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Full Length Research Paper

Correlation and path coefficient analysis of yield and agronomic characters among open pollinated maize varieties and their F_1 hybrids in a diallel cross

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A two-year study was conducted on maize (*Zea mays* L.) at the University of Ilorin Teaching and Research Farm Ilorin, Nigeria, during 2005 and 2006 growing seasons. The objective was to investigate correlation between grain yield and other agronomic parameters using 10 open-pollinated maize varieties and their 45 F_1 hybrids in a half diallel. Positive and significant phenotypic and genotypic correlations were found for days to 50% tasselling with plant and ear height, and grain yield with plant height, number of grains ear^{-1} and ear weight. Positive and significant environmental correlation was also recorded for grain yield with plant and ear height, and ear weight. The path analysis revealed that, days to 50% silking, ear weight and number of grains ear^{-1} had the highest direct effect on grain yield, while number of grains ear^{-1} had the highest moderate indirect negative effects on grain yield. Days to flowering, plant and ear height, number of grains ear^{-1} and ear weight could be the important selection criteria in improving open pollinated maize varieties and hybrids for high grain yield.

Key words: Correlation coefficient, path analysis, maize grain yield, agronomic characters.

INTRODUCTION

Maize (*Zea mays* L.) is an important staple food crops and provide bulk of raw materials for the livestock and many agro-allied industries in the world. Plant breeders are interested in developing cultivars with improved yield and other desirable agronomic and phenological characters. In order to achieve this goal, the breeders had the option of selecting desirable genotypes in early generations or delaying intense selection until advanced generations (Puri et al., 1982). The selection criteria may be yield, or one or more of the yield component characters. However, breeding for high yield crops require information on the nature and magnitude of variation in the available materials, relationship of yield with other agronomic characters and the degree of environmental influence on the expression of these component characters. Since grain yield in maize is quantitative in nature and polygenically controlled, effective yield improvement and simultaneous improvement in yield components are imperative (Bello and Olaoye, 2009). Selection on the basis of grain yield character alone is usually not very effective and efficient. However, selection based on its component characters could be more efficient and reliable (Muhammad et al., 2003). Knowledge of association between yield and its component traits and among the component parameters themselves can improve the efficiency of selection in plant breeding. Correlation coefficient measures the mutual association between a pair of variables independent of other variables to be considered. Where more than two variables are involved, correlation coefficient alone does not give complete picture of the interrelationship (Fakorede and Opeke 1985). To determine relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the evaluation of the most effective procedures for selection of superior genotypes. When there is positive association of major yield characters,

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component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Nemati et al., 2009).

Path coefficient analysis is a standardized partial regression coefficient that allows partitioning of correlation coefficient into direct and indirect effects of various traits towards dependent variable, and also helps in assessing the cause-effect relationship as well as effective selection. Path analysis plays an important role in determining the degree of relationship between yield and its components. Studies of correlation and path analysis have recently been conducted in groundnut by Izge et al*., (*2004); in sorghum by Ezeaku and Mohammed, (2006); in pear millet by Izge et al*., (*2006) and in pea by Togay et al*., (*2008). Researchers have been attempted also in determine association between the characters for selection of high maize grain yield. Findings from two independent studies, (You *et al*., 1998; Annapurna *et al*., 1998) revealed positive and significant correlations between grain yield and number of rows ear^{-1}, number of grains row^{-1}. Khatun *et al*. (1999) reported that grain yield plant^{-1} was positively and significantly correlated with number of grains ear^{-1}, ear weight, 1000-grain weight and ear height. Orlyan *et al*. (1999) and Gautam *et al*. (1999) suggested that most important characters in improving maize grain yield are number of grains row^{-1}, number of grain ear^{-1} and plant height. However, Mohammad et al. (2003) determined the interrelationship between grain yield and its components from eighteen maize lines/ hybrids, using genotypic correlation and path coefficient analysis. Grain yield was positively and significantly associated with plant and ear height, ear diameter, number of grains ear^{-1}, number of grains row^{-1} and 1000-grain weight. Geetha and Jayaraman (2000) studied direct and indirect effects of different quantitative traits on grain yield in 90 hybrids and reported that number of grains ear^{-1} exerted a maximum direct effect on grain yield. They therefore suggested that selection of number of grains ear^{-1} could be highly effective for improvement of grain yield. Kumar and Kumar (2000) also stressed that plant height with higher number of grains row^{-1}, ear weight, and number of grains ear^{-1} could be selected for high yielding.

