

Genetic variances, heritability and traits association of early maturing maize hybrids under induced drought at seedling and flowering stages

ABSTRACT

Aims: Information on traits association and inheritance are crucial to designing appropriate breeding strategies for improving maize production and productivity in drought-prone ecologies. The objectives of this study were to investigate inter-trait relationships among maize hybrids and estimate genetic variances and heritability of drought tolerance parameters under seedling and flowering drought conditions.

Methodology: Sixty-six single cross hybrids generated using diallel mating design plus nine hybrid checks were evaluated using a 5 x 15 alpha lattice and randomized complete block designs in three replicates on the field and in the screenhouse respectively, during 2015 cropping season. Data were collected on grain yield, ears per plant, anthesis-silking interval, seedling aspect, chlorophyll content and leaf area and these data were subjected to analysis of variance as well as correlation and path coefficient analyses.

Results: Significant mean squares ($P = .05$) were observed for all measured traits except leaf area and shoot fresh weight. Narrow-sense heritability estimate for grain yield was moderate (33.4%) on the field and low (0 – 25%) for all the seedling traits. The low narrow-sense heritability estimates observed for most seedling traits implied that the scope for improvement of these traits in the genotypes is limited. Seedling traits under drought stress were not directly correlated with grain yield on the field except number of dead leaves relative to the total number of leaves. Results of the path analysis revealed that number of leaves, number of dead leaves and chlorophyll content under the screenhouse conditions had significant direct effects on grain yield on the field.

Conclusion: Number of leaves, and chlorophyll content under drought at seedling stage could therefore be used as indicator traits for grain yield improvement in maize exposed to drought stress at flowering stage.

Keywords: Drought, heritability, genetic variance, path analysis, maize hybrids, screenhouse conditions.

36 **Introduction**

37 Maize is an important staple food, animal feed and industrial crop in sub-Saharan Africa
38 (SSA). The savannas of the sub region offer ideal environments for maize production because
39 they are characterized by high solar radiation, low night temperatures, low incidence of pests,
40 and diseases. Over 85% of the population of people in the rural areas in Africa grows maize
41 due to its suitability in diverse farming systems and its ability for increased yield under
42 improved management practices as compared to other cereal crops [1]. Auta et al. [2]
43 recommended that the development and accelerated deployment of maize hybrids would
44 increase maize yields in the major maize producing countries of West and Central Africa
45 (WCA). Studies have demonstrated that hybrids can increase farmers' maize yields by more
46 than 40% in favourable growing environments and by more than 30% even under stressful
47 conditions [3].

48 Drought is a major constraint in boosting maize production in Africa especially in the SSA,
49 coupled with other abiotic stresses it has resulted in maize displacement by high value crops
50 to marginal areas [4]. Drought exerts its effects on yield through its effects on physiological
51 processes, and through losses in plant stand when such stress occurs during emergence and at
52 the seedling stage. The extent of grain yield reduction in maize due to drought stress depends
53 on the stage of crop development at the time of the stress and its severity. However, the
54 flowering period in maize is the most sensitive to drought. The most economically feasible
55 and sustainable way to boost maize production and productivity in SSA is to develop drought
56 tolerant varieties for the farmers. Earlier studies conducted in the rainforest agro-climatic
57 zone showed that maize planted early significantly out-yielded those planted later in the
58 season primarily because grain filling coincided with the period of relatively high incident
59 solar radiation [5]. Maize plants with excellent adaptive response to drought at seedling stage
60 will help in combating the effect of early season drought in the rainforest agro-ecology of
61 southwestern Nigeria. Therefore, the evaluation of maize crop at the seedling stage is an
62 important aspect of crop breeding program with the objective to evolve drought tolerant
63 varieties. Developing specific maize genotypes which can tolerate drought at seedling stage,
64 especially in southwestern Nigeria where the rainfall pattern is bimodal, will offer the farmers
65 in this region the opportunity of planting maize earlier in the year (that is, late February to
66 early April), immediately after the first few rains and by extension West Africa. Therefore,
67 development of high yielding cultivars that combine tolerance to drought at both seedling and
68 flowering stages could be a coping strategy to combat detrimental effects of climate change
69 on maize production and productivity in the sub-region.

