International Journal of Genetics
ISSN: 0975-2862 & E-ISSN: 0975-9158, Volume 9, Issue 10, 2017, pp.-304-308.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000226

Research Article

IMPACT OF MOISTURE STRESS REGIMES ON YIELD AND QUALITY IN MAIZE SINGLE CROSSES

SONI N.V.[1,2*], DHADUK H.L.[1], KHANORKAR S.M.[3] AND PATEL J.R.[2]

[1]Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, 388 110, Gujarat, India
[2]Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India
[3]Main Maize Research Station, Anand Agricultural University, Godhra, 389 001, Gujarat, India
*Corresponding Author: Email- soni1211@gmail.com

Received: November 14, 2017; Revised: November 20, 2017; Accepted: November 21, 2017; Published: November 28, 2017

Abstract- Significant yield reduction in maize (*Zea mays* L.) is expected under rainfed areas in India due to climate change. The study aimed to identify genotypes with immense yield potential with good quality under moisture stress. Ten yellow kernel inbreds having a differential response to stress were used to generate forty five F_1s with diallel mating design and evaluated under stress as well as irrigated condition at flowering at two locations, Anand and Derol. Soil moisture content reduced drastically up to 44% signifying enough stress, to carry out study. Genotypic mean exhibited 47.30% yield penalty under stress. This might be due to reduced rates of photosynthetic activity and unbalanced associations between plant hormones and biological processes under stress. Whereas, the grain quality attributes, protein, oil, starch and β-carotene content increased by 5.38%, 3.63%, 1.82% and 2.44% in F_1s under stress in hybrids, respectively. ANOVA revealed preponderance of non-additive gene actions for days to 50% tasseling and silking, anthesis-silking interval, leaf rolling, grain yield, number of ears per plant, seed index, shelling percentage, protein, oil, starch and β-carotene content in seed. Hybrids with a good level of stress tolerance with less yield penalty involved at least one tolerant or moderately tolerant parent, although the hybrids with both the susceptible parents didn't perform well for grain yield under stress. The overall study concluded that crosses, CM140 × IL111, IL101 × IL111 and IL103 × IL109 found promising for grain yield and β-carotene content under stress. Also, genotypes having shorter Anthesis-Silking Interval reported higher grain yield under stress.

Keywords-β-carotene, Maize, Moisture Stress, Stability, Yield.

Citation: Soni N.V., et al, (2017) Impact of Moisture Stress Regimes on Yield and Quality in Maize Single Crosses. International Journal of Genetics, ISSN: 0975- 2862 & E-ISSN: 0975-9158, Volume 9, Issue 10, pp.-304-308.

Academic Editor / Reviewer: P. C. Patel, Darshan Dharajiya, Nalin K. Pagi

Introduction

Nowadays food security and water scarcity are the two major problems around the globe. The impact of water scarcity strongly affects agriculture production, mostly in context to climate change [1]. This has largely shown its influence on hydrological cycles, most strikingly increasing the occurrence of extreme water stress and water logging conditions throughout the world. Out of the total cultivated area, approximately 80% area is rainfed and rest 20% is irrigated. It has been estimated that about 29% of the total arable land affected by water shortage conditions which resulted in nearly 15% yield penalties of irrigated potential globally, accounting 120 million tonnes of food grain productions [2].

Maize (*Zea mays* L.) is one of the three important cereals, cultivated worldwide with the highest production potential among the cereals [3]. It provides food to 60% of the global food energy intake having a wide range of agro-climatic adaptability, including tropical, subtropical and temperate climates [4]. Its production has increased by 3.4% in the last ten years to 967 million tonnes in 2013-14 worldwide. In India, it has been increased by 5.5% in the last ten years from 14 million tonnes in 2004-05 to 23 million tonnes in 2013-14 [5]. In India, about 57% of the net cultivated area is rainfed contributing 44% of the total food grain production, where water is the most important constraint to production [6]. Current trends in maize productions are highly affected predominantly due to drought under rainfed areas of cultivation causing reduction in average productivity up to 1.60 t ha^{-1} (Gujarat) and 2.56 t ha^{-1} (India), as about 1/3 and 1/2 of the global average productivity of 5.46 t ha^{-1}[5].