Review of literatures shows that determining relationships between yield and its components is essential for high maize yield. Although all the experimental results were not in agreement with one another, but in most experiments, some yield parameters such as number of grains ear^{-1} and ear weight feature prominently in improving grain yield. Thus, by determining association between maize grain yield and yield components and between yield components themselves as well as recognition of the parameters that have significant effect on yield, is a prerequisite plan for a meaningful breeding programme. The objectives of the present research therefore was to determine the association between maize grain yield and some other agronomic characters with the view to identifying characters whose selection could be used in improving grain yield.

MATERIALS AND METHODS

Ten open pollinated maize varieties (OPVs) developed for grain yield and adaptation to abiotic (drought) and biotic (Stalk rot, Striga and Downy mildew) stresses were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. They are early to medium maturing white cultivars with maturity period of 90 to 100 days. The origin, genetic background, breeding emphasis and ecological adaptation of the maize parents are shown in Table 1. The ten varieties were crossed in a partial diallel to generate 45 F_1 hybrids during 2004 and 2005 growing seasons at the Teaching and Research (T and R) farm of University of Ilorin (Latitude 80 29'N, Longitude 40 35'E and annual average rainfall of 945 mm). The resultant hybrids were harvested, processed and stored in the cold room prior to field evaluation. It is worthwhile to note that the ultimate goal is not diallel analysis in which using pure lines as parents is necessary. Soil samples were collected from the trial site before cropping and were analyzed in the laboratory for selected physical and chemical properties and presented in Table 2. The soil texture is loamy sand. At 0-15cm depth, the amounts of silt, sand and clay were 8, 84 and 8 respectively, with soil pH = 7.30 and CEC = 2.83 (C. mol kg^{-1}).

The parents and hybrids were evaluated using a randomized complete block design (RCBD) with 4 replicates in 2005 and 2006. Entries were made in 4-row plots of 5 x 1.5 m each and planted at inter-row spacing of 75 cm and within row spacing of 50 cm to enhance a population of about 53,333 plants ha^{-1}. Three seeds were initially planted per hill and were thinned to two plants per hill. Fertilizer was applied in split-dosage at three and seven weeks after planting (WAP) at the rate of 80 kg N, 60kg P and 60kg/ha K respectively from compound NPK fertilizer (20-10-10). Agronomic parameters measured in each year were seedling emergence, days to 50% tasselling, pollen shed and silking; anthesis-silking interval, plant and ear height (cm), number of grains ear^{-1} and ear weight. Plant height was measured from soil level to the node of the flag leaf and to the highest ear-bearing node respectively at harvest stage. Days to 50% tasselling, pollen shed and silking were calculated as the number of days from planting to when 50% of the population have tasseled, shed pollen and silked respectively. Anthesis-silking interval was estimated as the difference between days to pollen and silking, and grain yield (t/ha) measured after adjusting to 12% moisture content. Combined analysis of variance and means over years were computed using SAS PROC, (1999) for the parents OPVs and hybrids with respect to grain yield and other agronomic parameters respectively. The phenotypic (rph), genotypic (rg) and environmental (re) correlation coefficients were estimated from the mean squares and mean across products as suggested by Mode and Robinson (1959). The correlation coefficients were partitioned into direct and indirect effects using the path coefficient analysis according to Dewey and Lu (1959).

RESULTS AND DISCUSSION

In the study, phenotypic and genotypic correlation coefficients calculated among examined characteristics in maize genotypes are presented in Table 3 and 4. The correlation coefficients of the pairs of characters revealed the presence of significant and positive ($P < 0.05$) phenotypic correlation of grain yield ha^{-1} with days to 50% tasselling (rph = 0.34*), plant height (rph = 0.56*) and ear height (rph = 0.45*), number of grains ear^{-1} (rph = 0.59*), and ear weight (rph = 0.46*) (Table 3). This indicated that

Table 1. Origin, genetic background, breeding emphasis and ecological adaptation of the maize parents.

