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Association and path coefficient analysis among grain yield and related traits in Ethiopian maize *(Zea mays* L.*)* inbred lines

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Twenty four inbred lines developed by the Ethiopian National Maize Breeding Program were evaluated at Jimma Agricultural Research Center during the main season of the year 2016 in an 8 X 3 Alpha Lattice (0, 1) design with three replications. The objective was to determine the phenotypic and genotypic association among traits in Ethiopian maize inbred lines and to compare the direct and indirect effects of traits on grain yield. Analysis of variance showed statistically significant ($p<0.01$) differences among the tested maize inbred lines for most of the traits indicating the existence of sufficient genetic variability which can be exploited in future breeding programs. Grain yield per hectare, thousand kernels weight, ear height, ear diameter, anthesis-silking interval, and plant aspect had higher phenotypic and genotypic coefficients of variation. Grain yield showed positive and highly significant ($p<0.01$) genotypic association with ear diameter, number of kernels per row, days to 50% silking, number of kernel rows per ear, 1000-kernels weight and leaf width. Grain yield also had positive and highly significant ($p<0.01$) phenotypic correlation with number of kernels per row and ear diameter. Path coefficient analysis revealed that number of kernels per row, number of kernel rows per ear, plant height, days to maturity, 1000-kernels weight, leaf width and plant aspect had a positive direct genotypic effect on grain yield. Number of kernels per row, number of kernel rows per ear, plant height and 1000-kernels weight exerted high direct effects and also indicated positive and strong association with grain yield indicating that they can be used for indirect selection of inbred lines having higher yield potential *per se*.

Key words: Character association, inbred lines, morphological traits, path coefficient analysis.

INTRODUCTION

Having been originated and domesticated in Central America, specifically in Mexico, maize was reported to have been distributed over the world by the Portuguese Merchants (McCann, 2009). It is believed to have been

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introduced to Ethiopia in the 1600s to 1700s. It has since gained a growing popularity as food and feed crop and currently stands as the third important crop in the world following rice and wheat (McCann, 2009). About 208 million people in Sub-Saharan Africa (SSA) depend on maize as a source of food and economic wellbeing (FAOSTAT, 2015). Maize has also been recognized for supporting millions of people as a staple food crop in Ethiopia. It is currently grown by 9 million households in 2 million hectare of land from which more than 7.0 million metric tons are produced annually.

Maize is also gaining popularity in Ethiopia for its growing demand for animal feed and as source of fuel for rural families. It constitutes about 20% consumption as food and constitutes about 13% as feed in total cereals (FAO, 2013). It contributes about 29% of the calorie intake from total cereal consumption, followed by wheat and teff which contribute about 21 and 17%, respectively (FAO, 2013).

An increase in production of this staple crop is believed to invariably lead to higher consumption and reduced poverty across households in Ethiopia. Maize has, therefore, been one of the priority crops for research and development to which significant resources have been allocated to boost its productivity through genetic improvement. Significant efforts have been made since the early 1900s (Kebede et al., 1993) to develop well adapted and high yielding hybrid and open-pollinated varieties for different agro ecologies. Combined use of these varieties with improved agronomic practices has helped farmers to produce mean grain yield of 6 t/ha. As a result maize production and productivity grew much from 1.5 million tones and 1.7 t/ha in the early 1900s to their current level of 7.0 million tones and 3.7 t/ha, respectively.

With the vision of exploiting the genetic potential of this crop there remains a lot to genetically improve it for tolerance to biotic and abiotic constraints that limit production in different agroecologies (Abate et al*.,* 2015). The positive contribution to this vision is expected from use of inbred lines developed from diverse sources which are eventually used in developing stress tolerant hybrids. Characterization of these inbred lines for key traits that directly or indirectly influence success in selection of better parents for use in hybrid breeding program has always been of great emphasis in breeding program. Despite this fact, information on association among quantitative traits has been inadequate in inbred lines developed through successive self-pollination followed by selection.

A study on associations among quantitative traits is indispensable in order to assess the feasibility of selection based on two or more traits and hence for evaluating the effect of selection for secondary traits on genetic gain for a primary trait under consideration. Estimation of simple correlation coefficients between various agronomic traits provides guiding information necessary for plant breeders when selection is based on two or more traits simultaneously. It provides useful information on the nature, extent and direction of selection (Zeeshan et al*.,* 2013).

