

DIFFERENTIAL RESPONSE OF EARLY AND EXTRA-EARLY MAIZE HYBRIDS TO DROUGHT IMPOSED AT SEEDLING AND FLOWERING STAGES

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ABSTRACT

Information on response of maize hybrids that are bred for tolerance to drought at flowering when planted under drought at seedling stage is important to identify germplasm that combined tolerance to drought at both stages. It has been reported that maize of different maturity groups responded differently to drought at flowering but no information is available on response of different maturity class to drought at seedling stage. Thus, the primary objective of this study was to evaluate the response of early and extra-early maize hybrids to drought stress imposed at both seedling and flowering stages. Thirty hybrids which comprised 15 early- and 15 extra-early maize hybrids were evaluated under drought imposed at seedling and at flowering stages. The experiment was laid out in a randomized incomplete block design with three replicates. In the screenhouse, data were collected on seedling aspect, root and shoot length, and leaf shed and total biomass. In the field, data were collected on grain yield and other agronomic traits. Data collected were subjected to analysis of variance to compare hybrid performance and correlation analysis to assess relationship among traits. Results showed that effects of variety and maturity were significant for seedling traits such as total leaf shed, root length, fresh shoot weight, total fresh weight and seedling aspect. Extra-early maturing maize had higher values for seedling aspect, root length, total leaf shed, but lower values for fresh shoot weight, total fresh weight. This indicates differences in the response of maize hybrids in the two maturity groups to drought at seedling stage. It was concluded that early and extra-early maize hybrids responded differently under induced drought stress imposed at both seedling and flowering stages. Two early-maturing and one extra-early maturing hybrids were identified which expressed combined tolerance to drought at both stages.

Keywords: Drought, Hybrid maize, Tropical germplasm

INTRODUCTION

Maize (*Zea mays* L.) is a major staple food crop in the sub-Saharan Africa. It is adapted to a wide range of agro-ecological environment throughout the world rapidly replacing traditional cereals such as sorghum

(*Sorghum bicolor* (L.) Moench) and millet (*Pennisetum glaucum* (L.) R.Br.) in areas of the savannas with good access to fertilizer inputs and markets (Badu-Apraku and Fakorede, 2003).

Drought is a major abiotic constraint to maize productivity in the sub-Saharan Africa and it causes great economic loss at any growth cycle of maize including seedling establishment, post-emergence growth, flowering or reproduction, and grain filling. Prolonged drought stress during the seedling and vegetative stages affects the length of the internodes by influencing the cell size development and, thus, the capacity for storing assimilates (Denmead and Shaw, 1960). The flowering and grain filling stages in maize is considered the most critical period in maize growth when maize is highly sensitive to water stress Banziger et al. (2000) reported that if drought stress occurs at seedling and vegetative stage, total crop loss often result. Although, a lot of research efforts has been put into developing maize of different maturity classes which can tolerate drought at flowering and grain filling periods, the However, maize developed for tolerance to drought at flowering do not tolerate drought at seedling (Meeks et al., 2013).

Differential demands for maize has facilitated the development of maize of different maturity classes, ranging from extra-early maturing, which matures within 85 and 90 days to extra-late varieties which matures in 120 days and above. Early and extra-early maize play an important role in filling the hunger gap in July in the Sudan savanna and the northern Guinea savanna zones after the long dry season. The early and extra-early maize are also used for late plantings when the rains are delayed, Harvest from early and extra-early maize attracts premium price when used as green maize in the forest agro-ecology because they enjoy early access to the market before the main season sales.

