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Stability Analysis of Maize (*Zea mays* L.) Hybrids for Grain Yield and Its Attributing Traits Using Eberhart and Russel Model

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A genotype is considered to be most adaptive / stable, when it registers high mean yield but show a minimum interaction with the environment. Knowledge of genotype × environment interaction and yield stability are important parameters in breeding new cultivars with improved adaptation to environmental constraints prevailing in the target environments. Therefore, an effort was made to know the genotype - environment interaction and to identify stable single cross hybrids across the environments. Eight newly synthesized single cross maize hybrids and 7 checks were evaluated in a Randomized Block Design with three replications during *Rabi*-2016 across three locations spread

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over different agro-climatic zones of Karnataka state, India. Different stability parameters as suggested by Eberhart and Russell [1] were estimated. Joint analysis of variance revealed significant differences among environments, hybrids and environments × hybrids interactions advocating the adequacy of stability analysis. Hybrids, *viz.,* MAI 349×MAI 283, KDMI 16×BGUDI 118 were stable for days to anthesis and silking, respectively. Whereas, hybrids *viz.,* KDMI 16×BGUDI 118, BGUDI 120×VL 109252 and MAI 283× KDMI 16 registered mean values lower than the overall mean with bi value nearer to unity and non significant S^2di for anthesis silking interval. Hybrid, MAI 349×MAI 283 for plant height and cob length, KDMI 16×MAI 283 for cob length, number of kernel rows^{-1} and 100 grain weight, BGUDI 88×MAI 349 for cob diameter, MAI 394×BGUDI 88 for shelling % and KDMI 16×BGUDI 118 for grain yield plant^{-1} registered stable performance across the environments. Based on the positive and negative environmental indices, production environment at location 1 (K Block UAS, GKVK, Bengaluru), was most favorable for expression of majority of characters studied. Hybrid KDMI 16×MAI 283 was found stable across the environments for most of the characters studied.

Keywords: Stability analysis; Zea mays L.; linear regression; regression coefficient; genotype × environment interaction; environmental indices.

1. INTRODUCTION

Maize is the most versatile crop among cereals with respect to its adaptability, types and uses. It is the second most important cereal crop in the world in terms of acreage and is called the 'Queen of Cereals' [2]. The multiple utilities of maize as a 'food', 'fodder' and 'feed' makes it further more demand friendly and insulates it against low demand situations. These unique characteristics of maize make the crop a suitable candidate for enhancing farmer's income and livelihoods in India. The current maize production scenario highlights presence of hybrid maize at about 65-70 percent acreages and most of it accounts for feed and industrial grade Maize, while food grade Maize is produced using traditional cultivars (OPVs). In the recent years, farmers continue to replace traditional cultivars/old hybrids with the newer higher-yielding hybrid varieties. On the demand side, Maize consumption has increased by 2 percent over previous year reaching it to a figure of 24 Mn MT during FY 2016–17 [2]. In order to meet the desired demand levels all breeding programmes should aim at development of a stable and adaptable variety/hybrid which could perform more or less uniformly under different environmental conditions. The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is tested [3].

The ability of an individual/ a genotype to achieve the maximum potential encoded in its genome is a function of the environment in which it completes its life cycle. Evolution provides numerous examples of exquisite adaptations that allow individuals to excel in specific environmental contexts [4]. Expression of a phenotype is a function of the genotype, the environment and differential phenotypic response of genotypes to different environments, also known as genotype by environment (G × E) interaction.

Stability analysis helps in understanding the adaptability of a genotype/hybrid over a wide range of environments. The use of adaptable genotype/hybrid for general cultivation over wide range of environments helps in achieving stabilization in crop production over location and seasons/years [5]. Therefore, an individual / a genotype is said to be stable/adaptable, if it registers high mean yield and its among-environment variance is small and possesses an unchanged or least changed performance regardless of any variation of the environmental conditions [3]. According to Eberhart and Russell, [1] stability is the ability of a genotype to show a minimum interaction with the environments. Hence, the stability of genotype performance is directly related to the effect of interaction between genotype and environment [6].

It is well known fact that a specific genotype does not always exhibit the same phenotypic expression under all environments and different genotypes respond differently to specific environment. Therefore, the understanding the interaction between genotype and environment and stability are important for breeding new cultivars with improved adaptation to environmental conditions prevailing in the target environments. Therefore, an effort was made to know the genotype - environment interaction and to identify stable single cross hybrids across the environments.

