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Combining Ability, Gene Action and Heterosis in Maize (*Zea mays* L.) under Drought Stress

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Abstract – **Combining ability, gene action and heterosis for grain yield and yield contributing traits were studied under drought stress at flowering in maize. The experiment was conducted at Institute for Agricultural Research farms, located at Samaru (11°11'N; 07°38'E) and Kadawa (11°39'N; 08°02'E) in Nigeria during the 2012/2013 dry season. Seven drought susceptible maize inbred lines used as female parents (designated as S1-S7) and six drought tolerant maize inbred lines used male parents (designated as P1, P2, P3, P4, P7 and P8) were crossed in North Carolina mating design II to generate 42 F_1 hybrids. The evaluation trial was laid out using simple lattice design replicated two times. Data were collected on days to flowering, plant and ear heights, leaf senescence, number of ears per plant and grain yield. Results of the combining ability analysis revealed that both additive and dominance gene actions were responsible for the control of the traits. However, the effects of dominance gene action were preponderant in the genetic control of all the traits. The study showed that S7 and P8 were the best male and female general combiners among the parents, respectively. The cross S7 x P8 was the best among the hybrids having the highest desirable specific combining ability effect for grain yield. The hybrid also recorded high parent heterosis in terms of grain yield (133.33%) and days to 50% tasseling (-13.55%). It was concluded that these parental lines can be desirable for inclusion in breeding program since they may contribute favorable alleles in the synthesis of new varieties of this very important crop for drought stress environments.**

Keywords – **Drought, Combining Ability, Gene Action Heterosis, Maize.**

I. INTRODUCTION

Maize is one of the important cereal crops in world agricultural economy as food (Morris *et al*., 1999) for humans, feed for animals and also a crop of industrial utilization (White and Johnson, 2003). The majority of farmers in the developing world, including Sub-Saharan Africa, depend on it for their daily caloric intake. However, an estimated 80% of maize crop suffers periodic yield reduction due to drought stress (Bolanos and Edmeades, 1993). Drought may occur at any stage of maize growth, but when it coincides with the flowering and grain filling periods it causes yield loss of 40-90% (Menkir and Akintunde, 2001). Thus breeders need to develop such maize genotypes which may sustain periods of water stress without lowering their yield potential.

Combining ability and heterosis are prerequisites for developing a good economically viable maize variety. Information on the combining ability and heterotic patterns among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al*., 1990). Combining ability studies provide information on the genetic mechanisms controlling the inheritance of quantitative traits and enable the breeders to select suitable parents for further improvement or use in hybrid breeding for commercial purposes. In biometrical genetics two types of combining abilities are considered i.e. general combining ability (GCA) and specific combining ability (SCA). GCA refers to the average performance of the genotype in a series of hybrid combinations and is a measure of additive gene action whereas SCA is the performance of a parent in a specific cross in relation to general combining ability (Sharief *et al*., 2009). SCA is due to genes showing non-additive effects (Sprague and Tatum, 1942). In maize, appreciable percentage of combining ability and heterosis for yield and other traits were studied by several workers. Aminu *et al.* (2014) reported significant differences of GCA effects of parents and that of SCA effects of hybrids for grain yield and other agronomic traits and that both additive and non-additive gene effects controlled most traits, but non-additive genetic effect was more prevalent. Aminu and Izge (2013) also reported that both additive and non-additive gene actions were responsible for the control of traits evaluated but the effects of non-additive gene action were preponderant in respect of the genetic control of grain yield and yield contributing traits. Mhike *et al.* (2011) reported significant differences for environments, genotypes and genotype x environment interactions in their study. They also reported significant GCA effects for all the traits measured except plant height and stem lodging with five lines identified as having good GCA effects for grain yield and non-additive genes were also predominant in most traits except for anthesis date, anthesis silking interval and ear height. Atif *et al.* (2012) reported that both GCA and SCA variances were highly significant for most of the characters studied indicating importance of additive as well as non-additive types of gene action in controlling the traits. Moreover, variances due to SCA were higher in magnitude than GCA for yield and yield components except cob diameter, number of rows/cob, number of kernels/row and harvest index. GCA to SCA ratios were less than one for most of the traits except cob diameter, number of kernel rows/cob, number of kernels/row and harvest index indicating preponderance of additive over no additive gene action. They also found high positive heterosis for grain yield and its components for more than half of the hybrids evaluated. Badu-Apraku *et al.* (2013) reported gene action controlling grain yield and most other traits to be predominantly non-additive. Hussain and Ali (2014) reported that dominance genetic variance was greater than additive genetic variance for all characters at both sowing dates, which depicts the importance of dominance gene effect for controlling these characters. Their results also indicated that the characters were affected by over-dominance effect which is reflected in the low narrow sense heritability. They also reported high heterosis for most characters at both sowing dates. Umar *et al.* (2014) also reported that both additive and non-additive gene actions were responsible for the control of grain yield and other traits studied under water stress and non-stress conditions but non-additive variances were greater than additive variances depicting the importance of non-additive gene action. They also reported that low narrow sense heritability estimates indicate the importance of non-additive gene action. The objectives of this study were to estimate general combining ability of parents, specific combining abilities of crosses and heterosis for grain yield and other traits of maize under drought stress.

