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Correlation and Path Coefficient Analysis of Grain Yield and Yield Related Traits in Maize (*Zea mays* L.) Hybrids, at Bako, Ethiopia.

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Abstract:
Maize is one of the most important grown plants in the world. Superior position of maize is due to his very wide and variety utilisation and because of that, the main goal of all maize breeding programs is to obtain new inbred lines and hybrids that will outperform the existing hybrids with respect to a number of traits. For efficient selection of grain yield, like the most important economic trait, in regard to its on the great influence the environmental factors, has complex mode of inheritance and low heritability, is necessary to know relation between grain yield and morphological traits which are influencing on the grain yield. One of the objectives of this paper was to determine relationship between grain yield and morphological traits. A total of forty eight maize hybrids produced through a factorial Design II mating design and two standard checks were evaluated at Bako Western Ethiopia to determine the genetic parameters governing the inheritance of grain yield and related agronomical traits. The analysis of variance revealed that mean squares due to entries and crosses were highly significant ($p<0.01$) or significant ($p<0.05$) for most traits studied, indicating the existence of variability among the materials evaluated, which could be exploited for the improvement of respective traits. Grain yield showed positive and highly significant correlations with most traits except anthesis date at phenotypic and genotypic levels. Ear diameter, length and weight, anthesis date, plant and ear height exerted positive and highly significant effect with grain yield. Direct effect and association with grain yield were positive at phenotypic and genotypic levels. Traits having strong relationship with grain yield can be used for indirect selection to improve grain yield because grain yield can be simultaneously improved along with the traits for which it showed strong relationship and also imply that the desirable traits in these hybrids could be exploited in further breeding activities for the development of composites and synthetics for the resource constrained maize farmers who can not access hybrid seeds every year.
Keywords: phenotypic and Genotypic Correlation coefficients, Path coefficients, Grain Yield, Maize

INTRODUCTION

Maize is one of the most important grown plants in the world. Superior position of maize is due to his very wide and variety utilisation and because of that, the main goal of all maize breeding programs is to obtain new inbred lines and hybrids that will outperform the existing hybrids with respect to a number of traits. For planning yield improvement program, the knowledge of relationship between yield and yield contributing characters are important. Information on correlation coefficients between yield and yield contributing characters has always been helpful as a basis for selection for yield in a breeding program. Therefore, correlations between yield and different yield contributing characters are an aspect, which should be kept in mind for planning yield improvement program. Path coefficient which is a standardized partial regression coefficient (Wright, 1921) specifies the causes and effects and measures the relative importance of each variable. So, correlations in combination with path coefficient analysis are an important tool to find out the association and quantify the direct and indirect influences of yield contributing characters on grain yield. For such reasons relation between yield and yield contributing characters have been studied through genotypic and phenotypic correlations and the path coefficient analysis by many authors in spring wheat (Das and Mondal, 1984).

Correlation is the degree to which two or more variables are related and change together (Gomez and Gomez, 1984). According to Hallauer and Miranda report (1988) correlation measures the degree of association between two or more characters and is measured by a correlation coefficient. This could be genetic or environmental (non-genetic) in nature. Genetic correlation is associated with the breeding values of two characters (Falconer, 1989) and their measurements can be identified directly in a number of individuals in a population. For instance if two variables, X and Y are said to be correlated, then values of Y are associated with increase or decrease in values of X. In this sense, association of these two variables can either be positive or negative. When values of X causes an increase or are associated with high values of Y, a positive correlation exists. When high values of X are associated with low values of Y, a negative correlation exists. Usually more than one trait is measured on progenies evaluated either for a specific trait in cyclical selection programs or in applied breeding programs that require a combination of traits to satisfy growers. Correlation is simply a measurement of mutual association without regards to causation, whereas path coefficient analysis indicates the causes and measures their importance. Two characters may show correlation just because they are correlated with a common third one.

Elias (1992) suggested understanding the interrelationship among various characters is essential in formulating selection criteria. Yield is a complex trait and is dependent on a number of related characters. Therefore, yield in crop plants is usually dependent upon the action and interaction of a number of important characters. Thus it is essential to examine various components and give more attention to those having the greatest influence on yield. The relationship between yield and its components have been studied in maize through correlation analysis (Jayakumar *et al*., 2007). As Berhanu (2009) indicated ear diameter was positively correlated with grain yield. Similar observations were made for kernel rows, grains per row, grain weight, ear length and shelling percentage.

