EVALUATION OF CASHEW (*Anacardium occidentale* L.) HYBRIDS FOR YEILD AND QUALITY

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(2019-12-047)

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KERALA, INDIA
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DEPARTMENT OF PLANTATION CROPS AND SPICES
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2021

DECLARATION

I, hereby declare that this thesis entitled **"Evaluation of cashew (*Anacardium occidentale* L.) hybrids for yield and quality"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
Date:30-12-2021

Jintu Varghese
(2019-12-047)

CERTIFICATE

Certified that this thesis entitled **"Evaluation of cashew (*Anacardium occidentale* L.) hybrids for yield and quality"** is a record of research work done independently by **Ms. Jintu Varghese (2019-12-047)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Jintu Varghese

Affectionately dedicated to my family

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LIST OF ABBREVATIONS AND SYMBOLS USED

Symbols	Abbreviations
%	Per cent
Mg	Milli gram
G	Gram
Kg	Kilo gram
Cm	Centimeter
cm^2	Centimeter square
Ml	Milli litre
^0C	Degree Celsius
MSL	Mean sea level
Rpm	Revolutions per minute
Nm	Nanometer
et al.	and other co workers
TMB	Tea mosquito bug
Ha	Hectare
CRS	Cashew Research Station
VRI-3	Vridhachalam-3
Madk-1	Madakkathara-1
Anak-1	Anakayam-1
CNSL	Cashew nut shell liquid

Introduction

1. INTRODUCTION

Cashew (*Anacardium occidentale* L.), belonging to the family Anacardiaceae, known as the "Gold mine in Waste Land," has evolved from its humble beginning as a crop designed to prevent soil erosion to become one of the country's most important dollar-earning crops. Cashew is traditionally farmed in the plains, ghats, and hill regions of states such as Orissa, Andhra Pradesh, Tamil Nadu, and West Bengal on the east coast; Kerala, Karnataka, Goa, and Maharashtra on the west coast. It is also grown in Madhya Pradesh, and in recent years, it is extended to other non-traditional places of West Bengal in the lower Gangetic plains and Tripura in the eastern Himalayas (Sethi *et al*.,2015).

Though almost all parts of cashew tree are used, the nut having nutrient rich kernel is considered as the most valuable product (Kapinga *et al*., 2017). Being the premier exporter of cashew kernels, there is an increasing demand for cashew nut in India. As one of the top cashew producing states of the country, Kerala has a remarkable contribution in the processing and export sector of Indian cashew industry. But over the years, Kerala showed a diminishing trend in the domestic production of cashew nuts which is pertaining to the decline in area under cashew cultivation and also the low productivity of the traditional crop (Sahoo *et al*.,2020). The current domestic production of the state is only 83000 MT and far below the quantity required for the smooth functioning of the cashew industry in Kerala. This gap can be bridged either by expanding the area under cashew cultivation or introducing high yielding varieties. The existing land ceiling laws, pressure on land and continued denial of plantation status to cashew has limited the opportunity of expanding cashew cultivation in Kerala. On the other hand, the aged local varieties which yields late in the season coinciding with the excessive rain fall explains the low productivity per hectare (Sajeev and Manjusha, 2016). Hence new varieties have an important role in increasing the productivity.

The earlier research programmes carried out at Kerala Agricultural University, Vellanikkara, Thrissur had identified of 16 high yielding varieties of cashew suitable

for the climatic conditions of Kerala state. Since, size is a major criterion that determines the market value of the nut and kernel in the global market (Aliyu and Awopetu 2011), cashew varieties with bigger and bold nuts having export quality are a necessity for the farmers to fetch premium price. Heterosis breeding programmes can harness this desirable nut characteristics to achieve crucial growth in cashew economy. However, development of varieties capable of producing premium kernels and high nut yield remain a huge challenge.

Heterosis breeding programmes can harness the hybrid vigour for important growth, nut and yield characters and 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 premium kernels are a necessity for the farmers to fetch premium price. In the above context, the present investigation was undertaken to investigate the hybrid vigour and variability for key yield related traits in cashew hybrid population. In the above context, the present investigation was undertaken to evaluate the hybrids developed at Kerala Agricultural University for yield and quality traits which can be utilized by the cashew farmers of Kerala. The findings of this study will also aid in more effective selection of hybrids.

The objective of the study was to evaluate cashew hybrids for yield and quality characters.

Review of literature

2. REVIEW OF LITERATURE

India contributes 20.3 per cent area under cashew cultivation and its share on production is only 16.10 per cent with a productivity of 782kg/ha. The main reason for low productivity of cashew nut is the lack of availability of improved high yielding varieties with high nut weight (Nayak *et al*., 2019). Cashew is highly cross pollinated and heterozygous in nature and exhibits enormous variability in their performance.

2.1. TAXONOMY

Cashew (*Anacardium occidentale* L.) belongs to the family Anacardiaceae, genus Anacradium and species occidentale. This family contains 73 genera and about 600 species. It is included under the phylum Spermatophyta and class Dicotyledonae (Berry and Sargent 2011). Centre of origin of cashew is believed to be tropical central and south America. Within central and south America as many as 20 species of Anacardium are known to exist (Rao *et al*., 1998). It was one of the first fruit trees from New World to be widely distributed throughout the tropics by the early Portuguese and Spanish adventurers. The country of origin is north Brazil from where it has been thoroughly dispersed throughout the tropical low land of Mexico and West Indies (Johnson, 1973).

2.2. CULTIVARS AND CLASSIFICATION

The cultivars of cashew can be broadly classified as *A. occidentale* L. species, and denominated as the common giant type and the dwarf type. The giant types, the common type grow to height ranging from 5 to 15 m, with a crown diameter of 12 to 14 m. The crown span can reach up to 20 m under wide spacing and high soil fertility. Whereas, dwarf types grow on average up to 4m height, with crown diameter of 6 to 8m, small stem diameter and prolonged seasonal period of fruiting (Bezerra *et al*., 2007). Sexually propagated cashew starts flowering between 24 and 36 months after planting and dwarfs between 6 and 18 months. The most suitable cashew cultivars are

the ones that possess the characters such as high yielding ability and desirable qualities of nuts (nut weight, kernel weight and percentage kernel out-turn) and apples (high juice and sugar content and less tannins). Other appreciated characteristics are tolerance to major cashew diseases and insect pests and adaptation to different agroecological conditions (Kappinga *et al*.,2017).

2.3. VARIABILITY IN MORPHOLOGY OF CASHEW

2.3.1. Growth and development

Cashew seedlings start bearing in the third or fourth year, reaches full bearing by the tenth year, survives for thirty to forty years and it can live up to seventy years (Rao, 1955). Rao and Hassan (1957) noticed two main growth periods in cashew; first flushing begins from October and ends in flowering and second is the fruit development between March and May. There are two types of branching in cashew viz. intensive and extensive. In intensive branching, the shoot grows and ends in a panicle and about 3 to 8 lateral shoots emerge below the apex. This kind of branch growth pattern gives a bushy appearance to the tree. On the other hand, in extensive branching, the shoot grows and rests without a panicle and single lateral shoot emerges below the apex. This growth pattern continues for two to three years without flowering and gives a spreading tree habit (Dasarathy, 1958).

Cashew tree is an evergreen perennial fast growing tree with umbrella shaped canopy. Generally, the tree attains a height of more than 10m and the roots grow to a considerable depth of 3m (Acland,1971). Generally, cashew bears two or more vegetative flushes and a reproductive flushing per year. Two reproductive flushes were produced in a year in the regions with two dry seasons (Ohler, 1979). Damodaran *et al*., (1978) and Nayar *et al*., (1981) found a wide range of growth characteristics in cashew trees, with respect to height, girth, and spread of the tree. Falade (1981) studied varietal differences in tree size and yield of cashew in Nigeria condition. The variation in the size of the tree was found to be comparably narrower than that in the yield.

Wide variability was observed with respect to canopy spread in an evaluation of 161 cashew germplasm accessions conducted at NRRC, Puttur (Swamy *et al*., 1990). Eleven accessions were found to have a bushy to medium plant habit and a compact to medium canopy spread. Spreading types were not preferred for high density planting system (Chacko *et al*., 1990), whereas, dwarf varieties with good pruning responsive were found suitable. Manoj *et al*., (1993) studied the growth traits of cashew in 56 hybrids and 16 parents and identified substantial degree of variation in growth traits such as canopy spread, tree height and tree girth.

A study of performance evaluation of 18 varieties conducted at Cashew Research Station, Madakkathara (CRS,1997) reported the variety Vengurla-3 (7.0m) as the tallest and M44/3 (5.4m) as the shortest. In this study, canopy spread varied widely and ranged between 7.97 and 10.35m. Nalini (1994) studied the angle of order of different branches, branching and subsequent canopy development in seedlings, grafts and layers and identified six classes of branches in seedlings. The high and medium yielding varieties were found to extend their canopy more than low yielding varieties (Pushpalatha, 2000). Saroj and Nayak (2016) identified the varieties, VRI-3, NRCC- Selection-2, K-22-1 and Ullal-1 as pruning responsive types suitable for high density planting.

2.3.2. Flowering phenology

According to Rao (1995) flowering begins in November, lasts until February, and the fruits ripen from March to May. He also noticed two to three separate waves of flower appearance and the flowers that appeared in the middle phase being the most productive. The harvest lastbetween 40 and 70 days. Dasarathi (1958) recorded the peak flowering during mid-January to mid-February.

The inflorescence of cashew is a terminal indeterminate panicle of polygamo monoecious type (Damodaran *et al*., 1965) with staminate and pistillate flowers on the same panicle (Rao and Hassan, 1957 and Thimmaraju *et al*., 1980). But abnormal flower types have also been reported (Northwood, 1966 and Joseph, 1979). Cashew is reported as a cross pollinated tree crop (Free and Williams, 1976) which requires four,

and even five months to complete the sequential anthesis in the panicle. The average length of panicle varies from 14 to 21 cm and the number of flowers per panicle from 200 to 1600 over a period of 70-90 days of flowering period (Damodaran *et al*., 1966). The staminate and pistillate flowers varies with respect to variety, environmental conditions and planting materials used. Murthy *et al*., (1974) observed 106 to 1380 number of staminate flowers in a panicle with bisexual flowers ranging from 0 to 74.

Pillai(1980) studied the phenological phase of cashew inflorescence and identified three distinct phase as first male phase, second mixed phase and third male phase. Long mixed phase with plenty of bisexual flowers result in high sex ratio, and this could aid in development of optimal variety for different climatic conditions.

The days from flowering to fruit maturity was recorded as 55-75 days (Woodruff, 1979). Male flowers start opening from 6.0 am and continued till 1.0 pm. The peak period of anthesis of bisexual flowers is between 9am to11am and male flowers between 7am to 8am. As compared to female flowers, male flowers have a shorter period of lifespan of 3-4 days. And it is clearly indicated that a large proportion of bisexual flowers remained unpollinated. He opined that pollination was not very effective in cashew under natural conditions. The proportion of male phase in the total flowering duration was significantly low in trees above medium yield (Parameswaran *et al*., 1984). The percentage of hermaphrodite flowers was observed to fluctuate between 5.94 to 20.69 percent under Orissa conditions (Patnaik *et al*., 1985). Nambiar and Thankamma (1985) found a large variation in the number of perfect flowers depending on the environmental circumstances. Hanamashetti *et al*. (1986) observed that the total number of flowers per panicle ranged from 165 to 837, with a sex ratio ranging from 4:1 to 6.1:1. Kishnappa *et al*., (1991) reported highest number of panicles per meter square in M44/3 (23.25).

The impact of the quantity of flowers per panicle on nut yield was highlighted by Lenka *et al*., (2001). The highest number of flowering laterals per square meter

found in Bapatala by Dorajeerao *et al*., (2002) was 21. Samal (2002) found flowering laterals ranging from 11.6 to 24.9 in 16 cultivars of cashew at Bhubaneswar (Odisha).

Samal *et al.,* (2006) evaluated cashew varieties under Bhubaneswar conditions and found highest number of flowering laterals in Vridhachalam -2 (24.88). They recorded maximum flowering duration of 95 days in BPP-3 and minimum of 40 days in Jhargram-1. The varieties Kanaka, Vridhachalam-2, Priyanka and NRCC-2 exhibited higher sex ratio of more than 0.70.

Singh *et al*., (2008) evaluated the flowering behavior of 19 cashew cultivars and noticed the ratio of perfect to staminate flowers ranging from 0.07 (BLA-39/4) to 1.34 (Kanaka). Total number of flowers, were significantly high in BLA-39/4(449.0). The least number of flowers were found in the variety VTH-30/4 (180.0), the number of staminate flowers per panicle ranged from 104.25 (VTH-30/4) to 418.33(BLA-39-4).

Sharma *et al*., (2009) studied the phenological characters of cashew at West Bengal conditions and observed that the number of perfect flowers per panicle ranged from 30.67 (BLA-39-4) to 114.98 (H-1598). Cashew flower bud differentiation takes place between October and November and lasts for about 48 to 93 days. Higher numbers of hermaphrodite flowers with poor staminate flowers were produced by hybrids H-255, H-30/1, H-303, and H-367. Even hybrid 3/28 and Vridachalam-2 have produced a large percentage of hermaphrodite flowers, indicating that hermaphrodite ratio has more opportunities for fruit setting and production.

During the year 2019-20, Sharma and co-workers evaluated 15 cashew genotypes at Cashew Research Station (AICRP on cashew), Odisha University of Agriculture and Technology, Bhubaneswar. Among the tested genotypes M-44/3 (0.38) recorded the highest sex ratio while number of nuts per panicle was recorded maximum in genotype, RP-1(15.65).

2.3.3. Apple characters

Wide variability exists in the growth habit, size, colour and shape of cashew apples (Aiyadurai 1966). Yellow coloured apples were found to be heavier, softer, and less astringent than red apples (Albuquerque *et al*., 1960). Aiyadurai (1966) also mentioned the existence of cashew apples in a variety of yellow, red, and blended tints of these two colours.

Vilasachandran and Damodaran (1981) confirmed that the cashew variety, K 10-2 ranked first in the mean weight of apple among the other sixteen high yielding cashew genotypes under Kerala conditions. Percentage of fruit set varied from 2.6 to 5.66 under Bhubaneswar conditions (Sahu, 1984) whereas Pattanik *et al*., (1985) recorded 11.92 to 54.50 per centage of fruit set under Odissa conditions. Kumar and Aravinakshan(1985) studied the colour variation in cashew apples at different climatic conditions. The colour of cashew apple could be divided into three categories: red, yellow, and mixed shades of these two colours. Cashew apple colour was red in Ansur-1, BLA-1, BLA-139-1, BLA-256-1, and M-10-4, and Sawantwadi variety. At Kerala conditions, the variants Vengurla 36-3, M-6-1, K-27-1, and T-20 showed mixed colour of these two. According to Antarkar and Joshi (1986) the colour of cashew nuts altered from brownish green at fruit set to grey at maturity in the Dapoli condition. Aravindhakshan *et al*., (1986) found a substantial variation in the apple weight of 13 cashew genotypes. The highest apple weight was observed in H-3/13 (132.67g) and lowest in K-28-2 (31.33g).

Cashew apples can be round, oblong or pyriform in shape (Hallad *et al*., 1993). Owaiye (1996) found that yellow pseudo apple colour variants yielded significantly more than pink. The fruit weight of 25 apples ranged from 10.9 to 35.5 grammes, with the highest value in Ullal-1. These findings suggest that varieties can be distinguished based on their pseudo-apple colour. Lenka *et al*., (1998) evaluated thirteen cashew cultivars for apple character and discovered substantial differences in the length, width, and weight of cashew apples.

