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Genetic variability, repeatability, traits relationships and path coefficient analysis in low nitrogen donor white inbred lines of maize (Zea mays L)

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Abstract

Genetic variability of agronomic traits of crops broadens the gene pool of crops. Repeatability and genetic advance determine the effectiveness of selection in breeding programme. Hence, phenotypic and genotypic variances, genotypic coefficient of variation, repeatability and expected genetic advance were estimated for three flowering and six morphological traits of white kernel low nitrogen donor maize inbred lines. Significant difference existed in the nine traits. Genotypic and phenotypic variances were equal for floral traits. Thus, gene actions for the traits was additive. Repeatability was high for the nine traits. In addition to high repeatability, anthesis-silking interval showed high genetic advance with high coefficient of variation suggesting its efficiency for selection. Phenotypic and genotypic correlations of grain yield with each of days to anthesis, plant height, ear height, leaf area and number of ear per plant were positive and significant. Genetic effect for grain yield correlated with that of days to silking, but this was not for phenotypic effect. Any of these traits can be selected for grain yield and the lines studied were considered suitable as gene pool in maize breeding for nitrogen stress tolerance. Path analysis showed that days to silking, leaf area and ear per plant had high positive effect with grain yield of the crop.

Keywords: correlation, genotype, genetic advance, heritability, path analysis, phenotype

Introduction

Genetic improvement of crops for quantitative traits requires reliable estimates of genetic variability, heritability and genetic advancement of intending parent materials to identify traits useful in planning an efficient breeding programme through selection (Vidya et al, 2002). Effectiveness of genetic improvement of a crop depends on the variability in the agro-morphological traits of individual genotype in a crop population. Selection is effective and rapid where the variation is large and the traits are highly heritable. Understanding the variation that exists will allow the breeder to determine the breeding strategies to adopt in his breeding programme.

Ojo et al (2006) reported metroglyph analysis, simple and multiple regression, single linkage and principal component analyses as among the techniques that have been used to describe the variability in plant population of many crops including maize so as to select suitable parents. These techniques show relative positions or dependence of the genotypes on others, but they do not relate breeding and phenotypic values of genotypes for the traits. These techniques may not adequately guide the breeders in breeding programs.

Performance of crop genotypes varies with changes in the environment. Measure of heritability of a trait is, therefore, essential to predict the performance of the genotypes for the trait considered. Falconer and Mackay (1996) compared breeding values and phenotypic values of a genotype and defined heritability as the measure of the breeding values in the phenotypic values of a genotype for a particular trait. Heritability plays a predictive role in breeding program, expressing the reliability of phenotype as a guide to its breeding value (Tazeen et al, 2009). There is a direct relationship between heritability and genetic advance. Genetic advance measures the response of the traits to selection. High genetic advance associated with high heritability estimates offers the most effective condition for selection (Larik et al, 2000; Soomro et al, 2008). Heritability is, therefore, more useful when used to calculate genetic advance.

Variability in the genetic components of agronomic traits of crops is the foundation of breeding programs. More importantly are genetic variations in stress tolerance among crop genotypes and the heritability for the trait in breeding improved cultivars for adaptation to stress growing conditions (Yadav et al, 2001). This study estimated the phenotypic and genotypic variabilities, repeatability and genetic advance in low nitrogen donor white inbred lines of maize. It also analyzed the path coefficient in the inheritance of significant relevant traits.

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Materials and Methods

Germplasm collection

A total of 25 white kernel inbred lines of maize were evaluated in the research. Eleven of the 25 inbred lines were obtained from International Institute of Agricultural Research (IITA) and 14 were obtained from International Centre for the Improvement of Maize and Wheat (CIMMYT).

Agronomic practices

Seeds of the inbred lines were planted in two-row plots, 5 m long with a spacing of 0.75 m between rows and 0.50 m between plants in a row in Ibadan, located in forest-savanna transition agro-ecology of Nigeria. Field were over-sown with three seeds and seedlings were thinned to two per stand two weeks after planting (WAP) to achieve a plant density of 53,333 plants ha^{-1}. The experiment was laid out in a randomized complete block design (Gomez and Gomez, 1984) with three replications. Standard cultural practices were applied for field maintenance and harvesting as recommended by Institute of Agricultural Research and Training (IAR&T, 2010).

