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Genetic architecture of cashew germplasm accessions

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Abstract

The variability and genetic architecture was assessed deploying 13 important quantitative characters of 478 cashew germplasm accessions evaluated and conserved in National Cashew Field Gene Bank, Directorate of Cashew Research, Puttur in India. Considerable variability was observed for all characters and the highest co-efficient of variation (CV) was observed for sex ratio followed by cumulative yield per plant and apple weight. The lowest CV was observed for shelling percentage followed by shell thickness. Frequency distribution patterns showed highly positively skewed distribution for characters such as nut weight, sex ratio, apple weight and apple to nut ratio. Genetically, it is evident that decreasing alleles are in excess and dominant for these characters. Tree spread, kernel weight and cumulative yield per plant showed moderately positively skewed distribution indicating decreasing alleles are in slight excess and dominant. Flowering intensity showed moderately negative skewed distribution indicating the presence of increasing alleles in slight excess and their dominant nature. Tree height, shell thickness, flowering duration, shelling percentage and leaf area showed approximately symmetric distribution indicating increasing and decreasing alleles are in equal proportion and the dominance is ambi-directional. Significant positive correlations with cumulative yield per plant were observed for tree height, tree spread, sex ratio, flowering duration, apple to nut ratio, shelling percentage and leaf area and significant negative correlation for shell thickness. The present germplasm collection represents sufficient number of accessions for both quantitative and qualitative characters in desired direction. However, based on the frequency distribution patterns, it is imperative to collect germplasm with dwarfness, less tree spread, high nut weight, apple weight and high yield.

Keywords: Cashew, frequency distribution, genetic architecture, germplasm

Introduction

Germplasm in any crop is the basic resource for a breeder to develop improved varieties and hybrids. Hence, robust germplasm collection representing wide array of variability is essential for any meaningful improvement in terms of yield and quality parameters. In many crops, considerable efforts towards germplasm collection and conservation have been documented (Singh and Srivastava, 2004). However, comprehensive evaluation and characterization of this germplasm needs greater attention and it is often discussed in scientific circles that proper assessment of the worth of the germplasm and its subsequent utilization in crop improvement program is very crucial. This would also facilitate systematic exploration for trait specific germplasm.

The objective of this study was to assess variability and the genetic architecture of cashew germplasm conserved in National Cashew Field Gene Bank, Directorate of Cashew Research (DCR), Puttur, Karnataka, India. Since establishment of National Research Centre for Cashew (NRCC) at Puttur in 1986 and its up gradation to DCR during 2009, vegetatively propagated material of cashew has been collected through joint surveys by teams consisting of scientists of DCR and the All India Coordinated Research Project (AICRP) on Cashew centers of the states namely Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal (Swamy *et al.*, 1997, 1998, 2000) and eventually conserved in the National Cashew Field Gene Bank (NCFGB). This gene bank serves as a

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repository of cashew germplasm to be used for breeding and other purposes.

Material and methods

Evaluation and characterization was undertaken in 478 accessions (up to 2003 planting) after six annual harvests as per Cashew Descriptors (Anonymous, 1986) using 27 quantitative and 41 qualitative characters. The evaluated accessions are active collections in the field gene bank with 4 softwood grafts per accession planted at 4m x 4m spacing under rainfed conditions by adopting recommended package of practices. Colour of mature cashew apple was recorded by referring "RHS colour chart" (Anonymous, 1995). In the present paper, 13 important quantitative characters such as tree height, spread, nut weight, sex ratio, apple weight, shell thickness, flowering duration, apple to nut ratio, shelling percentage, kernel weight, leaf area, cumulative yield per plant and flowering intensity, were recorded following experimental manual on cashew (Thimmappaiah *et al.,* 2005) and used for analysis. The mean, standard deviation, skewness and kurtosis were calculated and frequency distribution was arrived for the selected characters using Descriptive Statistics option of IBM SPSS Statistics version 20. Further, correlation among these quantitative characters was worked out using 'correlate' option in the same software.

An attempt was made to identify accessions having desirable magnitude of these quantitative characters. The number of accessions in each category of 7 desirable qualitative characters was identified. The desirability and importance of the selected characters were decided based on previous experience in cashew breeding and the requirements for further improvement.

