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Correlation and Path Coefficient Analysis for Grain Yield and Yield Related Trait of Maize (*Zea mays* L.) Inbreed Lines

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Abstract

In an attempt to study the association of different yield and yield contributing traits are required to know their direct and indirect effects on grain yield. Therefore, the study emphasized to assess the extent of association between traits among themselves and yield to conduct effective selection for grain yield in breeding process. Thirty maize hybrids were planted using Alpha-Lattice Design with three replications during 2018 main cropping season at Haramaya University Research Farm (Raare). The result revealed significant differences between the test entries were observed for all the yield and yield contributing traits. Grain yield had significant positive correlations with above ground biomass, number of ear per plant and thousand kernel weight at genotypic and phenotypic levels. However, days to 50% tasseling and days to 50% silking exhibit negative correlation with grain yield. On the other hand plant height exhibited significant positive correlations with ear height, days to maturity, ear length, ear diameter, number of kernel per row and number of kernel row per ear at phenotypic and genotypic level. There were also significant positive correlations of number of kernel per row with plant height, ear height and number of days to maturity; and number of kernel row per ear with ear length and ear diameter at phenotypic and genotypic level. The path analysis revealed that 1000-kernel weight, number of kernel rows per ear, above ground biomass, and ear length had positive direct effect on grain yield at genotypic and phenotypic level. Therefore, the information generated from this study could be useful for researchers who intend to develop high yielding maize varieties and desirable to recommend the selection criteria for further improvement in maize yield.

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Keywords

Association, correlation coefficient, grain yield, maize, path analysis.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops, which is cultivated throughout the world for the purpose of food grain, feed, forage and raw materials for industrial uses. Maize is highly cross pollinated and widely adapted species, which belongs to the tribe Maydeae of the grass family*Poacea*. Global food security is being haunted by the rapidly enlarged population and drastic climate changes. Therefore, to meet the growing demand, particular attention is paid to improve yield of maize through breeding. Maize is strategic crops to enhance food security in developing country, which is gaining popularity among farmers mainly due to its high yield, genetic diversity, more economic return and versatile uses.

In Ethiopia, maize is one of the most important cereal crops grown in different agro ecology [1]. According to CSA [2]report Ethiopia by 2017/2018 main cropping season out of the total grain crop area, 80.71% was under cereals of which maize share as large area as 16.79%, after tef (23.85%). Regarding total annual production, cereals contributed 87.48% in which maize ranked first 27.43% followed by teff and sorghum [2]. Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain [3]. The national average maize yield in Ethiopia is still as low as 3.9 t/ha compared to world average maize yield (5.65 metric ton per hectare) which implies the importance of increasing maize productivity as high national priority issue. The reason behind these wide gaps in the yield is attributed to an array of abiotic and biotic stresses, old varieties dominating the seed system in the country and inadequate quantity and quality of foundation seed for the major food staples [3]. Therefore, greater efforts should be taken to improve the yielding ability of maize crop through evaluation of inbreed lines for effective selection of parent for grain yield and yield related trait.

The efficiency of breeding programme depends mainly on the direction and magnitude of association between yield and its components as well as the relative importance of each factor that contribute to grain yield [4]. To determine such relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis.

Correlation coefficient is the linear association between two variables [5] measured by correlation coefficient, which is required in plant breeding because it quantifies the degree of genetic and non-genetic association between two or more traits, allowing the indirect selection. Moreover estimation of simple correlation among various characters may provide valuable information necessary for maize breeders, when, selection is based on two or more traits simultaneously [6] and thereby provide the basis for planning more efficient breeding program. The path coefficient analysis was proposed by Wright [12] not only partitions the correlation coefficient into direct and indirect effects, it also provides the information on the actual contribution of a trait on the yield. Thus correlation and path coefficient analysis form a basis for selection and helps the breeder in understanding yield contributing characters affecting yield in maize [7]. Furthermore, Mallikarjuna *et al.,* [8] and Zeeshan *et al.,* [9] also reported that correlation and path coefficient analysis were used to measure the level of relationships between the traits, give reliable and useful information on nature, extent and direction of selection. The path analysis provides the effective measures of direct and indirect causes of association and depicts the relative importance of each factor involved in contributing to the final product [4]. The correlations of cause and effect with grain yield, particularly for maize, are important tools to assist breeders in defining priority traits for the selection, and the relationship among them, such that allow choosing which genetic changes should be done to increase the yield. Likewise, path analysis enables breeder to conduct faster-indirect selection of lines in breeding process. Therefore, this study aimed to assess the extent of association between traits among themselves and yield in order to increase the selection accuracy of superior genotypes for feature breeding scheme.

