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Drumstick (*Moringa oleifera* Lamk.) improvement for semiarid and arid ecosystem: Analysis of environmental stability for yield

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Integrating yield and stability of genotypes tested in unpredictable environments is a common breeding objective. The importance of stability estimation has more values in perennial crops such as drumstick (*Moringa oleifera* Lamk), as it has occupied the area for many years. Drumstick is found both in annual and perennial forms, where the former type bears only edible pods and the latter produces both edible and non edible bitter pods. In India, the west and northern part has perennial types predominantly due to which the commercial cultivation of drumstick remain at poor level in this region. Hence, the main goal of the study is to identify a superior genotype for the rain fed areas among 14 genotypes. Stability analysis was assessed by yield stability statistic (*yi*), yield regression statistic (*ri*) and yield distance statistic (*di*). The analysis of variance revealed that the genotype were highly significant for all characters under the environment studied. However, number of flowers per plant showed non significance for environments in the study. G × E (Genotypic × Environment interaction), E+ (G × E) [Environment + (Genotype × Environment)] and E [Environment (Linear)] showed significant values for all the characters. Pooled deviation exhibited significance for number of fruits per plant and yield per plant. Among the genotypes studied, PKM-2, MO-1 and PKM-1 were found stable for number of fruits per plant and yield due to b_i value around unity and non significant S^2_{di} value. Hence, PKM-2 and MO-1 were found to fit for favorable environment and PKM-1 for unfavorable environment for commercial cultivation for semi arid region of India.

Key words: Annual drumstick, adaptation, genotypes, stability, yield.

INTRODUCTION

Plant breeders engaged in crop improvement program often with a desire to develop genotypes, which are adapted to wide range of environments. The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is grown. The phenotypic performance of a genotype may not be the same under diverse agro-climatic conditions. This variation is due to G × E interactions, which reduces the stability of a genotype under different environments (Ashraf et al.,2001). Hence, phenotypic stability assessment is more imperative for perennial crops, as they are long duration and remain in the field for several years and also incur more investment for raising and maintaining crops unlike annual crops.

Drumstick is one of the important perennial vegetable grown in many tropical countries. Its origin is the sub-Himalayan tracts of north-western India, Pakistan, drumstick can further be increased as it grow well in all

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types of soil, from acid to alkaline (Duke, 1983) and can tolerate up to 6 months of dry season. It grows well at altitudes from 0 to 1800 m a.s.l. and rainfall between 500 and 1500 mm per year. It is therefore useful for semi-arid and arid ecosystem, which covers 37.0% geographical area and 16.7% arid area (Velayutham, 1999) by facilitating irrigation.

In nutritional and medicinal view, almost every part of plant has value for food. The pods, seeds, leaves and flowers are consumed by humans as nutritious vegetables in some countries (Makkar and Becker 1997). Drumstick is mainly grown for edible pods; however, it has huge commercial value for seed also as it contains 38 to 40% oil (Irvine, 1961) which is highly used in arts, for lubricating watches and other delicate machineries (Simmonds, 1854), useful in the manufacturing of perfumes and hairdressings (Le Poole, 1996). Drumstick seed powder is said to be an effective organic clarifier of even very turbid water by removing up to 99% of bacteria in the process (Folkland and Sutherland, 1996).

A peculiar phenomenon in drumstick is that there are two types which differ in duration for first harvest after planting of seeds. The first type comes to harvest in 6 months (annual type) after planting and the second type starts bearing after 3 to 4 years (perennial type). Although, drumstick can be propagated through cuttings as well (Morton, 1991), there was no such difference is evidenced among the types, despite of requirement of huge quantity of cuttings. Although, it is drought hardy crop, the quantum of marketable pods harvesting in the main crop (March to April) is drastically reduced due to high temperature and moisture stress, be it by the reduction in the capacity of photosynthesis, be it in an increase of respiration and the assimilate consumption of the leaves (Prange et al., 1990; Reynolds et al., 1990, Wolf et al., 1990) also affects quality with a reduction of the dry matter content (Haynes and Haynes, 1983; Prange et al., 1990). Considering the aforementioned facts, the annual type is established as stable commercial type in recent years and fitting well in the integrated cropping system. Hence, the lack of suitable annual types is considered to be the most probable reason for not attaining commercial status of drumstick, therefore identification of phenotypically stable annual genotype with wide adaptation is very much imperative.

