



Short Communication

## Evaluation of cashew hybrids for yield contributing traits in the plains of mid land north central laterite agro ecological unit of Kerala

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### Abstract

A study was conducted at Cashew Research Station, Madakkathara, Kerala Agricultural University, to evaluate the hybrid vigor of 19 cashew hybrids developed during 2003. These hybrids selected from an initial evaluation trial, resulted from a cross between 11 parents. The hybrids were evaluated along with the parents for morphological, phenological and yield characters for two consecutive seasons. Poornima, the latest released variety of cashew, was used as check. The analysis of results based on mean values on various flowering parameters and yield parameters showed significant variations among the genotypes for all the characters. The highest nut weight and nut yield per tree was observed in the hybrid, H03-21/10. Hybrids, H03-97/2, H03-110/1, H03-36/8, H03-52/5 and H03-21/10 can be considered as high yielders (> 18 Kg/tree/year) with bold sized nuts (>10 g), premium quality kernels (>2.5 g) and high shelling percentage (> 28%). These hybrids also exhibited better heterosis in terms of nut weight and kernel weight. The five potential hybrids were identified for replicated yield trials for commercialization in future.

**Keywords:** Cashew, Correlation, Heterosis, Hybrids, Nut weight

Cashew (*Anacardium occidentale* L.) is a cross pollinated, heterogenous cash crop with a high degree of variation in yield and yield contributing characters. The research programmes at Kerala Agricultural University, Vellanikkara, Thrissur has resulted in the identification of 15 high yielding varieties of cashew suitable for the climatic conditions of Kerala state, of which 10 were evolved through hybridization and selection. Heterosis breeding programmes can harness the hybrid vigour for growth, nut and yield characters and these hybrids can be directly utilized through clonal propagation to achieve crucial growth in cashew economy (Eradasappa et al., 2020). Since, size is a major criterion that determines the market value of the nut and kernel in the cashew global market (Aliyu and Awopetu, 2011), cashew varieties

capable of producing high nut yield with bigger nut and kernel are a necessity for the farmers to fetch a premium price. In this context, the present study was undertaken to investigate the hybrid vigour and variability for key yield related traits in cashew hybrid population.

Nineteen hybrids selected from an initial evaluation trial of hybrid seedlings of various cross combinations planted at Cashew Research Station, Madakkathara, during the year 2003, served as the material for study (Table 1). Cashew hybrids were designated by numerical numbers to refer cross combination and hybrid plant number. These hybrids comprising 13 cross combinations and 11 parents were planted in the main field with a spacing of 8 x 8 m and managed under rainfed condition as

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Table 1. Details of the hybrids and their cross parents used for the study

Hybrid	Parentage
H03-36/8	Dhana x Madakkathara-1
H03-55/11	Priyanka x Anakayam-1
H03-55/10	Priyanka x Anakayam-1
H03-53/9	Amrutha x Anakayam-1
H03-57/4	Priyanka x Madakkatara-1
H03-92/3	Vridhachalam-3 x Sulabha
H03-95/8	Vridhachalam-3 x Sulabha
H03-97/2	Sulabha x Madakathara-1
H03-110/1	Poornima x Priyanka
H03-110/2	Poornima x Priyanka
H03-110/3	Poornima x Priyanka
H03-111/2	Dharasree x K-22-1
H03-113/1	Poornima x Dharasree
H03-95/4	Vridhachalm-3 x Priyanka
H03-18/17	Damodar x K-22-1
H03-52/7	Priyanka x Vridhachalam-3
H03-52/6	Priyanka x Vridhachalam-3
H03-52/5	Priyanka x Vridhachalam-3
H03-21/10	Sulabha x Priyanka

per the package of practice recommendation of Kerala Agricultural University (KAU, 2016). Poornima, the high yielding variety of cashew released from the station, was used as a standard check. Observations on tree habit, inflorescence, nut and kernel characters were recorded based on the descriptor of cashew (Nayak et al., 2014) for two production seasons (2020 and 2021) to reduce the ambiguity due to influence of climatic factors. The number of flowering laterals (LM) and panicles (PM) were counted from one square meter area of the canopy in four cardinal positions, and the mean of four directions was taken. For counting number of flowers and nuts per panicle (NP), five panicles were selected from each side of the observational tree and tagged. The number of bisexual (BF) and male flowers (MF) appearing in each panicle were counted on alternate days over a period of 16 weeks (October-February). A non-destructive technique using permanent marker was adopted to distinguish new flowers from old. Data on fruit weight (FWT) were collected on 10 randomly selected cashew fruits across each of the four directions of tree canopy (Masawe et al., 1996). Nut weight (NWT) and nut dimensions, were taken from 40 raw nuts dried in sun for three days and mean values were

recorded. The nut dimensions such as length (NL), width (NW) and thickness (NT) were measured using digital vernier caliper in centimeters. Similarly, the weight (KWT), length (KL), width (KW) and thickness (KT) of kernel with testa was recorded after shelling the nuts. The shelling percentage was recorded as the ratio between weight of kernels with testa and weight of nuts and presented as percentage. The total nuts collected from each observational tree were sundried for three days and weighed separately and expressed as nut yield per tree in kilogram (TY).

