World Journal of Agricultural Sciences 2 (3): 352-358, 2006
ISSN 1817-3047

Heritability, Character Correlation and Path Coefficient Analysis among Six Inbred-Lines of Maize (*Zea mays* L.)

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Abstract: Correlation coefficients and estimates of broadsense heritability of eleven (11) characters associated with grain yield were obtained for six inbred-lines of maize sown in the teaching and research farm of the University of Agriculture, Abeokuta, Nigeria in June 2002. Correlation coefficients of the 11 characters were also partitioned into direct and indirect effects using path coefficient analysis. All characters evaluated, with the exception of tassel number per plant and 100-kernel weight, were positively associated with grain yield per plant. Of all characters, only total number of grains per ear was positively and significantly correlated with grain yield (r = 0.940) whereas other characters were not significant correlated with grain yield. Ear-weight with sheath and ear-weight without sheath had the largest heritability estimate (99.99% each) while days from planting to harvesting had the lowest heritability estimate of 32.29%. Total number of grain per ear had very low direct effect (1.3) on grain yield and largest indirect effects of 87.27 through reduction of days from planting to silking. The study showed that total number of grain per ear can be used as the most reliable selection index for yield improvement in maize inbred lines.

Key words: Correlation · heritability · inbreds · yield-related traits · path analysis · *Zea mays* L.

INTRODUCTION

The presence of morpho-genetic variations in agronomic characters of a crop would be of considerable importance in determining the best method needed to improve the yield of that crop. It is necessary to have a good knowledge of those characters that have significant association with yield because the characters can be used as indirect selection criteria or indices to enhance the mean performance of varieties in a new plant population [1]. Genotypic and phenotypic correlation coefficients tell us the association between and among two or more characters. A significant association suggests that such characters could be improved simultaneously. However, such an improvement depends on phenotypic correlation, additive genetic variance and heritability [1].

A number of techniques are available for determining the extent of variability in a plant population or accessions. Principal Co-ordinate analysis (PCO) proposed by Gower [2] is an ordinational numeric technique which enables multi-dimensional relationship to be represented on two or three principal axes. Metroglyph analysis has been used to study the patterns of morphological variation in okra [3]. Simple and multiple regression analysis have been used to study character association in maize [4, 5]. The single linkage analysis has also been observed to produce a clearer and more informative display of the relative position of breeding lines in accessions of yam [6, 7].

As the number of independent variables influencing a particular dependent variables increases, the amount of interdependence of variables also increase such that indirect association becomes more complex and important. Under such a situation, correlation is not sufficient to explain the true association for effective manipulation of characters. It does not also indicate the cause and effect relationship and consequently, one may not be able to know which of the independent characters has the most direct effect on yield. Consequently, path coefficient analysis that analysis inter-character association in an array of crops has been suggested [3]. A path coefficient is a standardized partial regression coefficient that measures the direct

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influence of one variable upon another [8]. It also provides a means of partitioning both direct and indirect effects and effectively measuring the relative importance of causal factors.

Fakorede [9], reported that leaf virus infection exerted the greatest direct effect on yield in maize. Ariyo [3], showed that edible pod weight had the largest positive direct effect on pod yield with its largest indirect effect in the early seasons cultivation. Ataga [10], also reported that number of bunches per plant exhibited the largest direct effect on mesocarp oil yield in Oil palm (*Elaeis guineensis*). More recently, Banganwa and Kairon [11], reported that 100 - seed weight and number of grains per cob exhibited positive direct effect while number of cobs per plant showed negative effects on grain yield of winter maize. Grain yield in maize is a complex trait that is influenced by many factors including physiological and morphological yield-related characters that play interdependent roles [12]. Selection for desirable maize genotypes should be carefully made, based on the type of influence each character makes on yield.

The objectives of the study therefore were, to determine the inter-relation of grain yield and some yield related traits in six inbred lines of maize, estimate heritability of characters that have significant association with grain yield and to identify those characters that have direct and consistent association with grain yield.