Data collection

Data collected included days from planting to 50% tasseling (DTA), days from planting to 50% silk emergence (DTS), plant height (PH) and ear height (EH). PH was taken as the average height from the base of the plant to where tassel branching begins whereas EH was the average height from the base of the plant to the node bearing the uppermost ear. Anthesis-silking interval (ASI) was estimated by subtracting days to anthesis from days to silking. Number of ears per plant (EPP) were counted as the number of ears with at least one fully developed grain divided by the number of harvested plants and ear per plot were weighed according to International Board of Plant and Genetic Resources (IBPGR) and CIMMYT (1991). Leaf area (LA) was estimated by leaf length × leaf breadth × 0.75, and number of leaf per plant (NoL) were counted. Grain yield (GRY) was determined by the components of the plants ha^{-1} according to Bänziger et al (2000) as: Grain yield = plants ha^{-1} × ears per plant × grains per ear × weight per grain.

Data analysis

Data collected were subjected to Analysis of variance using SAS (2004) and significant means were compared using least significant difference at P≤ 0.05 and 0.01. Scored data were log-transformed before subjecting to analysis of variance. Phenotypic (δ^2_p) and genotypic (δ^2_g) variances were obtained according to Comstock and Robinson (1952). The mean values were used for genetic analyses to determine phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), according to Singh and Chaudhury (1985) as:

$$GCV = \frac{\sqrt{\delta_g^2}}{x} x100 \quad PCV(\%) = \frac{\sqrt{\delta_p^2}}{x} x100$$

where: δ^2_g = genotypic variance, δ^2_p = phenotypic variance and x = sample mean.

Genetic advance as percentage of means were obtained using method suggested by Allard (1960). The repeatability (broad sense heritability: h^2) estimate of each trait was computed according to Falconer (1989) as:

$$h^2 = \frac{\delta_g^2}{\delta_p^2}$$

where: δ^2_g = genotypic variance and δ^2_p = phenotypic variance.

Results

Analysis of variance showed that there were significant differences for all the parameters considered among the maize lines (Table 1). Table 1 also showed mean and range for each trait. The range for each of the trait was considerable wide. Table 2 presented phenotypic and genotypic variances, genotypic coefficient of variation, repeatability and genetic advance for the traits studied. The phenotypic and genotypic variances, respectively ranged from 0.04 to 1470.12 and 0.03 to 1,378.60. Repeatability for DTA, DTS, and ASI were 100% but least in number of ear per plant (81.82%). Coefficient of variation, repeatability and genetic advance was highest for ASI than for other traits.

Table 1 - Mean values, ranges and mean squares of some relevant agronomic traits of low nitrogen donor white inbred lines of maize.

Trait		Range		Mean square	
	Mean	Minimum	Maximum	Between lines (df = 24)	Error (df = 48)
Days to anthesis	53.84	49.00	59.00	31.92*	0.00
Days to silking	57.20	51.00	62.00	35.25*	0.00
Anthesis-silking interval	3.36	-2.00	7.00	12.22*	0.00
Plant height (cm)	105.20	86.57	133.50	440.95**	16.10
Ear height (cm)	41.02	23.80	56.80	140.62**	7.67
No. of leaf / plant	9.99	8.20	12.00	2.91*	0.02
Leaf area (cm^2)	341.12	268.46	405.75	4412.11*	276.31
No. of ear/plant	1.09	0.93	1.87	0.11*	0.02
Grain yield (kg / 7.5 cm^2)	1.06	0.84	1.71	0.25**	0.04

*,** mean significant at P=5% and 1%, respectively.

Table 2 - Variability, repeatability and expected genetic advance of some relevant agronomic traits of low nitrogen donor white inbred lines of maize.

