Studies on Genotype-Environment Interaction (GxE) in Half-sib Progenies of Cashew (*Anacardium occidentale* L.) in Tanzania

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Abstract

*The aim of the work was to provide information on the variability in performance of cashew over different geographic growing sites and on the potential to carry out effective selection. Half-sib progenies of 16 selected cashew clones (***Anacardium occidentale*** L.) were used to establish progeny test trials at Kibiti and Chikomo. These sites were taken to represent cashew growing areas in north and south Tanzania respectively. Yield data and vegetative measurements recorded from 1989 to 1992 in both sites, were used to investigate the effect of site, progenies and their interaction. The performances of the progenies were compared in terms of their means and variances. There were differences in performance of the progenies in the two sites indicating the existence of genotype-environment interaction. The study identified progenies, which performed well at both sites, ones that performed badly at both and ones that varied in their performance. Thus it was possible to identify parents giving progenies which have wide adaptation under Tanzanian conditions. The data were used to calculate the heritability and response to selection for yield, canopy diameter, trunk cross sectional area and height. The heritabilities, and hence the response, of yield were low (3-40%) whereas that for height (47-72%) suggested that it would be a character amenable to selection.*

Key words: Cashew, genotype-environment interaction, progeny, yield, height, canopy diameter, trunk cross sectional area, heritability.

Introduction

The existence of genotype-environment interaction (GxE) in plants has been recognized for many years (Finlay and Wilkinson,1963; Knight, 1970; Caligari, 1991; Romagosa and Fox, 1993). The presence of GxE implies that the performance of a genotype in one environment cannot be used reliably in predicting the performance of the same genotype in other environments (Finlay and Wilkinson ,1963). It is important to know if environmental differences have any effects on cashew genotypes, since such differences have been appreciated already in other tree crops. For example, in rubber the presence of GxE interactions were reported in clones but were difficult to detect in progenies (Tan, 1991). In oil palms GxE has been observed to be small in progenies (Rajanaidu *et al.*, 1991) but significant interactions were observed in clones (Hee and Donough 1991) and hybrids (Yong *et al.*, 1991).

Knowledge of GxE interactions in cashew is urgently needed to help to determine the optimal breeding strategies e.g. highly significant GxE interaction requires breeding for stability or alternatively high yielding cashew genotypes may be recommended to be restricted to a specific environment. In other words, it is important to know whether genotypes bred and selected from a base in Naliendele, Southern Tanzania, need to

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be trialled in their early generations in other cashew growing regions (and hence entail considerable extra resources and expenses) or whether genotypes selected here will be suitable for other areas. If the latter is true then only the most likely genotypes near to proposed release to growers, need to be checked in these other regions in their final stages of selection.

However, in the present study cashew progenies were used because suitable clonally established trials were too immature and hence not ready for observations at the time of recording. Results from the present study will form a basis for further studies of GxE in cashew clones and cashew hybrids as well as the major objective of determining breeding protocols. The objective of the study was to take two representative sites, one in the north and one in the south of Tanzania, to determine the degree of genotype by environment interaction that will be displayed by a range of relevant cashew germplasms.

Materials and Methods

The present investigation was carried out in two progeny test trial sites (Kibiti and Chikomo) of the Agricultural Research Institute Naliendele, Tanzania. The Kibiti experimental site is located at a latitude of 7° 40′ S, longitude of 38° 55′ E and an altitude between 100-200m above sea level in Rufiji district, Coast region. The mean annual temperature is about 28°C and the mean annual rainfall is 900mm falling in two main seasons (March-June and October-December) (Mwenkalley, 1998). The soil type is a dominating clay loam with patches of sand clay loam with pH ranging between 5.7-6.0 (NCDP, 1994). The soil fertility levels are low (as reflected by the crops that are grown in this area, being mainly cassava, pineapples and citrus) and tend to decrease under continuous cropping, as soil structures are weakly developed (NCDP, 1994). The Chikomo experimental site is located at a latitude of 11° 20′ S, longitude of 37° 08′ E and an altitude of 744m above sea level in Tunduru district, Ruvuma region. The mean annual temperature is around 25°C and mean annual rainfall is about 1150 mm which falls in a single six months season (November-April). Soils in Tunduru are sandy with some little clay increased in the subsoil. These soils are moderately acidic, but have much higher cation exchange capacity and have more exchangeable bases, which makes soil fertility to be good (Soils Department Agricultural Research Institute-Naliendele Mtwara-personal communications) as judged by the successful cultivation of crops such as maize, beans, sesame, tobacco and rice. These sites therefore represent the two ends (north and south) of the cashew growing areas in Tanzania.