Gajbhiye *et al*., (2018) studied the performance of different cashew genotypes under Konkan region of Maharashtra. Out of 12 types/ hybrid tested, H-367 showed the maximum nut weight (9.98 g) and apple weight (91.33 g).

2.4. CROP IMPROVEMENT THROUGH HYBRIDIZATION

Indian Council of Agricultural Research (ICAR) initiated the cashew research in 1950 through ad-hoc scheme. All India Coordinated Spices and cashew nut improvement project (AICS and CIP) at Central plantation Crop Research Institute (CPCRI), Vittal started the research activities on cashew at 1971. Now the ICAR – Directorate of Cashew Research at Puttur coordinates the research activities of cashew all over the India. Fourteen research centers are located all over the India. In Kerala, there are two centers at Cashew Research Station, Madakkathara in Thrissur and Regional Agricultural Research Station, Pilicode in Kannur. Initially, impetus was given for germplasm collection and collected germplasm were conserved at different AICRP centers, which include high yielding, bold nut, semi tall, compact, CNSL free, purple pigmented, high shelling percentage types. The germplasm accessions are effectively utilized and 54 cashew varieties have been released all over the India. Among them 34 are selections and 20 are hybrids. Presently, DCR, Puttur and AICRP centers were carrying out hybridization programmes of cashew (Saroj and Mohana, 2016).

Northwood (1966) reported that even though the yields of the best tree were more than twice that of the mean, percentage of such trees were very low and it is necessary to consider quality. Since, trees producing large number of nuts often has small nuts, hybridization programmes should be used to break this linkage of undesirable characters. He opined that hybridization can increase the gene pool in cashew and the hybrids are able to produce segregating progeny in future generations with different adaptive values. An increase in hybrid vigour up to 153 per cent in nut yield as compared to out crossed plants were also reported (Damodaran ,1975). In Kerala, the hybridization and selection programmes during 1963-1973 resulted in the development of 216 hybrid plants from 28 parental combinations. The hybrid H-3-17

was selected as promising hybrid for large scale cultivation in Kerala and released as 'Dharasree' (Damodaran *et al*.,1978). Both nut weight and shelling percentage should be considered while selecting parents for hybridization programmes in cashew (Gowda *et al*., 1989).

The hybrids showed better performance when compared with open pollinated and self-pollinated progenies (Nambiar *et al*., 1990). Veeraraghavan (1990) evaluated 163 hybrids of cashew developed at Cashew Research Station, Madakkathara during the period of 1973-1979 and identified 14 superior hybrids. Nawalae (1990) investigated the inheritance pattern in cashew hybrids and reported that the yield has improved on hybridization. Hybridization with appropriate parental combinations could result in larger nuts, higher shelling percentage, and other desired tree development, flowering, and fruiting characteristics. The results of parent studies clearly showed that small nut sized parental combinations should be avoided in cashew hybridization. Nawale and Selvi (1990) also found similar facts about the transmission of nut weight parameters from parents to hybrids in cashew.

Manoj (1994) evaluated heterosis of six hybrids of ten years old and noticed heterosis over their better parent as well as the standard variety, Madakktahra-1, with respect to nut yield per plant, demonstrating the efficiency of hybridization in cashew for yield enhancement. More effort should be given to heterosis breeding in cashew improvement since hybrids were found to be better than selections (Barros *et al*., 2002). Ghatge *et al*., (2009) found a lot of variation in nut weight across thirty cashew hybrids and recorded the highest nut weight (9.9g) and shelling percentage (32.7%) in H-815.

Aliyu and Awopetu (2011) studied 33 cashew nut accessions, to understand the relationship between nut yield and different morphological and flowering characters. Among the characters highest variability was observed for number of hermaphrodite flowers. They noticed special influence of climatic conditions on the yield of the cashew. They also suggested the non-preference of jumbo nut (>15g) for

2.3.4. Nut and kernel characters

Nut weight and shelling percentage showed the most variation across the cashew nut features (Devi,1981). Both, Falde (1981) and Devi (1981) observed a substantial degree of variability in nut yield per tree. Plant spread, number of lateral shoots, panicle per unit area and high fruit set per panicle were positively associated with yield and should be considered for cashew breeding programmes. In addition to nut size and kernel size, and shelling percentage also be addressed while developing cashew varieties for processing (Nawale, 1983).

Nalini and Santhakumar (1991) measured nut weights of cashew genotypes from 5.1 to 8.9g and shelling percentages from 25.8 to 27.11 at Cashew Research Station, Anakkayam, Kerala. Manoj *et al*., (1993) recorded yield per plant ranging from 13.13 kg (H-402) to 23.48 kg (H-342), nuts per panicle from 3.0 to 6.5. They also observed highest shelling percent of 32.56 in H-419 with a nut yield of 21.43 kg per tree. Kernel weight has the greatest beneficial direct effect on nut yield in cashew (Manoj *et al*., 1994). In an evaluation study of 36 high-yielding cashew varieties, Nalini *et al*., (1994) at Anakayam, Kerala, found that hybrids H-1-1, H-3-4, H-7-6, H-8-8, and H-8-10 were the best yielders and H-8-10 showed the highest yield of approximately 12.43 kg/tree.

When compared to all other yield attributing factors, the total quantity of nuts produced by the plant was determined to be the most relevant character, positively and very statistically connected with nut yield (Kumar and Udupa, 1996). Based on 12 years of observations, Sapkal *et al*., (1998) reported that the variety, Vengurla-7 is suitable for cultivation in Maharashtra, Goa, Orissa, and Madhya Pradesh, with a mean yield of 14.5 kg/tree/year.

The development pattern of apple and nut in cashew was extensively studied by Narayankutty (2000). Cashew apple took 52 to 60 days for the development and maturation process. The pedicel length increased 6 to 10 times as it reached the ripe stage. Relative growth rate of fruit was found maximum during the first 15 days after pea nut stage. Kernel formation started from 20 days after fruit set.

Lenka *et al*., (2001) and Aliyu (2006) identified the highest contribution of number of flowers per panicle, nut weight and number of nuts per panicle towards nut yield. High heritability of kernel weight and shelling percentage revealed significant room for crop improvement programmes in cashew (Blaikie *et al*., 2003). According to Chijojola *et al*., (2009), selection of nut and kernel weight can be regarded as a valuable source of variations in the cashew development programme, and kernel weight has the greatest beneficial direct effect on nut yield in cashew.

Dashmohapatra *et al*., (2012) explained the influence of number of reproductive shoots, number of bisexual flowers per panicle, fruit set, fruit retention, and total number of nuts produced/tree on the overall variability in cashew nut yield. The impact of shelling percentage on kernel yield, kernel size and quality were identified by Sethi *et al*., (2015a). Kernel recovery was said to be best when the shelling percentage is more than 28.

Jena *et al*., (2016) investigated the genetic diversity of 12 promising cashew varieties including 9 local selections and 3 hybrids on the basis of yield parameters under Odissa conditions. Apple weight varied from 23.71 (Chintamani-1) to 42.14g (Vengurla-4), number of nuts per panicle varied from 1.42 (Ullal-4) to 2.25 (Chintamani-1), nut weight from 6.23 (Madakkathara-1) to 9.44 (Amrutha), kernel weight from1.63g (BPP-4) to 3.02 (Amrutha) and yield per plant from 2.80 (BPP-4) to 10.90 (Amrutha).

Yuvaraj *et al*., (2017) conducted a field experiment to evaluate the adaptability of new entries of 11 cashew genotypes developed at different research centers all over India under Bapatla conditions. Among the genotypes nut weight ranged from 4.37 (H.14) to 7.0g (B.H.6), apple weight from 27.66g (H.675) to 73.53g (B.H.6), number of nuts per panicle from 1.77 (H.11) to 3.9 (H.32/4). Among the tested genotypes the variety, BPP-8 recorded the highest nut yield per tree (8.16kg tree^{-1}), indicating the suitability of this variety for cultivation in Bapatla conditions.

commercial cultivation because of its less yield per tree. Suggested cashew nut weighing 9-12g are suitable for commercial cultivation.

Adiga *et al.,* (2015) conduct a massive hybridization programme to develop a bold nut variety under ICAR ad-hoc scheme. A hybrid, H-126 (NRCC- Selection-2 and Bhedasi) has been identified as promising hybrid, performing good for yield with a special character of jumbo nut (11.5-12g), with a kernel weight of 3.3g and shelling percentage of 29.1%. Zachariah *et al*., (2015) compare the performance of released hybrid Poornima with some released cultivars. This hybrid has upright compact tree habit with intensive branching, mid-season flowering with nut weight of 7.8g and high shelling percentage of 31%.

Sethi *et al*., (2015a) analyzed nut and apple parameters of 71 cashew genotypes, including 60 hybrids, 8 parents, and 3 check varieties. The results revealed significant differences between the hybrids, parents, and check types. Cashew genotypes RP-1 and RP-2 were selected as suitable female parents for transmission of nut and apple characters and VTH-711/4 and KBN were identified as suitable male parents. They also assessed cashew hybrids for vegetative parameters and nut yield, and the results showed that both VTH-711/4 and KBN as male parents produced better vegetative growth characters in the tested hybrids (Sethi *et al*., 2015b).

According to Saroj and Mohana (2016), the breeding objectives for cashew improvement are high yield potential, dwarf and compact canopy types, short flowering duration, high sex ratio, resistance or tolerance to tea mosquito bug and cashew stem and root borer, disease resistance, high shelling percentage, nutrition quality, breeding for cashew apple and varied CNSL content.

Sreenivas *et al*., (2016) evaluated 9 cashew hybrids under Bhubaneswar conditions and recorded mean apple weight from 25.93g(H-319) to 37.72g(H-313), nut weight from 3.96g (H-292) to 7.08g (H-313), kernel weight from 1.14g (H-338) to 2.18g (H-313). They noticed maximum nut yield per tree in H-313 (5.22kg) and

minimum in H-292 (1.87kg) They also suggested that variability in apple weight and kernel weight is due to genetic and varietal character.

Nayak and Muralidhara (2019) described cashew hybrid H-130 (NRCC-Selection-2 x Bedasi) released from ICAR-DCR, Puttur, as bold nut variety (13g) with long flowering duration and good responsive to pruning. Jhargram-2, the selection made from seedling plantation, was released by Regional Research Station, Jhargam with average nut weight of 9.2gm, kernel weight of 2.85gm and export grade of W180. The bold nut variety, Vengurla-9 (Vengurla-4 x Vridhachalam-1) released from Fruit research station Vengurla, had bunch bearing nature with an average nut weight of 8.9g, shelling of 29.35 per cent, and kernel weight of 2.2g. BPP-10, clonal selected variety from Cashew Research Station, Baptala, exhibited bold sized nut with average nut weight of 8.10g and shelling percentage of 29.3.

2.5. BIOCHEMICAL CHARACTERS

Vilaschandran and Damodaran (1981) investigated 16 high-yielding cashew varieties and observed that K-10-2, M-6/1, BLA, and Sawantivadi had greater TSS, specific gravity, and percentage juice recovery, suggesting that they might be utilised to make alcoholic beverages. H-3/17, which produces more apples, was the most cost-effective variety for processing, followed by BLA-139-1 and H-3/13.

Attri and Singh (1997) examined the fruit weight, specific gravity, juice production, TSS, brix acid ratio, acidity, and ascorbic acid of five commercial cashew cultivars and discovered differences in fruit weight, specific gravity, juice yield, TSS, brix acid ratio, acidity, and ascorbic acid.

Lenka *et al.,* (1998) studied the biochemical characters of 23 cashew genotype. According to them, H-303(14.35 ^{0}Brix) has the greatest total soluble solids content, followed by M-15/4 (14.05 ^{0}Brix). M-44/3 (5.3) had the lowest apple nut ratio, whereas BPP10/19(7.9) and H-367 had the greatest (7.7). The concentration of titrable acidity ranged from 0.34 (H-68) to 0.50 percent (BPP 3/13 and H-367).

According to Sethi *et al*., (2015b), the TSS content of 60 hybrids studied ranged from 9.93^0 brix in F-38 to 17.45^0 brix in C-30. The TSS of the cross parent had an effect on the TSS of the corresponding hybrids, according to the findings. The greatest TSS was found in KBN (15.92^0 brix), whereas the lowest was found in the parent, M-44/3 (12.95^0 brix). It varied from 11.02^0 brix to 14.02^0 brix in the majority of cross pairings.

Mirdha *et al*., (2019) evaluate the fifteen diverse cashew genotypes for their physico-chemical parameters as well as value addition of cashew apple juice. Among that variety Dhana exhibited superiority for total cashew apple yield (19.35kg plant^{-1}), titrable acidity (0.35%) and ascorbic acid content (254.54mg 100g^{-1}). Genotype D-19 recorded maximum TSS (15.52^0 brix). Total sugar was recorded maximum in genotypes, NRCC Sel-2 (9.90%) and BPP-8 (10.53%) respectively. Genotype Bhubaneswar-1 (1.76mg ml^{-1}) recorded minimum amount of tannin.

2.6. CORRELATION STUDIES

Damodaran *et al*., (1965) observed a weak positive correlation between the number of hermaphrodite flowers and yield in cashew trees. In contrary to this, Gopikumar (1978) revealed that no correlation exists between sex ratio and the yield. Simple correlation analysis by Parameswaran (1984) indicated a positive correlation between yield and bisexual flowers.

Ramdas and Thatham (1982) studied the correlation of yield and 7 nut and kernel traits in cashew and found that yield was the most and shell weight is the least variable traits. They also concluded that individual tree yield offered the best scope for selection for improved yield. Parameswaran *et al*., (1984) reported the relationship between yield and duration of different phases of flower opening in cashew.

Anitha *et al*., (1991) made correlation and regression studies of 11 yield contributing characters. The nut yield showed a positive and highly significant

correlation with number of nuts per panicle and mean number of perfect flowers per panicle. Mean nut weight had negative correlation with the number of nuts per panicle that reached maturity. Manoj *et al.,* (1994) carried out an experiment with 56 number of ten-year-old hybrids of cashew belonging to 12 parental combinations.

The correlation studies and path coefficient analysis identified weight of kernel, mean canopy spread, no of nuts per panicle, girth of tree, leaf area, duration of flowering and height of tree as important biometric characters which contribute towards nut yield per tree in cashew (Manoj *et al*., 1994).

Sena *et al.,* (1994) studied correlation between nut yield and yield components in 17 cultivars. They noticed greatest effect of fruit set per panicle and single nut weight on nut yield per plant. Nut weight and apple weight had high positive associations with nut yield. Abdul Salam (1998) stated that nut yield and shelling percentage was significantly and positively correlated with tree yield of cashew. The flowering characters exhibited a strong positive correlation with yield. Among them the number of panicles per meter square, percentage of hermaphrodite flowers and number of nuts per panicles were prominent (Pushpalatha, 2000). Sethi *et al*., (2016) correlated the agro-economic traits associated with the nut yield of 71 cashew genotypes. Strong significant positive correlation was observed for nut weight, kernel weight and apple weight. But, nuts per panicle exhibited a significant negative correlation with nut weight, kernel weight and apple weight.

Chandrasekhar *et al*., (2019) studied variability, heritability and genetic advance for quantitative and qualitative traits in 25 cashew hybrids. Studies on genetic variability revealed that characters like sex ratio, yield per plant, nuts per panicle and nuts per metre square had high heritability and high genetic advance shown for characters like, indicating possibility of improvement of these characters.

