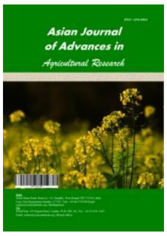



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# Genetic Variability, Correlation and Path Coefficient Analysis in Hybrid Maize (*Zea mays* L.)


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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*


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## ABSTRACT


The goal of the current investigation was to determine correlation coefficient, path analysis and genetic variability among twenty four maize hybrids for ten characters in a Randomized Block Design (RBD) with three replications at the research field of Plant Breeding Division, Regional Agricultural Research Station, Barisal, Bangladesh Agricultural Research Institute (BARI), Bangladesh during rabi season of 2014-15.

The measured traits were Days to 50% tasseling (DT), days to 50% silking (DS), anthesis silking interval (ASI), plant height (PH), ear height (EH), days to maturity (DM), cob length (CL), cob diameter (CD), thousand seed weight (TSW) and yield(yield t/ha). Here yield was considered as dependent variable and the rest of the parameters were independent variable. The data were submitted to analysis of variance and mean values were compared by DMRT test at both 5% and 1% of probability. Positive and significant genotypic, phenotypic correlation coefficient were



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recorded for yield with cob diameter ($r_g$=0.75**, $r_p$=0.61**), cob length ($r_g$=0.66** and $r_p$=0.42**), plant height ($r_g$=0.62** and $r_p$=0.55**), ear height ($r_g$=0.66** and $r_p$=0.55**) and thousand seed weight ($r_g$=0.36** and $r_p$=0.44**). High genotypic coefficient of variation (GCV) was obtained from anthesis silking interval (17.26), yield (15.17), ear height (13.80) and thousand seed weight (9.43). The highest phenotypic coefficient of variation (PCV) were observed in anthesis silking interval (26.49) followed by yield (20.51), ear height (16.19) and the lowest in days to maturity (0.70). The difference between GCV and PCV of yield indicated that the characters had some environmental influence. The highest heritability was observed for plant height (73.78) followed by ear height (72.67), thousand seed weight (59.52) and days to maturity (55.97) but the lowest heritability identified for days to silking (18.98). The characters with higher values of GCV and heritability of the aforementioned traits were indicative for selection. The plant height had the highest positive direct effect (1.34) on yield followed by days to silking (0.75), cob diameter CD (0.46) and thousand seed weight (0.41), days to maturity (0.21) and cob length (0.20) indicating the effectiveness of direct selection. Direct negative effect on yield was shown by ear height (-1.03), days to tasseling (-0.52) and anthesis silking interval (-0.50) was indicating the effectiveness of indirect selection.

*Keywords: Genetic variability; correlation; path co-efficient; maize.*

## 1. INTRODUCTION

Maize *(Zea mays* L.) is a $C_4$ plant having higher yield potential compared to the rice and wheat [1]. It is the second most abundant crop in the world [2]. “It is an important crop throughout the world and has both social and economic repercussions. It is widely used for various applications, but mainly as animal feed. However maize is the basis for food security in some of the world’s poorest regions in Africa, Asia, and Latin America. The crop provides over 20% of total calories in human diets in 21 countries, and over 30% in 12 countries that are home to a total of more than 310 million people [3]. “Maize breeding researchers seek to combine increased grain yield with improved nutritional quality, especially regarding protein and energetic content. It is, therefore, of fundamental importance to identify the agronomic and nutritional traits of maize genotypes” [4]. “It is also the cereal that is most produced in the world, due to its wide scope and utilization in human and animal diet” [5].

“Presently maize is cultivated in 165 countries on 184 million hectares (ha), and has a production of 1,016 million tons (t) and productivity of 5.52 t/ha globally” [6]. In Bangladesh its area and production are increasing rapidly due to wide adaptability and versatile uses. According to DAE [7] the production in Bangladesh was 25.16, 23.61, 27.59, 35.78, 38.93 lac metric ton in the year of 2013-14, 2014-15, 2015-16, 2016-17, 2017-18 with an area occupying 3.64,3.55, 3.95, 4.34, 4.47 lac ha. The yield was 6.91, 6.65, 6.98, 8.25, and 8.71 t/ha respectively.