Maize is sensitive crop to moisture deficit conditions and affected at any stage of development leading to reduced grain yield [7]. Among the different stages of crop growth and development, flowering stage is the most sensitive stage for moisture stress [8]. Maximum yield loss is caused when stress occurs fortnight either side of flowering which severely affect delayed silking [9]; increases Anthesis-Silking Interval (ASI) resulted in non-synchronization of flowering which affects grain setting in cobs [10].

The crop requires 500-800 mm of water during its life cycle of 80 to 110 days [11]. The water requirement of maize increases under dry windy conditions. This situation can be handled either by giving additional irrigation to the standing crop under stress conditions or by evolving tolerant genotypes. The provision of supplementary irrigation is not feasible in some areas due to water shortage. Under such circumstances, evolution of stress resilient, high yielding genotype is reliable option to cope with the menace of water shortage and to close the gap between rainfed and well-watered yields [12]. The diallel analysis [13, 14] of the genetic traits could be an important breeding tool for improved hybrids and synthetics under stress conditions. The general combining ability (GCA) and specific combining ability (SCA) effects give information to determine the efficacy of breeding strategies for trait improvement and to identify parents in a breeding work. For example, some researchers [15] reported that non-additive gene action is important for inheritance of grain yield under drought, whereas others [16] showed additive genetic action for the same trait under drought stress. Therefore, it is essential to find out which type of gene action is important for inheritance of important traits under stress.

The genotypes which are bred for stress tolerance should also perform better under irrigated conditions and offer good yields by using the available resources under irrigated conditions as the occurrence of stress can't be predicted in advance. So, stability analysis under moisture regimes at different locations will give you more information about the performance of genotypes over varying environments. The stability parameters provide information about the genotypic adaptability to specific or all environment and such genotypes could be advanced for further testing. Hence, an attempt was made to study heterosis, gene action and stability of the maize genotypes under moisture stress at flowering stage (here after stress) and well-watered at every stage of crop growth (irrigated) conditions to get the genotype/s with stable yields under varying conditions.

Materials and methods

Field experimentation and stress treatment

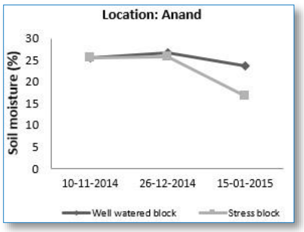
Nineteen yellow kernel inbred lines maintained at All India Coordinated Maize Improvement Project, Main Maize Research Station, Anand Agricultural University, Godhra were used in the field trial for screening under stress and irrigated conditions with three replications in split plot design during dry season of 2013-14 to avoid rain during experimentation at B. A. College of Agriculture Farm, Anand (22°-35' N, 72°-55' E, 45.10 m asl). For experimentation, the lines were grouped into different maturity groups from early to late maturing genotypes and stress application was given as it affects the flowering in each block. Based on study inbreds were grouped into tolerant, moderately tolerant and susceptible clusters according to [17]. Out of which ten inbred lines (IL101, IL103, IL104, IL105, IL109, IL111, IL112, IL113, HKI-193-1 and CM140) having a diverse genetic background and differential response to stress were selected to generate forty-five single crosses using diallel mating scheme during the rainy season of 2014-15. These 45 single cross hybrids, ten inbreds and two standard checks *viz.,* HIM129 and HQPM1 were evaluated using complete randomized block design with three replications each under stress and irrigated conditions at two different locations *i.e*., B. A. College of Agriculture Farm, Anand and Agricultural Research Station, Derol (22° 36' N, 73° 27' E, 83.14 m asl) during the dry season of 2014-15. The genotypes under irrigated conditions received recommended cultural practices with irrigation at an interval of 12-15 days to avoid stress. Same genotypes under the stress condition received recommended cultural practices but irrigation was stopped at flowering so they experienced stress. Lifesaving irrigation was given 10 days after the grain filing stage. The irrigated and managed stress experiments were separated from each other by a five-meter buffer zone of maize crop and two meters of fallow land.

Soil moisture data

The soil moisture content at 60 cm depth [Fig-1] was recorded to confirm that plants under stress treatment get enough moisture stress. The soil moisture was recorded from time to time in both the blocks at both the locations. The initial soil moisture content before sowing was 25.51% and 28.66% at Anand and Derol, respectively. After the crop growth just before the stress implication soil moisture was analyzed at both locations and it was nearly 26% percent at all the four environments. Afterwards it was noted that even 20 days after irrigation; soil moisture reduced only 11.86% and 19.60% in irrigated blocks as compared to previous conditions at Anand and Derol, respectively. But, stress blocks depicted higher soil moisture loss up to 34.79% and 43.39%, 20 days after stress implications at Anand and Derol, respectively. Reduction of the soil moisture, increase the soil temperature around the root zone areas which may indirectly affect the yield loss [18]. Weather data depicted that there were no rains before and after four weeks of anthesis at both the locations so it didn't affect stress evaluation.