The trials were established in 1982 (Kibiti) and 1983 (Chikomo). The materials used comprised 16 half-sib progenies from the following parents; AC1, AC4, AC6, AC10, AC22, AC28, AC43, AZA2, AZA17, AIN62, AM6, AT58, ATRIN, ATA19, AT301 and LOCAL. Progenies with abbreviations AC, AIN, AM and ATRIN are from selected cashew clones originating in Ceylon (Sri Lanka), India, Malaysia and Trinidad respectively; while those with abbreviation AT, ATA, AZA and LOCAL are cashew clones from Tanzania. All progenies came from open pollinated seeds taken from selected clones in the Mass Selection Trial at the Agricultural Research Institute Naliendele, southern Tanzania. These trees were chosen as representative based on data collected over several years, on the individual mother trees, specifically in terms of yield and percentage kernel out-turn. It should be noted that the data were collected in years before powdery mildew was evident as a significant disease in Tanzania. The seed was sown directly into the ground, three seeds per planting point and the weaker seedlings rogued out to leave one tree per planting point. The design used was Randomized Complete Block, five replicates and 6 trees per plot at a spacing of 12m between rows and 12m within rows.

Yields of the 16 half-sib progenies were recorded on a tree by tree basis from 1985 to 1992 in both sites. Nuts, which had fallen to the floor were collected from under each tree, at a frequency depending on the time within the season (every 2-4 days initially, becoming 1-2 days and, towards the end of the season, every 2-4days), the apple detached and the nuts weighed using field scales (0-10 kgs). However, only yield data from 1989 to 1992 were used for analysis in the present study. The main harvesting season was observed to extend from September to December but at times it was prolonged to as late as February. The vegetative data in the analysis, which were recorded in 1992, were height of the tree (cm), canopy diameter (m) measured on assumption that the canopy of the cashew tree was a circle (Masawe *et. al.* 1998a) and trunk cross sectional area (m^2) The height of the cashew tree was measured using a measuring tape raised parallel to the trunk from the ground level to the top of the tree canopy using a long wooden pole. The canopy diameter was taken as the mean of the two diameters taken from north-south and east-west of the tree canopy. The trunks cross sectional area was calculated from the circumference of the trunk measured at a height of approximately one meter above the ground, using a measuring tape. Both yield and vegetative data were used to investigate the genotype-environment effects, specifically these were: yield (gms), yield per canopy ground cover area (yldCGCA)(gms/m^2), canopy diameter (m), tree height (m) and trunk cross sectional area (X-area) (cm^2). The chemical control of pests and diseases was not carried out during the four years of observation. Insect pests damage particularly Helopeltis Bugs (*Helopeltis spp*) and Coconut bugs (*Pseudotheraptus wayii*) were observed in all years of the experimentation which may be features contributing to loss of yield (Masawe and Millanzi 1997).

Before the analysis of variance was carried out, the distribution of the variables were tested for normality (Snedecor and Cochran, 1980). Since most variables showed skewness or kurtosis the data were transformed using $\log_{10}$ before analysis. Further, some characters like yield had occasional values of 0; therefore 1 was added to all variables before transformation as recommended by Steel and Torrie (1980). The low or zero yields was probably due to powdery mildew disease pressure (Waller *et. al.* 1992) and/or insect-pest attack (Masawe and Millanzi, 1997, Martin *et al*, 1997), the slight tendency, to a biennial bearing habit of some of the observed progenies or some missing plots. The data were analysed using ANOVA in the SAS statistical package (SAS Institute, North Carolina, USA).

The genetic interpretation followed the Ditlevsen (1985a) model of half-sib progenies in which the analysis of variance was derived as shown in Table 1.

The narrow sense heritability for yield and vegetative measurements were estimated from half-sib progeny variances (Falconer, 1982; Ditlevsen, 1985b). The expected response to seection (R) was calculated following the formula of Falconer (1982); $R = ih^2 s_A$ where h^2 is the narrow sense heritability (V_A/V_P), s_A is the standard deviation of breeding values (i.e. square-root of the additive genetic variance which is equal to %V_A) and i (which was equal to 1.271) is the intensity of selection of 25% proportion of the population (Falconer, 1982).

Table 1: Expected means squares in the analysis of variance and their genetic interpretation.

