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Phenotypic Stability for Nut Yield and its Components in Cashew (*Anacardium occidentale* L.)

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ABSTRACT

Eleven cashew genotypes collected from different coordinated centers of All India Coordinated Research Project on Cashew were planted in the year 2003 at Cashew Research Station, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India, by adopting Randomized Block Design with three replications. Each experimental plot was comprised of four plants and was planted at 7.5 m apart on both the ways. All the recommended agronomic practices were adopted uniformly to raise a good crop. The cashew fruiting season from the year 2010 to 2016 were considered for the present study. All the vegetative parameters, yield attributes and nut yield plant^{-1} were subjected to stability analysis to identify the most stable genotype(s). The genotypes BH-6, H-1597, H-11, Goa-11/6 and BPP-8 were found stable for plant height and canopy spread (in East-West and North-South), which indicated that these genotypes did not exhibit environmental effect on vegetative parameters. Genotype, Goa-11/6 exhibited stability for maximum vegetative (plant height, trunk girth, canopy spread (East-West and North-South) and yield attributing traits (flowering laterals, total laterals, nut weight and shelling %) compared to the other tested genotypes. None of the eleven genotypes were found to be stable for nut yield. The genotypes, BH-85 is considered to be specifically adapted to favorable environment while genotype, H-675 is considered stable for poor environments.

Keywords Cashew, Phenotypes, Nut yield, Stability.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) a miracle nut crop, belongs to family Anacardiaceae and comprises of 75 genera and 700 species (Nakasone and Paul 1998). Cashew is native to Brazil and was introduced into India by Portuguese with a prime objective to check soil erosion, but later on emerged as dollar earning crop of the country. This crop has very significant role in India's economy. India ranks first in consumption and second in production and export of cashew (FAOSTAT 2017). Presently the total cashew area in the country is 10.62 lakh hectare with raw nut production of 8.17 lakh metric tons and productivity of 753 kg ha^{-1}. The productivity of cashew nut in the country is very low compared to the

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world's leading cashewnut producing countries. India has to import large quantity of cashewnut from other countries to meet the demand of processing industries in the country. 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 program (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 meagre. According to Knight (1970) the major objective of plant breeding is to select genotypes that are consistently high yielding over a range of environment, regardless of location and /or season. 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. The use of regression method to investigate G × E interaction was originally described by Yates and Cochran (1938). 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. 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. The above three measures for 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.

MATERIALS AND METHODS

Eleven cashew genotypes collected from different coordinated centers of All India Coordinated Research Project on Cashew were planted in the year 2003 at Cashew Research Station, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India, by adopting Randomized Block Design with three replications. Each experimental plot was comprised of four plants and was planted at 7.5 m apart on both the ways. All the recommended agronomic practices were adopted uniformly to raise a good crop. The cashew fruiting season from the year 2010 to 2016 were considered for the present study. All the vegetative parameters, yield attributes and nut yield plant^{-1} were subjected to stability analysis to identify the most stable genotype (s). The observations on vegetative characters, yield attributes and nut yield plant^{-1} were recorded for the cashew fruiting season from the year 2010 to 2016 following the standard procedure as described by Bhat *et al.* (2010). Stability parameters for different characters were computed using the regression approach Eberhart and Russell (1966).

RESULTS AND DISCUSSION

In this study, the mean performance coupled with the regression coefficient (b) and deviation from regression (s^2d) of each genotype represented its stability. With these conditions, evaluation and classification were done for genotypic stability with respect to vegetative, yield attributes and nut yield of cashew. Since the Genotype × Environment (G×E) interactions were found significant for most of the characters, the data of vegetative, yield attributes and nut yield were subjected to stability analysis to identify stable genotypes, which interact less with the environments. The linear regression (b) is regarded as the measure of linear response of a particular hybrid to the changing environment where as deviation from regression (S^2d) is the measure of stability across the environments (Gray 1982 and Gazal *et al.* 2013).

Evaluation of phenotypic stability through G×E is very important for a crop system like cashew that is cultivated across diverse ecologies (Ohler 1979). In the present study the average plant height over seven environments was less than the general mean (4.32) in case of four genotypes (Table 1). The genotypes BH-6 (4.58), BH-85 (4.64), H-1597 (4.55), H-11(4.42), H-32/4(4.87), Goa-11/6 (4.49) and BPP-8(4.71) re-

Table 1. Stability parameters for vegetative traits of cashew genotypes. *Significant at 5% level, ** significant at 1% level.