Data collection and statistical analysis

The experiments were sown on 12th and 15th November, 2014 at Anand and Derol, respectively. Each genotype was grown at a spacing of 60 cm × 20 cm in a plot size of two rows of 4 m length. The traits *viz.,* days to 50 per cent tasseling (DT), days to 50 per cent silking (DS), Anthesis-Silking Interval (ASI) and leaf rolling (LR) were recorded on plot basis. The other component traits *viz.,* number of ears per plant (NEP), grain yield per plant (GY), seed index (SI), shelling percentage (SH), grain protein content (PC), oil content (OC), starch content (SC) and β-carotene content (BC) from seed were recorded on five randomly selected competitive plants per replication per entry. Each genotype was measured for above said biochemical characters as per the procedure mentioned by [19]. ASI was calculated as the difference between days to silking and tasseling. Leaf rolling was scored as per [20]. The stability analysis is done to identify the stable genotype for grain yield and other related characters over environments.



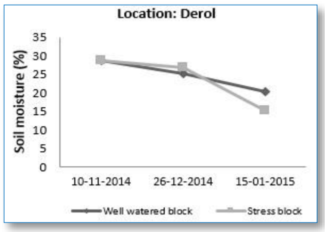


Fig-1 Soil moisture content (%) before sowing, before irrigation or stress implication and 20 days after irrigation or stress at both the locations

Analysis of variance (ANOVA) for individual traits was done as per [21] for completely randomized block design. ANOVA for diallel analysis was carried out based on model 1 and method 2 of [13, 14] for individual and pooled environments. *Per se* performance of 57 genotypes of four environments was subjected to stability analysis proposed by [22].

Results and discussion

Per se performance

The analysis of variance revealed that mean square values due to genotypes were significant for all the characters in each individual environment as well as pooled over the environments except for shelling percentage in E_1, indicating the presence of sufficient amount of genetic variability in the material studied. The results revealed that the lowest and the highest grain yield was 100.20 g (IL105 × CM140) and 149.65 g (IL101 × CM 140) with an overall hybrid mean yield of 125.97 g under irrigated conditions at both locations [Table-3]. However, under stress conditions, IL113 × IL103 (30.62 g) and IL113 × IL111 (102.82 g) recorded minimum and maximum grain yield with an average hybrid yield of 66.83 g. The yield penalty of hybrids under stress ranged from 22.91% to 70.37% with an average of 47.30% as compared to irrigated mean. Similar results were obtained in tropical maize hybrids, varieties and landraces [10, 16]. This might be due to reduced rates of photosynthetic activity and unbalanced associations between plant hormones and biological processes in the crop plant under moisture stress [23]. Similarly, for β-carotene content, the lowest and the highest mean performance ranging from 4.02 ppm (IL112 × CM140) to 7.38 ppm (HKI-193-1 × IL105) with an average of 5.73 ppm under irrigated conditions, respectively. These results are confirmed by a group of scientists at the Directorate of Maize Research, New Delhi who reported β-carotene content in yellow maize varied from 0.11 to 2.90 μg g^{-1} [24]. Overall hybrid means increased to 5.87 ppm with an increase of 2.44% under the stress as compared to irrigated block. Apart from β-carotene, hybrid mean average of other biochemical attributes such as grain protein, oil and starch also found to be increased by 5.38%, 3.63% and 1.82% under stress conditions of their irrigated hybrid mean [Fig-2]. Hence, it is confirmed that the biochemical content of the hybrids increased under stress compared to irrigated block. Group of scientists [25] observed a significant increase in grain protein content under the low soil moisture conditions. Similarly, some scientists [26] observed that grain protein and starch percentage improved significantly under stress conditions; however, oil content showed non-significant difference under different soil moisture conditions. Under stress condition some genes induce as response to stress mechanisms expression of which produces the protein for mitigating the effect of stress and thereby might induce the protein level in the seed content under stress as compared to optimum irrigation.