Materials and Methods

Description of Study Area

The experiment was conducted on research farm of Haramaya University (Raare) in the 2017/18 main cropping season. The study area is located at an altitude of 2020m.a.s.l. and lies at 9° 26' N latitude and 42°3' E longitude. The area received average annual rainfall during 2018 main cropping season was 727 mm. The minimum and maximum mean annual temperatures were 8.99°C and 25.15°C, respectively (Haramaya University weather station, 2018).

Experimental Materials

The planting materials were comprised of eight maize inbred lines which were crossed in 8×8 half diallel mating design. The resulting 28 F_1 hybrids and two standard checks (BHQPY 545 and MH 138) were evaluated in 2017/2018 main cropping seasons at Haramaya University Research Site (Raare). The details of parental lines used in the diallel cross are illustrated in Table 1.

Experimental Design and Field Management

The experimental materials which were comprised of twenty eight F_1 progenies along with two standard checks (BHQPY545, MH138), which were evaluated using alpha-lattice designs with three replications at Haramaya University Research Farm (Raare) during 2017/2018 main cropping seasons. In all cases, two rows per plots were used, where the length of each row was 5.1 m with spacing of 0.75 m between rows and 0.3 m within rows, using three replications. An alley of 1.5m left between the blocks. At planting, two seeds were planted per hill to ensure enough stand, and then thinned to one plant per hill after two weeks of emergence (when seedlings were 3-4 leaf stage) to attain a population density of 44,444 plants per hectare. Urea and NPS fertilizers were applied at the rates of 140kg/ha and 118kg/ha, respectively. Urea was applied in two equal splits. The first half application was done at sowing along with NPS fertilizer and the second was applied at the knee high stage of the crop. More over all other necessary field management practices were carried out as per the recommendation for the study area and the crop.

Data Collection

Data on grain yield and yield related traits were collected on plot and individual plant basis. Characters were recorded on plant basis by taking five random plants. The average was taken as the mean of the treatment.

Data collected on the plot basis

Days to anthesis (DA)

The number of days taken from planting up to the date when 50% of the plants started pollen shedding was recorded.

Days to silking (DS)

This is the number of days taken from planting to the date when 50% of the plants produced about 2-3cm long silk.

Days to physiological maturity (DM)

Days to physiological maturity (DM) was recorded as the number of days after planting to when 50% of the plants in the plot form a black layer at the point of attachment of the kernel with the cob.

Stand count at harvest (SH)

Stand count at harvest (SH) was recorded as the total number of plants at harvest from each experimental unit.

Number of ears harvested (NEH)

Number of ears harvested (NEH) was recorded as the total number of ears harvested from each experimental unit.

Thousand kernel weight (TKW)

After shelling, random kernels from the bulk of shelled grain in each experimental unit were taken and a thousand kernels were counted using seed counter and weighted in grams and then adjust to 12.5% grain moisture content.

Grain moisture

Moisture content (%) present in the grain was measured at harvesting by taking a sample of ears and shelling separately for each plot using portable digital moisture tester.

Above ground biomass yield (AGB)

Plants from the experimental unit were harvested at physiological maturity and weighed in kg after sun drying and converted to hectare basis.

Grain yield/plot (GY)

Grain yield per plot adjusted to 12.5% of moisture content was recorded for each plot in kg/plot using the formula below.

$$\text{Adjusted grain yield (kg plot}^{-1}\text{)} = \frac{\text{Field of weight (kg/plot)} \times (100\text{-MC}) \times \text{shelling\%}}{(87.5) \times \text{Area harvested (plot size)}}$$

Grain yield/ha (GY)

Grain yield/ha (GY) was obtained by converting the grain yield obtained per plot into a hectare basis.

