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GENOTYPE X ENVIRONMENTAL INTERACTION AND STABILITY FOR YIELD AND ITS COMPONENTS IN ELITE MAIZE TYPES UNDER MOISTURE STRESS CONDITIONS

V. ULAGANATHAN[1*], S. M. IBRAHIM[2], P. GOMATHINAYAGAM[3] and A. GURUSAMY[4]

[1]Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India
[2&3]Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625 104, Tamil Nadu, India
[4]Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625 104, Tamil Nadu, India
Corresponding Author's Email: ulagunbourne@gmail.com
Email addresses of co-authors: gomathinayagamprof@gmail.com, guruwms2009@gmail.com

SUMMARY

Maize is one of the most important grain crop in South Asia and is produced throughout the country under diverse environments. Evaluation of maize hybrids under different stresses would be useful for identifying hybrids that combine stability with high yield potential for drought-prone areas. This study was conducted to evaluate 15 maize hybrids and 8 parents including 5 quality protein maize, 2 sweet corn and 1 baby corn to study the stability parameters for grain yield and drought resistance under varied moisture stress conditions. Among the treatments studied, irrigated condition recorded the highest and positive environment index for the traits number of grains per row and single plant yield. Hence, these traits appeared to be the most favorable for irrigated conditions. The induced drought condition was favorable for the expression of high chlorophyll content, protein content and total sugar content since it had positive and high environmental index. Hence, these traits appeared to be the most favorable for drought conditions. The hybrids QPM-6 x S.C.B.7853-1, QPM-13 x Co (BC) 1, QPM-14 x S.C.B.7853-1, QPM-18 x Co (BC) 1, QPM-18 x S.C.B.1457-6 and QPM-18 x S.C.B.7853-1 responded favorably under better environment, but failed to perform under stress condition. The hybrids QPM-12 x S.C.B.1457-6 and QPM -13 x S.C.B.7853-1 was specifically adapted to poor environments and suitable for moisture stress or drought conditions. The hybrid QPM-6 x S.C.B.1457-6 stable for all the 3 treatments and it is adaptable to wider environments. Therefore, these aforesaid maize hybrids are the promising genotypes in future for evolution of location specific superior maize hybrids for irrigated/rainfed maize growing situations.

Key words: Quality protein maize, stable variety, drought resistance, moisture stress, superior hybrid

Key findings: The hybrid QPM-6 x S.C.B.1457-6 proved to be most stable over the 3 treatments for single plant yield, QPM-12 x S.C.B.1457-6 was the most stable under stress conditions and these hybrids are recommended for favorable/stress conditions.

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INTRODUCTION

Maize (*Zea mays* L.) is a major cereal crop for both livestock feed and human nutrition in a number of developed and developing countries, worldwide. It has the highest level of industrial utilization because of its higher production potential and wider adaptability. Maize is also the third most important crop in the world, after wheat and rice, in terms of growing area, production and grain yield (Shiri *et al.*, 2010). Among the maize varieties Quality Protein Maize (QPM) contains nearly twice as much usable protein and yields 10% more grain yield than traditional varieties of maize. The studies indicated that the QPM protein contains, in general, 55% more tryptophan, 30% more lysine and 38% less leucine than that of normal maize (Prasanna *et al.*, 2001). The other nutritional benefits of QPM include higher niacin availability due to a higher tryptophan and lower leucine content, higher calcium, carbohydrate and carotene utilization. Considering the nutritive value and ever-increasing demand for maize based foods, there is an urgent need to evolve new high yielding hybrids. Maize hybrids are reported to give higher yields under good management than open pollinated varieties of similar maturity (Gul *et al*., 2009).