MATERIALS AND METHODS

Location of experimental area

The present investigation was initiated with fourteen diverse annual genotypes collected from diversified region in three diversified environments. The experimental site located at 22° 41′ 33″ and 73° 33′ 22″ and lies between 110 and 115 M above mean sea level. The annual rainfall mainly confined to three months (July to September) with an average of 35 rainy days a year. The annual maximum and minimum temperature ranges from 42 to 43°C in May and 6 to 7°C in January, respectively. The annual potential evapo-transpiration ranged from 1500 to 1600 mm against the annual precipitation 750 mm. The dry season is between March and June and a wet season is between July and December.

Soil preparation and sowing

The experiment was laid out in Randomized block design with three replications. The seedlings of drumstick were raised in a poly bags (15 × 25 cm) filled with mixture of soil: farm yard manure: sand at 1:1:1 ratio. Two seeds were sown in each poly bag at 2 cm depth and the seeds germinated at 5 to 6 days after sowing. After 15 days of germination, one seedling was thinned out and one healthy seedling was retained in each bag. One month old seedlings were transplanted in the 45 cm^3 size pit spaced at 5.0 × 3.0 m in the main field. Irrigation was applied after transplanting as life saving and no irrigation was applied thereafter. The terminal shoot tips of the seedlings were nipped off at 1 m height from ground level so as to encourage branching. Each plant was fertilized at the rate of 200 g urea, 100 g of super phosphate and 50 g murate of potash per plant at three month after planting. However, urea was applied in two split occasions, one at three month of transplanting and the other after three months of first application. Control of weeds was done manually around seedlings at 30 days after transplanting. Inter-cultivation using tractor was performed twice in the inter space to control weeds. Leaf eating caterpillar, the major pest was controlled by spraying of pesticide periodically. The recommended package of practices (Veeraragavathatham et al., 1998) was followed to assess the real potential of different genotypes.

Statistical analysis

Five randomly selected plants per treatment were tagged to take observations on height at first branch emergence (cm), height at first panicle emergence (cm), number of flowers per panicle, number of fruits per plant, average fruit weight (g) and average yield per plant (kg). Analysis of variance for each environment and pooled analysis over environment were computed for stability analysis. The mean of each variety was regressed on the environment index. Regression coefficient and deviation from regression were calculated. A genotype, which has high mean yield, regression coefficient (b_i) close to unity and deviation from regression (S^2_{di}) near to zero, is defined as a stable cultivar (Eberhart and Russell, 1966).

RESULTS

Variance analysis

It is evident from the data of Table 1, the highly significant mean squares estimates for HFBE, HFPE, NFLP, NFTP, AFW and AYP for individual effects of Genotype and Environments. Also, differences manifested in study environments in all characteristics were very important. Specific response of a genotype, that is, its genotype to ecological factors over a three environments, proved that Genotype × Environment interaction was also a significant source of variability in all characteristics. Hence, the stability analysis was further carried out. The mean sum of square value for Genotype × Environment interaction (Linear) effects were significant for all the characters indicated that greater part of genotypic response was a

Table 1. Variance for G x E interaction for Yield and its attributes in annual drumstick.

Source of variation	d.f.	Mean sum of square					
		Height at first branch emergence (HFBE)	Height at first flower panicle emergence (HFPE)	Number of flowers per panicle (NFLP)	Number of fruits per plant (NFTP)	Average fruit weight (AFW)	Average yield per plant (AYP)
G	13	968.477**	1545.958**	489.086**	27567.18**	20342.56**	255.182**
E	2	179.062**	91.828**	7.738	125287.4**	29783.48**	1986.360**
G × E	26	5.362*	3.659**	2.617**	1050.512**	2270.76**	21.950**
E + (G × E)	28	164.224**	84.212**	27.842**	92628.85**	39537.78**	1507.560**
E (L)	1	116.992**	56.66**	5.159**	83524.48**	19857.4**	1318.440**
G × E (L)	13	3.486**	1.201	1.476**	602.89**	1489.240**	13.136**
PD	14	0.136	0.852	0.248	90.480*	22.869	1.940*
PE	84	1.876	2.330	1.557	46.609	15.724	1.004

**Significant at P = 0.01; *Significant at P = 0.005.

linear function of environments which showed diversity in growing condition and its influence on genotype. The existence of real genotypic differences for regression over environmental mean was revealed from the highly significant mean sum of square value of environment (Linear) for all the characters. Higher magnitude of variance due to Environment (Linear) as compared to Genotype × Environment (Linear) was observed for all the traits which might be responsible for high adaptation in relation to yield and its attributes.