Data collected on plant basis

Ear height (EH)

Ear height (EH) was measured from the ground level to the uppermost useful ear- bearing node of five randomly taken plants.

Plant height (PH)

Plant height (PH) was measured from the soil surface to the tassel starts branching of five randomly taken plants.

Ear length (EL)

Ear length (EL) was measured in centimeters from the base to the tip of ear.

Ear diameter (ED)

Ear diameter (ED) was measured at the midsection along the ear length, as the average diameter of five randomly taken ears using a caliper.

Number of kernel rows per ear (NKRE)

Number of kernel rows per ear (NKRE) was recorded as the average number of kernels row per ear from five randomly taken ears.

Number of kernels per row (NKR)

Number of kernels per row (NKR) was counted and the average was recorded from five randomly taken ears.

Data Analysis

Data obtained for thirteen traits were subjected to analysis of variance (ANOVA) using PROC GLM procedure of SAS, version 9.0 [10].

For the analysis of variance, parameters like ear rot and husk covers were transformed using square root transformation, X'= √x+0.5, as most of the plots had zero values [5]. Mean separation was done by using Least Significant Difference test (LSD).

Estimation of Phenotypic correlation and genotypic correlation was computed by the method described [11].

$$r_p = \frac{p\ cov\ x.y}{\sqrt{\delta^2 px\ .\delta^2 py}}$$

$$r_g = \frac{g\ cov\ x.y}{\sqrt{\delta^2 gx\ .\ \delta^2 gy}}$$

Where, r_p and r_g are phenotypic and genotypic correlation coefficients, respectively; pcovx.y and gcovx.y are phenotypic and genotypic, covariance between variables x and y, respectively; δ^2px and δ^2gx are phenotypic and genotypic, variances for variable x; and δ^2py and δ^2gy are phenotypic and genotypic variances for the variable y, respectively.

The correlations were partitioned into direct and indirect effects by means of path analysis [12]. In the regression model established, grain yield was taken as the dependent variable and the other traits were considered as independent variable.

Results and Discussion

Analysis of Variance

The analysis of variance (ANOVA) due to mean square of genotypes (entries) that comprised thirty maize hybrids which were evaluated for thirteen traits showed significant difference for all traits considered presented in Table 2.

The existence of highly significant differences suggests the presence of substantial variation among the genotypes studied, which allows conducting effective selection for further improvement of the respective traits in breeding process. Likewise, there was less coefficient of variation in all of the traits that indicated good precision of the experiment.

Analysis of Genotypic and Phenotypic Correlation

Phenotypic and genotypic correlation coefficient of statistical analysis was done for the response of thirty maize genotypes for thirteen traits in order to figure out the intensity of relationship between traits among themselves and yield. Yield is a complex and polygenically inherited character resulting from multiplicative interaction of its component traits. The cumulative effect of such traits determines the yield. Therefore to determine such relationships, correlation analyses were used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. Estimates of phenotypic and genotypic correlations of grain yield and other yield-related traits were presented in Table 3.

Assessment of the pair-wise associations among different characters of maize revealed that some of the characters are positively correlated while others are negatively correlated indicating that improving specific character will have positive or negative influence on the other characters in such degree apparent from the correlation coefficients Table 3. The results indicated that grain yield had positive phenotypic correlations with all traits except days to 50% tasseling and days to 50% silking. Above ground biomass had the highest statistically positive and significant phenotypic correlations with grain yield (rp= 0.8897; $p \leq$ 0.01) followed by 1000- kernel weight (rp= 0.8603; $p \leq$ 0.01), number of ear per plant (rp= 0.6352; $p \leq$ 0.01).Therefore, these positive and significantly inter-correlated characters will help in selecting genotypes with high grain yield. Kumar *et al.*, [13] and Reddy and Jabeen[14] reported that significant positive correlation of 1000-kernel weight with grain yield.

Grain yield also exhibit non-significant positive phenotypic correlations with plant height, ear height, days to maturity, ear length, ear diameter, number of kernels per rows, number of kernels rows per ear. The result in line with Kumar *et al.*, [15], who reported that grain yield revealed positive phenotypic correlation with number of days to maturity, plant height, ear height, ear length, number of kernel rows per ear and number of kernels per row. The result of correlation analysis indicated that increasing ear diameters caused an increase in the number of kernel rows per ear and consequently ear length as they are significantly inter correlated with each other, which contributes to grain yield in maize.