With this background information, several researches have been conducted to find out the nature of the relationship between yield and yield component traits. Tulu (2014) indicated positive and highly significant phenotypic correlation of grain yield with plant height, ear height, inter-node length, ear length, number of nodes per plant, ear diameter, stalk diameter, number of kernels per row and 1000-kernels weight in quality protein maize (QPM) inbred lines. Bello et al. (2010) reported positive and highly significantly correlation of grain yield with plant height, ear height, number of nodes per plant, inter-node length, ear length, ear diameter, stalk diameter and number of kernels per row. Later on Fekadu (2014) reported number of kernels per row had the highest positive direct effect on grain yield followed by yield per plant and harvest index among the studied traits. Number of ears per plant, ear length, and leaf width and leaf length were also reported having a direct negative influence on grain yield (Rafiq et al*.,* 2010).

The National Maize Breeding Program of Ethiopia developed several maize inbred lines for use in its hybrid breeding program. Though some efforts have been made to determine variability of maize inbred lines considering their different morphological traits, the association between yield and yield related traits in mid-altitude maize inbred lines were not studied in details. Secondary traits which can be targeted for guiding selection of plants in developing inbred lines through successive self-pollination have not been identified following correlation studies in Ethiopian maize inbred lines developed from diverse sources and evaluated under Ethiopian condition. Therefore, this study was undertaken to determine the phenotypic and genotypic association among traits in Ethiopian maize inbred lines and to compare the direct and indirect effects of traits on grain yield. We hope the information generated in this study will contribute to genetic improvement of maize in Ethiopia by guiding selection of ideal plant types of maize inbred lines for use in future hybrid breeding program.

MATERIALS AND METHODS

Description of the study site

The study was conducted at Jimma Agricultural Research Center during the main cropping season of 2016. The experimental site is located in Ethiopia, Oromia National Regional State in Jimma zone, 343 km South West of the capital city Addis Ababa. It is situated around 07°46'N latitude and 36°47'E longitude coordinate and at an elevation of 1753 m above the mean sea level. It represents the mid-altitude agro ecological zones which receive mean annual rainfall of 1600 mm with minimum and maximum mean temperatures of 16.6 and 31.48°C, respectively. The major soil type of the area is Eutric Nitosol and Cambisol (reddish brown) of upland and fluvisol of bottom land with a pH of around 5.2 (JARC, 2016).

Table 1. List of inbred lines used in the study.

S/N	Designation of inbred lines	Source
1	124-b(109)	BNMRC
2	142-1-e	BNMRC
3	144-7-b	BNMRC
4	35B-190-0-S10-2-1-2-2-1-2	BNMRC
5	A-7033	BNMRC
6	BKL001	BNMRC
7	BKL002	BNMRC
8	BKL003	BNMRC
9	CML124-b(113)	BNMRC
10	CML159	BNMRC
11	CML144	BNMRC
12	CML161	BNMRC
13	CML165	BNMRC
14	CML197	BNMRC
15	CML202	BNMRC
16	CML312	BNMRC
17	CML334	BNMRC
18	CML395	BNMRC
19	CUBA	BNMRC
20	F-7215	BNMRC
21	ILOO,EI-1-9-1-1-1-1-1	BNMRC
22	MBRC5BCF108-2-3-1-B-5-2-B-B-B-B	BNMRC
23	PO,OOE3-2-1-2-1	BNMRC
24	SC22	BNMRC

Source: *Bako National Maize Research Center.

Plant materials

Twenty-four inbred lines obtained from Bako National Maize Research Center were used in this study. Designation of the inbred lines is indicated in Table 1.