	Variety	Origin and genetic background	Breeding emphasis	Ecological adaptation
1	ACR 90 POOL 16-DT	Early white dent CIMMYT cultivar, derived from crosses among large numbers of early late white flint materials from Mexico, the Caribbean area, Central and South America. Selected for drought tolerance.	Stalk rot, *Striga* and drought tolerance.	Forest and savannah.
2	TZE COMP 4-DMR SRBC2	Early maturing white and semi dent cultivar, derived from diverse sources of early mid-altitude germplasm, intermatted with TZESR-W and DMR-ESRW.	Yield and *Striga* tolerance.	Forest and savannah.
3	TZE COMP4 C2	Early maturing white and semi dent cultivar, derived from diverse sources of early mid-altitude germplasm, intermatted with EV 8430-SR and IK 8149 SR. It has synchronous male and female flowering, lower plant height and small tassel size.	Yield and *Striga* tolerance.	Forest and savannah.
4	ACR 97 TZE COMP3 C4	Early white flint dent cultivar, derived from early mid-altitude germplasm with EV 8430-SR, DMR-ESRW, TZESR-W and IK 8149 SR intermatted.	Yield, downy mildew and *Striga* tolerance.	Forest and savannah.
5	HEI 97 TZE COMP3 C4	Early white flint dent cultivar, derived from early mid-altitude germplasm with EV 8430-SR, DMR-ESRW, TZESR-W and IK 8149 SR intermatted.	Yield, downy mildew and *Striga* tolerance.	Forest and savannah.
6	ACR 94 TZE COMP5	Early white flint dent cultivar, derived from early mid-altitude germplasm with Striga intermatted with TZE-WC3.	*Striga* tolerance.	Savannah.
7	TZE COMP3 DT	Early white flint dent cultivar, derived from diverse sources of early mid-altitude germplasm with drought tolerant cultivars, intermatted with TZESR-W and DMR-ESRW.	Drought tolerance.	Forest and savannah
8	TZE COMP3 C2	Early white and flint dent cultivar, derived from diverse sources of early mid-altitude germplasm, produced by intermating TZESR-W and DMR-ESRW.	Downy mildew and *Striga* tolerance.	Forest and savannah.
9	AK 95 DMR-ESRW	Early maturing and flint dent cultivar, developed from intermating diverse sources of early mid-altitude germplasm, produced by intermating DMR sources from Philippines with TZB, TZBP, TZSR and tropical late. Selected for earliness.	Downy mildew and *Striga* tolerance.	Forest.
10	TZE MSR-W	Early white semi dent cultivar, derived from early mid-altitude germplasm, developed from intermating local and early cultivars with TZSR.	Yield and *Striga* tolerance.	Forest and savannah.

Source: IITA Archival Report 1988-1992.

by increasing these attributes, could invariably increase grain yield. Khatun *et al*. (1999) found that grain yield plant^{-1} was positive and significantly correlated with number of kernels ear^{-1}, ear weight and ear insertion height. High correlation of grain yield with plant height is also reported by other researchers (Annapurna *et al*., 1998; Gautam et al., 1999). The relationship between seedling emergence and number of grains ear^{-1} was also positive and significant, indicating that early emergence genotypes could result in increased number of grains ear^{-1} and consequently increase grain yield. Days to anthesis was positive and significantly ($P < 0.05$) associated with plant and ear height and number of grains ear^{-1}. Troyer and Larkins (1985) observed that plant height was positively correlated with days to flowering morphologically, as internodes' formation stops at floral initiation, and that early flowering maize varieties are usually shorter in height. Genotypic correlation coefficients (Table 4) followed a similar trend in magnitude and significance with that of phenotypic coefficients, except plant and ear height with negative and non-significant correlation with number of grains ear^{-1}. There were positive significant phenotypic and genotypic correlations of days to flowering with plant and ear height; and grain yield with plant height, number

Table 2. Selected physical and chemical characteristics of the soil before cropping of maize.