Similarly, ear length exhibit significant positive phenotypic correlation with ear diameter, plant height, ear height and number of kernel rows per ear implying that selection for these significantly correlated characters will have possibility to increase grain yield.

On the other hand genotypic correlation coefficients revealed that all traits examined in the study have a positive correlation with grain yield except days to 50% tasseling and days to 50% silking (Table 3). Traits that showed high genotypic correlations with grain yield are thousand kernel weight (rg= 0.9451; $p \leq 0.01$) followed by above ground biomass (rg= 0.8982; $p \leq 0.01$), number of ear per plant (rg= 0.7378; $p \leq$ 0.01), ear length (rg = 0.5142; $p \leq 0.01$) and ear diameter (rg= 0.4580; $p \leq 0.05$) and hence simultaneous selection for this character might bring an improvement to grain yield.

Ear length exhibit significant genotypic correlation with ear diameter, plant height, ear height, number of kernel rows per ear, number of kernel per rows, number of days to maturity, 1000-kernel weight and grain yield. The result in line with Pandey *et al.*,[16], who reported that number of kernel per row, number of kernel row per ear, plant height, 1000-kernel weight, and grain yield significantly correlated with ear length. Therefore, these traits showing significant positive correlation with grain yield helps to conduct effective selection for grain yield. Ear diameter had significant positive genotypic correlation coefficient with number of kernels row per ear, 1000-kernel weight, ear length, plant height, and ear height. Consequently, this could be part of a good selection index for high yielding maize hybrids. The highest positive genotypic correlation was observed between 1000-kernel weight and grain yield (rg= 0.9451; $p \leq$ 0.01). Similar observation was reported by Reddy and Jabeen[14]. Such observation help in making reasonable decisions in selecting traits controlled by multiple genes, and there by leading the overall improvements of the genotypes.

The characters days to tasseling and days to silking exhibit significant negative correlation with grain yield at genotypic and phenotypic levels. Such result showed that breeding for earliness has a potential of increasing yield unlike selection for flowering. This also implies that the trait is less influenced by the environment, hence it is more influenced by genetic factors and thus it is more heritable which makes it a suitable trait when selecting for grain yield indirectly. These result were comparable with Kumar *et al.,* [15], Tatenda *et al.,* [17] and Reddy and Jabeen[14], who observed a negative correlation between grain yield days to 50% anthesis and days to 50% silking but in contrast with Selvaraj and Nagarajan[23] who reported that anthesis date and silking date showed positive nonsignificant association with grain yield. The negative correlation between yield and days to silking is very important to the breeder to identify early and late maturing cultivars. It means that yield is compromised when silk emergence is delayed. The results were in accordance with the reports of Tatenda *et al.,* [17].

Number of days to maturity revealed significant positive correlation with plant height, ear height and number of kernel per row at genotypic and phenotypic level. This suggested that hybrids with taller plants, longer maturity periods. The result was comparable with the report of Mandefro[18]. There were also positive and significant phenotypic and genotypic correlations for number of kernel per row with plant height, ear height and number of days to maturity; and number of kernel row per ear with ear length and ear diameter. Similarly, number of kernel per row significantly correlated with plant and ear height reported by Reddy and Jabeen[14], and number of kernel row per ear significantly correlated with ear length reported by Pandey *et al.,* [16]. On the other hand plant height, number of kernel per row, number of kernel row per ear, ear height and days to maturity showed non-significant positive association with grain yield at genotypic and phenotypic level.

Path Coefficient Analysis

Although grain yield is a complex trait; path coefficient analysis can provide an effective means of partitioning the correlation coefficient into direct and indirect effects and gives a clear understanding of their association with grain yield.

Therefore, path coefficient analysis was conducted to obtain further information on the nature of the interrelationships among the various characters and their effects on grain yield. Such information would be of great value that enables to increase selection accuracy of superior genotypes for feature breeding scheme. Path coefficient analysis was carried out taking grain yield as dependent variable and the other characters as independent variables to verify if correlation magnitudes represented cause and direct or indirect effect of other traits.