Results and discussion

Mean, skewness, kurtosis and frequency distribution

The mean represented in the Table 1 are values generally expected in cashew for respective characters. Considerable variability for all 13 characters was evident by the respective ranges and CVs. Highest CV (52.2%) was observed for sex ratio followed by cumulative yield per plant (49.2%) and apple weight (37.8%). The lowest CV was observed for shelling percentage (15.2%) followed by shell thickness (16.8%). The higher CV observed for sex ratio and yield indicated that there is wide variation for these characters in the germplasm collection. Hence, it is possible to make selections for these characters as desired level of the character can be chosen. Lowest CV observed for shelling percentage and shell thickness indicated that selection will not considerably improve these characters though they are important for cashew industries.

Table 1. Descriptive statistics of 478 germplasm accessions

Character	Minimum	Maximum	Mean	SE of mean	SD	CV (%)	Skewness	SE of skewness	Kurtosis	SE of kurtosis
Tree height (m)	1.50	9.70	5.01	0.07	1.43	28.56	0.47	0.11	-0.22	0.22
Tree spread (m)	1.50	11.10	6.20	0.07	1.57	25.30	0.72	0.11	0.36	0.22
Nut weight (g)	2.00	16.78	6.88	0.10	2.09	30.41	1.02	0.11	1.91	0.22
Sex ratio	0.01	0.30	0.09	0.00	0.05	52.21	1.08	0.11	1.76	0.22
Apple weight (g)	10.00	180.00	61.82	1.07	23.37	37.81	1.10	0.11	2.45	0.22
Shell thickness (mm)	1.50	4.70	3.06	0.02	0.52	16.83	0.36	0.11	0.68	0.22
Flowering duration (days)	42.00	130.00	82.54	0.82	18.03	21.85	0.16	0.11	-0.78	0.22
Apple to nut ratio	2.00	28.10	9.32	0.14	3.14	33.64	1.10	0.11	2.75	0.22
Shelling percentage	15.30	42.60	28.50	0.20	4.32	15.15	-0.10	0.11	0.42	0.22
Kernel weight (g)	0.40	4.40	1.94	0.03	0.55	28.30	0.79	0.11	1.49	0.22
Leaf area (m^2)	37.00	168.30	87.33	1.11	24.30	27.83	0.36	0.11	-0.36	0.22
Cumulative yield per plant (kg)	0.29	27.53	10.49	0.24	5.16	49.19	0.88	0.11	0.49	0.22
Flowering intensity (%)	14.30	96.80	65.78	0.73	16.06	24.42	-0.60	0.11	0.00	0.22

Table 2. Correlation among different characters in cashew

Characters	TH	TS	NW	SR	AW	ST	FD	ANR	SP	KW	CYP	FI	LA
Tree height (m)	1												
Tree spread (m)	0.753 **	1											
Nut weight (g)	0.106 *	0.102 *	1										
Sex ratio	0.042	-0.054	0.000	1									
Apple weight (g)	0.176 **	0.192 **	0.547 **	0.041	1								
Shell thickness (mm)	-0.060	-0.124 **	0.527 **	0.104 *	0.223 **	1							
Flowering duration (days)	0.001	-0.159 **	-0.094 *	0.324 **	0.091 *	0.089	1						
Apple to nut ratio	0.141 **	0.198 **	-0.173 **	0.030	0.553 **	-0.169 **	0.143 **	1					
Shelling percentage	0.103 *	0.252 **	-0.326 **	0.032	-0.115 *	-0.373 **	-0.155 **	0.079	1				
Kernel weight (g)	0.166 **	0.241 **	0.804 **	0.005	0.511 **	0.325 **	-0.170 **	-0.099 *	0.215 **	1			
Cumulative yield per plant (kg)	0.397 **	0.500 **	-0.088	0.171 **	0.031	-0.107 *	0.090 *	0.108 *	0.315 **	0.075	1		
Flowering intensity (%)	0.022	0.088	0.152 **	-0.279 **	0.177 **	0.069	0.062	0.098 *	-0.051	0.131 **	-0.067	1	
Leaf area (m^2)	0.068	0.133 **	0.315 **	0.117 *	0.196 **	0.085	-0.132 **	-0.022	0.054	0.340 **	0.162 **	0.029	1