Soil properties	Value of 0-15cm depth	Value of 15-30cm depth
Texture	Loamy sand	Loamy sand
Soil PH (water)	7.30	6.30
Sand %	84.00	88.00
Clay %	8.00	8.00
Silt %	8.00	4.00
Exchangeable Ca^{2+} (C. mol kg^{-1})	1.10	2.10
Exchangeable Mg^{2+} (C. mol kg^{-1})	1.60	2.10
Exchangeable Na^{+} (C. mol kg^{-1})	0.18	0.19
Exchangeable K^{+} (C. mol kg^{-1})	0.01	0.01
Total acidity H^{+} (C. mol kg^{-1})	0.04	0.04
Cation exchange capacity (C. mol kg^{-1})	2.83	4.44
% Organic Carbon	0.26	0.33
% Total Nitrogen	1.30	0.90
Available P (Mg kg^{-1})	4.10	3.80

Table 3. Analysis of phenotypic correlation for maize grain yield and other agronomic characters combined across years in Ilorin, Nigeria.

	Seedling emergence	Days to 50% tasselling	Days to 50% pollen shed	Days to 50% silking	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Number of grain ear^{-1}	Ear weight (t/ha)	Maize grain yield (t/ha)
Seedling emergence	1.00									
Days to 50% tasselling	0.02	1.00								
Days to 50% pollen shed	0.01	0.07	1.00							
Days to 50% silking	0.03	0.06	0.05	1.00						
Anthesis-silking interval	0.05	0.02	0.02	0.05	1.00					
Plant height (cm)	0.04	0.57*	0.04	0.04	0.04	1.00				
Ear height (cm)	0.02	0.72*	0.12	0.07	0.08	0.11	1.00			
Number of grain ear^{-1}	0.07	0.45*	0.45	0.08	0.05	0.47*	0.53*	1.00		
Ear weight (t/ha)	0.05	0.05	0.08	0.67*	0.05	0.71*	0.02	0.03	1.00	
Maize grain yield (t/ha)	0.04	0.34*	0.04	0.05	0.06	0.56*	0.45*	0.59*	0.46*	1.00

*, Significant at < 0.05 level of probability.

of grain ear^{-1} and ear weight. This suggests that genetic factors are responsible for these associations. Therefore, plant height, number of grain ear^{-1} and ear weight could also be considered for selection and improvement for high yielding varieties. Even though, both phenotypic and

Table 4. Analysis of genotypic correlation for maize grain yield and other agronomic characters combined across years in Ilorin, Nigeria.

	Seedling emergence	Days to 50% tasselling	Days to 50% pollen shed	Days to 50% silking	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Number of grain ear $^{-1}$	Ear weight (t/ha)	Maize grain yield (t/ha)
Seedling emergence	1.00									
Days to 50% tasselling	0.02	1.00								
Days to 50% pollen shed	0.12	0.02	1.00							
Days to 50% silking	0.02	0.05	0.45*	1.00						
Anthesis-silking interval	0.01	0.07	0.02	0.03	1.00					
Plant height (cm)	0.05	0.74*	0.05	0.45*	0.42*	1.00				
Ear height (cm)	0.02	0.54*	0.07	0.02	0.06	0.09	1.00			
Number of grain ear $^{-1}$	0.35*	0.02	0.02	0.05	0.02	-0.07	-0.02	1.00		
Ear weight (t/ha)	0.02	0.05	0.04	0.43*	0.35*	0.34*	0.37*	0.02	1.00	
Maize grain yield (t/ha)	0.02	0.08	0.02	0.03	0.08	0.44*	0.05	0.34*	0.43*	1.00

*, Significant at < 0.05 levels of probability

Table 5. Analysis of environmental correlation for maize grain yield and other agronomic characters combined across years in Ilorin, Nigeria.

	Seedling emergence	Days to 50% tasselling	Days to 50% pollen shed	Days to 50% silking	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Number of grain ear $^{-1}$	Ear weight (t/ha)	Maize grain yield (t/ha)
Seedling emergence	1.00									
Days to 50% tasselling	0.04	1.00								
Days to 50% pollen shed	0.05	0.07	1.00							
Days to 50% silking	0.12	0.05	0.03	1.00						
Anthesis-silking interval	0.15	0.11	0.03	0.02	1.00					
Plant height (cm)	0.12	0.13	0.04	0.12	0.03	1.00				
Ear height (cm)	0.57*	0.11	0.02	0.02	0.03	0.02	1.00			
Number of grain ear $^{-1}$	0.15	0.03	0.06	0.13	0.11	0.03	0.02	1.00		
Ear weight ((t/ha)	0.04	0.05	0.04	0.15	0.02	0.01	0.03	0.02	1.00	
Maize grain yield (t/ha)	0.04	0.12	0.03	0.11	0.03	0.87*	0.75*	0.34	0.61*	1.00