70 Grain yield is a complex trait and it is collectively influenced by various component traits,
71 besides being polygenically inherited and highly influenced by environmental variation. The
72 appropriate knowledge of interrelationships between grain yield and its contributing
73 components can significantly improve the efficiency of breeding programs using appropriate
74 selection indices [6]. In making selection for improved genotypes in maize, yield is the
75 primary trait but selection under drought based on grain yield alone is inefficient due to low
76 heritability of grain yield and the complexity of genotype-environment interactions [7].
77 Genetic variance and heritability of maize grain yield are reduced under drought whereas
78 secondary traits have relatively high genetic variance and heritability [8,9]. However, the
79 relative usefulness of secondary traits as indirect selection criteria for grain yield is often
80 inconclusive for all experiments because of the nature of the genetic materials and different
81 conditions of experiments [10]. In the past years, the use of secondary traits with grain yield
82 in making selection has increased selection breeding efficiency in maize grown under stress
83 conditions by 20 to 50% [11, 12]. Badu-Apraku et al. [13] reported that the most reliable
84 traits for selection for improved grain yield under drought stress in the early maturing
85 germplasm were ear aspect, ears per plant, anthesis-silking interval, and plant aspect. There is
86 dearth of information on reliable seedling drought traits for predicting improved grain yield
87 under flowering drought conditions.

88 Correlation analysis helps to measure the level of relationships among traits and to establish
89 the level at which these traits are mutually different [14]. Path coefficient analysis helps to
90 know the nature, extent and direction of selection; it is the most valuable tool commonly used
91 to establish the exact relationships in terms of cause and effect, identifying the direct, indirect
92 and total (direct plus indirect) causal effects, as well as to remove any spurious effect that
93 may be present [15]. Studies had reported that tolerance to drought stress at seedling stage
94 and at flowering stage has no relationship, using correlation analysis [16]. However,
95 correlation analysis, being a bivariate analysis only detect linear relationships between two
96 variables while it assumes no significant influence of interrelationship of other variables.
97 Therefore, the use of multivariate techniques such as path coefficient analysis, which
98 considers the effect of several independent traits on a target (dependent) trait by partitioning
99 the total correlation into direct and indirect effects (effects exerted through other independent
100 variables) is necessary. In such analysis, traits with significant direct effect on a target trait
101 are identified while those with indirect effect through other traits are also detected.
102 Information obtained from such analysis is more important than mere correlation and would

103 not only help in identifying important secondary traits that could be used as indirect selection
104 criteria for improving maize genotypes for a desired trait, but will provide adequate
105 information useful to formulate base index which will in turn improve the efficiency of
106 selection for the target trait.

107 The primary objectives of this present study were to (i) estimate genetic variance and
108 heritability of traits for drought tolerance at seedling and flowering stages of maize hybrids;
109 and (ii) investigate the inter-trait relationships under seedling and flowering drought stress
110 conditions, using simple correlations and path co-efficient analyses.

111

112 **Materials and Methods**

113 **Generation of crosses**

114 Twelve inbred lines were planted in breeding nursery in a single-row plot, 5 m long at a
115 spacing of 0.75 m x 0.25 m. Standard agronomic practices were employed to ensure good
116 crop stand. At flowering, the twelve inbred parents were crossed in a diallel fashion to
117 generate 66 single-cross hybrids. The different crosses were harvested separately, processed
118 and packaged into trials for evaluation.

119

120 **Field performance evaluation**

121 Drought stress at flowering stage was achieved in the field. The experiment was conducted at
122 the Crop Science Unit of the Teaching and Research Farm, Obafemi Awolowo University, Ile
123 Ife ($7^{\circ}28'N$ $4^{\circ}33'E$, 244 m, 1200 mm rainfall) during the 2015 cropping season. The planting
124 was done on the 21st September, such that flowering could coincide with a period of no
125 rainfall (drought). A trial composed of the sixty-six (66) single cross hybrids plus nine checks
126 was laid out using a 5 x 15 alpha lattice design with three replications. Each entry was
127 planted into a single-row plot, 5 m long with 0.75 m spacing between rows and 0.50 m
128 spacing between plants within a row. Three seeds were sown per hole and later thinned to
129 two plants per hill to attain a population density of 53,333 plants ha⁻¹. A compound fertilizer
130 of NPK 15:15:15 was applied at the rates of 60 kgN, 60 kgP and 60 kg K₂O ha⁻¹ at two weeks
131 after planting. An additional 60 kgN ha⁻¹ was also applied as side dressing at four weeks after
132 planting (WAP) using urea (46% N). On each plot on the field, data were collected on days to
133 anthesis, days to silking, number of ears per plant (EPP), plant and ear heights. Plant aspect
134 was rated on a scale of 1 to 9, where 1 = excellent overall phenotypic appeal and 9 = poor