Source	df	MS	Expected MS
Blocks	b-1		
Progenies	a-1	M1	$\sigma_w^2 + 6\sigma^{e2} + 16*6\sigma_a^2$
Error	(a-1) (b-1)	M2	$\sigma_w^2 + 6\sigma_e^2$
Within plots	a*b*(w-1)	M3	σ_w^2

A = Number of progenies; b = Number of blocks; w = Number of trees per plot; $\sigma a^2 = (M1-M2)/(b*w)$; $\sigma a^2 = 1/4 V_A$; $VA = 4\sigma a2$; $\sigma_e^2 = (M2-M3)/w$; $\sigma_w^2 = M3$; $V_p = \sigma a^2 + \sigma_e^2 + \sigma_w^2$; $H_{n.s}^2 + Va/V_p$; σa^2=Variance due to progenies; σ_e^2 = Environmental variance among plots; s_w^2= Environmental varience among trees within a plot; V_A = Additive variance; V_P = Phenotypic variance.

Results

The combined analysis of variance for Chikomo and Kibiti showed highly significant differences between the two sites, between progenies and the interaction of Site with Progeny ($P<0.001$) (Table 2). When the effect of site was tested using blocks within site {Block(Site)} as an error term similar results were observed as when tested against the error term. The progenies mean squares were highly significant ($P<0.001$) when tested against the overall error indicating the presence of genetic variability in the progenies studied. However, the progenies were not significantly different when tested using Site-Progeny as an error term for any character except yield of 1989 and height (Table 2). The interaction of Site*Progeny was highly significant ($P<0.001$) and this can be ascribed to differences in sensitivity of different progenies i.e. the environmental differences had more effect on some progenies that they had on others. Thus clearly establishing the presence of GxE interactions for all the characters studied.

Comparisons of the means and the variances of both sites showed highly significantly different for all characters ($P<0.001$) (Table 3). This may be partly due to environmental factors like disease pressure and abiotic differences, rather than simple soil fertility, as yields at Chikomo are consistently low and very variable from year to year compared to Kibiti in which yield increased from year to year (Table 3). This stresses the need to carry out such trials in order to empirically assess performance at these different sites. Since the variances were different, each site was analysed separately to compare the performance of the progenies in greater detail.

Analysis of variance for Chikomo site

The analysis of variance for each character for the Chikomo site alone is presented in Table 4. The progeny mean square was highly significant ($P<0.01$) for all characters suggesting the presence of genetic variability between the progenies (Table 4), irrespective of what error comparison was made.

When considering the mean yield over the four years and the mean yield corrected by dividing it by the CGCA, the progeny mean squares were highly significant ($P<0.001$) (Table 4). This indicates that there were detectable genetic differences between the progenies for yield potential and opens the possibility of identifying better-performing progenies and hence allowing selection of the parent trees. The coefficient of variation (CV) for the vegetative characters ranged from 6.0% (trunk cross-section area) to 10.1% (height) (Table 4). However, the range of CVs for the yields was high, from 7.5% for the yield of 1989 to 65.1% for

Table 2: Combined analysis of variance for each of the characters over the two sites, Chikomo and Kibiti

Source	df	Mean Squares Yield log 10) gms						Diam (m)	X_area cm²	Height(m)
		1989	1990	1991	1992	mean	per cgca			
Site	1	14.27***	452.03***	415.70***	845.02***	211.72***	84.86***	7.09***	7.72***	11.66***
Site (BS)	1	14.27***	452.03***	415.70***	845.02***	211.72***	84.66***	7.09***	7.72***	11.66***
Block(site)	6	2.29***	15.62***	2.41***	8.67***	0.67***	0.75***	0.02***	0.09***	0.18***
Progeny	15	1.35***	3.66***	3.58***	3.73***	0.56***	0.61***	0.04***	0.13***	0.05***
Progeny (SP)	15	1.35***	3.68	3.58	2.73	0.56	0.61	0.04	0.13	0.05
Site*Progeny	15	1.14***	3.84***	1.73***	3.63***	0.33***	0.35***	0.02***	0.07***	0.01***
Error	882	0.36	1.01	0.78	0.93	0.11	0.10	0.01	0.03	0.00
Mean		3.03	2.58	3.11	2.86	3.26	1.72	0.89	2.58	0.76
CV		20.38	39.15	28.42	33.73	10.09	18.48	8.54	8.60	8.36

***=P<0.005 ** = P<0.01 * = P<0.05; Site(BS) = Site tested using Block (Site) (Mean square) as an error term. Progeny (SP) = Progeny tested using Site*Progeny (Mean square) as an error term.