Phenotypic direct and indirect effects of various traits on grain yield

The traits which indicated significant phenotypic correlation with grain yield were further analyzed for direct and indirect contribution to grain yield illustrated in Table 4.The results of phenotypic path coefficient analysis revealed that all characters had positive direct effects on grain yield except ear height, days to silking, days to maturity, and ear diameter. Bello *et al.,* [19] reported that days to 50% silking showed negative direct effect on grain yield. The highest positive direct effect on grain yield was exhibited by above ground biomass followed by plant height, number of ear per plant, ear length, number of kernel per row, number of kernel row per ear, days to anthesis and 1000-kernel weight. Hence, these characters can be considered as the main components for selection in a breeding program for grain yield improvement. This finding were in agreement with Tadesse and Leta[20] reported on number of kernel per row, number of kernel row per ear, days to anthesis and 1000-kernel weight contributed directly to grain yield.

Besides its maximum direct effect on maize yield, above ground biomass, exhibited positive indirect effects on days to anthesis, plant height, number of ear per plant, ear length, number of kernel row per ear, number of kernels per row and 1000-kernels weight. The phenotypic direct effect of 1000-kernels weight on grain yield was very small, while the phenotypic correlation was positive and statistically significant.

Table.1 Details of maize inbreeds used for hybridization in this study at Haramaya eastern Ethiopia

Inbred Lines	
Code	**Pedigree**
L1	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-8-4-2-2-1-#-1-B-2
L2	[KIT/SNsyn[N3/TUX]]c1F1-##(GLS=2.5)-32-1-1-#/CML176BC1F1-12-1-3-4-2-#-2-B-1
L3	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-8-4-3-3-4-#-1-B-4
L4	[POOL9Ac7-SR(BC2)]FS48-1-1-1-1-1-#/CML144(BC2)-6-22-1-1-1-4-#-3-B-1
L5	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-8-4-3-2-2-#-1-B-1
L6	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-21-1-3-2-2-#-2-B-4
L7	[POOL9Ac7-SR(BC2)]FS59-2-2-1-1-#/CML144(BC1)F1-3-2-1-2-1-#-1-B-2
L8	[KIT/SNsyn[N3/TUX]]c1F1-##(GLS=2.5)-17-1-1-#/CML144(BC1)F1-5-1-2-1-1-#-2-B-1

Source: Haramaya university maize research program 2017.

Table.2 Mean Square of Genotypes for Grain Yield and Related Traits Evaluated at Haramaya, Eastern Ethiopia.

Source of variation	df	Mean squares												
		GY (t/ha)	DA (day)	DS (day)	EPP (#)	DM (day)	EL (cm)	ED (cm)	PH (cm)	EH (cm)	NKR (#)	NKRE (#)	TKW (gm)	BM (t/ha)
Rep	2	5.03	3.34	4.57	0.02	1.42	1.41	0.09	112.83	198.28	3.83	2.44	1277.02	39.63
Blk/(Rep)	10	1.26	0.87	1.69	0.01	0.77	5.66	0.19	141.15	37.1	3.54	4.03	3644.99	7.45
Genotypes	29	6.80**	9.55**	8.40**	0.18**	97.97**	9.38*	0.77*	1212.08**	401.90**	30.04**	8.33*	10491.39**	48.58**
Error	48	1.75	1.08	1.19	0.02	0.69	5.29	0.45	192.26	65.18	4.17	4.63	4056.71	17.09
Means		7.96	1.26	1.25	1.23	164.34	17.50	4.44	193.17	93.94	39.67	12.95	360.40	19.97
CV (%)		16.60	79.12	82.26	12.48	0.51	13.14	15.07	7.18	8.59	5.16	16.62	17.67	20.70

Note: a GY = grain yield; BM = biomass yield; DA = days to anthesis; ED = ear diameter; EH = ear height; EL = ear length; EPP = number of ear per plant; NKR = number of kernels per row; PH = plant height; NKRE = number of kernel rows per ear; DS = number of days to silking; TKW = thousand kernels weight; DM = days to maturity. ** = Significant at P<0.01 level of probability and * = Significant at P<0.05 level of probability.