II. MATERIALS AND METHODS

The study was carried out at Samaru (11°11'N, 07°38'E, 686m above sea level) in the northern Guinea Savanna ecological zone and Kadawa (11°39'N, 08°02'E, 496m above sea level), in the Sudan Savanna ecological zone of Nigeria under water stress at flowering. The experimental materials consisted of seven female inbred lines designated as S1, S2, S3, S4, S5, S6, and S7 crossed to six drought tolerant testers (male parents) designated as P1, P2, P3, P4, P7 and P8 using North Carolina mating design II according to Comstock and Robinson (1948) to produce 42 hybrids during 2012 rainy season. Parents and their resulting 42 F_1's were sown in a 7 x 8 simple lattice design, replicated twice during the 2012/2013 dry season for evaluation. Each replication had one row of 3m length for each genotype while plant-to-plant and row to row distance was 0.25m and 0.75m, respectively. Water stress was imposed by withdrawing irrigation water as from 5 weeks after planting to ensure drought stress at flowering stage. Because the average anthesis-silking interval was between 3-5 days at Samaru, an additional irrigation was applied at about 14 days after the end of male flowering to ensure that the small amounts of grains formed were filled adequately according to Banziger *et al.* (2000). No further irrigation water was applied at Kadawa because the average anthesis-silking interval was less than 3 days. Non experimental lines were raised at the beginning and end of each replication to minimize edge border effects. Observations and measurements were recorded from each plot for the following characters: days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height (cm), ear height (cm), leaf senescence, number of ears per plant and grain yield (kg/ha). Data from each site was subjected to analysis of variance separately to detect the significance of genotypic differences (Gomez and Gomez, 1984) before a combined analysis of variance. The combining ability analysis and the estimates of GCA and SCA effects were done based on the procedures described by Comstock and Robinson (1948) and Singh and Chaudhary (1985). Narrow sense heritability was estimated according to Grafius *et al.* (1952) and high parent heterosis according to Liang *et al.* (1972).

