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Gene action and combining ability for dual purpose traits in maize (*Zea mays* L.) under water deficit stress prevailing in eastern India

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Abstract
The present experiment dealt with for performance of newly developed inbred, development of newer hybrid combinations, their performance under water deficit stress (WDS) condition and nature gene action governing the green fodder yield, grain yield and yield attributing traits in maize. Twenty-Four F_1's were developed in Line x Tester mating design using drought tolerant tester as donor. All the hybrids, parents and checks were evaluated under 7 WDS prevailing in eastern India in wet season 2013 and dry 2013-14. Significant response for genotypes and WDS were observed for forage and grain yield traits. Out of the all genetic materials, the lines BAUIM-2, BAUIM-3 and HKI-1532 were desirable for crossing for high fodder yield. But for grain yield BAUIM-2, BAUIM-3, BAUIM-5, HKI-1532 and HKI-488 were suitable because of good general combing ability. The best three hybrids suitable for both dual purpose and WDS condition were BAUIM-2 x HKI-1532, BAUIM-3 x HKI-1532 and BAUIM-5 x HKI-1532. The degree of dominance was >1, which indicated that dominant gene action was prominent for forage yield and grain yield traits. It also indicated that the parents expressing more number of dominant genes for traits under WDS would produce the hybrids suitable.

Keywords: Combining ability, Drought, Fodder maize, Gene action, Grain yield, Water deficit stress

Abbreviations: ASI: Anthesis-silking interval; **CR**: Cross; **DA**: Day to anthesis; **DDH**: Days to 75% dry husk; **GCA**: General combining ability; **GFYP**: Green fodder yield per plant; **GYP**: Grain yield per plant; **HY**: Hybrids; **KR**: Kernels per row; **KRC**: Number of kernel rows per cob; **PA**: Parents; **PH**: Plant height; **TW**: Test weight; **WDS**: Water deficit stress

Introduction

Maize (*Zea mays* L.) is the third most important cereal worldwide. It is being used as green fodder, grain, green cob, specialty corn, animal feed and other industrial uses (Pandit *et al*., 2016). In India, wet season crops mostly grown at rainfed condition which face water deficit stress (WDS) during growing season. Whereas dry season crops, totally dependent upon the assured irrigation, requires high water input due to high evapo-transpiration. Hence, in both season crop has to face different intensity of WDS. The WDS reduces the normal growth and function of the plants there by limiting maize production (Sah *et al*., 2015). The loss of yield varies from 30-90% depending upon crop stage, degree and duration of WDS. Generally, Pre-flowering to grain filling stages in maize was more susceptible to WDS, which limits reproductive functions (Pandit *et al*., 2017), reducing height of plant, biomass, number of leaves, pollen viability, stigma receptivity and seed setting.

Maize is cross-pollinated crop, where the performance of hybrids depends upon the quality of inbred. But inbred of maize are very poor yielders due to homozygosity, whereas hybrids derived from them were highly productive, responsive to nutrients, more stable in performance, high yielding, more uniform in maturity and adaptive to abnormal weather conditions or high buffering capacity. Thus hybrid in maize must be utilized for unfavorable environments for higher production. Further the genetics of responsive traits under unfavorable environments in hybrid maize also need to be understood properly (i) to develop better hybrid combination and (ii) to select the stable traits under variable WDS condition. Hence genetic variances, genetic effects of inbred parents and hybrids need to be analyzed to know genetic mechanisms controlling dual purpose traits (Chakraborty *et al*., 2012; Memon *et al*., 2015). Moreover, the number of genes which contribute to variation (Chakraborty and Sah, 2012) in dual purpose maize.