2.7. PRINCIPAL COMPONENT ANALYSIS

Chipojola *et al*., (2009) studied the genetic diversity and relationship among 40 accessions using quantitative and qualitative traits and the most of the variation accounted by kernel weight, number of bisexual flowers, nut weight, apple to nut ratio and apple length. Sethi *et al*., (2016) analyzed 14 traits comprising of yield and ancillary traits using principal component analysis. first component accounted for 88.70 per cent variation followed by PC2 with 8.66 per cent and the maximum variation was exhibited by number of staminate flowers, apple weight and number of perfect flowers**.**

Carneiro *et al*., (2019), analyzed the principal components analysis, based on the 12 morphological descriptors and 81.72 per cent of total variability were explained by three principal components. The characters related to the peduncle, such as its length, apex diameter, and base diameter showed more variability on PC1 and presented positive combinations in terms of constituting that component. The determination of Principal Component 2 (PC2) revealed associations between variables related to the cashew nut length and width.

2.8. HETEROSIS STUDIES

The greater performance of the hybrid over its parents is defined as heterosis, also known as hybrid vigour (Shull, 1914). The hybrid vigour could manifest itself in increased growth and yield characteristics. It has been widely used to boost productivity in a variety of crops. Mid parent heterosis (F1 superiority over the mean value of two parents), heterobeltiosis (F1 superiority over the better parent), and standard heterosis (F1 superiority over the standard commercial variety/check) are the three types of heterosis. Manivannan *et al*., (1989) and Subramanian *et al*., (1994) examined hybrid vigour of cashew hybrids with respect to nut yield and nut weight and found positive heterosis.

Since, cashew is a widely cross pollinated and heterozygous crop, substantial variations in nut yield, nut characteristics, and other tree growth features can be noticed (Nawale and Salvi, 1990). Due to the vast variation in these traits, cashew hybrids used to exhibit high degree of relative heterosis, heterobeltiosis, and standard heterosis, indicating the effectiveness and potential enhancement of the character, which could lead to an increase in crop yield (Manoj and George, 1993; Shankarnarayanan, 1996). For the cashew development initiative, a higher magnitude of heterosis for nut weight and kernel weight have also been suggested (Chipojola *et al*., 2009).

Sethi *et al*., (2016) undertook a study to investigate the level of heterosis shown by twenty hybrids. The results revealed that the hybrids A-71, B-27, C-30, and C-41 had better heterosis in terms of nut weight (-0.27 to 19.68%), kernel weight (18.89 to 32.26%), and overall nut yield (15.51 to 30.70%) than the other hybrids studied. These superior hybrids have relative heterosis, heterobeltiosis, and standard heterosis ranging from 85.71 to 94.88 percent, 57.33 to 65.85 percent, and 15.51 to 30.70 percent, respectively. As a result, these hybrids may be recommended for cultivation to boost cashew production and productivity in the East Coast's coastal agro-climatic conditions.

2.9. PEST AND DISEASE INCIDENCE

Cashew stem and root borer is the most severe pest of cashew which is capable of complete collapse. The grubs of *Plocaedercus ferrugiencis* occur throughout the year. They bore the sap wood of the tree as a result of which resinous substances ooz out from the wounds along with a thick reddish mass of chewed fibres. In due course, the tree is killed. According to Abraham (1958) this cerambycid was more attracted to the trees which were more than 15 years old.

Tea mosquito bug (*Helopeltis antonii*) can be considered as the most devastating pest of cashew and the extent of loss in nut yield has been reported from 25 to 50per cent (Abraham and Nair, 1981). Devasahyam and Nair (1986) recorded

wide host range of *H. antonii* including 17 plant species representing 13 families. It was also known as tea mosquito, as the pest resembles the mosquito and was formerly found to attack tea plant.

Hypatima haligramma is one of the major foliage feeding pest found in almost all the plantation of Odisha. On an average 31 per cent of the shoot damage is accounted by this pest (Mohapatra and Senapati, 1994). The pest, shoot tip caterpillar, *Chelaria haligramma* was recorded from July to November (Jena *et al*.,1980). Incidence of tip caterpillar, *Chelaria haligramma* was also reported in severe proportion in south India (Abraham, 1958 and Pillai,1980).

Tea mosquito bug was reported to be mostly seen in the southern part of Odisha particularly in Ganjam, Koraput and some parts of Nayagarh district, where infestation is moderate to heavy i.e., 6.5 to 22 per cent in shoot and 7.5 to 32 per cent in inflorescence. Very scare infestation was reported in the coastal districts (Mohapatra and Senapati, 1994). Sundararaju *et al*., (1999) and Sahu *et al.,* (2020) recorded Tea mosquito bug as the most important limiting factor of cashew. *Helopeltis antonii* is known as a sap sucker since the nymphs and adults suck the liquid of the young plants and succulent parts (Karmavati 2007).

The research was conducted in small holder cashew plantation in Ngadirejo, Indonesia from March 2004 to May 2006 by Siswanto *et al*., (2008) and the results shows that population is high during flushing-flowering seasons of cashew plants, and it indicates regular or random distribution when the population is low during post-flowering seasons. The aggregated distribution on cashew plants indicated that there is a preference to food sources of the plants and an individual behavior to aggregate. Therefore, sampling and monitoring *H. antonii* in cashew plantation should be carried out systematically during flushing-flowering seasons.

Sundararaju (2009) reported the infestation of various lepidopteran insect species on cashew. Among the lepidopteran insect pest species, the shoot tip caterpillars, *Hypatima haligramma* Meyrick and *Anarsia epotias* Meyrick (Fam:

Gelechiidae) were found to be the most important. The others include the apple and nut borer, *Thylacoptila paurosema* Meyrick (Fam: Pyralidae); panicle and flower feeding caterpillars, *Archips spp*. (Fam: Tortricidae); *Rapala* sp. and *Cheritrafreja* (F.) (Fam: Lycaenidae); *Aetholix flavibasalis* (Guenee) (Fam: Pyralidae); loopers, *Oenospila flavifuscata*Walker and the hairy caterpillar, *Euproctis scintillans* (Walker) (Fam: Lymantriidae). The ratio of shoot tip caterpillars to the other lepidopteran pests was estimated as 1.0:0.5. The overall yield loss due to the lepidopteran pests on cashew (cv. Bhaskara) was estimated to range from 61.7 to 74.6 per cent.

Bhaskara and Swamy (1994) conducted a survey on TMB damage on 11 cultivars of cashew at Cashew Research Station, Madakkatahara during 2009-2010. And reported two peaks of TMB population; one during December and another during June, coinciding with flowering and flushing respectively. Maximum population of TMB was recorded during June which coincided with maximum flushing in all the cultivars. The extent of shoot damage in young Cashew plants was high during July to September. And a positive correlation between intensity of flushing and TMB population. Jalgaonkar *et al*., (2015), screened 18 cashew accessions including released cultivars and promising hybrids at the Regional Fruit Research Station at Vengurle during 2004 to 2011, and the result indicated that all the accessions are susceptible to tea mosquito bug infestation. Kar and Poduval (2016) conducted a survey on red and laterite zone of West Bengal during 2014-2016 and identified cashew stem and root borer, leaf miner, thrips and apple and nut borer as the major insect pest associated with cashew.

Materials and methods

3. MATERIALS AND METHODS

The present study was carried out in the Department of Plantation Crops and Spices College of Agriculture, Vellanikkara and Cashew Research Station, Madakkathara during the period 2020– 2021.

Thirty genotypes of cashew comprising of 19 hybrids and 11 parents formed the material for the study. The variety, Poornima, released from Cashew Research Station, Madakkathara during 2006 was used as the standard check variety. The selected hybrids have been developed at Cashew Research Station, Madakkathara during 2003 and have already reached steady bearing stage. The experimental field is located at agroecological unit 10 at an altitude of 23 m above MSL and is between 10^0 32' N latitude and 70^0 16' E longitude. The details of hybrid population and parental combinations are given in Table 1.

3.1 MORPHOLOGICAL EVALUATION OF CASHEW HYBRIDS AND CROSS PARENTS

Both qualitative and quantitative characters were considered for morphological evaluation. The descriptor list developed by Directorate of Cashew Research, Puttur (Nayak *et al*., 2014) was used for recording the observations. The descriptor and the descriptor states are presented in Table 2.

3.1.1. Qualitative characters

Observations on 30 qualitative characters were recorded on all hybrids and their cross parents. Jaccard's similarity coefficients (Jaccard, 1908) are used to estimate the genetic association among the hybrids and parents using NTSYS pc version 2.1 (Rohlf, 1992). Similarity matrix used for performing the cluster analysis and dendrograms were constructed (Sneath and Sokal,1973).

Observations on growth, inflorescence, apple, nut and kernel traits were recorded for both hybrids and cross parents and categorised, wherever applicable, as per the standard descriptor of cashew (Nayak *et al*., 2014).

Table 1. Details of cashew hybrids and their cross parents

Sl. No.	Hybrids	Cross parents
1.	H03-36/8	Dhana x Madakkathara-1
2.	H03-55/11	Priyanka x Anakkayam-1
3.	H03-55/10	Priyanka x Anakayam-1
4.	H03-53/9	Amrutha x Anakayam-1
5.	H03-57/4	Priyanka x Madakkatara-1
6.	H03-92/3	Vridhachalam-3 x Sulabha
7.	H03-95/8	Vridhachalam-3 x Sulabha
8.	H03-97/2	Sulabha x Madakathara-1
9.	H03-110/1	Poornima x Priyanka
10	H03-110/2	Poornima x Priyanka
11.	H03-110/3	Poornima x Priyanka
12.	H03-111/2	Dharasree x K-22-1
13.	H03-113/1	Poornima x Dharasree
14.	H03-95/4	Vridhachalm-3 x Priyanka
15.	H03-18/17	Damodar x K-22-1
16.	H03-52/7	Priyanka x Vridhachalam-3
17.	H03-52/6	Priyanka x Vridhachalam-3
18.	H03-52/5	Priyanka x Vridhachalam-3
19.	H03-21/10	Sulabha x Priyanka

3.1.2. Quantitative characters

The quantitative evaluation was based on 31 quantitative characters. The quantitative characters recorded are given below.

1. **Tree height (m)**

   The height of the cashew tree was measured vertically from the ground to the top of the tree using marked bamboo pole and expressed in meters.

2. **Trunk girth (m)**

   The trunk girth was measured at 30cm above the ground level using a measuring tape and expressed in meter.

3. **Canopy spread (m)**

   The diametric length of the ground space occupied by the tree was measured in two directions and recorded as "North-South and East-West" directions. Tree spread was expressed as mean of the diameter in two directions.

4. **Internode length of twig (cm)**

   Recorded as the distance between 3rd and 4th node after cessation of leaf emergence. Mean internodal length was calculated by measuring internodal length of five twigs in all four directions of the tree and grouped accordingly as short (<1cm), medium (1-2cm) and long (>2cm).

5. **Twig diameter (mm)**

   The diameter of current shoot was measured at an internode after the current season's growth has ceased. Five twigs each on four sides of the canopy were observed and mean value was calculated and can be grouped as thin (<4.5mm), intermediate (4.5-9mm) and thick (>9mm).

6. **Number of leaves per twig**

Number of leaves on twig was recorded on current season shoot. The mean of 20 randomly selected twigs from four sides of the canopy was calculated and expressed as number of leaves per twig. The number of leaves per twig can be classified as low (<9), medium (9-19) and high (>19).

Table 2. Descriptor and descriptor state used for recording qualitative characters

Sl. No.	Character Name	Descriptor state	Code
a.	**Tree characters**		
1.	Branching pattern	Extensive	1
		Intensive	2
2.	Tree habit	Upright and compact	3
		Upright and open	5
		Spreading	7
b.	**Leaf characters**		
3.	Colour of young leaves	Red	1
		Yellow red	2
		Green yellow	3
		Purple	4
4.	Colour of mature leaves	Light green	1
		Green	2
		Dark green	3
		Purple	4
5.	Leaf margin	Smooth	1
		Wavy	2
6.	Leaf shape	Obovate	1
		Ovate	2
		Oblong	3
		Circular	4
7.	Leaf apex shape	Pointed	1
		Rounded	2
		Indented	3
8.	Leaf cross section	Level	1
		Reflexed	2
		Incurved	3
		Twisted	4

Table 2. Contd. Descriptor and descriptor state used for recording qualitative characters

Sl. No.	Character Name	Descriptor state	Code
c.	**Inflorescence characters**		
9.	Season of flowering	Early (November-December)	3
		Mid (December- Januvary)	5
		Late (Januvary- Februvary)	7
10.	Inflorescence shape	Narrowly pyramidal	3
		Pyramidal	5
		Broadly pyramidal	7
11.	Secondary flowering	Absent	0
		Present	+
12.	Flower colour	White	1
		Cream	2
		Pink	3
13.	Flowering duration	Short (< 60 days)	3
		Medium (60-90 days)	5
		Long (>90 days)	7
14.	Compactness of inflorescence	Loose	3
		Compact	5
15.	Harvesting duration	Short (<30 days)	7
		Medium (30-75 days)	5
		Long(>75days)	7
d.	**Apple and nut characters**		
16.	Mature cashew apple colour	Yellow	1
		Red	2
		Yellow red	3
		Red purple	4
17.	Cashew apple shape	Cylindrical	1
		Conical- obovate	2
		Round	3
		Pyriform	4
18.	Shape of cashew apple base	Angular	1
		Rounded	2
		Flattened	3
19.	Ridges on cashew apple	Absent	0
		Broken	1
		Entire	2
20.	Cashew apple apex	Level	1
		Oblique	2

Table 2. Contd. Descriptor and descriptor state used for recording qualitative characters

Sl. No.	Character Name	Descriptor state	Code
21.	Grooves on apex of cashew apple	Absent	0
		Shallow	3
		Deep	7
22.	Cavity at apex of cashew apple	Absent	0
		Shallow	3
		Deep	7
23.	Attach of nut to apple	Loose	3
		Intermediate	5
		Tight	7
24.	Colour of mature nut shell	Buff	1
		Grey	2
		Purple	3
25.	Nut shape	Kidney	1
		Oblong-ellipsoid	2
26.	Shape of nut base	Round	1
		Flattened	2
		Obliquely flattened	3
		Angular	4
27.	Suture of nut	Round	1
		Angular	2
28.	Flanks of nut	Flattened	3
		Round	5
		Bulging	7
29.	Stylar scar on nut	Small	3
		Large	7
30.	Relative position of suture and apex	Suture projection in front of apex	1
		Suture projection in line with apex	2

7. **Leaf size (cm^2)**

Leaf size was measured on a matured lateral shoot and 4^{th} leaf was used as index leaf. The length and breadth of twenty leaves randomly selected from four sides of the canopy were observed and leaf size was calculated by multiplying these values. As per the descriptor (Nayak *et al*., 2014), leaf size can be grouped as small (<60cm^2), intermediate (60-120cm^2) and large (>120cm^2) depending on the average leaf size.

8. **Number of flowering laterals per meter square**

The number of flowering laterals were counted from one square meter area of canopy from four directions at peak flowering period. An iron frame of one metre square size was hand held on tree canopy and laterals falling within the frame were counted and the mean value was recorded as flowering laterals per square meter.

9. **Number of panicles per meter square**

The number of panicles were counted from four cardinal directions using an iron frame of size one metre square and mean number of panicles per square meter was calculated.