135 overall phenotypic appeal. Ear aspect was scored on a scale of 1 to 9, where 1 = clean,
136 uniform and large ears and 9 = rotten, variable and small ears. Stay-green characteristic (leaf
137 death score) was scored per plot at 70 days after planting, on a scale of 1 to 9, where 1 =
138 almost all leaves green and 9 = virtually all leaves dead. Harvested ears from each plot were
139 shelled to determine the percentage grain moisture. Grain yield in kg ha⁻¹ was adjusted to
140 15% moisture content and computed from the shelled grain weight.

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142 **Screenhouse evaluation**

143 Drought stress at seedling stage was imposed in the screenhouse. The sixty-six single-cross
144 hybrids plus nine hybrid checks were planted under drought stress imposed at the seedling
145 stage at the screen house, Department of Crop Production and Protection, Obafemi Awolowo
146 University, Ile Ife in 2015. The trial was laid out in a randomized incomplete block design
147 with three replications. Six seeds of each inbred were sown per pot. The methodology
148 proposed by Akinwale **et al.** [17] for screening maize genotypes for tolerance to drought at
149 seedling stage was adopted, water was applied to each pot at the rate of 0.6 litres daily for 7
150 days, after which watering stopped. Data were collected at two-day intervals from 3 days
151 after watering had stopped (DAWS) till 9 DAWS on the following: plant height, number of
152 leaves, number of dead leaves, leaf length and breadth, leaf area, and number of dead leaves
153 relative to the total number of leaves (RDL) in percentage. In addition, seedling aspect was
154 scored on a scale of 1 to 9, where 1 = absence of visible symptoms of stress: vigorous plants,
155 no wilting, no dead leaves, no chlorosis, no height reduction and unrolled turgid leaves and 9
156 = total collapse or 100% death of seedlings, dried leaves and stem, as described by Akinwale
157 **et al.** [17].

158

159 **Data analysis**

160 Data collected were subjected to analysis of variance using PROC general linear model
161 (GLM) procedure of Statistical Analysis Software (SAS), version 9.2 [18]. In the analysis,
162 genotype was considered as a random factor and to achieve that, random statement option in
163 GLM was used. Genetic variances were estimated using Proc Varcomp procedure of SAS.
164 Estimate of narrow-sense heritability was performed as the proportion of additive variance
165 over phenotypic variance expressed in percentage and this was done on plot mean basis for
166 all traits under the two study conditions. In addition, path coefficient analysis was carried out
167 to partition total correlation among traits into direct and indirect effects considering grain

168 yield as the dependent variable. Pearson correlation (phenotypic correlation) was first
169 calculated and then the correlation coefficients were partitioned into direct and indirect
170 effects through path coefficient analysis using PATHSAS program developed by Cramer et
171 al. [19].
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173 **Results and Discussion**

174 Results of analysis of variance (ANOVA) showed significant ($P = .05$) differences among the
175 genotypes for all seedling traits evaluated in the greenhouse except leaf area and fresh shoot
176 weight (Table 1). Similarly, significant ($P = .05$) effects were observed for genotype for all
177 measured traits under stress conditions on the field (Table 2). The significant mean squares
178 observed among the genotypes under the different stress conditions indicated presence of
179 wide genetic variability within the genetic materials, which implies that genetic progress
180 could be achieved from selection for improvement for drought tolerance at both growth
181 stages. The coefficients of variation (CVs) associated with the stressed environments are
182 usually higher and the coefficients of determination (R^2) lower than those associated with the
183 non-stressed environments. Thus, CVs of less than 30% was obtained only for seedling
184 aspect score, chlorophyll content and plant height under seedling drought conditions and for
185 all traits measured under flowering drought conditions except ear aspect. In addition, the
186 proportion of variation explained by the ANOVA model (R^2) is greater than 50% for
187 chlorophyll content, dry shoot weight and number of dead leaves and greater than 60% for all
188 the flowering drought traits, indicating the reliability of the model.