2. MATERIALS AND METHODS

2.1 Study Location, Experimental Material and Experimental Design

The experimental material for the present investigation comprises of eight newly synthesized single cross maize hybrids *viz.* KDMI 16×MAI 283, KDMI 16×BGUDI 118, BGUDI 88×MAI 349, BGUDI 120×VL 109252, MAI 394×BGUDI 88, MAI 283×KDMI 16, MAI 349×MAI 283, MAI 283×BGUDI 120 and seven checks (three public bred hybrids *viz*., Arjun, Nityashree and Hema and four private bred hybrids *viz*. DKC 9133, DKC 9150, CP 818 and NK 6240). These hybrids along with checks were evaluated in a Randomized Block Design with three replications, having a plot length of 3 m with inter and intra row spacing of 60 cm and 30 cm, respectively, during *Rabi*-2016 across three locations spread over different agro-climatic zones of Karnataka state, India *viz.* Agricultural Research Station, Bheemarayanagudi, University of Agricultural Sciences, Raichur {(Zone-3) (16º43' N latitude and 76º51' E longitude, 411.75 meters above mean sea level, average annual rainfall: 774.1 mm)}, K-Block, Department of Genetics and Plant breeding, University of Agricultural Sciences, GKVK, Bangalore {(Zone-5) (13º05' N latitude and 77º34' E longitude, 924 meters above mean sea level, average annual rainfall: 915 mm)} and farmer's field at Kudupali village, Hirekerur Taluk, Haveri district {(Zone-8) (14º80' N latitude and 75º40' E longitude, 632 meters above mean sea level, average annual rainfall: 825 mm)}.

The crop was raised under irrigated conditions following the recommended package of practices. Five plants from each hybrid from each replication were randomly selected and tagged for recording the observations. The data was recorded on eleven different morphological and yield parameters *viz.,* days to anthesis, days to silking, Anthesis Silking Interval (ASI), cob length, cob diameter, plant height, kernels rows^{-1}, kernel rows ear^{-1}, test weight, shelling % and grain yield plant^{-1}.

2.2 Statistical Analysis

Regression of the mean yield and its attributing traits of the individual genotypes on the environmental index and deviations of the regression coefficient from the unity as suggested by Eberhart and Russell [1] were used to calculate stability of the trait for each genotype.

The model is:

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

Where,

Y_{ij}= Mean of the i^{th} variety at jth environment.
μ_i= Mean of the i^{th} variety over the environments.
β_i= Regression coefficient of i^{th} variety to varying environments indices.
I_j= Environmental index *i.e.* mean of all varieties at j^{th} environment minus grand mean.
δ_{ij} = Deviation from regression of i^{th} variety at j^{th} environment.

The yield performance for each hybrid was calculated by regressing the mean yield of individual genotypes on environmental index and calculating the deviations from regressing the mean yield of individual genotypes on environmental index and calculating the deviations from regression. Regression coefficient (bi) was considered as an indication of the response of the genotype to varying environment while the environment and genotype × environment interactions were partitioned into three components *viz.,* environment (linear), genotype x environment (linear) and deviation from regression (pooled deviation over the genotypes). Environmental index i.e. mean of all varieties at j^{th} environment minus grand mean δ_{ij}=Deviation from regression of i^{th} variety at j^{th} environment.

2.3 Environmental Indices

The environmental index was calculated as the mean of all the 15 maize hybrids at each environment by subtracting the grand mean.

$$E_j = Y_{.j} - \overline{Y}_{..}$$

Where,

E_j= Deviation from the mean yield from the j^{th} environment
$Y_{.j}$= The Total, over all the varieties under j^{th} environment
$\overline{Y}_{..}$ = $\sum_i \sum_j Y_{ij}$ / Total number of observation

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The combined analysis of variance is represented in Table 1. The results of joint analysis of variance for grain yield and its attributing traits displayed significant differences among environments, hybrids and environments × hybrids interactions advocating the adequacy of stability analysis. Similarly, Dewdar [7] and Sirlene et al. [8] reported significant differences among the environments, hybrids and their interactions in their study. Mean sum of squares due to hybrids were significant for all the characters studies except cob diameter and kernel rows ear $^{-1}$ which revealed the presence of substantial amount of variation among the hybrids evaluated. Significance of Hybrids × environment interaction for anthesis silking interval and plant height revealed that genotypes interacted significantly with environments / locations and indicating that macro environmental differences were present under all three environments studied. Mean sum of squares due to Environments were significant for all the characters studies indicating that environments selected for study were highly diverse.

