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Research Article

Genetic variation and trait association of maize hybrids under irrigated and drought-stress environments

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Abstract
Drought stress is the principal cause of production losses in maize (*Zea mays* L.), especially in a rainfed ecosystem. Reducing the yield penalty of maize under stress conditions demands the development of hybrids with improved tolerance to drought stress. The extent of genetic variability and association among the traits over yield under irrigated and water stress conditions of 72 hybrids were studied. The analysis of variation reveaeds that significant variability was observed among the hybrids under stress conditions, which provides the scope for identifying drought-tolerant hybrids. The average yield reduction was 60.26 per cent under drought stress in this study and the ASI increased by 56.20 per cent. Under stress, high GCV was observed for ASI (36.74 %), plot yield (31.96 %), leaf rolling (29.65 %), leaf senescence (27.79 %) and ears per plant (24.40%) Furthermore, the traits such as plant height (0.95), leaf width (0.83), number of leaves (0.68), ear height (0.67), plot yield (0.64) and ears per plant (0.61) found to have high heritability under drought stress condition.. The correlation studies revealed that yield is harmonized positively with all the yield attributes and negatively associated with Anthesis silking interval (ASI). Moreover, path coefficient analysis suggests that ears per plant and number of kernels per row are the essential secondary traits exhibits high positive direct effect on yield. Thus, the consideration of traits with a significant effect on yield coupled with high heritability will be helpful in selecting a potential drought-tolerant hybrids.

Keywords: Maize, drought, heritability, yield, path coefficient

INTRODUCTION

Maize (*Zea mays* L.) is a wonder crop with multiple purposes and plays a vital role in the cropping system around the globe. In India, spectacular expansion in the area, production and productivity of maize has been seen in the past few decades due to the endorsement of single-cross hybrids. However, majority of maize-growing areas depends on rainfed ecosystem which are highly variable and unpredictable that are prone to drought (Bhupender *et al.*, 2016). The adverse effects of the maize leads to production losses which inturn affects the economy and livelihood of millions of people. It has been determined that 20-25% of world's maize area was affected by drought in any given year (Heisey and Edmeades,1999). The consequence of climate change and depletion of ground water table leads to the competition of irrigation water which demands the need for development of drought-tolerant maize hybrids. Hence, the prime objective is the breeding for drought tolerant genotypes that perform considerably well in irrigated and water-stress environments. In past, the significance of drought stress in a rainfed ecosystem and the adaptation of maize under various stresses have been well studied (Bänziger and Araus, 2007; Holzkämper *et al.*, 2013; Monterroso Rivas *et al.*, 2011). Pragmatic field-based breeding techniques brought about average gains of approximately 100 kg/ha/annum under water stress environment (Bänziger and Araus, 2007). Therefore, reliable traits contributing to drought tolerance should be identified to select the drought-tolerant cultivar. Thus, critical analysis of genetic variance, heritability, association and interrelationship between the traits over yield present in the breeding materials is the pre-requisite (Venugopal *et al.*, 2003). The presence of drought tolerant alleles in the population depends on the variability among them. In addition, the estimates of heritability and genetic advance provide the scope for improving genotypes under drought stress through selection. In maize, yield is most important trait but selection of improved cultivars only depends on the yield is not sufficient because of their low heritability and complex genotype x environment interactions. The studies revealed that the heritability and genetic advance of the secondary traits was relatively high. Nevertheless, the utilization of secondary traits as indirect criteria for improving yield is not conclusively entrenched in all experiments due to the nature of genetic materials and evaluation environment. Additionally, association of yield and secondary traits are determined by the direct as well as the indirect effect of the traits on yield which could also be taken into account during selection (Ha *et al.*, 2016). Thus, this study aims to determine the traits that contributes to drought tolerance using the genetic parameters.

MATERIALS AND METHODS

The 72 hybrids were derived from the nine inbreds (**Table 1**) using diallel mating system and the popularly grown commercial hybrids COH(M) 6 and COH(M) 8 was used as the check. The field experiment was conducted in department of Millets, Tamil Nadu Agricultural University, Coimbatore during summer 2022. The experiment with two replicates each in irrigated and drought stress at reproductive stage was evaluated in randomized completely block design (RCBD). The individual line contains two 4 m plots with 60 × 20 cm spacing. The package of practices and fertilizer requirements were followed as per the recommendation. The drought stress was achieved by withholding the irrigation by 10 days prior to anthesis which imparts reproductive phase stress on the stress plot whereas the control plot was irrigated at regular intervals. The stress was given for the period of 30 days (**Table 2**). On site minimum and maximum temperatures and rainfall quantity was recorded daily throughout the growing period (**Table 2**). The observation was recorded for 20 morphometric traits, including flowering, plant height, leaf traits, yield and yield-associated traits.

The variance components, broad sense heritability and genetic advance as percent of mean, were estimated from the plot raw data in R software (R version 4.1.3) using the variability package (Popat *et al.*, 2020). The direct and indirect path coefficients were also calculated using

Table 1. Genotypes / Germplasm lines used for crossing

S.No.	Genotypes	Tolerance level
1	N09-162	Tolerant
2	N10-51	Tolerant
3	52485	Moderately Tolerant
4	52099	Tolerant
5	N10-105	Moderately Tolerant
6	HKI 488	Susceptible
7	VL 299	Susceptible
8	DQL 80	Susceptible
9	N10-84	Susceptible

Table 2. Average monthly weather data throughout the growth period

	Max. (Temp) °C	Min. (Temp) °C	Rainfall (mm)	Growth period	Stress period
JAN	31.0	20.4	0	Vegetative	-
FEB	32.1	21.3	0	Vegetative to flowering	Last week of February
MAR	34.5	21.7	9.2	Flowering and grain filling	Throughout the month
APR	34.6	24.6	41.2	Grain filling and maturity	Rewatering
MAY	32.9	23.8	19	Harvest	

variability package (Popat *et al*., 2020).The correlation plot was derived using metan package (Olivoto and Lucio, 2020) .