*,Significant at < 0.05 level of probability

genotypic correlations are comparable in magnitude, the genotypic correlations are of higher magnitude than their corresponding phenotypic correlations, indicating a strong inherent relationship among the characters studied. Environmental correlation coefficients between studied traits illustrated in Table 5 showed that plant and ear height, and ear weight have highly positive and significant correlation (re=0.87*, 0.75* and 0.61*) with grain yield. Days to plant emergence was also positive and significantly correlated with ear height. Westermann and Crothers (1977)

Table 6. Path coefficient analysis of grain yield of maize genotypes combined across years in Ilorin, Nigeria

Character		Means	Direct effects	Total effects									Total effect
				1	2	3	4	5	6	7	8	9	
1	Seedling emergence	38	0.191		0.035	-0.042	0.023	-0.034	0.045	0.011	0.034	0.056	-0.257
2	Days to 50% tasselling	52	0.034	0.044		0.045	0.032	0.056	0.033	0.054	0.045	-0.034	0.854
3	Days to 50% pollen shed	53	0.182	-0.061	0.047		0.034	-0.045	0.067	-0.066	0.067	0.065	0.452
4	Days to 50% silking	55	-0.443	0.073	0.085	0.012		0.044	0.056	0.034	-0.065	0.034	0.245
5	Anthesis-silking interval	3	0.147	0.046	0.047	0.041	0.045		0.072	0.005	0.127	0.033	0.342*
6	Plant height (cm)	121	0.314	-0.057	0.057	0.034	0.057	0.046		0.006	0.072	0.256	-0.234
7	Ear height (cm)	35	0.176	0.001	0.067	-0.053	-0.076	0.089	0.018		0.194	0.023	0.045
8	Number of grain ear $^{-1}$	54	0.525	0.003	0.043	0.063	0.053	-0.078	-0.083	-0.007		-0.141	0.786*
9	Ear weight (t/ha)	6.4	0.582	-0.013	0.082	0.045	0.052	0.098	0.045	0.005	0.426		0.843**

*, ** Significant at < 0.05 < 0.01 level of probability, respectively

reported that changes in yield and yield components had been attributed to plant's response to its environment which may or may not permit full genetic expression of each character. Thus, plant and ear height, and ear weight could be considered in improving maize yield in the breeding programmes. Significant positive correlations between yield and other agronomic characters that can improve yield are quite desirable in plant breeding, because it facilitates selection process and gains from selection.

Path coefficient analyses was also used to obtain further information on the interrelationships among traits and their effects on grain yield and are presented in Table 6. Ear weight showed the greatest direct effect on grain yield (pc = 0.582), followed by number of grain ear^{-1} (pc = 0.525) and days to 50% silking (pc = 0.443). Nemati *et al*. (2009) reported that ear weight has direct effect on grain yield. They opined that by increasing ear weight due to more absorption of photo assimilates, the most portion of assimilates remobilizes to grains, and invariably increase grain weight. Days to 50% silking showed high negative direct effect on grain yield (pc = -0.443). The number of grains ear^{-1} had the highest moderate indirect positive effects on grain yield by ear weight (p = 0.426), while ear weight had the highest moderate indirect negative effects on grain yield by days to seedling emergence (p = -0.013). It is also shown that, plant height had the highest moderate indirect positive effects on grain yield by ear weight (p = 0.256), while number of grain ear^{-1} had the highest moderate indirect negative effects on grain yield by ear height (p = -0.007). However, It is obvious that other variables could have effects on grain yield. In this study, days to flowering, plant and ear height, number of grains ear^{-1} and ear weight appeared to be the prominent characters that could be used in selecting for high yield, because of their highly significant genotypic and phenotypic correlations with grain yield. These characters also had the highest direct and indirect effects through most of the other characters. It is therefore, concluded that these agronomic parameters could be considered as important selection criteria in improving open pollinated maize varieties and hybrids for high grain yield.

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