Maize production is limited by several factors including drought, which affects maize grain yield to some degree at almost all the stages of crop growth. However, flowering is the most susceptible and critical stage (Claassen and Shaw, 1970). Drought induced yield losses can be substantial and researchers have been attempting to improve the tolerance of crop for limited supplies of water for decades. This has been accomplished by improving the locally adapted, elite genotypes for drought resistance. One way to alleviate this constraint is through development of higher yielding hybrids which give stable yield across the environments. Grain yield stability is influenced by the capacity of a genotype to react to environmental conditions, which is determined by the genotype's genetic composition. Improved grain yield and stability in maize cultivars have been attributed to increased drought tolerance. Extensive testing of maize hybrids developed for drought prone conditions, under both severe and mild drought stress, as well as in optimal growing environments, would be useful for identifying hybrids that combine high grain yield potential and stability (Meseka *et al.*, 2008).

Knowledge of genotype x environmental interaction (GEI) and stability of genotypes across environments is essential for breeding programme. It helps in identifying genotypes that are widely or specifically adapted to unique environments. Multi-environment evaluation experiments are essential to evaluate grain yield and to quantify adaptability and stability of the hybrids since these are the complex traits and highly influenced by environments (Crossa, 1990). Genotype x environmental interactions may originate from environmental variation in the timing and severity of water deficits, genetic variation in flowering time, nutrient deficiencies and toxicities whose occurrence and severity interact with water deficits (Banziger and Cooper, 2001). There are various methods for stability analysis and investigation the interaction effect of genotype × environment (Asgariniya *et al*., 2008). Stability analysis is a general solution for genotypes reaction to environmental changes (Chogan, 2011). Keeping all these considerations in view, this study was undertaken to study the mean performance of parents and hybrids and to determine the stability parameters for different traits including drought tolerance and to find out the performance of hybrids in different moisture stress levels.

MATERIALS AND METHODS

This experiment was carried out using a line x tester mating design involving 5 Quality Protein Maize (QPM) genotypes as lines and 3 testers comprising of 2 sweet corn and 1 baby corn type collected from Department of Millets, Tamil Nadu Agricultural University, Coimbatore during 2009-2010 (Table 1). The resultant 15 hybrids along with their 8 parents were evaluated at 3 different moisture stress conditions. The moisture stress condition was artificially created through surface irrigation with regulated varied water regimes based on the climatological approaches given by Mishra and Ahmed (1985). Besides variation in moisture level, the different dates of sowing and raising crop in fields of distal ends in Agricultural College and Research Institute farm Madurai, Tamil Nadu with different physical and chemical soil properties which contributed varied environmental factors for resorting to genotypic stability studies (Table 2). Surface irrigation was scheduled based on climatological approach. Sowing irrigation and life irrigation on third day were given to all plots irrespective of the treatment schedule. Subsequent irrigations were given as per the treatments based on IW/CPE ratio of 0.8 *i.e.*, irrigation was given whenever the cumulative pan evaporation reaches 50 mm after pervious irrigation. Total water use was computed as the sum of irrigation water applied and effective rainfall. The irrigation schedule is furnished in Table 3. At flowering and maturity stages, biometrical observations were recorded *i.e.*, number of kernels per row for yield index, chlorophyll stability index for drought index, protein content for QPM index, total sugar content for sweetness index and single plant yield from five randomly selected plants in each entry in each treatments. Chlorophyll stability index was measured by using Soil and plant analysis development (SPAD) developed from Minolta (Minolta Ltd, Tokyo, Japan) it quantifies green colour in plants immediately by non-destructive measuring method (Yadava, 1986). Protein content was estimated by microkjeldahl method (Humpries 1956). Total sugar content was measured by using Hand refractometer and expressed in Brix values (Meier *et al*., 1982).

Table 1. Details of the maize genotypes studied.

Genotypes	**Source**	**Special features**	**Status**
QPM-6	DMR	Quality protein maize	Breeding line
QPM-12	DMR	Quality protein maize	Breeding line
QPM-13	DMR	Quality protein maize	Breeding line
QPM-14	DMR	Quality protein maize	Breeding line
QPM-18	DMR	Quality protein maize	Breeding line
Co (BC) 1	TNAU	Baby corn	Released variety
S.C.B.1457-6	DMR	Sweet corn	Breeding line
S.C.B. 7853-1	DMR	Sweet corn	Breeding line

DMR-Directorate of Maize Research, TNAU- Tamil Nadu Agricultural University

Table 2. Different environments.