Stability analysis for vegetative parameters

Environmental stability estimates were determined using the linear regression model procedure based on an environmental index (Eberhart and Russell, 1966). In this procedure, the response of a genotype to a number of environments was compared to the other genotypes in the study using three values such as genotype mean over all environments (X), regression coefficient *(b* value) and deviation mean square which is the deviation from the linear regression (S^2d_i) line over all environments. In the present study, the genetic stability among genotypes and their response to environment for six characters (Table 2) was considered. Among them, the height at first branch emerges ranged from 23.0 to 59.6 cm with mean of 39.18 cm. A wide range of b and S^2_{di} value was found among the genotypes which were non significant indicating that the genotype responses to environmental conditions fitted linearity. Out of fourteen genotypes studied, PKM-1 and Dwarf moringa registered lower mean value (x = <39.1 cm) with regression coefficient (b_i>1) more than the unity, the genotypes MO-11, MO-10, MO-9, MO-7 and MO-5 had recorded the regression coefficient value (b_i<1) lesser than unity, and the genotype PKM-2 and MO-12 recorded the regression coefficient value lesser than unity. All the genotypes showed negative values for regression deviation coefficient for this character.

Stability analysis for flowering parameters

The height at first panicle emergence ranged from 70.793 to 121.48 cm with a mean of 88.823 cm. A wide range of b value was found among the genotypes and showed non significance indicating there was relationship of environment influence on this character. Genotypes Dwarf moringa and MO-11 recorded the lower mean value with regression coefficient (b_i = 1.738, b_i = 1.336) higher than unity against the genotypes PKM-1, M-10, M-9, M-7 and MO-6 which registered lower value lesser than unity. Whereas, Dwarf moringa exhibited significant deviation coefficient (S^2_{di}) indicating the genotypic response to the environments did not fit a linear regression model.

Number of flowers per panicle ranged from 74.250 to 99.350 with a mean of 87.919. No significant difference among the genotypes for bi value indicated that there was relationship with the character and environment. The genotype Dwarf moringa, PKM-1 and MO-8 exhibited the lower mean values as compared to the general mean (x_i

Table 2. Grouping of drumstick genotypes on the basis of mean, regression coefficient (bi) deviation from regression (S^2d) of yield and yield attributing traits.

Characters	x_i = < and b_i = >1 (Favorable)	x_i = < and b_i =<1 (Unfavorable)	x_i = > and b_i =>1 (Favorable)	x_i = > and b_i =<1 (Unfavorable)	b_i = <=> (Wide adaptable)
Height at first branch emergence (cm)	Dwarf Moringa	MO-11, MO-10, MO-9, MO-7, MO-5	MO-1, MO-2, MO-3, MO-6, MO- 8	PKM-2, MO-12	PKM-1
Height at first flower panicle emergence (cm)	Dwarf Moringa, MO-11	PKM-1, MO-10, MO-9, MO-7, MO-6	MO-12, MO-8, MO-3, MO-2, MO-1	PKM-2	
Number of flowers per panicle	Dwarf Moringa, PKM-1, MO-8	MO-2	MO-12, MO-11, MO-10, MO-6	MO-9, MO- 7, PKM-2	MO-3, MO-5
Number of fruits per plant	MO-8	Dwarf Moringa	MO-10, MO- 9, MO-7, MO-6,	MO-5	PKM-2, PKM-1
Average fruit weight (g)	MO-5	MO-2, MO-7, 9, MO-10, MO-11, MO-12	PKM-2, PKM-1, Dwarf Moringa, MO-3	MO-8, MO-6, MO-1	
Average yield per plant	MO-10, MO-6	MO-12, MO-9, MO-8, MO-7, MO-5, MO-3, MO-2	Dwarf Moringa	PKM-1, PKM-2	MO-1

= 87.9) with regression coefficient value (b_i = 1.534, 1.347 and 1.119) more than unity. The genotypes MO-3 and MO-2 had higher mean value with bi value lesser than unity. The higher mean with regression coefficient more mean with bi than unity was observed in MO-12, MO-11, MO-10 and the genotypes MO-6. MO-9, MO-7 and PKM-2 registered the higher mean value with b_i value lesser than unity. None of the genotypes showed significance for deviation from regression indicating that the genotype response to the environments fit a linear regression model. Genotype PKM-1 exhibited the value of deviation from regression around (S^2_{di} = 0.084) zero, and was believed to be stable.