10. **Panicle length (cm)**

At peak flowering stage, the average length of twenty panicles from all the four sides of the tree were recorded.

11. **Panicle width (cm)**

Recorded as the average width of twenty panicles selected from four directions of the tree at peak flowering stage.

12. **Number of bisexual flowers per panicle**

Five panicles were selected randomly from East, West, North, and South direction of the selected tree and tagged. The number of perfect flowers appeared in the selected panicles were counted on alternative days and counting was continued till all the flower buds are opened.

13. **Number of male flowers/ panicles**

Five panicles were selected randomly from East, West, North and South direction of the selected tree and were tagged. The number of male flowers appeared in the selected panicles were counted on alternative days and counting was continued till all the flower buds are opened.

14. **Sex ratio**

Five panicles were selected randomly from each side of the tree and tagged. The number of bisexual flowers and male flowers appeared in the selected panicles were counted on alternate days till all the flower buds of a particular panicle are opened. Sex ratio was calculated as the ratio of bisexual flowers to total number of flowers (bisexual plus male flowers).

15. **Apple weight (g)**

Weight of apples from 40 randomly selected fruits were recorded immediately after harvest. and grouped accordingly into low (<27g), medium (27-52 g) and high (>52g) groups.

16. **Nut weight (g)**

The weight of 40 randomly selected nuts after harvest were weighed using weighing balance and grouped as low (<5g), intermediate (5-7g) and high (>7g).

17. **Apple to nut ratio**

From the fresh weight of apple and nut, the apple to nut ratio was worked out by dividing apple weight by nut weight and grouped into low (<6), medium (6-12) or high (>12).

18. **Number of nuts/panicles**

Number of nuts in 20 panicles from each cardinal directions of the canopy at peak fruiting stage was taken and calculated average number of nuts per panicle.

19. **Nut dimensions**

After harvesting, the nuts were separated from the apple. Raw nuts collected from each genotype were pooled and sun dried for 2 to 3 days. Observations were taken from 40 randomly selected dried nuts.

a. Nut length (cm)

Distance from point of attachment to apex of each nut was recorded and the average worked out and expressed in centimetre.

b. Nut width (cm)

Maximum distance between shoulders of each nut were recorded and average worked out and expressed in centimetre(cm).

c. Nut thickness (cm)

Maximum distance between flanks of each mature nuts were recorded and average worked out and expressed in centimetre(cm).

20. **Nut yield (kg/plant)**

Total weight of raw nuts collected from each tree during the entire season was recorded in kilogram and expressed as nut yield/ tree/ year. Based on this, yield of cashew genotypes can be classified as high (>18kg), intermediate (9-18kg) and low (<9kg).

21. **Number of nuts per kilogram**

Total number of nuts in one kilogram was counted and recorded as number of nuts per kilogram.

22. **Kernel dimensions**

The dried nuts were shelled after steam boiling and nuts were split to separate kernels. Kernels were dried for 6-7 hrs at 70^0 C and peeled. Kernels were again dried at 70^0 C. Observations were taken from 40 randomly selected samples of kernel.

a. Kernel length (cm)

Recorded using vernier calliper as average distance from base (location of plumule) to apex of 40 random kernels.

b. Kernel width (cm)

Recorded using vernier calliper as average width of 40 random kernels

c. Kernel thickness (cm).

Recorded using vernier calliper as maximum distance between flanks of 40 kernels.

23. **Kernel weight (g)**

The kernel weight of 40 randomly selected sample nuts were measured using weighing balance and grouped into low (<1.2g), intermediate (1.2 – 2.5g) or high (>2.5g).

24. **Shelling percentage**

The average kernel weight of 10 randomly selected dry nut was divided by the dry nut weight and expressed as percentage and grouped into high (>28%), intermediate (18-28%) or low (<18%).

25. **Export grade of kernels**

The number of kernels in one pound (454g) were counted and corresponding export grades were recorded as per CEPC, 2010 (Table 3).

Table 3. Export grades of cashew kernels

Grade designation	Count/454 gm (Size description)
W-180	170-180
W-210	200-210
W-240	210-240
W-280	240-280
W-320	280-320
W-450	320-450

3.2. BIOCHEMICAL EVALUATION OF APPLE

Fully matured apples harvested from the hybrids and cross parents were washed with water followed by distilled water. Nuts were removed. Fruits after removal of nuts (1 kg) were squeezed and extracted the juice with the help of juice extractor. This juice was used for the estimation of total soluble solids, vitamin C, tannins, total sugars and acidity using standard procedures.

3.2.1. Determination of total soluble solids content (TSS)

The total soluble solids content of cashew apple juice was determined by the index of refraction. This was measured using a hand refractometer by placing a drop of representative samples of apple juice on the equipment and expressed in degrees Brix.

3.2.2. Determination of ascorbic acid content

The vitamin C content of the cashew apple juice was estimated by the volumetric method as suggested by Sadasivam and Manickam (1996) using 2,6-dichloro phenol - indophenol dye.

Stock solution was prepared by dissolving 100mg ascorbic acid in 100ml of 4 percent oxalic acid solution. Four percent oxalic acid is prepared by dissolving 0.4g of oxalic acid in 100 ml distilled water. 10ml of stock solution was diluted to 100 ml with 4 percent oxalic acid to get the working standard of 100mg/100ml. 5ml of the working standard solution was pipetted into a 100ml conical flask to which 10 ml of 4% oxalic acid was added. The contents were titrated against the dye, here the ascorbic acid reduces the dye to a colourless leuco-base. The ascorbic acid gets oxidised to dehydroascorbic acid. Though the dye is a blue coloured compound, the end point of titration is the appearance of the pink colour which persists for a few minutes. The cashew apple sample 5g was crushed with the help of pestle and motor with 4% oxalic acid and the volume was made up to 100ml and the contents were filtered. 5 ml of the supernatant was pipetted out, to which 10ml of 4 percent oxalic

acid was added and titrated against the dye. The ascorbic acid content was calculated by using the formula as given below.

$$\text{Amount of ascorbic acid (mg 100 g}^{-1}) = \frac{\text{Dye factor x T.V}_1 \text{ x V}_1 \text{ x 100}}{\text{T.V}_2 \text{ x V}_2 \text{ x W}_1}$$

$T.V_1$- Titre value of sample, $T.V_2$- Titre value of standardisation, V_1- Volume of sample made up, V_2 – Volume of sample pipetted out, W_1- Weight of the sample taken.

3.2.3. Determination of tannin content

The tannin content of cashew apple juice was estimated by Folin -Denis's method. This is based on the non-stochiometric oxidation of the molecules containing a phenolic hydroxyl group. In alkaline solution, tannin like compounds reduce phosphotungstomolybdic acid to produce a highly blue coloured solution, the intensity of which is proportional to the tannin content of sample (Schanderl,1970).

A known volume of cashew apple (5g) was weighed and crushed with the help of pestle and motor and transferred the juice into a 250ml conical flask. To this 75 ml of distilled water was added and boiled for 30 minutes. Then centrifuged at 2000 rpm for 20 minutes. The supernatant was collected in 100ml standard flask and the volume was made up. 1ml of this sample extract was transferred into a 100ml standard flask and 75 ml of water, 5ml of Folin-Denis reagent, and 10ml of sodium carbonate solution was added to this and made up to 100 ml. After that shake well and read the absorbance at 700 nm after 30 minutes. Folin- Denis reagent was prepared by dissolving 100mg sodium tungstate and 20g phosphomolybdic acid in 750ml distilled water in a suitable flask by adding 50ml phosphoric acid. Reflux the mixture for 2 hours and made up to 1 litre with water. Sodium carbonate solution was prepared by dissolving 350g sodium carbonate in one litre of water at 70-80^{0}C and filtered through glass wool after allowing it to stand overnight. The blank was prepared with water instead of the sample. The tannin content of the sample was calculated as tannic acid equivalents from the standard graph.

3.2.4. Determination of titratable acidity

Titratable acidity was estimated as per standard procedure given by Sadasivam and Manickam (1996) and expressed as per cent of malic acid.

Five grams of representative sample of cashew apple was crushed with the help of pestle and motor and made up to 100ml with distilled water in a standard flask and filtered using filter paper (9Cms). From this 10 ml was taken and 1 to 2 drops of phenolphthalein indicator was added to it. It was titrated against 1N NaOH (40g NaOH in 1 lit). The titration was repeated to get consecutive values. The titratable acidity content was calculated by using the formula as given below.

$$\text{Titratable acidity (\%)} = \frac{\text{TV* x N* x Volume made up x Equivalent weight of acid*100}}{\text{Weight of sample taken x 1000}}$$

*TV- Titre value, N- Normality of alkali

3.2.5. Determination of total sugar

The volume of unknown sugar solution required to completely reduce a measured volume of Fehling's solution was used to estimate total sugar content of the given sample (Ranganna,1986).

Sample (20-30g) was weighed and grinded with pestle and motor and transferred to 250ml standard flask. 2ml of 45 per cent neutral lead acetate (45g in 100ml distilled water) and 2ml of 22 per cent potassium oxalate solution (22g in 100ml distilled water) was added to this to form a precipitate. Filtered and 50ml of filtrate was taken into a 250ml conical flask. Boiled this solution after adding citric acid (5g in 50ml distilled water). The cooled solution was then transferred to a 250ml standard flask. Then 1 drop of phenolphthalein was added to this. When light pink colour appeared, neutralised with 1N NaOH. The volume was made up to 250 ml and transferred to a burette. 5ml of felhing solution A and 5ml of fehling solution B were mixed together in a conical flask. 1ml of this was taken in another conical flask,

boiled and added 1 drop of methylene blue indicator. This was titrated against the solution in the burette till brick red colour indicating the end point of titration was appeared. The total sugar content was calculated by using the formula given below.

$$\text{Total sugar (\%)} = \frac{\text{Factor x Dilution x 100}}{\text{Titre value x Volume of filtrate x Weight of sample}}$$

3.3. PESTS AND DISEASE INCIDENCE

A preliminary observation of all cashew hybrids and cross parents was also done under natural field conditions during 2020-21 for their susceptibility to pests and diseases. The experimental trees were inspected throughout the year and all pest and disease incidence was recorded. Tea mosquito bug damage was observed and their severity was recorded.

3.3.1. Preliminary scoring for Tea mosquito bug damage (TMB)

On the basis of the number and nature of necrotic lesions in cashew shoots, the TMB damage scoring method was given by Ambika *et al.*, (1979) (Table 4). This damage rating system has been widely accepted and adopted in India and by the All India Coordinated Research project on Cashew (AICRP on Cashew) (NRCC, 2005).

On each tree, 52 leader shoots were tagged suitably on any directional quadrant and TMB damage was recorded following 0-4 scale (Table 3) separately from lateral shoots and panicles. Scoring for TMB damage was done during the regular flushing (November- December), flowering and fruiting season (January – March) during 2020-2021. The mean score per tree was worked out from the total 52 leader shoots using the following formula.

$$\text{Mean score value} = \frac{\text{Total score}}{\text{Total number of lateral shoots + panicles}}$$

From the mean score value, the intensity of TMB population was estimated as given in Table 5.

Table 4. Damage scoring method for TMB in cashew

Score	Description
0	No lesions/streak
1	Up to 3 necrotic lesions/streaks, general vigour of shoot/panicle unaffected
2	4-6 coalescing/non-coalescing lesions/streaks
3	Above 6 coalescing/non-coalescing lesions/streaks
4	Lesions/streaks confluent/complete drying of the affected shoot/panicle

Table 5. Intensity of TMB Population

Mean damage score	Intensity of TMB population
0.75-1.0	Highly Susceptible to TMB (HS)
0.75-1.0	Susceptible to TMB(S)
0.25-0.50	Medium susceptible to TMB (MS)
0.1-0.25	Less susceptible to TMB (LS)

3.4. STATISTICAL ANALYSIS

The statistical analysis was conducted in the R based software 'GRAPES' (R-shiny Based Analysis Platform Empowered by Statistics) Version 1.0.0. (Gopinath *et al*., 2020). The observations on morphological and yield characters were analyzed in one way ANOVA and hybris and parents were grouped accordingly**.**

3.4.1. Estimation of variance

Analysis of variance was done for 25 quantitative characters observed to detect the proportional contribution of each source of variation to the total variation.

3.4.2. Estimation of correlation

Correlation coefficient was used to measure the association between 18 variables.

3.4.3. Principal component analysis

The characters showing positive and significant correlation with tree yield were used for Principal Component Analysis. Using PCA, the minimum numbers of components that can explain maximum variation out of the total variance were identified. Scores of the principal component axes were used to produce a tri-dimensional figure to reveal the specific grouping of the 19 hybrids and their parents within the plane.

3.4.4. Estimation of heterosis

Heterosis of hybrids were also studied for yield contributing characters and estimated in three ways.

1.Mid parent heterosis/ Relative heterosis (RH)

When the heterosis is estimated over the mid parent *i.e.*, mean value or average of the two parents is known as mid parent heterosis. It is also known as average heterosis or relative heterosis and calculated by using formula

Relative heterosis = (F1-MP)/MP*100

Where, F1 is the mean value of F_1 hybrids, MP is the average of two parents involved in the cross.

Test of Significance for relative heterosis (RH)

SE = $\sqrt{}$3/2r x EMS

t value for RH = F1 – MP/ SE

Calculated t value greater than table value, the characters are significant

SE – Standard error

4. Better parent heterosis/ Heterobeltiosis (HB)

When the heterosis is estimated over the better parent is known as better parent heterosis. It is also known as heterobeltiosis and calculated by using formula

Heterobeltiosis = (F1-BP)/BP*100

Where, BP is the mean value of better parent of the particular cross.

Test of Significance for heterobeltiosis (HB)

SE = $\sqrt{}$2/r x EMS

t value for HB = F1 – BP/ SE

Calculated t value greater than table value, the characters are significant

3.Standard heterosis (SH)

It refers to the superiority of F1 over the standard commercial check variety. It is also called as economic heterosis or useful heterosis and calculated by using formula

Standard heterosis= (F1-SV)/SV*100

Where, SV is mean value of standard variety/hybrid

Test of Significance for standard heterosis

SE = $\sqrt{}$3/2r x EMS

t value for RH = F1 – MP/ SE

Calculated t value greater than table value, the characters are significant.

Result

4. RESULTS

Cashew hybrids of known parentage developed as a part of hybridization and selection programme of Cashew Research Station, Madakkathara were evaluated for morphological, yield and quality characters. The experiment population comprised of 19 cashew hybrids and 11 cross parents. The results of the present investigation on the performance of hybrids and cross parents are presented below in different headings.

4.1. MORPHOLOGICAL EVALUATION

Both qualitative and quantitative characters were used for evaluating the accessions morphologically. An evaluation of morphological characters in cashew (*Anacardium occidentale* L.) would assist in planning for future selection of good high yield germplasm that will produce nuts of high quality and fetch high prices on the market (Chipoja *et al*., 2009). Variability could exist in typical cashew field for most morphological characters and such morphological traits continue to be the first step in the studies of genetic relationships. Thus, genetically divergent genotypes identified on the basis of morphological data can be used in future breeding programmes.

4.1.1. Qualitative evaluation

The observations on 30 qualitative characters are presented in Table 6,7,8 and 9. Wide variability was present among the hybrids for the studied qualitative traits.