III. RESULTS AND DISCUSSION

Analysis of combining ability

The combined analysis of variance for combining ability of traits measured under drought stress across locations is presented in Table 1. The result revealed that mean squares due to locations were highly significant (P<0.01) for all traits except number of ears per plant. This indicates that the conditions in the two locations were not similar in many ways and that is why the genotypes did not perform in the same way in the two locations. These findings agreed with those reported by Mhike *et al.* (2011), Badu-Apraku *et al.* (2013) and Umar *et al.* (2014). The mean squares due to GCA_f were highly significant (P<0.01) for days to 50% tasseling, days to 50% silking and ear height while for leaf senescence and grain yield were significant at P<0.05 and were non-significant for other traits. The GCA_m were significant difference at P<0.05 for anthesis-silking interval, ear height and leaf senescence and were non-significant for other traits. The SCA mean squares were significantly different at P<0.05 for days to 50% tasseling, days to 50% silking, ear height, leaf senescence and grain yield and were non-significant for other traits. These results revealed the importance of additive as well as dominance types of gene action in controlling the traits. These results are in agreement with those reported by Aminu and Izge (2013) Badu-Apraku *et al.* (2013), Aminu *et al.* (2014) and Umar *et al.* (2014). The GCA_f x loc mean squares were only highly significant (P<0.01) for ear height while for grain yield it was significant at P<0.05. The GCA_m x loc mean squares was highly significant (P<0.01) for days to 50% silking while for days to 50% tasseling, anthesis-silking interval, ear height and grain yield, the difference were significant at P<0.05. The SCA x loc mean squares were only significant (P<0.05) for ear height and grain yield. The presence of significant mean squares for location for these traits indicated that the test environments were unique confirming the results of Mhike *et al.* (2011) and Badu-Apraku *et al.* (2013). Furthermore, the values of SCA variances were greater than the GCA variances for all traits and all the ratios of GCA: SCA variances were less than unity, which depicts the importance of dominance gene action in controlling the inheritance of the characters. Such results were also reported by Mhike *et al.* (2011), Aminu and Izge (2013), Badu-Apraku *et al.* (2013), Aminu *et al.* (2014) and Umar *et al.* (2014). Narrow sense heritability estimates were low for all the traits studied and ranged from 1.45% for number of ears per plant to 14.88% for anthesis-silking interval. This also indicates that the traits are mainly controlled by non-additive genes and that direct phenotypic selection for these traits may not be effective. Similar results were reported by Mhike *et al.* (2011) and Umar *et al.* (2014). However, the magnitudes of heritability estimates are product of the population being tested, environment within which testing is done and the traits being measured (Falconer and Mackay, 1996). It should, therefore, be understood the heritability values reported in this study are specific to the population and environments under study. The best exploitation of this type of gene action would be in the F_1 hybrids implying that breeding gain can be made through inbreeding then crossbreeding, with selection being made in later generations.

Combining ability effects

The estimates of GCA effects of parents are presented in Table 2. Among the female parents, the inbred line S7 had significant and desirable GCA effects for days to 50% tasseling, days to 50% silking, number of ears per plant and grain yield. S5 had significant and desirable GCA for days to 50% silking, plant height and ear height. S4 had significant and desirable GCA effects for leaf senescence and grain yield. Among the male inbred lines, P1 had significant and desirable GCA effects for days to 50% tasseling while P2 had significant and desirable GCA effects for days to 50% tasseling and days to 50% silking. P3 had significant and desirable GCA effects for plant height while P4 had significant and desirable GCA effects for days to 50% tasseling and ear height. P7 had significant and desirable GCA effects for anthesis-silking interval while P8 had significant and desirable GCA effect for plant height, number of ears per plant and grain yield. The female inbred line, S7, and the male inbred line, P8, were the best general combiners for grain yield and other traits. These results indicate that these inbred lines can be considered as good combiners for improving these traits and can be further used as source materials in the development of segregating generation.

The results of SCA effects are presented in Table 3. The result showed that the hybrid S7 x P8 had significant and desirable SCA effects for the maximum number of characters (days to 50% tasseling, days to 50% silking, anthesis-silking interval and grain yield). The hybrid S5 x P1 showed significant and desirable SCA effects for plant height and ear height while S7 x P1 showed significant and desirable SCA effects for days to 50% tasseling and days to 50% silking. Also hybrids S1 x P7 and S6 x P4 showed significant and desirable SCA effects for days to 50% tasseling while the hybrids S3 x P2 and S6 x P1 showed significant and desirable SCA effects for days to 50% silking. S2 x P7 and S4 x P3 showed significant and desirable SCA effects for plant height while S2 x P8 and S3 x P1 showed significant and desirable SCA effects for number of ears per plant. S1 x P8 showed significant and desirable SCA effects for grain yield. The hybrid S7 x P8 was a good specific combiner in desirable direction for most traits and involved parents that are good general combiners. This cross could be selected and used in breeding programs for improving these traits. In contrast, the results indicated that some of the superior hybrids had one of the two parents with desirable GCA effect, suggesting that involvement of one good general combiner appears to be essential to get better specific combination. Mhike *et al.* (2011), Aminu and Izge (2013), Badu-Apraku *et al.* (2013), Aminu *et al.* (2014), Hussain and Ali (2014) and Umar *et al.* (2014) have also identified good general combiners and superior hybrids in maize.