As study of Vijayabharathi *et al.*(2009) implied knowledge of the direct and indirect effects of different components on dependent traits such as yield and yield related traits, and the interrelationship among different components is essential during the selection process in a breeding program. Path coefficient analysis gives information about the direct and indirect effects of different traits on a complex trait. Path coefficient analysis also suggests the selection criterion, and reduces the time taken by a breeder during the selection process (Qaizar *et al.*, 1991; Vijayabharathi *et al.*, 2009). For example, the breeder focuses only on the traits with a large direct effect on a dependent traits such as maturity and yield, thus selection is only restricted to a few essential traits (Vijayabharathi *et al.*, 2009). In addition, Darvishzadeh *et al.* (2011), Machikowa and Saetang (2008) and Makanda *et al.* (2009) added separating correlation coefficients into direct and indirect effects using path coefficient analysis facilitates the breeding process. The relationship between secondary traits and their direct and indirect effects on seed yield and yield related traits will be beneficial in the improvement of seed yield. Understanding direct and indirect effects of agronomic traits on a complex trait can be attained if correlations among secondary traits are determined (Manggoel *et al.*, 2012). KASHIANI *et al.* (2010) found from path analysis, highest direct effect on grain yield was exhibited by 100-grain weight followed by grains per row, kernel rows per ear, ear length and ear diameter in maize yield and yield related. With this he also indicated direct and indirect effects on yield components associated with the heritability and can significantly improve the efficiency of breeding programs through the selection indices.

Knowledge of interaction among the characters is very essential in plant breeding to determine the extent and nature of relationship between yield, yield components and physiological characters. Path Coefficient analysis enables a plant breeder to separate direct and the in indirect effects through attributes by partitioning the correlations. Thus Correlation and Path coefficient analysis form a basis for selection and helps in understanding yield contributing characters affecting yield in maize.

Path coefficient analysis for seed yield showed that traits like anthesis silking interval, days to anthesis, ear length and ear diameter showed highest positive direct effect towards seed yield (Table 2). This means that a slight increase in one of the above traits may directly contribute to seed yield.

In the breeding programs, understanding of the mode of inheritance of the yield components, the correlations among them and the association between each component and yield is necessary for an intelligent choice of breeding procedures for evolving high-yielding varieties (Khodambashi *et al*., 2012). The choice of an efficient breeding procedure depends to a large extent on knowledge of the genetic system controlling the character to be selected (Bitaraf *et al*.,2010).

Path coefficient analysis was used to measure the direct and indirect influence of plant weight components on the estimation of plant weight by partitioning phenotypic and genotypic correlation coefficients into components of direct and indirect effects. Phenotypic and genotypic direct effects were all positive, indicating that selection for any of the plant weight components should translate into an increase in plant weight. The study was aimed to: To determine the association between yield and yield related characters and to setting selection criteria for the desired characters in breeding program based on the relation ship. As well as, one of the goals of this study was founding the direct and indirect effects of morphological traits on grain yield.

MATERIALS AND METHODS

Description of Experimental Site and Experimental Materials

The experiment was carried out in 2014 main cropping season at Bako National Maize Research Center (BNMRC). Bako is one of the major maize producing areas in the country, representing the mid-altitude sub humid agro-ecological zone. The site lies at 9^{0}06'N latitude and 37^{0}09'E longitude, 255 km west of Addis Ababa at an altitude of 1650 meter above sea level (masl).

Mean annual maximum temperature is 31 0^{C} and the minimum being 11.2 0^{C}. The mean soil temperature at the depth of 50 cm is 23.3 0C with mean annual rain fall of 1300mm. The soil type is characterized by reddish brown clay loam (Nitosol) with pH of 6.0. The area is known for cultivation of a

number of major annual crops including maize (Zea *mays*), *teff* (Eragrostis *tef*), sorghum (Sorghum *bicolour*), hot pepper (Capsicum *frutescence*) and haricot bean (Phaseolus *vulgaris*) (Asfaw *et al*., 1997).
The experimental materials used for the current experiment consisted of a total of 50 entries (Table 1) which comprised of 48 F1 crosses obtained from 8 × 6 line by tester, and two standard checks; namely, BH-546 and BH-547.

Table 2. List of the Single cross Hybrids Generated using line by Tester Mating Design at Bako, 2014.