Development of good hybrid requires identification of superior inbred parents (Hallauer and Miranda, 1988) by tapping better combining ability of the parents, especially in genetically distant parental female lines and male testers (Vasal *et al*., 1992; Sah *et al*., 2014). However, it can be further improved at genetic level if an inbred is chosen from stress-tolerant source populations (Ribaut *et al*., 2009). It is a well know phenomena that all the hybrids may not equally perform in all the environments, because the contribution from lines, tester and its interaction with environment interplay the overall performance of the hybrids (Sah *et al*., 2016; 2017). Thus results might change under changing environmental condition and controversy on results remained the main concern of maize breeders that some researchers believe that additive variances and genes are more important, while others argue that the non-additive components are more significant than additive ones (Memon *et al*., 2015). Under such situation evaluation under variable WDS must be done so as to determine more authentic value of the genetic parameters. Keeping the view of above facts, the present study was undertaken (i) to determine the potentiality of newly developed female lines and known drought tolerant testers using target WDS environments (ii) to know gene action and combining ability across the variable moisture regimes so as to help maize breeders for designing efficient breeding strategies for selection and improving of dual purpose traits.

Materials and Methods

Genetic materials: A set of 29 maize lines were evaluated initially under WDS in 2010-2011 to identify WDS tolerant parents. Eleven parents out of 29 maize lines were selected based on maturity, pedigree and performance under WDS condition. Among which 8 female lines [5 were newly developed viz. BAUIM-1, BAUIM-2, BAUIM-3, BAUIM-4, BAUIM-5 (at S_{8}:$_{9}$generation), 3 developed earlier viz. BQPM-4, CM-500 & CM-111] and 3 testers known to be drought tolerant were used as male viz. HKI-1532, HKI-335 and HKI-488. The above 8 lines and 3 testers were mated in line x tester mating design (Kempthorne, 1957) and 24 F_1's were developed in wet season in 2011 and 2012.

The seed of 11 parents, 24 F_1 hybrids and 2 national checks (HQPM-1 and Bio-9637) were sown in a randomized complete block design with three replications in 2013 (wet season, crop duration: July- October) and 2013-14 (dry season, crop duration: December - May). All the 35 genetic materials were evaluated under 7 different WDS prevailing in eastern India (Table 1). Recommended agronomic practices were followed for raising a good crop. Morpho-physiological data were recorded for day to anthesis (DA), days to 75% dry husk (DDH), anthesis-silking interval (ASI), plant height (PH), kernels per row (KR), number of kernel rows per cob (KRC), test weight (TW), grain yield per plant (GYP) and green fodder yield per plant (GFYP). All the ears harvested from each plot were weighed and representative samples of ears were shelled to determine moisture percent. GYP was adjusted to 15% grain moisture content. The GFYP was measured at DDH stage with stay green.

Biometrical analysis: The data were analyzed for determining the differences among genotypes, parents, cross (CR), parents vs. CR according to Singh and Chaudhary (1985), while mean squares for general combining ability (GCA) were determined from lines and

Table 1. Water deficit stress (WDS) regimes followed for evaluation of maize genotypes

Year	Location	Stress stages/irrigation schedule
Wet season-2013		
Irrigated	Field	No stress, normal irrigation
Rainfed	Field	Stress observed during 30-35 DAS and reproductive stage
Light stress	Rainout shelter	Stress imposed during flowering and grain filling
Dry season-2013-14		
Irrigated	Field	No stress, normal irrigation
Light stress	Field	Mild stress at flowering and mild severe stress during grain filling
Medium stress	Rainout shelter	Mild severe stress at flowering and severe stress during grain filling
Severe stress	Rainout shelter	Severe stress during flowering and grain filling

Irrigation in stress trials were applied when the tensiometer reading reached to the given WDS level. No stress was imposed up to knee height stage to obtain uniform plant population and growth

Table 2. Analysis of variance over the 2013 & 2013-14 and pooled genetic analysis for forage and yield related traits in maize