Data collected were summarized and statistically analyzed for one way ANOVA, correlation coefficient using the R based statistical software GRAPES version 1.14.02 (Gopinath, 2020). The heterosis over mid parent (Relative heterosis), better parent (Heterobeltiosis) and standard variety Poornima (Standard heterosis) were carried out for the characters exhibited positive correlation with yield (NWT, KWT, BF, FWT) using the formulae suggested by Hayes et al. (1965).

In the present study, considerable variation was observed in the characters as indicated by their range values. Upright and compact canopy is generally suitable for high density planting (Haripriya, 2014) and noticed in 58 per cent of hybrids and 82 per cent of parents. Among the hybrids, the flowering laterals per metre square ranged from 8.00 to 13.75 and number of panicles per meter square from 9.75 to 17.75. A positive linear relationship was found between the number of flowering laterals and panicles per meter square. Both these yield contributing characters were found to be the highest in the hybrid, H03-97/2. This is also reflected in its yield (24.5 kg/tree/year). Aliyu and Awopetu (2011), Dorajeerao et al. (2002), Sharma et al. (2020) also observed variations in number of laterals and panicles per metre square.

The number of male flowers per panicle varied widely among hybrids and parents, ranging from 406.75 in hybrid H03-55/10 to 787 in hybrid H03-

Table 2. Variations in floral characters of cashew hybrids and parents

Hybrids/ parents	No. of flowering laterals per meter square	No. of panicle per metre square	No. of bisexual flowers per panicle	No. of male flowers per panicle	Sex ratio
H03 - 36/8	10.50 <sup>bdefghi</sup>	13.00 <sup>cdefghi</sup>	68.00 <sup>cdef</sup>	662.25 <sup>cdef</sup>	0.103
H03 - 55/11	13.50 <sup>abe</sup>	16.75 <sup>a</sup>	60.50 <sup>defg</sup>	569.75 <sup>defghi</sup>	0.106
H03 - 55/10	8.50 <sup>ghi</sup>	10.25 <sup>hi</sup>	46.00 <sup>ghi</sup>	406.75 <sup>i</sup>	0.113
H03 - 53/9	12.25 <sup>abcde</sup>	15.00 <sup>abcde</sup>	53.25 <sup>fghi</sup>	647.75 <sup>bdef</sup>	0.082
H03 - 57/4	10.25 <sup>cdefghi</sup>	12.75 <sup>cdefghi</sup>	47.75 <sup>ghi</sup>	522.75 <sup>fghij</sup>	0.091
H03 - 92/3	10.75 <sup>bdefghi</sup>	12.75 <sup>cdefghi</sup>	77.75 <sup>abc</sup>	701.00 <sup>cd</sup>	0.110
H03 - 95/8	10.50 <sup>bdefghi</sup>	13.50 <sup>bdefgh</sup>	39.75 <sup>i</sup>	473.25 <sup>hij</sup>	0.083
H03 - 97/2	13.75 <sup>ab</sup>	17.75 <sup>a</sup>	53.50 <sup>fghi</sup>	787.00 <sup>a</sup>	0.067
H03 - 110/1	12.75 <sup>abcde</sup>	15.25 <sup>abcd</sup>	57.25 <sup>efgh</sup>	564.75 <sup>defghi</sup>	0.101
H03 - 110/2	10.50 <sup>bdefghi</sup>	13.75 <sup>bdefg</sup>	70.50 <sup>bcd</sup>	644.5 <sup>bdefg</sup>	0.109
H03 - 110/3	12.00 <sup>abcdef</sup>	13.75 <sup>bdefg</sup>	57.25 <sup>efgh</sup>	609.75 <sup>cdefgh</sup>	0.102
H03 - 111/2	11.50 <sup>bdefgh</sup>	14.00 <sup>bdef</sup>	53.00 <sup>fghi</sup>	591.5 <sup>cdefghi</sup>	0.089
H03 - 113/1	12.25 <sup>abcde</sup>	14.00 <sup>bdef</sup>	42.25 <sup>hi</sup>	489.75 <sup>hij</sup>	0.086
H03 - 95/4	8.50 <sup>ghi</sup>	10.25 <sup>hi</sup>	56.75 <sup>efgh</sup>	778.00 <sup>b</sup>	0.072
H03 - 18/17	11.75 <sup>bdefg</sup>	15.25 <sup>abcd</sup>	47.25 <sup>ghi</sup>	666.25 <sup>bdef</sup>	0.070
H03 - 52/7	11.00 <sup>bdefghi</sup>	13.50 <sup>bdefgh</sup>	85.25 <sup>ab</sup>	670.75 <sup>bcd</sup>	0.127
H03 - 52/6	8.00 <sup>j</sup>	9.75 <sup>i</sup>	91.25 <sup>a</sup>	716.50 <sup>bc</sup>	0.123
H03 - 52/5	13.75 <sup>ab</sup>	16.00 <sup>abc</sup>	74.50 <sup>abcd</sup>	564.75 <sup>defghi</sup>	0.131
H03 -21/10	8.25 <sup>hi</sup>	13.50 <sup>bdefgh</sup>	86.00 <sup>ab</sup>	707.75 <sup>bed</sup>	0.121
Dhana	9.50 <sup>efghi</sup>	11.50 <sup>fghi</sup>	46.50 <sup>ghi</sup>	466.50 <sup>hij</sup>	0.099
Madak -1	12.75 <sup>abcde</sup>	13.75 <sup>bdefg</sup>	59.00 <sup>defgh</sup>	500.75 <sup>shij</sup>	0.117
Priyanka	8.75 <sup>fghi</sup>	10.50 <sup>ghi</sup>	48.75 <sup>ghi</sup>	501.75 <sup>shij</sup>	0.097
Anak-1	10.50 <sup>bdefghi</sup>	12.00 <sup>bdefghi</sup>	51.50 <sup>fghi</sup>	523.25 <sup>fghij</sup>	0.098
Amrutha	8.75 <sup>fghi</sup>	10.25 <sup>hi</sup>	39.75 <sup>i</sup>	606.50 <sup>cdefgh</sup>	0.068
Vri -3	13.25 <sup>abcd</sup>	13.50 <sup>bdefgh</sup>	46.25 <sup>ghi</sup>	552.75 <sup>efgh</sup>	0.083
Sulabha	10.00 <sup>defghi</sup>	11.75 <sup>efghi</sup>	43.75 <sup>ghi</sup>	452.00 <sup>ij</sup>	0.096
Poornima	15.25 <sup>a</sup>	17.75 <sup>a</sup>	85.00 <sup>ab</sup>	680.00 <sup>bcd</sup>	0.110
K-22-1	11.00 <sup>bdefghi</sup>	13.75 <sup>bdefg</sup>	55.25 <sup>efghi</sup>	568.75 <sup>defghi</sup>	0.097
Dharasree	15.25 <sup>a</sup>	17.50 <sup>a</sup>	57.75 <sup>defgh</sup>	537.00 <sup>efghij</sup>	0.107
Damodar	10.00 <sup>defghi</sup>	12.00 <sup>defghi</sup>	58.00 <sup>defgh</sup>	572.50 <sup>cdefghi</sup>	0.101
CV (%)	20.75	17.37	20.60	17.20	
SE(m)	5.38	5.50	144.47	10784.46	
SE(d)	1.64	1.66	8.49	73.43	