It is a general belief that early and extra-early varieties respond to drought by escape mechanism but Badu-Apraku et al. (2011) had identified early and extra-early inbreds with genes for drought tolerance at flowering and grain-filling periods. Information from evaluation of early and extra-early hybrids developed by crossing drought tolerant inbreds under drought at seedling is necessary to identify maize genotypes that combine tolerance to drought at seedling and flowering stage. Such maize genotypes are needed to increase productivity of maize in the west and central African sub-region. Limited research attention has been given to drought tolerance at seedling stages among tropical maize germplasm unlike at flowering stage. Reports from earlier studies showed that when drought occurs at seedling and vegetative stages, total crop loss may result (Edmeades et al., 1997). Moser (2004) found that pre-anthesis drought significantly reduced the number of kernel rows, number of kernels per row, and 1000-kernel weight while it consistently increased harvest index. Earlier studies have reported that mechanism of tolerance to drought at seedling stage was independent of drought responses at flowering period among temperate germplasm (Meeks et al., 2013). Akinwale et al. (2016a) worked on methodology for drought screening at seedling stage and reported that withdrawing water supply at 7 days after planting was most effective to determine drought tolerance among traits at seedling stage. The availability of early and extra-early maize with tolerance to drought at seedling and early vegetative stages promises to greatly contribute to the expansion of maize productivity in the forest regions due to the possibility of production of maize during marginal periods when soil moisture is relative

sub-optimal for maize growth. Examples of such marginal periods are the beginning of the dry season in mid-September when maize flowering coincides with drought and shortly before rains stabilize when maize suffers moisture stress at seedling/vegetative stages in the rainforest agro-ecological zones.

The primary objectives of this study was to evaluate the response of early and extra-early maize hybrids to drought stress imposed at seedling and flowering stages and to determine relationship between seedling drought traits and drought adaptive traits at flowering periods.

MATERIALS AND METHODS

Thirty maize hybrids (15 early and 15 extra-early) obtained from International Institute of Tropical Agriculture (IITA) Ibadan were used for the study. This research was conducted in two phases. The first was carried out in a greenhouse facility of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria where drought at seedling was imposed on the hybrids. The second phase of the experiment was carried out at the Teaching and Research Farm of the same University where the hybrids were deliberately planted to ensure that flowering coincided with natural drought.

In the first phase of the experiment, pots were filled with 5 kg of soil each and six seeds of each hybrid seeds were sown per pot. The experiment was laid out in a randomized complete block design with three replications. Water was applied to each pot at the rate of 0.6 litre per pot daily for 7 days and the plants were left without watering for the rest of the experiment period (Akinwale et al. (2016a). Data were collected on seedling emergence percentage, seedling height (SHT), number of

leaves per plant (NL), leaf area (LA), and number of shed leaves (LSHD). At the end of the experiment, 42nd day, the plants with the ball of soil were carefully removed from each pot and the roots washed free of sand under a gentle running tap. The roots were detached from the shoot at the cotyledonary node. Data were recorded on number of plants per pot, total number of leaves per plant, total number of dead leaves, and length of primary root (RL) (in cm) using a meter rule. In addition, fresh shoot weight (g), fresh shoot weight (g), dry shoot weight (g), and dry root weight (g) were measured using a Metler balance. Dry weights were determined by subjecting plant tissue samples to oven-drying for days until a constant weight was achieved. Seedling aspect (SASP) was scored on a scale of 1 to 9 where 1 = No visible symptom of stress: vigorous plants, no wilting, no dead leaves, no chlorosis, no height reduction and unrolled turgid leaves and 9 = total collapse or 100% death of seedling, dried leaves and stem. Seedling aspect rating scales of 1-5 indicated different levels tolerance of the seedlings while scales of 6-9 indicated levels of susceptibility of the seedlings (Akinwale et al., 2016b).

In the field, the land was cleared by ploughing twice after which the field was harrowed to pulverize the soil. The 30 hybrids were planted in the 3rd week of September so that flowering coincided with terminal drought. Observation of rainfall pattern over years in this region has shown that incidence of dry season coincide with flowering period of maize when maize is planted later than first week in September. Farmers are always advised not to delay planting of late season maize beyond August ending because yield is greatly reduced or may even cause total crop loss. The experiment was

laid out in a randomized incomplete block design with three replicates. A compound fertilizer, NPK 15:15:15, was applied at the rate of 90 kg N ha⁻¹ in two splits. Weed was controlled manually by uprooting as needs arose. Other management practices that ensure good establishment of the experiment were carried out.

Data were collected on seedling emergence, 7 days after planting (DAP), number of harvested ears, plant aspect (scored on a scale of 1 to 9 where 1 = excellent plant appeal and 9 = poor plant stand), incidence of streak disease and ear rot, husk cover, leaf death scores, and plant height in cm. At 13th week after planting, harvesting was done and data were collected on number of ears per plot, number of plants per plot, ear aspect, ear weight, and moisture, number of kernel rows, ear length, and ear diameter. Data were recorded on plot basis for grain yield per hectare based on 80% shelling percentage (800 g grain kg⁻¹ ear weight) and adjusted to 150 g kg⁻¹ moisture content.