Particulars	Environment		
	E1	E2	E3
pH	6.7	6.9	7.2
EC(dsm^{-1})	0.25	0.35	0.45
Organic carbon (%)	0.12	0.13	0.15
Available N (kg/ha)	200	290	325
Available P (kg/ha)	25	28	30
Available K (kg/ha)	180	190	200
Texture	Sandy loam	Sandy loam	Clay loam
Soil type	Red soil	Red soil	Red soil

Table 3. Irrigation Environments.

Irrigation	Condition
E_1 – Irrigation at IW/CPE ratio of 0.8	Rainfed
E_2 – Irrigation at IW/CPE ratio of 0.6	Partially irrigated
E_3 – Irrigation at IW/CPE ratio of 0.4	Irrigated

IW-Irrigation water CPE-Cumulative pan evaporation

Table 4. Analysis of variance for different traits in maize.

Source	df	Mean squares				
		Number of grains / row	Chlorophyll content	Protein content (%)	Total sugar content (Brix)	Single plant yield (g)
Genotype	22	93.44**	125.01**	2.09**	3.59**	1970.89**
Environment + (G x E)	46	11.88**	1.28**	1.29*	1.19**	108.34**
Environment (linear)	1	265.69**	51.15**	35.74**	35.52**	3169.11**
Genotype x Environment (linear)	22	7.15	0.26**	0.15	0.44	60.79**
Pooled deviation (nonlinear)	23	5.37**	0.094**	0.88**	0.42**	20.74**
Pooled Error	138	0.25	0.034	0.019	0.001	2.62

***** Significant at 5% level**, **** Significant at 1% level

Table 5. Environmental indices for different characters in maize.

Characters	E_1	E_2	E_3
Number of grains / row	-3.49	-2.28	1.55
Chlorophyll content	1.06	0.00	-1.05
Protein content (%)	0.99	-0.26	-0.72
Total sugar content (Brix)	0.91	-0.77	-0.84
Single plant yield (g)	-6.7	-2.58	9.29

Statistical analysis

The mean values for all the traits across the 3 environments were subjected to stability analysis as suggested by Eberhart and Russell (1966) for various stability parameters *i.e.*, mean regression coefficient (b_i) and deviation from their regression (S^2d_i) to get the individual genotype response by partitioning the pooled deviation. The significance of the stability parameters *i.e.*, b_i, its deviation from unity and deviation from regression were tested by using appropriate t and F tests. In addition, environmental index (Ij) and phenotypic index (Pi) were also estimated from the mean data averaged over replications in the environments. Data were analyzed using GENRES Statistical Software Package, version 3.11 (Pascal Intl Software Solutions, 1994)

RESULTS AND DISCUSSION

Analysis of variance for stability showed significant mean squares for genotypes and environments (linear), indicating that the genetic variation was present and the treatments were distinct from one another (Table 4). The pooled analysis of variance revealed that genotype x environment (linear) interactions were significant for 2 characters *i.e.*, chlorophyll content and single plant yield implying differential response of genotypes under 3 locations for these characters. Similar reports were earlier made by Panwar *et al.* (2008) and Ramya and Senthilkumar (2008).The genotype x environment (linear) interactions for the remaining 3 characters *i.e.*, number of grains / row, protein content and total sugar content were non-significant. Therefore, further analysis of stability was not carried out for these 3 characters. Highly significant variation due to environments represented adequate heterogeneity among the treatments for all the traits. Variance due to environment + (genotype x environment) interaction and pooled deviation (nonlinear) were significant indicating presence of variation in the mean performance of all genotypes over treatments *i.e.*, differential behavior of the genotypes under different treatments. Mean sum of squares due to environments + (genotypes x environments) were significant for the characters number of grains / row, chlorophyll content, protein content, total sugar content and single plant yield depicting the distinct nature of environments and genotype x environment interaction on phenotypic expression. These findings are in consistent with Deshpande and Dalvi (2006), Panwar *et al.* (2008), Ramya and Senthilkumar (2008) and Krishnappa *et al.* (2009).