Rep	Bloc	Plot	Entry	Pedigree	cont'd	Rep	Bloc	Plot	Entry	Pedigree
1	7	32	1	KULENI 320-2-3-1-1-2-1-1/30H83-5-1-1-1-1-1		1	3	15	26	POOL 9A-128-5-1-1-1-1/30H83-5-1-2-1-1-1-1
1	4	16	2	KULENI 320-2-3-1-1-2-1-1/30H83-5-1-2-1-1-1-1		1	6	29	27	POOL 9A-128-5-1-1-1-1/DE-78-Z-126-3-2-2-1-1-1(g)
1	9	41	3	KULENI 320-2-3-1-1-2-1-1/DE-78-Z-126-3-2-2-1-1-1(g)		1	8	40	28	POOL 9A-128-5-1-1-1-1/DE78-Z-126-3-2-2-1-1-1(P)
1	6	26	4	KULENI 320-2-3-1-1-2-1-1/DE78-Z-126-3-2-2-1-1-1(P)		1	3	14	29	POOL 9A-128-5-1-1-1-1/GIBE-1-178-2-1-2-1
1	7	33	5	KULENI 320-2-3-1-1-2-1-1/GIBE-1-178-2-1-2-1		1	2	7	30	POOL 9A-128-5-1-1-1-1-#/ILO'00E-1-9-1-1-1-1-1
1	4	18	6	KULENI 320-2-3-1-1-2-1-1/ILO'00E-1-9-1-1-1-1-1		1	2	10	31	Gibe-1-91-1-1-1-1/30H83-5-1-1-1-1-1
1	6	28	7	IL0'OOE-47-2-3-1-1/30H83-5-1-1-1-1-1		1	10	48	32	Gibe-1-91-1-1-1-1/30H83-5-1-2-1-1-1-
1	1	2	8	IL0'OOE-47-2-3-1-1/30H83-5-1-2-1-1-1-1		1	2	9	33	Gibe-1-91-1-1-1-1/DE-78-Z-126-3-2-2-1-1-1(g)
1	9	43	9	IL0'OOE-47-2-3-1-1/DE-78-Z-126-3-2-2-1-1-1(g)		1	4	20	34	Gibe-1-91-1-1-1-1/DE78-Z-126-3-2-2-1-1-1(P)
1	9	45	10	IL0'OOE-47-2-3-1-1/DE78-Z-126-3-2-2-1-1-1(P)		1	5	22	35	Gibe-1-91-1-1-1-1/GIBE-1-178-2-1-2-1
1	10	47	11	IL0'OOE-47-2-3-1-1/GIBE-1-178-2-1-2-1		1	4	17	36	Gibe-1-91-1-1-1-1/ILO'00E-1-9-1-1-1-1-1
1	9	42	12	IL0'OOE-47-2-3-1-1/ILO'00E-1-9-1-1-1-1-1		1	8	38	37	Gibe-1-20-2-2-1-1-1/30H83-5-1-1-1-1-1
1	7	35	13	POOL 9A-4-4-1-1-1/30H83-5-1-1-1-1-1		1	10	46	38	Gibe-1-20-2-2-1-1-1/30H83-5-1-2-1-1-1-1
1	3	12	14	POOL 9A-4-4-1-1-1/30H83-5-1-2-1-1-1-1		1	3	11	39	Gibe-1-20-2-2-1-1-1/DE-78-Z-126-3-2-2-1-1-1(g)
1	5	21	15	POOL 9A-4-4-1-1-1/DE-78-Z-126-3-2-2-1-1-1(g)		1	2	8	40	Gibe-1-20-2-2-1-1-1/DE78-Z-126-3-2-2-1-1-1(P)
1	8	39	16	POOL 9A-4-4-1-1-1/DE78-Z-126-3-2-2-1-1-1(P)		1	10	49	41	Gibe-1-20-2-2-1-1-1/GIBE-1-178-2-1-2-1
1	5	24	17	POOL 9A-4-4-1-1-1/GIBE-1-178-2-1-2-1		1	1	5	42	Gibe-1-20-2-2-1-1-1/ILO'00E-1-9-1-1-1-1-1
1	6	27	18	POOL 9A-4-4-1-1-1/ILO'00E-1-9-1-1-1-1-1		1	8	37	43	30H83-7-1-3-1-1-1-1/30H83-5-1-1-1-1-1
1	3	13	19	SZSYNA 99F2-7-2-1-1/30H83-5-1-1-1-1-1		1	8	36	44	30H83-7-1-3-1-1-1-1/30H83-5-1-2-1-1-1-1
1	1	1	20	SZSYNA 99F2-7-2-1-1/30H83-5-1-2-1-1-1-1		1	2	6	45	30H83-7-1-3-1-1-1-1/DE-78-Z-126-3-2-2-1-1-1(g)
1	1	4	21	SZSYNA 99F2-7-2-1-1/DE-78-Z-126-3-2-2-1-1-1(g)		1	7	31	46	30H83-7-1-3-1-1-1-1/DE78-Z-126-3-2-2-1-1-1(P)
1	10	50	22	SZSYNA 99F2-7-2-1-1/DE78-Z-126-3-2-2-1-1-1(P)		1	9	44	47	30H83-7-1-3-1-1-1-1/GIBE-1-178-2-1-2-1
1	5	25	23	SZSYNA 99F2-7-2-1-1/GIBE-1-178-2-1-2-1		1	1	3	48	30H83-7-1-3-1-1-1-1/ILO'00E-1-9-1-1-1-1-1
1	7	34	24	SZSYNA 99F2-7-2-1-1/ILO'00E-1-9-1-1-1-1-1		1	6	30	49	CML395LCML202//BKL001-BH-546 (standard check)
1	5	23	25	POOL 9A-128-5-1-1-1-1/30H83-5-1-1-1-1-1		1	4	19	50	BKL002/CML312/BKL003 - BH-547(standard check)