SV	DF	DA	DDH	ASI	PH	KR	KRC	TW	GYP	GFYP
Environments	6	88128.16***	81454.55***	607.19***	37048.61***	3912.85***	765.74***	155707.80***	132646.40***	124177.10**
Genotypes	34	198.48***	191.75***	18.39***	10268.15***	97.39***	28.52***	10667.34***	5345.35***	7106.345**
PA	10	230.68***	135.81***	23.43***	5511.29***	72.08***	15.87***	5354.02***	440.63***	2397.325**
PA (Line)	7	249.70***	162.15***	17.95***	4839.27***	63.26***	19.15***	6956.82***	204.07***	3480.445**
PA (Testers)	2	223.32***	103.61***	11.61***	10525.49***	110.66***	11.29***	334.57	1164.90***	729.735
PA (L vs T)	1	112.29***	15.91	85.50***	186.97	56.63**	2.09	4173.28**	648.04***	2610.66**
PA vs CR	1	793.88***	1.02*	166.44***	197749.70***	798.97***	472.41***	107797.60***	138556.80***	122177.2**
CR effect	23	158.59***	224.37***	9.75***	4184.98***	77.89***	14.73***	8754.43***	1686.03***	5520.23**
WDS* T	204	62.49***	86.00***	9.45***	765.75***	51.57***	10.67***	2895.40***	642.13***	1648.765**
WDS* P	60	64.36***	28.72***	13.87***	630.98***	47.59***	13.31***	2971.87***	121.47***	1456.67**
WDS* P (L)	42	56.21***	25.69***	15.18***	783.78***	53.43***	13.88***	3009.69***	101.53***	1655.61**
WDS* P (T)	12	58.11***	30.32***	3.23***	326.47*	11.05	15.43***	1438.41**	202.56***	790.485**
WDS* P (L vs T)	6	133.90***	46.67***	25.96***	170.41	79.80***	5.02***	5774.03***	98.84**	2736.435**
WDS* P vs C	6	64.81***	67.27***	58.33***	463.06**	292.25***	3.25*	7933.50***	13593.78***	9763.64**
Error	476	2.66	5.13	0.58	154.54	6.66	1.27	523.23	27.59	175.41

*** (P<0.001); ** (P<0.01); * (P<0.05)

testers, and specific combing ability from lines x tester interactions according to statistical procedures developed by Kempthorne (1957). Line x tester analysis over the WDS condition was done following Elitriby *et al.* (1981). Estimate of GCA of a tester (male) was obtained in terms of its performance in F_1 hybrid combinations with all possible lines (females). Likewise, GCA of a line was determined in terms of its performance in F_1 hybrid combinations with all possible testers.

Results and Discussion

Genetic variation: The test of homogeneity of variance (Bartlett test) was estimated over seven WDS and significant differences were observed (P<0.01) in performance of the hybrids. The mean sum of square (MSS) among genotypes and environments for all the traits were also assessed and found significant. Thus the genetic materials were worthy for analysis and interpretation to answer the objectives (Table 2). Productive maize hybrids were developed by crossing selected female lines with drought tolerant testers. We observed that the performance of hybrids was higher under irrigated condition than other WDS. Further a single hybrid did not perform similar with other hybrids and also in all WDS. Thus it signified the differential genetic constitution of the parents and diverse WDS condition. This was also evident from significant MSS value in parents and hybrids for all the traits. The interaction between genotypes x WDS was also significant for all the traits, which suggests a relationship between genotypic performance and environments situation (Table 2). Similar observations were also reported by Memon *et al.* (2015). Further partitioning the variance due to lines and testers was significant for DA, DDH, ASI, PH, KR, KRC and GYP. This significance of lines and testers was a measure of GCA whereas significance of lines x tester interactions was a measure of specific combining ability (SCA).

Mean performance of parents and hybrids: The performance of parents and derived hybrids were varied from one to another. The DA ranged from 68.75-77.83 days for PA, but they deciphered a higher range of 66.75-74.71 days DA in hybrids. Similar higher magnitude in hybrids were seen for PH (PA: 97.63 - 157.08 cm and HY: 129.10 - 183.87 cm), KR (PA: 16.59 - 23.82 and HY: 17.49 - 27.41), KRC (DA: 10.51- 13.28 and HY: 14.49- 27.41), TW (PA: 170.26- 227.68 g. and HY: 205.79- 278.26 g), GYP (PA: 35.54- 50.16 g. and HY: 51.79- 92.04 g) and GFYP (PA: 48.06- 107.54 and HY: 101.95- 364.96 g.). Further desirable variation for DDH and ASI in hybrids

Table 3. Mean performance of 8 female lines, 3 male testers for forage and grain yield related traits in maize