MATERIALS AND METHODS

Six inbred-lines of maize (*Zea mays* L.) obtained from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria, were shown at the teaching and research farm University of Agriculture, Abeokuta (UNAAB) on latitude 7°N and longitude 3° 23'E in the rain forest vegetational zone of south- western, Nigeria, in June, 2002. The cultural practices of clearing, stumping and ridging were carried out manually. The six inbred-lines were planted in randomized complete block design (RCBD) with 3 replicates. Planting in each replicate was done in 10-row plots of 10 m with a spacing of 0.75 m between and 0.25 m within the hills and with 2 seeds per hill. Seedlings were later thinned to one plant per stand four weeks after planting (WAP).

Weeding was carried out twice manually; the first weeding was done fourth weeks after planting while the second weeding was effected eight weeks after planting. Fertilizer (NPK 20-10-10) was applied four and eight weeks after planting at a rate of 200 kg ha^{-1} in two split applications. Insecticides (vertox 85 and carbonfuran) were applied against stem-borer at six and nine weeks after planting. The maize inbreds were manually and individually harvested at harvest maturity. Individual inbred-lines were harvested separately so that agronomic characteristics can be measured and analyzed separately.

Measured variables: The measured variables included plant height (cm), tassel number for three plants, days from planting to silking (day), days from planting to harvesting (day), 100-kernel weight (g), number of kernel rows per ear, total number of grains per ear, ear weight with sheath, ear weight without sheath, shelling percentage, grain yield per plant (g).

Following data collections, the data obtained were subjected to analysis of variance (ANOVA). Pearson's correlation analysis was used to obtain correlation coefficients between pairs of characters and estimates of broad-sense heritability were obtained on entry mean basis using the mean squares from the analysis of variance table. Path-coefficient analysis was also done according to Dewey and Lu [8]. The nature of the causal scheme including eleven characters and grain yield is illustrated in Fig. 1. Hence, the following formulae were used to obtain path co-efficient analysis table according to Ahmed [13].

$$r_{1y} = P_1 + r_{1.2}P_2 + r_{1.3}P_3 + \ldots\ldots\ldots\ldots + r_{1'.10}P_{10} + r_{1.11}P_{11}$$
$$R_{2y} = r_{12}P_1 + P_2 + r_{23}P_3 + \ldots\ldots\ldots\ldots + r_{2.10}P_{10} + r_{2.11}P_{11}$$

$$R_{10y} = r_{1.10}P_{10} + r_{2.10}P_2 = r_{3.10}P_3 + \ldots\ldots\ldots\ldots + P_{10} + r_{10.11}P_{11}$$
$$R_{11y} = r_{1.11}P_{11} + r_{2.11}P_2 + r_{3.11}P_3 + \ldots\ldots\ldots\ldots + r_{10.11}P_{10} + P_{11}$$

The residual effect, which determines how best the causal factor accounts for the variability of the dependent factor (yield) was obtained using the formula [14].

$$P_X = 1 - P_{Xy}\, r_{Xy}$$

Where:
P_x is the residual effect of variable X
$P_{xy}r_{xy}$ = the product of direct effect of variable X and its correlation coefficient (r) with yield (y)

RESULTS

Mean squares from analysis of variance (ANOVA) of grain yield and related characters are shown in Table 1. Significant effects of replication were observed in days from planting to silking, 100-kernel weight and number of grain per row. Also all characters had significant treatment