Experimental Design
The 48 F^1 single maize crosses along with two standard hybrid checks (BH-546 and BH-547) were planted at Bako using the experimental design of alpha lattice of 5 x 10 genotype arrangement (0, 1) (Patterson and Willianms, 1976) with two replications. The genotypes were assigned at random to experimental unit in each block. Each replicate consisted of 10 incomplete blocks and 5 plots in each block. Each replication consisted of one-row plots, with the assumption that inter-genotypic competition from single-row plots is unlikely to substantially affecting the results (Bänziger *et al*., 1995). Each entry was placed in a one-row plot of 5.1 m long at 75 cm and 30cm inter and intra-row spacing, respectively. Experimental plots with in replications were

separated each other by 75cm, while the replications were separated by 1m apart.

Trial Management

Planting was done manually by placing two seeds per hill, which were later thinned to one plant per hill. At the onset of the main rainfall following reliable precipitation, seeds of the experimental materials were sown on May 26, 2014 on the prepared plots as per the design. Two seeds per hill were sown at prescribed inter and intra-row spacing. Thinning was done after germination to a single healthy seedling to attain a final plant density of 44,444 plants ha^{-1}. Non-experimental lines were planted to minimize the edge border effects. For the plant basis yield related traits data, five competitive plants from the middle of each row was sampled and the yield and yield related traits were recorded for each entry. All the recommended agronomic practices like hoeing, weeding, and fertilizers applications for maize specified for the site particularly. Urea and Dap fertilizers were applied at the rate of 100 kg/ha each. The whole required amount of DAP was applied at planting, while Urea was applied in split in such a way that half at planting and the other half at knee height and flowering.

Data Collection

Yield and yield related traits were recorded following the standard procedures used for maize. Some of these parameters were recorded on plot basis, while some others were recorded on plant basis by taking the average value of five representative plants per plot.

Traits measured on plot basis

The following parameters were recorded on plot basis:

Days to 50% Anthesis (AD): number of days from planting to the time when 50% of the tassels of plants shedding pollen.

Days to 50% silking (DS): number of days from planting to the time when 50% of plants have emerged silks with 3-4 cm long.

The anthesis-silking interval (ASI): was calculated as the difference between days to 50% silking and 50% anthesis.

Days to 95% Physiological maturity (DM): number of days from planting to when 90% of the plants in a plot reached physiological maturity *i.e.* when the kernels form black layers on tip.

Ears per plant (EPP): was obtained by dividing the total number of ears per plot by the number of plants harvested.

Stand count at harvest (SCH): total number of plants harvested per plot.

100 seed weight (HKWt) - After shelling, sample of kernels from the bulk of shelled grain in each experimental plot was taken randomly and hundred kernels were counted using a manually and weighed with sensitive electrical balance and then adjusted to 12.5% grain moisture.

Moisture content at harvest (MC %): grain moisture measured with moisture tester at harvest and expressed in percentage.