Table.3 Estimate of phenotypic (below diagonal) and Genotypic (above diagonal) correlations for yield and yield contributing characters in maize.

Trait	BM	DA	DS	PH	EH	EPP	DM	EL	ED	NKR	NKRE	TKW	GY
BM	1	-0.4402*	-0.3943*	-0.0535	0.0829	0.6125**	0.1608	0.1469	0.1967	-0.029	-0.1516	0.8632**	0.8982**
DA	-0.3792*	1	0.9982**	-0.6480**	-0.6292**	-0.4634**	-0.5566**	-0.0653	-0.0783	-0.6141**	-0.0048	-0.5695**	-0.5071**
DS	-0.3445	0.9869	1	-0.6749**	-0.6522**	-0.4276*	-0.6000**	-0.0745	-0.0524	-0.6661**	0.0278	-0.5360**	-0.4661**
PH	-0.0312	-0.5709**	-0.5859**	1	0.9471**	0.2272	0.6888**	0.6925**	0.4324*	0.7860**	0.3663*	0.2648	0.1333
EH	0.1267	-0.5775**	-0.5841**	0.8717**	1	0.3167	0.6699**	0.7877**	0.5319**	0.7994**	0.3802*	0.323	0.2565
EPP	0.4743**	-0.4240**	-0.3937**	0.1889	0.2692	1	0.4935**	0.2558	0.3428	0.0565	0.2956	0.6190**	0.7378**
DM	0.1695	-0.5837**	-0.6192**	0.6779**	0.6460**	0.4489*	1	0.3856*	0.2096	0.5651**	0.1206	0.2828	0.2449
EL	-0.0107	-0.0983	-0.1034	0.4475*	0.4559*	0.1289	0.2142	1	0.9941**	0.3810*	0.8832**	0.7610**	0.5142**
ED	0.003	-0.0607	-0.0375	0.2953	0.321	0.2279	0.1114	0.8307**	1	0.0481	0.8839**	0.4257*	0.4580*
NKR	-0.0534	-0.5547**	-0.5973**	0.6746**	0.6876**	0.0645	0.5789**	0.266	0.0738	1	0.0927	0.2337	0.0702
NKRE	-0.192	-0.0189	-0.0006	0.2509	0.2331	0.2089	0.0462	0.6966**	0.8581**	0.1043	1	0.1879	0.1667
TKW	0.7703**	-0.4757**	-0.4436*	0.2186	0.2712	0.4734**	0.2053	0.3361	0.1785	0.2083	0.036	1	0.9451**
GY	0.8897**	-0.4515*	-0.4190*	0.1254	0.2496	0.6352**	0.2382	0.2902	0.2887	0.0699	0.1364	0.8603**	1

Note: a GY = grain yield; BM = biomass yield; DA = days to anthesis; ED = ear diameter; EH = ear height; EL = ear length; EPP = number of ear per plant; NKR = number of kernels per row; PH = plant height; NKRE = number of kernel rows per ear; DS = number of days to silking; TKW = thousand kernels weight; DM = days to maturity. ** = Significant at P<0.01 level of probability and * = Significant at P<0.05 level of probability.

Table.4 Partitioning phenotypic in to direct (diagonal bold) and indirect (off diagonal) effects of different characters on grain yield of maize.