Heterosis

The heterosis of hybrids over high parents is presented in Table 4. The results indicated that S5 x P8 and S7 x P8 had the highest level of heterotic effects for days to 50% tasseling while S6 x P4 had the highest level of heterotic effects for days to 50% silking and S5 x P7 had the highest level of heterotic effects for anthesis-silking interval. Negative heterosis is actually desirable for days to 50% tasseling, days to 50% silking and anthesis-silking interval implying that these hybrids may mature earlier and can escape end of season drought. Similar results were reported by Aminu and Izge (2013) and Aminu *et al.* (2014). The hybrid S7 x P8 had the highest high parent heterosis (133.33%) with respect to grain yield. High heterosis values are desirable for grain yield in maize. High heterotic values for grain yield have also been reported in maize by Aminu and Izge (2013) and Aminu *et al.* (2014). Aminu *et al.* (2014) reported that in maize, short plants are preferred over tall types, and therefore negative heterosis is considered desirable for plant height and ear height for development of shorter hybrids that that could resist lodging particularly in windy environments. The hybrids, S4 x P2 and S3 x P2 exhibited the highest negative heterosis for plant height and ear height, respectively, indicating their superiority for the traits. On the other hand, the best desirable heterotic effect for number of ears per plant was exhibited by S7 x P2 while S5 x P2 exhibited the highest level of heterosis effects for leaf senescence. The extent of heterotic response of the F_1 hybrids largely depends on the breeding value and genetic diversity of the parents included in crosses, and on the environmental conditions under which the hybrids are grown (Hallauer and Miranda, 1988).

IV. CONCLUSION

In this study, variances due to SCA were higher in magnitude than the GCA variances for all traits studied. The narrow sense heritability values reported in this study are specific to the population and environments used. The inbred lines S7 and P8 could be regarded as the best general combiners for grain yield and one or more other traits under water stress. These parents can be used to produce high yielding and drought tolerant maize hybrids to enhance production in drought prone environments. The hybrid S7 x P8 exhibited good SCA effects for grain yield and involved parents which are good general combiners. This hybrid also recorded high parent heterosis in terms of grain yield and days to 50% tasseling under water-stress condition. This hybrid can therefore be utilized for grain production thereby exploiting the hybrid vigor.

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Table 1: Combined analysis of variance for combining ability of traits measured under drought stress across locations

Source	**df**	**DYTS**	**DYSK**	**ASI**	**PLHT**	**EHT**	**SEN**	**EPP**	**GY**
Rep (L)	2	53.24**	33.51*	14.98**	8438.67**	3267.78**	11.05**	0.48	5715483.90**
Location	1	2958.48**	2415.29**	27.52**	105525.66**	73096.78**	40.02**	1.38	47502673.86**
GCA_f	6	31.87**	36.42**	3.09	356.78	297.59**	2.01*	1.21	1880267.09*
GCA_m	5	16.47	15.41	5.86*	336.09	234.46*	2.51*	1.13	1228692.58
SCA	30	17.95*	18.66*	2.94	258.20	251.15*	2.00*	1.08	1474917.98*
GCA_f x L	6	12.47	18.51	1.98	232.00	549.67**	0.97	0.28	1609644.64*
GCA_m x L	5	18.24*	36.76**	4.50*	245.21	137.39*	0.44	0.07	2189071.00*
SCA x L	30	12.61	12.42	1.62	187.75	137.50*	1.83	0.18	1311699.77*
Error	82	6.73	8.05	1.21	120.03	46.21	0.70	1.06	645145.70
σ^2_{GCA}	-	0.48	0.56	0.12	6.79	1.14	0.02	0.01	6120.14
σ^2_{SCA}	-	0.81	0.94	0.22	10.72	27.07	0.02	0.22	32708.77
$\sigma^2_{GCA}/\sigma^2_{SCA}$	-	0.59	0.60	0.54	0.63	0.04	0.84	0.03	0.19
$h^2_n(\%)$	-	14.87	14.87	14.88	12.64	3.24	7.89	1.45	3.85