Genotypes	DA	DDH	ASI	PH	KR	KRC	TW	GYP	GFYP
Female lines									
BAUIM-2	77.63	111.33	5.79	124.68	22.20	12.43	227.68	39.45	112.04
BAUIM-3	76.71	111.08	6.83	123.11	21.10	12.77	200.33	44.61	117.54
BAUIM-4	77.83	112.88	7.67	122.88	20.72	12.72	187.46	38.10	94.92
BQPM-4	72.75	109.33	7.25	97.63	16.59	13.28	207.01	35.62	59.48
BAUIM-5	76.29	110.67	6.50	157.08	22.13	12.67	170.26	35.70	77.39
BAUIM-1	69.63	107.38	5.83	110.60	19.06	11.43	201.80	40.36	82.38
CM-500	70.67	105.96	6.50	113.32	19.16	11.13	209.31	37.49	51.23
CM-111	71.42	105.42	6.03	117.83	21.89	10.51	173.94	37.49	48.06
Male lines/ testers									
HKI-1532	74.04	110.17	5.29	149.69	23.82	12.17	212.44	50.16	208.96
HKI-335	68.75	107.96	6.04	116.88	18.82	11.55	216.13	40.68	176.49
HKI-488	75.50	110.58	4.92	104.36	21.02	11.91	215.44	35.54	54.79
Parental mean	73.75	109.34	6.24	121.64	20.59	12.05	201.98	39.56	98.48

Table 4. Mean performance of selected hybrids for forage and grain yield related traits in maize

Genotypes	DA	DDH	ASI	PH	KR	KRC	TW	GYP	GFYP
BAUIM-2 x HKI-1532	74.71	113.08	4.63	168.36	27.41	14.74	211.29	92.04	364.96
BAUIM-2 x HKI-335	71.50	111.33	5.25	142.71	24.78	13.20	236.90	77.05	228.10
BAUIM-3 x HKI-1532	73.67	111.50	4.79	164.71	23.58	13.67	243.75	87.20	270.91
BAUIM-3 x HKI-488	71.00	109.42	6.01	167.88	23.59	13.65	236.83	85.31	120.45
BAUIM-4 x HKI-1532	73.29	112.21	5.33	171.13	19.92	12.74	211.10	62.43	197.49
BAUIM-4 x HKI-335	71.25	109.88	5.04	149.68	23.63	13.91	230.22	82.55	213.57
BAUIM-4 x HKI-488	70.54	108.08	4.67	156.63	22.76	13.19	228.72	73.21	135.43
BQPM-4 x HKI-1532	69.33	110.29	4.96	165.80	21.23	14.39	248.13	71.32	275.47
BQPM-4 x HKI-488	69.96	107.13	5.75	147.95	22.33	13.84	230.26	64.01	191.74
BAUIM-5 x HKI-1532	72.08	108.38	5.71	179.05	20.57	16.72	242.83	83.32	272.80
BAUIM-5 x HKI-335	69.54	107.25	4.88	159.40	24.68	13.85	253.07	82.43	175.74
BAUIM-1 x HKI-1532	70.63	106.83	5.58	164.62	20.99	11.87	222.25	64.02	192.22
BAUIM-1 x HKI-335	67.58	110.08	5.63	146.21	17.49	13.61	250.49	51.79	176.32
CM-500 x HKI-1532	72.50	106.75	4.79	147.25	21.48	14.96	253.37	69.84	197.43
CM-500 x HKI-335	67.17	111.21	4.67	129.10	19.27	12.69	270.42	63.82	177.53
CM-111 x HKI-488	66.75	101.46	5.96	164.70	23.12	13.00	245.29	59.77	122.25
Mean	70.93	109.14	5.37	158.18	22.30	13.74	237.21	72.38	195.44

were observed, where hybrids were little earlier for DDH than the parents (PA: 105.42- 112.88 days and HY: 101.46- 113.08 days) and lower ASI in hybrids than parents (PA: 4.92- 7.67 days and HY: 4.63- 6.42 days). The earlier DDH along with higher yield in maize hybrid might help to escape certain drought phases and lower ASI improved the grain setting by supplying viable pollen during stigma receptivity. The variation in parents was also due to pedigree sources and their variable degree of buffering capacity under WDS regimes.