Maize is an essential food crop both globally and in underdeveloped nations such as Bangladesh. Bangladesh's food production is insufficient to meet domestic demand. Cropping intensity has already surpassed 155% and is approaching 200% in areas where intensification is possible. Maize could be a good source of nutrition for Bangladesh's undernourished and malnourished people. It is currently widely utilised in poultry farms, fisheries, and animal feed, and people in Bangladesh consume roasted and fried maize.

“Knowledge of the linear association between agronomic and nutritional maize traits could lead to significant advances in breeding programs, especially when defining crossings, with the aim of targeting animal feed to increase efficiency and cut production costs” [8]. “Associations between traits can be studied by analyzing a linear correlation coefficient ranging from -1 to 1. However, this coefficient measures the degree of relatedness between two traits and does not allow direct and indirect influences to be quantified” [8].

“Path coefficient and correlation analyses are used widely in many crop species by plant breeders to define the nature of complex interrelationships among yield components and to identify the sources of variation in yield. Knowledge derived in this way can be used to develop selection criteria to improve grain yield in relation to agricultural practices” [9-13].

Considering the above facts, the present investigation was undertaken with following objectives:

i). To identify the relationship between grain yield and other morphological traits and
ii). To estimate the direct and indirect effects of other agronomic traits on yield

## 2. MATERIALS AND METHODS

The study was conducted at the research field of Plant Breeding Division, Regional Agricultural Research Station, Barisal, Bangladesh Agricultural Research Institute (BARI), Bangladesh during rabi season of 2014-15. Twenty one locally developed hybrids along with three check varieties (BARI hybrid maize 7, BARI hybrid maize 9 and NK40) were evaluated in this study. The experiment was laid out in Randomized Complete Block Design having three replications. The twenty one hybrids were developed from seven parental lines using the diallel mating design excluding the reciprocals in rabi season in 2012-2013. Seven inbred lines collected both from BARI and CIMMYT were used as source materials such as E1=BIL20, E2 =BML36, E3= BIL77, E4= BIL106, E5 = CLQRCY44, E6 = BIL79 and E7 = BIL 31. The parents were chosen based on their general combining ability (GCA) and specific combining ability performances (SCA). The following hybrids were created using a diallel mating design: E1×E2, E 1× E3, E1×E4, E1×E5, E1×E6, E1×E7, E2×E3, E2×E4, E2×E5, E2×E6, E2×E7, E3×E4, E3×E5, E3×E6, E3×E7, E4×E5, E4×E6, E4×E7, E5×E6, E5×E7 and E6×E7.

Each entry's seeds were planted in two rows of four-meter-long plots, with hills and rows spaced, respectively, at intervals of 60 and 20 cm. The day of the sowing was November 20, 2014. After thinning, one healthy seedling was kept each hill. Fertilizers were applied at the rate of 250, 55, 110, 40, 5 and 1.5 kg/ha of N, $P_2O_5$, $K_2O$, S, Zn and B respectively. Standard agronomic procedures were observed, and necessary steps for plant protection were done [14]. To reduce the border effect, two border rows were used at the ends of each replication. Data on days to 50% tasseling (DT), days to 50% silking (DS), and anthesis silking interval (ASI), plant height (PH), ear height (EH), days to maturity (DM), cob length (CL), cob diameter (CD), thousand seed weight (TSW) and yield (t/ha) were measured. The plot yield was calculated using all the plants in two rows, and the result was converted to t/ha. Analysis of the path co-efficients computed by Dewey and Lu [15]. In accordance with Sheoran et al. all the data were processed and examined [16].

## 3. RESULTS AND DISCUSSION

The pooled analysis' mean sum of squares showed substantial influence on yield. Significant treatment effects were seen in all the characters, showing that there was enough variation between them (Table 1).