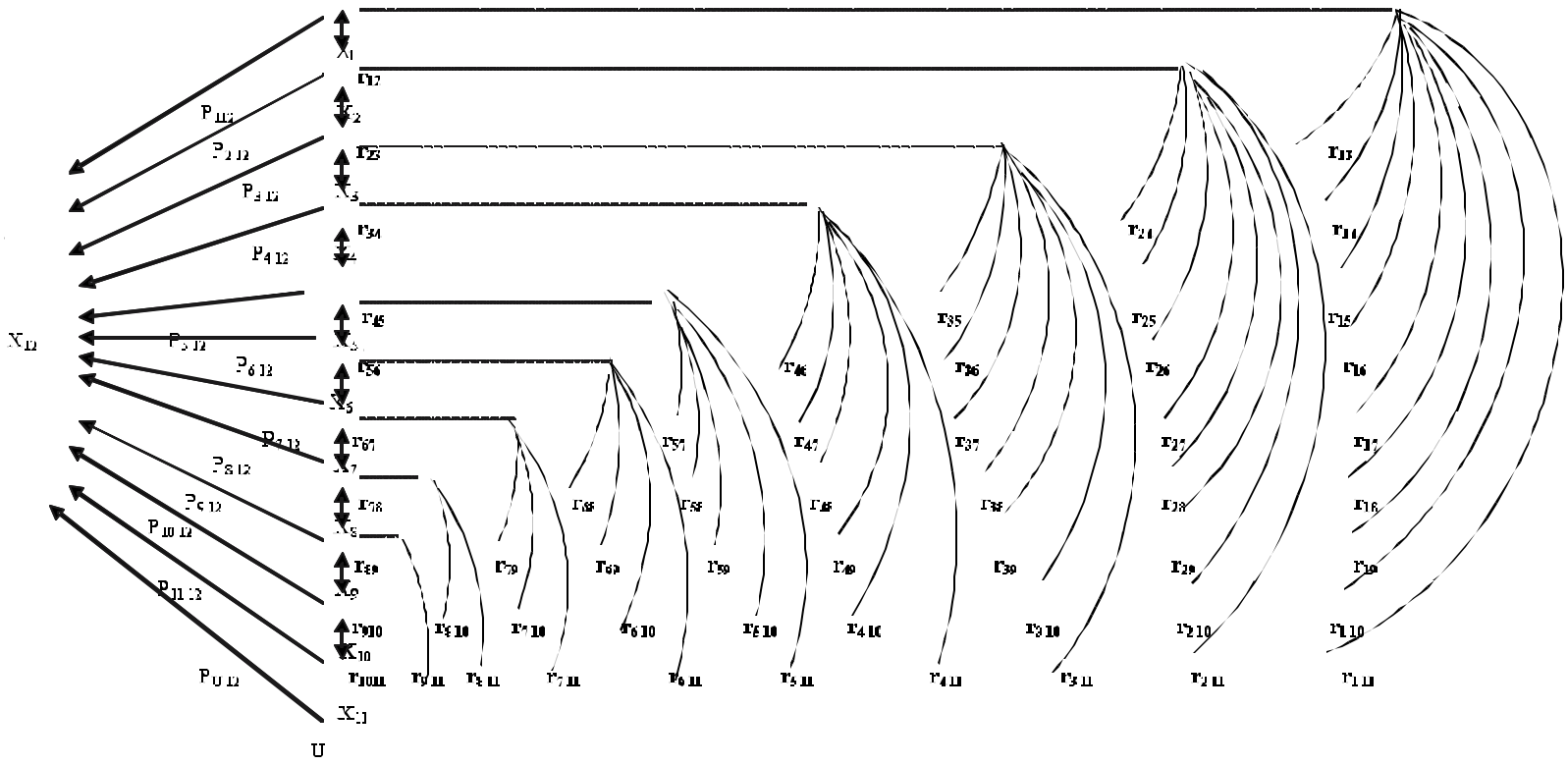

Fig. 1: Path diagram showing casual relationships of eleven (11) predictor variables (yield traits) with a response variable (dry root yield)

Table 1: Mean squares from analysis of variance of grain yield and other yield-related characters in six inbred lines of maize

Source of variation	DF	Grain yield (g)	Plant height (cm)	Tassel number	Days from planting to harvesting	Days from planting to silking	100-kernel weight (g)	Number of kernel rows/ear	Number of grains per row	Total No. of grains/ear	Ear weight with sheath (g)	Ear weight without sheath (g)	Shelling Percentage (%)
Replication	2	0.277	4.321	3.388	2.166	9.500**	0.856*	0.055	9.500*	1.166	0.179	0.041	1.517
Treatment	5	199.636**	999.893**	23.688**	10.400*	18.133**	102.790**	39.022**	52.500**	2998.100**	927.959**	393.191**	716.906**
Error	10	0.190	1.995	2.655	2.366	1.233	0.173	1.055	1.500	1.366	0.183	0.099	1.185

**, * Significant at 0.01 and 0.05 probability levels, respectively

Table 2: Mean performance of six maize lines evaluated for grain yield and related characters