*, ** Significant at 0.05 and 0.01 probability levels, respectively, df=degrees of freedom; Rep=replication; L=location; GCA_f=general combining ability due to females; GCA_{males}=general combining ability due to males; SCA = specific combining ability, DYTS=Days to 50% tasseling, DYSK=Days to 50% silking, ASI=Anthesis-silking interval, PLHT=Plant height, EHT=Ear height, SEN= Leaf senescence, EPP=Number of Ears per plant, GY=Grain yield, σ^2_{GCA} =GCA variance, σ^2_{SCA} =SCA variance, $h^2_n(\%)$ =Narrow sense heritability

Table 2: GCA effects of parents for traits measured under drought stress across locations

Parents	DYTS	DYSK	ASI	PLHT	EHT	SEN	EPP	GY
Females								
S1	0.18	0.38	0.21	-1.61	-2.24	-0.10	0.04	-330.95
S2	0.68	1.65*	-0.03	6.29*	-4.27*	0.18	0.01	123.68
S3	-0.06	1.02	0.08	0.23	-0.26	0.03	-0.73*	-544.84*
S4	1.47*	0.46	-0.01	-0.19	1.62	-0.64**	-0.01	623.68**
S5	-0.60	-1.93*	-0.34	-7.14*	-5.15*	-0.07	-0.08	-398.56
S6	0.26	0.19	-0.07	2.39	5.27*	0.51*	0.00	-126.32
S7	-1.93*	-1.77*	0.16	0.03	4.03*	0.09	0.77*	653.31**
SE±	0.75	0.82	0.32	3.16	1.96	0.24	0.30	231.87
Males								
P1	-1.49*	-0.15	0.34	10.35**	2.10	0.07	-0.03	-148.28
P2	-1.36*	-1.46*	-0.32	6.16*	-0.39	-0.11	0.02	50.93
P3	1.66*	0.62	-0.03	-7.88*	-0.93	0.05	-0.65*	-111.77
P4	-1.42*	-0.19	1.04**	-1.31	-4.76**	0.02	-0.01	-164.15
P7	1.33	-0.03	-1.16**	0.29	4.07*	-0.05	0.03	-108.61
P8	1.28	1.21	0.13	-7.61**	-0.09	0.02	0.64*	481.88*
SE±	0.69	0.76	0.29	2.93	1.82	0.22	0.28	214.67

*, ** Significant at 0.05 and 0.01 probability levels, respectively, DYTS=Days to 50% tasseling, DYSK=Days to 50% silking, ASI=Anthesis-silking interval, PLHT=Plant height, EHT=Ear height, SEN= Leaf senescence, EPP=Number of ears per plant, GY=Grain yield

Table 3: SCA effects of hybrids for traits measured under drought stress across locations