Genotypes	Plant height (m)				Trunk girth (cm)			
	X_i	b_i	S^2d_i	R^2	X_i	b_i	S^2d_i	R^2
BH 6	4.58	0.83	-0.01	93.57	64.28	1.20**	-2.31	98.89
BH 85	4.64	0.79**	-0.02	97.06	66.00	1.17**	-3.77	99.40
H 1597	4.55	0.95	0.00	92.74	69.00	1.31**	0.80	98.14
K 22-1	3.75	0.15*	0.22**	3.51	43.00	0.12**	66.60**	3.68
H 662	3.29	1.77**	0.03	95.16	34.00	1.04	-3.00	98.86
H 675	4.06	0.48	0.10	40.28	44.36	0.45	169.01**	18.14
H 11	4.42	0.99	0.00	94.23	61.50	1.15**	-2.72	98.17
H 14	4.12	1.53**	-0.01	98.46	50.87	1.06	-0.95	97.98
H 32/4	4.87	1.26**	-0.01	97.64	72.04	1.20**	0.59	97.82
Goa 11/6	4.49	1.15	-0.01	97.79	64.67	1.05	-4.26	99.50
BPP8	4.71	1.07	-0.02	98.20	66.20	1.22**	0.56	97.93
GM	4.32				57.69			
SEm(±)	0.60				0.87			
CV(%)	6.35				6.92			

Table 1. Continued.

Genotypes	Canopy spread(E-W) (m)				Canopy spread(N-S)(m)			
	X_i	b_i	S^2d_i	R^2	X_i	b_i	S^2d_i	R^2
BH 6	6.82	1.11	0.00	95.05	7.00	0.85	0.09	86.95
BH 85	7.25	1.03	-0.05	97.81	7.02	1.08	-0.03	96.36
H 1597	7.00	1.05	-0.01	95.20	6.84	1.11	-0.07	98.22
K 22-1	3.73	0.11**	0.58**	2.64	4.00	0.45	1.38**	19.41
H 662	3.90	1.60**	0.08	95.45	3.87	1.43**	0.10	94.54
H 675	3.91	0.22*	0.93**	6.71	4.00	0.09**	0.48	2.49
H 11	6.84	0.92	-0.05	97.00	6.74	1.06	-0.02	95.98
H 14	5.66	1.50**	-0.02	97.74	6.00	1.31**	-0.04	97.80
H 32/4	7.00	1.08	0.01	94.70	7.00	1.06	-0.04	96.78
Goa 11/6	6.56	1.23	0.04	94.45	6.67	1.15	-0.02	96.40
BPP8	7.40	1.11	0.10	90.41	7.34	1.37	0.32	88.56
GM	5.98				6.01			
SEm(±)	0.11				0.12			
CV(%)	8.59				9.29			

corded high mean values. The linear sensitivity coefficient (b_i) ranged from 0.15 (K-22-1) to 1.77 (H-662). The linear regression coefficient (b_i) was significant in case of five genotypes. Of these five genotypes H-662, H-14 and H-32/4 had b_i>1. Two genotypes viz, BH-85 and K-22-1 had b_i<1. Deviation from regression S^2d_i was significant in genotype K-22-1. The genotype BH-6, H-1597, H-675, H-11, Goa-11/6 and BPP-8 showed non-significant regression coefficients nearing unity but only BH-6, H-1597, H-11, Goa-11/6 and BPP-8 recorded high mean values than general mean. Hence these genotypes could perform well under average environmental conditions as they exhibited high mean performance with near to unity regression and least deviation from regression. The genotypes H-662, H-14 and H-32/4 can be considered to be stable for favorable environmental condition as they exhibited high means with greater than unity regression, whereas the genotype BH-85 showed high mean with less than unity regression, could perform well for this character even under poor environmental conditions. The average trunk girth above general mean was recorded in seven genotypes viz., BH-6 (64.28), BH-85 (66.0), H-1592 (69.0), H-11 (61.5), H-32/4 (72.04) and Goa-11/6 (64.67). The linear sensitivity coefficient (b_i) ranged from 0.12 (K-22-1) to 1.31 (H-1597). Six genotypes (BH-6, BH-85, H-1597, H-11, H-32/4 and BPP-8) had b_i>1 while one geno-

Table 2. Stability parameters for yield attributing traits and nut yield of cashew genotypes. *Significant at 5% level, ** significant at 1% level.

