Some Genetic Parameters and Path Coefficient of Three-Way Crosses in Maize

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Abstract

Correlation and path coefficient analysis were worked out for ten morphological traits in 30 three-way crosses of maize. Phenotypic and genotypic correlation analysis indicated that ear length; row numbers per ear, grain numbers per row, leaf area and leaves numbers had a positive significant correlation with grain yield per plant. Further partitioning of correlation coefficients into direct and indirect effects showed that traits days to silking, row numbers per row and leaves numbers had a positive direct effect on grain yield per plant. The traits ear length, grain numbers per row and leaf area had a maximum total effect on grain yield. Furthermore, PCA analysis has gave interested results and it supported the results of correlation and path analysis. The correlation and path analysis obviously indicated that direct selection based on these attributes may be useful in raising grain yield in maize.

Keywords: Coefficient, Maize, Environmental.

1. Introduction

Selection of superior genotypes on the base of yield often is not efficient due to it is a complex quantitative trait governed by a large number of alleles and it highly affected by environmental factors. For a rational approach towards the improvement of yield, selection has to be made for its components which it actively affect it. Determination the superior traits and ted with yield can accelerate the process of selection, and dismiss undesirable genotypes, which enables focus resources on those potentially superiors [1,2]. Genetic correlation expresses the magnitude of the cause-effect relationship between various plants traits that define the components of the traits on which selection can be done for improvement in yield. Therefore, it is necessary to analyze the correlation relationship, detailing the defining effects to the main trait. Path analysis is defined as a modified partial regression coefficient that divides the correlation coefficient into direct and indirect effects of a set of independent characteristics on which the dependent factor depends. The path parameter divides the correlation factor into its components, so one of the components is the path coefficient, or the so-called partial standardized regression, which measures the direct and indirect effect of the influencing factor on the dependent factor through another influencing factor [3]. Therefore, path analysis elevates the correlation coefficient deployment in a cause and effect relation between traits [4]. The concept of path parameter analysis was first developed by Wright in 1921, but Dewey and Lu were the first to use the path parameter in the plant selection in 1959. Studies of the relationships among traits, through path analysis, are useful to the early selection inbred lines, or to the simultaneous selection when more than one trait is desired. That is because the indirect selection based on the correlated response, with high heritability and simple assessment, may lead in higher genetic progress if compared to the use of direct selection [5], [6], who found that studied traits contributed with 99% and 85% of yield variance at spring and fall under 200 kg N ha⁻¹ and 99% and 93% under 400 N ha⁻¹ respectively. [7], conclude the highest value of direct effects are for the ear height and number of leaves plant⁻¹, in spring and watered treatment, number of leaves plant⁻¹ in water stress for same season. In fall season the highest direct effect is for dry weight in both treatment watered and water stress, referred that three traits considered an important selection criteria for increasing the yield. [8] referred that plant breeders rely on the indirect selection for the yield components in order to raise it. Indirect selection is supposed to be one of the components that can be highly correlated with grain yield which ultimately has more effect on it and which can progress it. The aim of this study is to estimate the genotypic, phenotypic coefficient of correlation, and estimate the direct and indirect effect for many characters in grain yield in order to find some selection indicators.
2. Materials and Methods

The experiments were conducted at the research station of agriculture college/Al-Jadrya. The used crosses were generated from five inbreds lines viz, ZM49W3E, ZM60, ZM43WIZE, ZM19 and CDCN5 which are introduced from Yugoslavia and Italy. Ten single crosses were derived from crossing between the inbred lines according to half diallel matting during spring season 2016. Single crosses were included in a crossbreeding program during the 2016 fall season to derive 30 three-way crosses. As a result, 30 three-way crosses were grown in randomized Complete Block Design (RCBD) with four replications at the research station of agriculture college/Al-Jadrya during spring season 2017. A plot dimensions 3x3m consisted of five rows, 70 cm between rows and 25 cm within rows, population density was 57143 plants hect-1. The recommended package of practices was followed to raise a good crop. Harvesting was performed after the grains reached maturity and plants were dried, at grain moisture was determined. Observations were recorded on ten randomly plants for plant height (cm), leaf area (cm²), leaves number per plant, ear height (cm), ear length (cm), number of rows per ear, number of kernels per row, and grain yield per plant. Whereas, the observations for the characters namely days to 50 % tasselling, days to 50 % silking, days to maturity were recorded on a plot basis. Individual analysis of variance was carried out for each trait (the effects of populations are fixed). The evaluation of the genotypic and phenotypic correlation between the studied traits was obtained, tested at 1% probability by the t-test. The correlations between the nine traits and grain yield (dependent variable) were deployed in direct and indirect effects through path analysis, establishing relationships of cause and effect among the traits [9]. The statistical analysis was performed out using GENSTAT software. Principal component analysis (PCA) in a balanced form was done for a total of ten traits based on sum of square variables using SPAR2 [10].