Hybrid	DYTS	DYSK	ASI	PLHT	EHT	SEN	EPP	GY
S1 x P1	0.45	-0.06	-2.51**	-1.64	-4.13	-0.53	0.02	-11.90
S1 x P2	-0.53	-0.50	0.03	17.09*	4.31	0.27	-0.11	83.33
S1 x P3	0.95	1.18	0.23	3.54	2.07	0.11	0.06	23.81
S1 x P4	-0.32	-0.40	-0.08	-5.74	-2.07	-0.23	-0.10	31.75
S1 x P7	-4.68*	-1.06	-0.38	-3.92	-1.02	0.22	0.15	-246.03
S1 x P8	0.13	4.84*	1.71*	0.66	0.84	0.15	-0.02	1119.05*
S2 x P1	-0.30	-0.83	-0.53	1.38	-2.35	-0.18	-1.56*	-72.09
S2 x P2	5.34**	4.35*	0.01	-0.77	-1.11	0.13	0.01	-226.85
S2 x P3	0.45	4.03*	-0.42	15.39*	2.47	-0.03	-0.04	-175.26
S2 x P4	-0.82	-0.92	-0.10	-0.35	-0.24	-0.25	0.10	1277.12*
S2 x P7	-0.68	0.42	2.10**	-15.61*	-1.16	0.20	-0.04	221.56
S2 x P8	1.00	-0.06	-0.06	17.96*	2.38	0.13	1.52*	-1024.47*
S3 x P1	4.43*	0.67	0.24	-0.52	0.88	0.47	1.50*	-81.35
S3 x P2	-0.68	-4.65*	0.03	-2.71	-3.34	0.15	0.07	152.78
S3 x P3	0.18	0.28	0.10	-0.43	-5.43	-0.26	-0.10	-17.86
S3 x P4	4.91**	2.08	0.17	3.46	10.39*	0.02	-0.01	-65.48
S3 x P7	-0.95	-1.33	-0.38	0.82	4.02	-0.15	-0.07	101.19
S3 x P8	-0.89	-1.06	-0.17	-0.61	-1.52	-0.23	0.11	-89.29
S4 x P1	-0.09	0.36	0.45	2.90	4.01	0.12	0.00	94.58
S4 x P2	-3.82*	-1.84	-0.01	-4.46	-1.12	-0.08	-0.03	106.48
S4 x P3	0.78	0.59	-0.19	-23.34**	-0.41	0.26	0.05	-8.60
S4 x P4	0.39	0.40	0.01	15.25*	-2.22	-0.08	-0.04	-167.33
S4 x P7	1.03	0.99	-0.05	0.45	-0.92	-0.01	0.05	54.89
S4 x P8	-0.29	-0.50	-0.21	4.19	0.66	-0.21	-0.03	-80.03
S5 x P1	0.85	0.63	-0.21	-17.15*	-9.59*	-0.30	-0.03	39.02
S5 x P2	1.11	4.31*	0.20	2.85	2.65	-0.25	0.06	162.04
S5 x P3	-1.78	-1.64	0.14	3.98	-0.85	-0.16	0.02	130.29
S5 x P4	5.45**	0.17	-0.29	-0.09	-2.03	0.50	0.02	-1278.44*
S5 x P7	-0.15	-0.49	-0.34	5.69	4.43	0.07	-0.04	54.89
S5 x P8	-0.48	0.02	0.50	-15.28*	0.39	0.13	-0.02	-107.80
S6 x P1	-1.01	-5.49**	0.51	0.86	2.57	0.26	-0.05	122.36
S6 x P2	0.26	0.06	-0.20	-1.08	-2.57	-0.06	-0.03	134.26
S6 x P3	0.37	5.36**	0.00	-4.80	2.06	0.28	0.07	185.85
S6 x P4	-4.28*	-1.46	-0.18	2.30	1.00	-0.43	0.08	166.01
S6 x P7	-0.01	0.13	2.14**	15.54*	-2.24	-0.61	-0.02	-1167.33*
S6 x P8	1.67	1.40	-0.27	-15.81*	-0.83	0.57	-1.55*	-441.14
S7 x P1	-4.32*	-5.29**	0.04	4.18	3.61	0.16	0.11	-90.61
S7 x P2	0.32	0.27	-0.05	-0.92	1.18	-0.16	0.03	-412.04
S7 x P3	-0.95	-0.80	0.14	0.65	0.09	-0.20	-0.05	-138.23
S7 x P4	-0.34	0.13	0.47	0.17	0.18	0.46	-0.05	36.38
S7 x P7	1.45	1.35	-0.09	-2.97	-3.12	0.29	-0.03	-19.19

S7 x P8	-4.15*	-5.64**	-2.50**	-1.11	-1.92	-0.54	-0.01	1623.68**
SE±	1.83	2.01	0.78	7.75	4.81	0.59	0.73	567.95

*, ** Significant at 0.05 and 0.01 probability levels, respectively, DYTS=Days to 50% tasseling, DYSK=Days to 50% silking, ASI=Anthesis-silking interval, PLHT=Plant height, EHT=Ear height, SEN= Leaf senescence, EPP=Number of ears per plant, GY=Grain yield

Table 4: Percent High parent heterosis of hybrids for traits measured under drought stress across locations