Lines	Grain yield (g)	Plant height (cm)	Tassel number	Days from planting to harvesting	Days from planting to silking	100-kernel weight (g)	Number of kernel rows/ear	Number of grains per row	Total number of grains/ear	Ear weight with sheath (g)	Ear weight without sheath (g)	Shelling percentage (%)
111	29.40	136.00	6.70	87.00	57.00	22.40	19.00	12.00	119.00	77.20	44.10	66.60
114	21.30	153.60	5.00	91.00	55.30	37.40	14.00	10.00	59.70	75.10	55.10	38.60
115	10.10	106.30	8.70	86.00	50.70	22.60	10.00	10.00	44.70	30.40	21.50	46.90
211	24.40	136.00	12.00	86.00	57.00	23.80	9.70	19.00	97.70	60.30	47.20	51.70
212	15.50	109.70	9.00	88.00	53.00	26.40	11.00	16.00	59.00	59.70	37.10	41.60
213	8.90	138.00	12.00	88.00	55.00	22.50	15.00	8.00	39.00	73.80	44.80	19.90
Mean	18.20	129.90	8.90	87.70	54.70	25.80	13.10	12.50	69.80	62.70	41.60	44.20
L.S.D. (5%)	0.79	2.57	2.96	2.80	2.02	0.76	1.87	2.23	2.13	0.78	2.23	1.98
C.V%	2.40	1.10	18.30	1.80	2.00	1.60	7.80	9.80	1.80	0.70	0.80	2.50

Table 3: Mean, phenotypic and genotypic variances and heritability estimates of grain yield and yield-related characters in six inbreds of maize

Character	Mean	Range Min.	-	Max.	Phenotypic variance	Genotypic variance	Heritability (H_b)
Grain yield	18.27	8.90	-	29.40	348.26	348.07	99.95
Plant height	129.90	106.30	-	153.60	36.89	16.94	45.92
Tassel number	8.90	5.00	-	12.00	5.30	2.64	49.81
Days from planting to harvesting	87.67	86.00	-	91.00	3.50	1.13	32.29
Days from planting to silking	54.67	50.70	-	57.00	5.80	4.57	78.79
100-kernel weight	25.85	22.40	-	37.40	197.89	197.72	99.91
Number of kernel rows per ear	13.12	9.70	-	19.00	13.05	12.00	91.95

(Line) effects indicating that the six lines differed in respect of these characters.

Table 2 shows the mean performance of the six inbred lines of maize evaluated for grain yield and related characters. Mean grain yield per plant ranged between 8.9 g for line 213 and 29.4 g for line 111. Line 114 had the tallest height (153.6 cm) while line 213 had the lowest height (110.0 cm). All the six lines except line 114 mature at around the same time. All lines except line 115 also attained silking stage at around the same time. Line 114 had the highest 100-kernel weight of 37.4 g compared with line 111 that had 100-kernel weight of 22.4 g. Grain yield per plant of 29.4 g for line 111 against 21.3 g for line 114 suggests that 100-kernel weight is negatively correlated with grain yield per plant. However, line 213 had the lowest number of grains per ear (39.0) and lowest shelling percentage (19.9%) where as line 111 had the highest values of 119.0 and 66.6% for the two traits, respectively.

Mean performance, phenotypic and genotypic variances and heritability estimates of grain yield and other characters are presented in Table 3. Days from planting to harvesting had the lowest broadsense heritability estimate of 32.29% while ear weight with sheath and ear weight without sheath showed highest heritability value of 99.99% each.

Table 4 presents the correlation matrix between yield and yield-related characters. Differences were observed in the correlation coefficients in terms of magnitude and direction. Shelling percentage, ear-weight without sheath, ear-weight with sheath, number of grains per row, number of kernel rows per ear, days from planting to silking, days from planting to harvesting and plant height exhibited positive correlation coefficients with grain yield per plant. However, tassels number and 100-kernel weight exhibited negative correlation coefficient of -0.393 and -0.185, respectively, with grain yield per plant. Only total number of grain per ear had significant positive correlation (0.940) with grain yield per plant. Shelling percentage showed significant positive association with total number of grain per ear. Also ear weight without sheath showed significant positive correlation (0.884) with ear weight with sheath, days from planting to silking (0.827) and plant height at harvested (0.920). The same things applied to ear weight with sheath which had