Genotype	Flowering laterals (m^{-2}) X_i	b_i	S^2d_i	R^2	Nuts panicle^{-1} X_i	b_i	S^2d_i	R^2	Nut weight (g) X_i	b_i	S^2d_i	R^2
BH 6	17.61	1.33*	-1.585	93.97	4.33	1.00	0.105	85.40	8.76	2.25**	0.096	88.31
BH 85	20.77	1.00	-1.00	83.32	4.84	0.65**	-0.087	90.72	7.63	1.10	0.024	78.48
H 1597	18.23	2.21	16.083**	64.22	3.73	1.35	0.427	82.90	8.37	0.07	0.147	0.65
K 22-1	15.62	0.3*	0.937	16.30	3.35	1.02	0.093	86.63	6.16	0.35	0.534**	4.42
H 662	14.33	1.04	4.914	50.44	3.06	0.66	0.147	69.24	7.21	0.68	1.812*	5.06
H 675	16.93	0.45	1.80	20.98	4.21	1.43	0.235	89.01	4.68	0.30	0.175	8.12
H 11	20.35	1.30	-0.709	87.41	4.33	1.11	0.090	88.56	5.94	0.65	-0.002	66.95
H 14	17.41	0.65	-1.26	72.50	4.06	0.97	0.026	89.02	5.57	0.81	0.054	58.31
H 32/4	16.5	0.48	7.60	13.70	4.4	1.10	0.083	88.64	7.56	1.58	0.384**	55.12
Goa 11/6	17.45	1.50	0.70	83.13	4.67	0.93	1.313**	47.56	7.38	0.96	0.022	74.2
BPP8	16.51	0.70	4.74	31.62	3.68	0.73	0.793	46.21	8.47	2.21*	0.229	78.91
GM	17.43				4.06				7.07			
SEm(±)	0.58				0.14				0.08			
CV(%)	15.24				16.80				5.25			

Table 2. Continued.

	Shelling (%) X_i	b_i	S^2d_i	R^2	Nut yield (kg plant^{-1}) X_i	b_i	S^2d_i	R^2
BH 6	32.83	1.747**	-0.14	89.82	6.15	1.35	2.45**	87.73
BH 85	30.36	1.601	0.247	68.77	7.30	1.42**	0.58	96.37
H 1597	30.84	0.148**	-0.12	5.25	4.88	1.61**	2.39**	91.21
K 22-1	30.33	0.77	1.49	13.50	2.03	0.71*	0.41	89.30
H 662	30.61	1.769	0.406	67.59	2.26	0.77**	0.02	96.42
H 675	31.02	0.947	0.544	33.34	1.93	0.58**	-0.06	95.97
H 11	29.7	0.641	1.968*	7.87	4.70	1.15	1.39**	89.51
H 14	30.44	0.565	0.283	20.43	3.60	0.74**	0.18	93.61
H 32/4	28.71	-0.211	3.136*	0.61	3.90	0.68*	0.67	84.35
Goa 11/6	30.89	2.312	0.919	67.37	4.67	0.88	1.72**	80.52
BPP8	28.74	0.71	-0.108	54.98	5.02	1.06	3.47**	75.91
GM	30.41				4.22			
SEm(±)	0.208				0.17			
CV(%)	3.14				18.86			