189 The additive variance measures the variation due to the average effects of alleles (additive
190 effects) and the variation in the effects that are transmitted from one generation to another
191 while the dominance variance is the variance due to interaction of average effects of alleles
192 (dominance effects) [20]. The dominance variance is a function of allele frequencies and the
193 level of dominance. In our present study, the additive variance was greater than non-additive
194 (dominance) variance for all traits except number of ears per plant under the flowering
195 drought conditions (Table 3). In contrast, the dominance variance was greater than the
196 additive variance for all traits under the seedling drought conditions, which implied that
197 tolerance to drought involves different genes or combination of genes depending on the stage
198 at which the drought set in in the crop cycle. Estimates of additive genetic variance were
199 significantly different from zero for all traits under field drought conditions and for all traits
200 under the greenhouse conditions except seedling aspect, dry shoot weight and fresh shoot

201 weight. Dominance variances were significantly different from zero for all measured traits
202 except seedling fresh shoot weight. Due to negative estimates, additive variance of dry shoot
203 weight and dominance variance of fresh shoot weight were equated to zero. Thus, their
204 dominance to additive genetic variance ratio could not be estimated. The dominance to
205 additive genetic variance ratios were greater than 0.5 for four out of the eight traits under
206 drought at the flowering stage and for seven out of the nine traits under seedling drought
207 conditions.
208

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209 Table 1: Mean squares of seedling aspects and other seedling traits of 66 hybrids plus 9 checks evaluated under induced drought at seedling stage at the
 210 screen house, 2015

SV	Df	Seedling aspect score	Chlorophyll content ($\mu\text{mol L}^{-1}$)	Plant height (cm)	Leaf area, (cm^2)	Number of dead leaves	Number of leaves	RDL	Fresh shoot weight (g)	Dry shoot weight (g)
Rep	2	12.20**	25.39	102.09**	90.15	5.32	39.66	854.30	9.07**	0.16*
Entry	74	1.83*	55.62**	29.04*	94.20	10.00**	55.56**	717.58**	0.26	0.05**
Error	148	1.27	16.39	19.34	79.73	3.17	35.91	416.36	0.26	0.03
R^2		0.46	0.63	0.45	0.37	0.62	0.44	0.47	0.49	0.53
CV		20.65	11.95	18.61	40.84	37.11	30.95	41.90	50.95	41.68

211 * significant at 0.05 probability level, ** significant at 0.01 probability level

212 RDL = number of dead leaves relative to the total number of leaves.

213 Table 2: Mean squares for grain yield and other agronomic traits of 66 hybrids plus 9 hybrid checks evaluated under drought at flowering stage, at the
 214 Teaching and Research Farm Obafemi Awolowo University, Ile Ife, 2015

Source of variation	Df	Grain yield	Ears per plant	Plant aspect	Ear Aspect	Anthesis - silking interval	Plant height	Ear height	Stay green characteristics
Block (Replicate)	12	652613.3**	0.16**	6.91**	5.64**	9.55**	1223.52**	388.68**	3.99**
Replicate	2	977096.1**	0.47**	9.76**	21.63**	9.75**	2628.29**	882.79**	13.26**
Genotype	74	318140.3**	0.112**	2.24**	2.73**	4.69**	455.57**	162.38**	2.17**

Error	136	120633.0	0.06	0.77	1.59	1.65	124.48	50.26	0.93	215
R ²		0.68	0.62	0.75	0.63	0.71	0.79	0.75	0.68	
CV		27.26	33.22	15.35	16.7	31.69	11.35	16.35	16.3	

217 * significant at 0.05 probability level, ** significant at 0.01 probability level

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222 Table 3: Additive ($\hat{\sigma}_A^2$) and non-additive ($\hat{\sigma}_{NA}^2$) variances, narrow-sense heritability estimates (h^2),
 223 for grain yield and other agronomic traits of hybrids generated from diallel crosses evaluated under
 224 terminal drought in the field and under imposed drought in the screen house