4.1.1.1. Tree characters

The results on tree habit and branching pattern of 19 cashew hybrids 11 parents are presented in Table 6. Majority of cashew hybrids and parents were having upright and compact canopy with intensive branching habit. Only four hybrids (H03-97/2, H03-52/7, H03-52/6 and H03-52/5) and one parent (Amrutha) exhibited spreading type of tree habit. Seven hybrids showed extensive branching habit similar

to that of variety, Amrutha. Upright and open canopy was observed in the hybrids, H03-55/10, H03-110/2, H03-111/2, H03-95/4, and the parents, Priyanka and Sulabha.

4.1.1.2. Leaf characters

The observations on visual morphology of leaves with respect to colour of young and matured leaves, shape, apex, margin and cross section of leaves of 19 cashew hybrids and 11 varieties are presented in Table 6. Yellow-red coloured flushes were observed in all the genotypes of cashew studied expect the hybrid H03-113/1, where the colour of young leaves were red. (Plate 1).

The colour of matured leaves was observed as green in 16 hybrids and dark green in H03-55/10, H03-95/8 and H03-110/2. Whereas all the cross parents exhibited green coloured mature leaves. Leaf shape was obovate in 4 hybrids, ovate in H03-110/3 and oblong in 14 hybrids. All the parents showed oblong shaped leaf except variety Dharasree, which was obovate. The leaf apex was indented in 11 hybrids and 9 parents, round in 7 hybrids and 1 parent, but it was pointed in H03-18/17 and Poornima. Leaf cross section was level in 15 hybrids and 9 parents while it was incurved in four hybrids and parent, K-22-1. Reflexed leaf cross section was observed in the variety, Anakayam-1. Margin of leaves of all parents and 16 hybrids were smooth, but it was wavy in 3 hybrids (H03-52/5, H03-92/3, H03-18/17).

Table 6. Qualitative growth parameters of cashew hybrids and its parents

Hybrids/parents	Tree habit	Branching pattern	Colour of young leaves	Colour of matured leaves	Leaf shape	Leaf apex	Cross section of leaves	Leaf Margin
H03-36/8	Upright and compact	Intensive	Yellow red	Green	Obovate	Indented	Incurved	Smooth
H03 -55/11	Upright and compact	Intensive	Yellow red	Green	Oblong	Rounded	Level	Smooth
H03- 55/10	Upright and open	Extensive	Yellow red	Dark Green	Oblong	Rounded	Incurved	Smooth
H03-53/9	Upright and compact	Extensive	Yellow red	Green	Oblong	Rounded	Level	Smooth
H03-57/4	Upright and compact	Intensive	Yellow red	Green	Oblong	Rounded	Level	Smooth
H03-92/3	Upright and compact	Intensive	Yellow red	Green	Oblong	Indented	Level	Wavy
H03-95/8	Upright and compact	Extensive	Yellow red	Dark Green	Oblong	Indented	Level	Smooth
H03-97/2	Spreading	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth
H03-110/1	Upright and compact	Intensive	Yellow red	Green	Oblong	Rounded	Level	Smooth
H03-110/2	Upright and open	Intensive	Yellow red	Dark Green	Obovate	Indented	Level	Smooth
H03-110/3	Upright and compact	Intensive	Yellow red	Green	Ovate	Indented	Level	Smooth
H03-111/2	Upright and open	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth
H03-113/1	Upright and compact	Extensive	Red	Green	Oblong	Indented	Level	Smooth
H03-95/4	Upright and open	Extensive	Yellow red	Green	Obovate	Rounded	Level	Smooth
H03-18/17	Upright and compact	Intensive	Yellow red	Green	Obovate	Pointed	Incurved	Wavy
H03-52/7	Spreading	Extensive	Yellow red	Green	Oblong	Rounded	Level	Smooth
H03-52/6	Spreading	Extensive	Yellow red	Green	Oblong	Indented	Level	Smooth
H03-52/5	Spreading	Intensive	Yellow red	Green	Oblong	Indented	Level	Wavy
H03-21/10	Upright and compact	Intensive	Yellow red	Green	Oblong	Indented	Incurved	Smooth

Table 6. Contd. Qualitative growth parameters of cashew hybrids and its parents

Hybrids/parents	Tree habit	Branching pattern	Colour of young leaves	Colour of mature leaves	Leaf shape	Leaf apex	Cross section of leaves	Leaf Margin
Dhana	Upright and compact	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth
Madakkathara-1	Upright and compact	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth
Priyanka	Upright and open	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth
Anakkayam -1	Upright and compact	Intensive	Yellow red	Green	Oblong	Indented	Reflexed	Smooth
Amrutha	Spreading	Extensive	Yellow red	Green	Oblong	Indented	Level	Smooth
Vri– 3	Upright and compact	Intensive	Yellow red	Green	Oblong	Rounded	Level	Smooth
Sulabha	Upright and open	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth
Poornima	Upright and compact	Intensive	Yellow red	Green	Oblong	Pointed	Level	Smooth
K-22-1	Upright and compact	Intensive	Yellow Red	Green	Oblong	Indented	Incurved	Smooth
Dharasree	Upright and compact	Intensive	Yellow red	Green	Obovate	Indented	Level	Smooth
Damodar	Upright and compact	Intensive	Yellow red	Green	Oblong	Indented	Level	Smooth

4.1.1.3. Inflorescence characters

The qualitative characters of inflorescence and flowering season were observed and presented as Table 7. Cream coloured flowers were observed in all the cashew genotypes studies except in H03-52/6 and H03-52/5, where the flower colour was white. flowers. Shape of the inflorescence was pyramidal in 18 cashew hybrids and 10 parents while it was broadly pyramidal in the hybrid, H03-97/2 and variety, Amrutha. Irrespective of the shape, the inflorescence was loose in all hybrids except H03-97/2 (Compact) (Plate 2).

Early flowering from October was recorded in 13 cashew hybrids and four parents (Anakkayam-1, Makkathara-1, Poornima and Vridhachalam-3) during the year 2020. Six hybrids and parents showed mid-season flowering from December to January. The variety, Sulabha, showed late flowering commencing from January onwards. Secondary flowering was observed in the hybrids, H03-55/11, H03-97/2 and H03-21/10. In case of cross parents, Madakkathara-1, Anakkayam-1 and Poornima showed secondary flowering. Long flowering and harvesting duration of more than 90 days was recorded in H03-97/2, H03-21/10 and Poornima. Eleven hybrids and 6 parents showed medium duration of flowering duration (60-90 days). Flowering duration was less than 60 days in six hybrids and three parents (Priyanka, Anakayam-1 and Sulabha).

4.1.1.4. Apple characters

The hybrids showed variation in apple skin colour (Table 8). Apple colour of nine hybrids were yellow, five were yellow-red and 4 were red. The cashew apple of hybrid, H03-95/8, was red purple in colour. The apple colour of five parents were yellow, four were yellow-red and two (Vri-3, K-22-1) were red coloured (Plate 3).

Table 7. Qualitative inflorescence characters of cashew hybrids and its parents

Sl. No.	Hybrid/parent name	Flower colour	Inflorescence shape	Compactness of inflorescence	Season of flowering	Flowering duration	Harvesting duration	Secondary flowering
1.	H03 - 36/8	Cream	Pyramidal	Loose	Early	Medium	Medium	Absent
2.	H03 - 55/11	Cream	Pyramidal	Loose	Early	Medium	Medium	Present
3.	H03 - 55/10	Cream	Pyramidal	Loose	Early	Short	Short	Absent
4.	H03 - 53/9	Cream	Pyramidal	Loose	Early	Medium	Medium	Absent
5.	H03 - 57/4	Cream	Pyramidal	Loose	Mid	Short	Short	Absent
6.	H03 - 92/3	Cream	Pyramidal	Loose	Early	Medium	Medium	Absent
7.	H03 - 95/8	Cream	Pyramidal	Loose	Early	Short	Medium	Absent
8.	H03 - 97/2	Cream	Broadly pyramidal	Compact	Early	Long	Long	Present
9.	H03 - 110/1	Cream	Pyramidal	Loose	Early	Medium	Medium	Absent
10.	H03 - 110/2	Cream	Pyramidal	Loose	Early	Medium	Medium	Absent
11.	H03 - 110/3	Cream	Pyramidal	Loose	Early	Medium	Medium	Absent
12.	H03 - 111/2	Cream	Pyramidal	Loose	Mid	Medium	Short	Absent
13.	H03 - 113/1	Cream	Pyramidal	Loose	Mid	Short	Short	Absent
14.	H03 - 95/4	Cream	Pyramidal	Loose	Early	Short	Short	Absent
15.	H03 - 18/17	Cream	Pyramidal	Loose	Early	Short	Medium	Absent
16.	H03 - 52/7	Cream	Pyramidal	Loose	Mid	Medium	Medium	Absent
17.	H03 - 52/6	White	Pyramidal	Loose	Mid	Medium	Medium	Absent
18.	H03 - 52/5	White	Pyramidal	Loose	Mid	Medium	Medium	Absent
19.	H03 -21/10	Cream	Pyramidal	Loose	Early	Long	Long	Present

Table 7. Contd. Qualitative inflorescence characters of cashew hybrids and its parents

Sl. No.	Hybrid name	Flower colour	Inflorescence shape	Compactness of inflorescence	Season of flowering	Flowering duration	Harvesting duration	Secondary flowering
20.	Dhana	Cream	Pyramidal	Loose	Mid	Medium	Medium	Absent
21.	Madakkathara -1	Cream	Pyramidal	Loose	Early	Medium	Medium	Present
22.	Priyanka	Cream	Pyramidal	Loose	Mid	Short	Short	Absent
23.	Anakkayam -1	Cream	Pyramidal	Loose	Early	Short	Medium	Present
24	Amrutha	Cream	Broadly pyramidal	Loose	Mid	Medium	Medium	Absent
25.	VRI– 3	Cream	Pyramidal	Loose	Early	Long	Medium	Absent
26.	Sulabha	Cream	Pyramidal	Loose	Late	Short	Short	Absent
27.	Poornima	Cream	Pyramidal	Loose	Early	Long	Long	Present
28.	K-22-1	Cream	Pyramidal	Loose	Mid	Medium	Medium	Absent
29.	Dharasree	Cream	Pyramidal	Loose	Mid	Medium	Medium	Absent
30.	Damodar	Cream	Pyramidal	Loose	Mid	Medium	Medium	Absent

Apple shape was conical obovate in 16 hybrids and seven parents, while apples of hybrids, H03-36/8, H03-95/4, H03-18/17 and variety, Priyanka were cylindrical. Varieties, Dhana, Vridhachalam-3 and K-22-1 produced round shaped cashew apples (Table 8). Broken ridges were observed on the cashew apples of 18 hybrids and 10 parents, but it was entire in the hybrid, H03-52/7. Ridges were absent on variety, Dhana. Apex of cashew apple was levelled in majority of the genotypes evaluated. The fruits of H03-18/17 and H03-52/5 had oblique apex. Grooves on apex was absent in H03-52/5, H03-55/10 and H03-110/3 whereas shallow grooves were observed in all other hybrids and parents. Fourteen cashew hybrids and 9 parents showed shallow cavity at apex of apple. But it was absent in the hybrids, H03-55/10, H03-55/11, H03-52/7, H03-52/6, H03-52/5 and parents, Vridhachalam-3, Dharasree. Hybrids, H03-55/11, H03-55/10, H03-52/7, H03-52/6, H03-52/5 and parents, Dhana, Madakkathara-1, Amrutha were having smooth and glossy of cashew apple.

4.1.1.5. Nut characters

Nuts were kidney shaped in all the genotypes of cashew under study. Colour of mature nut shell was buff in all hybrids and parents except in three hybrids. The nuts were grey coloured in H03-52/6, H03-52/5 and H03-110/2. Nuts were loosely attached to apples in majority of hybrids and cross parents. In hybrids, H03-55/10 and H03-52/6, nuts were tightly attached to apples. Obliquely flattened nut base was present in H03-52/7, H03-52/6 and H03-52/5. The base of nut was round shaped in H03-53/9 and H03-18/17. Other hybrids and parents showed flattened nut base (Plate 4).

Suture of nut was angular in all hybrids except H03-55/10 (Round). Flanks of nut was round in 11 hybrids and 6 parents. Large sized stylar scar was present on the nuts of hybrids, H03-36/8, H03-53/9, H03-110/1, H03-18/17, H03-52/7, H03-21/10 and variety, Priyanka. Nut apex was pointed in the hybrids, H03-52/6, H03-52/5, H03-110/3, H03-92/3, H03-36/8, H03-55/10, H03-18/17 and H03-110/1 while intermediate in H03-55/11, H03-57/4, H03-95/8, H03-111/2 and H03-21/10, and round in rest of the hybrids. Except in two hybrids viz., H03-52/7 and H03-52/5, all other hybrids and varieties have suture in line with the apex.

4.1.2. Clustering based on qualitative characters

Agglomerative hierarchical clustering was performed based on the Jaccard's similarity coefficient using the UPGMA method with 30 qualitative characters and dendrogram was constructed (Fig.1). This clustering was done to identify the similarity between hybrids and parents with respect to qualitative characters.

Table 8. Qualitative cashew apple characters of hybrids and its parents

Sl. No.	Hybrids/ parents	Apple colour	Apple shape	Shape of apple base	Ridges on apple	Cashew apple apex	Grooves on apex of apple	Cavity at apex of apple	Skin of cashew apple
1.	H03 - 36/8	Yellow red	Cylindrical	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
2.	H03 - 55/11	Yellow	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Smooth and glossy
3.	H03 - 55/10	Yellow	Conical-obovate	Flattened	Broken	Level	Absent	Absent	Smooth and glossy
4.	H03 - 53/9	Red	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
5.	H03 - 57/4	Yellow red	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
6.	H03 - 92/3	Yellow	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
7.	H03 - 95/8	Red purple	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
8.	H03 - 97/2	Yellow	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
9.	H03 - 110/1	Red	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
10.	H03 - 110/2	Red	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
11.	H03 - 110/3	Yellow	Conical-obovate	Flattened	Broken	Level	Absent	Absent	Rough and dull
12.	H03 - 111/2	Yellow	Conical-obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
13.	H03 - 113/1	Red	Conical-obovate	Angular	Broken	Level	Shallow	Shallow	Rough and dull
14.	H03 - 95/4	Yellow red	Cylindrical	Flattened	Broken	Level	Shallow	Absent	Rough and dull
15.	H03 - 18/17	Yellow red	Cylindrical	Angular	Broken	Oblique	Shallow	Absent	Rough and dull
16.	H03 - 52/7	Yellow	Conical obovate	Rounded	Entire	Level	Shallow	Shallow	Smooth and glossy
17.	H03 - 52/6	Yellow	Conical obovate	Angular	Broken	Level	Shallow	Shallow	Smooth and glossy
18.	H03 - 52/5	Yellow	Conical obovate	Rounded	Broken	Oblique	Absent	Absent	Smooth and glossy
19.	H03 -21/10	Yellow red	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull

Table 8. Contd. Qualitative cashew apple characters of hybrids and its parents

Sl. No.	Hybrids/ parents	Apple colour	Apple shape	Shape of apple base	Ridges on cashew apple	Cashew apple apex	Grooves on apex of apple	Cavity at apex of apple	Skin of cashew apple
20.	Dhana	Yellow	Round	Rounded	Absent	Level	Shallow	Shallow	Smooth and glossy
21.	Madakkathara -1	Yellow	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Smooth and glossy
22.	Priyanka	Yellow red	Cylindrical	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
23.	Anakkayam-1	Yellow	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
24.	Amrutha	Yellow	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Smooth and glossy
25.	VRI– 3	Red	Round	Flattened	Broken	Level	Shallow	Absent	Rough and dull
26.	Sulabha	Yellow red	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
27.	Poornima	Yellow	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
28.	K-22-1	Red	Round	Flattened	Broken	Level	Shallow	Shallow	Rough and dull
29.	Dharasree	Yellow red	Conical obovate	Flattened	Broken	Level	Shallow	Absent	Rough and dull
30.	Damodar	Yellow red	Conical obovate	Flattened	Broken	Level	Shallow	Shallow	Rough and dull