type K-22-1 had b_i<1. Deviation from regression S^2di was significant in two genotypes (K-22-1 and H-675). The genotypes H-622, H-14 and Goa-11/6 showed non-significant regression coefficients nearing unity but only one genotype Goa-11/6 recorded high mean value than general mean. Hence this genotype (Goa-11/6) will perform well under average environmental conditions as it exhibited high mean performance with near to unity regression and least deviation from regression. The genotypes BH-6, BH-85, H-1592, H-11, H-32/4 and BPP-8 are thus adapted to favorable environmental condition as they exhibited high means with greater than unity regression. The average canopy spread in both directions (E-W and N-S) above general mean was recorded in seven genotypes viz., BH-6, BH-85, H-1592, H-11, H-32/4, Goa-11/6 and H-2/16. The linear sensitivity coefficient (b_i) was significant in genotypes H-622, H-14, H-675 and K-22-1. Genotype, H-622 and H-14 genotype had b_i>1 while the genotype K-22-1 and H-675 had b_i<1. Deviation from regression S^2d_i was significant in case of two genotypes (K-22-1 and H-675). The genotypes BH-6, BH-85, H-1592, H-11, H-32/4, Goa-11/6 and BPP-8 showed non-significant regression coefficients nearing unity and least deviation from regression as well as recorded mean value higher than

Table 3. Cashew genotypes classified in different groups according to Eberhart and Russel (1966) stability model.

Characters	Group-I Stable for average environmental condition	Group-II Stable or favorable environmental condition	Group III Stable for poor environmental condition
Plant height	BH-6, H-1597,H-11,Goa 11/6, BPP-8	H-662, H-14, H32/4	BH-85
Trunk girth	Goa 11/6	BH-6,BH-85, H-1597,H-11, H32/4, BPP-8	–
Canopy spread (E-W)	BH-6,BH-85, H-1597,H-11, H-32/4, Goa 11/6, BPP-8	–	–
Canopy spread (N-S)	BH-6,BH-85, H-1597,H-11, H32/4, Goa 11/6, BPP-8		–
Flowering laterals	BH-85,H-11, Goa 11/6	BH-6	K-22-1
Total laterals	BH-6,BH-85, H-11, H-14,, Goa 11/6	–	
Nuts panicle-1	BH-6,H-675, H-11, H-14, H32/4	–	BH-85
Nut weight	BH-85,H-1597, Goa 11/6	BH-6,BPP-8	–
Shelling %	H-662, H-675, H-14, Goa 11/6	BH-85	H-1597
Nut yield	-	–	H-675

general mean. Hence these seven varieties are stable for average environmental conditions.

Flowering laterals is an important reproductive trait in cashew contributing to total yield. The average flowering laterals above general mean was recorded in five genotypes viz., BH-6 (17.61), BH-85 (20.77), H-1592 (18.23), H-11 (20.35) and Goa-11/6 (17.45). The linear sensitivity coefficient (b_i) ranged from 0.3 (K-22-1) to 2.21 (H-1597). Genotype, BH-6 had b_i>1 while the genotype K-22-1 had b_i<1. Deviation from regression S^2d_i was significant in genotype, H-1597. The genotypes BH-85, H-11 and Goa-11/6 showed non-significant regression coefficients nearing unity and least deviation from regression. Hence these three genotype will perform well under average environmental conditions as they exhibited high mean performance with near to unity regression. The genotypes BH-6 is adapted to favorable environmental condition as it exhibited high means with greater than unity regression while the genotype K-22-1 is adapted to poor environmental conditions. The average number of nuts panicle^{-1} computed over seven environments was less than the general mean (4.06) in four genotypes. The b_i values ranged from 0.65 (BH-85) to 1.43 (H-675). None of the genotypes had significant b_i value >1. The S^2d_i value was significant for Goa-11/6. Five cashew genotypes (BH-6, H-675, H-11, H-14 and H-32/4) exhibited high mean performance with near to unity regression and least deviation from regression and hence can be considered stable genotypes well adapted to all environmental conditions. The genotype BH-85 could perform well for this character even under poor environmental conditions as it exhibited high mean with less than unity regression. Six genotypes possessed higher weight of nut plant^{-1} than the general mean (7.07 g). The b_i values ranged from 0.07 (H-1597) to 2.25 (BH-6) and were significant for two genotypes viz., BH-6 and BPP-8 (b_i>1). Three genotypes showed significant S^2d_i values viz., K-22-1, H-662 and H-32/4. Three genotypes i.e. BH-85, H-1597 and Goa-11/6, exhibited high mean performance with near to unity regression and least deviation from regression (Table 2). These three genotypes are well adapted to all conditions for this character. The genotypes BH-6 and BPP-8 are adapted to rich environment and hence suitable for favorable environmental conditions. On the basis of mean values averaged over seven years, five genotypes have less shelling percent than the general mean (30.41). The b_i values ranged from -0.211 (H-32/4) to 2.31 (Goa-11/6). The b_i values of BH-6 was significantly greater than one while that of H-1597 it was less than one. Deviation from linear regression was found significant for two genotypes viz., H-11 and H-32/4. For this character four genotypes viz., H-622, H-675, H-14 and Goa-11/6 are well adapted to all types of environmental conditions, one genotype BH-6 will perform well only under favorable conditions while the genotype H-1597 will perform well under poor environmental conditions. Similar reports on stability were reported by Aliyu *et al.* (2014) while working with nine yield component characters of cashew.