Traits	$\hat{\sigma}_A^2 \pm SE$	$\hat{\sigma}_{NA}^2 \pm SE$	$\hat{\sigma}_{NA}^2 / \hat{\sigma}_A^2$	h^2 (%)
Flowering drought environment				
Grain yield	40465.76±3512.730	36639.40±2026.930	0.91	33.4
Ears per plant	0.02±0.001	0.02±0.001	1.00	7.3
Plant aspect	0.35±0.030	0.22±0.020	0.63	35.7
Ear aspect	0.53±0.040	0.06±0.020	0.11	46.0
Anthesis-silking interval	0.90±0.070	0.37±0.030	0.41	45.0
Plant height	99.55±7.380	30.60±2.590	0.31	49.9
Ear height	17.70±1.590	13.58±1.010	0.77	31.1
Stay green characteristic	0.436±0.030	0.20±0.020	0.45	44.0
Seedling drought environment				
Seedling aspect	0.002±0.010	0.140±0.015	61.670	0.39
Chlorophyll content	3.154±0.390	15.270±0.360	4.840	17.0
Plant height	2.000±0.240	2.080±0.230	1.040	18.7
Leaf area	1.520±0.540	4.970±0.910	3.270	4.3
Number of dead leaves	0.412±0.070	2.080±0.060	5.060	11.6
Number of leaves	6.870±0.690	12.200±0.500	1.770	25.0
RDL	5.320±1.190	30.060±1.630	5.650	7.6
Fresh weight	0.001±0.001	0±0.003	0	0.38
Dry weight	0±0.0002	0.011±0.001	0	0.0

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236 Narrow-sense heritability estimate for grain yield was moderate (33.4%). The values of
237 narrow-sense heritability for the traits ranged from 7.3% for ears per plant to 50% for plant
238 height under drought at flowering and 0.38% for fresh weight to 25% for number of leaves
239 under seedling drought conditions. Heritability estimates provide information on how
240 probable a trait could be transmitted from parents to their offspring [20]. Low narrow-sense
241 heritability estimate observed for most measured traits, especially under drought at seedling
242 stage is an indication that the scope for improvement of these traits in the parents is limited.
243 However, it might be desirable to increase the number of replications and locations to
244 increase the accuracy of estimated entry means, and thus the heritability.

245 Adequate knowledge on the inter-relationship among traits is important in designing effective
246 selection programs for crop improvement. Results showed that seedling traits were not
247 directly correlated with grain yield except number of dead leaves relative to the total number
248 of leaves which displayed significant negative relationship (Table 4). Ears per plant showed
249 significant negative relationship with number of dead leaves and number of dead leaves
250 relative to the total number of leaves. This implied that a hybrid with high number of dead
251 leaves under drought at seedling stage will possibly give lower number of ears harvested per
252 plot under drought conditions at flowering. Plant aspect had significant negative relationship
253 with leaf area, number of leaves, shoot fresh weight and shoot dry weight. This suggests that
254 maize hybrids under drought stress at seedling stage with high number of leaves, leaf area,
255 shoot fresh weight and shoot dry weight would give rise to plants with excellent physical
256 appearance under the same condition at flowering stage. In addition, stay green characteristic
257 showed significant positive relationship with number of dead leaves and number of dead
258 leaves relative to the total number of leaves. Though some of the seedling drought traits were
259 found to be significantly correlated with traits taken on the field under flowering drought
260 conditions, the strength of the relationships was generally low. Therefore, the results of this
261 study showed that seedling drought tolerance traits cannot be used as the main criteria for
262 predicting grain yield in the hybrids under flowering drought conditions. This corroborates
263 the findings from the study of Meeks et al. [16] who reported that the seedling drought
264 conditions were independent of drought responses at flowering on the field, possibly due to
265 the type of screening environments used and the high genetic diversity that segregated for
266 traits conditioning drought tolerance. Even though low values of correlation coefficients (r)
267 were obtained, r measures only linear relationship, which path analysis helps to decompose

268 among the studied characters, thereby enhancing better interpretation of relationships as well
269 as pattern of the effects of one trait on the other.

270 An important objective of this study was to identify seedling drought traits with greatest
271 influence on grain yield for use in future breeding programs. Thus, the correlation
272 coefficients of the seedling drought traits with grain yield were further partitioned into direct
273 and indirect effects through path analysis (Table 5). The low residual effect (0.25) indicates
274 that the seedling traits altogether contributed substantially to grain yield. Among the seedling
275 traits, path analysis identified number of leaves (0.294), and number of dead leaves (-0.242),
276 chlorophyll content (0.052) as traits with significant direct contributions to grain yield,
277 whereas number of leaves had the highest direct effect. This result was not surprising since
278 leaf synthesizes the photosynthates, which are stored in plant tissues and culminate in yield
279 for the crop. Number of leaves was related to the number of photosynthetic components such
280 as chloroplasts and therefore an increase in the number of leaves improves photosynthetic
281 capacity. Path coefficient analysis showed that number of seedling leaves was the most
282 important trait for grain yield improvement through its direct and indirect effects on grain
283 yield. Number of leaves, relative number of dead leaves to the total number of leaves are
284 contributing indirectly to the number of dead leaves. For number of leaves, number of dead
285 leaves recorded the highest indirect effect. Under seedling drought conditions, in our study,
286 number of leaves, chlorophyll content and leaf area were identified as the most important
287 traits contributing to the variation in grain yield, suggesting that they are reliable secondary
288 traits under drought stress conditions. In addition, these traits can be used as criteria for
289 selecting for drought-tolerant genotypes under seedling stress conditions in early maturing
290 maize hybrids. Under the field conditions, the path analysis identified ear aspect (-0.48), ears
291 per plant (0.331), ear height (0.283), plant height (-0.255) and plant aspect (-0.219) as traits
292 with the highest direct effect on grain yield (Table not shown). These results are similar with
293 those of Badu-Apraku et al. [9], who identified plant and ear aspects and plant and ear heights
294 as the most reliable traits for the simultaneous selection in the extra-early inbreds for
295 improved yield under low-N and drought stress environments.