Table 3: Comparison of means and variances for the yields in different years at the two sites Chikomo and Kibiti.

Character	Chikomo		Kibiti		T-test	F-ratio
	Mean	Var.	Mean	Var.	Means	Var.
yield 89	2.91	0.05	3.19	0.79	15.20**	16.50**
yield 90	1.09	1.53	3.32	0.36	186.93**	4.24**
yield 91	2.46	1.05	3.81	0.30	80.29**	3.49**
yield 92	1.94	1.54	3.87	0.19	123.27**	7.87**
yldmean	2.79	0.14	3.75	0.05	55.81**	2.38**
yldCGCA	1.46	0.12	1.99	0.06	58.43**	2.02**
Diameter(m)	0.81	0.01	0.99	0.01	37.49**	1.00
Height	0.65	0.00	0.88	0.00	56.15**	1.33*
X_area	2.49	0.02	2.68	0.03	13.65**	1.39*

** = significant at P<0.01.
* = significant at P<0.05.
Var= Variance.

Table 4: Results of the analyses of variance for the different characters at the Chikomo site.

Source	df	MEAN SQUARES YIELD(log10) gms						diameter m	X_area cm²	height m
		1989	1990	1991	1992	mean	per cgca			
Block	4	0.26 ***	28.92***	4.01***	17.16 ***	1.16 ***	1.123 ***	0.03 ***	0.168 ***	0.36 ***
Progeny	15	0.16 **	6.84 ***	5.05 ***	7.18 ***	0.69 ***	0.84 ***	0.04 ***	0.12 ***	0.04 ***
Progeny (BP)	15	0.16	6.84 ***	5.05 **	7.16 ***	0.69 ***	0.84 ***	0.04 ***	0.12 ***	0.04 ***
Block*Progeny	60	0.16 ***	1.98	2.13 ***	2.07	0.22 ***	0.17	0.01 *	0.04 ***	0.04 *
Error	400	0.05	1.53	1.05	1.54	0.14	0.12	0.01	0.02	0.00
Mean		2.91	1.09	2.48	1.94	2.79	1.46	0.81	2.49	0.65
CV		7.50	65.06	41.66	63.71	13.22	24.08	8.83	6.03	10.13

*** = P<0.005** = P<0.01* = P<0.05.
Progeny (BP)=Progeny tested using Block*Progeny (Mean square) as an error term.

the yield of 1990 despite the data being transformed to log10.

Analysis of variance for Kibiti site

The analysis of variance for each of the characters for the Kibiti site is summarised on Table 5. For most of the characters the progeny mean square was initially highly significant ($P<0.001$) but if the Block-Progeny (mean square) was used as the error term then there were no significant differences in yield (except yield 1992, $P<0.05$) but there were significant differences in the vegetative characters. Further, in contrast to the Chikomo site, there were no significant differences between the blocks ($P>0.05$) for the yield of 1991 and 1992 or for trunk cross section area and height.

The Coefficient of variations (CVs) ranged from 11.4% (1992) to 27.8. The CV for mean yield for four years was 6.4%. The CVs for vegetative were low and ranged from 6.5% to 7.5 only indicating a high level of experimental precision.

Heritability and response of progenies to selection

Generally the heritabilities were low for yield compared to vegetative characters in both sites (Table 6). Height at both Chikomo and

Table 5: Results from the analyses of variance for different characters at the Kibiti site.

Source	df	Mean Squares Yield(log₁₀) gms						diam	X_area	height
								m	cm²	m
		1989	1990	1991	1992	mean	per cgca			
Block	4	5.27***	2.68***	0.809	0.189	0.15*	0.39***	0.014*	0.04	0.01
Progeny	15	1.87 ***	0.93 ***	0.54*	0.44***	2.00***	0.14**	0.03***	0.08***	0.02 ***
Progeny (BP)	15	1.87	0.93	0.54	0.44*	2.00	0.14	0.03**	0.08***	0.02 ***
Block*Progeny	60	1.12 **	0.62 ***	0.46**	0.22	1.12 ***	0.12***	0.01***	0.04	0.00 *
Error	369	0.79	0.36	0.30	0.19	0.06	0.06	0.01	0.03	0.00
Mean		3.19	3.32	3.81	3.87	3.75	1.986	0.987	2.679	0.878

Kibiti was the most heritable character, (71.6% for Chikomo and 46.6% for Kibiti) followed by tree diameter but yields were the lowest suggesting that selection in a cashew breeding programme will be more effective for the size of the cashew tree than selection for yield, at least in the early stages. Generally it might be considered that small trees are most desirable because they will allow high density planting, giving greater yield per unit area. Already maternal effects have been reported to exist in cashew (Masawe *et al.*, 1998b).