The highest $\sigma^2$g (1392.72) and $\sigma^2$p (2339.88) variance were found for TSW (Table 2) which was in agreement with Matin et al. [17]. The lowest magnitude of$\sigma^2$g (0.06), $\sigma^2$p (0.12) variance were observed in CD. High genotypic coefficient of variation (GCV) were obtained for ASI (17.26), Yld (15.17), EH(13.80) and TSW (9.43). Al-Amin et al. [18] observed high GCV in PH, CD and Yld/plant. The characters with high GCV indicated high potential for selection. Alam et al. [19] selected some traits with high GCV in *B juncea*. The lowest GCV recorded in DM (0.52) that was identical with DS (1.03) and DT (1.49). The highest phenotypic coefficient of variation (PCV) were observed in ASI (26.49) followed by Yld (20.51), EH (16.19) and the lowest in DM (0.70). The difference between GCV and PCV of yield indicated that the characters might have been influenced by the environment. Most of the traits showed high heritability except DS and DT indicating lower influence of environment which also observed in the study of Begum et al. [20]. The highest Hb was observed for PH (73.78) followed by EH (72.67), TSW (59.52) and DM (55.97) but the lowest Hb identified for DS (18.98). The higher values of heritability of aforementioned traits could be considered for selection that corroborates the findings of Matin et al. [17], Ali et al. [21] and Moulin et al. [22]. Hb was recorded higher in EH and Yld in the study of Al-Amin et al. [18]. The highest GA was reported in TSW (59.31) followed by PH (29.74), EH (26.55).The highest GAPM observed in EH (24.23), Yld (23.13), ASI (23.16), TSW (14.99) and PH (14.28) but the lowest in DM (0.80) that was followed by DS (0.92). Al-Amin et al. [18] observed higher GAPM in CD & PH. According to Panse [23] the characters having high Hb value coupling with high GA was due to additive gene effects that was observed in TSW, PH, EH. Matin et al. [17] stated similar findings in TSW, PH, EH and CD. High heritability coupled with low GA observed in PH, EH, CL and CD indicating the exploitation of these traits in hybrid maize development as stated and observed in the findings of Munawar et al. [24] in PH, EH, CL, CD and grain weight. Begum et al. [20] also showed that "high heritability accompanied with low genetic advance revealed non-additive gene action that was identified in CD, Yld, DM, CL, respectively".

## 3.1 Genotypic and Phenotypic Correlation Coefficients with Yield

Table 3 displays the genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients. The yield had the highest positive significant genotypic ($r_g$) and phenotypic ($r_p$) correlation coefficient with CD ($r_{g=}0.75^{**}$, $r_p=0.61^{**}$), CL ($r_{g=}0.66^{**}$, $r_p=0.42^{**}$), PH ($r_g=0.62^{**}$and $r_p=0.55^{**}$) and EH ($r_g=0.66^{**}$and $r_p=0.55^{**}$). Positive correlation coefficient with yield was recorded with CD and EH in the study of Matin et al. [17], Nataraj et al. [25], Ojo et al. [26] and Batool et al. [27]. Positive correlation with yield also estimated in the studies of Al-Amin et al. [18], Bello et al. [28] and Sadek et al. [29]. PH and EH had positive correlation with yield in the study of Bankole et al. [30]. Barosa et al. (2019) mentioned "positive correlation on yield by TSW. TSW had moderate significant and positive correlation with yield ($r_{g=}0.36^{**}$, $r_p=0.44^{**}$), at both genotypic and phenotypic levels". "The study revealed that that genotypic correlation was higher than phenotypic correlation representing the association was due to genetic reason (strong coupling phase)" [31].

Negative significant correlation was found in DT ($r_{g=}$ -0.21$^{NS}$and $r_p$= -0.35$^{NS}$), DS ($r_{g=}$ -0.19$^{NS}$and $r_p$= -0.36$^{**}$) with yield at both genotypic and phenotypic levels but ASI ($r_p$= -0.01$^{NS}$) only at phenotypic levels. The observation of Sadek et al. [29] also revealed similar results.