296 Table 4: Pearson correlation of traits evaluated under drought induced at the seedling at the greenhouse, Faculty of Agriculture and under drought at
 297 flowering stage at the Teaching and Research Farm, Obafemi Awolowo University, Ile Ife, 2015.

		Traits under drought at flowering stage							
		Anthesis- silking interval	Ears per plant	Plant height	Ear height,	Plant aspect	Stay green characteristics	Ear aspect	Grain yield,
Traits under drought at seedling	Number of dead leaves	0.15*	-0.15*	0.07	0.03	0.01	0.30**	0.17**	-0.07
	Leaf area	0.02	0.08	0.06	0.02	-0.14*	-0.08	-0.02	-0.02
	RDL	0.14*	-0.18**	-0.03	-0.06	0.11	0.28**	0.24**	-0.14*
	Number of leaves	0.06	-0.11	0.11	0.10	-0.18**	0.09	0.05	0.12
	Seedling aspect	0.02	-0.13	-0.03	-0.05	0.12	0.13	0.07	-0.02
	Chlorophyll content	0.06	0.07	-0.09	-0.03	0.08	0.05	-0.03	0.09
	Shoot fresh weight	-0.03	0.03	0.10	0.08	-0.20**	-0.12	-0.09	0.04
	Shoot dry weight	-0.09	0.09	0.17**	0.16**	-0.22**	-0.10	-0.11	0.06

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

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304 Table 5: Estimates of direct (diagonal values in bold) and indirect (off-diagonal values) effects based on path analysis of yield attributing characters on grain
 305 yield, evaluated under drought induced at the seedling stage in the screenhouse, and under drought that coincided with flowering stage.

	Seedling height	Number of dead leaves	Leaf area	RDL	Number of leaves	Seedling aspect	Chlorophyll content	Shoot fresh weight	Shoot dry weight
Seedling height	-0.051	-0.055	0.003	0.001	0.108	-0.002	-0.005	-0.006	-0.018
Number of dead leaves	-0.011	-0.242	0.001	0.149	0.169	0.003	0.001	0.006	-0.002
Leaf area	-0.021	-0.023	0.008	-0.007	0.069	-0.001	-0.009	-0.005	-0.020
RDL	0.000	-0.183	-0.003	0.196	0.035	0.003	-0.001	0.005	0.005
Number of leaves	-0.019	-0.139	0.002	0.023	0.294	0.001	-0.001	-0.001	-0.013
Seedling aspect	0.012	-0.109	-0.001	0.086	0.055	0.007	0.006	0.013	0.019
Chlorophyll content	0.005	-0.003	-0.001	0.001	-0.007	0.001	0.052	0.002	0.008
Shoot fresh weight	-0.013	0.068	0.002	-0.047	0.008	-0.004	-0.004	-0.022	-0.034
Shoot dry weight	-0.013	-0.007	0.002	-0.014	0.052	-0.002	-0.006	-0.011	0.073

306 Residual effect = 0.2517

307 **Conclusion**

308 There was narrow genetic base for seedling drought tolerance traits in the early-maturing
309 maize germplasm studied and this might limit the scope of improvement of the traits under
310 drought stress. In addition, low additive variances and heritability estimates were obtained
311 for most traits. Number of leaves and number of dead leaves under seedling drought stress
312 had the highest direct effects on grain yield under field conditions, indicating that these
313 seedling traits are reliable predictors of grain yield of early maize hybrids.

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