Statistical Analysis

All data collected in the screenhouse experiment and on the field were subjected to separate analysis of variance (ANOVA) to test for significant effect of the experimental treatment on all the hybrids and significant means were separated using Least Significant Difference (LSD) at 0.05. Correlation analysis was carried to study relationship between performance of hybrids under seedling drought stress and flowering drought stress. All analyses were performed using Statistical Analysis Software, version 9.2 (SAS Institute, 2002).

RESULTS AND DISCUSSION

Results of analysis of variance (ANOVA) showed significant differences between maturity groups for shoot dry weight, number of leaves, root length, and plant height under (Table 2). Extra-early hybrids had significantly higher values for root length, shoot dry weight, number of leaves and plant height (Table 3). The higher values for root length suggests that extra-early hybrids were more tolerance to drought than early maize hybrids. However, extra-early hybrids had higher number of dead leaves relative to total leaf number, implying that they are more susceptible than early hybrids. Moreso, seedling aspect and fresh shoot weight which were identified as better indicators of drought tolerance at seedling stage, by Akinwale et al. (2016b) showed no significant difference between the two maturity groups (Tables 1 and 3). Under drought at flowering stage, early maturing hybrids had better scores for plant aspect, leaf death score and ear rot (lower scores for these traits are desirable) while extra-early hybrids had a better score for husk cover. Badu-Apraku et al. (2011) identified plant aspect as a good predictor of drought tolerance at flowering and Banziger et al. (2000) reported leaf death score as a drought adaptive traits. Based on these traits, it could be inferred that early maturity hybrids were more tolerant to drought at flowering than extra-early maturing hybrids.

Furthermore, significant differences were recorded among hybrids within maturity groups for total number of leaf shed, seedling aspect, fresh shoot weight and total fresh biomass, under drought at seedling stage (Table 1). The hybrids within each maturity group did not show any significant different for traits such as

seedling height, leaf area, root length among others (Table 1). Similarly, hybrids within maturity group were significant for all measured traits except plant height (Table 2). Based on seedling aspect, the best tolerant maize hybrids identified under drought at seedlings stage were TZEI5 × TZEI98, (TZEEI82 × TZEEI63) × (TZEEI79 × TZEEI58), TZEI9 × TZEI16, (TZEEI29 × TZEEI21) × (TZEEI14 × TZEEI39), (TZEI108 × TZEI63) × (TZEI59 × TZEI87), TZEI11 × TZEI24, and TZEI7 × TZEI26 (Table 4). Any of these hybrids could be advanced to F₂ singly and a recurrent selection program can be employed to develop a new variety with improved tolerance to seedling drought from which a new set of inbred lines can be extracted. Alternatively, any of the hybrids can further be tested in multi-environment trials for commercial release, or crossed to an inbred tester to form a three-way cross or crossed with another hybrids to form a double cross hybrid with improved level of tolerance to drought at seedling stage can be extracted. Under drought at flowering, the top 10 high yielding hybrids with tolerance to drought at flowering were TZEEI9 × TZEEI79, TZEEI29 × TZEEI49, TZEI9 × TZEI16, (TZEEI29 × TZEEI21) ×

(TZEEI14 × TZEEI39), (TZEI2 × TZEI63) × (TZEI108 × TZEI87), TZEI11 × TZEI136, (TZEI17 × TZEI129) × (TZEI157 × TZEI16), (TZEI129 × TZEI125) × (TZEI157 × TZEI16), TZEI7 × TZEI26, and (TZEEI29 × TZEEI14) (Table 4). Three of the top 10 hybrids which include TZEI9 × TZEI16, (TZEEI29 × TZEEI21) × (TZEEI14 × TZEEI39), TZEI7 × TZEI26, were among those that exhibited good tolerance to drought at seedling stage. Thus, maize germplasm that combined tolerance to drought at both seedling and flowering stages are available in the early and extra-early tropical germplasm. The inbred parents involved in the crosses could serve as sources of introgression of drought tolerance at both stages. TZEI 7 had been identified in earlier study as outstanding for *Striga* tolerance, drought and low N (Badu-Apraku and Akinwale, 2011a, b).

