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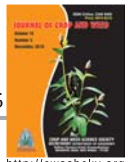

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Interaction between genotype and environment and its stability analysis in cashew (*Anacardium occidentale* L.)

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ABSTRACT

The objective of this study was to determine the magnitude of genotype × environment interaction in cashew genotypes for yield and its contributing characters, using the regression approach thereby determining stability over different years in a location. Results showed that considerable variations existed in yield within genotypes, years and genotype × year interactions. The genotype Goa-11/6 was found to be most stable over all the seven environments. The genotypes BH-85 is considered to be specifically adapted to favorable environment and genotype H-675 is considered stable for poor environments.

Keywords: Cashew, genotype, environment and stability

Cashew (*Anacardium occidentale* L.) a tropical nut crop that belongs to the family *Anacardiaceae*, was introduced in India during 16th century for the purpose of soil conservation. But later on the crop was exploited commercially due to its versatile uses. India is the largest producer of cashewnut in the world contributing 29 per cent of global production (Malhotra *et al.*, 2016). In spite of substantial contribution to the global cashewnut production, the domestic production is not sufficient to meet the requirement of cashewnut processors in the country. India imported nearly 8.36 lakh metric ton of raw cashewnut during the year 2016 to meet the requirement of cashewnut processing industry. This is practically due to large scale senile plantation of old as well as inferior varieties and non-adoption of scientific management practices in traditional cashew growing areas of the country. Therefore, development of stable high yielding varieties to improve nut production will play a very vital role towards achieving the sustainable cashew industries. In general, very few information is available on cashew genetic resources to exploit the cashew crop improvement programme (Dhanraj *et al*. (2002), Aliyu and Awopetu (2007) and Desai *et al*. (2010). However, information on performance of cashew genotypes in different environment interaction (G×E) that could influence the phenotypic stability, are very scanty. Therefore, it is of prime importance to isolate superior genotypes manifesting adaptation in general or specific environments. The study of stability in performance of a genotype is the most important factor to measure genotype × environment interaction before it is released for wide cultivation. Many stability models have been developed to identify the stable genotypes. Earlier, Finlay and Wilkinson (1963) considered the linear regression (b_i) as a measure of stability, but later, Eberhart and Russell (1966) emphasized the need of both b_i and S^2d_i in judging the stability of a genotype. According to Eberhart and Russell (1966) model, a genotype having unit regression coefficient (b_i=1) and non-significant deviation from regression (S^2d_i = 0) with high mean was considered as stable. A genotype with high mean performance with near to unity regression and least deviation from regression could perform well under average environmental conditions. Genotypese × habiting high mean with greater than unity regression were considered to be stable for favorable environmental condition. However, if a genotype possessed high mean with less than unity regression, the genotype is considered suitable for poor environmental conditions. Once the genotype × environment interactions were found to be significant, the next task is to identify stable genotypes. The stable genotypes are one which interact less with the environment thus giving a near consistent performance across different environments. Allard and Bradshaw (1964) suggested selection of stable genotypes that interact less with environments in which they are to be grown with a view to reduce the genotype × environment interaction to a considerable extent. Hence, three measures of assessing the stability of genotype *viz.*, mean, regression coefficient (b_i) and the mean square deviation (s^2d_i) were employed in assessing the stability of cashew genotypes included in the present study. The linear regression (b_i) could simply be regarded as the measure of response of a particular genotype and if it is greater than one then, the genotype is said to be sensitive to environmental changes but adapted to favorable environments. If it is less than one, then it indicates above

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average stability. If this is accompanied by a high mean value then, the genotype is said to be better adapted to widely differing conditions or unfavorable environments and if the mean value is low, greater G × E interaction is indicated (Finlay and Wilkinson, 1963). On the other hand, deviation around the regression line is considered as a better measure of stability. With respect to the non-linear component of the G × E interaction, the genotype with the lowest standard deviations will be the most stable and vice- versa. The multivariate statistics which includes the AMMI (additive main effect and multiplicative interaction) is now widely accepted but due to its mathematical complexity the conventional analysis of variance followed by a joint regression analysis as stated above is still a preferred choice.

The objective of the present study was to determine the magnitude of G × E interaction variation in cashew for nut yield, thereby determining stability of cashew genotypes over different years in a location. So the most stable genotype could be recommended for cultivation as it is able to prevent production loss over the years and it could also be used as parent in breeding programmes for its existing genetic potential.

MATERIALS AND METHODS

A multi locational trial was laid out at Cashew Research Station, Ranasinghpur, Bhubaneswar during the year 2003 using clonal planting materials of eleven diverse cashew genotypes collected from different co-operating centers of AICRP on Cashew, India. The grafts were raised by using the scion materials collected from different centers and grafted plants were planted at a spacing of 7.5 ×7.5 m following Randomized Block Design (RBD) having four plants per treatment replicated thrice. The experimental area is located 25.5 m above mean sea level at 20°15' North latitude and 82°52' East longitude. Recommended package of practices were adopted uniformly to raise a good crop. The present study was undertaken during the fruiting season 2010 to 2016. Data were recorded on various vegetative growth parameters, yield attributes and nut yield of different cashew genotypes adopting standard procedure as described in the Experimental Manual on Cashew (Experimental Manual on cashew, 2005). Stability parameters for different characters were computed using the regression approach (Eberhart and Russell, 1966).