RESULTS AND DISCUSSION

The significant variation was observed for most of the traits in irrigated and stress conditions, which provides scope for selecting genotypes tolerance to drought (**Table 3**). Drought stress significantly affects crop development by increasing the ASI by 56.20 per cent and reduced the plot yield by 60.26 per cent and ears per plant by 56.86 per cent (Table 3 and **Fig. 1**). Similar findings of a decrease in yield and increase in ASI was observed by Bhupender *et al.* (2016). The SPAD value get decreased by only 17 per cent in 15 days after stress but sudden decline of SPAD values (32 %) was observed after 25 days of drought stress (**Fig. 1**). This implies the downswing of chlorophyll content as the severity of stress increases (Zho et al.2010). The relationship between ears per plant and number of kernels per row on plot yield was shown in **Fig. 2.**

The estimates on variability parameters are presented in **Table 4** for well-watered and water-stress condition. It was observed that the traits studied exhibit higher phenotypic coefficients of variation (PCV) than genotypic coefficients of variation (GCV) under irrigated and drought environments. The high GCV was observed for the plot yield (24.21%) in irrigated condition while ASI (36.74%), plot yield (31.96%), leaf rolling (29.65), leaf senescence (27.79%) and ears per plant (24.40%) recorded highest GCV under drought stress. The ASI, ear height, leaf width, tassel length, tassel branches were found to have moderate GCV and PCV. In irrigated condition, the number of kernels per rows exhibits moderate GCV and high PCV, whereas ear height, cob width, leaf length, tassel length, tassel branches, number of rows per cob and SPAD values shows low GCV and moderate PCV under stress condition. Similarly, high PCV and GCV values was observed by Bisen *et al.* (2018) and Islam *et al.* (2020) for yield and ASI by Bartaula *et al.* (2019), Dar *et al.* (2018) and Gazal *et al.* (2017) in maize. The similar results of moderate GCV and PCV for tassel length and tassel

Table 3. Phenotypic variation of maize hybrids under irrigated and drought stress condition

Traits	Irrigated				Drought			
	Mean ± SE	Range	MSG	Error	Mean ± SE	Range	MSG	Error
DTA	53.41 ± 0.97	49.00 – 61.00	7.95***	1.89	53.18 ± 0.608	49.00 – 61.00	12.92 ***	0.73
DTS	55.97 ± 1.03	51.00 – 63.00	8.34***	2.15	57.23 ± 0.79	51.00 – 68.00	21.52***	1.251
ASI	2.58 ± 0.40	1.00 – 4.00	0.329^{ns}	0.325	4.03 ± 0.46	2.00 – 9.00	3.75***	0.43
PH (cm)	188.80 ± 2.00	150.00 -232.00	699.33***	8.01	172.13 ± 2.93	120.00 - 215.14	679.87***	17.24
EH (cm)	101.64 ± 2.46	68.00 – 146.00	478.33***	12.12	96.98 ± 1.74	64.00 - 134.50	485.54***	6.06
LL (cm)	89.05 ± 1.19	72.00 – 107.00	129.95***	2.86	87.09 ± 0.91	64.00 - 110.00	201.815***	1.69
LW (cm)	10.73 ± 0.22	7.40 - 13.70	3.09***	0.093	10.57 ± 0.30	8.4 - 13.6	2.046***	0.18
NL	14.66 ± 0.34	13.00 – 17.00	1.058***	0.233	14.2 ± 20	10.5 - 16.5	1.819***	0.336
TL (cm)	35.80 ± 1.14	25.00 – 48.00	35.17***	2.86	35.47 ± 1.19	24.00 – 46.00	34.291***	2.64
TB (cm)	13.23 ± 0.87	10.00– 23.00	12.59***	0.72	12.89 ± 0.60	7.5 -19.00	3.449***	1.52
CL (cm)	16.61 ± 0.55	14.00 – 20.00	2.93***	0.609	12.67 ± 0.62	7.50 - 16.75	6.878***	0.76
CW (cm)	4.23 ± 0.115	3.60 - 5.10	0.1826***	0.026	3.25 ± 0.16	1.95 - 4.20	0.261***	0.052
NR	14.80 ± 0.49	12.00 – 18.00	2.368***	0.48	13.63 ± 1.14	8.00 - 18.00	4.324*	2.61
NKR	36.50 ± 1.02	29.00 – 42.00	14.064***	2.104	23.79 ± 2.31	7.50 - 37.50	48.368***	10.68
SPAD15	46.44 ± 1.21	38.80- 53.20	13.61***	2.95	38.66 ± 2.61	28.00 - 49.50	19.64^{ns}	13.67
SPAD25	46.91 ± 1.09	40.20 - 52.60	11.075***	2.41	31.43 ± 1.34	22.30 - 46.00	31.09***	3.59
EPP	1.53 ± 0.05	1.00 - 1.87	0.0608**	0.005	0.66 ± 0.06	0.21-1.00	0.0631***	0.0078
PY (g)	1705.88 ± 136.98	759.50 – 2685.00	2815104***	37531	678.73 ± 109.97	70.00 -1414.5	119181***	24189
LR	-	-	-	-	2.06 ± 0.45	1.00 – 4.00	1.204***	0.40
LS	-	-	-	-	2.67 ± 0.66	1.00 – 7.00	1.978***	0.87