There was no significant correlation between traits under grain yield under drought at flowering and seedling drought for both maturity and across maize maturity groups, indicating that tolerance to drought at seedling may not lead to improved grain yield under drought at flowering (Table 5).

Table 1: Mean squares from analysis of variance of seedling traits of 30 early and extra-early maize hybrids evaluated under drought tolerance at seedling stage at the Screenhouse, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife in 2014

Source	DF	Emergence, %	Seedling height, cm	Number of leaves	Leaf area, cm ²	Number of shed leaves	Root length, cm	RelDL [‡]	Seedling aspect	Root fresh weight, g	Shoot fresh weight, g	Root dry weight, g	Shoot dry weight, g	Total fresh biomass, g	Total dry biomass, g
Block/Rep	6	1018.7*	27.09*	1.35*	42.07	1.70	36.24	0.07	1.62	0.001	0.09	0.001	0.001	0.09	0.01
Rep	2	3758.0*	4.70	3.01	744.89	1.38	37.24	0.16	3.90	0.010	0.19	0.010*	0.001	0.19	0.01
Maturity	1	494.1	7.31	0.00	76.28	4.15	96.60*	0.12*	3.65	0.011	0.04	0.001	0.031*	0.08	0.05
Hybrid/Maturity	28	345.9	17.11	0.33	71.59	13.52**	59.16	0.03	9.94**	0.002	0.53**	0.001	0.002	0.52**	0.01
Error	52	416.7	13.79	0.40	61.17	1.25	50.08	0.03	0.65	0.010	0.11	0.001	0.010	0.12	0.01
R-Square (%)		0.68	0.68	0.71	0.62	0.90	0.59	0.65	0.93	0.49	0.81	0.55	0.48	0.78	0.47
CV (%)		27.79	7.18	12.81	25.29	71.85	24.72	21.45	14.64	44.77	36.07	42.23	42.57	33.04	37.59

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

‡ RelDL Number of dead leaves relative to total number of leaves produced

Table 2: Mean squares from analysis of variance of grain yield and other agronomic traits of 30 early and extra-early maize hybrids evaluated under drought at flowering stage at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, in 2014

Source of variation	DF	Emergence, %	Plant height, cm	Plant aspect	Husk cover	Leaf Death Score	Number of ears harvested	Ear aspect	Ear rot	Ears per plant	Grain Yield, kg ha ⁻¹
BLOCK/REP	6	45.92*	6387.5	1.34	0.15	1.15	68.76*	1.47	10.6*	0.05*	125162
REP	2	306.0*	14975.4	2.41	0.11	1.24	88.74*	3.33	13.3*	0.15**	691734
MATURITY	1	3.98	26340.2	5.45*	0.95**	8.25**	91.84*	0.99	15.9*	0.17**	3957.
HYBRID/MATURITY	28	367.6**	11740.5	3.16**	0.24*	3.21**	129.58**	2.51**	7.8**	0.06**	396718**
Error	52	12.12	11288.3	1.15	0.13	0.79	24.18	1.20	3.7	0.02	174900
R-Square (%)		95	43	64	55	72	77	59	66	70	70
CV (%)		7.3	18.6	21.1	11.98	15.76	26.1	18.7	50.8	25.7	18.5

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

Table 3. Mean values for early and extra-early maize maturity classes under drought imposed at seedling and flowering stages in 2014.

Traits	Early hybrid	Extra-early hybrid	Grand mean	LSD (0.05)
Traits under drought at seedling stage				
Shoot dry weight (g)	0.18	0.22	0.18	0.03
Number of leaves	3.58	3.78	3.58	0.18
Plant height (cm)	50.17	51.92	50.17	1.60
Root length (cm)	26.61	30.65	28.63	3.02
RelDL (%) ‡	18.2	21.1	19.6	2.56
Traits under drought at flowering stage				
Plant aspect	3.33	4.83	5.08	0.45
Husk cover	3.10	2.90	3.00	0.15
Leaf Death Score	5.35	5.96	5.66	0.38
Ear rot	3.34	4.20	3.77	0.81
Grain yield (kg/ha)	804.98	818.52	811.75	176.92