The environmental indices computed for 5 characters are presented in the Table 5. Environmental index directly reflects the environment by negative and positive values. Among the 3 moisture stress conditions, irrigated condition recorded the highest and positive environmental index for the traits like number of grains per row and single plant yield. Therefore, this treatment appeared to be the most favorable for particular conditions. None of the traits had positive indices in partially irrigated condition. The induced drought condition was favorable for the expression of high chlorophyll content, since it had positive and high environmental index. Hence, these traits appeared to be the most favorable for drought conditions. Negative values of environmental index indicated the unfavorable nature of that particular condition. In this study, the mean performance coupled with the regression coefficient (b_i) and variance of deviation from regression (δ^2_{di}) of each genotype represented its stability (Table 6a and 6b). With these conditions, the parents and hybrids were classified and evaluated for their adaptability and stability in respect of yield and other component characters studied.

Water stress slows ear growth and silk emergence more than tassel growth or anthesis resulting in widening the interval between anthesis and silking (ASI). Yield under stress at flowering shows a strong dependency on number of grains per row, bareness and ASI in tropical maize (Bolanos and Edmeades, 1996). For number of grains per row, high mean than the general mean (32.0), regression coefficient more than unity and non-significant deviation from regression were observed in the hybrids QPM-6 x S.C.B. 7853-1 (33.7) and QPM-13 x S.C.B.7853-1 (33.1) indicating that these hybrids responded to favorable conditions and can produce higher yields when provided with suitable environments. Similar reports were earlier reported by Kalla *et al.* (2001).

The hybrid QPM-12 x S.C.B.7853-1 (32.9) showed regression coefficient less than 1, high mean than the general mean and non-significant deviation from regression was specifically adapted to poor environments and suitable for moisture stress or drought conditions. These findings are consistent with Sreedhar *et al.* (2011). The hybrid QPM-14 x S.C.B.1457-6 (40.5) appeared with high mean than the general mean, around unity and non-significant deviation from regression are considered to be stable for wider conditions.

Leaf relative water content has been emphasized as a better indicator of water status of a plant than water potential (Sinclair and Ludlow, 1985). High accumulation of proline is effective in chlorophyll stability and helps in stress tolerance of plants (Ashraf *et al.*, 1995). For chlorophyll content, the hybrid QPM-14 x Co (BC) 1 (37.9) were having high mean than the general mean (35.66), regression coefficient more than unity and non-significant deviation from regression indicated their best adaptation to favourable conditions. The hybrids QPM-6 x S.C.B.7853-1 (38.7), QPM-12 x Co (BC) 1 (43.4), QPM-13 x S.C.B.1457-6 (36.1) and QPM-14 x S.C.B.7853-1 (51.7) showed regression coefficient less than 1, high mean then the general mean and non-significant deviation from regression and were found to be suited for unfavorable/stress environments. Similar results were observed by Bhakta and Das (2008) and Panwar *et al.* (2008). The hybrid QPM-12 x S.C.B.7853-1 (37.2) appeared with high mean than the general mean, unit regression co-efficient and non-significant deviation from regression. Hence, this hybrid was suitable for over all treatment conditions and they are considered as stable hybrid.

Maize protein is highly characterized by high levels of glutamic acid, leucine and low levels of lysine and tryptophan. Glover and Mertz (1987) observed that endosperm protein content in 13 QPM lines were on par or better than the normal maize.

Table 6a. Estimates of stability parameters for different traits in maize.

