

Original Research Article

Genetic variances, heritability and traits association of early maturing maize hybrids under drought imposed 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]. [2] recommended that
43 the development and accelerated deployment of maize hybrids would increase maize yields in
44 the major maize producing countries of West and Central Africa (WCA). Studies have
45 demonstrated that hybrids can increase farmers' maize yields by more than 40% in
46 favourable growing environments and by more than 30% even under stressful conditions [3].
47 Drought is a major constraint in boosting maize production in Africa especially in the SSA,
48 coupled with other abiotic stresses it has resulted in maize displacement by high value crops
49 to marginal areas [4]. Drought exerts its effects on yield through its effects on physiological
50 processes, and through losses in plant stand when such stress occurs during emergence and at
51 the seedling stage. The extent of grain yield reduction in maize due to drought stress depends
52 on the stage of crop development at the time of the stress and its severity. However, the
53 flowering period in maize is the most sensitive to drought. The most economically feasible
54 and sustainable way to boost maize production and productivity in SSA is to develop drought
55 tolerant varieties for the farmers. Earlier studies conducted in the rainforest agro-climatic
56 zone showed that maize planted early significantly out-yielded those planted later in the
57 season primarily because grain filling coincided with the period of relatively high incident
58 solar radiation [5]. Maize plants with excellent adaptive response to drought at seedling stage
59 will help in combating the effect of early season drought in the rainforest agro-ecology of
60 southwestern Nigeria. Therefore, the evaluation of maize crop at the seedling stage is an
61 important aspect of crop breeding program with the objective to evolve drought tolerant
62 varieties. Developing specific maize genotypes which can tolerate drought at seedling stage,
63 especially in southwestern Nigeria where the rainfall pattern is bimodal, will offer the farmers
64 in this region the opportunity of planting maize earlier in the year (that is, late February to
65 early April), immediately after the first few rains and by extension West Africa. Therefore,
66 development of high yielding cultivars that combine tolerance to drought at both seedling and
67 flowering stages could be a coping strategy to combat detrimental effects of climate change
68 on maize production and productivity in the sub-region.

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

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

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

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

110

111 **Materials and Methods**

112 **Generation of crosses**

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

118

119 **Field performance evaluation**

120 Drought stress at flowering stage was achieved in the field. The experiment was conducted at
121 the Crop Science Unit of the Teaching and Research Farm, Obafemi Awolowo University, Ile
122 Ife (7^o28'N 4^o33'E, 244m, 1200 mm rainfall) during the 2015 cropping season. The planting
123 was done on the 21st September, such that flowering could coincide with a period of no
124 rainfall (drought). A trial composed of the sixty-six (66) single cross hybrids plus nine checks
125 was laid out using a 5 x 15 alpha lattice design with three replications. Each entry was
126 planted into a single-row plot, 5 m long with 0.75 m spacing between rows and 0.50 m
127 spacing between plants within a row. Three seeds were sown per hole and later thinned to
128 two plants per hill to attain a population density of 53,333 plants ha⁻¹. A compound fertilizer
129 of NPK 15:15:15 was applied at the rates of 60 kgN, 60 kgP and 60 kg K₂O ha⁻¹ at two weeks
130 after planting. An additional 60 kgN ha⁻¹ was also applied as side dressing at four weeks after
131 planting (WAP) using urea (46% N). On each plot on the field, data were collected on days to
132 anthesis, days to silking, number of ears per plant (EPP), plant and ear heights. Plant aspect
133 was rated on a scale of 1 to 9, where 1 = excellent overall phenotypic appeal and 9 = poor

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

140

141 **Screenhouse evaluation**

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

156

157 **Data analysis**

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

167 calculated and then the correlation coefficients were partitioned into direct and indirect
168 effects through path coefficient analysis using PATHSAS program developed by [19].

169

170 **Results and Discussion**

171 Results of analysis of variance (ANOVA) showed significant ($P = .05$) differences among the
172 genotypes for all seedling traits evaluated in the screenhouse except leaf area and fresh shoot
173 weight (Table 1). Similarly, significant ($P = .05$) effects were observed for genotype for all
174 measured traits under stress conditions on the field (Table 2). The significant mean squares
175 observed among the genotypes under the different stress conditions indicated presence of
176 wide genetic variability within the genetic materials, which implies that a good progress from
177 selection for improvement for drought tolerance at both growth stages could be achieved.

