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Studies on variability, heritability and genetic advance for quantitative and qualitative traits in cashew (*Anacardium occidentale* L.)

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ABSTRACT

Clonal planting materials of 25 cashew varieties were studied for their variability, heritability and genetic advance for qualitative and quantitative traits in cashew. Results revealed that variety, Vengurla-7 was the most vigorous, but dwarf in stature, and hence this cultivar can be used for high density planting. Chintamani-1 variety exhibited superiority in respect to floral traits like number of total laterals per m^2, flowering laterals per m^2, number of staminate flowers and total flowers per panicle. Bhubaneswar-1 variety recorded the highest number of perfect flowers per panicle, sex ratio, number of nuts per panicle and total soluble solid. Dhana and Jharagram-1 variety recorded the shortest and longest duration of flowering (89.5 vs. 150.5 days), respectively. Nut weight and kernel weight were recorded the maximum in Vengurla-7. The maximum shelling percentage (32.76%) was recorded in variety Kanaka. Among the evaluated varieties, BPP-8 recorded the maximum number of nuts per m^2; mean annual nut yield (16.75 kg per plant) and cumulative nut yield (56.27 kg per plant). Studies on genetic variability revealed that characters like sex ratio, yield per plant, nuts per panicle and nuts per m had high heritability and high genetic advance together with high genotypic coefficient of variation (GCV). Thus, these traits should be selected for cashew crop improvement. In the traits plant height, nut weight, trunk girth, canopy spread (E-W), total laterals per m^2, flowering laterals per m^2, flowering duration, kernel weight and apple weight showed high heritability, moderate genetic advance and moderate GCV, indicating improvement of these characters would be expected.

Key words: Cashew, heritability, morpho-economic traits, qualitative traits, variability

INTRODUCTION

Cashew, an important commercial plantation crop of India, is widely cultivated in states like Kerala, Tamil Nadu, Maharashtra, Goa, Karnataka, Andhra Pradesh, Orissa, West Bengal and North Eastern states. Presently, area under cashew is about 10.41 lakh ha with the total raw nut production of 7.79 lakh metric tons and productivity of 753 kg ha^{-1} (Hubballi, 2018). Odisha is the third largest producer of cashew nut in the country covering a total cashew area of 1.83 lakh ha with annual nut production of 0.93 lakh ton. Productivity of cashew nut in Odisha is only 513 kg ha^{-1} for which the cashew processing industry is facing a shortfall of 35,000 metric tons raw cashew nut per annum. One of the reasons of wide gap between the present level of productivity and potential productivity (2.0 ton ha^{-1}) of cashew nut in the country as well as in the state is use of traditional varieties with low yield potential.

So, crop improvement through breeding is one of the tools to address the issue of its low productivity.

Cashew is a highly cross pollinated crop, as a result large variations are observed among the quantitative and qualitative traits. Available genetic variability and inheritance of desirable traits decide the success of any breeding programme. Therefore, studies on genetic parameters become highly indispensible for an effective crop improvement programme (Hore et al., 2015; Bhoomika and Sudha Rani, 2018). So, an effort has been made to understand the variable and heritable traits of cashew, which can be utilized to formulate an effective breeding programme.

MATERIALS AND METHODS

A field experiment was laid out in 2008 using clonal planting materials of 25 released cashew varieties collected from different co-operating centres of All India Coordinated Research Projects on Cashew, India (Table 1). The grafted plants were planted at a spacing of 7.5 m × 7.5 m following randomized block design having six plants per treatment replicated twice.

The study was undertaken at Cashew Research Station, Ranasinghpur during the fruiting season 2016-17 (10 year old plants) with an objective to study variability, heritability and genetic advance in cashew. Observations on vegetative, yield and yield attributing traits were recorded as per the standard descriptor of cashew (Swamy et al., 1998). Statistical procedures were followed for analysis of variance and covariance (Panse and Sukhatme, 1954; Singh and Choudhury, 1985).

Table 1. Details of source of collection of cashew varieties used in the study

Sl.	Name of the cashew types	Sources of collection
1.	BPP-4, BPP-6, BPP-8	Cashew Research Station (CRS), Bapatla, Andhra Pradesh
2.	Bhubaneswar-1	Cashew Research Station (CRS), Bhubaneswar, Odisha
3.	Chintamani-1, Ullal-1, Ullal-3, Ullal-4	Cashew Research Station (CRS), Hogalagere, Karnataka
4.	Jhargram-1	Cashew Research Station (CRS), Jharagram, West Bengal
5.	Madakkathara-1, Madakkathara-2, K-22-1, Dhana, Kanaka, Priyanka, Amrutha, UN-50	Cashew Research Station (CRS), Madakkathara, Kerala
6.	Vengurla-1, Vengurla-4, Vengurla-6, Vengurla-7	Regional Fruit Research Station (RFRS), Vengurle, Maharashtra
7.	VRI-3	Regional Research Station (RFRS), Vridhachalam, Tamil Nadu
8.	Bhaskara, NRCC Sel-2	Directorate of Cashew Research Puttur (DCR), Karnataka
9.	Goa-1	ICAR Research Complex for Goa, Ela, Old Goa.