Hybrids × environment (Lin) interactions were significant only for plant height, indicating that the behavior of the genotypes could be predicted over the environments more precisely and accurately as the G × E interaction was the outcome of the linear function of the environmental components. Significance of mean square due to G × E (linear) for plant height was reported by Gami et al. [9] and Matin et al. [10]. Mean sum of squares due to Environments (Lin) were significant for all the characters except anthesis silking interval. The significance of mean square due to G (Hybrids) × E (linear) revealed that the behavior of the genotypes could be predicted over the environments more precisely and accurately as the G (Hybrids) × E interaction was the outcome of the linear function of the environmental components.

The higher magnitude of mean squares for environment (linear) compared to hybrids × environments (linear) interaction indicated that linear response of environment accounted for the major part of total variation for all the characters studied and may be responsible for high adaptation in relation to yield and other traits. Therefore, prediction of performance of hybrids over environments would be possible for the various characters. Significance of mean sum of squares due to pooled deviation for test weight and grain yield plant $^{-1}$ indicates genotypes differed considerably with respect to their stability. The magnitude of linear component i.e. Environment (linear) was higher than that of the non linear component (pooled deviation). Mean sum of squares due to Environment + (Hybrids ×environment) were significant for only for cob length and plant height which suggested the distinct nature of environments and hybrids × environment interactions in phenotypic expression [11].

3.2 Stability Analysis

3.2.1 Flowering

An analysis of variance for deviations in the linear regression (S^2d) was performed to measure the stability of genotypes. Three stability parameters *viz.,* mean (X), regression coefficient (bi=1) and mean square deviation from regression line ($S^2di=0$) were estimated for all the eleven traits and the results obtained are presented in this section. High value of regression (bi>1) indicates that the variety is more responsive for input rich environment, while, low value of regression (bi<1), is an indication that the variety may be adopted in poor environment.

The mean values for days to anthesis ranged from 55.97 (KDMI 16×BGUDI 118) to 61.04 days (NK 6240), but the hybrid KDMI 16×BGUDI 118 even though it recorded lowest mean values but it registered highest values (bi=2.37) and non significant deviation from regression ($S^2di=0.02$) indicating that it is adapted for high performance environments. Check hybrid NK 6240 registered highest mean values but recorded lowest bi value (bi = - 0.40). Hybrid, MAI 349×MAI 283 recorded mean value of 58.01 which is on far with overall mean (58.20) along with regression value nearer to unity (bi=1.10) and non significant deviation from regression ($S^2di= -1.03$) indicating that this hybrid is stable across the environments. Similarly, Rahman et al. [12] reported stable maize hybrids with regression coefficient comparatively closer to unity and non significant deviation from regression in their study. The mean values for days to silking ranged from 57.79 (KDMI 16×MAI 283) to 62.91 days (CP 818). Hybrid KDMI 16×BGUDI 118 (2.99) recorded higher value of regression (2.99) (bi>1) but has S^2di value of 0.28, indicating that the hybrid is responsive for input rich environment. Check hybrid Arjun recorded mean value (60.07) lower than overall mean value (60.27) along with regression value nearer to unity (bi=0.82) and non significant deviation from regression (S^2di= - 0.95) indicating that this hybrid is stable across the environments. These findings are in agreement with conclusions reached by Khalil [13] (7) in his studies. The mean values for anthesis silking interval ranged from 1.26 (Hema) to 3.68 (MAI 283×BGUDI 120). Hybrids *viz.,* KDMI 16×BGUDI 118, BGUDI 120×VL 109252, MAI 283× KDMI 16 and check hybrid Arjun registered mean values lower than the overall mean values along with regression (bi) value nearer to unity and non significant deviation from regression (S^2di) (Table 2). Though, hybrids MAI 394 ×BGUDI 88 and MAI 349×MAI 283 recorded regression (bi) value nearer to unity and non significant deviation from regression (S^2di), their mean values were more than the overall mean values. For characters like anthesis silking interval, the genotype with mean value lower than the overall mean value is preferred. The findings of present investigation are in line with the findings of Rahman et al. [12] who reported stable maize hybrids with regression coefficient comparatively closer to unity and non significant deviation from regression for anthesis silking interval.