178 The additive variance measures the variation due to the average effects of alleles (additive
179 effects, same locus) and the variation in the effects that are transmitted from one generation
180 to another while the dominance variance is the variance due to interaction of average effects
181 of alleles (dominance effects, same locus) [20]. The dominance variance is a function of
182 allele frequencies and the level of dominance. In our present study, the additive variance was
183 greater than non-additive (dominance) variance for all traits except number of ears per plant
184 under the flowering drought conditions (Table 3). In contrast, the dominance variance was
185 greater than the additive variance for all traits under the seedling drought conditions, which
186 implied that the dominance component is more important than the additive components for
187 these traits. Estimates of additive genetic variance were significantly different from zero for
188 all traits under field drought conditions and for all traits under the screenhouse conditions
189 except seedling aspect, dry shoot weight and fresh shoot weight. Dominance variances were
190 significantly different from zero for all measured traits except seedling fresh shoot weight.
191 Due to negative estimates, additive variance of dry shoot weight and dominance variance of
192 fresh shoot weight were equated to zero. Thus, their dominance to additive genetic variance
193 ratio could not be estimated. The dominance to additive genetic variance ratios were greater
194 than 0.5 for four out of the eight traits under drought at the flowering stage and for seven out
195 of the nine traits under seedling drought conditions.

196

197 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
 198 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
C.V		20.65	11.95	18.61	40.84	37.11	30.95	41.90	50.95	41.68

199 *, ** Significant at 0.05, 0.01 probability levels respectively.

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

201 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
 202 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**

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Error	136	120633.0	0.06	0.77	1.59	1.65	124.48	50.26	0.93	203
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	204

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209 *, ** Significant at 0.05, 0.01 probability levels respectively; NS= not significant

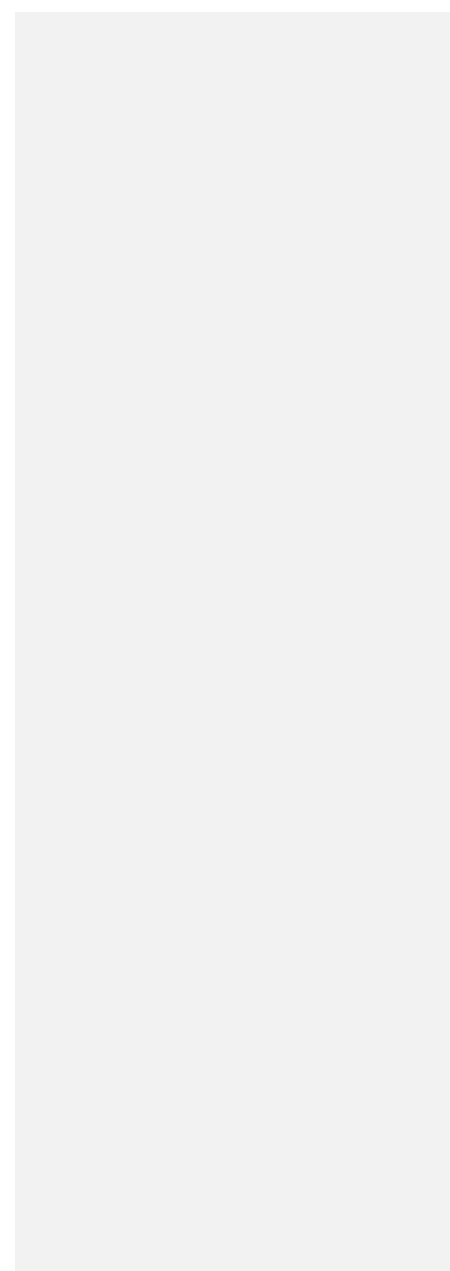
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214 Table 3: Additive ($\hat{\sigma}_A^2$) and non-additive $\hat{\sigma}_{NA}^2$ variances, narrow-sense heritability estimates (h^2),
 215 for grain yield and other agronomic traits of hybrids generated from diallel crosses evaluated under
 216 terminal 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, kg/ha	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, cm	99.55±7.380	30.60±2.590	0.31	49.9
Ear height, cm	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	0.390
Chlorophyll content, umol L⁻¹	3.154±0.390	15.270±0.360	4.840	17.000
Plant height	2.000±0.240	2.080±0.230	1.040	18.700
Leaf area	1.520±0.540	4.970±0.910	3.270	4.300
Number of dead leaves	0.412±0.070	2.080±0.060	5.060	11.600
Number of leaves	6.870±0.690	12.200±0.500	1.770	25.000
RDL	5.320±1.190	30.060±1.630	5.650	7.600
Fresh weight, kg	0.001±0.001	0±0.003	0	0.380
Dry weight, kg	0±0.0002	0.011±0.001	0	0

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228 Narrow-sense heritability estimate for grain yield was moderate (33.4%). The values of
229 narrow-sense heritability for the traits ranged from 7.3% for ears per plant to 50% for plant
230 height under drought at flowering and 0.38% for fresh weight to 25% for number of leaves
231 under seedling drought conditions. Heritability estimates provide information on how
232 efficient a trait could be transmitted from parents to their offspring [20]. Low narrow-sense
233 heritability estimate observed for most measured traits, especially under drought at seedling
234 stage is an indication that the scope for improvement of these traits in the parents is limited.
235 However, introgression of genes for tolerance to seedling drought stress into the genotypes
236 under study could guarantee continued progress from selection for improved grain yield and
237 seedling traits under drought stress conditions. In addition, it might be desirable to increase
238 the number of replications and locations to increase the accuracy of estimated entry means,
239 and thus the heritability.