**significant at the 1 %; *significant 5%

TH= Tree height; FD= Flowering duration; TS= Tree spread; ANR= Apple to nut Ratio; NW= Nut weight; SP= Shelling percentage; SR= Sex ratio; KW= Kernel weight; AW= Apple weight; CYP= Cumulative yield per plant; ST= Shell thickness; FI= Flowering intensity; LA= Leaf area

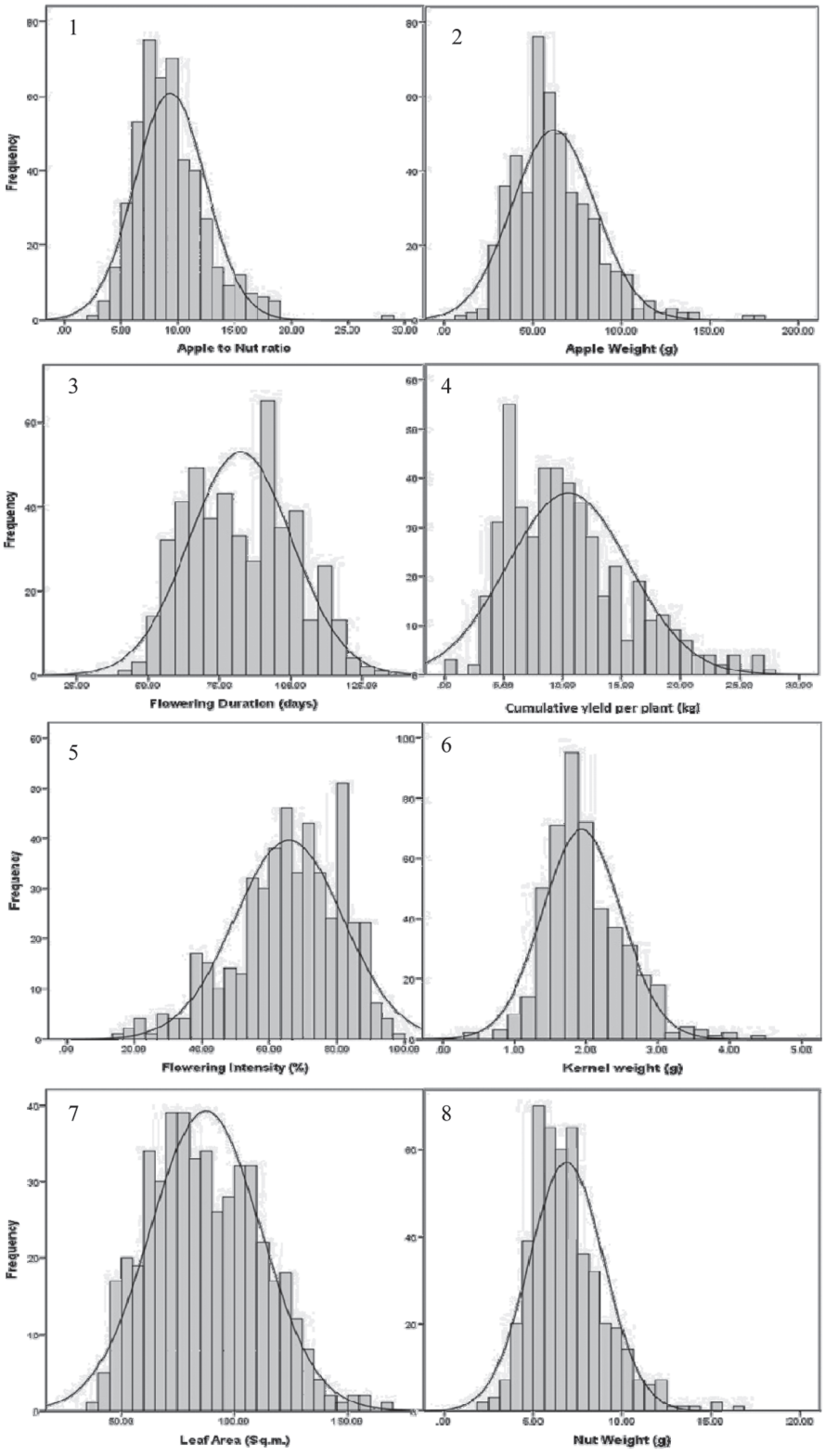

Fig. 1-8. Frequency distribution of different quantitative characters

Table 3. Number of accessions for desirable quantitative characters

Character	No of accessions	Top accessions (character values in parenthesis)
Tree height (< 2.5 m)	5	NRC 153 (1.5), NRC 128 (2.3), NRC 131 (2.4),NRC 100 (2.5), NRC 239 (2.5)
Tree spread (<3.0 m)	4	NRC 153 (1.5), NRC 121 (2.5), NRC 131 (2.7), NRC 190 (3.0)
Leaf area (>120 m^2)	50	NRC 270 (168.3), NRC 291 (159.0), NRC 279 (156.0), NRC 277 (152.0), NRC 278 (150.3)
Nut weight (>7.0 g)	190	NRC 269 (16.78), NRC 183 (15.4), NRC 161 (15.0),NRC 402 (14.2), NRC 383 (13.4)
Sex ratio (>0.13)	74	NRC 60 (0.30), NRC 63 (0.29), NRC 68 (0.27), NRC 279 (0.27), NRC 278 (0.25)
Weight of cashew apple (>52 g)	306	NRC 385 (180.0), NRC 301 (169.8),NRC 140 (142.8), NRC 164 (141.0), NRC 333 (135)
Weight of cashew apple (>100 g)	29	NRC 385 (180.0), NRC 301 (169.8),NRC 140 (142.8), NRC 164 (141.0), NRC 333 (135.0)
Shell thickness (<2.5 mm)	40	NRC 152 (1.5), NRC 153 (1.5), NRC 285 (1.5),NRC 87 (1.7), NRC 281 (1.8)
Shell thickness (>4.0 mm)	16	NRC 160 (4.7), NRC 278 (4.6), NRC 166 (4.5), NRC 180 (4.5), NRC 270 (4.5)
Flowering duration (<60 days)	50	NRC 266 (42), NRC 246 (47), NRC 238 (48), NRC 265 (48), NRC 221(50)
Flowering duration (>90 days)	161	NRC 24 (130), NRC 12 (128), NRC 11 (128), NRC 03 (121), NRC 20 (121)
Flowering intensity (> 70 %)	205	NRC 126 (96.8), NRC 175 (95.5), NRC 141 (95.2),NRC 148 (95.0), NRC 385 (93.7)