‡ RelDL Number of dead leaves relative to total number of leaves produced

Table 4. Mean values of selected seedling traits of 30 early and extra-early maize hybrids evaluated at the screenhouse under drought induced at seedling stage at Obafemi Awolowo University, Ile-Ife, Nigeria in 2014

Hybrid	Drought at Seedling						Drought at Flowering			
	Maturity	Seedling aspect	Seedling height, cm	Number of shed leaves	Fresh shoot weight, g	Total fresh biomass, kg	Grain yield, kg ha ⁻¹	Ear aspect	Stay green characteristics	Ears per plant
(TZEEI129 × TZEEI37) × TZEEI13	Extra-early	3.7	50	0	1.4	1.5	211	6.5	4.4	0.7
TZEEI29 × TZEEI21	Extra-early	7.7	54	0	0.7	0.9	989	4.5	3.9	0.7
(TZEEI29 × TZEEI21) × (TZEEI14 × TZEEI39)	Extra-early	3	54	0	2.1	2.3	1304	5.1	5.9	0.6
(TZEEI29 × TZEEI14)	Extra-early	7.7	53	0	0.4	0.6	997	6	6.1	0.8
TZEEI29 × TZEEI49	Early	6.3	52	3	0.9	1	1381	4.5	5.2	0.7
TZEEI3 × TZEEI46	Extra-early	4.3	57	5	0.9	1.2	799	5.6	4.8	0.6
TZEEI39 × TZEEI90	Extra-early	5.7	52	1	0.5	0.6	829	5.5	6.2	0.6
TZEEI63 × TZEEI95	Extra-early	6.3	55	0	0.5	0.6	601	6.8	6.2	0.6
(TZEEI79 × TZEEI163) × TZEEI78	Extra-early	8.3	51	3	0.4	0.6	781	6	6.2	0.5
TZEEI79 × TZEEI82	Extra-early	4.3	51	4	0.8	1	374	5.8	7.6	0.4
(TZEEI82 × TZEEI63) × (TZEEI79 × TZEEI58)	Extra-early	2.7	53	0	1.9	2.1	336	7.3	7.1	0.4
TZEEI82 × TZEEI95	Extra-early	3.7	55	4	1.1	1.2	769	6.3	5.9	0.6
TZEEI9 × TZEEI79	Extra-early	9	48	0	0.4	0.6	1404	4.8	6.4	0.6
(TZEEI9 × TZEEI79) × TZEEI63	Extra-early	5.7	53	0	0.5	0.7	981	7.3	6.5	0.7
(TZEEI95 × TZEEI58) × (TZEEI82 × TZEEI79)	Extra-early	6.7	49	0	0.8	1	522	7.3	7.3	0.5
(TZEI108 × TZEI59) × TZEI63	Early	6.7	50	0	0.9	1	916	4.7	5.4	0.8
(TZEI108 × TZEI63) × (TZEI59 × TZEI87)	Early	3.3	51	0	1.2	1.3	949	6.1	6.2	0.6
TZEI11 × TZEI136	Early	6.7	53	3	0.6	0.8	1138	5.7	4.8	0.6
TZEI11 × TZEI24	Early	3.3	56	0	1	1.2	322	6.3	4.2	0.4
(TZEI129 × TZEI125) × (TZEI157 × TZEI16)	Early	5.7	53	3	0.7	0.9	1032	5.3	5.3	0.6
TZEI129 × TZEI16	Early	8.7	50	7	0.3	0.5	831	5.7	5.1	0.5
TZEI14 × TZEI25	Early	7.3	54	3	0.6	0.7	491	7	6.3	0.4
(TZEI17 × TZEI129) × (TZEI157 × TZEI16)	Early	7.3	53	1	0.9	1.2	1115	4.6	4.7	0.6
(TZEI2 × TZEI63) × (TZEI108 × TZEI87)	Early	6.3	53	0	0.9	1.1	1281	4.9	5.9	0.7
TZEI3 × TZEI26	Early	4.7	52	8	1	1.1	839	5.3	6.4	0.5
TZEI3 × TZEI4	Early	8.3	48	0	0.2	0.4	230	7.8	6.9	0
TZEI5 × TZEI98	Early	2	41	2	1.4	1.6	267	6	5.2	0.3
TZEI7 × TZEI26	Early	3.3	51	0	1.4	1.5	1010	5.3	3.6	0.5
TZEI87 × TZEI2	Early	3.7	52	0	1.2	1.4	301	6.9	6.8	0.5
TZEI9 × TZEI16	Early	2.7	47	0	1.2	1.3	1352	4.7	3.4	0.7
Grand mean		5.5	52	2	0.9	1.1	812	5.9	5.7	0.6
LSD		1.3	6.1	1.8	0.51	0.6	685.21	1.79	1.46	0.23