240 Adequate knowledge on the inter-relationship among traits is important in designing effective
241 selection programs for crop improvement. Results showed that seedling traits were not
242 directly correlated with grain yield except number of dead leaves relative to the total number
243 of leaves which displayed significant negative relationship (Table 4). Ears per plant showed
244 significant negative relationship with number of dead leaves and number of dead leaves
245 relative to the total number of leaves. This implied that a hybrid with high number of dead
246 leaves under drought at seedling stage will possibly give lower number of ears harvested per
247 plot under drought conditions at flowering. Plant aspect had significant negative relationship
248 with leaf area, number of leaves, shoot fresh weight and shoot dry weight. This suggests that
249 maize hybrids under drought stress at seedling stage with high number of leaves, leaf area,
250 shoot fresh weight and shoot dry weight would give rise to plants with excellent physical
251 appearance under the same condition at flowering stage. In addition, stay green characteristic
252 showed significant positive relationship with number of dead leaves and number of dead
253 leaves relative to the total number of leaves. Though some of the seedling drought traits were
254 found to be significantly correlated with traits taken on the field under flowering drought
255 conditions, the strength of the relationships was generally low. The highest value of r (0.30)
256 was obtained between number of dead leaves at seedling and stay-green characteristics at
257 flowering. Therefore, the results of this study showed that seedling drought tolerance traits
258 cannot be used as the main criteria for predicting grain yield in the hybrids under flowering
259 drought conditions. This corroborates the findings from the study of [16] who reported that
260 the seedling drought conditions were independent of drought responses at flowering on the
261 field, possibly due to the type of screening environments used and the high genetic diversity

262 that segregated for traits conditioning drought tolerance. Even though low values of
263 correlation coefficients (r) were obtained, r measures only linear relationship, which path
264 analysis helps to decompose among the studied characters, thereby enhancing better
265 interpretation of relationships as well as pattern of the effects of one trait on the other.

266 An important objective of this study was to identify seedling drought traits with greatest
267 influence on grain yield for use in future breeding programs. Thus, the correlation
268 coefficients of the seedling drought traits with grain yield were further partitioned into direct
269 and indirect effects through path analysis (Table 5). The low residual effect (0.25) indicates
270 that the seedling traits altogether contributed substantially to grain yield. Among the seedling
271 traits, path analysis identified number of leaves (0.2949), and number of dead leaves (-0.242),
272 chlorophyll content (0.0524) as traits with significant direct contributions to grain yield,
273 whereas number of leaves had the highest direct effect. This result was not surprising since
274 leaf synthesizes the photosynthates, which are stored in plant tissues and culminate in yield
275 for the crop. Number of leaves was related to the number of photosynthetic components such
276 as chloroplasts and therefore an increase in the number of leaves improves photosynthetic
277 capacity. Path coefficient analysis showed that number of seedling leaves was the most
278 important trait for grain yield improvement through its direct and indirect effects on grain
279 yield. Number of leaves, relative number of dead leaves to the total number of leaves are
280 contributing indirectly to the number of dead leaves. For number of leaves, number of dead
281 leaves recorded the highest indirect effect. Under seedling drought conditions, in our study,
282 number of leaves, chlorophyll content and leaf area were identified as the most important
283 traits contributing to the variation in grain yield, suggesting that they are reliable secondary
284 traits under drought stress conditions. In addition, these traits can be used as criteria for
285 selecting for drought-tolerant genotypes under seedling stress conditions in early maturing
286 maize hybrids. Under the field conditions, the path analysis identified ear aspect (-0.48), ears
287 per plant (0.331), ear height (0.283), plant height (-0.255) and plant aspect (-0.219) as traits
288 with the highest direct effect on grain yield on grain yield (Table not shown). These results
289 are similar with those of [9], who identified plant and ear aspects and plant and ear heights as
290 the most reliable traits for the simultaneous selection in the extra-early inbreds for improved
291 yield under low-N and drought stress environments.

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294 Table 4: Pearson correlation of traits evaluated under drought induced at the seedling at the screenhouse, Faculty of Agriculture and under drought at
 295 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, cm	Ear height, cm	Plant aspect	Stay green characteristics	Ear aspect	Grain yield, kg/ha
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, cm ²	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, cm	-0.03	0.03	0.10	0.08	-0.20**	-0.12	-0.09	0.04
	Shoot dry weight, cm	-0.09	0.09	0.17**	0.16**	-0.22**	-0.10	-0.11	0.06

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

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302 | 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
 303 | 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

304 | Residual effect = 0.2517

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305 **Conclusion**

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

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