The percentage response to selection (R) for the progenies was higher for most characters at Chikomo compared to Kibiti (Table 6) indicating that performance of the progenies was more pronounced at Chikomo as opposed to Kibiti.

Correlation of various characters in Chikomo and Kibiti

The correlation between the characters studied, for Chikomo site (Table 7), were highly significant (P<0.05) except the correlation between trunk cross-section area versus yield in 1992, and height versus yield per CGCA. In Kibiti there were highly significant correlation between most characters (P<0.01) except for the correlation of yield with height in 1989 (P>0.05), (Table 8). Generally the individual year yields were highly correlated with yield in other years at both sites. Equally vegetative characters were highly correlated with each other in both sites (Tables 7 & 8).

It is interesting to note that yields of individual years and the mean yield of four years were positively correlated with vegetative characters. However, vegetative characters were negatively correlated with yield per CGCA; but diameter was more strongly (negatively) associated with

Table 6: Heritabilities (h²) and percentage response to selection (R%) for yields and vegetative characters for Chikomo and Kibiti sites.

Character	Chikomo h²%	Kibiti h²%	Chikomo (R%)	Kibiti (R%)
Yield89	0.1	11.5	0.002	0.72
Yield90	36.6	9.8	9.11	0.39
Yield91	29.3	3.3	2.67	0.11
Yield92	38.0	14.4	5.30	0.36
Yldmean	37.8	16.0	1.09	0.22
YldCGCA	57.9	3.2	3.05	0.09
Diameter	61.5	30.4	1.18	0.48
Height	71.6	46.6	1.52	0.64
X_area	38.9	14.7	0.52	0.21

Table 7: Correlations between the yields in different years and with the vegetative characters at Chikomo site

Character	yield 1990	yield 1991	yield 1992	diameter	height	X_area	yield mean	yield per cgca
yield 1989	0.3718 ***	0.3999 ***	0.3929 ***	0.1230 **	0.1618 ***	0.0997 *	0.5606 ***	0.5140 ***
yield 1990		0.6226 ***	0.6290 ***	0.2017 ***	0.1607 ***	0.1153 *	0.8066 ***	0.7072 ***
yield 1991			0.7394 ***	0.1978 ***	0.1762 ***	0.1813 ***	0.9023 ***	0.8037 ***
yield 1992				0.1205 ***	0.1372 **	0.0719	0.8571 ***	0.7999 ***
diameter					0.5531 ***	0.6880 ***	0.2039 ***	-0.2183 ***
height						0.5012 ***	0.1891 ***	-0.0506
X_area							0.1534 ***	-0.1474 ***
mean yield								0.8939 ***

*** = P<0.005
** = P<0:01
* = P<0.05

Table 8: Correlations between the yields in different years and with the vegetative characters at Kibiti

Character	yield 1990	yield 1991	yield 1992	diameter	height	X-area	mean yield	yield per cgca
Yield 1989	0.53 ***	0.38 ***	0.45 ***	0.31 ***	0.09 **	0.34 ***	0.71 ***	0.49***
Yield 1990		0.31 ***	0.41 ***	0.21 ***	0.14 ***	0.21 ***	0.60 ***	0.44***
Yield 1991			0:39 ***	0.26 ***	0.20 ***	0.32 ***	0.73 ***	0.51***
Yield 1992				0.29 ****	0.26 ***	0.37 ***	0.82 ***	0 60***
diameter					0.51 ***	0.73 ***	0.34***	-0.34***
height						0:56 ***	0.26***	-0.11
Mean Yield							0.42***	-012
								0.72***

*** = P<0.005; ** = P<0.01; * = P<0.05

yield per unit area than is height and X-area (Table 7 and 8). This suggests that as the tree canopy grows bigger the yield per unit area decreases. Therefore cashew trees with extended branching pattern may not be desirable in attempts to increase yield per unit area. Indeed the pattern of correlation suggests that there is little to be lost from selecting smaller trees, in terms of height and canopy diameter, as reflected in likely correlated responses.