97/2, and from 452.0 in variety Poornima to 680.0 in variety Sulabha. Significantly high variation was observed among the varieties and hybrids for the number of bisexual flowers. In hybrids, number of bisexual flowers per panicle varied from 39.75 (H03-95/8) to 91.25 (H03-52/6). Hedge et al. (2000) reported the number of bisexual flowers under Karnataka conditions as 45 to 95.6. Under Bhubaneswar conditions, the number of bisexual flowers in hybrids was found to vary between 37.56 and 98.5 (Sethi et al., 2016). Bapatla hybrids were reported to have hermaphrodite flowers ranging from 50.08 to 75.08 (Sreenivas et al., 2017). In this study, panicle of variety Poornima had a mean of

765 flowers of which 680 were male and 85 were hermaphrodite flowers working out to a mean sex ratio of 0.11 (Table 2) whereas 32.75 number of bisexual flowers were recorded under Bhubaneswar conditions (Mohapatra et al., 2017). The number of bisexual flowers per panicles was found higher in most of the hybrids with Poornima as one of the parents, suggesting the potential of Poornima as a parent in improving the number of bisexual flowers in crop improvement programmes.

The number of nuts per panicle varied from 1.25 to 4.65 among the tested hybrids. Parents, Madakathara-1 and Anakkayam-1, having cluster