Significance level - *P<0.05,**p<0.01,***p<0.001

DTA- Days to anthesis, DTS – Days to silking, ASI- Anthesis silking interval, PH-Plant height, EH- Ear height, NL- Number of leaves, LL-leaf length, LW-Leaf width, TL-Tassel length, TB- Tassel branching, CL-Cob length, CW-Cob width, NR- Number of rows per cob, NKR- Number of kernels per row, EPP- Ears per plant, PY- Plot yield, LR-leaf rolling LS-Leaf senescence; MSG -Mean squares of genotype

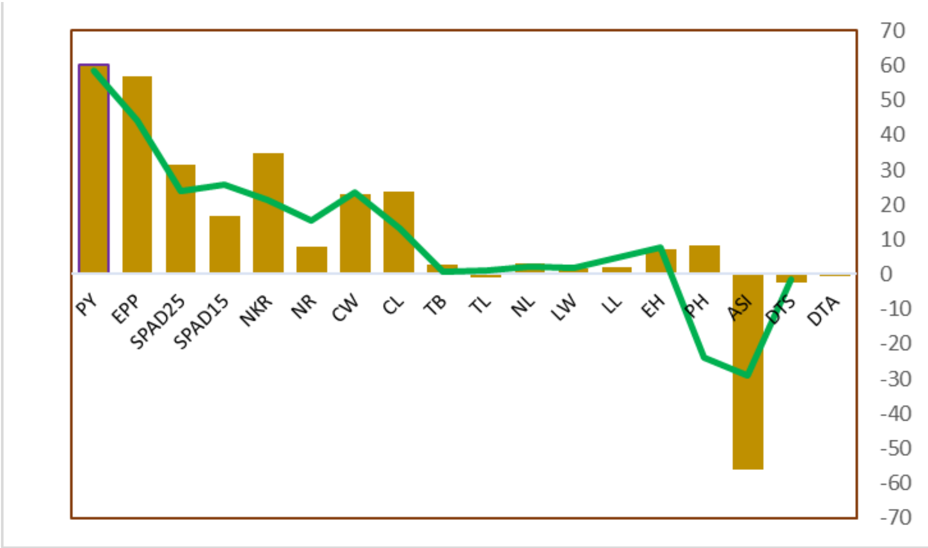

Fig. 1. Effect of drought stress on the component traits

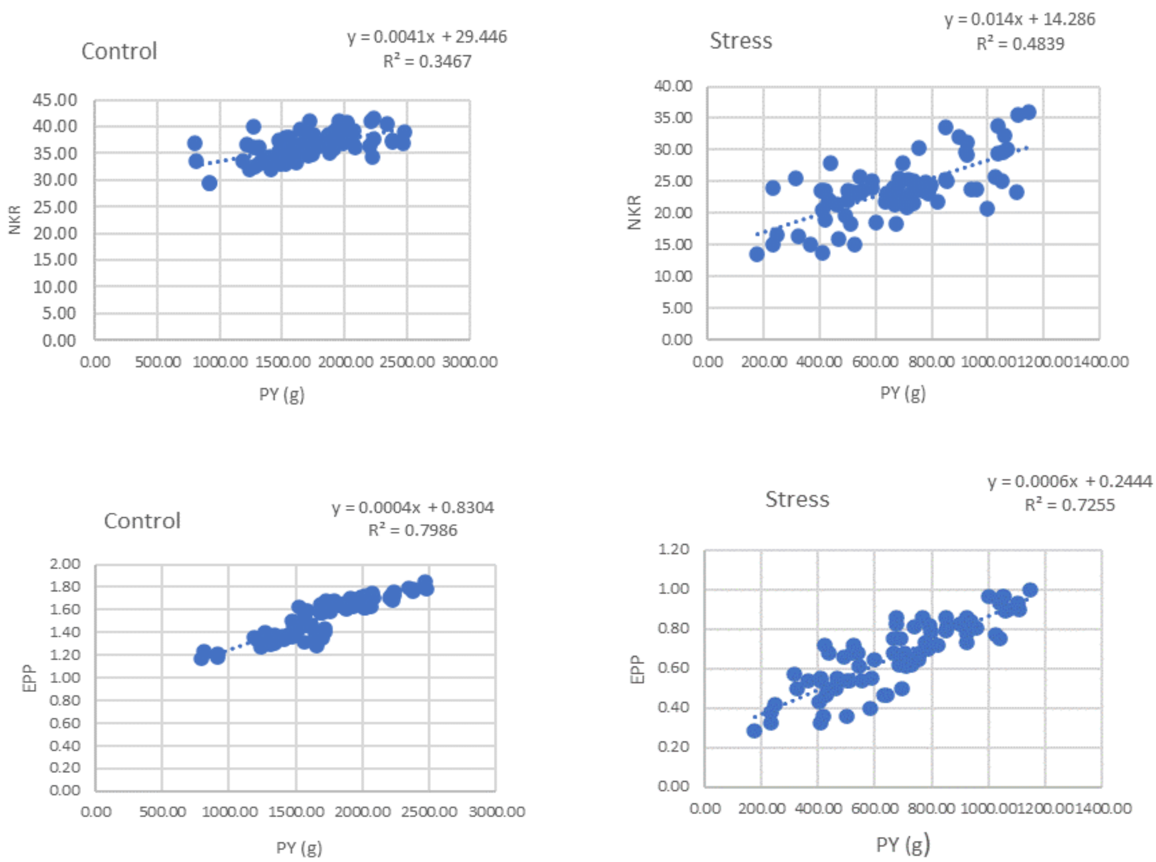

Fig. 2. Relationship between number of kernels per row and ears per plant on yield

Table 4. Estimates of genetic parameters under well-watered and water stress condition

Traits	Irrigated				Drought			
	GCV (%)	PCV (%)	h^2 (%)	GAM	GCV (%)	PCV (%)	h^2 (%)	GAM
DTA	1.79	4.75	0.66	11.39	2.63	4.90	0.23	2.34
DTS	2.11	4.96	0.54	10.82	6.28	6.72	0.44	12.09
ASI	12.86	19.21	0.66	12.31	36.74	45.41	0.56	22.23
PH	9.84	9.96	0.97	20.05	10.61	10.88	0.95	21.32
EH	15.02	15.40	0.95	30.16	9.17	16.10	0.67	10.77
LL	8.95	9.15	0.95	18.03	5.66	11.81	0.22	5.59
LW	11.40	11.75	0.94	22.00	9.12	9.98	0.83	17.16
NL	2.79	6.71	0.57	9.40	6.06	7.30	0.68	10.35
TL	10.55	13.63	0.59	16.81	6.97	11.97	0.28	6.93
TB	18.88	20.00	0.89	36.71	7.41	11.91	0.38	9.51
CL	5.81	8.86	0.42	7.81	12.59	17.45	0.52	18.71
CW	5.34	7.96	0.51	9.84	8.86	13.58	0.42	11.90
NR	6.69	9.49	0.49	9.72	6.76	13.66	0.24	6.91
NKR	4.99	9.26	0.29	5.52	17.511	24.51	0.51	25.76
SPAD15	1.34	3.78	0.11	1.33	6.78	15.64	0.22	7.87
SPAD25	1.44	4.37	0.19	2.33	10.41	19.71	0.35	9.17
EPP	10.84	11.83	0.83	20.46	24.40	31.04	0.61	39.52
PY	24.21	34.21	0.45	16.14	31.96	41.26	0.64	50.98
LR	-	-	-	-	29.65	43.55	0.34	40.12
LS	-	-	-	-	27.79	44.62	0.38	35.66

DTA- Days to anthesis, DTS – Days to silking, ASI- Anthesis silking interval, PH-Plant height, EH- Ear height, NL- Number of leaves, LL-leaf length, LW-Leaf width, TL-Tassel length, TB- Tassel branching, CL-Cob length, CW-Cob width, NR- Number of rows per cob, NKR- Number of kernels per row, EPP- ears per plant, PY- Plot yield, LR-leaf rolling LS-Leaf senescenc, GCV- Genotypic coefficient of variation, PCV- phenotypic coefficient of variation, h^2 – Heritability GAM- Genetic advance percent of mean

branches was obtained by Belay (2018) and Varalakshmi *et al.* (2018) in maize. The days to 50% anthesis and silking exhibit low GCV and PCV under stress and non-stress conditions. Similar results were observed in maize by Bharathi *et al.* (2021) and Islam *et al.* (2020).