The impact of stress on the expression of some quantitative and qualitative traits in the 45 F_1 hybrids [Fig-2] was done to identify superior hybrid under stress condition. The hybrid mean value for all the single crosses under stress and irrigated conditions differed significantly for ASI, LR, NEP, SI and GY. The average hybrid means of traits *viz.,* DT, DS, ASI, LR, SC, PC, OC and BC increased under stress conditions, whereas, it was reduced for NEP, GY, SI and SH under stress showing the negative impact of stress on expression of these traits [Fig-2]. Similar results of the effects of moisture stress on flowering, yield and biochemical quality traits have been reported by [8]. Yield losses might occur due to a reduction in soil moisture content under stress conditions that leads to increase in air and soil temperature. Similar findings of the significant effect of soil moisture on maize yield have been reported by [27]. Also, the genotypes which depicted shorter ASI exhibited higher grain yield under stress due to synchronize maturity of male and female organs leading to higher rate of seed set [10]

ANOVA and combining ability

The genetic variation existing within the experimental material was partitioned into different sources *viz.,* parents, hybrids, GCA × environments, SCA × environments, error GCA and SCA variance. Both of these variances were significant ($p < 0.05$) for all the characters measured across individual stress and irrigated as well as pooled over environments [Table-1]. Estimates of genetic variance revealed the importance of both additive and non-additive gene actions. The ratio of GCA to SCA variance was less than one suggesting the prime role of non-additive genetic variance for the inheritance of all the qualitative and quantitative traits. Similar types of results were reported by [28] for days to pollen shed, ASI, GY and SH. The importance of additive gene actions was reported for ASI, number of ears per plant and grain yield [29], seed index [30]. Interaction variances resulted from SCA × environments were found significant for all the characters which revealed that σ^2sca was influenced by environments. This confirms that F_1s didn't have a similar relative performance through environments which might be due to the higher sensitivity of single crosses to external macro environmental factors *i.e.*, weather, soils and pests compared to double cross or three-way cross hybrids [31].

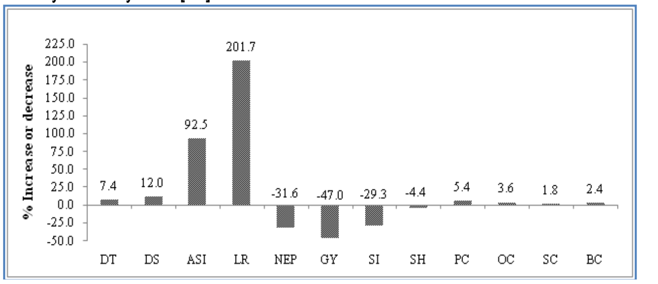


Fig-2 Impact of stress on trait expression of hybrid progeny of inbred lines for different qualitative and quantitative traits (DT: days to 50% tasseling; DS: days to 50% silking; ASI: Anthesis Silking interval; LR: leaf rolling; NEP: number of ears per plant; GY: grain yield per plant; SI: seed index; SH: shelling percentage; PC: protein content; SC: starch content; OC: oil content; and BC: β-carotene content)

Table-1 *Mean squares and genetic variances from the ANOVA of diallel analysis of yellow maize evaluated in subtropical conditions, 2014-15*

Source	Environments	Parents	Hybrids	GCA x Environment	SCA x Environment	Error	σ^2gca ($\sum g_i^2$)	σ^2sca ($\sum\sum s_{ij}^2$)
df	3	9	45	27	135	432		
DT	3498.39**	20.71**	16.31**	3.43**	4.19**	1.08	0.40*	15.23*
DS	4436.97**	34.04**	16.66**	5.82**	5.28**	1.29	1.58*	15.38*
ASI	185.27**	3.52**	1.36**	1.31**	0.70**	0.27	0.20*	1.09*
LR	107.66**	0.28**	0.11**	0.08**	0.078**	0.03	0.02*	0.08*
NEP	2.40**	0.04**	0.04**	0.006**	0.007**	0.003	0.001*	0.04*
GY	65718.84**	2327.30**	581.80**	129.56**	68.52**	21.80	158.68*	560.00*
SI	1006.17**	34.91**	5.33**	4.74**	1.93**	1.25	2.69*	4.09*
SH	331.08**	64.89**	26.44**	8.41**	7.09**	4.56	3.50*	21.88*
PC	7.58**	1.21**	0.28**	0.31**	0.14**	0.02	0.08*	0.26*
OC	0.81**	0.26**	0.17**	0.06**	0.02**	0.007	0.01*	0.17*
SC	27.74**	10.57**	12.52**	14.38**	8.51**	2.26	0.18*	10.27*
BC	1.65**	8.60**	2.23**	1.60**	0.24**	0.01	0.58*	2.22*