Apple to nut ratio (<6.0)	51	NRC 298 (2.0), NRC 156 (3.2), NRC 255 (3.3), NRC 238 (3.4), NRC 460 (3.6)
Apple to nut ratio (>12)	74	NRC 41 (28.1), NRC 385 (18.9), NRC 370 (18.6), NRC 115 18.5), NRC 327 (18.1)
Shelling percentage (>28 %)	265	NRC 406 (42.6), NRC 343 (41.0), NRC 393 (40.5),NRC 405 (40.5), NRC 327 (40.3)
Kernel weight (>2.5 g)	62	NRC 183 (4.4), NRC 323 (4.0), NRC 333 (4.0)NRC 160 (3.7), NRC 409 (3.5)
Cumulative yield per plant (>18 kg) 6 years	48	NRC 352 (Ullal- 1; 27.53), NRC 457 (Estamol-1; 26.82), NRC 349 (NDR-2-1; 26.21), NRC 356 (Chintamani-1; 26.08), NRC 354 (Ullal-3; 25.95), NRC 465 (Banjha Kusum-1 ;24.96), NRC 346 (Vengurla-4; 24.65), NRC 475 (Amritha; 24.42), NRC 452 (Anakkayam-1; 24.06), NRC 434 (Petamalapalli-1; 23.70)

The frequency distribution patterns of some characters are depicted in figures 1-8. Highly positively skewed distribution (Skewness value >1.0) was observed for characters such as nut weight, sex ratio, apple weight and apple to nut ratio. The characters such as tree spread, kernel weight and cumulative yield per plant showed moderately positively skewed distribution (Skewness >0.5 and <1.0). In the present study, flowering intensity showed moderately negatively skewed distribution (Skewness >-0.5 and <-1.0). For characters such as tree height, shell thickness, flowering duration, shelling percentage and leaf area, the distribution was approximately symmetric (Skewness between -0.5 and 0.5). None of the characters showed highly negatively skewed distribution. Positive kurtosis was observed for most characters except tree height, flowering duration and leaf area, which showed negative kurtosis. The kurtosis for flowering intensity was found to be zero.