Residual effect ($R^2$) = 0.241

## 3.2 Path Coefficient Analysis

"Correlation coefficient analyses are useful tools for selecting the traits that influence grain yield" [32]. "Normally it exploits the degree of association among continuous traits" [33]. "Despite the usefulness of these estimates in the understanding of complex traits such as grain yield, direct and indirect effects of these traits on productivity are not well defined" [34]. In this regard, Wright [35] proposed "a method to partition the correlation coefficients into components of direct and indirect effects known as path coefficient analysis". "The analysis not only partitions the correlation coefficient into direct and indirect effects, but also provides the information on the actual contribution of a trait on the yield" [15].

Being a dependent variable and complex trait yield is often affected by several factors. So, if selection is made considering the correlations only avoiding the cause and effect relationship it may mislead the interpretation [36].

Association of characters assessed by correlation co-efficient may not always express the exact view of the relative importance of direct and indirect influence of each of the independent variable on dependent variable.

"So, to represent the inter-relationship between yield and its components, direct and indirect effects were worked out using path analysis both at genotypic and phenotypic level that also measured the relative importance of each component. Yield being considered as a resultant variable other characters estimated as causal or independent variable" [37].

**Table 1. Pooled analysis of variance using ten characters in maize**

| S.V | d.f | DT | DS | ASI | PH (cm) | EH(cm) |
|---|---|---|---|---|---|---|
| Replication | 2 | 48.667 | 27.167 | 2.181 | 405.941 | 152.012 |
| Treatment | 23 | 8.783** | 6.429ns | 1.418** | 947.609** | 771.800** |
| Error | 46 | 3.623 | 3.775 | 0.441 | 100.377 | 85.992 |

**Table 1. Contd.**

| S.V | d.f | DM | CL(cm) | CD (cm) | TSW(gm) | Yld (t/ha) |
|---|---|---|---|---|---|---|
| Replication | 2 | 5.014 | 4.188 | 0.034 | 381.056 | 4.284 |
| Treatment | 23 | 2.229** | 6.013** | 0.245** | 5,125.318** | 7.143** |
| Error | 46 | 0.463 | 1.333 | 0.057 | 947.157 | 1.543 |

** indicates significant at 5% level and ** indicates significant at 1% level*

*Days to 50% tasseling (DT), days to 50% silking (DS), Anthesis silking interval (ASI), plant height (PH), ear height (EH), days to maturity (DM), cob length (CL), cob diameter (CD), thousand seed weight (TSW) and yld (yield t/ha)*

**Table 2. Estimates of genetic parameters for ten characters in maize**

| Characters | $\sigma^2g$ | $\sigma^2p$ | GCV (%) | PCV (%) | Hb (%) | GA | GAPM |
|---|---|---|---|---|---|---|---|
| DT | 1.72 | 5.34 | 1.49 | 2.62 | 32.19 | 1.53 | 1.74 |
| DS | 0.88 | 4.66 | 1.03 | 2.36 | 18.98 | 0.84 | 0.92 |
| ASI | 0.33 | 0.77 | 17.26 | 26.49 | 42.44 | 0.77 | 23.16 |
| PH | 282.41 | 382.79 | 8.07 | 9.40 | 73.78 | 29.74 | 14.28 |
| EH | 228.60 | 314.59 | 13.80 | 16.19 | 72.67 | 26.55 | 24.23 |
| DM | 0.59 | 1.05 | 0.52 | 0.70 | 55.97 | 1.18 | 0.80 |
| CL | 1.56 | 2.89 | 6.59 | 8.97 | 53.92 | 1.89 | 9.96 |
| CD | 0.06 | 0.12 | 5.05 | 6.98 | 52.23 | 0.37 | 7.52 |
| TSW | 1392.72 | 2339.88 | 9.43 | 12.23 | 59.52 | 59.31 | 14.99 |
| Yld | 1.87 | 3.41 | 15.17 | 20.51 | 54.75 | 2.08 | 23.13 |