The estimates of heritability provide the basic understanding of selection based on morphometric traits. Heritability and genetic advance would be more helpful in predicting genetic gain under selection (Johnson *et al.,* 1955), and their estimates were given in **Table 4**. The high heritability was observed for days to anthesis (0.66), silking (0.54), ASI (0.66), plant height (0.97), ear height (0.95), leaf length (0.95), leaf width (0.94), tassel branches (0.89) and ears per plant (0.83) in well watered condition whereas plant height (0.95), leaf width (0.83), number of leaves (0.68), ear height (0.67), ears per plant (0.61) and plot yield (0.64) under drought stress. The low heritability of leaf rolling (0.34) and leaf senescence (0.38) was observed which was similar with the reports of Dao *et al.* (2017). However, the heritability estimate of plot yield under water-stress conditions was higher than the irrigated condition which indicates the stability of hybrids under drought stress. As accordance with Almeida *et al.* (2013) and Dao *et al.* (2017) high heritability of grain yield under stress environment suggested the stability of drought-tolerant genotypes over diversified environment. Furthermore, the plant height, ear height and ears per plants have high heritability under irrigated and drought stress conditions, indicating that these traits should be considered when selecting high yielding drought tolerant genotype. In the present study, leaf width and number of leaves per plant also shows high heritability, implying that involvement of these secondary traits in selection will also be effective. The ASI (22.23), plant height (21.32), number of kernels per row (25.76), ears per plant (39.52) and plot yield (50.98) were found to have high genetic advance in stress conditions while plant height (20.05), ear height (30.16), leaf width (22.00), tassel branches (36.71) and ears per plant (20.46) under control environment. The plant height, ear height, tassel branches and ears per plant have high heritability coupled with high genetic advance as percent mean (GAM) in irrigated conditions. These results were in agreement with the results of Bartaula *et al.* (2019), Ahmed *et al.* (2020) and Islam *et al.* (2020) in maize. In drought stress, plant height, ears per plant and plot yield exhibits high heritability along with high genetic advance. Similar results for drought stress were obtained by Bharathi *et al.* (2021). Hence, selection of genotypes based on these traits would perform better under stress condition and will helps in enhancing genetic gain.