Experimental design and trial management

The experiment was laid out in an 8 X 3 Alpha Lattice (0, 1) design (Patterson and Williams, 1976*)* with three replications. Each plot had four rows having length of 5.1 m each, and spacing of 0.75m between rows and 0.3 m between plants. Two seeds were planted per hill and the seedlings were thinned to one plant per hill at 2-3 fully grown leaf stage to achieve final plant density of 44,444 per ha. The field management and agronomic practices pertinent to maize were carried out as per the research recommendations for maize production in the area. The plots were fertilized with the UREA and DAP at the rate of 200 and 150 kg/ha, respectively. The whole of DAP was applied at planting while UREA was applied in three equal splits. The first, second and third applications were given at sowing, knee height and tasseling stage, respectively.

Data collected

Data on all agronomic characters and grain yield were recorded on the middle two rows at appropriate growth stages according to the standard evaluation system of maize plant (IBPGR, 1991).

Data recorded on plant basis

Data on quantitative traits were recorded on plant basis in ten randomly selected plants per plot. The plants were measured individually and the mean value was recorded for the plot. All quantitative traits including plant height, ear height, leaf length and width, leaf area, ear length, ear diameter, number of kernel rows per ear and number of kernels per row were recorded on plant basis as described in Tadesse et al. (2018). Similarly days to 50% anthesis and silking, anthesis and silking interval, tassel size, plant aspect, days to maturity, thousand kernels weight and grain yield were recorded on plot.

Data analysis

The data collected for each character were subjected to analysis of variance (ANOVA) using SAS version 9.3. The correlation coefficients and path coefficients of traits on grain yield were analyzed using Plant Breeding Statistical Program (PLABSTAT) software version 3A (2011).

Characters association and path coefficient analysis

Correlation coefficient (r)

Genotypic and phenotypic coefficients of correlation between two traits were calculated by using variance and covariance components as described by Weber and Mouthy (1952).

$$\text{rg (xy)} = \frac{covg\,(xy)}{[\sqrt{\sigma 2g(x)}]\,[\sqrt{\sigma 2g(y)}]}$$

$$\text{rp(xy)} = \frac{cov\,(xy)}{[\sqrt{\sigma 2p(x)}]\,[\sqrt{\sigma 2p(y)}]}$$

$$\frac{covp\,(xy)}{(\sqrt{\sigma g(x)})(\sqrt{\sigma p(y)})}$$

Where: rg(xy) and rp(xy) are genotypic and phenotypic correlation coefficients among character X and Y, respectively.

Covg (xy) and covp (xy) are genotypic and phenotypic covariance of characters X and Y respectively. σ^2g(x), σ^2p(x) and σ^2g(y), σ^2p(y) are genotypic and phenotypic variances of characters X and Y, respectively. These coefficients of correlation were tested for their statistical significance using `t`- test as:

$$\text{t} = r\sqrt{(n-1)}/\sqrt{(1-r2}\mathbf{)}$$

The calculated value of t was compared with `t` table value at n-2 degrees of freedom at 1 and 5 percent level of significance.

Path coefficient analysis

Path coefficient analysis was computed according to the method suggested by Dewey and Lu (1959):

rij = pij + ∑rikpkj

The residual effect (h) was estimated using the formula shown below (Dewey and Lu, 1959).

$$\text{h} = \sqrt{1-R^2}\sqrt{1-R^2}$$

Where: R^2= ∑rijpij

RESULTS AND DISCUSSION

Association among characters

Correlation of grain yield with yield related traits

Genotypic and phenotypic correlations among the 16 characters are presented in Table 2. Ear diameter, number of kernels per row, kernel rows per ear, 1000-kernels weight and leaf width had positive and highly significant genotypic correlation with grain yield which suggests that these traits are the most important ones to be considered for indirect selection in breeding strategy designed to improve grain yield. The result is in line with the findings of Iqbal et al*.* (2014) that reported positive and highly significant genotypic correlation coefficient of grain yield with leaf width, number of kernel rows per ear, days to 50% silking, ear diameter, number of kernels per row and 1000-kernels weight. Similarly, Aliu et al*.* (2013) reported positive and highly significant correlation of grain yield with cob diameter and 1000 grain weight and significant correlation with plant height. On the other hand, grain yield had non-significant correlation with anthesis-silking interval and leaf length which implies lack of functional relationship between grain yield and these traits (Dagne, 2008). Therefore, selection for these characters may not bring a significant improvement in grain yield. Similar findings were reported by Bello et al*.* (2012).