Hybrid	DYTS	DYSK	ASI	PLHT	EHT	SEN	EPP	GY
S1 x P1	-8.92	-10.69	-30.00	10.60	-5.64	-66.67	3.78	-20.83
S1 x P2	-10.78	-12.76	-35.00	6.60	-11.55	-22.22	-16.28	30.00
S1 x P3	-4.09	-5.17	-5.56	6.62	6.83	0.00	6.69	-10.00
S1 x P4	-10.41	-11.72	-28.57	6.35	-5.17	-33.33	-23.73	0.00
S1 x P7	-10.41	-13.40	-59.26	7.22	0.65	16.67	26.77	-40.00
S1 x P8	-9.52	-6.27	22.22	21.94	5.94	16.67	-10.31	60.00
S2 x P1	-5.45	-6.59	-40.00	15.66	-0.71	-12.50	-27.55	8.33
S2 x P2	0.78	-1.10	-45.00	-1.53	-19.74	-11.11	-1.10	41.18
S2 x P3	0.39	-1.83	-37.50	4.78	4.36	0.00	-28.65	17.65
S2 x P4	-6.59	-8.96	-38.10	8.86	-2.83	-25.00	9.09	90.00
S2 x P7	-7.20	-8.59	-22.22	3.17	-3.06	12.50	-18.43	90.00
S2 x P8	-8.42	-8.01	-12.50	18.18	6.48	12.50	-10.07	111.76
S3 x P1	-5.81	-3.68	-5.00	12.03	14.41	175.00	-12.30	-33.33
S3 x P2	-8.14	-8.12	-40.00	-4.26	-24.97	-22.22	49.80	100.00
S3 x P3	-3.10	-2.21	-6.25	3.49	-13.42	-28.57	-26.38	0.00
S3 x P4	-0.39	-2.15	-23.81	14.09	19.38	75.00	-20.34	-20.00
S3 x P7	-10.23	-15.12	-62.96	12.48	17.76	25.00	-32.32	20.00
S3 x P8	-13.19	-12.54	16.67	8.88	0.75	0.00	0.00	71.43
S4 x P1	-8.65	-6.74	0.00	15.92	30.45	-25.00	-13.14	33.33
S4 x P2	-12.78	-13.83	-45.00	-7.22	-15.30	-66.67	-10.00	100.00
S4 x P3	-2.63	-3.90	-25.00	-1.41	11.08	-12.50	-8.57	44.44
S4 x P4	-6.39	-6.74	-33.33	7.80	9.74	-50.00	-21.75	10.00
S4 x P7	-3.38	-7.56	-55.56	10.55	16.54	-50.00	-2.53	60.00
S4 x P8	-9.89	-9.76	-18.75	14.90	21.07	-62.50	-21.58	88.89
S5 x P1	-3.97	-6.62	-40.00	-1.65	-6.77	-63.64	-31.58	-8.33
S5 x P2	-1.98	-5.17	-50.00	1.45	-15.30	-72.73	2.48	114.29
S5 x P3	-9.80	-10.70	-25.00	7.96	-2.06	-54.55	-25.39	43.75
S5 x P4	-6.59	-10.39	-57.14	5.08	-5.15	-9.09	-24.86	-50.00
S5 x P7	-9.47	-15.46	-74.07	16.32	17.37	-45.45	-35.10	20.00
S5 x P8	-13.55	-12.20	6.67	-1.78	4.38	-36.36	-33.09	108.33
S6 x P1	-12.69	-13.61	-23.08	20.93	28.07	100.00	-16.40	0.00
S6 x P2	-7.84	-12.93	-65.38	0.91	-17.18	-33.33	8.31	100.00
S6 x P3	-5.22	-9.18	-50.00	0.25	20.74	42.86	14.95	50.00
S6 x P4	-12.69	-16.33	-53.85	26.73	36.72	-20.00	7.91	25.00
S6 x P7	-7.84	-11.56	-51.85	28.99	26.54	-60.00	-16.41	-25.00
S6 x P8	-4.76	-7.48	-53.85	22.80	41.40	140.00	-24.46	9.09
S7 x P1	-11.20	-12.37	-25.00	22.45	27.44	28.57	41.96	25.00
S7 x P2	-8.11	-11.66	-50.00	-2.10	-11.25	-44.44	65.88	57.14
S7 x P3	-9.65	-11.66	-33.33	4.78	10.82	-14.29	22.76	62.50
S7 x P4	-10.42	-11.31	-20.83	19.11	29.26	57.14	-7.06	70.00
S7 x P7	-5.68	-9.97	-51.85	11.40	19.02	28.57	-5.30	70.00
S7 x P8	-13.55	-13.59	-50.00	21.03	29.20	-57.14	-4.56	133.33

DYTS=Days to 50% tasseling, DYSK=Days to 50% silking, ASI=Anthesis-silking interval, PLHT=Plant height, EHT=Ear height, SEN= Leaf senescence, EPP=Number of ears per plant, GY=Grain yield