This also suggests that the genes controlling drought tolerance at seedling stage are different from the those at flowering stage and thus, yield improvement and seedling drought tolerance cannot be simultaneously achieved in a breeding population. This result agrees with the findings of Meeks et al. (2013). In contrast, there were some interesting significant relationship between other traits under seedling drought and traits under drought at flowering stage and the pattern of relationship suggested that response of hybrids from the two maturity classes were different. For instance, for extra-early hybrids, number of dead leaves relative to the total leaf number had significant relationship with plant height at flowering (-0.52*) both no significant relationship was found among the early hybrids. Instead, dead leaves relative to the total leaf number had significant correlation with leaf death score under field conditions. In the same vein, seedling aspect had significant correlation with PASP (0.56*) for extra-early but no relationship between the two traits for early hybrids. In addition, plant height under drought at flowering had significant correlation with fresh shoot weight (0.66**) and total fresh biomass (0.64**) under drought at seedling stage but for early hybrids, plant height under drought at flowering had significant correlation with different traits, fresh root weight (0.57*) and total dry biomass (0.54*), under drought at seedling stage.

In general, across the two maturity classes, leaf death score under drought at flowering stage had significant correlation with dead leaves relative to total number of leaves (0.40*) and total number of dead leaves

(0.43*) under drought at seedling stage (Table 5). This indicates that leaf senescence which is an indicator of drought tolerance at flowering (Banziger et al., 2000) had a significant positive association with number of dead leaves relative to total number of leaves. Thus, even though no seedling drought adaptive traits had significant relationship with grain yield, selection based on number of dead leaves at seedling stage in the screenhouse could improve leaf death scores on the field. Similarly, plant height under drought at flowering had significant correlation with fresh shoot weight (0.54**) and fresh biomass (0.54**) under drought at seedling stage.

It was concluded from this study that early and extra-early maize hybrids responded differently under drought stress imposed at both seedling and flowering stages. Hybrids TZEI9 × TZEI16, (TZEEI29 × TZEEI21) × (TZEEI14 × TZEEI39), TZEI7 × TZEI26 were identified as hybrids with combined tolerance to drought at both stages of maize development. In addition, significant relationship was detected between plant height under drought at flowering had significant correlation with fresh shoot weight and fresh biomass under drought at seedling stage.

Table 5: Correlation among agronomic traits of maize hybrids under drought at seedling stage and drought at flowering stages

