

Original Research Article

Genetic variability, correlation and path coefficient analysis in Hybrid Maize (*Zea mays* L.)

Abstract

The present study was carried out to investigate the correlation coefficient, path analysis and genetic variability among twenty four maize hybrids for ten characters in a Randomize 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 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) were 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 high of GCV and higher of 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.

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Comment [a2]: Mention the final concluding line of your study

Key words: Genetic variability, correlation, path co-efficient, maize

Introduction

Maize (*Zea mays* L.) is a C₄ plant having higher yield potential comparing ~~withed to the~~ rice and wheat (Gong *et. al.*, 2015). It is the second most abundant crop in the world (Ort and Long, 2014). 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. ~~Demand for maize, for both human and animal consumption, is expected to increase. However M~~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. (You *et. al.*, 2012). 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 (Alves and Filho, 2017). It is also the cereal that is most produced in the world, due to its wide scope and utilization in human and animal diet. (Barbosa *et. al.*, 2019).

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. (Yadav *et. al.*, 2014). In Bangladesh its area and production ~~are~~ increasing rapidly due to wide adaptability and versatile uses. According to DAE (2019) 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.

Comment [a3]: Try to explain in a graphical way and mention only current year statistics in the text

Maize is one of the most important food grains in the world as well as in developing countries like Bangladesh. The food produced in Bangladesh is not adequate to meet domestic requirements. Cropping intensity is already more than 155%, and approaching 200% wherever intensification is possible. Maize could be good source of nutrition for under nourished and malnourished population in Bangladesh. It is now widely used in the poultry farms, fisheries and animal feeding, as well as the people consume roasted and fried maize in Bangladesh.

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Knowledge of the linear association between agronomic and nutritional maize traits could lead to significant advances in ~~genetic~~ breeding programs, especially when defining crossings, with the aim of

targeting animal feed to increase efficiency and cut production costs. 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 (Cruz *et al.*, 2012).

Comment [a5]: One side you are mentioning malnourished people nutrition. On the other side you are saying animal feed efficiency...justify

Comment [a6]: Reference?

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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 (Board *et al.*, 1997; Finne *et al.*, 2000; Gravois and McNew, 1993; Samonte *et al.*, 1998; Sinebo, 2002).

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

- i) ~~to~~To identify ~~the relationship~~the relationship between grain yield and other morphological traits and
- ii) ~~to~~To estimate the direct and indirect ~~effects~~—~~oneffects of other agronomic traits on~~ yield

Materials and Methods

Comment [a8]: How did you estimate genetic parameters viz., pcv, gcv and their classification..references etc.

The experiment 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 selected based on their combining ability performance such as general combining ability (GCA) and specific combining ability (SCA). The hybrids developed through diallel mating design were as follows E1×E2, E1×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.

Comment [a9]: Give the parents details and source in a table...

Seeds of each entry were sown in two rows of four meters long plots with 60×20 cm spacing between rows and hills, respectively. Seeds were sown on 20 November, 2014. One healthy seedling per hill was kept after thinning. Fertilizers were applied at the rate of 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P₂O₅, K₂O, S, Zn and B respectively. Standard agronomic practices were followed (Quayyum, 1993) and plant protection measures were taken as required. Two border rows at both end of each replication were used for minimize the border effect. 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

Comment [a10]: Not required

(CL), cob diameter (CD), thousand seed weight (TSW) and yield (t/ha) were measured. All the plants in two rows were considered for plot yield and finally converted to t/ha.

Path co-efficient analysis estimated by Dewey and Lu (1959). All the data were processed and analyzed according to Sheoran *et. al.* (1998).

Comment [a11]: Any software used? If so mention the reference of it.

Results and Discussion

Mean sum of squares from pooled analysis recorded significant effects for yield. All the characters identified showed significant treatment effects indicating sufficient variability among them (Table 1).

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**	6.429 _{ns}	1.418**	947.609**	771.800**
Error	46	3.623	3.775	0.441	100.377	85.992

Comment [a12]: Mention as a single table..landscape alignment..