3.2.2 Plant height

The mean value for plant height ranged from 183.70 (KDMI 16×MAI 283) to 214.40 (MAI 349×MAI 283). Hybrid MAI 349×MAI 283 recorded mean value (214.40) above the overall mean (195.30) along with regression value nearer to unity (bi=1.02) and non significant deviation from regression (S^2di= - 94.69) indicating stability of this hybrid across the environments. Similarly, Khalil [13], Sayed Towseef Ahmad et al. [14] and Nirmal Raj et al. [11] reported stable hybrids for height in their respective investigations. Hybrid MAI 283× BGUDI 120 recorded mean value (192.60) lesser than overall mean of 195.30 along with regression value nearer to unity (bi=1.10) and non significant deviation from regression (S^2di= - 92.60) indicating its performance under lower input environments (Table 2).

3.2.3 Cob characteristics

The mean values for cob length ranged from 14.82 (MAI 283× BGUDI 120) to 19.47 (MAI 349×MAI 283). Hybrids, KDMI 16×MAI 283 (17.46; 1.02; -0.72) and MAI 349×MAI 283 (19.47; 0.98; -0.67) recorded mean values greater than overall mean value along with regression value (bi) nearer to unity and non significant deviation from regression (S^2di). Similar finding on identifying stable genotype for cob length using Eberhart and Russel's stability analysis was reported by Nadagoud et al. [15], Karadavut and Akilli [16], Syed Towseef Ahmad, et al. [14], Matin et al. [10], Sowmya et al. [17] and Nirmal Raj et al. [11]. Though, check hybrid DKC 9150 recorded regression value nearer to unity (bi=0.89) and non significant deviation from regression (S^2di= -0.41) but its mean values (16.68) were less than the overall mean indicating that this hybrid is responsive for low input environment. Cob diameter among the tested hybrids ranged from 13.03 (MAI 283×BGUDI 120) to 14.72 (MAI 349×MAI 283). Three hybrids *viz.,* BGUDI 88×MAI 349 (13.46; bi=1.08; S^2di= -0.02), CP 818 (14.03; bi=0.94; S^2di = -0.29) and DKC 9133(13.89; bi= 0.99; S^2di = - 0.16) recorded mean value on far with overall mean value of 14.10 along with regression value nearer to unity and non significant deviation from regression indicating these hybrids are suited for low input environment (Table 2). Similar findings were reported by Matin et al. [10] for cob diameter.

Mean values for kernel rows ear^{-1} ranged from 13.90 (MAI 283×BGUDI 120) to 15.38 (BGUDI 120×VL 109252). None of the hybrids including check hybrids registered regression (bi) value nearer to unity and non significant deviation from regression (S^2di). Six hybrids recorded mean values higher than the overall mean but exhibited higher regression (bi) and non significant deviation from regression (S^2di) indicating they perform better under high input environment. Nirmal Raj et al. [11] also reported hybrids which performed better under high input environment. Hybrid MAI 349×MAI 283 (36.56) registered highest mean number of kernel rows^{-1} whereas, hybrid MAI 283×BGUDI 120 (26.59) recorded lowest mean number of kernel rows^{-1}. Hybrid KDMI 16×MAI 283 registered mean value (32.84) greater than overall mean (32.58) along with regression value nearer to unity (bi=1.04) and non significant deviation from regression (S^2di= - 0.08) indicating its stability across the environments. Sowmya et al. [17] and Nirmal Raj et al. [11] identified stable hybrids for kernel rows ear^{-1} across the environments in their study. Mean values for Kernal rows^{-1} ranged from 26.59 (MAI 283× BGUDI 120) to 36.56 (MAI 349×MAI 283). KDMI 16×MAI 283 recorded mean value

(32.84) above the overall mean (32.58) along with regression value nearer to unity (bi= 1.04) and non significant deviation from regression (S2di = -0.08) indicating its stable performance across the different environments (Table 2). The results are in accordance with the findings of Sowmya et al. [17].