*,** Significant at 0.05 and 0.01 levels of probability, respectively. (DT: days to 50% tasseling; DS: days to 50% silking; ASI: Anthesis silking interval; LR: leaf rolling; NEP: number of ears per plant; GY: grain yield per plant; SI: seed index; SH: shelling percentage; PC: protein content; SC: starch content; OC: oil content; and BC: β-carotene content)

Among the parents, CM140, IL111 and IL104 depicted significant and desirable GCA effects found to be a good general combiner for ASI, GY and other parameters [Table-2]. Nevertheless, the parents IL112, IL105, HKI-193-1 and IL111 recorded good GCA for grain protein, oil and β-carotene content. Only 24 single crosses depicted positive and significant SCA effects for grain yield and β-carotene content. The perusal of estimates of SCA effect revealed that crosses IL103 × IL109, IL101 × CM140, IL101 × IL111, IL103 × CM140 and IL113 × IL109 were good specific combiners across individual and pooled over the environments for grain yield. For β-carotene content, crosses, CM140 × IL104, CM140 × IL111, IL103 × CM140, IL104 × IL109 and IL112 × IL109 registered significant SCA effects in the desired direction across stress and irrigated environments. Among the selected crosses, CM140 × IL111, IL103 × CM140, IL104 × IL109 and IL113× HKI-193-1 recorded desirable SCA effects for grain yield and β-carotene which can be used further for improvement of these traits.

Table-2 *GCA effects for grain yield, related and quality traits of yellow maize inbreds assessed in subtropical conditions*

Parents	DT		DS		ASI		LR		NEP		GY		SI		SH		PC		OC		SC		BC	
IL112	0.03	ns	0.2	ns	0.17	*	0.1	ns	0.06	**	-4.65	**	-1.43	**	-2.05	**	-0.04	ns	0.12	**	0.56	*	-0.01	ns
IL113	0.16	ns	0.18	ns	0.01	ns	0.12	ns	0.02	*	-10.13	**	-1.49	**	-1.47	**	-0.22	**	-0.14	**	-0.49	*	-0.14	**
IL101	0.7	**	0.9	**	0.2	*	-0.06	ns	-0.06	**	-5.55	**	-0.25	ns	0.21	ns	-0.16	**	0.06	**	-0.37	ns	0.15	**
IL103	-0.55	**	-0.29	ns	0.26	**	0.02	ns	-0.03	**	0.91	ns	-0.55	**	0.45	ns	-0.21	**	0.01	ns	0.4	ns	0.17	**
HKI-193-1	0.57	**	1.04	**	0.47	**	0.13	ns	-0.01	ns	-4.89	**	0.32	ns	-0.6	ns	0.39	**	-0.08	**	0.23	ns	1.09	**
IL105	0.26	ns	0.6	**	0.34	**	0.05	ns	-0.05	**	-12.56	**	-1.06	**	-2.19	**	0.24	**	-0.1	**	-0.2	ns	-0.38	**
CM140	-2.08	**	-2.78	**	-0.7	**	-0.15	ns	0	ns	15.46	**	1.71	**	2.19	**	-0.17	**	0.06	**	1.09	**	0.02	ns
IL111	-0.37	*	-0.72	**	-0.36	**	-0.1	ns	0.07	**	10.78	**	1.27	**	1.59	**	-0.1	**	-0.1	**	-0.73	**	0.6	**
IL104	1.1	**	0.84	**	-0.25	**	-0.02	ns	0.01	ns	8.94	**	0.99	**	1.58	**	0.15	**	0.12	**	0.35	ns	-0.76	**
IL109	0.18	ns	0.03	ns	-0.15	ns	-0.11	ns	-0.03	**	1.69	*	0.51	**	0.29	ns	0.12	**	0.06	**	-0.85	**	-0.73	**
Min.	-2.08		-2.78		-0.7		-0.15		-0.06		-12.56		-1.49		-2.19		-0.22		-0.14		-0.85		-0.76	
Max.	1.1		1.04		0.47		0.13		0.07		15.46		1.71		2.19		0.39		0.12		1.09		1.09	
S.E.	0.17		0.19		0.09		0.03		0.01		0.77		0.18		0.35		0.03		0.01		0.25		0.02	
SE gi-gj	0.26		0.28		0.13		0.04		0.01		1.15		0.28		0.53		0.04		0.02		0.37		0.03	
CD	0.5		0.55		0.25		0.08		0.02		2.26		0.54		1.03		0.08		0.04		0.73		0.05	