RESULTS AND DISCUSSION

Results on performance of twenty five cashew varieties are presented in Table 2 and 3, which revealed that among the tested varieties, Vengurla-7 recorded the maximum for the vegetative parameters like tree height (5.45 m), trunk girth (84.05 cm) and canopy spread in North-South direction (8.75 m); while canopy spread in East-West direction was recorded maximum in variety, BPP-8 (8.75 m). Cashew varieties such as K22-1 (4.20 m) and VRI-3 (4.25 m) recorded the minimum plant height among the evaluated cashew varieties, indicating their suitability for high density planting (Hore et al., 2015; Malhotra et al., 2016). The number of total laterals m^{-2} ranged from the minimum 16.37 in Bhubaneswar-1 to the maximum 29.50 in Chintamani-1. Similar variation in vegetative growth parameters among cashew varieties were also reported previously by various workers from different locations across India (Hanumanthappa et al., 2014; Tripathy et al., 2015).

Table 2. Mean of vegetative and yield attributing traits of twenty five cashew varieties

Sl. No.	Varieties	Plant height (m)	Trunk girth (cm)	Canopy spread (m)		Total laterals m^{-2}	Number of flowering laterals m^{-2}	Nuts per panicle	Number of nuts m^{-2}	Nut weight (g)	Kernel weight (g)	Shelling (%)
				(E-W)	(N-S)							
1	BPP-4	4.55	58.65	6.42	6.45	21.00	19.37	5.5	41.75	7.20	2.04	28.31
2	BPP-6	4.90	66.90	7.60	6.65	24.50	23.50	7.5	36.50	6.45	1.85	28.56
3	BPP-8	5.25	71.80	8.75	6.85	28.25	25.50	6.0	46.00	9.30	2.66	28.68
4	Bhubaneswar-1	4.53	62.30	5.95	6.30	16.37	14.00	9.0	25.62	6.45	1.97	30.59
5	Chintamani-1	5.35	73.55	8.35	7.15	29.50	28.87	4.5	15.25	7.10	2.13	30.02
6	Jhargram-1	5.25	71.80	8.25	7.75	23.00	20.87	1.0	3.50	6.80	2.05	30.25
7	Madakkathara-1	4.75	67.25	6.30	6.65	27.75	23.12	7.5	34.87	7.30	2.37	32.40
8	Madakkathara-2	4.35	52.75	5.60	5.50	24.25	24.87	3.0	13.50	6.90	2.08	30.19
9	K-22-1	4.20	61.95	5.95	5.70	28.50	28.00	4.5	15.75	6.40	1.99	31.08
10	Dhana	4.75	68.90	6.60	7.30	28.75	27.87	3.0	14.50	7.40	2.09	28.25
11	Kanaka	5.00	70.55	6.55	6.00	20.87	18.75	3.0	21.37	5.70	1.87	32.76
12	Priyanka	4.85	63.10	7.62	7.55	19.00	18.37	1.5	9.12	9.45	2.78	29.42
13	Amrutha	4.25	54.70	5.45	6.45	26.25	25.87	3.5	13.75	6.95	2.10	30.13
14	Vengurla-1	4.95	62.50	7.25	7.15	24.00	21.87	3.5	17.75	6.95	2.12	30.45
15	Vengurla-4	4.75	61.40	6.20	6.50	21.00	19.12	5.5	26.50	7.35	2.20	29.87
16	Vengurla-6	4.85	60.25	6.80	6.65	22.00	24.87	7.5	21.62	8.95	2.62	29.28
17	Vengurla-7	5.45	84.05	8.70	9.47	21.00	20.12	3.5	17.75	9.60	3.02	31.38
18	VRI-3	4.25	53.00	5.75	5.80	22.25	21.62	5.5	37.87	7.05	2.34	28.14
19	NRCC Sel-2	4.68	62.15	8.05	6.60	19.25	17.50	4.0	26.50	8.55	2.51	29.29
20	Ullal-1	4.75	69.00	6.60	7.00	28.87	24.25	2.5	25.50	7.10	2.13	30.10
21	Ullal-3	4.80	53.30	6.30	6.40	20.62	20.50	4.0	23.12	8.15	2.20	26.97
22	Ullal-4	4.55	57.85	6.10	7.15	19.75	15.25	5.0	24.75	8.15	2.54	31.20
23	UN-50	4.95	65.60	6.40	5.60	20.50	17.87	2.0	25.37	8.20	2.38	29.12
24	Goa-1	4.65	67.35	6.45	6.65	23.00	20.25	5.5	34.87	7.55	2.45	32.39
25	Bhaskara	4.65	69.75	7.50	6.55	16.62	16.50	6.0	34.37	7.15	2.16	30.31
SEm (±)		0.15	1.26	0.16	0.21	1.52	1.61	0.47	1.43	0.17	0.05	0.34
CD (5 %)		0.46	3.70	0.47	0.63	4.44	4.72	1.39	4.19	0.49	0.15	0.99

