h^2_{b.s}$ Heritability in the broad sense **(%)**
Days number from sowing until 50% male flowering	**4.5424**	**0.436**	**4.9793**	**91.22**
Days number from sowing until 50% female flowering	**4.369**	**0.386**	**4.7560**	**91.87**
plant height (cm)	**84.149**	**1.072**	**85.221**	**98.74**
Leaf area index	**0.0226**	**0.00078**	**0.0234**	**96.58**
stem diameter (mm)	**5.1190**	**0.1808**	**5.2998**	**96.58**
cobs number per plant (cobs plant-1)	**0.0040**	**0.00049**	**0.00453**	**88.30**
grains number of a cob (grains cob-1)	**1254.17**	**357.1**	**1611.27**	**77.83**
grains weight (g) 300	**25.603**	**0.8930**	**26.4966**	**96.62**
Grains yield (t ha-1)	**0.1554**	**0.00736**	**0.1627**	**95.51**
Biological yield (t ha-1)	**0.6153**	**0.1850**	**0.8003**	**76.88**
Harvest index (%)	**1.7171**	**0.5186**	**2.2357**	**76.80**
Protein in grains (%)	**1.688**	**0.7739**	**2.4624**	**68.55**

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