The performance of parents was also recorded (Table 3). The desirable magnitude of traits was observed in BAUIM-1 for DA (early flowering, 69.63 days), CM-111 for DDH (early maturity, 105.42 days) and lowest ASI (6.03 days). However, BAUIM-5 had highest PH (157.08 cm) and KR (22.13). Further BQPM-4 developed highest KRC (13.28); BAUIM-2 highest TW (227.68g), BAUIM-3 highest GYP (44.61 g) and GFYP (112.04 g). Similarly testers HKI-1532 was the earliest in anthesis (ASI) and highest in KR, KRC, produced more number of seeds, maximum GYP and GFYP, whereas HKI-335 was earliest in DDH and highest PH and TW. The tester HKI-488 had lowest ASI among all.

The *per se* performance of selected F_1 hybrids were recorded (Table 4). The best hybrids with desirable mean for different traits were BAUIM-2 x HKI-1532 with lowest ASI (4.63 days), highest KR (27.41), highest GYP (92.04 g.) and GFYP (364.96 g), whereas BAUIM-5 x HKI-1532 recorded longest PH (179.05 cm), higher KRC (19.72) with high GYP (83.32 g.).

Combining ability and effect: BAUIM-1 and CM-111 showed negative and desirable GCA effects for DA and DDH, whereas among testers HKI-335 for DA and HKI-488 for DDH exhibited desirable negative GCA effects (Table 5). However, BAUIM-2, BAUIM-4 and HKI-1532 were the most desirable for ASI. Higher and significant GCA effect for PH was observed in BAUIM-2, BAUIM-3, BAUIM-4, BAUIM-5, HKI-1532, HKI-488; for KR in BAUIM-2 and CM-111; for KRC in BAUIM-5 and CM-500; for TW in BAUIM-5, CM-500, CM-111 and HKI-335, for GYP in BAUIM-2, BAUIM-3, BAUIM-5 and HKI-1532; for GFYP in BAUIM-2, BAUIM-3, HKI-1532 and HKI-335. The parents BAUIM-1, CM-111, HKI-335 and HKI-488 revealed desirable negative GCA effect for early maturity traits such as DA and DDH. However, CM-111 was not good for the yield related traits.

Inbred lines identified for good GCA could be utilized for improvement of the traits of interest as the lines have highest possibility to transfer desirable traits to their crossed progenies. In such cases, both positive and negative GCA effects were important (Legesse *et al*., 2009; Shenawy *et al*., 2009). Considerably, high positive GCA effects for most of the traits suggested that female lines BAUIM-2, BAUIM-3 could be crossed with good general combiner testers like HKI-1532 and HKI-335 to develop dual purpose hybrids, synthetics and composite varieties for WDS. This improvement could also be done through improvement of indirect traits like, PH, KR and KRC in hybrids (Vasal *et al*., 1992; Vasal, 1998).

Further, it is generally presumed that cross combinations with higher mean values, favorable SCA estimates and involving at least one of the parents with high GCA are likely to enhance the concentration of favorable alleles to improve the targeted traits and suitable for hybrid crop development (Yadav *et al*., 2009). Thus the parents with high breeding value might not necessarily transmit such characteristics to their offspring. Similarly the *per se* performance of parents might not produce the luxuriance in hybrids always. But it could be possible due to interaction between paternal and maternal gene or due to additive/dominance nature when together. So nature and magnitude of combining ability of the parents and gene action involved for traits play an important role in productiveness of the hybrid. Rani *et al.* (2015) reported that crossing two good general combiners might not produce good hybrids always. Hence both the mean value and combining ability should be taken together as selection criteria for good hybrid.