Highly positively skewed distribution for characters such as nut weight, sex ratio, apple weight and apple to nut ratio indicated that majority of accessions are having less magnitude of these characters. In other words, it is difficult to find accessions with required higher values for these characters. Based on the skewness patterns, it is possible to infer about the magnitude and nature of alleles governing the character (Fisher *et al.,* 1942). Accordingly, for characters which are highly positively skewed, it is evident that decreasing alleles are in excess and dominant. For characters with moderately positively skewed distribution *i.e.,* tree spread, kernel weight and cumulative yield per plant, it implies that decreasing alleles are in slight excess and dominant. Cruz and Fletcher (2001) observed similar positive skewed distribution of nut yield and nut weight. Further, for flowering intensity, moderately negatively skewed distribution was observed which indicates the presence of increasing alleles in slight excess and their dominant nature.

However, tree height, shell thickness, flowering duration, shelling percentage and leaf area showed approximately symmetric distribution. This implies that increasing and decreasing alleles are in equal proportion and the dominance is ambi-directional for these characters. There was no character with highly negatively skewed distribution indicating the lack of presence and hence dominance of increasing alleles. Most characters except tree height,

Table 4. Some Combinations of two characters

Particulars	Accessions (character values in parenthesis)
Plant height < 2.5 m and apple to nut ratio < 6.0	NRC 153 (1.5, 6.0)
Plant height <2.5 m and shelling percentage >28.0	NRC 178 (2.3, 28.8)
Flowering duration <60 days and shelling percentage >28.0	37 accessions ; NRC 266 (42, 31.64), NRC 246 (47, 33.66), NRC 265 (48, 33.8) NRC 225 (50, 33.6), NRC 229 (50, 33.8)
Apple to nut ratio <6.0 and shelling percentage >28.0	24 accessions ; NRC 298 (1.97, 29.66), NRC 255 (93.26, 30.0), NRC 271 (3.80, 31.60), NRC 03 (4.10, 32.90), NRC 302 (4.21, 30.06)
Flowering duration <60 days and apple to nut ratio < 6.0	7 accessions ; NRC 217 (53, 5.46), NRC 238 (48, 3.38), NRC 244 (53, 5.65), NRC 255 (59, 3.26), NRC 259(57, 4.82), NRC 262 (51, 4.5), NRC 460 (52, 3.6)
Flowering duration <60 days and cumulative yield > 18 kg plant^{-1}	NRC 451 (56, 20.5), NRC 452 (51, 24.0), NRC 474(56, 19.5)
Apple to nut ratio <6.0 and cumulative yield >18 kg plant^{-1}	NRC458 (4.3,19.89)
Shelling percentage >28.0 and cumulative yield >18 kg plant^{-1}	39 accessions; NRC 352 (30.43, 27.5), NRC 457 (35.6, 26.8), NRC 472 (30, 26.8), NRC 349 (31.9, 26.2), NRC 356 (30.4,26.0)

Table 5. Some Combinations of three characters

Particulars	Accessions(character values in parenthesis)
Flowering duration <60 days,	NRC 255 (59.00, 3.26, 30.00)
apple to nut ratio <6.0	NRC 259 (57.00, 4.82, 33.10)
and shelling percentage >28.0	NRC 262 (51.00, 4.50, 33.48)
Flowering duration <60 days,	NRC 451 (56.00, 29.30, 20.55)
shelling percentage >28.0 and	NRC 452 (51.00, 32.10, 24.06)
cumulative yield >18 kg plant^{-1}	
Apple to nut ratio <6.0,	NRC 458 (4.30, 35.60,19.89)
shelling percentage >28.0	
and cumulative yield >18 kg plant^{-1}	

flowering duration and leaf area showed positive kurtosis which indicated that intermediate values are less likely and central and extreme values are more likely for characters with positive kurtosis and *vice versa* for characters with negative kurtosis. The normal distribution of flowering intensity was reflected by the zero kurtosis observed for the character.