Grain yield had significant and positive phenotypic correlation with number of kernels per row, ear diameter, number of kernel rows per ear, 1000-kernel weight and ear length. Habtamu and Hadji (2010) and Tulu (2014) also reported positive and highly significant phenotypic correlations of grain yield with ear diameter, ear length, number of kernels per row and thousand kernel weight which is very well in consistence with the current finding. This shows that in the process of inbred line development positive selection for either one or more of these traits may lead to an inbred line having better yield potential *per se.* On the other hand, grain yield was negatively and significantly correlated with days to 50% anthesis and silking, and plant aspect both at phenotypic and genotypic level indicating difficulty of simultaneous improvement of these characters through selection (Table 2).

Genotypic correlation coefficients of grain yield with ear diameter and number of kernels per row were higher than the phenotypic counter parts indicating higher genetic association of the traits with grain yield and low modifying effect of environment on the association of the characters. Similar results were reported by Hossain and Joarder (2006) and Kumar et al. (2014). Ear diameter, number of kernels per row, days to 50% silking, number of kernel rows per ear, 1000-kernels weight and leaf width had positive and highly significant phenotypic and genotypic correlation coefficients with grain yield. These traits can, therefore, be considered as secondary traits for guiding selection in developing maize inbred lines.

Correlation among yield related traits

Number of kernels per row, ear length, days to maturity, plant height, ear height, and 1000-kernels weight, leaf area and leaf width had positive and highly significant genotypic correlation coefficient with ear diameter. The positive relationships of the above mentioned traits with ear diameter indicate that desirable genes influenced co-heritability of the traits and as a result these traits can be improved simultaneously through appropriate selection scheme. Strong genotypic association these traits manifested among themselves and with grain yield confirmed true association with low modifying effects of the environment. These can be due to either linkage of the genes controlling these traits because of their close

Table 2. Genotypic coefficients of correlation (below diagonal) and phonotypic coefficients of correlation (above the diagonal) among the sixteen quantitative characters.