The mutual relationship between numerous traits was studied through association analysis, which helps determine the selection of potent traits for the genetic enhancement of grain yield in stress and non-stress conditions. The correlation coefficient among the various characters in well-watered and water-stress condition was presented in **Fig. 3. and Fig. 4.**, respectively. The association studies revealed that ASI had a significant negative association with plot yield (-0.42), number of kernels per row (-0.30) and ears per plant (-0.57) under drought stress, whereas it is not significantly associated in control environment. These results agreed with the results of Bharathi *et al.* (2021), Dao *et al.* (2017) and Richards (2006) in maize. Equally, Bolaños and Edmeades (1996), Ngugi *et al.* (2013b) and Badu-Apraku *et al.* (2018) linked a high grain yield under stress to a shorter ASI. The earliness creates an advantage under water stress condition, although early maturing varieties generally yield less than full season varieties. However, earliness and other yield-associated traits is influenced by G x E effects and the relationship between this trait and grain yield may not be that straight forward as shown by the negative non-significant association between yield and days to anthesis in **Fig 3**. Under such circumstances, ASI would be a better indicator of grain yield under drought stress (Ngugi *et al.*, 2013a). The yield is associated positively with ear height, plant height, leaf length and other yield attributes *viz*., cob length, cob width, number of kernels per row, number of rows in cob and ears per plant in both stress and non-stress condition. The similar association of these traits over grain yield was observed by Bharathi *et al.* (2021), Belay (2018) Bartaula *et al.* (2019) and Khodarahmpour (2013) in maize. Anthesis silking interval and ears per plants are the important secondary traits considered in the IITA selection index for the selection of superior genotypes under drought stress (Meseka *et al.*, 2006). Banzinger (2000) evident that the selection efficiency for water stress tolerance can be enhanced through utilizing these secondary traits that can be simply measured with high heritability and intense correlation with yield under stress environment. Alternatively, SPAD value at 15 days after drought (0.26) and 25 days after drought (0.23) are harmonized positively with yield in drought condition but is not correlated significantly under irrigated condition, whereas leaf senescence (-0.24) was negatively significantly associated with yield under water stress condition. The tassel length and tassel branches show non-significant positive correlation in optimal condition, but it shows negative association under drought stress. Similar results were obtained by Chandana (2018) for tassel length and tassel branches.