Stability analysis for fruiting parameters

Number of fruits per plant ranged from 78.477 to 314.760 with an average of 213.289. Although, wider variation for b and S^2_{di} value was found among the genotypes, none of them showed significance for bi indicating that there was relationship with the character and environment. The genotypes MO-10, MO-9, MO-7, MO-6, PKM-1 and PKM-2 recorded higher mean value with regression coefficient higher than unity against MO-5, which showed higher mean value with bi value lesser than unity (Table 3). MO-12, PKM-1 and PKM-2 were found stable with higher mean value and non significant regression coefficient value and approaching unity (b_i =0.974, b_i =1.094 and b_i =1.077), thus these genotypes can be classified as widely adaptable to any environment and predictive capacity (S^2_{di}) indicated that PKM-1 and PKM-2 are phenotypic stable genotypes (Table 4). Out of fourteen genotypes MO-9, MO-11, Dwarf moringa showed significant deviation from regression, which indicates that these genotypes cannot be predicted for number of fruits per plant over environments.

Average fruit weight ranged from 76.897 to 285.883 g with a mean of 134.490 g. PKM-2 (b_i = 4.070), PKM-1 (b_i = 1.499), MO-3 (b_i = 1.119) and Dwarf moringa (b_i = 1.824) recorded the higher mean value with bi value higher than unity as against the genotypes MO-8, MO-6 and MO-1 which had bi value lesser than unity. Wide range of S^2_{di} value was observed among genotypes, the genotypes MO-3, MO-1 and MO-6 showed higher mean value with significant S^2_{di} value indicating that the genotype response to the environments is non predictable. Average fruit yield per plant ranged from 16.960 to 44.257 kg with an average of 26.235 kg. Out of fourteen genotypes, only four genotypes recorded higher mean values than the general mean. Dwarf moringa recorded higher mean value coupled with regression coefficient higher than unity, and PKM-1 and PKM-2 recorded

Table 3. Estimation of Stability parameters for vegetative and floral attributes in annual drumstick.

Genotypes	Height at first branch emergence			Height at first panicle emergence			Number of flowers per panicle		
	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}
MO-1	47.460	1.916	-0.265	121.48	2.137	1.912	79.670	-3.315	-0.241
MO-2	41.290	1.248	-0.391	89.033	1.189	-0.462	83.247	-1.469	0.356
MO-3	46.272	1.426	-0.586	94.690	1.222	0.250	74.250	-0.021	-0.469
PKM-2	46.720	0.613	-0.624	89.047	0.253	-0.514	88.343	0.518	-0.316
MO-5	23.067	0.316	-0.605	98.860	0.452	-0.776	96.413	-0.013	-0.504
MO-6	59.673	2.138	-0.391	82.763	0.721	-0.739	90.477	2.588	-0.496
MO-7	31.123	0.774	-0.595	73.75	0.524	-0.765	89.563	0.479	-0.472
MO-8	47.240	0.134	-0.614	112.11	1.381	-0.504	76.543	1.119	-0.517
MO-9	34.263	0.747	-0.623	77.377	0.610	-0.776	94.607	0.346	-0.454
MO-10	25.733	0.525	-0.497	79.607	0.749	-0.561	99.350	4.311	0.681
PKM-1	36.340	1.065	-0.178	87.107	0.488	-0.560	86.473	1.347	0.084
MO-11	29.307	0.673	-0.517	80.307	1.336	-0.300	95.393	3.343	-0.400
MO-12	50.393	0.454	-0.332	89.627	1.193	-0.776	95.193	3.231	-0.518
D. Moringa	29.217	1.964	-0.617	70.793	1.738	5.634*	81.360	1.534	-0.517
	39.181	1.00		88.823	1.00		87.919	1.00	
	0.65			0.99			0.95		

b_i **,* Regression coefficient significantly different from unity at P=0.001 and P=0.005, respectively; S^2_{di}**, * deviation from regression significantly different from zero at P = 0.001 and P = 0.05, respectively.

Table 4. Estimation of stability parameters for yield attributes in annual drumstick.