Shelling % ranged from 79.52 (MAI 283× BGUDI 120) to 84.91 (KDMI 16×BGUDI 118). Hybrid MAI 394×BGUDI 88 recorded mean value (84.17) above the overall mean (82.77) along with regression value nearer to unity (bi=1.01) and non significant deviation from regression (S^2di = -1.16) indicating its stable performance across the environments. Similar findings were reported by Sowmya et al. [17]. Check hybrid Nityashree recorded mean value (79.75) below the overall mean (82.77) along with regression value nearer to unity (bi=1.12) and non significant deviation from regression (S^2di = -1.07) indicating suitability of this hybrid in low input environments for shelling % character. The mean values for 100 grain weight ranged from 26.14 (MAI 283× BGUDI 120) to 34.88 (NK 6240). Hybrid KDMI 16×MAI 283 recorded mean value (32.96) above the overall mean (30.49) along with regression value nearer to unity (bi=0.85) and non significant deviation from regression (S^2di = -1.66) indicating its stable performance across the environments. In the same way Syed Towseef Ahmad et al. [14], Matin et al. [10] and Nirmal Raj et al. [11] reported stable hybrids for 100 grain weight in their investigation. Hybrids *viz.,* BGUDI 88× MAI 349 (27.81; bi=1.13; S^2di = 3.18), MAI 394 ×BGUDI 88 (28.04; bi= 96; S^2di = -2.29), MAI 283× KDMI 16 (29.53; bi=1.16; S^2di = 3.66) and BGUDI 120×VL 109252 (27.11; bi= 1.00; S^2di = -2.88) recorded mean value lesser than the overall mean along with regression value nearer to unity and non significant deviation from regression revealing that their performance is better in resource poor environment for this character (Table 2).

3.2.4 Grain yield plant^{-1}

Grain yield plant^{-1} ranged from 142.70 (Nityashree) to CP 818 (CP 818). The performance of hybrid KDMI 16×BGUDI 118 was stable across the environment as it recorded mean value (179.40) above the overall mean (175.80) along with regression value nearer to unity (bi=1.13) and non significant deviation from regression (S^2di = -108.54). Hybrid MAI 283× BGUDI 120 118 recorded mean value (164.30) below the overall mean (175.80) along with regression value nearer to unity (bi=1.13) and non significant deviation from regression (S^2di =55.23) revealing that it performance is better in resource constraint environment (Table 2). Whereas, check hybrid DKC 9133 recorded mean value (186.30) above the overall mean (175.80) along with regression value nearer to unity (bi=0.87) and non significant deviation from regression (S^2di = 134.07) revealing that its performs better in resource rich environments. Earlier, Khalil [13], Carlos Busanello et al. [18] Syed Towseef Ahmad et al. [14] (8), Ravindra Babu et al. [19] (15), Matin et al. [10] and Nirmal Raj, et al. [11] reported similar results for grain yield plant^{-1} in maize crop.

3.3 Favourable and Unfavourable Environments

Cultivar performance is a function of the genotype and the production environment where it grows. Different production environments are not equally favourable or unfavourable for expression of the genotypes grown under them. The variation in grain yield and its related traits was detected in all the three environments in which maize hybrids were evaluated. Production environments with a negative index considered as unfavourable and those with positive regarded as favourable for expression of the characters. Based on the positive and negative environmental indices, production environment at location 1 {(K Block UAS, GKVK, Bengaluru (Zone 5)}, was most favourable for expression of characters *viz.,* days to anthesis, days to silking, cob length, cob diameter, kernal rows^{-1}, kernal rows ear^{-1}, plant height, 100 grain weight and grain yield plant^{-1}. (Table 3) Production environment at location 3 was favourable for expression of characters *viz.* days to anthesis, days to silking, cob diameter, 100 grain weight, shelling % and grain yield plant^{-1} as indicated by positive environment indices. Location 3 was favourable for expression of only one characters i.e anthesis silking interval. Based on the positive and negative environment indices, it can be concluded that location 3 is unfavourable and location 1 and 2 are favourable production environments for expression of the characters. Earlier, Emre Ilker [20] and Lalisa Ararsa et al. [21] have reported positive and negative environmental indices which indicate the favourable and unfavourable production environments for expression of different traits in maize.