3. Results

The individual analysis of variance presented significant differences (ANOVA P<0.01) among populations regarding the agronomic traits of DTS, DTS, PH, EH, LN, LA, EL, RNE, GNR and GYP (Table 1) indicated the presence of sufficient variability in the material studied. The coefficient variation of error was low for all traits and this refers to faint environmental conditions. The individual analysis of variance presented significant differences (ANOVA P<0.01) among populations regarding the agronomic traits of DTS, DTS, PH, EH, LN, LA, EL, RNE, GNR and GYP (Table 1) indicated the presence of sufficient variability in the material studied. The coefficient variation of error was low for all traits and this refers to faint environmental conditions. The correlation is used to describe the nature of the relationship between the yield and other traits, and the genetic correlation is more important for plant breeders because it’s roles in determinate the traits that on the basis of which selection is made. The results of genetic and phenotypic correlation coefficients were positive among grain yield and the studied traits except for the days to tasselling and days to silking traits (Table 2 and 3). The highest genetic correlation coefficient was recorded between grain yield and length ear, row numbers per ear and leaf area, while highest phenotypic correlation coefficient was recorded between grain yield and length ear, grain numbers per ear and leaf area. Exist a correlation among traits would support the breeder decision in choosing some components as selection indicators. In the current study, length ear, grain number per ear and leaf area showed a positive and significant correlation coefficient among them at the genetic and phenotypic level, in addition to high heritability coefficient (data don’t show).

### Table 1. Values and significances of mean squares for ten traits obtained of 30 three-way crosses of maize populations.

| SOV | Df  | DTT | DTS | PH  | EH  | LN  | LA  | EL  | RNE | GNR | GYP  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Rep | 3   | 5.17 | 4.78 | 2.22 | 21.05 | 1.83 | 0.008 | 20.39 | 0.72 | 1.05 | 7.16 |
| Treat | 29 | 45.08** | 25.22** | 1124.82** | 686.08** | 4.38** | 0.0372** | 4256.2** | 13.72** | 5.51** | 3394.9** |
| Error | 87 | 0.70 | 0.80 | 3.98 | 4.89 | 0.25 | 0.0005 | 8.09 | 0.38 | 0.30 | 7.97 |

D TT: Days To Tasselling; DTS: Days To Silking; PH: Plant Height; EH: Ear Height; LN: Leaves Number; LA: Leaf Area; EL: Ear Length; RNE:Row Number Ear-1; GNR: Grain Number Row-1; GYP: Grain Yield Plant-1.

Correlation is used to describe the nature of the relationship between the yield and other traits, and the genetic correlation is more important for plant breeders because it’s roles in determine the traits that on the basis of which selection is made. The results of genetic and phenotypic correlation coefficients were positive among grain yield and the studied traits except for the days to tasselling and days to silking traits (Table 2 and 3). The highest genetic correlation coefficient was recorded between grain yield and length ear, row numbers per ear and leaf area, while highest phenotypic correlation coefficient was recorded between grain yield and length ear, grain numbers per ear and leaf area. Exist a correlation among traits would support the breeder decision in choosing some components as selection indicators. In the current study, length ear, grain number per ear and leaf area showed a positive and significant correlation coefficient among them at the genetic and phenotypic level, in addition to high heritability coefficient (data don’t show).