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. The S^2d_i values were significantly greater than zero for five genotypes (BH-6, H-1597, H-11, Goa 11/6 and H-2/16). The varieties BH-6, H-11, Goa-11/6 and BPP-8 showed 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 indicate that they have general adaptability. But these varieties are unstable ($S^2d_i \neq 0$) hence 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 favorable seasons. They are unstable but are able to exploit favorable conditions better thereby giving relatively higher yields than others. These two varieties are very sensitive to changes in environment indicating below average stability. Small changes in environment produce large changes in yield. Hence they will perform well under favorable 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 is because they are evaluated along with low yielders which have different nut yielding behavior altogether. Therefore, they deviate significantly from regression. The findings in this study corroborates with the results of Murthy *et al.* (1984); Aliyu (2006), Aliyu and Awopetu (2011) and Sethi *et al.* (2017).

The results obtained through the study of mean performance, linear regression (b_i) and the deviation from regression (S^2d_i), indicated that linear regression (b_i) should simply be regarded as a measure of the response of particular genotype, whereas the deviations from the regression line (S^2d_i) should be considered as a measure of stability. The genotypes having least deviations are the most stable and vice-versa. Based on these stability parameters viz., high mean (X), non-significant b_i and non-significant deviation from regression for all the quantitative characters, the cashew genotypes are grouped into three groups (Table 3). Group-I comprised of stable genotype for average environmental conditions i.e. genotypes with high mean, near to unity regression and least deviation from regression. In this group none of the two components were significant, hence, indicated total absence of the G×E interactions. Group II consisted of stable genotypes for favorable environmental conditions i.e. genotypes exhibiting high mean, greater than unity regression and least deviation from regression. The genotypes in this group exhibited only linear component as significant. Thus, the performance of these genotypes in varying environments can be predicted. Group III included stable genotypes for poor environmental conditions characterized by high mean, less than unity regression and least deviation from regression i.e. non-predictable component was significant. The genotypes were classified into the above groups character-wise (Table 3). Stability of the genotypes for yield contributing traits according to their adaptation for different environments (all, rich and poor) indicated that the genotype BH-6 was specifically stable for rich environment as concerned with trunk girth, flowering laterals, nut weight, shelling % and nut yield. The genotypes BH-85 showed stability specifically to poor environment for plant height and nuts panicle^{-1}. Genotypes, BH-6, H-1597, H-11, Goa-11/6 and BPP-8 genotypes were found to be most stable over all environments for plant height. The genotypes BH-6, H-675, H-11, H-14 and H-32/4 were most stable for the number of nuts panicle^{-1}, while the genotypes BH-85, H-1597 and Goa-11/6 were most stable for nut weight for all environments. In respect to nut yield the genotype BH-85 will perform well under favorable conditions while the genotype H-675 will perform well under poor or unfavorable conditions. The genotypes K-22-1, H-622, H-675, H-32/4 and H-14 are specifically adapted to poor environments while the cashew genotype BH-85 will perform well under favorable conditions. Each genotype recorded deviation in stability over the years for different phenotypic and yield contributing traits. The effect of climate on flowering and nut yield of some tree crop are well documented by Gorden (1976), Ohler (1979), Alvim and De (1984), Blaike *et al.* (1998), Paria *et al.* (1999), Omojola *et al.* (2009), Omonona and Akintunde (2009).

CONCLUSION

None of the eleven genotypes were found to be superior for all the ten parameters in all the environments. The performance of these genotypes can be improved by adopting suitable management practices. These genotypes can be used as parents in hybridization program for development of high yielding genotypes with wider adoptability. The genotypes BH-85 was considered to be specifically adapted to favorable environment while genotype, H-675 was considered stable for poor environments.

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