Table 1. Analysis of variance for pooled data [1] for eleven quantitative traits in maize over three locations

Source of variation	Df	Mean sum of squares										
		Days to anthesis	Days to silking	Anthesis silking interval	Cob length (cm)	Cob diameter (cm)	Kernal rows ear^{-1}	Kernals row^{-1}	Plant height (cm)	Shelling %	Test weight (g)	Grain yield plant^{-1} (g)
Replication Within environment	6	0.93	0.48	0.36	0.56	0.36	0.42	1.82	55.94	0.83	7.57	90.14
Hybrids	14	6.09**	8.05**	1.43**	3.33**	0.67	0.47	19.92*	429.85**	8.44**	22.53*	971.99*
Environment+ (Hybrids × environment)	30	2.49	2.09	0.36	7.40**	1.34	0.50	13.08	261.48**	3.29	11.13	618.01
Environments	2	17.22 **	8.06*	1.36*	96.99**	14.29**	2.15**	103.16**	2184.16**	22.31**	85.01**	4642.69**
Hybrids ×environment	28	1.44	1.67	0.28*	1.00	0.42	0.39	6.64	124.14*	1.93	5.85	330.54
Environments (Lin)	1	34.44**	16.12**	2.72	193.98**	28.59**	4.30**	206.32**	4368.32**	44.62**	170.03**	9285.39**
Hybrids ×environment (Lin)	14	1.65	1.47	0.29	1.43*	0.19	0.43	6.97	193.08**	2.18	4.61	232.50
Pooled Deviation	15	1.14	1.74	0.26	0.52	0.60	0.33	5.90	51.52	1.57	6.61*	400.00**
Pooled error	84	1.18	1.10	0.23	0.74	0.26	0.27	3.74	97.46	1.21	2.58	174.98

**Significant at P=0.05, ** Significant at P=0.01*

Table 2. Estimate of stability parameters for economic traits in maize hybrids grown at three locations during *rabi* 2016 over three locations

Sl.	Characters	Days to anthesis			Days to silking			Anthesissilking interval			Cob length (cm)			Cob diameter (cm)		
No	Test hybrids	Mean	bi	S^2 Di	Mean	bi	S^2 Di	Mean	Bi	S^2 Di	Mean	bi	S^2 Di	Mean	bi	S^2 Di
1	KDMI 16×MAI 283	56.46	1.68	0.21	57.79	2.09	3.85*	1.56	-0.02	0.58	17.46	1.04	-0.72	13.96	0.66	-0.17
2	KDMI 16×BGUDI 118	55.97	2.37	0.02	57.84	2.99	0.28	1.96	0.82	0.09	17.25	0.79	-0.44	14.45	0.57	0.05
3	BGUDI 88× MAI 349	56.50	0.57	-0.40	58.80	-0.18	0.44	2.41	2.61	-0.20	16.24	1.45*	-0.73	13.46	1.08	0.02
4	BGUDI 120×VL 109252	58.37	2.02	-0.50	59.27	1.56	-0.37	1.70	0.81	-0.23	17.18	1.32	-0.53	14.29	0.68	1.28*
5	MAI 394 ×BGUDI 88	57.35	0.88	1.23	59.49	1.32	4.80*	2.25	1.00	0.32	15.94	0.61	-0.58	13.53	1.36	0.03
6	MAI 283× KDMI 16	56.81	1.94	1.69	58.88	2.28	2.46	2.08	0.80	-0.22	16.45	0.87	-0.53	14.43	1.19	-0.25
7	MAI 349×MAI 283	58.01	1.10	-1.03	60.22	1.30	-0.06	2.36	1.06	-0.05	19.47	0.98	-0.67	14.72	0.55*	-0.27
8	MAI 283× BGUDI 120	58.93	1.62	1.60	62.61	1.82	0.48	3.68	1.78	-0.15	14.82	1.82	-0.33	13.03	1.52	0.77
Check Hybrids																
1	Arjun	58.32	0.80	-1.20	60.07	0.82	-0.95	1.74	0.66	-0.20	17.31	1.02	1.11	14.23	0.65	0.88*
2	CP 818	60.14	0.17	1.41	62.91	1.34	3.04	2.77	-1.48	0.36	17.36	1.25	-0.16	14.03	0.94	0.29
3	NK 6240	61.04	-0.40	-1.14	62.60	-1.20	-0.88	1.61	2.18	-0.20	16.51	0.63	1.67	14.57	1.12	0.31
4	Nityashree	58.01	0.45	0.23	61.44	-0.82	0.07	3.46	3.20	-0.15	16.40	0.71	-0.41	14.59	1.48	0.25
5	Hema	59.35	-0.30	-0.65	60.61	-0.14	-0.96	1.26	-0.58	-0.05	16.90	0.86	0.36	14.32	1.00	2.07**
6	DKC 9133	58.88	0.45	-1.12	60.56	0.59	-0.92	1.68	-0.22	-0.01	15.47	0.77	-0.69	13.89	0.99	-0.16
7	DKC 9150	58.97	1.62	-0.78	60.88	1.24	-1.04	1.91	2.38	0.41	16.68	0.89	-0.41	14.00	1.22	-0.20
	Mean	**58.20**			**60.27**			**2.16**			**16.77**			**14.10**		