Field Weight (FWt): total field weight of all harvested ears of each experimental plot was recorded in kilograms. This was then adjusted to 12.5% moisture level and 80% shelling percentage to estimate grain yield in tons per hectare.

Grain yield (GY t ha^{-1})- total grain yield can be obtained from all harvested plants in the middle part of the rows of each plot and converted in to hectare basis. But in this study, grain yield was computed from field weight (kg/m^2), adjusted to 15% moisture content and 80% shelling percentage (Salami *et al.*, 2003)

Grain yield (kg ha^{-1}) (at 15% moisture) = Fresh ear weight (kg plot-1) × (100-MC) ×0.8 ×10,000(m^2)/(100-15) ×area harvested or net plot size

Where: MC = moisture content in grains at harvest (%), 0.8 = Shelling co-efficient, Area harvested $plot^{-1}$ (0.75 x 5.1)(m^2), 1 hectare = 10,000 $m^{2,}$ 85= Grain moisture standard value at 15% MC, 15 % = moisture content required for maize grain at storage

Traits measured on representative individual plant basis

The following parameters on the other hand were measured on representative individual plant basis:

Plant height (PH): Average height of randomly selected five plants in centimeters from the ground level to the node bearing of the flag leaf using graduated measuring stick.

Ear height (EH): average height of the upper most ears of the same plants used for plant height measurement from ground level to the node bearing in cm using graduated measuring stick.

Ear length (EL): average cob length of the upper most ears of sampled plants in cm after dehusking.

Ear diameter (ED): average diameter of the upper most peeled ears of the middle part of the sampled plants at their middle part in cm.

Number of kernel rows per ear (NRE): average number of kernel rows in the central part of the uppermost ears of the sampled plants in the middle row.

Number of kernels per row (NKR): average number of kernels per row of the upper most ears of the sampled plants.

Ear weight (EWt): average fresh weight of the upper most peeled ears of the 5 randomly selected plants to the nearest kilo gram.

Data analysis

Analysis of Variance (ANOVA)

The data of different yield and yield related traits collected from field measurement were organized and analyzed using SAS statistical package (SAS, 2002). Apart from SAS, the data were also subjected to additional soft ware analysis like, Gene Stat for path coefficient analysis.

Correlation coefficient

Estimates of correlation coefficients were determined to show the degree of association between yield and its components, and among yield components. The genetic (rG) and phenotypic correlations (rP) between two characters, X and Y, were estimated according to Akhtar *et al*. (2011). In selection programmes, grain yield and some yield components (such as number of rows per cob, cob length and diameter) are among the most economic traits usually targeted by plant breeders. Therefore, special preferences should be given to these parameters when formulating indirect selection indices for grain yield improvement in maize.

$$r_G = \frac{COV_{G(XY)}}{\sqrt{V_{G(X)} . V_{G(Y)}}}$$

Where, COVG (XY) = Genetic covariance among trait X and Y.
VG(X) and VG(Y) = Genetic variance for trait X and Y, respectively.

$$r_P = \frac{COV_{P(XY)}}{\sqrt{V_{P(X)} . V_{P(Y)}}}$$

Where,
COVP (XY) = Phenotypic covariance among traits X and Y
VP(X) and VP(Y) = Phenotypic variance for traits X and Y, respectively.

Path Coefficient Analysis

Based on genotypic correlation, path coefficient which refers to the direct and indirect effects of the yield attributing traits (independent character) on grain yield (dependent character) was calculated following the method used by Dewey and Lu (1959) as follows:
rij = Pij + Σrik pkj where,
r*ij* = mutual association between the independent character(i) and the dependent character (j) as measured by the genotypic correlation coefficient, p*ij* =components of direct effect of the independent character (i) on the dependent character(j) as measured by the genotypic path coefficient. Σr*ik* p*kj* = Summation of components of indirect effects of a given independent traits (i) on the given dependent character (j) via all other independent traits (k). To determine p*ij* values, square matrix of the correlation coefficients between the independent traits in all possible pairs inverted and then multiplied by the correlation coefficients between the independent and dependent traits using Statistical Package for Agricultural Research (SPAR 11) (Microsoft, 1995) software. The residual effects will be estimated using the formula

$$\sqrt{1 - R_2}$$

Where R^2 Σp*ij* r*ij*

RESULTS AND DISCUSSION

Forty eight hybrids and two standard checks were evaluated for their yield and yield related traits and their results are presented and discussed here blow under Table 2.