* Significance at 0.05 level of probability, ** Significance at 0.01 level of probability, ns = non-significant (DT: days to 50% tasseling; DS: days to 50% silking; ASI: Anthesis silking interval; LR: leaf rolling; NEP: number of ears per plant; GY: grain yield per plant; SI: seed index; SH: shelling percentage; PC: protein content; SC: starch content; OC: oil content; and BC: β-carotene content)

Thus, the best specific combiners should be exploited to develop commercial high yielding genotype for yield and quality improvement under stress environment. In our study, we noticed that the hybrids, with a good level of stress tolerance involved at least one tolerant or moderately tolerant parent, although the hybrids with both the susceptible parents didn't perform well for grain yield under stress [Table-3]. Similar results were also reported by [32] for water-logging stress tolerance in tropical maize.

Stability analysis

The stability analysis of all the genotypes was carried out to identify stable genotype under stress and irrigated conditions separately, as well as pooled. The mean squares for G × E interaction were significant for six traits *viz.,* DT, DS, GY, PC, OC and BC. Only one cross IL113 × IL109 had higher genotypic mean than population mean, unit regression coefficients and non-significant deviations due to regression which proved to be stable across the environments. Whereas, crosses IL101 × IL111, IL103 × IL104, HKI-193-1 × CM140, IL105 × IL104 and CM140 × IL104 were high yielding, stable and found to be responsive to better environment, *i.e.*, irrigated condition (genotype mean > average crosses mean; b_i=1 significant and b_i>1; S^2d_i = 0 ns). Though the crosses, IL112 × IL109, IL103 × IL111 and IL103 × IL109 had above average stability, which found suitable for poor environments, *i.e.*, Stress environment (genotype mean > average crosses mean; b_i=1 significant and bi<1 and S^2d_i =0 ns).

Overall study concluded that moisture stress causes considerable grain yield loss in parents and single crosses as compared to normal irrigation. On other hand, the level of grain protein, starch, oil and β-carotene contents under stress increased as compared to irrigated condition. The parents, CM140, IL111,IL104 and crosses *viz.,* CM140 × IL104, CM140 × IL111 and IL103 × CM140 found good combiners for most of the traits under stress and irrigated conditions. Overall study depicted the preponderance of non-additive gene action under stress and irrigated conditions. The crosses, IL103 × IL109, IL101 × CM140 and CM140 × IL111 exhibited higher mean performance, standard heterosis along with high desirable SCA effects for days to 50 per cent tasselling and silking, grain yield, number of ears per plant, seed index, shelling percentage and quality traits under varying stress and irrigated environments. Only one cross IL113 × IL109 found stable under stress as well as irrigated systems plus at both the locations for grain yield. The progenies of these crosses might give the chances of selections for grain yield and important quality traits. All the crosses which performed well under irrigated or stress conditions possess at least one tolerant parent (CM140 and IL111). The crosses suitable for stress conditions involved more tolerant parents than susceptible parents. Hence, use of tolerant parent to generate hybrids help in minimizing the grain yield loss under stress conditions. From the above results it is concluded that the approach of hybrid breeding is advisable to mitigate the yield loss under stress conditions. Multiple crosses involving over two parents and bi-parental mating might be prove an effective and alternative approaches by breaking the close linkages for improvement of the maize crop for important traits.

Table 3 *Grain yield and β-carotene mean under irrigated and stress conditions with per cent yield penalty and increase under stress as compared to irrigated with pooled SCA effect and of selected stable maize hybrids for grain yield*