Greater extent of genetic variability in plant traits is essential for overall improvement in maize yield. It was reported that most of the traits in maize were governed by both additive and dominant gene action (Amiruzzaman *et al*., 2013). The cross showed significant SCA effect for a trait, which indicated that the traits were governed by dominant or over dominant type of genes. The hybrid BAUIM-4 x HKI-335 and BAUIM-5 x HKI-335 expressed

Table 5. General combining ability effect for forage and yield related traits in maize over 2013 & 2013-14

Lines	DA	DDH	ASI	PH	KR	KRC	TW	GYP	GFYP
BAUIM-2	2.10***	2.18***	-3.02**	4.11*	1.54**	0.11	-15.41***	6.85***	4.33***
BAUIM-3	1.89***	1.82***	-0.15	6.24**	0.20	-0.19	-7.67**	11.31***	6.17***
BAUIM-4	1.07***	0.94**	-0.49***	4.59*	-1.04*	-0.61**	-19.26***	-0.24	0.33
BQPM-4	-0.59*	0.32	0.34**	-3.53*	-0.60	0.34	1.93	-1.41	-0.50
BAUIM-5	-0.35	-2.22***	0.34**	12.46***	0.68	0.71**	7.05*	2.79**	0.28
BAUIM-1	-2.18**	-0.08	0.26*	-5.08**	-1.54**	-0.86***	-4.93***	-13.12***	-6.34***
CM-500	0.74**	0.53	-0.42**	-15.38***	-0.57	0.38*	31.94***	-4.39***	-1.85
CM-111	-2.68***	-3.50***	0.44***	-3.42	1.33**	0.11	6.35***	-1.79*	-2.54**
S.E. (gi.)	0.20	0.28	0.09	1.53	0.35	0.15	2.83	0.75	0.49
S.E. (gi-gj)	0.28	0.40	0.13	2.17	0.5	0.21	4.01	1.06	0.70
Testers									
HKI-1532	1.30***	0.63**	-0.34***	6.83***	0.37	0.08	-6.56**	3.44***	2.93**
HKI-335	-1.20***	1.40***	-0.06	-13.66***	-0.68*	0.06	5.46*	0.46	1.87*
HKI-488	-0.09	-2.03***	0.41***	6.82***	0.3	-0.14	1.09	-3.90***	-2.76**
S.E. (gi.)	0.12	0.17	0.05	0.94	0.21	0.09	1.73	0.46	0.30
S.E. (gi-gj)	0.17	0.24	0.08	1.33	0.31	0.13	2.45	0.65	0.43

***(P<0.001); **(P<0.01); *(P<0.05)

positive SCA effects for most of the traits including GFYP and GYP. The yield performance of these two hybrids were good, but many other hybrids like BAUIM-2 x HKI-1532, BAUIM-3 x HKI-1532 and BAUIM-5 x HKI-1532, also had higher yield potential, positive or significant SCA effect for GFYP and GYP.

Correlation between per se performance and combining ability: The genetic estimates might change with change in environmental conditions, where the relative phenotypic expression is being influenced by environmental changes. Specific combining effects represent dominance and epistatic components of variation, which were non-fixable and related to hybrid vigour produced by hybrid combination (Moll and Stuber, 1974). Hence SCA effect contributed more towards the improvement, where commercial exploitation of heterosis is feasible. It is generally assumed that hybrid performance *per se* is related to SCA (Memon *et al*., 2015). To validate this postulation, the correlations between *per se* performance and SCA were calculated. The significant correlations for PH, TW, GYP and GFYP suggested that such assumptions hold true in present studies (Table 6).

The hybrid which expressed significantly desirable negative SCA effects for DA, DDH and ASI contributed favourable dominant genes for earliness and seed setting. Out of 24 hybrids, top five exhibiting higher negative desirable SCA effects for DA were BAUIM-3 x HKI-488, BAUIM-4 x HKI-488, BQPM-4 x HKI-488, BAUIM-1 x HKI-335 and CM-500 x HKI-335; for DDH, BAUIM-2 x HKI-335, BAUIM-4 x HKI-335, BAUIM-1 x HKI-1532 and CM-500 x HKI-1532; for ASI, BAUIM-2 x HKI-1532, BAUIM-4 x HKI-488, BQPM-4 x HKI-1532, BAUIM-5 x HKI-335 and CM-500 x HKI-335. Four hybrids exhibited significantly positive SCA effects for PH, three hybrids for KR, three HY for KRC, three HY for TW, ten HY for GYP and ten HY for GFYP (Table 6).