RESULTS AND DISCUSSION

Genetic variability in respect of a particular character is needed to measure the variability present in the present set of materials. The analysis of variance (mean square values) revealed the existence of significant difference among the genotypes for nut yield (pd"0.01). Pooled analysis of variance over environment showed highly significant difference among genotypes, environments and genotype × environments (G × E) interaction (Table 1). Hence, the partitioning was done as per Eberhart and Russell (1966) model in order to know the magnitude of linear and non-linear components of variations which will provide information on predictable and unpredictable sources of variations respectively, contributing to genotype × environment interactions for nut yield. Highly significant G × E interaction components reflected differential response of the test genotypes to environmental changes. This indicates the presence of variability among the genotypes and environments.

According to Allard and Bradshaw (1964) large genotype × environment interaction indicated that treatments induce special environment. Further, partitioning of genotype × environment interactions into the relevant components as genotype × environment (linear) and pooled deviation, determine if these interactions are a linear function of environment effects. In the present study this partitioning revealed the differential response to seven environments as a linear function of improvement in the environmental mean yields. Significant differences among genotypes × environment (linear) (Table 1) indicated the response of each genotype to a change in environment, which may cause selection made in one environment to perform poorly in other environments (Romagosa and Fox, 1993; Sethi *et al*., 2017). Significant differences among slopes or regression coefficient indicate that each genotype has its own specific linear response to change in environment. Significant deviation from regression indicated linear as well as nonlinear response of cashew genotypes accounted for genotype × environment interaction which remains unexplained by additive environment effects. The mean square values of environmental linear was found tobe significant suggesting that the seven environment (linear) selected for testing varied in their effect influencing the performance of genotypes. There was considerable interaction of genotype with environment in different years. Similar result was reported by Sethi *et al*. (2017). Significant pooled deviations indicated the existence of a degree of non-linear effect in genotype × environment interaction. This could be due to interactions which are specific to individual combination or to a change in expression from environment to environment (Tai *et al*., 1982). The genotype × environment interactions were significant for most of the traits indicating considerable amount of interaction between the genotypes and environments.

In this study, the b-values of nut yield per plant ranged from 0.58 to 1.61. The linear regression (bi) is regarded as the measure of linear response of a particular hybrid

Table 1: ANOVA of G × E for nut yield plant^{-1} (kg) in eleven cashew genotypes (Eberhart and Russel Model, 1966)

Source of variation	DF	Sum of squares	Mean squares
Total	**140**	77.63	**0.21**
Variety	10	204.01	20.4**
Environment	6	565.98	94.33**
Var. X Envion.	60	139.61	2.32**
Env+Var X Env	10	705.59	
Env (Linear)	1	565.98	565.98**
Env X Var(Lin)	10	61.98	6.19**
Pooled Deviation	**55**	**77.63**	**1.41***
BH 6	5	13.29	2.658**
BH 85	5	3.95	0.790
H 1597	5	12.98	2.596**
K 22-1	5	3.11	0.622
H 662	5	1.155	0.231
H 675	5	0.745	0.149
H 11	5	7.985	1.597
H 14	5	1.95	0.390
H 32/4	5	4.415	0.883
Goa 11/6	5	9.67	1.934
BPP8	5	18.385	3.677**
Pooled Error	**144**	**32.356**	**0.225**

*Note:*significant at 5% level ** significant at 1% level*

Table 2: Stability parameters for yield in eleven cashew genotypes

Genotype	X_i	b_i	S^2d_i	R^2
BH 6	6.15	1.35	2.45**	87.73
BH 85	**7.30**	1.42**	0.58	96.37
H 1597	4.88	**1.61****	2.39**	91.21
K 22-1	2.03	0.71*	0.41	89.30
H 662	2.26	0.77**	0.02	96.42
H 675	**1.93**	**0.58****	-0.06	95.97
H 11	4.70	1.15	1.39**	89.51
H 14	3.60	0.74**	0.18	93.61
H 32/4	3.90	0.68*	0.67	84.35
Goa 11/6	4.67	0.88	1.72**	80.52
BPP 8	5.02	1.06	3.47**	75.91
GM	**4.22**			
SEm(±)	**0.17**			
CD	**0.48**			
CV(%)	**18.86**			

*Note: *significant at 5% level ** significant at 1% level*

to the changing environment where as deviation from regression (S^2d) is the measure of stability across the environments (Gray, 1982, Gazal *et al.*, 2013). If the regression coefficient (b_i) was greater than unity, the genotype is said to be highly sensitive to environmental fluctuations but adapted to high yielding environments. If the regression coefficient (b_i) is equal to unity, it indicates the average sensitivity to environmental fluctuations and adaptable to all environments. If the regression coefficient (b_i) was less than unity, it indicates less sensitivity to environmental changes and if this was accomplished by a high mean value, then the genotype