Trait	BM	DA	DS	PH	EH	EPP	DM	EL	ED	NKR	NKRE	TKW	rg
BM	**0.8560**	-0.0160	0.0335	-0.0098	-0.0593	0.1253	-0.0220	-0.0027	0.0000	-0.0090	-0.0197	0.0135	0.8897**
DA	-0.3246	**0.0422**	-0.0960	-0.1793	0.2703	-0.1120	0.0758	-0.0245	0.0008	-0.0940	-0.0019	-0.0083	-0.4515*
DS	-0.2949	0.0417	**-0.0973**	-0.1840	0.2734	-0.1040	0.0804	-0.0257	0.0005	-0.1012	-0.0001	-0.0078	-0.4190*
PH	-0.0267	-0.0241	0.0570	**0.3141**	-0.4080	0.0499	-0.0880	0.1114	-0.0041	0.1143	0.0258	0.0038	0.1254
EH	0.1085	-0.0244	0.0568	0.2738	**-0.4681**	0.0836	-0.0349	0.1135	-0.0044	0.1165	0.0239	0.0048	0.2496
EPP	0.4060	-0.0179	0.0383	0.0593	-0.1260	**0.2641**	-0.0583	0.0321	-0.0031	0.0109	0.0214	0.0083	0.6352**
DM	0.1451	-0.0246	0.0602	0.2129	-0.3024	0.1186	**-0.1298**	0.0533	-0.0015	0.0981	0.0047	0.0036	0.2382
EL	-0.0092	-0.0041	0.0101	0.1406	-0.2134	0.0340	-0.0278	**0.2490**	-0.0114	0.0451	0.0715	0.0059	0.2902
ED	0.0026	-0.0026	0.0036	0.0928	-0.1503	0.0602	-0.0145	0.2069	**-0.0138**	0.0125	0.0881	0.0031	0.2887
NKR	-0.0457	-0.0234	0.0581	0.2119	-0.3218	0.0170	-0.0752	0.0662	-0.0010	**0.1694**	0.0107	0.0037	0.0699
NKRE	-0.1643	-0.0008	0.0001	0.0788	-0.1091	0.0552	-0.0060	0.1735	-0.0118	0.0177	**0.1027**	0.0006	0.1364
TKW	0.6594	-0.0201	0.0432	0.0687	-0.1269	0.1250	-0.0267	0.0837	-0.0025	0.0353	0.0037	**0.0175**	0.8603**

Note: a GY = grain yield; BM = biomass yield; DA = days to anthesis; ED = ear diameter; EH = ear height; EL = ear length; EPP = number of ear per plant; NKR = number of kernels per row; PH = plant height; NKRE = number of kernel rows per ear; DS = number of days to silking; TKW = thousand kernels weight; DM = days to maturity. ** = Significant at P<0.01 level of probability and * = Significant at P<0.05 level of probability

Table.5 Partitioning Genotypic in to direct (diagonal bold) and indirect (off diagonal) effects of different characters on grain yield of maize.

Trait	BM	DA	DS	PH	EH	EPP	DM	EL	ED	NKR	NKRE	TKW	rg
BM	**0.4752**	0.9436	-0.9515	0.0583	0.1176	-0.1266	0.0449	0.0502	-0.1762	0.0173	-0.0769	0.5222	0.8982**
DA	-0.1213	**-0.9114**	0.8203	0.7059	-0.8928	0.0957	-0.1555	-0.0870	0.0701	0.3568	-0.0435	-0.3445	-0.5071**
DS	-0.1086	-0.8615	**0.7131**	0.6224	-0.8254	0.0835	-0.1676	-0.0304	0.0469	0.3717	0.0141	-0.3242	-0.4661**
PH	-0.0147	0.6978	-0.6286	**-0.0893**	0.3439	-0.0469	0.1924	0.1895	-0.3873	-0.4695	0.1859	0.1602	0.1333
EH	0.0228	0.6486	-0.5739	-0.0317	**0.4189**	-0.0654	0.1871	0.2156	-0.4764	-0.4775	0.1929	0.1954	0.2565
EPP	0.1687	0.2141	-0.0319	-0.2475	0.4494	**-0.2066**	0.1379	0.0700	-0.3070	-0.0337	0.1500	0.3744	0.7378**
DM	0.0443	0.4583	-0.4479	-0.7503	0.9505	-0.1020	**0.2793**	0.1055	-0.1877	-0.3375	0.0612	0.1711	0.2449
EL	0.0705	0.1711	-0.1798	-0.7543	0.9177	-0.0529	0.1077	**0.3737**	-0.8903	-0.2276	0.4481	0.5303	0.5142**
ED	0.0542	0.2052	-0.1264	-0.4710	0.7547	-0.0708	0.0586	0.2720	**-0.8956**	-0.0287	0.4485	0.2575	0.4580*
NKR	-0.0080	0.6090	-0.6074	-0.8273	0.5302	-0.0117	0.1858	0.4262	-0.0431	**-0.5973**	0.0470	0.3667	0.0702
NKRE	-0.0418	0.0126	0.0671	-0.3990	0.5395	-0.0611	0.0337	0.2417	-0.7916	-0.0554	**0.5074**	0.1137	0.1667
TKW	0.2378	0.4921	-0.2934	-0.2884	0.4583	-0.1279	0.0790	0.2082	-0.3813	-0.1396	0.0953	**0.6049**	0.9451**