Trait	Phenotypic coefficient of variability	Genotypic coefficient of variability	Repeatability	Expected genetic advance
Days to anthesis	6.06	6.06	100.00	12.48
Days to silking	5.99	5.99	100.00	12.34
Anthesis-silking interval	60.07	60.07	100.00	123.74
Plant height	11.52	11.31	96.35	22.87
Ear height	16.69	16.23	94.55	32.51
No. of leaf/plant	9.86	9.82	99.31	20.17
Leaf area	11.24	10.88	93.74	21.71
No. of ear/plant	17.57	15.90	81.82	29.62
Grain weight	27.26	0.01	84.00	14.03

Phenotypic and genotypic correlations of pairs of traits were presented in Table 3. Phenotypic and genotypic correlations of grain yield with DTA, plant height, ear height, leaf area, and number of ear per plant were positive and significant. Phenotypic correlation of grain yield with DTS was not significant. Plant height significantly correlated with ear height, leaf area and grain yield whereas ear height positively correlated with leaf area and grain yield but negatively correlated with number of leaf per plant. ASI negatively correlated with number of leaf per plant and number of ear per plant.

The direct, indirect and residual effects of some relevant agronomic traits on grain yield of the maize are shown in Table 4. Path coefficient analysis showed that the residual effect was 0.73. Only DTA and ASI had negative direct effects whereas the other traits had positive direct effects on grain yield. The DTS had the highest positive direct effect (1.26), though with high negative indirect effects of DTA (-0.78). The EH and NoL did not have indirect effects with the DTS on grain yield. The DTA had the highest negative direct effect (0.96), but high positive indirect effect of DTS on grain yield. The EPP also had a high positive direct effect on grain yield and all other traits except DTS had positive indirect effects. Table 4 also showed significant genotypic correlations of grain yield with DTA and EH at 5% probability whereas genotypic correlations of grain yield with LA and EPP at 1% probability was positively significant.

Discussion

The significant difference in the variance and wide range for all the parameters considered suggested that considerable variation existed among the inbred lines of maize. Thus, the lines may be efficient as gene pool for the improvement of the crop. The phenotypic variances that were higher than the genotypic variances for all the traits except DTA, DTS, and ASI implied that environmental factors influenced the agro-morphology and not flowering pattern of the inbred lines. The agronomic practices for the cultivation of the crop need to be thorough, appropriate and timely to reduce the effects of climate which may at times be difficult to control. The benefits of this is high repeatability for the traits. Values for DTA, DTS, and ASI that were same for variances and repeatability indicated that the effect of environment on these

Table 3 - Agro-morphological inter-traits relationship of some relevant agronomic traits of low nitrogen donor white inbred lines of maize.

Trait	Attribute	DTS	ASI	PH	EH	NoL	LA	EPP	GRY
DTA	P	0.82**	-0.23	-0.02	-0.03	0.15	0.11	-0.03	0.24*
	G	0.82**	-0.23	-0.03	-0.03	0.15	0.12	-0.04	0.26*
DTS	P		0.37**	-0.08	0.04	-0.02	0.05	-0.19	0.22
	G		0.37**	-0.08	0.04	-0.02	0.06	-0.21	0.24*
ASI	P			-0.10	0.11	-0.27**	-0.09	-0.26*	-0.02
	G			-0.10	0.12	-0.28**	-0.10	-0.29*	-0.02
PH	P				0.71**	0.12	0.34**	0.34**	0.38**
	G				0.73**	0.13	0.34**	0.38**	0.42**
EH	P					-0.24	0.38**	0.05	0.24*
	G					-0.25	0.40**	0.03	0.25*
NoL	P						-0.14	0.09	0.18
	G						-0.14	0.11	0.20
LA	P							0.33**	0.44**
	G							-0.15	0.48**
EPP	P								0.48**
	G								0.53**

*, and **, DTA, DTS, ASI, PH, EH, NoL, LA, EPP, GRY, P and G mean significant at P=5 % and 1 %, days to anthesis, days to silking, anthesis-silking interval, plant height, ear height, number of leaf per plant, leaf area, number of ear per plant, gain yield, phenotype and genotype

Table 4 - Path coefficient analysis of direct and indirect effects of some relevant agronomic traits of low nitrogen donor white inbred lines of maize.