Genotypes	Number of grains / row			Chlorophyll content			Protein content (%)		
	Mean	bi	δ^2di	Mean	bi	δ^2di	Mean	Bi	δ^2di
QPM-6	25.8	0.65	1.78*	31.5	0.72**	-0.03	8.3	0.94**	0.21**
QPM-12	31.2	0.73	4.93**	25.1	1.47**	0.21*	9.4*	0.83*	0.01
QPM-13	26.7	0.99	0.07	31.4	0.95**	0.01	10.0*	0.93**	0.02
QPM-14	28.9	1.51*	4.23**	37.1*	0.40**	0.03	9.2	1.16**	0.04
QPM-18	29.1	2.08**	0.28	40.0*	1.15**	0.12*	8.5	1.07**	0.27**
Co (BC) 1	24.6	-0.13	0.16	30.0	1.28**	0.01	6.2	1.99**	19.02**
S.C.B.1457-6	22.0	0.30	10.42**	34.4	0.69**	0.05	7.5	0.87*	0.00
S.C.B. 7853-1	24.7	0.47	16.26**	29.7	1.21**	0.10	7.4	1.10**	0.09*
QPM-6 x Co (BC) 1	23.8	-0.47	2.37**	27.8	1.83**	0.08	8.7	0.62	0.03
QPM-6 x S.C.B.1457-6	34.5*	0.38	6.59**	45.9*	1.48**	0.36**	9.0	0.70*	0.01
QPM-6 x S.C.B. 7853-1	33.7*	1.45*	0.21	38.7*	0.85**	-0.01	8.3	1.17**	-0.02
QPM-12 x Co (BC) 1	32.1	0.92	6.44**	43.4*	0.61**	0.01	9.2	0.70*	0.01
QPM-12 x S.C.B.1457-6	35.2*	2.40**	12.16**	29.6	0.71**	-0.01	8.6	1.03**	-0.01
QPM-12 x S.C.B. 7853-1	32.9	0.55	0.30	37.2*	0.96**	-0.03	8.5	1.22**	-0.02
QPM-13 x Co (BC) 1	32.7	1.96**	8.71**	32.3	0.66**	0.01	8.7	0.99**	-0.01
QPM-13 x S.C.B.1457-6	35.1*	0.35	1.54*	36.1*	0.84**	-0.02	9.4	1.32**	0.01
QPM-13 x S.C.B. 7853-1	33.1	1.26*	-0.06	35.2	0.98**	-0.03	9.2	1.27**	0.06
QPM-14 x Co (BC) 1	35.2*	2.21**	1.17*	37.9*	1.53**	0.09	8.3	1.25**	0.02
QPM-14 x S.C.B.1457-6	40.5*	0.95	-0.25	34.5	0.88**	-0.02	8.8	0.74*	0.18**
QPM-14 x S.C.B. 7853-1	39.4*	1.23*	5.53**	51.7*	0.85**	-0.03	9.9*	0.34	0.01
QPM-18 x Co (BC) 1	36.4*	-0.04	11.54**	35.1	0.88**	-0.02	9.0	0.94**	0.02
QPM-18 x S.C.B.1457-6	38.6*	1.97**	22.40**	30.1	0.82**	0.01	9.3	0.88**	-0.01
QPM-18 x S.C.B. 7853-1	41.8*	1.29*	0.85*	45.6*	1.26**	0.48**	9.2	0.98**	0.01
General mean	32.0			35.7			8.7		
SE (Mean)	1.63			0.21			0.66		
SE (bi)	0.569			0.170			0.315		

***** Significant at 5% level
****** Significant at 1% level

Table 6b. Estimates of stability parameters for different traits in maize.