Table 9. Qualitative nut characters of cashew hybrids and its parents

Sl. No.	Hybrids/ parents	Shape of nut	Colour of mature nut shell	Attachment of nut to apple	Shape of nut base	Suture of nut	Flanks of nut	Stylar scar on nut	Shape of nut apex	Relative position of suture and apex
1.	H03 - 36/8	Kidney	Buff	Loose	Flattened	Angular	Round	Large	Pointed	Line with apex
2.	H03 - 55/11	Kidney	Buff	Intermediate	Flattened	Angular	Round	Small	Intermediate	Line with apex
3.	H03 - 55/10	Kidney	Buff	Tight	Flattened	Round	Flattened	Small	Pointed	Line with apex
4.	H03 - 53/9	Kidney	Buff	Intermediate	Round	Angular	Round	Large	Round	Line with apex
5.	H03 - 57/4	Kidney	Buff	Loose	Flattened	Angular	Flattened	Small	Intermediate	Line with apex
6.	H03 - 92/3	Kidney	Buff	Loose	Flattened	Angular	Flattened	Small	Pointed	Line with apex
7.	H03 - 95/8	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Intermediate	Line with apex
8.	H03 - 97/2	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Round	Line with apex
9.	H03 - 110/1	Kidney	Buff	Loose	Flattened	Angular	Flattened	Large	Pointed	Line with apex
10.	H03 - 110/2	Kidney	Grey	Loose	Flattened	Angular	Round	Small	Round	Line with apex
11.	H03 - 110/3	Kidney	Buff	Loose	Flattened	Angular	Flattened	Small	Pointed	Line with apex
12.	H03 - 111/2	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Intermediate	Line with apex
13.	H03 - 113/1	Kidney	Buff	Intermediate	Flattened	Angular	Flattened	Small	Round	Line with apex
14.	H03 - 95/4	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Round	Line with apex
15.	H03 - 18/17	Kidney	Buff	Intermediate	Round	Angular	Round	Large	Pointed	Line with apex

Table 9. Contd. Qualitative nut characters of cashew hybrids and its parents

Sl. No.	Hybrids/ Parents	Shape of nut	Colour of mature nut shell	Attachment of nut to apple	Shape of nut base	Suture of nut	Flanks of nut	Stylar scar on nut	Shape of nut apex	Relative position of suture and apex
16.	H03 - 52/7	Kidney	Buff	Intermediate	Obliquely flattened	Angular	Flattened	Large	Round	Behind Apex
17.	H03 - 52/6	Kidney	Grey	Tight	Obliquely flattened	Angular	Round	Small	Pointed	Line with apex
18.	H03 - 52/5	Kidney	Grey	Intermediate	Obliquely flattened	Angular	Flattened	Small	Pointed	Behind apex
19.	H03 -21/10	Kidney	Buff	Loose	Flattened	Angular	Round	Large	Intermediate	Line with apex
20.	Dhana	Kidney	Buff	Intermediate	Flattened	Angular	Round	Small	Intermediate	Line with apex
21.	Madak -1	Kidney	Buff	Intermediate	Flattened	Angular	Flattened	Small	Intermediate	Line with apex
22.	Priyanka	Kidney	Buff	Loose	Flattened	Angular	Flattened	Large	Round	Line with apex
23.	Anak-1	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Intermediate	Line with apex
24.	Amrutha	Kidney	Buff	Intermediate	Flattened	Angular	Round	Small	Intermediate	Line with apex
25.	VRI– 3	Kidney	Buff	Loose	Flattened	Angular	Flattened	Small	Intermediate	Line with apex
26.	Sulabha	Kidney	Buff	Loose	Flattened	Angular	Flattened	Small	Pointed	Line with apex
27.	Poornima	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Intermediate	Line with apex
28.	K-22-1	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Intermediate	Line with apex
29.	Dharasree	Kidney	Buff	Loose	Flattened	Angular	Flattened	Small	Intermediate	Line with apex
30.	Damodar	Kidney	Buff	Loose	Flattened	Angular	Round	Small	Round	Line with apex

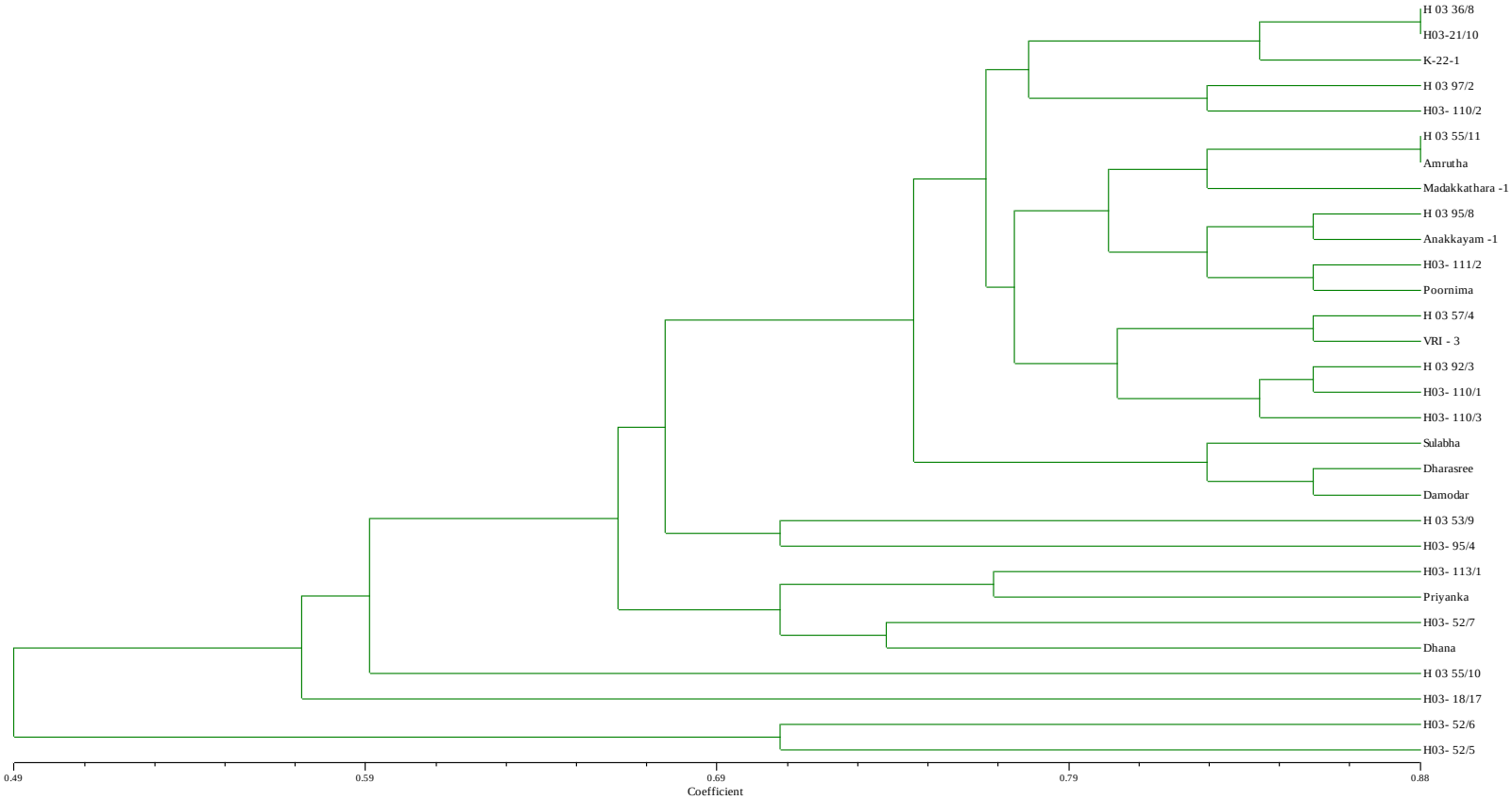


Fig.1.Dendrogram depicting genetic relationship among cashew varieties based on morphological characters using Dice's dissimilarity coefficient

Yellow red

Red

Colour of young leaves

Oblong Obovate oblong Oval

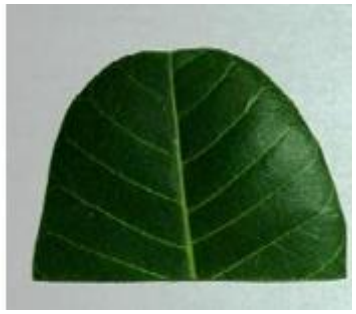
Leaf shape

Pointed

Rounded

Indented

Apex of leaf



Level

Reflexed

Incurved

Cross section of leaf

Plate 1. Variations in qualitative leaf characters

Pyramidal

Bi Pyramidal

Inflorescence shape

Loose

Compact

Compactness of inflorescence

White

Cream

Flower colour

Plate 2. Variations in qualitative floral characters

Yellow Yellow-red Red Purple red

Apple colour

Broken Entire

Ridges on cashew apple

Cylindrical Conical- obovate Round

Apple shape

Flattened Obliquely Flattened

Shape of apple base

Plate 3. Variations in qualitative apple characters

Infront of apex Line with apex Behind the apex

Relative position of suture and apex

Round Flattened

Flanks of nut

Flattened Rounded Obliquely flattened

Shape of nut base

Rounded Angular

Suture of nut

Plate 4. Variations in qualitative nut characters

The cashew hybrids and parents used in the present study were grouped into six clusters at 70 per cent similarity level. The six clusters obtained along with the genotypes included in each cluster are presented in figure 1. Among six clusters, cluster I was the biggest with 20 genotypes of cashew including 11 hybrids and 9 parents. Cluster II and IV contains two hybrids each. Hybrids, H03-113/1 and H03-52/7, were grouped in cluster III along with the varieties, Priyanka and Dhana. A single hybrid was included in cluster IV and V, H03-55/10 and H03-18/17, respectively.

4.1.3. Quantitative evaluation

Analysis of variance was carried out for each of the 25 quantitative characters observed in 19 cashew hybrids and 11 cross parents. Six quantitative characters viz., tree height, girth, canopy spread, sex ratio, tree yield, and number of nuts per kilogram were not analyzed statistically as the study only a preliminary evaluation of hybrids developed. All the characters showed significance difference among the genotypes.

4.1.3.1. Tree characters

Quantitative characters of tree like height, girth and canopy spread are presented in Table 10. Tree height of hybrids ranged from 6.25 m in H03-55/10 to 10.53 m in H03-52/5 and parents from 5.80 m (K-22-1) to 9.90 m (Damodar). In the hybrid population, maximum tree girth was observed for H03-36/8 (2.75m) followed by H03-52/6 (2.0m) and minimum in H03-55/10 (1.0m). Considerable variation was observed with respect to canopy spread among the hybrids and parents studied (Table 10). Maximum spread was recorded in H03-111/2 (14.35m) followed by H03-110/1(m) and minimum in H03-55/10(6.80m). Among the cross parents, maximum canopy spread was exhibited by Dharasree (10.7m) and minimum in Anakayam-1 (4.75m).

4.1.3.2. Growth parameters

Growth parameters like internodal length and diameter, leaf size and number of leaves per twig were also observed and mean values are given in Table 11. The internodal length of twig ranged from 1.31 to 2.35 cm. The lowest intermodal length was observed in the hybrids, H03 -18/17 (1.31cm), H03-52/6 (1.34cm), H03 95/4 (1.40cm), and parent, Priyanka (1.63cm). The highest internodal length was observed in the parents, K22-1 (2.35cm) and Sulabha (2.34cm) followed by the hybrid, H03-95/8 (2.30cm). Out of 19 hybrids and 11 parents evaluated, 14 genotypes were intermediate in intermodal length (1.0-2.0cm), 16 were having high internodal length (>2cm). All the hybrids and parents were having intermediate internode diameter ranging from 5.21 mm (H03-36/8) to 8.40 mm (H03-53/9).

The number of leaves per twig was the highest in hybrid H03-36/8 (17.10cm) and lowest in H03- 113/1 (9.70), H03-111/2 (9.40) and Priyanka (9.40). All the hybrids and parents were having medium number of leaves per twig (9-19). The leaf area was calculated from the length and breadth of leaves and expressed as leaf size. Leaf area ranged from 103.68 cm^2 (H03-55/10 and Dharasree) to 167.71cm^2 (H03-36/8). Four hybrids were having intermediate leaf size (60-120 cm^2) while, 15 hybrids produced large sized leaves (>120 cm^2).

4.1.3.3. Inflorescence characters

The mean values of inflorescence characters *viz.*, number of laterals and panicles per square meter, inflorescence size as panicle length and panicle width and number of bisexual and male flowers are presented in Table 12.

The number of flowering laterals per square meter varied from 8.00 to 15.25. The highest number of flowering laterals per square metre was produced by variety, Poornima (15.25) and Dharasree (15.25) followed by H03-97/2 and H03-52/5(13.75 each). In the samples studied, hybrids, H03-97/2 (17.75), H03-55/11(16.15) and parents, Poornima and Dharasree ((17.75) showed the highest number of panicles per square meter.