*$\sigma^2g$, $\sigma^2p$ -Genotypic variance and phenotypic variance, GCV, PCV-Genotypic and phenotypic coefficient of variation, Hb- Heritability, GA- Genetic advance, GAPM- Genetic advance as percentage of mean*

**Table 3. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation with yield**

| | DT | DS | ASI | PH | EH | DM | CL | CD | TSW | Yld. |
|---|---|---|---|---|---|---|---|---|---|---|
| DT | | $0.82^{**}$ | $-0.79^{**}$ | $-0.26^{*}$ | $-0.19^{NS}$ | $-0.22^{NS}$ | $0.01^{NS}$ | $-0.41^{**}$ | $-0.77^{**}$ | $-0.21^{NS}$ |
| DS | $0.90^{**}$ | | $-0.25^{*}$ | $-0.43^{**}$ | $-0.29^{*}$ | $-0.19^{NS}$ | $0.21^{NS}$ | $-0.16^{NS}$ | $-0.74^{**}$ | $-0.19^{NS}$ |
| ASI | $-0.29^{*}$ | $0.09^{NS}$ | | $-0.16^{NS}$ | $-0.07^{NS}$ | $0.19^{NS}$ | $0.23^{NS}$ | $0.49^{**}$ | $0.49^{**}$ | $0.09^{NS}$ |
| PH | $-0.15^{NS}$ | $-0.19^{NS}$ | $-0.11^{NS}$ | | $0.96^{**}$ | $0.08^{NS}$ | $0.19^{NS}$ | $0.54^{**}$ | $0.17^{NS}$ | $0.62^{**}$ |
| EH | $-0.11^{NS}$ | $-0.14^{NS}$ | $-0.07^{NS}$ | $0.94^{**}$ | | $0.20^{NS}$ | $0.30^{*}$ | $0.68^{**}$ | $0.20^{NS}$ | $0.66^{**}$ |
| DM | $-0.12^{NS}$ | $-0.09^{NS}$ | $0.02^{NS}$ | $0.06^{NS}$ | $0.12^{NS}$ | | $0.44^{**}$ | $0.41^{**}$ | $0.11^{NS}$ | $0.31^{**}$ |
| CL | $0.08^{NS}$ | $0.14^{NS}$ | $0.17^{NS}$ | $0.07^{NS}$ | $0.15^{NS}$ | $0.23^{NS}$ | | $0.59^{**}$ | $0.31^{**}$ | $0.66^{**}$ |
| CD | $-0.31^{**}$ | $-0.18^{NS}$ | $0.29^{*}$ | $0.38^{**}$ | $0.42^{**}$ | $0.22^{NS}$ | $0.46^{**}$ | | $0.53^{**}$ | $0.75^{**}$ |
| TSW | $-0.60^{**}$ | $-0.51^{**}$ | $0.27^{*}$ | $0.11^{NS}$ | $0.13^{NS}$ | $0.19^{NS}$ | $0.23^{NS}$ | $0.54^{**}$ | | $0.36^{**}$ |
| Yld. | $-0.35^{**}$ | $-0.36^{**}$ | $-0.01^{NS}$ | $0.55^{**}$ | $0.55^{**}$ | $0.16^{NS}$ | $0.42^{**}$ | $0.61^{**}$ | $0.44^{**}$ | |

** indicates significant at 5% level and ** indicates significant at 1% level*

*Days to 50% tasseling (DT), days to 50% silking (DS), Anthesis silking interval (ASI), plant height(PH),ear height (EH), days to maturity (DM), cob length (CL), cob diameter (CD), thousand seed weight (TSW) and yld (yield t/ha)*