Genotypes	Number of fruit per plant			Average fruit weight (g)			Average fruit yield (kg)		
	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}
MO-1	163.720	0.600	59.045	134.747	0.450	66.131*	26.577	1.048	1.781
MO-2	210.153	0.837	48.863	90.463	0.598	32.118*	19.463	0.677	-0.135
MO-3	86.647	0.456	20.765	190.927	1.192	40.164*	23.427	0.750	-0.012
PKM-2	214.937	1.077	123.056	285.883	4.070	27.034	44.257	0.967	2.342*
MO-5	299.943	0.529	6.916*	91.740	1.174	4.153*	22.883	0.489	4.333*
MO-6	249.137	1.130	-14.884	156.06	-0.207	56.299*	23.573	1.923	-0.135
MO-7	241.467	1.213	-7.656	76.897	0.645	8.846*	22.633	0.800	-0.298
MO-8	78.477	1.412	-1.095	152.320	0.509	-3.699	16.893	0.781	0.457
MO-9	278.510	1.146	67.823*	93.153	0.334	3.514	25.660	0.871	-0.025
MO-10	235.643	1.496	-15.202	75.907	0.843	15.129*	19.960	1.463	0.072
PKM-1	314.760	1.094	8.737	145.650	1.499	-0.127	36.733	0.877	-0.332
MO-11	267.797	1.232	548.61*	77.060	0.409	-1.036	28.567	1.298	1.124
MO-12	219.613	0.974	102.14*	94.770	0.654	0.338	21.500	0.795	2.832*
D. Moringa	125.267	0.796	102.08*	217.970	1.824	-2.072	35.187	1.255	1.649
	213.289	1.00		134.490	1.00		26.235	1.00	
	13.10			1.19			0.82		

b_i**,* Regression coefficient significantly different from unity at P = 0.001 and P = 0.005, respectively; S^2_{di}**, * Deviation from regression significantly different from Zero at P = 0.001 and P = 0.05, respectively.

bi value lower than unity. However, the genotype PKM-2 had significant S^2d value, and MO-3 and MO-9 recorded deviation from regression value around zero despite of its lower mean value.

DISCUSSION

The importance of GE interactions has long been acknowledged since, in the absence of GE interactions, the best cultivar in any one trial would yield more than all cultivars at all locations every year. Historically, various methodologies have been investigated to study GE interaction including linear regression (Mooers, 1921; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966), cluster analysis (Ghaderi et al., 1982; Johnson, 1977), and principal component analysis (Freeman and Dowker, 1973; Mandel, 1971; Williams, 1952). A linear regression approach, introduced by Mooers (1921), uses the mean performance of all genotypes in an environment as an index of that environment's productivity against which the performance of each genotype was plotted using linear regression where the mean regression slope would be 1.0. Finlay and Wilkinson (1963) further stated that the overall yield should be taken into account in addition to the slope of a genotype such that genotypes with a high mean yield and slope near 1.0 were well adapted to all environments and that, as mean yield decreased, a higher or lower slope indicated adaptation to favorable or unfavorable environments, respectively. Eberhart and Russell (1966) added that a stable variety would be one with a regression line slope near 1.0 with a small sum of squared deviations. The information on GE interaction in drumstick was found very scanty. In this study, highly significant F values were found for both main effects [genotype (G), environment (E)] and their interactions [G × E, G×E (linear)] for HFBE, HFPE, NFTP, AFW and AYP indicating the existence of substantial genetic diversity among the genotypes and variation among environments. It suggested that the accuracy and practical value of stability analyses depend on the extent of genetic diversity present among genotypes and the range of environments under which they are tested (Becker and Leon, 1988). The non significant value for environment (main effect) for NFLP indicating the character did not respond much as the other characters responded over environments. To reinforce this conclusion, highly significant differences among the genotypes in the measures of environmental stability (means, *b* values, S^2d) were found. The significant mean squares of E, G × E, E + (G × E), E(L) and G × E(L) for all the characters under study expressed that the heterogeneity between the years of experimentation and the phenotypic expression of genotypes varied considerably in different years. These results are in concordance with finding of Singh et al. (1984). The existence of real varietal differences for regression over environmental mean was revealed from the highly significant mean sum of square due to environment (Linear) for all the characters. Higher magnitude of variance due to Environment (Linear) as compared to Genotype × Environment (Linear) was observed for all the traits which might be responsible for high adaptation in relation to yield and its attributes. The significant value of pooled deviation for NFTP and AYP indicate presence of non linear interaction. This result is in conformity with results of Varalakshmi and Reddy (1998) in Ridge gourd and Arvindkumar et al. (2003) in Tomato.