Table 3. Variations in yield attributing traits of cashew hybrids and parents

Hybrids/ parents	Nuts per panicle	Apple weight(g)	Nut weight (g)	Kernel weight (g)	Tree yield (Kg/tree/yr)	Shelling percentage (%)
H03 - 36/8	2.80 <sup>hijkl</sup>	64.94 <sup>ghijkl</sup>	10.23 <sup>bc</sup>	2.9 <sup>ef</sup>	22.10	28.35
H03 - 55/11	3.65 <sup>cdefgh</sup>	56.95 <sup>ijklm</sup>	8.40 <sup>g</sup>	2.22 <sup>kl</sup>	16.60	26.43
H03 - 55/10	4.55 <sup>ab</sup>	16.83 <sup>q</sup>	4.64 <sup>j</sup>	1.83 <sup>n</sup>	15.0	36.44
H03 - 53/9	4.10 <sup>bcd</sup>	37.34 <sup>op</sup>	7.87 <sup>fgh</sup>	2.29 <sup>ijk</sup>	17.60	29.10
H03 - 57/4	1.75 <sup>mno</sup>	62.10 <sup>ghijkl</sup>	9.30 <sup>c</sup>	2.15 <sup>l</sup>	6.50	23.12
H03 - 92/3	3.90 <sup>bcd</sup>	74.36 <sup>defgh</sup>	7.89 <sup>fgh</sup>	2.27 <sup>ijk</sup>	20.20	28.77
H03 - 95/8	3.50 <sup>defghi</sup>	90.08 <sup>c</sup>	10.37 <sup>cd</sup>	2.54 <sup>g</sup>	14.50	24.49
H03 - 97/2	3.40 <sup>efghi</sup>	86.23 <sup>cd</sup>	10.1 <sup>de</sup>	3.12 <sup>c</sup>	24.50	30.89
H03 - 110/1	3.20 <sup>fghij</sup>	79.10 <sup>cde</sup>	11.18 <sup>b</sup>	3.44 <sup>b</sup>	23.40	30.77
H03 - 110/2	3.00 <sup>hijkl</sup>	37.52 <sup>op</sup>	6.37 <sup>i</sup>	1.92 <sup>mn</sup>	15.20	30.14
H03 - 110/3	4.20 <sup>bcd</sup>	41.94 <sup>nop</sup>	7.84 <sup>gh</sup>	2.38 <sup>hi</sup>	17.60	30.36
H03 - 111/2	3.35 <sup>efghij</sup>	74.59 <sup>defg</sup>	8.49 <sup>f</sup>	2.50 <sup>gh</sup>	10.0	29.45
H03 - 113/1	4.65 <sup>ab</sup>	56.17 <sup>ijklm</sup>	9.45 <sup>c</sup>	2.80 <sup>c</sup>	13.20	29.63
H03 - 95/4	1.65 <sup>mno</sup>	66.00 <sup>efghij</sup>	12.44 <sup>a</sup>	4.19 <sup>a</sup>	2.10	33.68
H03 - 18/17	1.50 <sup>nop</sup>	107.80 <sup>b</sup>	12.49 <sup>a</sup>	2.94 <sup>d</sup>	3.10	23.54
H03 - 52/7	2.15 <sup>lmn</sup>	67.57 <sup>efghi</sup>	10.21 <sup>cd</sup>	3.02 <sup>cd</sup>	16.50	29.58
H03 - 52/6	2.50 <sup>ijklm</sup>	61.26 <sup>hijkl</sup>	10.17 <sup>cd</sup>	2.62 <sup>fg</sup>	16.50	25.76
H03 - 52/5	2.25 <sup>klmn</sup>	120.82 <sup>b</sup>	10.40 <sup>cd</sup>	3.07 <sup>c</sup>	21.60	29.52
H03 - 21/10	1.25 <sup>op</sup>	80.93 <sup>cd</sup>	12.55 <sup>a</sup>	3.66 <sup>b</sup>	25.20	29.16
Dhana	3.10 <sup>ghijk</sup>	59.27 <sup>jkl</sup>	8.40 <sup>fg</sup>	2.36 <sup>ij</sup>	8.20	28.09
Madak-1	5.10 <sup>a</sup>	35.36 <sup>p</sup>	6.31 <sup>i</sup>	1.63 <sup>o</sup>	15.60	25.83
Priyanka	0.80 <sup>p</sup>	137.49 <sup>a</sup>	11.10 <sup>b</sup>	2.79 <sup>c</sup>	6.40	25.14
Anak-1	5.20 <sup>a</sup>	45.62 <sup>mno</sup>	5.91 <sup>i</sup>	1.66 <sup>o</sup>	11.50	28.09
Amrutha	3.35 <sup>efghi</sup>	49.80 <sup>lmno</sup>	7.32 <sup>h</sup>	2.20 <sup>kl</sup>	21.30	30.05
Vri – 3	2.70 <sup>jkl</sup>	52.86 <sup>klmn</sup>	7.30 <sup>h</sup>	2.17 <sup>kl</sup>	13.69	29.73
Sulabha	1.65 <sup>mno</sup>	74.82 <sup>defg</sup>	9.90 <sup>de</sup>	2.62 <sup>fg</sup>	10.60	26.46
Poornima	4.35 <sup>abcd</sup>	77.96 <sup>cdef</sup>	7.90 <sup>fgh</sup>	2.50 <sup>gh</sup>	20.0	31.65
K-22-1	1.55 <sup>nop</sup>	62.96 <sup>ghijk</sup>	6.40 <sup>i</sup>	1.62 <sup>o</sup>	10.20	25.31
Dharasree	4.05 <sup>bcd</sup>	53.16 <sup>ijklmn</sup>	7.52 <sup>h</sup>	2.25 <sup>kl</sup>	11.20	29.92
Damodar	4.45 <sup>abc</sup>	57.47 <sup>jklm</sup>	7.72 <sup>h</sup>	2.00 <sup>m</sup>	10.10	25.91
C.V(%)	19.471	14.109	11.405	3.475		
SE(m)	0.369	87.531	0.638	0.008		
SE(d)	0.430	6.616	0.565	0.044		

bearing nature, recorded highest number of nuts per panicle. In the hybrid population under evaluation, all hybrids with Anakkayam-1 as male parent, showed cluster bearing habit as seen in hybrids, H03-55/11 (Priyanka x Anakayam-1), H03-55/10 (Priyanka x Anakayam-1) and H03-53/9 (Amrutha x Anakayam-1). This indicates that, Anakayam -1 can be used as source of male donor of cluster bearing nature. Number of nuts per panicle in cashew is highly genetic controlled trait (Sharma et al., 2020). In an evaluation study of hybrids at Bhubaneswar, the number of nuts per panicle varied from 2.22 to 8.02 (Sethi et al., 2016).