	DA	DS	ASI	LL	LW	LA	PH	EH	PA	MD	ED	EL	TKW	KRPE	NKPR	GY
DA	1	0.99**	-0.36^{ns}	0.14^{ns}	-0.23^{ns}	-0.11^{ns}	-0.26^{ns}	-0.24^{ns}	0.52**	-0.15^{ns}	-0.63**	-0.44*	-0.67**	-0.37^{ns}	-0.55**	-0.64**
DS	0.99^{**}	1	-0.22^{ns}	0.15^{ns}	-0.25^{ns}	-0.12^{ns}	-0.27^{ns}	-0.24^{ns}	0.52**	-0.14^{ns}	-0.63**	-0.43*	-0.37^{ns}	-0.57**	-0.66**	-0.66**
ASI	-0.45*	-0.35*	1	0.03^{ns}	-0.09^{ns}	-0.04^{ns}	0.04^{ns}	0.02^{ns}	-0.16^{ns}	0.10^{ns}	0.23^{ns}	0.19^{ns}	0.49*	0.11^{ns}	0.08^{ns}	0.02^{ns}
LL	0.13^{ns}	0.16^{ns}	0.15^{ns}	1	-0.14^{ns}	0.53**	0.21^{ns}	0.21^{ns}	-0.04^{ns}	0.52**	-0.15^{ns}	0.22^{ns}	-0.40*	-0.08^{ns}	0.12^{ns}	-0.17^{ns}
LW	-0.29^{*}	-0.32^{*}	-0.12^{ns}	-0.18^{ns}	1	0.77**	0.17^{ns}	0.20^{ns}	-0.18^{ns}	0.10^{ns}	0.32^{ns}	0.23^{ns}	0.20^{ns}	0.09^{ns}	0.23^{ns}	0.37^{ns}
LA	-0.16^{ns}	-0.16^{ns}	0.03^{ns}	0.52^{**}	0.75^{**}	1	0.30^{ns}	0.32^{ns}	-0.18^{ns}	0.43*	0.20^{ns}	0.37^{ns}	-0.07^{ns}	0.01^{ns}	0.29^{ns}	0.20^{ns}
PH	-0.33^{*}	-0.34^{*}	0.10^{ns}	0.22^{*}	0.22^{ns}	0.37^{*}	1	0.88**	-0.41*	0.52**	0.22^{ns}	0.76**	0.31^{ns}	-0.18^{ns}	0.54**	0.33^{ns}
EH	-0.32^{*}	-0.32^{*}	0.09^{ns}	0.21^{ns}	0.26^{*}	0.38^{*}	0.94^{**}	1	-0.18^{ns}	0.42*	0.19^{ns}	0.52**	0.19^{ns}	-0.25^{ns}	0.37^{ns}	0.33^{ns}
PA	0.66^{**}	0.67^{**}	-0.21^{ns}	-0.10^{ns}	-0.25^{*}	-0.28^{*}	-0.49^{**}	-0.31^{*}	1	-0.57**	-0.38^{ns}	-0.63**	-0.44*	-0.45*	-0.67**	-0.66**
MD	-0.22^{ns}	-0.20^{ns}	0.28^{ns}	0.58^{**}	0.12^{ns}	0.51^{**}	0.60^{**}	0.53^{**}	-0.69^{**}	1	0.21^{ns}	0.63**	0.06^{ns}	-0.02^{ns}	0.50*	0.29^{ns}
ED	-0.92^{**}	-0.90**	0.50^{*}	-0.33^{*}	0.60^{**}	0.31^{*}	0.39^{*}	0.17^{ns}	-0.83^{**}	0.40^{*}	1	0.46*	0.50*	0.38^{ns}	0.39^{ns}	0.57**
EL	-0.48^{**}	-0.49^{**}	0.16^{ns}	0.29^{*}	0.29^{*}	0.49^{**}	0.88^{**}	0.65^{**}	-0.77^{**}	0.79^{**}	0.95^{**}	1	0.50*	0.12^{ns}	0.75**	0.41*
TKW	-0.73^{**}	-0.68^{**}	0.71^{**}	-0.42^{**}	0.21^{ns}	-0.08^{ns}	0.34^{*}	0.22^{*}	-0.50^{**}	0.05^{ns}	0.77^{**}	0.55^{**}	1	0.14^{ns}	0.38^{ns}	0.43*
KRPE	-0.46^{**}	-0.46^{**}	0.14^{ns}	-0.04^{ns}	0.20^{ns}	0.13^{ns}	-0.26^{*}	-0.28^{*}	-0.56^{**}	-0.06^{ns}	0.98^{**}	0.03^{ns}	0.17^{ns}	1	0.28^{ns}	0.50*
KNPR	-0.67^{**}	-0.71^{**}	-0.06^{ns}	0.19^{ns}	0.32^{*}	0.43^{*}	0.60^{**}	0.45^{**}	-0.83^{**}	0.64^{**}	0.90^{**}	0.78^{**}	0.43^{**}	0.19^{ns}	1	0.72**
GY	-0.73^{**}	-0.78^{**}	-0.12^{ns}	-0.18^{ns}	0.42^{**}	0.28^{*}	0.28^{*}	0.39^{*}	-0.84^{**}	0.28^{*}	0.95^{**}	0.37^{*}	0.43^{**}	0.59^{**}	0.80^{**}	1

DA=Days to 50% anthesis, **DS**=Days to 50% silking, ASI=Anthesis and Silking Interval, LL=Leaf Length, LW=Leaf Width, LA=Leaf Area, PH=Plant height, EH=Ear Height, PA=Plant Aspect, MD=Days to maturity, ED= Ear Diameter, EL=Ear Length, TKW=Thousand Kernel Weight, KRPE=Kernel row per ear, NKPR=Number of kernel per row, GY=Grain Yield.

position on the same chromosome or due to pleiotropic effect of few genes in simultaneously affecting all the traits.