Correlation

Significant positive correlations with cumulative yield per plant were observed (Table 2) for characters such as tree height (0.39), tree spread (0.5), sex ratio (0.17), flowering duration (0.09), apple to nut ratio (0.11), shelling percentage (0.31) and leaf area (0.16). Similar results were obtained where correlation of number of hermaphrodite flowers per panicle with nut yield was positive as shown by Aliyu (2004, 2006), Rao (1974), Lenka *et al.* (1999) and Murthy *et al.* (1984). Rao *et al.* (2002) observed that nut yield was positively correlated with canopy spread and leaf area. This indicates that improvement in positively correlated yield component can result in improvement of the yield. However, negative relationship between tree canopy and nut yield was observed by Aliyu (2006), Masawe (1994) and Masawe *et al.* (1998). Further, significant negative correlation was observed between nut yield and apple to nut ratio by Mendez-Natera (2003), flowering duration and nut yield by Rao *et al*. (2002).

Table 6. Number of accessions for desirable qualitative characters

Qualitative characters	No.
Tree habit (upright and compact)	62
Tree habit (upright and open)	378
Season of flowering (Early- November to December)	131
Season of flowering (Late- January to February)	45
Cashew apple shape (cylindrical)	137
Secondary flowering (Nil)	449
Attachment of nut to apple (loose)	167
Attachment of peel to kernel (loose)	412

Shell thickness showed significant negative correlation with cumulative yield and there was no significant correlation of characters such as nut weight, apple weight, kernel weight and flowering intensity with cumulative yield. Aliyu (2006) and, Cruz and Fletcher (1997, 2001) also observed insignificant association between nut weight and nut yield as obtained in this study. However, Northwood (1966) observed negative significant association between these two characters. Ushavani and Jayalekshmy (2009) observed significant negative relationship between apple weight and yield. However, these discrepancies in association between nut yield and other characters may be attributed the population under study in addition to pleiotrophic gene effect and nature of past selection methods (Falconer, 1972).

Significant positive correlation was observed among many other characters of importance. Akin to this study, positive correlation was observed between plant height and plant spread by Azevedo *et al.* (1998), Tavares *et al.* (2011) and Samal *et al.* (2001), nut weight and kernel weight by Rao and Hassan (1956) and Rao *et al.* (2002), apple weight and nut weight by Mendez-Natera (2003) and

Samal *et al.* (2001), canopy spread and apple weight by Samal *et al.* (2001) apple weight and apple to nut ratio by Mendez-Natera (2003) and, nut weight and shell thickness by Aliyu and Yahaya (2001).

Tree spread, nut weight and kernel weight have shown significant correlation with leaf area. Similar positive correlation of leaf size with nut weight was observed by Aliyu (2006). However, tree spread and flowering duration, nut weight and shelling percentage, sex ratio and flowering intensity, shell thickness and shelling percentage, flowering duration and leaf area and, apple to nut ratio and nut weight have shown significant negative correlation. But contrary to current study, Aliyu (2006) reported positive and significant correlation of weight of the whole fruit with nut weight.

Characters to be considered while exploration

Upon classification, it is evident that cashew germplasm collection represents sufficient number of accessions for most characters in the desired direction when one quantitative character is considered (Table 3). Germplasm with some combinations of two and three desirable quantitative characters have been identified (Table 4 and 5). The number of accessions under some qualitative characters has been depicted in Table 6. This will help in selecting germpalsm accessions for specific combination of characters based on breeding objectives. It is evident that few characters to be considered during germplasm collection include dwarfness and less tree spread as there are only five dwarf accessions (<2.5 m height) and four accessions having less than three meters tree spread as per Cashew Descriptors. Further, based on frequency distribution patterns, the germplasm with high nut weight, apple weight, apple to nut ratio, yield, sex ratio, kernel weight, should be given preference while collection. However, identification of trees based on characters such as kernel weight and sex ratio is quite difficult at the field level. Hence, collection based on dwarfness, less tree spread, high nut weight, apple weight, apple to nut ratio and yield is practical and useful.

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