Seedling Traits	-----Drought at flowering stage-----								
	EMERG	PASP	HUSK	LDS	PHT	EHARV	EASP	EPP	YIELD
Extra-early hybrids									
EMERG	0.20	0.37	-0.02	0.17	0.00	0.24	0.39	-0.02	-0.23
SHT	0.13	0.37	0.28	-0.36	0.21	0.25	-0.05	0.04	0.05
NL	0.03	0.38	0.12	-0.02	0.33	-0.01	0.22	-0.21	-0.22
LA	0.20	-0.01	0.52*	0.18	0.11	-0.02	-0.02	-0.33	-0.08
LSHED	0.25	0.28	0.31	-0.02	-0.20	-0.02	-0.20	-0.36	-0.07
RL	0.05	0.13	0.18	0.23	0.03	0.00	0.38	-0.13	-0.13
RELDLF	0.04	-0.33	-0.29	0.19	-0.52*	-0.02	-0.01	0.02	0.07
TNDL	0.02	0.15	-0.27	0.27	-0.46	-0.04	0.43	-0.07	-0.32
SASP	0.21	0.56*	-0.18	-0.05	-0.36	0.34	-0.31	0.31	0.44
FRW	0.02	0.07	0.16	-0.11	-0.17	0.02	0.17	-0.08	-0.01
FSW	-0.28	0.29	0.23	-0.03	0.66**	-0.37	0.11	-0.26	-0.19
DRW	-0.52	0.27	-0.08	-0.33	-0.25	-0.48	0.22	0.12	-0.30
DSW	0.02	0.08	0.35	-0.13	0.20	0.00	-0.01	-0.21	-0.01
FRESHBIOM	-0.28	0.29	0.24	-0.04	0.64**	-0.36	0.12	-0.27	-0.19
DRYBIOM	-0.20	0.18	0.24	-0.24	0.05	-0.21	0.08	-0.12	-0.14
Early maize hybrid									
EMERG	0.36	-0.03	0.05	-0.14	0.01	0.23	0.08	-0.08	-0.05
PLHT	-0.20	-0.40	-0.32	0.04	0.46	0.19	-0.02	0.26	0.19
NL	-0.38	-0.35	0.03	0.14	0.24	0.18	-0.14	0.46	0.05
LA	0.08	-0.14	-0.47	-0.14	0.05	0.13	0.00	0.15	0.19
LSHED	0.41	-0.09	0.12	0.16	0.04	0.17	-0.09	-0.04	0.02
RL	-0.19	-0.11	0.04	-0.05	0.35	0.13	-0.16	0.17	0.14
RELDLF	0.40	-0.18	-0.05	0.50*	0.18	0.27	0.15	0.10	0.20
TNDL	0.18	-0.41	-0.04	0.44	0.32	0.39	-0.07	0.32	0.35
SDASP	-0.04	0.04	-0.04	0.32	-0.01	-0.08	0.10	-0.04	0.08
FRW	0.16	-0.37	-0.28	-0.10	0.57*	0.28	-0.18	0.14	0.33
FSW	-0.02	-0.25	-0.06	-0.34	0.25	0.18	-0.31	0.24	0.06
DRW	0.24	-0.12	-0.11	-0.34	0.27	0.11	-0.27	-0.04	0.17
DSW	-0.35	-0.27	-0.03	-0.01	0.49	0.06	-0.07	0.18	-0.10
FRESHBIOM	-0.01	-0.29	-0.09	-0.35	0.30	0.21	-0.33	0.25	0.09
DRYBIOM	-0.15	-0.28	-0.08	-0.19	0.54*	0.11	-0.20	0.12	0.01
Across maturity groups									
EMERG	0.26	0.17	0.03	0.02	-0.02	0.22	0.25	-0.06	-0.15
PLHT	-0.03	-0.18	-0.13	-0.05	0.23	0.24	0.00	0.25	0.13
NL	-0.11	-0.02	0.03	0.08	0.31	0.09	0.09	0.18	-0.10
LA	0.13	-0.05	0.06	-0.04	0.03	0.04	-0.03	-0.06	0.07
LSHED	0.31	0.06	0.22	0.05	-0.13	0.08	-0.14	-0.16	-0.02
RL	-0.05	-0.08	0.00	0.15	0.14	0.11	0.13	0.14	0.02
RELDLF	0.20	-0.27	-0.22	0.40*	-0.23	0.17	0.10	0.13	0.14
TNDL	0.09	-0.26	-0.26	0.43*	-0.13	0.24	0.20	0.27	0.04

SASP	0.10	-0.21	-0.13	0.17	-0.21	0.12	-0.09	0.10	0.25
FRW	0.07	-0.24	-0.16	0.02	0.05	0.20	0.05	0.16	0.14
FSW	-0.19	0.03	0.12	-0.15	0.54**	-0.13	-0.06	0.00	-0.08
DRW	-0.24	0.03	-0.15	-0.26	-0.11	-0.17	0.04	0.08	-0.09
DSW	-0.07	-0.16	0.03	0.05	0.30	0.09	0.02	0.11	-0.03
FRES HBIOM	-0.19	0.01	0.10	-0.15	0.54**	-0.11	-0.05	0.01	-0.07
DRY BIOM	-0.16	-0.12	-0.03	-0.06	0.19	0.00	0.03	0.12	-0.07

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