Table 3. Mean of nut yield (kg per plant) and quality traits of twenty five cashew varieties

Sl. No.	Varieties	Annual nut yield (kg per plant)	Cumulative nut yield (kg per plant)	Apple colour	Apple weight (g)	TSS (°Brix)	Acidity (%)
1	BPP-4	13.77	31.21	Yellow	35.60	10.08	0.15
2	BPP-6	6.45	28.18	Yellow	42.27	10.63	0.14
3	BPP-8	16.75	56.27	Yellow	60.00	9.96	0.19
4	Bhubaneswar-1	9.45	30.67	Red	39.95	12.75	0.20
5	Chintamani-1	6.70	21.19	Reddish Yellow	39.30	11.80	0.15
6	Jhargram-1	1.60	9.95	Yellow	54.80	12.10	0.14
7	Madakkathara-1	13.97	35.95	Yellow	47.00	11.75	0.20
8	Madakkathara-2	2.57	14.05	Red	34.10	10.40	0.19
9	K-22-1	7.42	20.74	Red	51.75	10.05	0.11
10	Dhana	9.55	31.91	Yellow	52.50	10.59	0.16
11	Kanaka	6.27	24.88	Yellow	65.50	11.38	0.21
12	Priyanka	2.37	12.82	Reddish Orange	98.42	9.18	0.16
13	Amrutha	4.45	16.27	Yellow	37.80	11.90	0.21
14	Vengurla-1	5.32	18.33	Reddish yellow	38.20	10.64	0.19
15	Vengurla-4	12.15	33.04	Red	57.60	10.84	0.22
16	Vengurla-6	13.27	31.24	Yellow	69.70	9.51	0.17
17	Vengurla-7	12.8	46.96	Yellow	56.50	11.01	0.19
18	VRI-3	9.22	25.57	Red	34.30	10.75	0.18
19	NRCC Sel-2	11.30	31.38	Red	74.35	10.09	0.17
20	Ullal-1	6.30	17.82	Yellow	44.15	11.54	0.16
21	Ullal-3	5.10	21.19	Red	48.15	10.81	0.19
22	Ullal-4	6.50	20.68	Yellow	54.40	12.31	0.19
23	UN-50	6.95	16.78	Reddish yellow	52.55	10.46	0.19
24	Goa-1	9.15	24.73	Yellow	69.30	10.95	0.13
25	Bhaskara	13.10	38.38	Orange	65.20	10.53	0.16
SEm (±)		0.46	-	-	2.47	0.48	0.01
CD (5 %)		1.36	-	-	7.21	1.42	0.04

Number of flowering laterals per m^2 was recorded the maximum in var. Chintamani-1 (28.87), whereas the maximum number of nuts panicle^{-1} was recorded in Bhubaneswar-1 (9.0). Average number of nuts per m^2 ranged from 3.5 in Jharagram-1 to 46.0 in BPP-8. According to Poduval (2015) number of nuts per m^2 contributes towards total nut yield per plant in var. H-255 in West Bengal. The nut weight (g) varied from 5.7 in Kanaka to 9.6 in Vengurla-7. More than 8.0 g nut weight was recorded in BPP-8, Vengurla-6, Priyanka, NRCC Sel-2, Ullal-3, Ullal-4 and UN-50. Similar variations in nut weight of different cashew types was also reported by Tripathy et al. (2015) and Gajbhiye et al. (2015). It is also revealed that the kernel weight in most of the varieties was more than 2 g and the maximum kernel weight was recorded in variety Vengurla-7 (3.02 g). Among the tested varieties highest shelling (%) was recorded in variety Kanaka (32.76) followed by Goa-1 (32.39) and Madakkathara-1 (32.40). Similar variations in shelling percentage have been reported by Gajbhiye et al. (2015) and Poduval (2015). The tested varieties also revealed significant variations for mean annual nut yield (kg per plant) as well as cumulative nut yield per plant during the period of investigation (Table 3). The highest nut yield was recorded in var. BPP-8 (16.75 kg per plant) while that of the lowest in var. Jharagram-1 (1.60 kg per plant) at the 7th harvest. Cashew varieties which recorded > 10 kg annual nut yield per plant at 7th harvest (10 year old plants) were NRCC Sel-2 (11.30), Vengurla-4 (12.15), Vengurla-7 (12.80), Bhaskara (13.10), Vengurla-6 (13.27), BPP-4 (13.77) and Madakkathara-1 (13.97). Hence, these varieties have the potential of producing higher nut yield than rest of the tested varieties. Cumulative nut yield per plant for 7th harvest was also recorded the maximum for the above mentioned varieties during the study (Table 3). Tripathy et al. (2015) reported similar variations in nut yield of different cashew types under Odisha conditions.