* 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 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)

The highest σ^2_g (1392.72) and σ^2_p (2339.88) variance were found for TSW (Table 2) which was in agreement with Matin *et. al.* (2017). The lowest magnitude of σ^2_g (0.06), σ^2_p (0.12) variance were observed in CD. High genotypic coefficient of variation (GCV) were obtained from for ASI (17.26), Yld (15.17), EH(13.80) and TSW (9.43). Al-Amin *et. al.*(2019) observed high GCV in PH, CD and Yld/plant. The characters with high GCV indicated high potential for selection. Alam *et. al.* (1988) 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.* (2016). The highest H_b was observed

Comment [a13]: Write complete observation..for all traits. You can use abbreviated forms in tables.

Comment [a14]: Classification? I think these values are not high. They are low to moderate..

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Comment [a17]: Heritability (broad sense) Did you mention anywhere that H_b means heritability

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.* (2017), Ali *et. al.* (2012) and Moulin *et. al.* (2009). Hb was recorded higher in EH and Yld in the study of Al-Amin *et. al.* (2019). 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.* (2019) observed higher GAPM in CD & PH. According to Panse (1957) 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.* (2017) 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.* (2013) in PH, EH, CL, CD and grain weight. Begum *et. al.* (2016) also showed that high heritability accompanied with low genetic advance revealed non-additive gene action that was identified in CD, Yld, DM, CL, respectively.

Comment [a18]: Did you mention this in material and methods? What is the classification? What is GAPM?

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

Characters	σ^2_g	σ^2_p	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

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σ^2_g , σ^2_p -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

Genotypic and phenotypic correlation coefficients with yield

The genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients were presented in Table 3. 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.* (2017), *Nataraj et al.* (2014), *Ojo et al.*, (2006) and *Batool et al.* (2012). Positive correlation with yield also estimated in the studies of *Al-Amin et al.* (2019), *Bello et al.* (2010) and *Sadek et al.* (2006). PH and EH had positive correlation with yield in the study of *Bankole et al.* (2019). *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) (Sharma,1988). 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. Similar findings were also recorded in the observation of *Sadek et al.* (2006).

Comment [a21]: You need not mention all traits association.. just one or few important associations need to be mentioned.

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

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	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)

Residual effect (R²) = 0.241

Path coefficient analysis

Correlation coefficient analyses are useful tools for selecting the traits that influence grain yield ~~simultaneously~~ (Menkir, 2008). Normally it exploits the degree of association among continuous traits (Malik *et al.*, 2005). 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 (Baretta *et al.*, 2016). In this regard, Wright (1921) 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 (Dewey and Lu, 1959).

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 (Uddin *et al.*, 2015).

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~~ 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~~ relative importance of each ~~components~~ component. Yield being considered as a resultant variable other characters estimated as causal or independent variable (Shahidul *et. al.*, 2015).

Here, the genotypic correlation coefficients were partitioned into direct and indirect effects through path coefficient analysis in Table 4.

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.*, (2017), Kumar *et al.*, (2015) and Pavan *et.al.* (2011). Direct positive effect on yield by PH, CL, CD and 100 seed weight was noticed by Jakhar *et. al.* (2017). Al-Amin *et. al.* (2019) identified direct positive effect on yield/plant by CD and thousand kernel weight (TKW). Munawar *et.al.* (2013) 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.* (2015).

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.* (2016). ~~EH showed negative direct effect on yield mentioned by and~~ Jakhar *et. al.* (2017). ~~Direct negative effect indicating the effectiveness of indirect selection.~~ 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 there were also some other characters which although not studied but might have influenced the seed yield.

Conclusion

High genotypic coefficient of variation (GCV) ~~were was~~ obtained from anthesis silking interval, yield, ear height and thousand seed weight. The highest phenotypic coefficient of variation (PCV) ~~were was~~ observed in anthesis silking interval followed by yield, ear height and the lowest in days to maturity. The ~~highest 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 ~~high of~~ GCV and ~~higher of~~ heritability of aforementioned traits were could be considered for selection. Positive and significant genotypic, phenotypic correlation coefficient ~~were 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 ~~silkings~~ silking, cob diameter and

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thousand seed weight, days to maturity and cob length indicating the effectiveness of direct selection. Direct negative effect on yield was shown by ear height, days to tasseling and anthesis silking interval that indicated the effectiveness of indirect selection.

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Comment [a25]: What is this star?

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