**Significant at P=0.05, ** Significant at P=0.01*

Table 2. Continued……..

Sl	Characters	Kernal rows ear^{-1}			Kernal rows^{-1}			Plant height (cm)			Shelling %			100 grain weight (g)		
No	Test hybrids	Mean	Bi	S^2 Di	Mean	bi	S^2 Di	Mean	bi	S^2 Di	Mean	bi	S^2 Di	Mean	bi	S^2 Di
1	KDMI 16×MAI 283	13.91	0.48	-0.14	32.84	1.04	0.08	183.70	0.07	-47.92	84.13	1.41	-1.09	32.96	0.85	-1.68
2	KDMI 16×BGUDI 118	14.59	-0.55	-0.26	32.36	0.67	-3.60	192.10	1.78	-93.43	84.91	0.58	-0.64	30.93	1.28	2.03
3	BGUDI 88× MAI 349	14.61	1.41	-0.17	29.89	1.64	5.89	209.00	1.98	-79.49	81.57	0.19	-0.95	27.81	1.13	3.18
4	BGUDI 120×VL 109252	15.38	0.18	-0.20	34.96	1.95*	-3.60	184.10	0.55	-8.61	83.80	0.63	-1.12	27.11	1.00	-2.88
5	MAI 394 ×BGUDI 88	14.14	2.04	-0.27	33.42	0.23	4.05	190.40	0.48	-75.88	84.17	1.01	-1.16	28.04	0.96	-2.29
6	MAI 283× KDMI 16	14.65	2.19	-0.04	34.89	1.46	-3.57	184.90	0.37	-89.40	84.02	-0.86	-0.61	29.53	1.16	3.66
7	MAI 349×MAI 283	14.47	2.13	0.31	36.56	0.52	3.64	214.40	1.02	-94.69	80.53	0.60	2.25	28.57	1.50	-2.74
8	MAI 283× BGUDI 120	13.90	2.06	-0.19	26.59	2.83	-2.50	192.60	1.10	-92.60	79.52	-0.24	6.74*	26.14	0.21	-2.73
Check Hybrids																
1	Arjun	14.17	-0.05	-0.26	33.61	1.24	-3.60	175.20	-0.69	34.64	82.95	1.93	5.24*	33.59	1.43	3.91
2	CP 818	14.11	-0.33	-0.24	34.53	0.51	14.82*	203.50	1.43	-69.82	83.43	1.51	1.27	32.98	0.00	3.39

3	NK 6240	14.22	1.82	1.01*	33.56	0.59	20.04*	211.00	1.29	-79.78	82.31	2.08	-0.93	34.88	2.20	0.43
4	Nityashree	14.44	2.91	-0.25	31.67	0.51	-2.90	189.00	0.41	-69.34	79.75	1.12	-1.07	29.06	0.06	4.43
5	Hema	13.97	1.72	0.43	33.89	0.65	8.66	187.50	1.39	190.06	83.22	1.23	-1.16	29.73	0.52	17.90**
6	DKC 9133	13.94	-0.92	-0.17	30.22	0.38	-3.55	204.90	1.33	-3.09	83.79	2.03*	-1.18	32.59	0.77	30.11**
7	DKC 9150	14.06	-0.09	1.18*	29.69	0.79	0.52	206.70	2.50	-68.22	83.35	1.77	0.22	33.43	1.94	-1.24
	Mean	14.30			32.58			195.30			82.77			30.49		

*Significant at P=0.05, ** Significant at P=0.01

Table 2. Continued……..