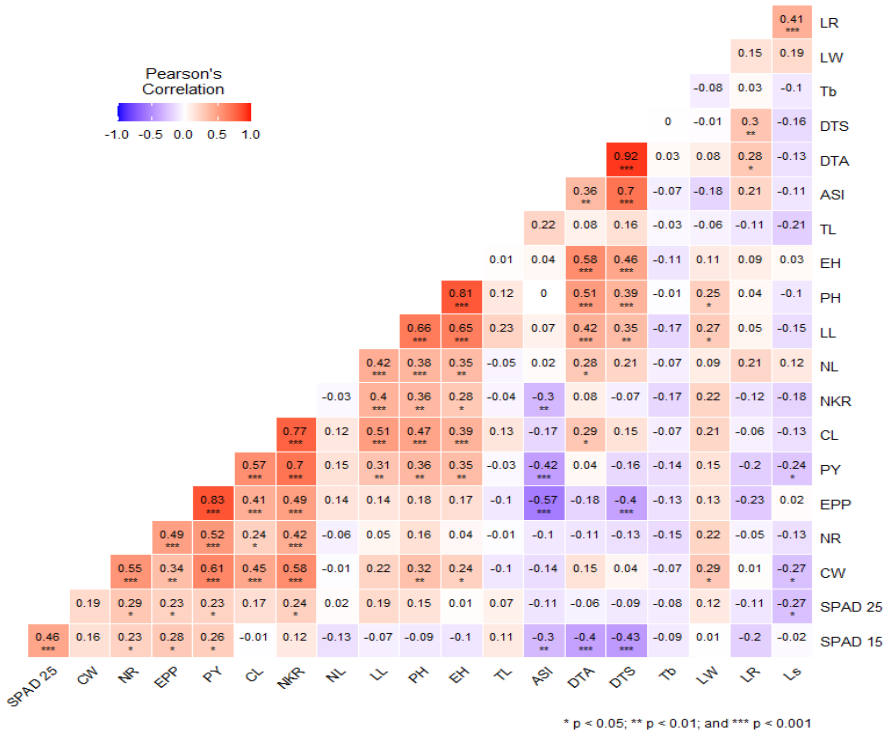

Fig. 3. Correlation coefficient among traits under drought condition

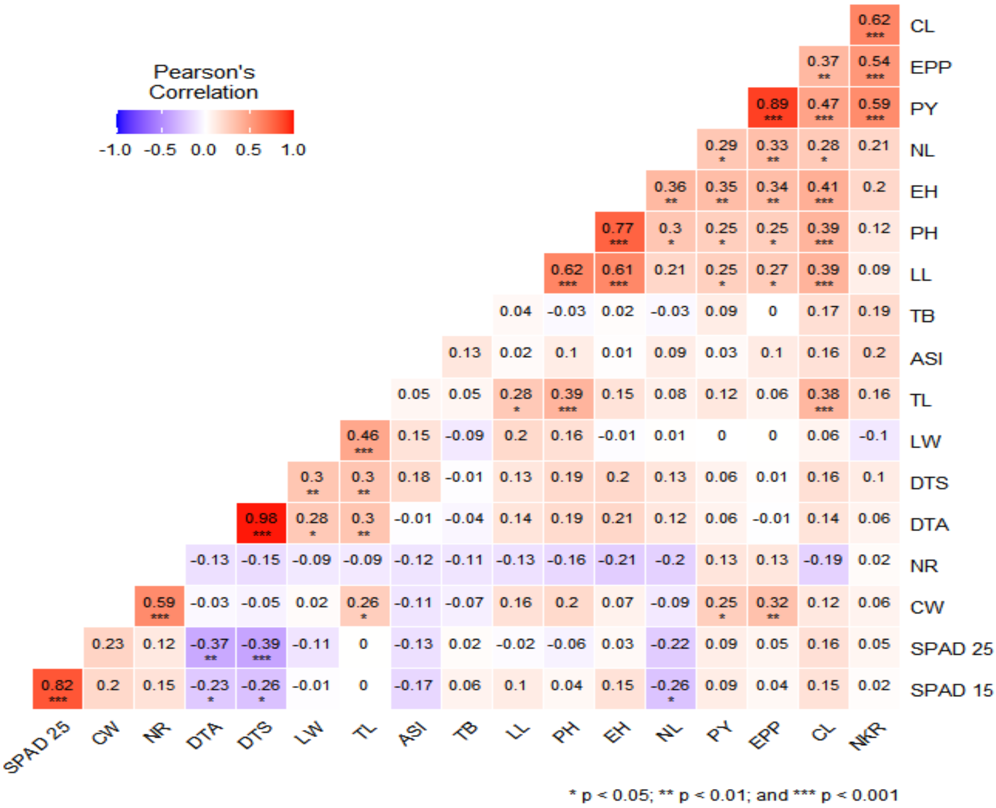

Fig. 4. Correlation coefficient among the traits under irrigated condition

The coefficients of association were further assayed by the path coefficient analysis, which proportionate the correlation coefficients into direct and indirect effects via various traits. The direct and indirect effects of the traits over yield under irrigated and drought condition was shown in **Table 5 and Table 6.** In control environment, the anthesis silking interval (-0.0110), leaf length (-0.0303), leaf width (-0.0397) and cob width (-0.0802) was found to have negative direct effects, whereas all other traits shows positive direct effects. In the drought environment, days to silking (-0.2079), anthesis silking interval (-0.0166), leaf length (-0.0402), tassel branching (-0.0349), cob length (-0.042) and SPAD value at 25th day (-0.0714) shows negative effects whereas other traits like ear height, plant height, leaf width, number of leaves, tassel length, cob width, number of rows per cob, number of kernels per row, SPAD value at 15th day and ears per plant shows positive direct effects with grain yield. Ahmad and Saleem (2003) and Ahmed *et al.* (2020) obtained similar direct effects for plant height, ear height and other yield attributes. The highest positive direct effect was observed for ears per plant (0.5232) followed by number of kernels per row (0.2410) and days to anthesis (0.2093). The Khazaei *et al.* (2010) reported the direct effect of number of kernels on the grain yield. The high positive direct effect of ears per plant on grain yield was explained by the high indirect effects of number of kernels per row (0.2429), cob length (0.2213), cob width (0.2076) and SPAD values at 15 days (0.1315) and 25 days (0.1065) after drought. Similarly, the highest direct effect of ears per plant on grain yield was reported by Dao *et al.* (2017). Although the direct effect of cob length and SPAD value at 25 days after drought is negative, the correlation of these traits with yield is positive indicates that these traits exhibit indirect effects via ears per plant and number of kernels per rows which would be the prime cause for their positive correlation. However, Selvaraj and Pothiraj (2011) studied the interrelationship between the traits states that the direct selection for ear length and number of rows per ear are effective for yield improvement since positive and significant relationship with grain yield was observed. Thus, the positive direct and indirect effects of a traits on grain yield will be potential for its exploitation in selection under specific conditions (Selvaraj and Pothiraj, 2011). The results from the present study suggest that the traits ears per plant, number of kernels per row might be the potential target traits for improving grain yield under stress condition.

The single cross hybrids plays a vital role in increasing the production and productivity of maize. However, 80% of the maize growing areas are under rainfed condition in India. Therefore assessing the variability of hybrids under drought stress is the primemost objective to develop and select hybrids based on the traits which really improves

Table 5. Path coefficient of various traits over plot yield under irrigated environment