### Table 2. Genotypic correlations among the variables studied in 30 three-way crosses of maize populations.

|          | DTT | DTS | PH  | EH  | LN  | LA  | EL  | RNE | GNR | GYP  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Day to tassling | 1.000 | 0.905 | 0.291- | 0.319- | 0.352- | 0.689- | 0.409- | 0.396- | 0.169- | 0.415- |
| Day to silking  | 1.000 | 0.439- | 0.423- | 0.0848 | 0.672- | 0.620- | 0.494- | 0.264- | 0.624- | 0.517- |
| Plant height   | 1.000 | 0.924 | 0.521 | 0.637 | 0.459 | 0.432 | 0.504 | 0.451 | 0.319 | 0.689 |
| Ear height     | 1.000 | 0.395 | 0.593 | 0.375 | 0.385 | 0.419 | 0.371 | 0.689 | 0.451 | 0.624 |
| Leaves number  | 1.000 | 0.571 | 0.613 | 0.465 | 0.149 | 0.613 | 0.371 | 0.593 | 0.385 | 0.624 |
| Leaf area      | 1.000 | 0.423 | 0.459 | 0.504 | 0.432 | 0.504 | 0.451 | 0.371 | 0.689 | 0.451 |
| Ear length     | 1.000 | 0.745 | 0.574 | 0.995 | 0.465 | 0.149 | 0.613 | 0.371 | 0.689 | 0.451 |
| Row No. Ear-1  | 1.000 | 0.526 | 0.725 | 0.995 | 0.465 | 0.149 | 0.613 | 0.371 | 0.689 | 0.451 |
| Grain No. Row-1| 1.000 | 0.597 | 0.624 | 0.995 | 0.465 | 0.149 | 0.613 | 0.371 | 0.689 | 0.451 |
DTT: Days To Tasseling; DTS: Days To Silking; PH: Plant Height; EH: Ear Height; LN: Leaves Number; LA: Leaf Area; EL: Ear Length; RNE: Row Number Ear\(^1\); GNR: Grain Number Row\(^1\); GYP: Grain Yield Plant\(^{-1}\).

Table 3. Phenotypic correlations among the variables studied in 30 three-way crosses of maize populations.

|                      | Day to tasseling | Day to silking | Plant height | Ear height | Leaves number | Leaf area | Ear length | Row No. Ear\(^1\) | Grain No. Row\(^1\) | GYP (gm) |
|----------------------|------------------|----------------|--------------|------------|--------------|-----------|------------|-------------------|---------------------|----------|
| Day to tasseling     | 1.000            | 0.830**        | 0.280**      | 0.298**    | 0.298**      | 0.369**   | 0.362**    | 0.164-             | 0.312-              | 0.398**  |
| Day to silking       | 1.000            | 0.403**        | 0.383**      | 0.412**    | 0.617**      | 0.438**   | 0.253**    | 0.358-              | 0.575-              |          |
| Plant height         | 1.000            | 0.908**        | 0.472**      | 0.617**    | 0.408**      | 0.447**   | 0.571**    | 0.442**             | 0.364**              |          |
| Ear height           | 1.000            | 0.352**        | 0.568**      | 0.363**    | 0.359**      | 0.577**   | 0.442**    | 0.364**             | 0.312**              |          |
| Leaves number        | 1.000            | 0.487**        | 0.408**      | 0.144      | 0.380**      | 0.544**   | 0.364**    | 0.312**             | 0.531**              |          |
| Leaf area            | 1.000            | 0.676**        | 0.418**      | 0.641**    | 0.608**      | 0.495**   | 0.618**    | 0.681**             | 0.646**              |          |
| Ear length           | 1.000            | 0.458**        | 0.720**      | 0.418**    | 0.641**      | 0.681**   | 0.681**    | 0.681**             | 0.646**              |          |
| Row No. Ear\(^1\)   | 1.000            | 0.372**        | 0.531**      | 0.372**    | 0.531**      | 0.372**   | 0.531**    | 0.531**             | 0.531**              |          |
| Grain No. Row\(^1\) | 1.000            | 1.000          | 1.000        | 1.000      | 1.000        | 1.000     | 1.000      | 1.000              | 1.000               |          |
| GYP (gm)             |                  |                |              |            |              |           |            |                   |                     | 1.000    |

DTT: Days To Tasseling; DTS: Days To Silking; PH: Plant Height; EH: Ear Height; LN: Leaves Number; LA: Leaf Area; EL: Ear Length; RNE: Row Number Ear\(^1\); GNR: Grain Number Row\(^1\); GYP: Grain Yield Plant\(^{-1}\).