Genotypes	Total sugar content (Brix)			Single plant yield (g)		
	Mean	bi	δ^2di	Mean	bi	δ^2di
QPM-6	11.8	1.51**	0.17**	91.3	0.82*	1.39
QPM-12	10.8	2.19**	2.76**	81.9	0.78*	41.20**
QPM-13	10.7	1.55**	0.49**	76.1	0.85*	9.13*
QPM-14	10.4	1.65**	1.25**	93.7	0.78*	40.92**
QPM-18	9.9	0.27	0.78**	93.4	1.09**	14.72*
Co (BC) 1	11.6	1.15**	0.62**	53.6	0.12	-1.49
S.C.B.1457-6	12.2*	0.64	0.07**	47.6	0.24	42.95**
S.C.B. 7853-1	12.6*	0.85*	0.14**	53.2	0.24	52.86**
QPM-6 x Co (BC) 1	10.4	0.79	0.17**	78.5	-0.36	12.79*
QPM-6 x S.C.B.1457-6	13.0*	0.67	0.21**	109.7*	0.92**	-1.88
QPM-6 x S.C.B. 7853-1	12.6*	0.64	0.01	117.7*	1.57**	0.89
QPM-12 x Co (BC) 1	12.3*	1.25**	0.05**	103.5*	0.67*	45.89**
QPM-12 x S.C.B.1457-6	12.8*	0.74	0.55**	113.5*	0.72*	-0.10
QPM-12 x S.C.B. 7853-1	12.8*	0.41	0.88**	107.4*	1.21**	102.52**
QPM-13 x Co (BC) 1	9.5	1.10*	0.02	123.6*	1.52**	-1.09
QPM-13 x S.C.B.1457-6	11.4	0.10	0.03**	95.5	1.24**	22.87**
QPM-13 x S.C.B. 7853-1	11.4	0.28	0.02**	99.3	0.79*	-0.78
QPM-14 x Co (BC) 1	12.4*	1.36**	0.02**	105.1*	1.98**	16.06*
QPM-14 x S.C.B.1457-6	12.9*	0.65	1.16**	106.6*	0.73*	12.15*
QPM-14 x S.C.B. 7853-1	12.0	0.80	0.27**	134.0*	2.79**	4.22
QPM-18 x Co (BC) 1	10.8	1.35**	0.02**	123.5*	1.45**	-1.87
QPM-18 x S.C.B.1457-6	11.9	1.80**	0.08**	128.0*	1.38**	4.66
QPM-18 x S.C.B. 7853-1	9.6	1.22**	-0.01	145.4*	1.47**	-1.22
General mean	11.6			99.2		
SE (Mean)	0.46			3.22		
SE (bi)	0.407			0.320		

***** Significant at 5% level
****** Significant at 1% level

Table 7. Stable genotypes for different traits in maize.

Characters	Hybrids for all environments	Hybrids for irrigated environments	Hybrids for drought environments
Number of grains / row	QPM-14 x S.C.B.1457-6	QPM-6 x S.C.B. 7853-1, QPM-13 x S.C.B. 7853-1	QPM-12 x S.C.B. 7853-1
Chlorophyll stability index	QPM-12 x S.C.B. 7853-1	QPM-14 x Co (BC) 1	QPM-6 x S.C.B. 7853-1, QPM-12 x Co (BC) 1, QPM-13 x S.C.B.1457-6, QPM-14 x S.C.B. 7853-1
Protein content (%)	QPM-18 x Co (BC) 1, QPM-18 x S.C.B. 7853-	QPM-13 x S.C.B.1457-6, QPM-13 x S.C.B. 7853-1	QPM-6 x S.C.B.1457-6, , QPM-12 x Co (BC) 1, QPM-14 x S.C.B. 7853-1, QPM-18 x S.C.B.1457-6
Total sugar content (Brix)	----	----	QPM-6 x S.C.B. 7853-1
Single plant yield (g)	QPM-6 x S.C.B.1457-6	QPM-6 x S.C.B. 7853-1, QPM-13 x Co (BC) 1, QPM-14 x S.C.B. 7853-1, QPM-18 x Co (BC) 1, QPM-18 x S.C.B.1457-6, QPM-18 x S.C.B. 7853-1	QPM-12 x S.C.B.1457-6, QPM-13 x S.C.B. 7853-1

The QPM endosperm proteins showed significantly higher percentage of tryptophan. For protein content, regression coefficient more than unity with high mean than the general mean (8.7) and non-significant deviation from regression as reported by Kozubenko *et al.* (1990) were observed in the parents QPM-14 (9.2) and the hybrids QPM-13 x S.C.B.1457-6 (9.4) and QPM-13 x S.C.B.7853-1 (9.2). While regression coefficient less than unity, non-significant deviation from regression with high mean than the general mean were exhibited by parents QPM 12 (9.4) and QPM 13 (10.0) and hybrids QPM-6 x S.C.B.1457-6 (9.0), QPM-12 x Co (BC) 1 (9.2), QPM-14 x S.C.B.7853-1 (9.9) and QPM-18 x S.C.B.1457-6 (9.3). The hybrids QPM-18 x Co (BC) 1 (9.0) and QPM-18 x S.C.B. 7853-1 (9.2) appeared with high mean than the general mean, around unity and non-significant deviation from regression. Therefore, these hybrids are recommended for cultivation across the tested treatments for particular trait.