	DTA	DTS	ASI	PH	EH	LL	LW	NL	TL	TB	CL	CW	NR	NKR	SPAD15	SPAD25	EPP	GY (r)
DTA	**0.0102**	0.0699	0.0002	-0.0043	0.0105	-0.0037	-0.0093	0.0021	0.0244	-0.0027	0.0121	0.0023	-0.0139	0.0005	-0.0088	-0.0082	-0.0109	0.06
DTS	0.0098	**0.0724**	-0.0025	-0.0043	0.0098	-0.0033	-0.0102	0.0022	0.0243	-0.0007	0.0136	0.0043	-0.0166	0.0012	-0.0101	-0.0085	0.0053	0.06
ASI	-0.0002	0.0163	**-0.0110**	-0.0014	-0.0012	-0.0004	-0.0052	0.0013	0.0032	0.0067	0.0115	0.0069	-0.0103	0.0032	-0.0050	-0.0018	0.0704	0.03
PH	0.0017	0.0122	-0.0006	**-0.0254**	0.0447	-0.0186	-0.0063	0.0057	0.0335	-0.0016	0.0446	-0.0142	-0.0187	0.0020	0.0015	-0.0013	0.1740	0.25^{*}
EH	0.0018	0.0120	0.0002	-0.0193	**0.0588**	-0.0180	0.0005	0.0071	0.0130	0.0013	0.0488	-0.0045	-0.0264	0.0039	0.0053	0.0003	0.2365	0.35^{**}
LL	0.0012	0.0080	-0.0002	-0.0156	0.0350	**-0.0303**	-0.0076	0.0041	0.0241	0.0030	0.0455	-0.0116	-0.0142	0.0017	0.0035	-0.0003	0.1820	0.25^{*}
LW	0.0024	0.0186	-0.0014	-0.0040	-0.0007	-0.0058	**-0.0397**	0.0003	0.0391	-0.0062	0.0104	-0.0010	-0.0118	-0.0016	-0.0004	-0.0024	0.0064	0
NL	0.0010	0.0074	-0.0007	-0.0068	0.0198	-0.0059	-0.0006	**0.0211**	0.0047	-0.0012	0.0255	0.0065	-0.0233	0.0037	-0.0101	-0.0042	0.2157	0.29^{*}
TL	0.0028	0.0196	-0.0004	-0.0095	0.0085	-0.0081	-0.0173	0.0011	**0.0898**	0.0026	0.0419	-0.0184	-0.0115	0.0028	0.0003	-0.0002	0.0222	0.12
TB	-0.0004	-0.0007	-0.0010	0.0005	0.0010	-0.0012	0.0033	-0.0003	0.0032	**0.0743**	0.0204	0.0054	-0.0129	0.0036	0.0021	0.0004	0.0032	0.09
CL	0.0009	0.0075	-0.0010	-0.0086	0.0219	-0.0105	-0.0032	0.0041	0.0287	0.0116	**0.1310**	-0.0097	-0.0259	0.0121	0.0057	0.0035	0.2455	0.47^{***}
CW	-0.0003	-0.0039	0.0010	-0.0045	0.0033	-0.0044	-0.0005	-0.0017	0.0207	-0.0050	0.0158	**-0.0802**	0.0765	0.0015	0.0058	0.0037	0.2117	0.25^{*}
NR	-0.0011	-0.0090	0.0009	0.0036	-0.0116	0.0032	0.0035	-0.0037	-0.0077	-0.0072	-0.0255	-0.0459	**0.1334**	0.0002	0.0056	0.0018	0.0876	0.13
NKR	0.0002	0.0042	-0.0017	-0.0025	0.0111	-0.0024	0.0030	0.0038	0.0122	0.0131	0.0770	-0.0057	0.0010	**0.0206**	0.0003	0.0005	0.3714	0.59^{***}
SPAD15	-0.0021	-0.0174	0.0013	-0.0009	0.0074	-0.0025	0.0004	-0.0051	0.0007	0.0038	0.0176	-0.0111	0.0177	0.0001	**0.0421**	0.0178	0.0098	0.09
SPAD25	-0.0036	-0.0266	0.0008	0.0014	0.0008	0.0004	0.0041	-0.0038	-0.0006	0.0013	0.0197	-0.0129	0.0105	0.0004	0.0323	**0.0231**	0.0310	0.09
EPP	-0.0002	0.0005	-0.0011	-0.0060	0.0190	-0.0075	-0.0004	0.0062	0.0027	0.0003	0.0439	-0.0231	0.0160	0.0105	0.0006	0.0010	**0.7321**	0.89^{***}

Residual effect=0.4005, Significance level - $^{*}P<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

DTA- Days to anthesis, DTS – Days to silking, ASI- Anthesis silking interval, PH-Plant height, EH- Ear height, NL- Number of leaves, LL-leaf length, LW-Leaf width, TL-Tassel length, TB- Tassel branching, CL-Cob length, CW-Cob width, NR- Number of rows per cob, NKR- Number of kernels per row , EPP-ears per plant , PY- Plot yield r-correlation coefficient

Table 6. Path coefficient of various traits over grain yield under drought environment