Since the correlation relation can’t determine how much each trait can contribute to direct and indirect effect, researchers should resort to other statistical methods such as path coefficient analysis, which it measures the direct and indirect effects for traits that are independent and correlate with dependent traits. The highest positive direct effect on the grain yield was 0.78, 0.46 and 0.39 for the traits of the days to tasseling, row numbers per ear and grain numbers per row respectively, while the highest negative direct effect on the grain yield was -1.0 and -0.53 for the days to tasseling and plant height traits respectively. The highest total positive effect (direct and indirect), on the grain yield, was 0.725 for ear length trait and this resulted from the positive indirect effects of the days to silking (0.494) and grain numbers per row (0.302) traits (Table 4). [11], found that the highest direct effect on the grain yield of maize is due to the length of the ear. Grain numbers per row trait also was superior in the indirect effect on grain yield through days to silking. Also, leaf area and grain numbers per row have a considerable total effect on the grain yield. It is noticed that the grain numbers per row had the highest direct effect (0.395) and total effect (0.674) on the grain yield. It is very hard to study all component traits of yield in plant breeding program. The residual effect permits accurate manifest of the pattern of interaction of other components of yield. In other words, residual effect measures the role of other independent components which do not include in the study on the grain yield. In the present study, the residual effect observed was low (0.33), and this indicating that the variables analyzed are the main determinants of grain yield.

Table 4. Estimates of direct (diagonal) and indirect effects of the studied traits on the trait grain yield plant (GYP).

|                      | Day to tasseling | Day to silking | Plant height | Ear height | Leaves number | Leaf area | Ear length | Row No. Ear\(^1\) | Grain No. Row\(^1\) | Total effects |
|----------------------|------------------|----------------|--------------|------------|--------------|-----------|------------|-------------------|---------------------|--------------|
| Day to tasseling     | 0.783            | -0.905         | 0.156        | -0.012     | -0.126       | -0.140    | 0.040      | -0.078            | -0.133              | -0.416        |
| Day to silking       | 0.709            | -1.00          | 0.235        | -0.016     | -0.174       | -0.137    | 0.050      | -0.121            | -0.169              | -0.624        |
| Plant height         | -0.228           | 0.439          | -0.536       | 0.035      | 0.186        | 0.130     | -0.044     | 0.232             | 0.235               | 0.451         |
| Ear height           | -0.250           | 0.424          | -0.495       | 0.038      | 0.141        | 0.121     | -0.039     | 0.193             | 0.238               | 0.371         |
| Leaves number        | -0.276           | 0.488          | -0.279       | 0.015      | 0.357        | 0.116     | -0.047     | 0.069             | 0.170               | 0.613         |
| Leaf area            | -0.540           | 0.673          | -0.341       | 0.023      | 0.204        | 0.203     | -0.074     | 0.210             | 0.272               | 0.630         |
| Ear length           | -0.310           | 0.494          | -0.231       | 0.015      | 0.166        | 0.149     | -0.101     | 0.242             | 0.302               | 0.725         |
DTT: Days To Tasseling; DTS: Days To Silking; PH: Plant Height; EH: Ear Height; LN: Leaves Number; LA: Leaf Area; EL: Ear Length; RNE: Row Number Ear$^{-1}$; GNR: Grain Number Row$^{-1}$; GYP: Grain Yield $Plant^{-1}$.

Based on Principle Component Analysis, the correlation coefficient between the studied traits is transformed into the cosine of the angle between the two vectors. It is a simple and clear representation of the relationship between the traits. Through this method, ten variables were reduced to two components with the help of the PCA method. The results showed that the PCA1 and PCA2 contributed eigenvalues of 73.95 and 23.26 respectively. Cumulatively these two PCAs contributed 97% of total variation to grain yield. Traits grain yield and plant height had a maximum positive contributed towards the variation of PCA1, while plant height and ear height own higher positive contributed towards the variation of PCA2 (Table 5). PCA1 had positive eigenvector coefficient all the studied traits, except days to tasseling and days to silking traits which had a negative effect (Figure 1).