Table 10. Quantitative tree characters of cashew hybrids and its parents

Hybrids/parent	Tree height(m)	Tree girth(m)	Canopy spread(m)
H03-36/8	7.30	2.75	10.45
H03 - 55/11	6.45	1.15	8.25
H03 - 55/10	6.25	1.00	6.80
H03 - 53/9	8.20	1.50	11.75
H03 - 57/4	7.60	1.40	10.75
H03 - 92/3	7.00	1.40	12.30
H03 - 95/8	8.00	1.40	10.95
H03 - 97/2	10.50	1.60	13.50
H03 - 110/1	8.90	1.45	13.75
H03 - 110/2	8.30	1.40	12.95
H03 - 110/3	8.40	1.10	8.90
H03 - 111/2	8.40	1.60	14.35
H03 - 113/1	8.50	1.30	11.40
H03 - 95/4	7.60	1.20	10.30
H03 - 18/17	8.30	1.38	11.25
H03 - 52/7	8.35	1.35	12.75
H03 - 52/6	9.70	2.00	10.95
H03 - 52/5	10.53	1.40	12.75
H03 -21/10	7.35	1.30	12.35
Dhana	6.50	1.30	6.90
Madak-1	6.90	1.40	7.00
Priyanka	7.50	1.60	8.75
Anak -1	6.30	1.30	4.75
Amrutha	6.40	1.50	6.45
VRI– 3	5.90	1.60	6.15
Sulabha	6.90	1.90	6.65
Poornima	7.00	1.50	6.95
K-22-1	5.80	1.50	6.45
Dharasree	9.70	1.70	10.70
Damodar	9.90	1.60	10.60

Table 11. Quantitative growth parameters of cashew hybrids and its parents

Hybrids/parent	Internode length(cm)	Internode diameter(mm)	No. of leaves per twig	Leaf size(cm^2)
H03-36/8	1.81^{h}	5.21^{m}	17.10^{a}	167.71^{a}
H03 - 55/11	1.62^{i}	7.67^{abcd}	13.80^{cd}	158.60^{abc}
H03 - 55/10	2.06^{ef}	7.49^{abcdef}	14.55^{bc}	103.68^{h}
H03 - 53/9	1.58^{i}	8.40^{a}	10.20^{jkl}	138.84^{abcdef}
H03 - 57/4	2.18^{bcde}	7.52^{abcde}	11.05^{hijk}	125.58^{defgh}
H03 - 92/3	2.08^{ef}	$6.69^{defghijk}$	15.60^{b}	119.95^{defgh}
H03 - 95/8	2.30^{ab}	$7.06^{cdefghi}$	11.85^{efgh}	135.12^{bcdefg}
H03 - 97/2	2.16^{bcde}	8.17^{ab}	14.40^{bc}	148.37^{abcd}
H03 - 110/1	1.63^{i}	$6.82^{defghij}$	13.60^{cd}	163.02^{ab}
H03 - 110/2	2.26^{abc}	$6.57^{efghijkl}$	12.70^{defg}	144.27^{abcd}
H03 - 110/3	2.28^{abc}	$7.39^{abcdefg}$	11.25^{hijk}	141.50^{abcde}
H03 - 111/2	2.26^{abc}	6.13^{Ijklm}	9.40^{l}	106.55^{gh}
H03 - 113/1	2.17^{bcde}	6.3^{hijkl}	9.70^{l}	128.39^{cdefgh}
H03 - 95/4	1.40^{j}	7.51^{abcde}	10.45^{ijkl}	159.59^{ab}
H03 - 18/17	1.31^{j}	5.995^{Jklm}	10.05^{kl}	163.36^{a}
H03 - 52/7	1.59^{i}	5.57^{lm}	10.70^{hijkl}	140.90^{abcde}
H03 - 52/6	1.34^{j}	5.90^{klm}	10.00^{kl}	125.29^{defgh}
H03 - 52/5	1.82^{gh}	6.07^{Ijklm}	11.50^{ghij}	120.74^{defgh}
H03 -21/10	1.60^{i}	5.59^{lm}	10.55^{hijkl}	106.54^{gh}
Dhana	2.10^{def}	6.37^{ghijkl}	10.35^{ijkl}	145.23^{abcd}
Madak-1	2.14^{cde}	5.96^{Jklm}	11.55^{ghi}	109.37^{fgh}
Priyanka	1.63^{i}	$6.97^{cdefghij}$	9.40^{l}	160.75^{ab}
Anak -1	2.08^{ef}	$6.48^{efghijkl}$	12.95^{def}	126.35^{defgh}
Amrutha	2.24^{abcd}	6.35^{ghijkl}	11.65^{fghi}	121.32^{defgh}
VRI– 3	2.28^{abc}	$6.45^{fghijkl}$	11.65^{fghi}	148.49^{abcd}
Sulabha	2.34^{a}	6.31^{hijkl}	11.50^{ghij}	108.05^{fgh}
Poornima	1.69^{hi}	6.33^{hijkl}	13.40^{cd}	106.31^{gh}
K-22-1	2.35^{a}	$6.72^{defghijk}$	13.05^{de}	111.52^{efgh}
Dharasree	1.97^{fg}	$7.31^{bcdefgh}$	10.55^{hijkl}	100.66^{h}
Damodar	1.81^{h}	8.02^{abc}	10.70^{hijkl}	109.28^{fgh}
C.V(%)	5.632	11.18	7.998	16.656
SE(m)	0.012	0.562	0.897	480.96
S.E.(d)	0.077	0.53	0.67	15.51

Length of panicles varied greatly among the hybrids and parents studied (Table 12). The lowest panicle length of 15.22 cm was recorded by hybrid H03 55/10. The highest panicle length of 26.3 cm was observed in H03-92/3 followed by hybrids H03-95/8(26.05cm) and H03-97/2 (25.78cm). Panicle width ranged from 18.99cm to 26.63cm (Table 12). The highest panicle width was recorded in H03-110/3(26.63cm) and H03-97/2(26.59cm). The panicle width of hybrid, H03-92/3 (26.3cm) was on par. The lowest panicle width of 18.99 cm was recorded in the hybrid, H03-52/5.

Significant variation was observed among the Parents and hybrids in number of bisexual flowers. Number of bisexual flowers ranged from 39.75 (H03-95/8 and Amrutha) to 91.25 (H03-52/6). Among the cross parents, Poornima (85.0) showed the highest number of bisexual flowers. It was observed that hybrids and Parents varied with respect to total number of male flowers per panicle. The number of male flowers showed a range of 406.75 (H03-55/10) to 787.0 (H03-97/2). In case of parents, greater number of male flowers were produced by Poornima (680.0) followed by Amrutha (606.50).

The sex ratio, the ratio of number of bisexual flowers to the number of flowers, in hybrids and parents under investigation ranged from 0.048 to 0.116. The hybrid, H03-52/5 (0.131) recorded the highest sex ratio followed by H03-52/7(0.127), Poornima (0.125), H03-21/10 (0.121), Madakkathara-1 (0.117) and H03-55/10 (0.113).

Table 12. Quantitative inflorescence characters of cashew hybrids and parents

Hybrids/ parents	No. of laterals/m^2	No. of panicles/ m^2	Panicle length(cm)	Panicle width(cm)	No. of bisexual flowers	No. of male flowers	Sex ratio
H03-36/8	$10.50^{bcdefghi}$	$13.00^{cdefghi}$	21.65^{defg}	24.98^{abcde}	68.00^{cdef}	662.25^{cdef}	0.103
H03- 55/11	13.50^{abc}	16.75^{a}	22.15^{cdef}	24.89^{abcde}	60.50^{defg}	569.75^{defghi}	0.106
H03-55/10	8.50^{ghi}	10.25^{hi}	15.22^{q}	23.77^{defg}	46.00^{ghi}	406.75^{j}	0.113
H03-53/9	12.25^{abcde}	15.00^{abcde}	19.70^{ghij}	21.77^{hijk}	53.25^{fghi}	647.75^{bcdef}	0.082
H03-57/4	$10.25^{cdefghi}$	$12.75^{cdefghi}$	24.05^{bc}	21.06^{ijklm}	47.75^{ghi}	522.75^{fghij}	0.091
H03-92/3	$10.75^{bcdefghi}$	$12.75^{cdefghi}$	26.30^{a}	26.3^{ab}	77.75^{abc}	701.00^{cd}	0.110
H03-95/8	$10.50^{bcdefghi}$	$13.50^{bcdefgh}$	26.05^{ab}	26.135^{abc}	39.75^{i}	473.25^{hij}	0.083
H03-97/2	13.75^{ab}	17.75^{a}	25.78^{ab}	26.590^{a}	53.50^{fghi}	787.00^{a}	0.067
H03-110/1	12.75^{abcde}	15.25^{abcd}	22.25^{cde}	26.01^{abc}	57.25^{efgh}	564.75^{defghi}	0.101
H03-110/2	$10.50^{bcdefghi}$	13.75^{bcdefg}	$17.73^{jklmnop}$	25.39^{abcd}	70.50^{bcde}	644.50^{bcdefg}	0.109
H03-110/3	12.00^{abcdef}	13.75^{bcdefg}	21.08^{defgh}	26.63^{a}	57.25^{efgh}	609.75^{cdefgh}	0.102
H03-111/2	$11.50^{bcdefgh}$	14.00^{bcdef}	19.35^{hijk}	23.50^{efgh}	53.00^{fghi}	$591.50^{cdefghi}$	0.089
H03-113/1	12.25^{abcde}	14.00^{bcdef}	16.13^{pq}	22.15^{ghij}	42.25^{hi}	489.75^{hij}	0.086
H03-95/4	8.50^{ghi}	10.25^{hi}	17.39^{klmnop}	19.80^{lmn}	56.75^{efgh}	778.00^{b}	0.072
H03-18/17	11.75^{bcdefg}	15.25^{abcd}	23.00^{cd}	19.77^{lmn}	47.25^{ghi}	666.25^{bcdef}	0.070
H03-52/7	$11.00^{bcdefghi}$	$13.50^{bcdefgh}$	18.75^{ijklm}	20.12^{klmn}	85.25^{ab}	670.75^{bcde}	0.127
H03-52/6	8.00^{I}	9.75^{i}	17.30^{lmnop}	19.30^{mn}	91.25^{a}	716.50^{bc}	0.123
H03-52/5	13.75^{ab}	16.00^{abc}	20.80^{efgh}	18.99^{n}	74.50^{abcd}	564.75^{defghi}	0.131
H03-21/10	8.25^{hi}	$13.50^{bcdefgh}$	$17.80^{jklmnop}$	24.45^{cdef}	86.00^{ab}	707.75^{bcd}	0.121
Dhana	9.50^{efghi}	11.50^{fghi}	16.72^{nopq}	21.30^{ijkl}	46.50^{ghi}	466.50^{hij}	0.099
Madak -1	12.75^{abcde}	13.75^{bcdefg}	$18.35^{ijklmno}$	20.01^{klmn}	59.00^{defgh}	500.75^{ghij}	0.117
Priyanka	8.75^{fghi}	10.50^{ghi}	20.15^{fghi}	22.88^{fghi}	48.75^{ghi}	501.75^{ghij}	0.097
Anak-1	$10.50^{bcdefghi}$	12.00^{defghi}	16.55^{opq}	24.52^{bcdef}	51.50^{fghi}	523.25^{fghij}	0.098
Amrutha	8.75^{fghi}	10.25^{hi}	16.95^{mnopq}	20.71^{jklmn}	39.75^{i}	606.50^{cdefgh}	0.068
VRI -3	13.25^{abcd}	$13.50^{bcdefgh}$	17.05^{mnopq}	19.60^{lmn}	46.25^{ghi}	552.75^{efgh}	0.083
Sulabha	10.00^{defghi}	11.75^{efghi}	18.60^{ijklmn}	21.10^{ijklm}	43.75^{ghi}	452.00^{ij}	0.096
Poornima	15.25^{a}	17.75^{a}	19.32^{hijk}	22.44^{ghij}	85.00^{ab}	680.00^{bcde}	0.125
K-22-1	$11.00^{bcdefghi}$	13.75^{bcdefg}	19.07^{hijkl}	19.70^{lmn}	55.25^{efghi}	568.75^{defghi}	0.097
Dharasree	15.25^{a}	17.50^{a}	$18.29^{ijklmno}$	20.05^{klmn}	57.75^{defgh}	537.00^{efghij}	0.107
Damodar	10.00^{defghi}	12.00^{defghi}	17.41^{klmnop}	22.26^{ghij}	58.00^{defgh}	$572.50^{cdefghi}$	0.101
C.V(%)	20.75	17.37	7.28	7.27	20.60	17.20	
SE(m)	5.38	5.50	2.05	2.05	144.47	10784.46	
SE(d)	1.64	1.66	1.01	1.01	8.49	73.43	

4.1.3.4. Apple and nut characters

The quantitative characters of apple and nut of the hybrids and varieties are given as Table 13. The apple weight was the highest in Priyanka (137.49g) followed by hybrid, H03 52/5 (120.82g). The lowest apple weight of 16.83 g was recorded by hybrid, H03 55/10. Eleven hybrids and 8 parents were grouped under high apple weight group with an apple weight more than 52g. Seven Hybrids and three parents were included in the medium weight group (27-52g). Only one hybrid, H03-55/10, recorded low apple weight of 16.83g. The apple to nut ratio was the highest in hybrid, H03-52/5(11.36) followed by parent, Priyanka (11.07). The lowest apple to nut ratio of 3.63 was recorded by hybrid, H03-55/10 (Table 13). The genotypes can be grouped as high, medium and low based on apple to nut ratio. Fourteen hybrids and all parents were identified as medium apple to nut ratio genotypes with an apple to nut ratio of 6 to 12. Five hybrids were included in the low apple to nut ratio group (<6). None of the hybrids and parents recorded high apple to nut ratio (>12).

The quantitative characters of nuts showed significance difference among the cashew genotypes evaluated (Table 13). The number of nuts per panicle, varied from 1.25 to 5.20. The highest nuts per panicle was present in parents, Anakkayam-1(5.20) and Madakkathara-1 (5.10). The nuts per panicle in the hybrids, H03-55/10(4.55), H03-113/1 (4.65) and variety Poornima (4.35) were on par.

Nut dimensions varied significantly among the hybrids and parents. The nut length ranged from 2.42cm to 3.92cm. This character was the highest in hybrids, H03-95/4(3.92cm), H03-21/10 (3.89cm), H03-18/17 (3.96cm) and variety, Priyanka (3.87cm). The lowest nut length of 2.42cm was recorded by hybrid, H03-55/10. Considerable variation was noticed among hybrids and varieties with respect to nut width. The highest nut width was recorded in H03-21/10 (3.20cm), H03-110/1 (3.17cm) and H03-18/17 (3.17cm). Nut width was the lowest for hybrid, H03-55/10 (2.10cm). Nut thickness ranged from 1.69 to 2.48cm. The highest nut thickness was shown by hybrids, H03-21/10 (2.48cm), H03-95/4 (2.46cm) and H03-113/1 (2.47cm). Lowest nut thickness was noticed in H03-55/10. For the parents, the nut thickness was in the range of 2.04cm (Priyanka) to 1.51cm (Vridhachalam-3) (Plate 7 and 8).

A significant variation in nut weight was noticed among hybrids and parents (Table 13). The average nut weight varied from 4.64g to 12.55g. The highest nut weight was observed in hybrids, H03 21/10 (12.55g), H03 18/17 (12.49g) and H03 95/4 (12.44g). The lowest nut weight was recorded by hybrid, H03 55/10 (4.64g) and parents, Madakkathara-1 (6.31g), Anakkayam -1 (5.91g) and K-22-1 (6.40g). The Average nut weight of above 10 g was noticed in ten hybrids *viz.*H03-21/10(12.55g), H03-18/17 (12.49), H03-95/4 (12.44), H03-110/1 (11.18), H03-36/8 (10.23) H03-52/5 (10.40), H03-52/6 (10.17g), H03-52/7 (10.21), H03-97/2(10.10) and parent, Priyanka (11.10g) and can be grouped under bold nut types. The hybrids, H03-21/10 (12.55g), H03-18/17 (12.49g), H03-95/4 (12.44), H03-110/1 (11.18g), H03-36/8 (10.23g), H03-52/5 (10.40g), H03-95/8 (10.37g), H03-52/7 (10.21g), H03-97/2 (10.10g), H03-113/1 (9.45g), H03-55/11 (8.4g), H03-92/3 (7.89g), (H03-57/4 (7.87g), and parents, Sulabha (9.90g), Dhana (8.49g), Poornima (7.90g), Damodar (7.72g), Dharasree (7.52g), Amrutha (7.32g), Vridhachalam-3 (7.30g) recorded a nut weight of more than 7g and can be grouped as high nut weight types. Hybrid, H03-110/2 (6.37g) and parents, K-22-1 (6.40g), Madakkathara-1 (6.31g), Anakkayam-1 (5.91g) recorded nut weight in the range 5-7g and represented the group intermediate nut weight types (5-7 g). Only one hybrid falls in the low nut weight group H03-55/10 (4.64g).