Significant differences were observed among the

cashew hybrids with respect to apple, nut and kernel weight (Table 3). The mean apple weight varied from 16.83g (H03-55/10) to 120.82g (H03-52/5) among the total hybrids under study. The variation in apple weight could be due to genetic variability and varietal characters (Sreenivas et al., 2016). According to the descriptor list, three hybrids having apple weight from 27 to 52g were considered as 'intermediate', while one hybrid weighing lower than 27g as 'low' and 15 hybrids with higher apple weight above 52g as 'high' class. Similar studies were also reported by Gajbhiye et al. (2018), Pereira et al. (2011), Desai (2009), and Lenka et al. (2003). Because of the larger apples, hybrids, H03-52/5 and H03-18/17, can be selected as better types for

Table 4. Correlation coefficients of yield attributing traits of cashew hybrids

Characters	NW	KW	SP	NP	AW	AN	BF	MF	SR	PM	LM
TY	0.16*	0.08*	0.11*	-0.36	0.9**	-0.05	*0.42	0.29	0.229	0.18	0.25
NW		0.84**	-0.43	0.70***	0.73***	0.19	0.12	0.52*	-0.27	-0.01	0.04
KW			0.09	0.72***	0.54*	0.01	0.12	0.62**	-0.30	-0.04	-0.01
SP				-0.04	-0.43	-0.38	-0.07	-0.01	0.01	-0.14	-0.12
NP					0.48*	-0.13	0.27	0.39	0.03	-0.17	-0.20
AW						0.19	0.09	0.28	-0.08	0.33	0.22
AN							-0.20	0.22	-0.47	0.07	0.27
BF								0.36	0.73***	-0.31	-0.34
MF									-0.37	0.04	0.01
SR										-0.28	-0.35
PM											0.86***

W- Nut weight, KW- Kernel weight, SP- Shelling percentage, NP- No. of nuts per panicle, AW- Apple weight, AN- Apple to nut ratio, BF- No. of bisexual flowers, MF- No. of male flowers, SR- Sex ratio, PM- Panicles per metre square, LM- Laterals per meter square

extracting juice for preparing value added products from cashew apple.

In this study, nut weight of hybrids ranged from 4.64g (H03-55/10) to 12.55g (H03-21/10) and kernel weight from 1.83g (H03-55/10) to 4.19g (H03-95/4). Out of the 17 hybrids having high nut weight (>7g) 12 were categorized under high kernel weight group (>2.5g). The processed kernel of cashew nut is the edible economical part. According to Manoj et al. (1994) and Sethi et al. (2015a) kernel weight has the greatest beneficial direct effect on nut yield in cashew.

The comparison of apple weight, nut weight and kernel weight among the hybrids evaluated indicated that even though there was some association between these traits, it is not important to have larger apples for producing heavier nuts and kernels (Sreenivas et al., 2016). Smaller apples were also found to bear larger nuts in some of the hybrids (H03-53/9 and H03 110/3). Heavier apples did not necessarily bear heavier nuts which in turn did not necessarily produce heavier kernels. Most of the weight in nut might have been contributed from shell part and therefore nut weight could not be in close harmony with kernel weight in some of the hybrids. Similar results of significant differences among the apple, nut and kernel parameters were also reported by Desai (2011), Desai (2009) and Mahesha et al. (2005).

From the present study, it is really interesting to note that hybrids, H03-21/10, H03-95/4, H03-110/1, H03-52/7, H03-52/6 and H03-52/5 having a nut weight more than 10g have Priyanka as either male or female parent. When cashew parents with large nut sizes are crossed as a male or female parent, the nut size improves significantly (Aliyu and Awopetu, 2011). They also opined that cashew trees with nut weight greater than 15g are represented as jumbo nut, not suitable for commercial planting, because of their poor yield. None of the hybrids in this study showed jumbo nut character.

The hybrids and parents varied significantly with respect to shelling percentage (Table 14). The shelling percentage ranged from 23.12 to 36.44. Shelling percentage above 28 was recorded in hybrids, H03-55/10 (36.44), H03-95/4 (33.68), H03-110/1 (30.77), H03-113/1 (29.63), H03-52/5 (29.52) and H03-21/10 (29.16) and parents, Poornima (31.65), Amrutha (30.05g), Vridhachalam-3 (29.73g), Dharasree (29.92), Anakayam-1 (28.09) and Dhana (28.09). Shelling percentage was medium in hybrids, H03-55/11 (26.43kg), H03-57/4 (23.12), H03-95/8 (24.49), H03-18/17 (23.54), H03-52/6 (25.76) and parents, Madakkathara-1 (25.83), Priyanka (25.14), Sulabha (26.46), K-22-1 (25.31) and Damodar (25.91). Fourteen hybrids and six parental varieties showed good shelling percentage of more than 28 per cent. None of the parents or hybrids were in the category of low shelling percentage below 18. Shelling per

Table 5. Magnitude of heterosis (%) over mid parent, better parent and standard check for various characters f cashew hybrids