Number of kernels per row had positive and highly significant phenotypic correlation with ear length, and plant height, and also it had a positive and significant correlation with days to maturity. On the other hand, 1000-kernels weight had positive and significant correlation with ear length, ear diameter, and anthesis-silking interval. In line with this finding Asrar-urRhman et al. (2007) reported that plant height had positive and significant correlation with number of rows per ear. Abou-Deif (2007) and Habtamu and Hadji (2010) also reported ear length had positive and significant correlation with 100-grain weight and number of kernels per row and it also had significant but negative correlation coefficient with ear diameter. Ear length had positive and highly significant correlation coefficient with plant height, days to maturity and ear height and it had a positive and significant correlation coefficient with ear diameter. The low phenotypic correlation coefficients recorded among the traits could arise due to the modifying effect of environment on the association of character at the genetic level (Alake et al., 2008). The positive relationships observed in this study also indicate that favorable genes are controlling these traits and could be utilized for the improvement of the population in maize breeding programs. Thus, the information on correlations among traits remains crucial in improving the efficiency of breeding programs by employing the appropriate selection indices in inbred line development.

Strong genotypic correlation (rg=0.94**) between ear height and plant height suggests that tall plants tend to have high ear placement compared to shorter plants. This could lead to high dry matter accumulation carried out by more number of leaves possessed in tall plants. It also implies that taller lines are in better position to support kernel growth through stem reserve mobilization (Nzuve et al., 2014). This was indicated by moderate genotypic correlation coefficient of plant and ear height with

Table 3. Genotypic direct effect (diagonal bold and underlined) and indirect effect (off diagonal) of the thirteen characters on grain yield of inbred lines evaluated at Jimma in the main crop season of 2016.

Traits	DA	DS	LW	LA	PH	EH	PA	DM	ED	EL	TKW	KRPE	KNPR	rg
DA	**0.105**	-0.174	-0.079	0.033	-0.182	0.032	0.137	-0.104	0.013	0.403	-0.229	-0.26	-0.441	-0.73**
DS	0.104	**-0.176**	-0.087	0.033	-0.187	0.032	0.138	-0.094	0.012	0.411	-0.213	-0.26	-0.467	-0.78**
LW	-0.03	0.056	**0.272**	-0.156	0.121	-0.026	-0.051	0.056	-0.008	-0.243	0.065	0.113	0.21	0.42**
LA	-0.016	0.028	0.204	**-0.209**	0.204	-0.038	-0.057	0.24	-0.004	-0.411	-0.025	0.073	0.283	0.28*
PH	-0.034	0.059	0.059	-0.077	**0.552**	-0.095	-0.101	0.283	-0.005	-0.738	0.106	-0.146	0.395	0.28*
EH	-0.033	0.056	0.071	-0.079	0.519	**-0.101**	0.064	0.25	-0.002	-0.545	0.068	-0.158	0.296	0.39*
PA	0.07	-0.118	-0.068	0.059	-0.271	-0.031	**0.207**	-0.325	0.012	0.646	-0.157	-0.316	-0.546	-0.84**
DM	-0.023	0.035	0.033	-0.107	0.332	-0.054	-0.143	**0.472**	-0.006	-0.664	0.016	-0.034	0.422	0.28*
ED	-0.096	0.158	0.163	-0.165	-0.018	-0.017	-0.171	0.188	**0.014**	-0.797	0.241	0.553	0.592	0.95**
EL	-0.051	0.086	0.078	-0.102	0.486	-0.066	-0.159	0.372	-0.013	**-0.839**	0.172	0.016	0.513	0.37*
TKW	-0.076	0.119	0.057	0.016	0.187	-0.022	-0.103	0.023	-0.011	-0.461	**0.313**	0.096	0.283	0.43**
KRPE	-0.048	0.081	0.054	-0.027	-0.143	0.028	-0.115	-0.028	-0.013	-0.025	0.053	**0.565**	0.125	0.59**
KNPR	-0.071	0.125	0.087	-0.089	0.331	-0.045	-0.171	0.302	-0.012	-0.654	0.134	0.107	**0.658**	0.80**

DA=Days to 50% anthesis, DS=Days to 50% silking, LW=Leaf Width, LA= Leaf Area, PH=Plant height, EH=Ear Height, PA=Plant Aspect, DM=Days to maturity, ED= Ear Diameter, EL=Ear Length, TKW=Thousand Kernel Weight, KRPE=Kernel rows per ear, NKPR=Number of kernels per row, GY=Grain Yield, rg= genotypic correlation, Residual = 0.214.

grain yield in the current study.