Variety, Dhana recorded the shortest duration of flowering (89.5 days) while Jharagram-1 had the longest duration of flowering (150.5 days). Nut weight and kernel weight were found the maximum in Vengurla-7. The highest shelling percentage was recorded in var. Kanaka. Among the evaluated varieties, BPP-8 recorded the maximum number of nuts per m^2, mean annual nut yield (16.75 kg per plant) as well as cumulative nut yield (56.27 kg per plant). Similar variations were also reported with respect to vegetative characters, yield attributes, nut yield and biochemical parameters (Anand et al., 2015; Gajbhiye et al., 2015; Lakshmana et al., 2015). Wide variations were observed for various physico-chemical parameters of cashew apple such as colour, weight, TSS (°brix) and acidity (%). The acidity percentage in different cashew varieties ranged from 0.11 (K-22-1) to 0.22 (Vengurla-4). The range for different characters among the varieties and superior varieties for different quantitative and qualitative characters are explained in Table 4.

Analysis of variance for all quantitative traits under study revealed significant variations among the twenty five genotypes. The co-efficient of variation, heritability and genetic advance estimated for different characters are presented in Table 5. Wide difference in coefficient of variation both at phenotypic (PCV) and genotypic (GCV) levels in most of the characters confirmed existence of genetic variability in the tested cashew genotypes (Table 5). Although all the component traits recorded higher value for PCV than GCV, but the difference was very narrow. This implies that component traits were least affected by environment. During evaluation, it was observed that the estimates of PCV varied from 4.77% for shelling percentage to 65.22% for sex ratio. The estimates of GCV also showed a similar trend and recorded minimum for shelling percentage (2.87) and maximum for sex ratio (63.64%). High magnitude of PCV as well as GCV were observed for the quantitative traits like sex ratio, nuts per panicle, nuts per m^2 and nut yield per plant. This indicates relatively higher contribution of these characters towards genetic variability in cashew. Rest of the quantitative traits like plant height, trunk girth, canopy spread (both in East-West and North-South direction), flowering laterals per m^2, total laterals per m^2, flowering duration, kernel weight,

nut weight and acidity recorded moderate PCV as well as GCV. The present study revealed that lot of variability exists for the quantitative traits of cashew that can be effectively exploited by simple selection method in crop improvement programme. Similar results were also reported earlier by Lenka et al. (2001), Dashmohapatra et al. (2012) and Mohapatra et al. (2018).

Table 4. Promising cashew varieties in relation to specific quantitative and qualitative traits

Sl. No.	Characters	Range of traits with varieties
1	Plant height (m)	4.20 (K-22-1) - 5.45 (Vengurla-7)
2	Trunk girth (cm)	52.75 (Madakkathara-2) - 84.05 (Vengurla -7)
3	Canopy spread (E-W)(m)	5.45 (Amrutha) - 8.75 (BPP-8)
4	Canopy spread (N-S)(m)	5.50 (Madakkathara-2) - 9.47 (Vengurla-7)
5	Flowering laterals per m^2	14.00 (Bhubaneswar-1) - 28.87 (Chintamani-1)
6	Total laterals per m^2	16.37 (Bhubaneswar-1) - 29.50 (Chintamani-1)
7	Flowering duration (days)	89.5 (Dhana) - 150.5 (Jhargram-1)
8	Sex ratio	0.05 (Chintamani-1 and Vengurla-1) - 0.46 (Bhubaneswar-1 and Kanaka)
9	Nuts per panicle	1.00 (Jhargram-1) - 9.00 (Bhubaneswar-1)
10	Nuts per m^2	3.50 (Jhargram-1) - 46.00 (BPP-8)
11	Nut weight (g)	5.70 (Kanaka) - 9.60 (Vengurla-7)
12	Kernel weight (g)	1.85 (BPP-6) - 3.02 (Vengurla-7)
13	Shelling percentage	28.14(VRI-3) - 32.76 (Kanaka)
14	Nut yield (kg per plant)	1.60 (Jhargram-1)- 16.75 (BPP-8)
15	Cumulative nut yield	9.95 (Jhargram-1) - 56.27 (BPP-8)
16	Apple weight (g)	34.10 (Madakkathara-2) - 98.42 (Priyanka)
17	TSS (°Brix)	9.18 (Priyanka) - 12.75 (Bhubaneswar-1)
18	Acidity (%)	0.11(K-22-1) - 0.22 (Vengurla-4)