Correlation and Path Coefficient analysis between Grain Yield and Yield Related Traits

Association between Grain Yield and Yield Related Traits

To determine the relationship between grain yield and secondary traits, phenotypic and genotypic correlation coefficient were calculated and resulted mixed both positive and negative. The study recorded significant positive phenotypic correlation between grain yield and anthesis date, plant height, ear height, ear length, number of ears per plant, ear length and ear weight. A day to maturity was associated positively and significantly with anthesis date, silking date, and anthesis silking interval. The association between anthesis date and silking date was the strongest (*r=0.88**, p<0.01*) of any two traits observed in this study followed by days to plant height and ear height (*r=0.72**, p<0.01*). Similarly, Stojsin and Kannenberg (1994) while studying five maize populations, found the highest correlation coefficients (*r=0.95*) between silking date and anthesis date and fairly in agreement with this study result. In line with the current study, Kebede (1989) found positive and significant correlations of grain yield with number of kernels per row, ear length and thousand kernel weights. In addition, strongest genotypic association also existed (*r=0.91**, p<0.01) between* anthesis and silking date. Plant and ear height, ear length, ear diameter and ears per plant were associated positively and significantly with grain yield (Table 2).

Ear diameter also significantly and positively with ear height, ear weight, number of kernel rows per ear and grain yield while negatively correlated with anthesis silking interval. Similarly, Dagne (2008) also found positive and highly significant phenotypic and genotypic correlations between grain yield and plant height, ear height, ear diameter, ear length, number of kernels per row and thousand kernel weight. Hence, the positive associations of the above mentioned traits with grain yield indicated that these traits are the most important ones to be considered for indirect selection to improve grain yield, because grain yield can be simultaneously improved with a trait for which it showed strong relationship.

Table 2**.** Estimates of correlation coefficients at phenotypic (above diagonal) and genotypic (below diagonal) levels among 14 traits in Line by Tester crosses of inbred lines at Bako, 2014

Variable	AD	SD	ASI	MD	PH	EH	EL	EP	ED	Ewt	NRE	NKR	HKW	GY_t ha
AD	**1**	0.88**	-0.14	0.41**	0.43**	0.31**	0.011	0.23	0.12	-0.06	0.27**	-0.03	-0.04	0.25*
SD	0.91**	**1**	0.35	0.5**	0.38**	0.21*	-0.03	0.17	-0.07	-0.12	0.19	-0.10	-0.06	0.13
ASI	-0.04	0.38**	**1**	0.22*	-0.07	-0.18	-0.08	-0.11	-0.37*	-0.12	-0.13	-0.14	-0.05	-0.212*
MD	0.4**	0.51**	0.32	**1**	0.06	-0.12	0.06	0.06	-0.10	-0.05	-0.19	0.11	-0.01	0.01
PH	0.49**	0.42**	-0.08	-0.01	**1**	0.72*	0.16	0.22*	0.09	0.16	0.29*	0.05	0.27*	0.44*
EH	0.37**	0.26	-0.20	-0.15	0.73**	**1**	0.16	0.17	0.38**	0.20*	0.27*	-0.03	0.20*	0.51**
EL	0.01	-0.03	-0.09	-0.01	0.23	0.25	**1**	0.14	0.07	0.46**	*0.25	0.55**	0.20*	0.38**
EP	0.31*	0.25	-0.09	0.02	0.35*	0.27	0.12	**1**	-0.06	-0.05	0.17	0.18	-0.15	0.32**
ED	0.09	-0.09	*-0.4	-0.14	0.14	0.46**	-0.02	-0.04	**1**	0.44**	0.36**	0.00	0.17	0.47***
Ewt	-0.05	-0.14	-0.22	-0.10	0.31*	0.32*	0.47**	-0.12	0.44**	**1**	-0.04	0.21	0.56**	0.35**
NRE	0.28	0.20	-0.13	-0.27	0.33*	0.31*	-0.30*	0.18	0.41**	-0.03	**1**	-0.03	-0.26	0.16
NKR	-0.27	0.29*	-0.09	-0.13	-0.08	-0.04	0.54**	0.04	-0.11	0.25	-0.05	**1**	-0.08	0.05
HKW	-0.05	-0.09	-0.10	0.01	0.34*	0.24	0.32*	-0.14	0.20	0.71**	*-0.32	-0.06	**1**	0.19
GY_tha	0.31*	0.17	-0.27	-0.01	0.52**	0.62**	0.44*	0.38**	0.56**	0.43**	0.21	0.04	0.26	**1**