Ranking the progeny means for yield per canopy ground cover area (log10)

In this experiment, high yield per canopy ground cover area was considered as the most desirable character. In this context the tree diameter appears to be an important indicator, as the wider the diameter the less the yield per unit area. Looking at the progenies (Table 9) giving the best overall rankings, AZA17 (ranked 1st at Chikomo and 2nd at Kibiti), AC22 (3rd & 3rd), AIN62 (5th & 8th) and AC28 (6th and 1st) showed fairly consistent performance at both sites as opposed to others, such as ATRIN (2nd & 13th). Some progenies like ATA19 (15th & 12th), AT58 (16th & 16th), AM6 (10th & 11th) and LOCAL (12th & 14th) performed poorly at both sites indicating that those progenies were generally not suitable at either site.

Table 9: Rankings of the progeny means for yield per canopy ground cover area kg/m^2 (log$_{10}$) at each of the two sites. Their rank order at each site is given in brackets ().

Progeny	Chikomo		Kibiti	
AZA17	1.777	a(1)	2.076	ab(2)
ATRIN	1.776	a(2)	1.926	bcd(13)
AC22	1.576	b(3)	2.049	abc(3)
AC43	1.557	b(4)	1.979	abcd(10)
AIN62	1.547	b(5)	1.988	abcd(8)
AC28	1.521	bc(6)	2.100	a(1)
AC4	1.485	bc(7)	1.891	cd(15)
AC6	1.431	bcd(8)	2.014	abc(6)
AC10	1.427	bcd(9)	2.011	abc(7)
AM6	1.422	bcd(10)	1.974	abcd(11)
AZA2	1.364	bcde(11)	2.030	abc(5)
LOCAL	1.362	bcde(12)	1.911	cd(14)
AT301	1.324	cde(13)	2.048	abc(4)
AC1	1.315	cde(14)	1.982	abcd(9)
ATA19	1.232	de(15)	1.929	bcd(12)
AT58	1.163	e(16)	1.845	d(16)
Mean	**1.456**		**1.985**	

Discussion

It is evident that there is wide variation in yields and vegetative characters across the sites and the size of the variances due to site have demonstrated the influence of environment on the performance of the progenies. In the combined analysis of variance for Chikomo and Kibiti, the interaction of Site-Progeny was highly significant suggesting that the response of many of the progenies was not the same to the environments of the two sites and hence indicating the existence of GxE.

Generally, heritabilities for most characters at Chikomo were than Kibiti, suggesting that it would be easier to make selections at Chikomo than at Kibiti. However, it should be noted that the disease (powdery mildew) pressure is higher at Chikomo than Kibiti (Anonymous, 1992) which will affect the yield potential of the progenies, a feature which will not always be a direct breeding consideration if disease protection methods are adopted. However, in most cases, with smallholder farmers, this finding is relevant and will mean that selection for good performance over the two sites should help ensure higher yields even in the face of the presence of disease. Secondly, it is clear from other evidence that soils are more fertile at Chikomo than Kibiti therefore yield of cashew might be expected to be higher at Chikomo, but in reality this was not the case. This clearly indicates that there are other factors which are limiting production other than soil fertility and which emphasise the need for empirical investigations such as this one. It can be concluded that progenies performing better in both Chikomo and Kibiti like AZA17, AC22, AIN62 and AC28 are clearly better adapted to the different environments. Magari and Kang (1993), when studying genotype selection in maize (*Zea mays*), cautioned that when GxE interaction is significant its nature cause and implication must carefully be examined. Our work suggests that simple consideration of physical; measurable environmental factors may be time consuming and not necessarily revealing. While empirical testing allows a practical answer to be obtained and breeding progress made, it would however be more interesting to investigate a number of biotic factors, including monitoring of the disease pressure, along side abiotic ones such as soil analysis, records of rainfall and temperature to characterise further the differences between the sites. This is however not necessary in the present context where the empirically observed reactions of the different progenies are paramount, irrespective of the factors they are reacting to.

Conclusion

The data indicated that cashew progenies responded differentially to environmental differences (whatever their cause). Some were stable across the two sites suggesting that 'in the presence of GxE the behaviour of the individual progenies need to be considered at each of the sites to facilitate the selection of those that perform well at both sites. Tree height appears to be the most heritable character in cashew, which need to be considered during hybridisation program in cashew breeding when selecting male or female parents. These results are observations on progenies studied at two representative sites. Obviously more sites will give even more information and this would allow an even clearer choice of the most diagnostic sites. However, these present results provide strong evidence for the effectiveness of such trial in a breeding and selection context. In addition we have highlighted the potential for selecting tree size at an early stage in the breeding cycle.

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