Gene action and contribution of line, tester & line x tester: The proportional contribution of lines, testers and their interactions revealed that female lines contributed higher compared to male lines (except PH) under WDS condition. Thus it indicated role of maternal parents for development of cultivar under drought tolerant situations (Shams *et al*., 2010). The proportional contribution of the female was higher for development of WDS tolerant hybrids *i.e*. good GCA in female lines might be said to be one of the essential criteria for WDS tolerant breeding.

Table 6. Specific combining ability effect for forage and grain yield related traits in selected hybrids over 2013 & 2013-14

Hybrids	DA	DDH	ASI	PH	KR	KRC	TW	GYP	GFYP
BAUIM-2 x HKI-1532	0.89*	1.60**	-0.48*	-1.34	0.71	0.50	-9.73	4.03*	10.59***
BAUIM-2 x HKI-335	-0.39	-1.52*	0.3	-6.65*	0.76	-0.50	1.04	-5.81**	-0.24
BAUIM-3 x HKI-1532	-0.33	0.24	-0.13	-2.06	0.1	-0.35	17.02**	-0.15	8.63**
BAUIM-3 x HKI-488	-1.55**	-0.29	0.25	-1.09	-0.07	0.11	7.86	4.95**	3.79
BAUIM-4 x HKI-1532	0.48	1.84**	0.27	3.49	-2.61**	-1.19**	0.62	-10.57***	1.23
BAUIM-4 x HKI-335	0.98*	-1.99**	0.42*	2.88	1.93*	0.93**	-4.07	5.94**	5.03*
BAUIM-4 x HKI-488	-1.47**	0.15	-0.69**	-6.38	0.67	0.26	3.44	4.63**	1.80
BQPM-4 x HKI-1532	-2.84	0.60	-0.55**	7.28*	-0.68	0.30	8.11	-0.28	4.36*
BQPM-4 x HKI-488	-0.16**	-0.01	-0.31	-11.14**	0.43	-0.80	-10.26	-1.39	-5.14
BAUIM-5 x HKI-1532	-0.15	1.79**	0.65**	-2.25	-1.74*	0.50	10.14	3.24*	5.97*
BAUIM-5 x HKI-335	0.2	-1.18*	-0.98***	-4.28	1.70*	-0.36	13.15*	5.33**	5.99*
BAUIM-1 x HKI-1532	-0.46	-1.92**	0.25	3.98	-0.61	-0.93**	-4.91	2.97*	-3.42
BAUIM-1 x HKI-335	-1.68**	-0.04	-0.03	4.44	-0.77	0.96**	18.73**	-4.35**	6.35*
CM-500 x HKI-1532	-10	-5.39***	-0.15	-9.23**	0.62	0.95**	-2.5	-2.29	-3.95
CM-500 x HKI-335	-4.03***	1.47*	-0.65**	-2.64	-1.05	-1.55***	-4.65	-1.01	-1.59
CM-111 x HKI-488	-2.56***	-5.03**	-0.34	0.62	-1.41*	-0.72*	20.24	-6.08**	7.61**
Correlation between per se hybrids and their SCA	0.31	0.60	0.59	0.36*	0.61	0.59	0.57**	0.51	0.62**
S.E. (si.)	0.35	0.49	0.15	2.66	0.62	0.26	4.91	1.3	1.71
S.E. (Sij-Skr)	0.49	0.69	0.22	3.77	0.87	0.37	6.74	1.84	2.6

***(P<0.001); **(P<0.01); *(P<0.05)

Table 7. Estimates of genetic component of variance and contribution of line, tester & line x tester to total variance in the crosses

Components	DA	DDH	ASI	PH	KR	KRC	TW	GYP	GFYP
σ^2GCA	1.98	3.22	0.14	120.76	0.53	0.07	92.95	24.41	1.63
σ^SSCA	5.73	3.36	0.35	49.04	3.41	0.64	231.28	33.26	4.22
σ^2SCA/ σ^2GCA	2.89	1.04	2.50	0.41	6.43	9.14	2.49	1.36	2.59
Degree of dominance (F=1)	1.20	1.08	1.11	0.45	1.79	2.06	1.11	0.82	2.27
Heritability (NS) %	10.34	11.17	10.14	40.56	6.29	3.19	15.06	25.49	21.05
Genetic advance 5 %	1.31	1.79	0.34	20.39	0.53	0.14	10.9	7.26	1.22
Contribution lines (%)	38.29	32.51	28.8	33.96	31.09	36.62	56.52	61.65	44.87
Contribution tester (%)	14.46	21.2	21.88	48.87	6.6	1.59	6.18	11.83	2.82
Contribution L x T (%)	47.24	46.28	49.3	17.15	62.3	61.78	37.29	26.5	52.3