### Table 5. Percent cumulative variance for two principal components (PCs) and factor loading between PCs and studied traits in maize.

| Traits       | % Var Exp | Cum. Var Exp | Factor Loading |
|--------------|-----------|--------------|----------------|
|              | PCA1      | PCA2         |                |
| DTT          | -0.04713  | -0.00580     |                |
| DTS          | -0.05173  | -0.00259     |                |
| PH           | 0.35521   | 0.69452      |                |
| EH           | 0.24731   | 0.57037      |                |
| LN           | 0.02122   | 0.00395      |                |
| LA           | 0.00243   | 0.00159      |                |
| EL           | 0.04266   | -0.00701     |                |
| RNE          | 0.02291   | 0.00503      |                |
| GNR          | 0.08054   | 0.03230      |                |
| GYP          | 0.89357   | -0.43720     |                |

Overall, the magnitudes of a simple correlation between morphological traits were high; referring that indirect selection is possible for gains in grain yield. According to [16], the correlation relationships could quantify the possibility of indirect selection gains between the correlated traits. Path coefficient analysis provides accurate information on the direct and indirect effects of different characters in respect to yield in order to understand the most influencing characters to be used as selection criteria in maize breeding programmes. Studies of the relationships among traits, through path analysis, are useful to the early selection or to the simultaneous selection in case there are more than one trait is desired. This is because the indirect selection based on the correlated response, with high heritability and simple assessment, may lead to higher genetic progress if it compared to the use of direct selection. The results are in agreement with [12], as they showed in their results the grain weight and number of grains per plant best selection criteria to improve the yield of maize population.

The direct contribution of ear length was negative (-0.1) but it showed positive indirect effect via grain number per row (0.302) and row number per ear (0.242). [6], recommended to discard of the traits of lower direct effect is important for an efficient indirect selection. According to this recommendation, the ear length trait is not suitable for indirect selection, since it has low direct effect on grain yield (Table 4). On the other hand, the high values of the genetic and phenotypic correlation between ear length and grain yield cannot be ignored. In spite of lowering of the direct effect of ear length on grain yield, but the total effect for ear length is still the largest and this is due to indirect effects across other traits.

4. Discussion

Investigating agronomic behavior and correlation among traits are critical for breeding programs; which it determines the genotypes traits that are correlated with the grain yield. The linear correlation coefficient can constitute the linear association trend between two traits, allowing the breeders to determine the selected characteristic [13,14]. Therefore, it is necessary to analyze the correlation relationship, detailing the defining effects of the main trait and path analysis could elevate the correlation coefficient role in a cause and effect relation between traits (3). In this study, phenotypic and genotypic correlations (Table 2&3) with the same sign and similar extent were observed, which suggests accuracy to use the phenotypic correlations for data interpretation.

Although the coefficients of genotypic correlation are higher than the coefficients of phenotypic correlations, evidencing greater contribution of genetic factors, the values found for genotypic correlations may be overestimated, since it comes from indirect calculations from components of variance and covariance [15]. Overall, the magnitudes of a simple correlation between morphological traits were high; referring that indirect selection is possible for gains in grain yield. According to [16], the correlation relationships could quantify the possibility of indirect selection gains between the correlated traits. Path coefficient analysis provides accurate information on the direct and indirect effects of different characters in respect to yield in order to understand the most influencing characters to be used as selection criteria in maize breeding programme.

Through the PCA method, ten variables were reduced to two components with the help of the PCA method. The results showed that the PCA1 and PCA2 contributed eigenvalues of 73.95 and 23.26 respectively. Cumulatively these two PCAs contributed 97% of total variation to grain yield. Traits grain yield and plant height had a maximum positive contributed towards the variation of PCA1, while plant height and ear height own higher positive contributed towards the variation of PCA2 (Table 5). PCA1 had positive eigenvector coefficient all the studied traits, except days to tasseling and days to silking traits which had a negative effect (Figure 1).
Ear length and grain numbers per row have the highest total effects (0.72 and 0.67) with significance correlation with grain yield. These traits that have a highly significant correlation and total effect on the grain yield refer to a true relationship, and the direct selection through this trait would be effective for improving the grain yield. However, the primary outcomes obtained in this research requires over and above studies by using another set of genotypes to confirm the results.

![Figure 1. A diagram of the principal component analysis for classifying ten traits.](image)

**Conclusion**

Grain yield trait exposed enough genetic variability to be efficacious in the selection process. The selection based on ear length, row numbers per ear and grain numbers per row traits is essential, due to their high correlation with grain yield and their positive direct and indirect effects on it.

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