Sugars play an important role in osmotic adjustment in maize. There are several reports on carbohydrate accumulation during various abiotic stresses in the temperate grasses and cereals from the *Gramineae* family where long term carbohydrate storage occurs during reproductive development. Accumulation of sugars in different parts of plants is enhanced in response to the variety of environmental stresses (Prado *et al.*, 2000). The accumulation of soluble sugars was strongly correlated to the acquisition of drought tolerance in plants (Hoekstra *et al*., 2001). For total sugar content, the hybrids QPM-13 x Co (BC) 1 (9.5) and QPM-18 x S.C.B.7853-1 (9.6) had more than unity and non-significant deviation from regression with less than the general mean (11.6). Similar results were reported by Zhao Ren Gui *et al.* (2000). The hybrid QPM-6 x S.C.B.7853-1 (12.6) appeared with high mean than the general mean, less than unity and non-significant deviation from regression indicated their adaptation to unfavorable condition. None of the genotypes had high mean, unit regression coefficients and non-significant deviations from regression for this trait.

Single plant yield is the most important trait in the development of maize hybrids. Identification of a hybrid with high grain yield and average stability is of immense value. A perusal of stability parameters for single plant yield indicated that both linear and non-linear components of genotype x environment interaction were found to be significant in the current study. Similar results were reported by Panwar *et al.* (2008) and Krishnappa *et al.* (2009). For single plant yield, the hybrids QPM-6 x S.C.B.7853-1 (117.7), QPM-13 x Co (BC) 1 (123.6), QPM-14 x S.C.B.7853-1 (134.0), QPM-18 x Co (BC) 1 (123.5), QPM-18 x S.C.B.1457-6 (128.0) and QPM-18 x S.C.B.7853-1 (145.4) had high mean than the general mean (99.2), non-significant deviation from regression and regression coefficient more than 1 were registered. Hence, these hybrids were found to be suitable for favorable conditions and there is yield reduction in the unfavorable conditions. The hybrids QPM-12 x S.C.B.1457-6 (113.5) and QPM-13 x S.C.B.7853-1 (99.3) were found to have regression co-efficient less than the unity in combination with high mean than the general mean and non-significant deviation from regression. Hence, these hybrids are having high stability and considered to be adaptable to stress conditions. These findings are consistent with Rahman *et al.* (2010), Dushyantha Kumar *et al.* (2010), Sreedhar *et al.* (2011). The hybrid QPM-6 x S.C.B.1457-6 (109.7) appeared with high mean than the general mean, unit regression co-efficient and non-significant deviation from regression. Therefore, this hybrid was stable for grain yield in all the conditions. Similar findings were reported by Gouri Shankar *et al.* (2008).

Eberhart and Russell (1966) described an ideal variety as one which should have high mean value over a wide range of environments, a regression coefficient around unity and non-significant deviation from regression coefficient. Genotypes based on their stability for different traits under the study were categorized in Table 7. From stability analysis studied, it can be inferred that the hybrid QPM-6 x S.C.B.1457-6 showed general adaptation to all conditions and stable for grain yield. The hybrids QPM-6 x S.C.B.7853-1, QPM-13 x Co (BC) 1, QPM-14 x S.C.B.7853-1, QPM -18 x Co (BC) 1, QPM-18 x S.C.B.1457-6 and QPM-18 x S.C.B.7853-1 responded favorably under better condition, but failed to perform better under stress condition hence they are suitable for irrigated condition.

The hybrids QPM-12 x S.C.B.1457-6 and QPM-13 x S.C.B.7853-1 were specifically adapted to poor conditions and suitable for moisture stress condition. This study makes a platform in evolution of maize hybrids and for release after multi-location and adaptive research trials to cater the future need of maize growers and to enhance their economic status.

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