KEY: **=Significant at 0.05 probability level; **=Significantat0.01probabilitylevel; GY=grain yield, EPP= number of ears per plant, AD=days to anthesis, SD=days to silking, ASI=Anthesis –silking interval, MD= days to maturity, PH=plant height, EH=ear height, EL=ear length, ED=ear diameter, EWt= ear weight, NRE=number of kernels row per ear, NKR=number of kernels per row, HKW=hundred kernel weight.*

Path Coefficient Analysis between Grain Yield and Yield Related Traits

Knowledge of interaction among the characters is very essential in plant breeding to determine the extent and nature of relationship between yield, yield related traits and physiological characters. Path Coefficient analysis enables a plant breeder to separate direct and indirect effects attributable by partitioning the correlations. Thus Correlation and Path coefficient analysis form a basis for selection and helps in understanding yield contributing characters affecting yield in maize. Correlation is simply a measurement of mutual association without regards to causation, whereas path coefficient analysis indicates the causes and measures their importance. Because two traits may show correlation just because, they are correlated with a common third one. In such cases, it becomes necessary to use a method which takes into account the causal relationship between the variables, in addition to the degree of such relationship. Path coefficient analysis therefore permits partitioning of the correlation co-efficient in to components of direct and indirect causes of association. The phenotypic direct and indirect effects of yield-related traits on grain yield are presented in Table 3. Path coefficient analysis for grain yield showed that traits like, days to tasseling, anthesis silking interval, ear diameter, ear length, number of ears per plant and plant height showed highest positive direct effect towards seed yield through 0.859, 0.445, 0.628, 0.315, 0.198 and 0.368 (Table 3). This means that a slight increase in one of the above traits may directly contribute to seed yield. These traits are there fore, very important components of grain yield and should be given high weightage in any selection process aimed at improving grain yield in maize. Similar results were reported by Selvaraj and Nagarajan (2011). On the other hand, the maximum negative direct effect was exhibited by days to silking (-0.752), followed number of kernels per row (-0.169) and days to maturity (-0.110). This is in agreement with the report of Amin *et al.* (2013) who noted that plant height and ear length had high positive direct effect on seed yield per plant. But, Mohammadi *et al.* (2003) reported that number of grains per row exerted a maximum direct effect on grain yield. Hence, selection of ear length will be highly effective for improvement of grain yield. Kumar and Kumar (2000) also put emphasis on plant height with greater ear weight, number of seed rows per ear and number of seeds per ear for better grain yield.

The direct and indirect components of maize grain yield are presented in Table 3, Direct contribution of ear length to the grain yield of maize was 0.315, while the highest indirect contribution via anthesis date, plant height, ears per plant, and number of kernel rows per ear were 0.051, 0.062, 0.034 and 0.045 respectively, giving a total contribution of 0.420. Direct contribution of ear diameter to grain yield was 0.628 where as highest indirect contributions via days to anthesis and plant height were 0.071, 0.075 respectively; giving total contribution of 0.548. Plant height was found to have direct positive effect on maize grain yield. Bello *et al.* (2010) and Amin *et al.* (2013) also noted direct positive effect of plant height on maize grain and seed yield per plant respectively. Muhammad *et al.* (2008) also reported that cobs per plot, plant height, cob weight, number of kernels row per ear, days to silking exerted positive direct effect on grain yield.

Generally, a review of the works of other researchers indicates that determining relationships between yield and its components has special importance. Although the results of all experiments were not in agreement with each other, but in the most experiments some yield components such as 100–kernel weight, ear length, kernels per row and kernels row per ear has big importance in determining yield.