Hybrids	Nut weight			Kernel weight			Apple weight			No. of Bisexual flowers per panicle		
	RH (%)*	HB (%)*	SH (%)*	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB(%)	SH (%)
H03-36/8	44.19*	26.25*	34.24*	36.48*	15.33*	9.10*	16.55	0.35	-18.08	28.9*	15.25	-5.77
H03-55/11	-1.05	-24.18	6.53*	-0.20	-20.43	-11.10	-34.60	-0.38	-26.94	20.69*	17.47	-9.19
H03-55/10	-45.40	-58.16	-41.22	-17.71	-34.39	-26.70	-74.72	-0.82	-78.40	-8.22	-10.6	-7.48
H03-53/9	18.97*	7.51*	-0.38	18.47*	3.85*	-8.40	-10.37*	-0.22*	-52.10	16.71*	3.398	-8.78
H03-57/4	6.86*	-16.19	17.75*	-2.71	-22.93	-13.90	-24.32	-0.28	-20.33*	-11.36	-19.06*	-1.70
H03-92/3	-8.20	-20.25	-0.06	-4.65	-12.50	-9.00	5.32*	0.08	-4.61*	72.77*	68.10*	-10.67
H03-95/8	20.58*	4.75*	31.27*	6.66*	-2.12	1.80	21.03*	0.30	15.54	-11.66	-14.05	-7.42
H03-97/2	22.21*	0.05*	25.38*	48.63*	20.96*	25.80*	25.62*	0.42	10.60	4.136*	-9.322	-8.72
H03-110/1	17.68*	0.72*	41.52*	30.17*	23.34*	37.80*	-28.62	-0.27	1.46	-28.22	-43.52	-3.41
H03-110/2	-32.98	-42.64	-19.41	-27.36	-31.17	-23.10	-70.20	-0.65	-51.87	5.42*	-17.05	-6.54
H03-110/3	-17.44	-29.34	-0.72	-9.88	-14.61	-4.60	-65.79	-0.61	-46.20	-14.39	-32.64	-7.54
H03-111/2	21.25*	11.68*	7.44*	29.49*	11.44*	0.30	16.53*	0.28	-4.325	-6.194	-8.225	-10.08
H03-113/1	21.94*	19.62*	19.62*	18.00*	24.56*	12.10*	-9.39*	-0.14*	-27.94*	-40.80	-50.29	-6.66
H03-95/4	35.22*	12.07*	57.47*	68.97*	50.20*	67.80*	-28.86	-0.30	-15.33	19.47*	16.41	-8.90
H03-18/17	75.88*	60.10*	58.07*	62.57*	47.25*	17.80*	47.59	0.79	38.27	-16.55	-18.53*	0.05
H03-52/7	12.28*	-6.94	30.76*	21.74*	8.22*	20.90*	-27.29*	-0.29	-13.32*	79.47*	74.87*	1.47
H03-52/6	10.54*	-8.38	28.73*	5.53*	-6.19	4.80*	-33.61	-0.35	-21.42	92.10*	87.17*	-2.47
H03-52/5	13.07*	-6.28	31.68*	23.96*	10.19*	23.10*	25.96	0.27	54.98	56.84*	52.82*	0.23
H03-21/10	21.48*	14.92*	61.47*	28.50*	24.06*	38.60*	-30.74	-0.28	3.81	85.94*	76.41	-9.08

\*R.H. - Relative heterosis, H.B. - Heterobeltiosis, S.H. - Standard heterosis

cent have a greater impact on kernel yield, kernel size, and quality, all of which are important economic factors in cashew. Kernel recovery is said to be best when the shelling percentage is more than 28. Similar variations on the shelling percentage were reported by Hedge et al., (2000) and Sreenivas et al., (2017). This study also found that hybrids viz., H03-110/1, 110/2, 110/3 and 113/1, having Poornima as female parent exhibited high shelling percentage (>28 %). Hence variety, Poornima with highest shelling percentage of 31.65 can be used as a source of female parent in breeding programmes for improving shelling percentage.

The findings regarding the transmission of characteristics such as nut weight and shelling percent from parents to hybrids in this study is consistent with the observations of Nawale and Selvi (1990) and Sethi et al. (2015b) and recommend that both nut weight and shelling percentage need to be taken into account while selecting parents for the development of improved hybrids. Selection of nut and kernel weight was regarded as valuable source of variations in the cashew development

programme, according to Chipojola et al. (2009). Yield is the ultimate target of any varietal evaluation. In India, various studies were conducted for estimating the nut yield of cashew genotypes (Sharma et al., 2020; Chandrasekhar et al., 2018; Sahoo et al., 2020). The average nut yield per plant in the hybrid population studied ranged from 2.1 kg to 25.20 kg. During the evaluation period, the hybrids, H03-21/10, H03-97/2, H03-111/10, H03-36/8, H03-52/5 and parents Poornima and Amrutha recorded a yield more than 18 kg per plant.

Nut yield was found to have a highly significant positive correlation with number of bisexual flowers per panicle (0.421), nut weight (0.16), kernel weight (0.08), shelling percentage (0.11) and apple weight (0.9) in the 19 cashew hybrids and 11 parents (Table 4). However, there is a weak negative link between apple to nut ratio, and number of nuts per panicle. Sena et al. (1994) and Parameswaran et al. (1984) found a strong positive association between yield and nut weight. A favourable association between yield and kernel weight was shown by Manoj et al. (1994). As indicated by their strength of substantial

positive correlation on nut production per plant and nut weight might be considered major yield contributing elements. This backed up the findings of Nayar et al. (1981), Reddy et al. (1996), and Rao et al. (2002).