Table 5. Genetic parameters of different component characters in cashew

Sl. No.	Characters	PCV (%)	GCV (%)	Heritability (Broad sense)	Genetic advance	Genetic advance (% of mean)
1	Plant height (m)	6.96	6.12	77.28	0.45	9.47
2	Trunk girth (cm)	11.50	11.33	97.06	12.65	19.64
3	Canopy spread (E-W)(m)	14.26	13.98	96.04	1.66	24.10
4	Canopy spread (N-S)(m)	12.27	11.84	93.08	1.35	20.10
5	Flowering laterals per m^2	18.74	17.17	83.94	5.97	27.68
6	Total laterals per m^2	16.86	15.51	84.65	5.80	25.15
7	Flowering duration (days)	13.04	12.80	96.42	25.36	22.12
8	Sex ratio	65.22	63.64	95.22	0.23	109.30
9	Nuts per panicle	44.24	42.98	94.41	3.35	73.50
10	Nuts per m^2	47.05	46.65	98.32	20.61	81.42
11	Kernel weight (g)	12.94	12.75	97.03	0.50	22.10
12	Nut weight (g)	13.53	13.34	97.18	1.74	23.15
13	Shelling percentage	4.77	2.87	36.19	0.91	3.04
14	Nut yield (kg per plant)	47.75	47.44	98.68	7.05	82.93
15	Apple weight (g)	28.68	28.30	97.36	26.01	49.14
16	TSS (°Brix)	9.01	7.83	75.41	1.30	11.96
17	Acidity (%)	15.60	13.05	70.04	0.03	19.23

The heritability estimates depend upon the amount of genetic variation in the population and the environmental conditions under which the population is evaluated. The heritability estimates ranged from 36.19% in shelling percentage to 98.68% in nut yield indicating varied seasonal effect on character expression. However, the relatively high estimates of heritability (>80%) was obtained for all the quantitative traits except plant height (77.28%), TSS (75.41%), acidity (70.04%) and shelling percentage (36.19%). Heritability is one of the factors influencing genetic gain under selection. Heritability estimates along with genetic gain is more reliable in predicting the effect of selection. Expected genetic advance for different traits expressed as percentage of population mean ranged from 3.04 in shelling percentage to 109.3% in sex ratio at 5% selection intensity. The genetic advance as percentage of mean was higher for sex ratio, nuts per panicle, nuts per m^2 and nut yield (>70%) indicating the predominance of additive gene effects. They can be taken as unit characters for effective selection. Low genetic gain was obtained for rest of the characters. High heritability (>90%) with moderate genetic advance was recorded for the characters like trunk girth, flowering duration, nuts per m^2 and apple weight. This indicates that these characters are governed by both additive and non- additive gene action, while high heritability with low genetic advance indicates non-additive gene action only. Sharma et al. (2011), Dasmohapathra et al. (2012) and Sethi et al. (2016) reported similar findings in cashew.

CONCLUSION

Evaluation of twenty five released cashew varieties revealed that var. Vengurla-7 was the most vigorous plant, while Chintamani-1 produced

the maximum vegetative as well as reproductive shoot. Nut weights as well as kernel weight were the highest in var. Vengurla-7 while variety, BPP-8 recorded the maximum nut per plant at 7th harvest. High magnitude of phenotypic coefficient of variation as well as genotypic coefficient of variation were observed for the quantitative traits like sex ratio, nuts per panicle, nuts per m^2 and nut yield per plant. This indicates relatively higher contribution of these characters towards genetic variability in cashew. The genetic advance as per cent of mean was higher for sex ratio, nuts per panicle, nuts per m^2 and nut yield (>70%) indicating the predominance of additive gene effects. They can also be taken as unit characters for effective selection.

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