Path coefficient analysis

Genotypic direct and indirect effect of characters on grain yield

Traits which indicated significant genotypic correlation with grain yield were further analyzed for direct and indirect effects on grain yield and the result is presented in Table 3. Positive and higher genotypic direct effects on grain yield was observed with number of kernels per row (0.658) followed by number of kernel rows per ear (0.565) and plant height (0.552). These characters can, therefore, be considered as the main components for selection in a breeding program designed for higher grain yield improvement. This finding is in agreement with Tulu (2014) who reported plant height, number of kernels per row, 1000-kernels weight, ear diameter and leaf width contributed positive direct effect towards grain yield. The negative direct effect was recorded with ear height (-0.101), leaf area (-0.209) and ear length (-0.839) on the grain yield. These traits, except days to 50% silking, had positive and significant genotypic correlations with grain yield (Table 2).

Number of kernels per row, number of kernel rows per ear, plant height and 1000-kernels weight exerted high direct effects and also had positive and highly significant association with grain yield. These traits could be used as reliable indicators in indirect selection for grain yield as they have positive and highly significant direct association with grain yield. Even though days to 50% anthesis and plant aspect associated negatively and significantly with grain yield, they exerted positive direct effects on grain yield. The negative association of days to 50% anthesis and plant aspect with grain yield was attributed to their negative indirect effects through days to 50% silking, leaf width, plant height, days to maturity, number of kernels per row, 1000-kernels weight and number of rows per ear. With this condition in place, a restricted simultaneous selection model is to be followed, that is, restrictions are to be imposed to nullify the undesirable indirect effects through days to 50% silking, leaf width, plant height, days to maturity, number of kernels per row, 1000-kernels weight and number of rows per ear. This is supported by the findings of Singh and Kakar, 1977).

In addition to its maximum direct effect on grain

Table 4. Phenotypic direct effect depicted diagonal (bold face) indirect effect off-diagonal for the studied traits.

Traits	DA	DS	PA	ED	EL	TKW	KRPE	KNPR	rp
DA	**0.01**	-0.136	-0.092	-0.125	0.152	-0.061	-0.055	-0.331	-0.64**
DS	0.01	**-0.138**	-0.092	-0.125	0.149	-0.056	-0.055	-0.343	-0.66**
PA	0.005	-0.072	**-0.178**	-0.114	0.218	-0.04	-0.067	-0.403	-0.66**
ED	0.199	-0.006	0.087	**0.102**	-0.16	0.046	0.057	0.235	0.56**
EL	-0.004	0.059	0.112	0.091	**-0.346**	0.045	0.017	0.451	0.42*
TKW	-0.006	0.085	0.078	0.099	-0.173	**0.091**	0.021	0.228	0.43*
KRPE	-0.003	0.051	0.08	0.075	-0.041	0.012	**0.149**	0.168	0.50*
KNPR	-0.005	0.078	0.119	0.077	-0.26	0.034	0.041	**0.601**	0.72**

DA= Days to 50% anthesis, DS=Days to 50% silking PA=Plant Aspect, ED= Ear Diameter, EL=Ear Length, TKW=Thousand Kernel Weight, KRPE=Kernel rows per Ear, NKPR=Number of kernel per row, rp=phenotypic correlation, residual =0.528.

yield, number of kernels per row exhibited positive indirect effect through kernel rows per ear, 1000-kernels weight, days to maturity, plant height, leaf width and days to 50% silking. Number of kernel rows per ear had not only positive direct effect on grain yield but also indicated indirect and positive effect on yield through 1000-kernels weight, ear height, leaf width, days to 50% silking and days to 50% anthesis. Plant height exhibited positive and direct effect on grain yield and also it had a positive indirect effect on yield through number of kernels per row, 1000-kernels weight, days to maturity, leaf width and days to 50% silking. Days to maturity, 1000-kernels weight, leaf width, plant aspect, and days to 50% anthesis contributed relatively medium direct effect with yield per hectare. These characters can, therefore, be considered as major components for selection targeting improved grain yields.