Sl No	Characters	Grain yield plant^{-1}(g)		
	Test hybrids	**Mean**	**bi**	**S^2 Di**
1	KDMI 16×MAI 283	189.00	0.69	-61.64
2	KDMI 16×BGUDI 118	179.40	1.13	-108.54
3	BGUDI 88× MAI 349	158.40	1.57	-116.57
4	BGUDI 120×VL 109252	159.40	2.03	3.77
5	MAI 394 ×BGUDI 88	155.60	0.67	-153.75
6	MAI 283× KDMI 16	189.50	0.05	-147.35
7	MAI 349×MAI 283	188.80	0.51	-167.99
8	MAI 283× BGUDI 120	164.30	1.13	55.23
Check Hybrids				
1	Arjun	176.00	1.54	167.82
2	CP 818	204.80	0.66	641.30*
3	NK 6240	200.60	1.33	-157.43
4	Nityashree	142.70	0.69	-84.83
5	Hema	161.70	0.11	3305.34**
6	DKC 9133	186.30	0.87	134.07
7	DKC 9150	179.90	2.03	150.80
	Mean	**175.80**		

*Significant at P=0.05, ** Significant at P=0.01

Table 3. Estimates of mean, range and environmental indices for economic traits of maize hybrids during *Rabi* 2016 over t three locations

Characters	Mean			Range			Environmental index		
	Loc 1	Loc 2	Loc 3	Loc 1	Loc 2	Loc 3	Loc 1	Loc 2	Loc 3
Days to anthesis	58.76	56.97	58.88	56.17 - 60.97	53.00 - 61.50	56.80 - 61.35	0.56	-1.23	0.68
Days to silking	60.51	59.44	60.84	57.80 - 62.10	55.17 - 63.67	57.67 - 64.90	0.25	-0.82	0.57
Anthesissilking interval	1.944	2.507	2.039	1.00 - 3.48	1.00 - 4.60	0.87 - 3.55	-0.20	0.34	-0.12
Cob length (cm)	19.62	14.77	15.88	17.63 - 22.33	10.83 - 17.67	13.72 - 18.40	2.86	-1.98	-0.88
Cob diameter (cm)	15.03	13.08	14.19	14.21 - 16.29	11.83 - 14.17	12.33 - 15.37	0.92	-1.02	0.091
Kernal rows ear^{-1}	14.73	14.01	14.16	13.50 - 15.67	13.00 - 15.50	13.07 - 15.13	0.43	-0.28	-0.14
Kernal rows^{-1}	35.22	29.97	32.53	31.33 - 40.08	19.67 - 36.33	25.60 - 37.50	2.64	-2.60	-0.04
Plant height (cm)	208.92	186.02	190.87	163.89 - 241.67	173.33 - 205.00	168.33 - 210.00	13.65	-9.25	-4.40
Shelling %	81.55	82.73	83.99	78.25 - 84.73	77.23 - 85.50	80.33 - 86.33	-1.20	-0.03	1.23
100 grain weight (g)	32.43	27.83	31.20	26.30 - 38.10	24.50 - 33.50	26.50 - 37.88	1.94	-2.65	0.71
Grain yield plant^{-1} (g)	185.56	155.46	186.28	156.00 - 212.67	118.33 - 191.83	121.67 - 231.67	9.79	-20.31	10.51

Loc 1- K Block University of Agricultural Sciences, GKVK, Bengaluru (Zone 5); Loc 2- Agricultural Research Station, Bheemarayanagudi, University of Agricultural Sciences, Raichur (Zone 3); Loc 3-Kudupali – Village, Taluk: Hirkerur District: Haveri (Zone 8)

4. CONCLUSION

Based on the above discussion, hybrids, *viz.,* MAI 349×MAI 283, KDMI 16×BGUDI 118, BGUDI 120×VL 109252 and MAI 283× KDMI 16 were found stable for flower characters. Hybrid KDMI 16×MAI 283 was found stable across the environments for most of the characters studied and the stable hybrid need to be re-tested under different environments to reconfirm its stable performance before its commerciali-zation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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