Sr. No.	Crosses	Mean[Grain yield per plant (g)]		% yield penalty under stress	SCA effect pooled	Mean [β-carotene content (ppm)]		% increase under stress	SCA effect pooled	Stability parameters for grain yield per plant		
		Irrigated	Stress			Irrigated	Stress			Mean	b_i	S^2d_i
1	CM140 × IL104	147.71	81.32	44.95	3.39**	5.35	5.48	2.43	0.22**	114.51	1.14##+	-3.31ns
2	CM140 × IL111	142.48	99.58	30.11	10.23**	6.23	6.38	2.41	0.06**	121.03	0.76##	36.9**
3	IL101 × CM140	149.65	83.74	44.04	20.77**	4.99	5.10	2.20	-1.16**	116.69	1.05##	366.54**
4	IL101 × IL111	142.05	74.08	47.85	13.96**	5.68	5.81	2.38	-0.82**	108.06	1.16##++	-14.77 ns
5	IL103 × CM140	146.08	93.41	36.06	18.39**	6.85	7.03	2.55	1.34**	119.74	0.98##	282.97**
6	IL103 × IL109	148.50	100.50	32.32	38.50**	4.89	5.00	2.25	-0.58**	124.50	0.81##++	-12.23 ns
7	IL104 × IL109	139.32	84.16	39.59	13.46**	4.95	5.07	2.32	0.43**	111.74	1.01##	436.93**
8	IL112 × CM140	140.21	91.61	34.66	18.83**	4.02	4.09	1.74	-2.32**	115.90	0.90##	307.39**
9	IL112 × IL109	120.30	80.74	32.89	12.09**	6.01	6.16	2.58	1.12**	100.52	0.67##++	-16.16 ns
10	IL113 × IL109	124.65	76.25	38.82	17.49**	4.84	4.95	2.17	-0.33**	100.45	0.84##	9.16 ns
11	IL113 × IL111	133.38	102.82	22.91	31.92**	5.57	5.70	2.43	-0.68**	118.09	0.56##++	45.27**
	Min.	100.20	30.62	22.91	-26.38	4.02	4.09	1.74	-2.32	66.97	--	--
	Max.	149.65	102.82	70.37	38.50	7.38	7.56	5.19	1.66	124.50	--	--
	Mean	125.97	66.83	47.30	--	5.73	5.87	2.52	--	96.13	--	--
	CD @5%	14.47	8.91	--	--	4.495	0.275	--	--	--	--	--
	CD (S_{ij}-S_{ik}) @5%	--	--	--	7.15	--	--	--	0.16	--	--	--
	CD (S_{ij}-S_{kl}) @5%	--	--	--	6.78	--	--	--	0.16	--	--	--

* Significance at 0.05 level of probability, ** Significance at 0.01 level of probability; ns- non-significant

#,## Significant at 0.05 and 0.01% level, respectively when H_0: b=0; +, ++ Significant at 0.05 and 0.01% level, respectively when H_0: b=1

Conclusion

From the above discussion it is concluded that preponderance of non-additive gene actions for days to 50% tasseling and silking, anthesis silking interval, leaf rolling, grain yield, number of ears per plant, seed index, shelling percentage, protein, oil, starch and β-carotene content in seed. Further the hybrids, CM140 × IL111, IL101 × IL111 and IL103 × IL109 found promising for grain yield and β-carotene content under stress which could be exploited through heterosis breeding programme in the future to breed high yielding stress tolerant hybrid in maize.

Acknowledgements

The authors would like to thank Dr. G.C. Jadeja, Ret. Professor & Head, Department of Genetics and Plant Breeding, BACA, Anand Agricultural University, Anand, Gujarat and Dr. J. S. Patel, Ret. Professor & Head, Department of Agril. Statistics, BACA, Anand Agricultural University, Anand, Gujarat for their contribution in designing this work plan.

Author Contributions

This work was carried out in collaboration between all authors. Authors Dhaduk, H. L. and Khanorkar, S. M. designed the experiment. Khanorkar, S. M. provided the maize parental genotypes for the study. Author Soni, N. V. performed the research work, managed the statistical analysis and prepared the first draft of the manuscript. Authors Soni, N. V. and Patel, J. R. reviewed the study and wrote the final draft of the manuscript with help from Dhaduk H. L. All authors read and approved the final manuscript.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors

Conflict of Interest: None declared

References

[1] Banziger M. and Araus J. (2007) *Springer, Netherlands,* 587-601.

[2] Edmeades G.O. (2013) *ISAAA: Ithaca, NY*, PP. 3.