Trait	Direct effect	DTA	DTS	ASI	PH	EH	NoL	LA	EPP	G_r with grain yield
DTA	-0.96		1.04	0.12	0.00	0.00	0.03	0.03	-0.01	0.24*
DTS	1.26	-0.78		-0.19	-0.01	0.00	0.00	0.01	-0.08	0.22
ASI	-0.52	0.22	0.47		-0.01	0.01	-0.06	-0.02	-0.11	-0.02
PH	0.09	0.02	-0.10	0.05		0.06	0.03	0.09	0.14	0.38
EH	0.09	0.03	0.05	-0.06	0.06		-0.05	0.10	0.02	0.24*
NoL	0.22	-0.14	-0.02	0.14	0.01	-0.02		-0.04	0.04	0.18
LA	0.27	-0.11	0.07	0.05	0.03	0.03	-0.03		0.13	0.44**
EPP	0.41	0.03	-0.23	0.14	0.03	0.00	0.02	0.09		0.48**

Residual effect = 0.73.

DTA, DTS, ASI, PH, EH, NoL, LA, EPP, GRY, P, G and Gr mean significant at P=5 % and 1 %, days to anthesis, days to silking, anthesis-silking interval, plant height, ear height, number of leaf per plant, leaf area, number of ear per plant, gain yield, phenotype, genotype and genotype correlation.

traits was negligible. The gene action for these trait was basically additive. Coefficient of variation, repeatability and genetic advance was highest for ASI than for other traits portraying the trait as probably most efficient for selection. This is possible because genetic advance indicates the degree of gain in a trait obtained under a particular selection pressure. Tazeen et al (2009) reported that repeatability plays a predictive role during selection and it indicates effective selection progress for phenotypic performance. Repeatability and genetic advance are important selection parameters (Larik et al, 2000; Soomro et al, 2008). High repeatability and high genetic advance offer the most effective condition for selection. It may not always be associated with a large genetic advance. This is responsible for suggestion to consider repeatability together with the corresponding expected genetic advance for the traits considered other than ASI. Based on this, all the traits can be reliably selected for in breeding maize for nitrogen stress because their repeatability were generally high.

Phenotypic and genotypic correlations of grain yield with DTA, plant height, ear height, leaf area and number of ear per plant were positive and significant. Thus, any of these traits especially number of ear per plant and possibly leaf area and plant height can be reliably used to select for grain yield because were relatively highly correlated with grain yield. Bello et al (2010) observed DTA was positive and significantly associated with plant and ear height. Ojo et al (2006) also observed number of grain per ear significantly correlated with grain yield. The selection will be rapid and effective when these traits are deployed because the genotypic correlation in each case was greater than their phenotypic coefficients. Significant high correlation of grain yield with leaf area and number of ear per plant can be due to the fact that both are yield contributing parameters. Leaves manufacture food which influences dry matter accumulation and cumulative effect of ear on plants determine the total yield. Barros et al (2010) also reported high number of phenotypic, additive genetic and environment correlations among agro-morphological traits of maize landraces populations.

Phenotypic correlation of grain yield with DTS was not significantly different but genotypic correlation was significant. The implication of this is that DTS can be selected for yield as it is capable of being inherited. Plant height highly significantly correlated with ear height. Either of these two traits can be selected in place of the other. Number of leaf per plant significantly and negatively correlated with ASI and ear height. This may be explained that as the number of leaf per plant increased, the ASI and ear height decreased. Thus, selection based on these traits have to be the reverse.

That all the traits except the DTA and ASI had positive direct effects on grain yield proved that any of them can be relied on, in maize improvement programs. However, the high positive indirect effects of the DTA and ASI are capable of balancing the negative direct effects on the grain yield. Thus, it can be suggested that all the traits be given priority in the crop improvement. Akinyele and Osekita (2006) found high indirect effects of trait can counterbalance low direct trait effects on crop yield. The EH and NoL did not have indirect effects with the DTS on grain yield implying that the effects of the two traits may not affect the direction of selection based on grain yield when DTS is considered. The EPP had a high positive direct effect on grain yield along with all other traits except DTS. This suggests that all the traits jointly contributed to the grain yield along with EPP except DTS. Ojo et al (2006) also observed this trend. High positive effect of the DTS, LA and EPP indicates that, with other variables constant, an increase in any of the three traits might increase grain yield. The positively significant genotypic correlations of grain yield with DTA, EH, LA, and EPP signifies that any of these four traits can be selected for grain yield.

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