A higher value of SCA variances (σ^2SCA) over the GCA variances (σ^2GCA) were observed except plant height, which was also evident from the higher ratio of σ^2SCA/ σ^2GCA or degree of dominance (σ^2SCA/σ^2GCA) was greater than one. Hence dominant gene action was observed for all the traits except PH (Table 7). Several researchers also reported predominance of non-additive genetic effects relative to additive genetic effects for GYP (Vincente *et al*., 1994; Bhatnagar *et al.,* 2004). But both additive and dominance variances were reported to be important under WDS conditions (Shams *et al*., 2010). Variation in gene action was natural under changing environments; it might remain same or change.

Out of the total variance, the tester parents had contributed higher towards PH and exhibited paternal influence with additive genes. The additive genetic variance was important for choosing suitable plants in segregating generations for exhibiting the best expression of genes for improving traits (Wannows *et al*., 2010), whereas dominant gene action for heterosis breeding. However, in female lines TW, GYP and GFYP manifested significant maternal effect. Line x tester interactions played maximum contribution as compared to female lines and tester, for DA, DDH, ASI, KR, KRC and GFYP (Table 7). So most of the traits were governed by dominant gene action (degree of dominance >1) except PH. Thus dominant gene action for traits must be exploited for breeding dual purpose maize cultivars.

Selection of desirable parents and hybrids: The maize growers require a high yielding short duration hybrids, because such hybrids escape from certain drought spell. Thus out of 11 parents, BAUIM-2 performed very well for GFYP, GYP & related traits and CM-111 could be used as donor for earliness in hybridization programme (Alam *et al*., 2008; Amiruzzaman *et al*., 2013). The hybrids combination CM-111 x HKI-488 might also be used for recovering desirable segregants for early maturity. Negative GCA effect is also important for the traits like ASI which is an important parameter for WDS tolerance, since lower the ASI in BAUIM-2, BAUIM-4 and HKI-1532 increased the seed setting under variable moisture regimes by providing sufficient fertile pollens during stigma receptivity and attained a considerable plant height for high forage yield (Chaudhary *et al*., 2016). Hence these three are the potential parents for dual purpose maize hybrid development. Among the hybrid combinations BAUIM-2 x HKI-1532, BAUIM-3 x HKI-1532 and BAUIM-5 x HKI-1532 performed very well for GFYP and GYP, hence suitable for dual purpose, whereas BAUIM-4 x HKI-1532 performed well specially for grain yield under different WDS. The above findings signified that lower ASI hybrids had higher seed setting and forage yield, and new promising hybrid combination could be developed by crossing BAUIM-2, BAUIM-4 and HKI-1532.

Conclusion

The findings of present investigation indicated for consideration of both GCA and SCA effects while selecting parent for hybrid breeding. At least one of the parents should be high general combiner for developing superior hybrids. Moreover, identified hybrid having high SCA for maximum number of desirable traits might be used directly or further be tested in different types of environments for yield related traits before commercial exploitation. Dominant gene action was much more important under such condition than additive gene action, since different genes were involved under different degree and duration of WDS for survival and production. Dominant gene (s) that expressed under different degree of moisture regimes would assure production up to a greater extent. Hence heterosis breeding must actively be used for drought adaptive parent with new female lines developed from different genetic sources. In the present study, the best parents were BAUIM-2, BAUIM-4 and HKI-1532 which had lower ASI, high seed setting, sufficient fertile pollens during stigma receptivity, consi-

-derable plant height, and high yield. Moreover, the best heterotic combinations for dual purpose were BAUIM-2 x HKI-1532, BAUIM-3 x HKI-1532 and BAUIM-5 x HKI-1532. These hybrids could also tolerate higher level of WDS.

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