**Table 4. Direct (bold) and indirect effect of different traits at genotypic level on yield**

| Characters | DT | DS | ASI | PH | EH | DM | CL | CD | TSW | $r_g$ with Yld. |
|---|---|---|---|---|---|---|---|---|---|---|
| DT | **-0.52** | 0.61 | 0.40 | -0.34 | 0.19 | -0.05 | 0.00 | -0.19 | -0.31 | $-0.21^{NS}$ |
| DS | -0.43 | **0.75** | 0.13 | -0.57 | 0.30 | -0.04 | 0.04 | -0.07 | -0.30 | $-0.19^{NS}$ |
| ASI | 0.41 | -0.19 | **-0.50** | -0.21 | 0.07 | 0.04 | 0.05 | 0.22 | 0.20 | $0.09^{NS}$ |
| PH | 0.13 | -0.32 | 0.08 | **1.34** | -0.98 | 0.02 | 0.04 | 0.25 | 0.07 | $0.62^{**}$ |
| EH | 0.10 | -0.22 | 0.03 | 1.28 | **-1.03** | 0.04 | 0.06 | 0.31 | 0.08 | $0.66^{**}$ |
| DM | 0.12 | -0.14 | -0.10 | 0.11 | -0.21 | **0.21** | 0.09 | 0.19 | 0.04 | $0.31^{**}$ |
| CL | 0.04 | 0.15 | -0.12 | 0.25 | -0.31 | 0.09 | **0.20** | 0.27 | 0.12 | $0.66^{**}$ |
| CD | 0.21 | -0.12 | -0.24 | 0.73 | -0.70 | 0.08 | 0.12 | **0.46** | 0.21 | $0.75^{**}$ |
| TSW | 0.40 | -0.55 | -0.25 | 0.23 | -0.21 | 0.02 | 0.06 | 0.24 | **0.41** | $0.36^{**}$ |

*Days to 50% tasseling (DT), days to 50% silking (DS), Anthesis silking interval (ASI), plant height(PH),ear height (EH), days to maturity (DM), cob length (CL), cob diameter (CD), thousand seed weight (TSW) and yld(yield t/ha)*

In Table 4, the genotypic correlation coefficients were divided into direct and indirect effects using a path coefficient analysis.

The PH had the highest positive direct effect (1.34) on yield followed by DS (0.75), CD (0.46) and TSW (0.41), DM (0.21) and CL (0.20) which was corroborated with the findings of Matin et al. [17], Kumar et al. [38] and Pavan et al. [39]. Direct positive effect on yield by PH, CL, CD and 100 seed weight was noticed by Jakhar et al. [40]. Al-Amin et al. [18] identified direct positive effect on yield/plant by CD and thousand kernel weight (TKW). Munawar et al. [24] cited that CL and CD showed positive effect on yield. Direct positive effect on yield by PH also cited in the investigation of Barosa et al. (2019) and Adesoji et al. [41].

Direct negative effect on yield was shown by EH (-1.03), DT (-0.52) and ASI (-0.50) which were in agreement with Begum et al. [20] and Jakhar et al. [40]. Among them EH ($0.66^{**}$) and ASI ($0.09^{NS}$) showed positive correlation with yield while DT ($-0.21^{NS}$) exhibited negative correlation.

The residual effect was 0.241, indicating that although not tested, additional features may have had an impact on seed output.

## 4. CONCLUSION

High genotypic coefficient of variation (GCV) was obtained from anthesis silking interval, yield, ear height and thousand seed weight. The highest phenotypic coefficient of variation (PCV) was observed in anthesis silking interval followed by yield, ear height and the lowest in days to maturity. The higher heritability was observed for plant height followed by ear height, thousand seed weight and days to maturity but the lowest heritability identified for days to silking. The characters with higher values of GCV and heritability of aforementioned traits were could be considered for selection. Positive and significant genotypic, phenotypic correlation coefficient was recorded for yield with cob diameter, cob length, plant height, ear height and thousand seed weight. The plant height had the highest positive direct effect on yield followed by days to silking, cob diameter and thousand seed weight, days to maturity and cob length indicating the effectiveness of direct selection [42]. Direct negative effect on yield was shown by ear height, days to tasseling and anthesis silking interval that indicated the effectiveness of indirect selection.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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