Table 3. The Direct (diagonal) and Indirect (out of Diagonal) Contribution of Maize Yield Attributes on Grain Yield of Maize at Bako, 2014

	Effects Through, Residual (R^2) = 0.227													
Traits	AD	SD	ASI	MD	PH	EH	EPP	ED	EL	Ewt	NRE	NKR	HKW	Total Cont.
AD	**0.859**	-0.691	-0.047	-0.050	0.197	-0.014	0.073	0.052	0.019	0.000	-0.050	-0.005	0.002	0.344
SD	0.789	**-0.752**	0.129	-0.064	0.168	-0.010	0.067	-0.047	0.004	-0.001	-0.027	-0.006	0.004	0.255
ASI	-0.091	-0.217	**0.445**	-0.042	-0.068	0.010	-0.011	-0.231	-0.044	-0.001	0.048	-0.002	0.009	-0.197
MD	0.388	-0.440	0.171	**-0.110**	0.064	-0.001	-0.015	-0.078	0.011	0.000	0.041	-0.005	0.002	0.030
PH	0.459	-0.343	-0.082	-0.019	**0.368**	-0.024	0.075	0.128	0.053	0.001	-0.054	-0.001	-0.029	0.532
EH	0.370	-0.224	-0.130	-0.002	0.270	**-0.033**	0.051	0.311	0.044	0.001	-0.057	-0.002	-0.018	0.582
EPP	0.316	-0.256	-0.026	0.009	0.139	-0.008	**0.198**	-0.082	0.054	0.000	-0.028	0.001	0.005	0.322
ED	0.071	0.056	-0.164	0.014	0.075	-0.016	-0.026	**0.628**	-0.002	0.001	-0.075	-0.002	-0.010	0.548
EL	0.051	-0.009	-0.062	-0.004	0.062	-0.005	0.034	-0.005	**0.315**	0.001	0.045	0.018	-0.021	0.420
Ewt	-0.086	0.140	-0.114	0.013	0.133	-0.009	-0.024	0.240	0.129	**0.003**	0.003	0.009	-0.050	0.386
NRE	0.252	-0.122	-0.126	0.027	0.117	-0.011	0.033	0.279	-0.084	0.000	**-0.169**	0.000	0.021	0.218
NKR	-0.145	0.143	-0.038	0.018	-0.015	0.002	0.009	-0.050	0.191	0.001	-0.001	**0.029**	0.004	0.147
HKW	-0.018	0.044	-0.054	0.003	0.146	-0.008	-0.013	0.091	0.093	0.002	0.049	-0.002	**-0.072**	0.259

Key: AD=days to anthesis, SD=days to silking, ASI=Anthesis –silking interval, MD= days to maturity, PH=plant height, EH=ear height, EPP= ears per plant, EL=ear length, ED=ear diameter, EWt= ear weight, FWt= field weight, NRE=number of rows per ear, NKR=number of kernels per row, HKW=hundred kernel weight.

Conclusions

Knowledge of the magnitude and type of association between yield and its components them selves greatly help in evaluating the contribution of different components towards yield. Yield being a polygenic character is highly influenced by the fluctuations in environment. Hence, selection of plants based directly on yield would not be very reliable. So, correlation and Path coefficient information provides realistic basis for allocation of appropriate weightage to various yield components.

Analysis of variance indicated that mean squares due to entries and crosses were significant for most studied traits indicating the existence of high level of variability and the possibility of selection among the hybrids for grain yield and agronomic traits of interest. Mean squares due to hybrids were significant for all traits except for anthesis silking interval, number of ears per plant, and number of kernels per row of the ear. Highly significant difference was recorded for checks versus hybrids for all characters except for number of ears per plant and number of kernels per row of the ear, indicating the presence of directional dominance resulting in heterosis and indicating the existence of variations between the mean performances of crosses and checks.

Grain yield showed positive and significant phenotypic and genotypic associations with most traits studied. Traits having strong relationship with grain yield can be used for indirect selection to improve grain yield because grain yield can be simultaneously improved along with the traits for which it showed strong relationship. High amount of differences were observed among hybrids for most traits which indicate the possibility of selection for improvement of yield and yield related traits.

The significant positive correlations between grain yield and other various yield-related traits indicate that improvement of these traits can contribute positively towards improved grain yield; and hence, can be considered when indirectly selecting for high grain yield in the process of breeding maize. Whenever a character had positive association and high positive indirect effects but negative direct effects, emphasis should be given to the indirect effects and thus, indirect causal factors are to be considered simultaneously for selection. The present study revealed that, direct selection for anthesis date, anthesis silking interval, ear diameter, ear length and ears per plant might be rewarding for the improvement of yield using the present elite inbreds and their F^1 hybrids.

Finally Selection based on days anthesis, plant height, ear length, ear diameter, ears per plant can be effective. Since this exploration is a one year and one location trial, it is suggested to evaluate in multilocation trial on large scale basis before their commercial cultivation of identified promising hybrids for grain yield and their stability over locations and seasons and then used for future breeding work.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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