[3] Bismillah Khan M., Hussain M., Raza A., Farooq S. and Jabran K. (2015) *Turkish Journal of Agriculture and Forestry,*39, 193-203.
[4] Kumar B., Chikkappa Karjagi G., Jat S.L., Parihar C.M., Yathish K.R., Singh V., Hooda K.S., Dass A.K., Mukri G. and Sekhar J.C. (2012) Directorate of Maize Research, Indian Council of Agricultural Research (ICAR), Technical Bulletin, 2012/2, PP.32.
[5] Singh A.D. (2014) "India Maize Summit '14." PP.11 http://www.ficci.com/spdocument/20386/India-Maize-2014_v2.pdf
[6] Sharma K.D. (2011) *Current science,*100(11), 1615-1616.
[7] Grant R.F., Jackson B.S., Kiniry J.R. and Arkin G.F. (1989) *Agronomy Journal,* 81,61-65.
[8] Campos H., Cooper M., Edmeades G.O., Loffler C., Schussler J.R. and Ibanez M. (2006) *Maydica,* 51, 369-381.
[9] Edmeades G.O., Bolanos J., Elings A., Ribaut J.M., Banziger M. and Westgate M.E. (2000) In: Westagate ME, Boote BJ (Eds.), Physiology and Modeling Kernel Set in Maize, CSSA Special Publication 29, CSSA, Madison, WI, PP. 43-73.
[10] Munyiri S.W., Pathak R.S., Tabu I.M. and Gemenet D.C. (2010) *The Journal of Animal and Plant Sciences,* 8(1), 892-899.
[11] Critchley W. and Siegert K. (1991) A manual for the design and construction of water harvesting schemes for plant production, Rome, PP. 15.
[12] Mory C.M., Blay E., Gracen V., Charles T. and Teme N. (2014) *International Journal of Material and Mechanical Engineering,* 3(2),17-30.
[13] Griffing B.(1956a) *Australian Journal of Biological Science,*9, 463-493.
[14] Griffing, B.(1956b) *Heridity*,10,31-50.
[15] Guei R.G. and Wassom C.E. (1992) *Maydica,* 37,157-164.
[16] Betran F.J., Beck D., Banziger M. and Edmeades G.O. (2003) *Crop Science*, 43, 807-817.
[17] Dubey L., Prasanna B.M. and Ramesh B. (2009) *Indian Journal of Genetics,* 69(4), 344-351.
[18] Haskell D. E., Flaspohler D. J., Webster C. R. and Meyer M. W. (2012) *Restoration Ecology*, 20, 113–121.
[19] Sadasivam S. and Manickam A. (1992) Biochemical methods. New Age International (P) Limited, Publishers.
[20] Banziger M., Edmeades G.O., Beck D. and Bellon M. (2000) From theory to practice. Mexico, D.F.CIMMYT, PP.34-42.
[21] Panse V.G. and Sukhatme P.V. (1967) Statistical Methods for Agricultural Workers. ICAR, New Delhi, India.
[22] Eberhart S.A. and Russell W.A. (1966) *Crop Science*, 6, 36-40.
[23] Mehasen S.A.S. and El-Gizawy N.Kh. (2010) The International Conference of Agronomy 20-22 September 2007; EL Arish, PP.26-38.
[24] DMR (2014) Annual Report 2013-14, Directorate of Maize Research, Pusa Campus, New Delhi- 110 012, PP. 98.
[25] Kebede H., Sui R.X., Fisher D.K., Reddy K.N., Bellaloui N. and Molin W.T. (2014) *Agricultural Sciences,*5, 1305-1315.
[26] Kebede H., Abbas H.K., Fisher D.K. and Bellaloui N. (2012) *Toxins,*4, 1385-1403.
[27] Soliman S.E. (2006) *Mansoura University Journal of Agriculture Science,* 31(12), 7525-7540.
[28] Hussain M., Shah K.N., Ghafoor A., Kiani T.T. and Mahmood T. (2014) *The Journal of Animal and Plant Science,* 24(4), 1230-1240.
[29] Wattoo F.M., Saleem M. and Sajjad M. (2014) *American Journal of Plant Sciences*, 5, 1945-1955.
[30] Grudloyma P., Thaitad S., Papintu K. and Kaewtien S. (2010) Proceeding of the 10th Asian Regional Maize Workshop, Makassar, Indonesia, 20-23, October 2008. Mexico D.F.: CIMMYT, PP. 345-348.
[31] Troyer A.F. (1996). *Euphytica,*92, 163-174.
[32] Zaidi P.H., Maniselvan P., Srivastava A., Yadav P. and Singh R.P. (2010) *Maydica,* 55, 17-26.