	DTA	DTS	ASI	PH	EH	LL	LW	NL	TL	TB	CL	CW	NR	NKR	SPAD15	SPAD25	EPP	PY (r)
DTA	**0.2093**	-0.1888	-0.0055	0.0257	0.0211	-0.0162	0.0216	0.0090	0.0063	-0.0001	-0.0124	0.0285	-0.0027	0.0190	-0.0272	0.0031	-0.0524	0.04
DTS	0.1900	**-0.2079**	-0.0114	0.0196	0.0169	-0.0136	0.0151	0.0073	0.0125	-0.0001	-0.0070	0.0116	-0.0044	-0.0169	-0.0310	0.0058	-0.1623	-0.16
ASI	0.0689	-0.1428	**-0.0166**	-0.0002	0.0022	-0.0030	-0.0019	0.0015	0.0170	0.0008	0.0050	-0.0205	-0.0051	-0.0699	-0.0231	0.0076	-0.2648	-0.42***
PH	0.1042	-0.0790	0.0001	**0.0515**	0.0291	-0.0266	0.0244	0.0122	0.0112	0.0011	-0.0194	0.0462	0.0071	0.0794	-0.0027	-0.0107	0.1148	0.36**
EH	0.1201	-0.0955	-0.0010	0.0410	**0.0367**	-0.0261	0.0182	0.0117	0.0014	0.0032	-0.0165	0.0362	0.0015	0.0617	-0.0053	0.0001	0.1172	0.35**
LL	0.0842	-0.0701	-0.0013	0.0341	0.0238	**-0.0402**	0.0288	0.0141	0.0181	0.0049	-0.0214	0.0315	0.0025	0.0839	-0.0036	-0.0130	0.0996	0.31**
LW	0.0433	-0.0301	0.0003	0.0121	0.0064	-0.0111	**0.1044**	0.0058	0.0041	0.0005	-0.0044	0.0209	0.0057	0.0331	0.0144	-0.0150	0.0674	0.15
NL	0.0516	-0.0418	-0.0007	0.0173	0.0119	-0.0156	0.0166	**0.0363**	-0.0014	0.0023	-0.0050	-0.0039	-0.0011	-0.0071	-0.0055	-0.0014	0.0765	0.14
TL	0.0156	-0.0308	-0.0033	0.0068	0.0006	-0.0086	0.0051	-0.0006	**0.0846**	0.0011	-0.0058	-0.0128	0.0005	-0.0062	0.0074	-0.0047	-0.0389	-0.03
TB	0.0005	-0.0007	0.0004	-0.0016	-0.0034	0.0056	-0.0015	-0.0024	-0.0027	**-0.0349**	0.0033	-0.0124	-0.0043	-0.0275	-0.0037	0.0063	-0.0556	-0.14
CL	0.0619	-0.0345	0.0020	0.0238	0.0145	-0.0205	0.0109	0.0043	0.0116	0.0027	**-0.0420**	0.0652	0.0127	0.1765	0.0060	-0.0106	0.2213	0.57***
CW	0.0376	-0.0153	0.0022	0.0150	0.0084	-0.0080	0.0137	-0.0009	-0.0068	0.0027	-0.0173	**0.1579**	0.0263	0.1258	0.0062	-0.0118	0.2076	0.61***
NR	-0.0103	0.0170	0.0016	0.0068	0.0010	-0.0019	0.0110	-0.0007	0.0008	0.0028	-0.0098	0.0772	**0.0540**	0.1051	0.0051	-0.0171	0.1910	0.52***
NKR	0.0165	0.0146	0.0048	0.0170	0.0094	-0.0140	0.0143	-0.0011	-0.0022	0.0040	-0.0307	0.0827	0.0235	**0.2410**	0.0097	-0.0153	0.2429	0.70***
SPAD15	-0.0680	0.0770	0.0046	-0.0017	-0.0023	0.0017	0.0180	-0.0024	0.0075	0.0016	-0.0030	0.0118	0.0033	0.0280	**0.0836**	-0.0291	0.1315	0.26*
SPAD25	-0.0091	0.0168	0.0018	0.0077	-0.0001	-0.0073	0.0219	0.0007	0.0055	0.0031	-0.0063	0.0262	0.0130	0.0516	0.0341	**-0.0714**	0.1065	0.23*
EPP	-0.0212	0.0654	0.0085	0.0115	0.0083	-0.0078	0.0137	0.0054	-0.0064	0.0038	-0.0180	0.0638	0.0200	0.1135	0.0213	-0.0147	**0.5232**	0.83***

Residual effect=0.2375, Significance level - *P<0.05,**p<0.01,***p<0.001

DTA- Days to anthesis, DTS – Days to silking, ASI- Anthesis silking interval, PH-Plant height, EH- Ear height, NL- Number of leaves, LL-leaf length, LW-Leaf width, TL-Tassel length, TB- Tassel branching, CL-Cob length, CW-Cob width, NR- Number of rows per cob, NKR- Number of kernels per row, EPP-Ears per plant , PY- Plot yield r-correlation coefficient genetic gain under drought condition. Thus, this experiment reveled the genetic variability present in the 72 hybrids and relationship among the major yield and drought tolerant traits studied. The results showed that ASI, plot yield, ears per plant, leaf rolling and leaf senescensce exhibits maximum genotypic coefficient of variation under drought stress condition. Thus, this ensures their significance for utilization in drought tolerance breeding programs of maize. In addition, high heritability coupled with high genetic adavance as percent of mean was observed for plant hight, ASI, ears per plant, number of kernels per row and plot yield under drought stress environment which shows that these traits are the best indicator of drought tolerance. Thus, the selection of hybrids based on these traits *viz.*, higher ears per plant, number of kernels per row and shorter ASI would be helpful for development of high yielding hybrids under drought stress without compensating grain yield. On considering these traits, N10-51 X DQL 80, followed by N10-51 X 52485, DQL 80 X 52099, DQL 80 X N10-51, DQL 80 X NO9-162 and 52099 X NO9-162 are found drought tolerant and can be commercialized in the drought prone areas of india after assessing their yield stability. The drought tolerance nature might be due the divergence and drought tolerance potential of their parents.

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