Table 4: Correlation coefficients between yield and yield-related characters

Character	Shelling percentage	Ear weight without sheath	Ear weight with sheath	grain per ear	Total of grain per row	Number kernel row per ear	Number of 100-kernel weight	Planting to silking	Days from planting harvesting	Days from Tassels number	Plant height	Grain yield
Shelling %	-	-0.111	-0.082	0.850*	0.449	0.189	-0.18	0.274	-0.414	-0.371	-0.112	0.77*
Ear weight without sheath		-	0.884**	0.330	0.090	0.416	0.57	0.827*	0.63	-0.17	0.920**	0.535
Ear weight with sheath			-	0.368	0.091	0.734*	0.33	0.804*	0.563	-0.191	0.798*	0.491
Number of grains/ear				-	0.523	0.401	-0.16	0.726	-0.289	-0.167	0.274	0.940**
Number of grains/row					-	-0.471	-0.12	0.293	-0.385	0.305	-0.185	0.466
Number of kernel rows per ear						-	0.01	0.519	0.293	-0.411	-0.51	0.415
100-kernel weight							-	0.092	0.897**	-0.656	0.532	-0.185
Days from planing to silking								-	0.124	0.038	0.777*	0.763
Days from planting to harvesting									-	-0.586	0.589	0.027
Tassels No.										-	-0.231	-0.393
Plant height											-	0.470
Grain yield												-

*, ** Significant at 5% and 1% levels, respectively

Table 5: Direct and indirect effects of yield related characters on grain yield and residual effects in six inbreds of maize

	Indirect effect on grain yield												
	Direct effect on grain yield	Shelling %	Ear weight without shealth	Ear weight with sheath	Number of grains per ear	Number of grains per row	Number of kernel rows per ear	100-Kernel weight	Day from planting to silking	Day from planting to harvesting	Tassel number	Plant height	Correlation coefficient
Character shelling %	0.09		-0.26	-0.32	1.11	3.09	1.13	-2.1	-32.94	-3.39	-10.53	1.02	0.779
Ear weight without sheath	2.34	-0.01		3.49	0.43	0.62	2.49	6.66	-99.41	5.15	-4.82	-8.35	0.535
Ear weight with sheath	3.95	0.01	2.07		0.48	-0.62	4.39	3.86	-96.65	4.61	-5.42	-7.25	0.490
Number of grains per ear	1.31	0.08	0.77	1.45		3.60	2.40	-1.87	-87.27	-2.36	-4.74	-2.49	0.940**
Number of grains per row	6.89	0.04	0.21	-0.36	0.69		-2.82	-1.4	-35.22	-3.15	8.65	1.68	0.466
Number of kernel rows per ear	5.99	0.02	0.97	2.89	0.53	-3.25		0.12	-62.38	2.39	-11.66	-4.63	0.415
100-kernel weight	11.69	-0.02	1.33	1.30	0.21	-0.83	0.06		-11.06	7.34	-18.61	-4.83	-0.185
Day from planting to silking	-120.21	0.02	1.94	3.18	0.95	2.02	3.11	1.08		1.01	1.08	-7.06	0.763
Day from planing to harvesting	8.18	-0.04	1.47	2.22	-0.38	-2.65	1.76	10.49	-14.91		16.62	-5.35	0.027
Tassel number	28.37	-0.03	-0.39	-75.00	-0.22	2.10	-2.46	-7.67	-4.57	-4.79		2.09	-0.393
Plant height	-9.08	-0.01	2.15	3.15	0.36	-1.27	3.05	6.22	-93.40	4.82	-6.55		0.470

Residual effect (R_x) = 82.49; ** = Significant at 1 percent probability level

significant and positive correlation with number of kernel row per ear (0.734), days from planting to silking (0.804) and plant height (0.7980). Also, 100-kernel weight had positive and significant correlation with days from planting to harvesting (0.897) and days from planting to silking also had positive and significant association (0.777) with plant height.

The direct and indirect effects of yield-related characters on grain yield and residual effects (R_x) are given in Table 5. From the table, tassel number had the largest positive direct effect (28.37) on grain yield with its largest indirect effect (-7.67) through reduction in 100-kernel weight.