Very few studies examined the environmental stability in drumstick especially for yield contributing traits. Raja et al. (2009) reported that considerable variations for various morphological characteristics in drumstick exist. Further, the present study proved that the existence of considerable genetic diversity within drumstick for yield contributing traits at diverse geographic areas indicating that selection for specific environments would be possible. In the present study, height at first branch emergence an indicator of selecting genotypes as proposed by Kader and Shanmugavelu (1982) and Raja et al. (2009) reported emergence of first branch and first panicle at lower height had significant correlation with yield, hence selection of genotypes having lower mean value would be an ideal. Considering the xi and bi value, the genotype PKM-1 displayed lower mean value (x_i = 36.340), stability due to its value of regression coefficient (b_i = 1.065) around unity (Table 3). Dwarf moringa perform better for favorable environment, whereas PKM-1, MO-1, MO-10, MO-9 and MO-7 were found to perform well under adverse environment condition. Genotypic performance on number of flowers per panicle indicated that MO-5 and MO-3 had negative bi value around unity (b_i = -0.013 and b_i = -0.021) indicated their stability for adverse environment. Based on the vegetative parameters both PKM-1 and PKM-2 could perform better under unfavorable condition of this region against Dwarf moringa which suits for favorable environment.

Number of fruits per plant is an important character that reflects on total yield of the plant. Among the genotypes, MO-12, PKM-1 and PKM-2 were found displayed stability with higher mean value and non significant regression coefficient. Hence, PKM-1, PKM-2 found to be the stable genotypes for favorable environment, and the number of fruits per plant is predictable. Similarly for fruit weight too, PKM-1 and PKM-2 showed higher mean value with regression coefficient value (b_i = 1.499, b_i = 4.070) higher than the unity indicating their suitability for favorable environment and it has predictable effect due to non significant S^2_{di}. Considering the rainfall pattern and soil moisture availability of the region, PKM-1 and PKM-2 could perform better as it is suitable for favorable environment for period of fruiting and fruit development.

PKM-1, PKM-2 showed their higher mean for yield per plant with non-significant regression coefficient lesser than unity indicating their stability over unfavorable environments. However, the later genotype had significant deviation from regression indicates its unpredictable over environment. Dwarf moringa and MO-1 exhibited the higher mean performance with non-significant regression coefficient (b_i = 0.967 and b_i = 1.048) around unity and non-significant deviation from regression could be recommended for general adaptability. This finding is confirmed from the findings of Baker (1988). Fakorede and Mock (1978) also concluded that regression coefficient is more significant than deviation from regression line. The results of the present paper confirmed that bi, being a stability parameter, is more significant than S^2_{di} in heterozygous genotypes the genotype of the majority of perennials. This result is in consonance with the findings of Rakonjac and Zivanovic (2008). The desirable variety should exhibit higher mean performance and low genotype × environment interaction for economically important characters like yield but more flexible for other characters. Such varieties are said to be well buffered as they could adjust their genotypic state in response to the changing environmental condition which is referred to as genotypic homeostasis (Lin et al., 1986). Drumstick being highly cross-pollinated is heterozygous and heterogeneous in nature. Phenotypic plasticity as well as physiological homeostasis is generally associated with heterozygosity, which confers the requisite adaptive capacity to the population over diverse environment by maintaining its gene frequency at equilibrium (Allard and Bradshaw, 1964). From the present study, it is concluded that PKM-2, MO-1, and PKM-1 had high mean performance (xi), regression coefficient (b_i) equal to one and deviation from regression (S^2_{di}) nearer to zero were identified as high yielding stable genotypes for yield across the environment of semi arid region. Further, it is understood that among the stable genotypes, PKM-1 and MO-1 showed stability for vegetative, flowering and fruiting parameters under unfavorable environment against PKM-2 which showed stability for fruiting parameter under favorable environments indicating it needs irrigation at fruiting stage for better yield under this region.

Conclusion

Pooled analysis of variance for yield and its contributing characters were significantly influenced by cultivar genotype. In addition, variability of those characteristics was significantly conditioned by ecological factors and interaction between genotype and environmental factors. Values of bi coefficient indicated that PKM-1, PKM-2 and MO-1 had the highest stability for early height for first branch, no. of fruits per plant and yield per plant for unfavorable environments. Values of S^2di, despite being relatively high, showed statistical significance for yield per plant (PKM-2), fruit weight (MO-1), which indicates a more significant deviation from regression and unsatisfactory stability of the studied genotypes. The results of the present work confirmed that bi, being a stability parameter, is more important than S^2di in heterozygous genotypes like drumstick.

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