Magnitude of heterosis for nut weight (g), kernel weight (g), number of bisexual flowers and apple weight (g) in terms of relative heterosis, heterobeltiosis and standard heterosis are presented in Table 5. Fourteen hybrids showed positive significant relative heterosis for nut weight, which ranged from minimum -45.40 to 75.88%. 10 hybrids exhibited heterosis over better parent, i.e., heterobeltiosis for nut yield; of course, the magnitude is relatively less as compared to relative heterosis which ranged from minimum -58.16 (H03-55/10) to maximum 60.10 (H03-18/17). Fourteen hybrids exhibited positive significant standard heterosis for nut weight varied from minimum -41.22 (H03-55/10) to 61.47 (H03-21/10).

Ten hybrids showed positive significant relative heterosis and standard heterosis for kernel weight. The relative heterosis for kernel weight varied from -27.36 (H03-110/2) to 68.97 (H03-95/4). The heterobeltiosis varied from -34.39 (H03-55/10) to 47.25 (H03-18/17) and the heterosis over standard varied from -26.70 (H03-55/10) to 67.80 (H03-95/4). The hybrids H03-21/10, H03-110/1, H03-97/2, H03-36/8, H03-52/7, H03-52/6, H03-52/5, H03-95/4 and H03-18/17 showed positive significant relative heterosis for nut weight and kernel weight, indicating the effectiveness of hybridization in crop improvement of cashew.

Eleven hybrids showed positive significant relative heterosis for number of bisexual flowers ranged from -40.80 (H03-113/1) to 92.10 (H03-52/6). None of the hybrids showed significant standard heterosis for number of bisexual flowers. Similar positive heterosis was also observed for nut yield and number of nuts in cashew by Manivannan et al. (1989) as well as Manoj et al. (1993). The higher magnitude of heterosis for nut weight and kernel

weight has also been suggested for cashew improvement programme (Chipojola et al., 2009). Hybrids namely H03-21/10, H03-110/1, H03-97/2, H03-36/8, H03-52/7, H03-52/6, H03-52/5, H03-95/4 and H03-18/17 exhibited better significant positive heterosis with respect to nut weight and kernel weight as compared to the other tested hybrids. Out of these, hybrids H03-21/10, H03-110/1, H03-97/2, H03-36/8, H03-52/5 having a nut yield above 18 kg/plant were recommended for replicated yield trial for getting suitable hybrids for commercial cultivation.

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### Reference

- Aliyu, O.M. and Awopetu, J.A. 2011. Variability study on nut size and number trade-off identify a threshold level for optimum yield in cashew (*Anacardium occidentale* L.). Int. J. of Fruit Sci. 11(4): 342-363.
- Chandrasekhar, M., Sethi, K., Tripathy, P., Das, T., Dash, M. and Roy, A. 2018. Studies on variability, heritability and genetic advance for quantitative and qualitative traits in cashew (*Anacardium occidentale* L.). J. E-palnet. 16(2): 139-146.
- Chipojola, F.M., Mwase, W.F., Kwapata, M.B., Bokosi, J.M., Njoloma, J.P. and Maliro, M.F. 2009. Morphological characterization of cashew (*Anacardium occidentale* L.) in four populations in Malawi. African J. Biotechnol. 8(20).
- Desai, A.R. 2009. Glimpses of cashew research in Goa. ICAR research for Goa. Technical bulletin number 17.
- Desai, A.R. 2011. Integrated Strategies through Classical and Modern Techniques for Crop Improvement in Cashew and Spices. Annual report 2011-12. ICAR research for Goa. 26-27.
- Dorajeerao, A.V.D., Ravisankar, C. and Reddy, M.L.N. 2002. Morphological and yield characters of certain promising clones of cashew nut under Bapatla conditions. J. South Indian Hortic. 50(1/3): 151-158.