Note: a GY = grain yield; BM = above ground biomass; DA = days to anthesis; ED = ear diameter; EH = ear height; EL = ear length; EPP = number of ear per plant; NKR = number of kernels per row; PH = plant height; NKRE = number of kernel rows per ear; DS = number of days to silking; TKW = thousand kernels weight; DM = days to maturity. ** = Significant at P<0.01 level of probability and * = Significant at P<0.05 level of probability

Therefore, if selection is made through 1000-kernels weight then the traits like above ground biomass, number of ear per plant and ear length should also be considered simultaneously as indirect effects through them were high and positive correlation.

Genotypic direct and indirect effects of various traits on grain yield

The genotypic direct and indirect effects of twelve yield related traits on grain yield are shown in Table 5. The maximum positive genotypic direct effect on grain yield was observed in number of days to silking(0.7131) followed by 1000-kernel weight(0.6049), number of kernel rows per ear (0.5074), above ground biomass (0.4752), ear height (0.4189), ear length (0.3737) and number of days to maturity (0.2793) and hence they are good indicators in indirect selection for higher grain yield. These observations are in consistent with the findings of Reddy and Jabeen[14]. On the other hand days to anthesis, plant height, number of ear per plant, ear diameter and number of kernel per row had negative direct effect on grain yield at genotypic level. These observations are in comparable with the findings of Pandey *et al.*, [16] and Abebe *et al.*, [21] for days to anthesis and plant height.

The trait, days to 50% silking recorded positive direct effects and significant negative association with grain yield at genotypic levels. Since, the direct effects are positive and the correlation coefficients are significantly negative, the indirect causal factors which are having positive effects *viz*., plant height and number of kernel per rows along with days to 50% silking are to be considered simultaneously during selection.

The negative direct effect of plant height was more than compensated by its indirect effects hence resulting in positive correlation with grain yield per plant, suggesting that grain yield can be improved through plant height indirectly. Zeeshan *et al.*,[9] and Parh *et al.*, [22] also reported negative direct effect of plant height on grain yield. The indirect positive effects through days to anthesis, ear height, days to maturity, ear length, number of kernel rows per ear and 1000-kernel weight are the possible cause of positive correlation between plant height and grain yield. Therefore, these traits must be considered if selection is made through plant height.Above ground biomass, 1000-kernel weight and ear length had significant positive genotypic correlation coefficient with grain yield and also positive direct effect on grain yield. Therefore, correlation explains the true relationship among above ground biomass, 1000-kernel weight, ear length and grain yield.

Determining the relationships between yield and its components is essential for effective selection of parent for grain yield and associated trait. Therefore, the study was aimed to examine the association between yield and yield contributing traits and identify traits those have direct and indirect effects on grain yield, to plan meaningful breeding programme.

The result revealed that grain yield had highly significant positive correlations at genotypic and phenotypic levels with above ground biomass, number of ear per plant and thousand kernel weight. However, days to 50% tasseling and days to 50% silking exhibit significant negative correlation with grain yield. The traits such as number of kernel rows per ear, 1000-kernel weight, ear length, and above ground biomass had positive direct effect on grain yield at phenotypic and genotypic level. In conclusion it can be said that those parameters that had positive correlation and positive direct effect on grain yield such that number of kernel rows per ear, 1000-kernel weight, ear length, and above ground biomass; could be used as target traits for selection and breeding criteria to bring out improvements in maize yield.

Generally, higher values of genotypic correlation than their corresponding phenotypic correlation were observed for most of the traits indicating that the apparent associations might be largely due to inherent relationship among the traits and low modifying effect of environment on the association of the characters.

The trait exhibits positive associations among traits indicate positive responses in the levels of one character when the other is selected, while the negative signify the reverse situation. Thus strong and positive association between grain yield and other traits provides the opportunity to improve grain yield and yield related traits simultaneously. Therefore, the selection of promising genotypes can be made based on grain yield and also other yield components that might influence the productivity of grains.

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