Moreover, days from planting to silking had the highest negative direct effect (-120.21) on grain yield though it had positive but non-significant correlation with grain yield yet, it had second highest positive indirect effect (3.18) with ear-weight with sheath. Plant height also had negative direct effect (-9.08) on grain yield with high positive indirect effect (6.22) through 100-kernel weight. Days from planting to harvesting had high positive direct effect (8.18) on grain yield. It also had the highest positive indirect effect (10.49) with 100-kernel weight. The shelling percentage had the lowest positive direct effects on grain yield with high negative indirect effect (-32.94) through days from planting to silking. Similarly, total number of grain per ear exhibited fairly low direct effect of 1.31 and largest negative indirect effect of -87.27 through days from planting to silking. Yet this trait (total number of grains per ear) had the highest positive and significant correlation (0.940) with grain yield. However, the path coefficient analysis revealed a residual effect of 82.49 (Table 5).

DISCUSSION

The facts that only days from planting to silking, 100-kernel weight and number of grains per row out of the twelves traits, had significant replication effects in the current study suggested that increasing the number of

replication was not important for yield and most yield-related characters. Highly significant treatment effects for all characters indicated that the six lines evaluated differed significantly in respect of these characters.

Very high heritability estimates (H_B) obtained for all character evaluated with the exception of plant height and days from planting to harvesting suggested that environmental influence was very low on these characters. It also suggested that the genotypic variance and genetic variability components [15] were very high. High H_B estimates according to Ojo and Amanze [16] strongly suggest that there is potential for large genetic determination for his characters which can be exploited for genetic improvement of grain yield in maize.

In terms of grain yield per plant, number of kernel rows per ear, total number of grain per ear, ear-weight with sheath and shelling percentage, line 111 appears to be the best candidate out of the six. Consequently, it can be used as a parent in the production of single-cross hybrids, although the line had relatively low 100-kernel weight of 22.4 g. However, 100-kernel weight was negatively correlated with grain yield per plant, number of grain per ear, number of grains per row and shelling percentage in the current study. For example, observed grain yield per plant of 29.4 g for line 111 as against 21.3 g for line 114 in this study confirms that 100-kernel weight is negatively correlated with grain yield. The implication is that high 100-kernel weight may not necessarily mean high grain yield per plant in maize. This observation is at variance with the reports of Singh [17], Satyanarayana [18] and Manivannan [19], who reported positive and significant association between 1000-seed weight and grain yield in maize.

The positive and significant associations between shelling percentage and grain yield on one hand and between shelling percentage and total number of grain per ear on the other hand suggest that maize lines of cultivars with high grain yield will always give high shelling percentage for grains. This observation is in consonance with observations of Rajesh and Godawat [20], who reported highly significant positive association between grain yield and shelling percentage in maize. Positive and significant association that existed between grain yield per plant and most yield-related characters suggests that grain yield can be improved through simultaneous selection for these characters. The total number of grains per ear that showed positive and significant correlation with grain yield, for instance, confirmed the observations above in addition to other reports [11, 20].

The significant and positive correlation between grain yield and total number of grains per ear according to Ariyo *et al.* [3] may be related to greater photosynthate and have accumulated in each grain of the ear. Consequently, total number of grains per ear could provide a good selection index for high-yielding maize lines.

Whereas, number of tassels per plant had a positive and high direct contributions (28.37) but non-significant and negative correlation (-0.393) with grain yield; total number of grains per ear had a low positive direct contribution (1.31) and highly significant correlation (0.940) with grain yield. This observation showed the extent of reliability of total number of grain per ear (and not tassel number) as a good selection index for grain yield. The observation that total number of grain per ear had positive direct contribution of 1.31 on grain yield with a similar report in Okra to Ariyo *et al.* [3] that in the late season cultivation, edible pod weight had a largest direct effects on pod yield with a large indirect effects through reduction in number of days of flowering.

In consideration of the highly significant association between grain yield and total number of grain per ear and large indirect effect between total number of grains per ear and days from planting to silking as obtained in this study, total number of grains per ear appeared to be the most reliable index in the improvement of grain yield in maize.

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