- Eradasappa, E.J.D. and Mohana, G.S. 2020. Hybrid vigour and variability for key growth characters and yield in cashew (*Anacardium occidentale* L.). *J. Plant. Crops*, 48(2):71-81.
- Gajbhiye, R.C., Pawar, S.N., Salvi, S.P., Zote, V.K. and Haldavanekar, P.C. 2018. Performance of different cashew (*Anacardium occidentale* L.) genotypes under Konkan region of Maharashtra. *Int. J. Chem. Stud* Y, 6, pp.1939-1942.
- Gopinath, P. P., Parsad, R., Joseph, B., and Adarsh, V. S. 2020. GRAPES: General Rshiny Based Analysis Platform Empowered by Statistics. <https://www.kaugrapes.com/home>. version 1.0.0. DOI: 10.5281/zenodo.4923220.
- Haripriya, S. 2014. Sustainable cashew production in cuddalore district—a case study. *Agropedia*.
- Hayes, J. K., Immer, R.R., and Smith, D.C. 1965. *Methods of Plant Breeding*, 2nd Eds, McGraw Hill Book Company, New York. pp. 329-332.
- Hegde, M.V., Hegde, R.V. and Sullikeri, G.S. 2000. Flowering behaviour and sex ratio in cashew cultivars under transitional tract of Karnataka. *J. The Cashew*, 14(1): 35-38.
- KAU [Kerala Agricultural University]. (2016). *Package of Practices Recommendations: Crops (15th Ed.)*. Kerala Agricultural University, Thrissur, 392p.
- Lenka, P.C., Mohapatra, K.C. and Samal, S. 2003. Performance of cashew (*Anacardium occidentale* L.) types at Bhubaneswar (Orissa). *J. The Cashew*. 17(4): 12-17.
- Manivannan, K., Veeraraghavathathan, D., Shah, H.A. and Manoharan, V. 1989. Hybrid vigour in cashew. *Cashew Bulletin*. 26(9):11-14.
- Mahesha, U.S., Hanamashetti, S.I. and Hegde, N.K. 2005. Performance of Cashew (*Anacardium occidentale* L.) varieties under hill zone of Karnataka. *The Cashew*. 19: 5-7.
- Manoj, P.S., George, T.E., and Krishnan, S. 1993. Evaluation of F1 hybrids of cashew (*Anacardium occidentale* L.) as influenced by hybridization. *J. The cashew*. 8(4): 10-13.
- Manoj, P.S., George, T.E., and Krishnan, S. 1994. Variability in cashew (*Anacardium occidentale* L.) as influenced by hybridization. *J. The cashew*, 8(40): 10-13.
- Masawe, P.A.L., Cundall, E. P., and Caligari, P.D.S. 1996. Distribution of cashew flower sex-types between clones and sides of tree canopies in Tanzania. *J. Ann. Bot.* 78:553–558.
- Mohapatra, M., Dash, D.K., Tripathy, P., Sethi, K. and Mukherjee, S.K. 2017. Performance of pre-released cashew (*Anacardium occidentale* L.) genotypes under Bhubaneswar condition. *Int. J. Current Agric. Sci.*7(1): 60-162.
- Nayar, M.N.C., George, T.E. and Lila, M. 1981. The relationship between height, girth and spread with yield in cashew (*Anacardium occidentale* L.). *Cashew Causerie* 3(2): 13-14.
- Nawale R.N. and Salvi, M.J. 1990. The inheritance of certain characters in hybrid progenies of cashew nut. *J. The cashew*, 4(1):11-14.
- Nayak, M.G., Mohana, G.S., Bhat, P.S., Saroj, P.L., Swamy, K. and Bhat, M., 2014. Catalogue of minimum descriptors of cashew germplasm accessions.
- Parameswaran, N.K., Damodaran, V.K. and Prabhakaran, P.V. 1984. Factors influencing yield in cashew (*Anacardium occidentale* L.). *Indian Cashew J.* 16(3):9-15.
- Pereira, A.C.S., Reges, C.M. and Reges, I.S. 2011. Quality, bioactive compounds and antioxidant activity of cashew apples from precocious dwarf cashew clones CCP-09, CCP-76 and BRS-189. *Acta hort.* 43-48.
- Rao, A.V.V.D., Ravishankar, C. and Reddy, M.L.N. 2002. Correlation between nut yield and plant characters in cashewnut. *ANGRAU J. of Res.* 30(1): 98-100.
- Reddy, S.N., Lingaiah, H.B. and Krishnappa, K.S. 1996. Correlation studies in cashew (*Anacardium occidentale* L.) genotypes. *Cashew Bulletin* 8(2): 15-19.
- Sahoo, S., Sethi, K., Dash, M. and Tripathy, P. 2020. Evaluation of F1 hybrids of cashew (*Anacardium occidentale* L.). *Internat. J. agric. Sci.* 16(1):79-85.
- Sena, D.K., Lenka, P.C., Jagadev, P.N. and Sashikala, B. 1994. Genetic variability and character association in cashewnut (*Anacardium occidentale* L.). *Indian J. Genet. and Plant Breed.* 54: 304-309
- Sethi, K., Lenka, P.C., Tripathy, S.K., Mukherjee, S.K. and Das, A.K., 2015b. Evaluation of cashew (*Anacardium occidentale* L.) hybrids for nut and apple parameters. *J. Crop and Weed.* 11(2):152-156.
- Sethi, K., Tripathy, S.K., Lenka, D. and Lenka, P.C. 2015a. Selection strategy for identification of high yielding cashew hybrids. *J. Plant. Crops*, 43(1):50-56.
- Sethi, Tripathy, S.K. and Lenka, P.C. 2016. Assessment of genetic diversity and identification of elite cashew



- hybrids. J. Advances in Life Sci. 5(16):6200-6205.
- Sharma, S., Sethi, K. and Dash, M. 2020. Evaluation of cashew (*Anacardium occidentale* L.) genotypes under Bhubaneswar condition. J. Pharm. Innov. 9(9): 552-556
- Sreenivas, M., Reddy, M.L., Dorajeerao, A.V.D. and Paratpararao, M. 2016. Flowering phases and their influence on nut yield in certain cashew nut hybrids. Plant Archives, 16(1): 317-320.
- Sreenivas, M., Reddy, M.L., Dorajeerao, A.V.D. and Paratpararao, M., 2017. Study on Sex-Ratio, apple and nut parameters in young cashew nut Hybrids. Int. J. Pure App. Biosci. 5(4):1770-177.