Table 3: Stability attributes of 11 cashew genotypes for nut yield

Mean nut yield	Linear (bi), non-linear (S^2di) both non-significant	Presence of G × E interaction		
	bi =1, S^2di = 0	**0 ≤ bi ≤ 1, S^2di = 0**	**bi=1, S^2di # 0**	**0 ≤ bi ≤ 1, S^2di # 0**
$x_1 < \bar{x}$	-	K-22-1, H-662, H-14, H-32-4	-	H-675
$x_1 > \bar{x}$	-	BH-85	BH-6, H-11, Goa 11/6, H2/16	H-1597

was said to be better adapted for poor conditions. The non-significant linear (b_i) and non-linear (S^2d_i) estimates indicate average stability of genotypes across different environments, whereas significant b_i and non-significant S^2d_i values indicate stability to specific environments. The genotype with unit regression coefficient (b_i=1) and non-significant deviation from regression (S^2d_i=0) are stable for nut yield in all the conditions and suitable or all the environments. The coefficient of determination (R^2) is also preferred for assessing varietal stability as it was in standardized form and the results were comparable between experiments directly without regard to scale of measurement. It results the proportion of genotypic variation attributed to linear regression.

In the present study the variation exhibited for nut yield plant^{-1} ranged from 1.93 (H-675) to 7.3 (B-85) with a mean value of 4.22 (Table 2). The genotypes BH-6 (6.15), BH-85 (7.30), H-1597 (4.88), H-11 (4.70), Goa-11/6 (4.67) and BPP-8(5.02) recorded high mean values. The regression coefficient values were significant for seven genotypes and ranged from 0.58 (H-675) to 1.61(H-1597). Two genotypes (BH-85 and H-1597) had b_i values significantly greater than one with above average yield. The S^2d_i values were significantly greater than zero for five genotypes *viz*., BH-6, H-1597, H-11, Goa 11/6 and H-2/16. The varieties BH-6, H-11, Goa-11/6 and BPP-8show average stability, with a linear regression coefficient (b) of 1.35, 1.15, 0.88 and 1.06 respectively. These four varieties also produced above average yields in all environments, which indicates that they have general adaptability. But these varieties are unstable (S^2d_i ‘“0) hence they will perform well only under specific environmental conditions. The two genotypes BH-85 and H-1597 are characterized by a regression coefficient significantly greater than one (b=1.42 and 1.61 respectively) with above average yield. The high b value is due to their sensitivity in response to favourable seasons. They are unstable but are able to exploit favourable conditions better thereby giving relatively higher yields than others. Under adverse conditions their yields are substantially reduced but are nevertheless significantly higher than others and consistently so over the years of study (Sallah *et al*., 1989).These two varieties are very sensitive to changes in environment indicating below average stability. Small changes in environment will produce large changes in yield. Hence they will perform well only under favourable conditions. Thus they can be described as being specifically adapted to high yielding environments. But the genotype H-1597 though performs well under good environmental conditions, it is unstable as evidenced from the significant mean square deviation ($S^2d_i \neq 0$).The genotypes K-22-1, H-622, H-675, H-32/4 and H-14 with a regression coefficient significantly less than one exhibit the opposite type of adaptation. These varieties are insensitive to environmental changes hence they produce low yield in a high yielding environment. These five varieties are specifically adapted to low yielding environments and maintain their yield compared to rest of the genotypes. The high S^2d_i value of BH-6, H-1597,H-11, GOA-11/6 and BPP-8 may be because they were evaluated along with low yielders which have different nut yielding behaviour altogether. Therefore, they deviate significantly from regression (Sallah *et al.*, 1989).

Based on these stability parameters *viz*., high mean (X), non-significant b_i and non-significant deviation from regression for nut yield, the cashew genotypes were thus classified (Table 3).It was observed that the genotype BH-6 was specifically stable for rich environment. The genotype BH-85 will perform well under favourable conditions while the genotype H-675 will perform well under poor or unfavourable conditions. The genotypes K-22-1, H-622, H-675, H-32/4 and H-14 are specifically adapted to poor environments. Paroda *et al*. (1973) classified the genotypes similarly and advocated the use of this technique in classifying the genotypes on the basis of b_i and S^2d_i.

Highly significant difference among genotypes, environments and genotype × environments (G × E) interaction for nut yield in eleven cashew genotypes was observed in the present study. The study also indicated that none of the genotypes were found stable for yield *i.e*. exhibited one of the linear and non- linear components to be significant, thus indicating high and predictable G × E interaction. However, only one genotype BH-85 was characterized by a regression coefficient significantly greater than one with above average yield thus it can be considered to be specifically adapted to favourable environment. The genotype H-675 is considered stable for poor environments. However, the performance of these genotypes can be improved by adopting suitable management practices. Also the high mean performing genotypes like BH-6, H-11, Goa 11/6, H2/16, BH-85 and H-1597 can be used as parents to breed for high yield and wider adaptation.

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