Leaf area, ear height and ear length exerted negative direct effects, but exhibited a positive correlation with grain yield. The positive association of these traits with grain yield was due to their positive indirect effects through other traits. Ear height indicated positive indirect effect on grain yield through number of kernels per row, 1000-kernels weight, days to maturity, plant aspect, plant height, leaf width and days to 50% silking.

Leaf area exerted a positive indirect effect on grain yield through number of kernels per row, kernel row per ears, days to maturity, plant height, leaf width and days to 50% silking. Ear length exerted a positive indirect effect on grain yield through leaf width, plant height, days to maturity, number of kernels per row and number of kernel rows per ear. Similar results were reported by Akbar et al. (2008); Rafiq et al. (2010); Fekadu (2014) and Tulu (2014). Selection for such characters may not bring improvement in grain yield as such. Their higher indirect positive effects could most likely be neutralized by negative indirect effect via other characters and this can lead to their low and non-significant genotypic correlations with grain yield. According to Singh and Chaudhary (1977) in a situation where a character is having positive association and high indirect effects but negative direct effects, emphasis should be given to the indirect effects and thus, indirect causal factors have to be considered simultaneously for selection. Therefore, it is evident from the result of the present study that higher emphasis should be placed on number of kernels per row, number of kernel rows per ear, plant height, days to maturity, 1000-kernels weight, leaf width and ear diameter since they exerted positive direct effect on grain yield and exhibited significant positive association with grain yield (Table 4).

Phenotypic direct and indirect effect of characters on grain yield

The path coefficient analysis at the phenotypic level based on grain yield as dependent variable revealed that number of kernels per row, ear diameter, number of kernel rows per ear and 1000-kernels weight exerted positive and direct phenotypic effect on grain yield and exhibited positive association with grain yield. This implies that given other characters are kept constant, improvement in one of these characters will concomitantly improve grain yield, which confirms that these characters are the major contributors to yield improvement at the phenotypic level. This is supported by the findings of Tulu (2014). Though days to 50% silking and plant aspect were negatively and highly significantly correlated with grain yield both showed a minimum negative direct effect on grain yield. Ear length indicated significant positive correlation coefficient with grain yield, but the direct effect of ear length was negative or negligible. However, it exerted positive indirect effect through number of kernels per row, number of kernel rows per ear, 1000-kernels weight, ear diameter, plant aspect and days to 50% silking. It was earlier explained that if correlation coefficient among traits is positive, but direct effect of character is negative or negligible the direct effects seem to be the cause of positive correlation (Singh and Chaudhary, 1977). In such instances the indirect causal factors should be considered for simultaneously selection.

Plant aspect exerted a positive indirect effect on grain yield through ear length and days to 50% anthesis even though it had a negative direct effect on grain yield. Besides, it had higher positive direct effect on grain yield, number of kernels per row and had a positive indirect effect on grain yield through number of kernel rows per ear, 1000-kernels weight, ear diameter, plant aspect and days to 50% silking. Even though number of days to 50% anthesis was associated negatively with grain yield this trait exerted a positive direct effect on grain yield. The negative association of days to 50% anthesis with grain yield was attributed to the negative indirect effects of this trait through days to 50% silking, plant aspect, ear diameter, 1000-kernels weight, number of kernels per row and number of kernel rows per ear.

Conclusion

Grain yield showed positive and highly significant genotypic correlation with ear diameter, kernel number per row, days to 50% silking, kernel rows per ear, 1000-kernels weight and leaf width indicating that these traits can be used for indirect selection to improve grain yield. At phenotypic level grain yield showed positive and highly significant correlation with number of kernels per row and ear diameter implying that any environment that favored the expression of grain yield also favored expression of associated traits and vice versa. The genotypic path coefficient analysis revealed that number of kernels per row had higher genotypic direct effect on the grain yield followed by number of kernel rows per ear and plant height and also correlated positively and significantly with grain yield. At phenotypic level grain yield had a positive direct effect with the kernel number per row, ear diameter, kernel rows per ear, 1000-kernels weight and days to 50% anthesis and also had a positive association with grain yield indicating the possibility of improving grain yield through selection for these traits. It can, therefore, be concluded that in the process of developing maize inbred lines selection of plants in successive stages of self-pollination should be exercised focusing on the major ear traits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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