The nut yield of nineteen hybrids and eleven parents for the year 2020-2021 are given in table 13. Nut yield above 18 kg tree^{-1} was recorded in six hybrids, H03-21/10 (25.20 kg), H03-97/2 (24.50 kg), H03-110/1 (23.40 kg), H03-36/8 (22.10 kg), H03-92/3 (20.20kg), H03-52/5 (21.60 kg) and parent, Amrutha(21.30kg) and check variety, Poornima (20.0 kg) and these can be considered as high yielders as per descriptor (Nayak *et al*., 2014). Six hybrids (H03-52/7, H03-52/6, H03-110/2, H03-55/10, H03-95/8, H03-113/1, H03-111/2) and 7 parents (Madakathara-1, Vridhachalam-3, Anakayam-1, Dharasree, Sulabha, K-22-1 and Damodar) having nut yield of 9-18 kgtree^{-1} were considered as medium yielders. The hybrids, H03-95/4 (2.1 kg), H03-18/17 (3.1 kg) H03 57/4 (6.5kg) and parents, Dhana (8.2kg) and Priyanka (6.4kg) were identified as low yielder (nut yield below 9kg). Variation in nuts per kilogram was prominent among hybrids and parents studied (Table 13). Lowest no. of nuts per kilogram was recorded in hybrids, H03-21/10 (90), H03-18/17

(93), H03-95/4 (95), H03-110/1 (101) and parent, Priyanka (100). The hybrids, H03-55/10 (198), H03-110/2 (180), H 03 110/3 (160) and parent Anakayam-1 (173) and Madakkathara-1 (168), K22-1 (165) recorded the highest number of nuts per kilogram.

4.1.3.5. Kernel characters

The dimensions of kernel, shelling percentage and export grades of hybrids and cross parents are presented as Table 14. Kernel length differed significantly among hybrids and parents. This character was the highest in hybrid, H03-18/17(3.20cm) and parent, Priyanka (3.19cm). The hybrids, H03-21/10 (3.16cm) and H03-110/1 (3.17cm) were on par. The lowest nut length was expressed in the hybrids, H03-55/10 (2.23cm) and Madakkathara-1 (2.19cm). Kernel width also showed considerable variation among hybrids and their parents. Significantly high kernel width was observed in the hybrids, H03-95/4 (2.12cm), H03-21/10 (2.09cm) and H03-52/7 (2.07cm). Significantly lower kernel width of 1.25cm was seen in hybrid, H03-55/10 and variety, Amrutha (1.26cm). Kernel thickness ranged from 1.12 to 2.12cm. The highest kernel thickness was shown by hybrids, H03-95/4 (2.12cm) and H03-52/7 (2.07cm) and the lowest kernel thickness by H03-53/9 (1.12cm). Shell thickness ranged from 0.18mm (H03-36/8) to 0.30mm (H03-110/1). Priyanka exhibited maximum shell thickness among the parents (0.29mm) (Plate 10).

Kernel weight per nut varied significantly among the hybrids and parents. The average kernel weight varied from 1.62 to 4.19g. The highest kernel weight of 4.19g was recorded by the hybrid, H03- 95/4. The lowest kernel weight was recorded by Madakkathara-1 (1.63g), Anakayam-1 (1.66g) and K22-1 (1.62g). The hybrids H03-95/4 (4.19g), H03-21/10 (3.66g), H03-110/1 (3.44g), H03-97/2 (3.12g), H03-52/5 (3.07g), H03- 52/6 (2.62g), H03-52/7 (3.02g), H03-113/1 (2.80g), H03-36/8 (2.90g), H03-95/8 (2.54g), H03-111/2 (2.50g), H 18/17 (2.94g) and parents, Priyanka (2.79g), Sulabha (2.62g) and Poornima (2.50g) recorded a kernel weight of more than 2.5g and represented as genotypes with high kernel weight.

Table 13. Quantitative apple and nut characters for cashew hybrids and its parents

Hybrids and parents	Apple weight (g)	Apple to nut ratio	Nuts per panicle	Nut length(cm)	Nut width(cm)	Nut thickness(cm)	Nut weight (g)	Tree yield (Kg)	No. of nuts per kg
H03 - 36/8	64.94^{fghijk}	6.15^{lmn}	2.80^{hijkl}	3.57^{cd}	2.84^{bcd}	2.10^{de}	10.23^{bc}	22.10	121
H0 - 55/11	56.95^{ijklm}	6.85^{jklm}	3.65^{cdefgh}	3.19^{jkl}	2.65^{def}	1.98^{efg}	8.40^{fg}	16.60	149
H0 - 55/10	16.83^{q}	3.63^{p}	4.55^{ab}	2.42^{r}	2.10^{i}	1.69^{l}	4.64^{j}	15.0	198
H03 - 53/9	37.34^{op}	4.73^{op}	4.10^{bcde}	3.27^{hijk}	3.02^{abc}	1.84^{ijk}	7.87^{fgh}	17.60	171
H03 - 57/4	62.10^{ghijkl}	6.69^{klm}	1.75^{mno}	3.24^{hijk}	2.69^{de}	1.96^{fgh}	9.30^{e}	6.50	153
H03 - 92/3	74.36^{defgh}	9.44^{cd}	3.90^{bcdefg}	3.21^{ijkl}	2.58^{defg}	1.86^{hij}	7.89^{fgh}	20.20	125
H03 - 95/8	90.08^{c}	8.78^{de}	3.50^{defghi}	3.40^{efg}	2.64^{def}	1.90^{ghi}	10.37^{cd}	14.50	110
H03 - 97/2	86.23^{cd}	8.71^{de}	3.40^{efghi}	3.50^{de}	3.00^{abc}	2.00^{efg}	10.1^{de}	24.50	128
H03- 110/1	79.10^{cde}	7.13^{hijkl}	3.20^{fghij}	3.70^{b}	3.17^{a}	2.25^{bc}	11.18^{b}	23.40	101
H03- 110/2	37.52^{op}	5.89^{mn}	3.00^{hijkl}	3.02^{mn}	2.35^{fghi}	1.73^{kl}	6.37^{i}	15.20	180
H03 - 110/3	41.94^{nop}	5.35^{no}	4.20^{bcde}	3.14^{ef}	2.66^{def}	1.98^{efg}	7.84^{gh}	17.60	160
H03 - 111/2	74.59^{defg}	8.77^{de}	3.35^{efghij}	3.16^{kl}	2.19^{hi}	2.19^{cd}	8.49^{f}	10.0	149
H03 - 113/1	56.17^{ijklm}	7.62^{fghijk}	4.65^{ab}	3.34^{fgh}	2.47^{efgh}	2.47^{a}	9.45^{e}	13.20	134
H03 - 95/4	66.00^{efghij}	5.35^{no}	1.65^{mnop}	3.92^{a}	3.12^{ab}	2.46^{a}	12.44^{a}	2.10	95
H03 - 18/17	107.80^{b}	8.68^{defg}	1.50^{nop}	3.96^{a}	3.17^{a}	2.26^{bc}	12.49^{a}	3.10	93
H03 - 52/7	67.57^{efghi}	6.71^{jklm}	2.15^{lmn}	3.63^{bc}	3.13^{ab}	2.06^{ef}	10.21^{cd}	16.50	115
H03 - 52/6	61.26^{hijkl}	6.055^{lmn}	2.50^{jklm}	3.25^{hijk}	2.72^{cde}	2.02^{ef}	10.17^{cd}	16.50	119
H03 - 52/5	120.82^{b}	11.36^{a}	2.25^{klmn}	3.55^{cd}	3.02^{abc}	2.34^{bf}	10.40^{cd}	21.60	110
H03 -21/10	80.93^{cd}	6.32^{lmn}	1.25^{op}	3.89^{a}	3.20^{a}	2.48^{a}	12.55^{a}	25.20	90
Dhana	59.27^{ijkl}	6.84^{jklm}	3.10^{ghijk}	2.85^{o}	2.43^{efgh}	1.82^{ijk}	8.40^{fg}	8.20	128
Madk-1	35.36^{p}	6.57^{klm}	5.10^{a}	2.50^{qr}	2.31^{ghi}	1.56^{m}	6.31^{i}	15.60	168
Priyanka	137.49^{a}	11.07^{ab}	0.80^{p}	3.87^{a}	2.85^{bcd}	2.04^{ef}	11.10^{b}	6.40	100
Anak-1	45.62^{mnop}	7.99^{efghi}	5.20^{a}	2.70^{p}	2.36^{fghi}	1.75^{jkl}	5.91^{i}	11.50	173
Amrutha	49.80^{lmno}	6.68^{klm}	3.35^{efghi}	2.94^{no}	2.51^{efg}	2.02^{ef}	7.32^{h}	21.30	145
VRI- 3	52.86^{klmn}	6.31^{lmn}	2.70^{ijkl}	2.57^{q}	2.49^{efgh}	1.51^{m}	7.30^{h}	13.69	142
Sulabha	74.82^{defg}	10.12^{bc}	1.65^{mnop}	3.32^{fghi}	2.60^{defg}	1.84^{ijk}	9.90^{de}	10.60	109
Poornima	77.96^{cdef}	8.15^{efgh}	4.35^{abcd}	3.29^{ghij}	3.14^{ab}	2.05^{ef}	7.90^{fgh}	20.0	120
K-22-1	62.96^{ghijk}	7.82^{efghij}	1.55^{nop}	3.10^{lm}	2.59^{defg}	1.90^{ghi}	6.40^{i}	10.20	165
Dharasree	53.16^{jklmn}	6.85^{ijklm}	4.05^{bcdef}	2.71^{p}	2.47^{efgh}	1.89^{hi}	7.52^{h}	11.20	134
Damodar	57.47^{ijklm}	7.55^{ghijk}	4.45^{abc}	2.70^{p}	2.46^{efgh}	1.99^{efg}	7.72^{h}	10.10	125
C.V(%)	14.109	11.02	19.471	2.456	8.045	4.143	11.405		
SE(m)_	87.531	0.405	0.369	0.006	0.047	0.007	0.638		
SE(d)	6.616	0.572	0.43	0.056	0.154	0.059	0.565		

Anakkayam-1

Madakkathara-1

H03-113/1

H03-55/10

H03-53/9

Plate 5. Cluster bearing cashew hybrids and parents

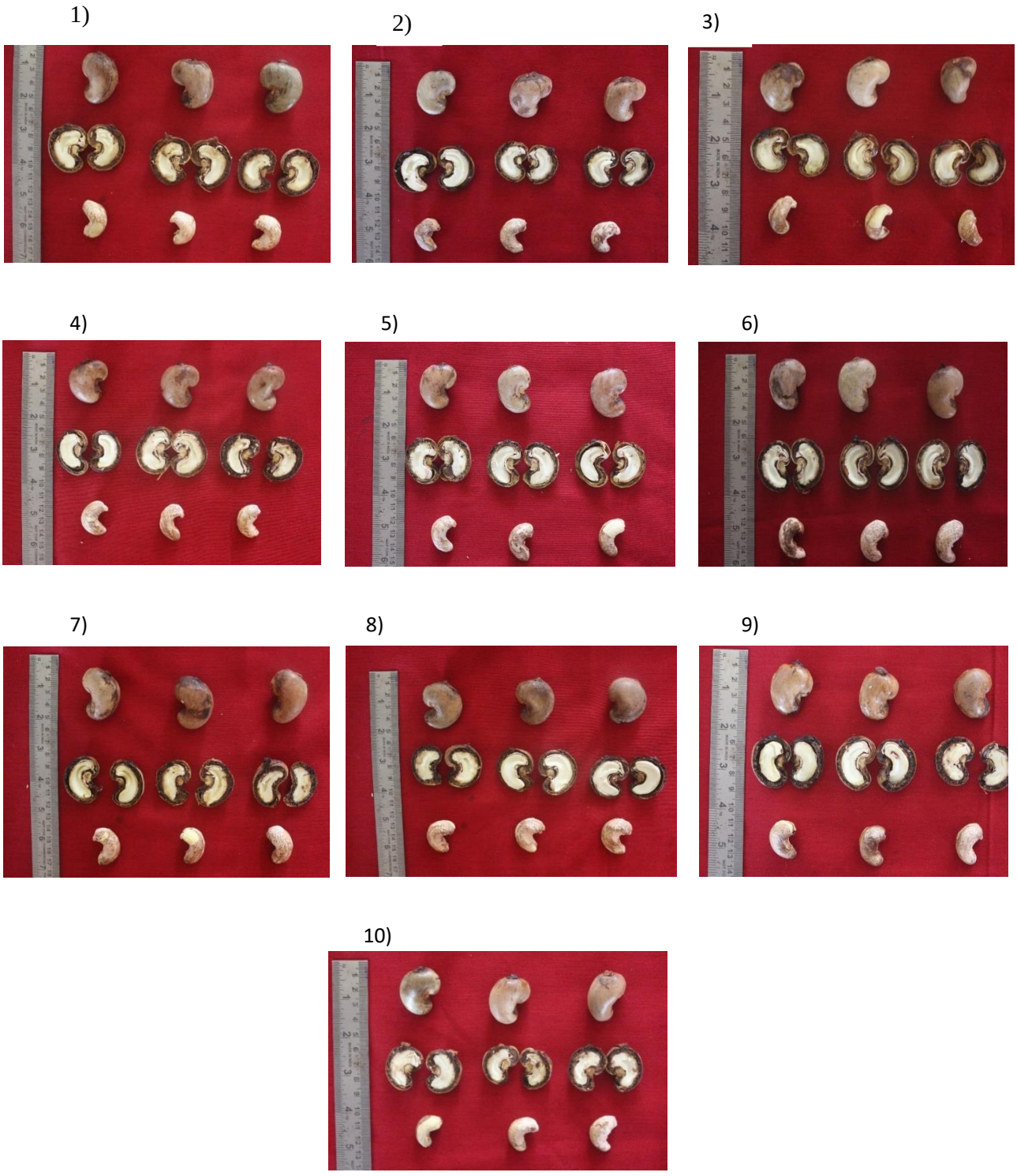


Plate 6. Nut and kernel of cashew hybrids and parents. 1) H03-36/8, 2) H03-55/11, 3) H03-55/10, 4) H03-53/9, 5) H03-92/3, 6) H03-57/4, 7) H03-95/8, 8) H03-97/2, 9) H03-110/1, 10) H03-110/2

11)

12)

13)

14)

15)

16)

17)

18)

19)

20)

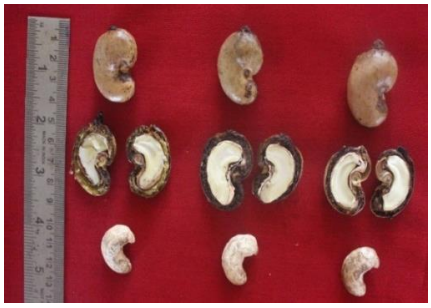
Plate 7. Nut and kernel of cashew hybrids and parents, 11)H03-110/3, 12) H03-111/2, 13) H03-113/1, 14)H03-95/4, 15) H03-18/17, 16) H03-52/7, 17) H03-52/6, 18) H03-52/5, 19) H03-21/10, 20) Dhana

21)

22)

23)

24)



25)

26)

27)

28)

29)

30)

Plate 8). Nut and kernel of cashew hybrids and parents, 21)Madk-1, 22) H03-Vri-3, 23) K-22-1, 24)H03-Poornima, 25) Amrutha, 26) Sulabha, 27), Damodar 18) H03-Anak-1, 29),Priyanka 30) Dharasree

Plate 9. Variations in nut characters of 19 cashew hybrids

Plate 10. Variations in kernel characters of 19 cashew hybrids

The kernel weight of 1.2 to 2.5g represented intermediate group and hybrids, H03-110/3(2.38g), H03-53/9 (2.29g), H03-92/3(2.27g), H03-55/11(2.22g), H03-110/2(1.92g), H03-55/10(1.83g), H03-57/4 and parents, Dhana(2.36g), Dharasree(2.25g), Amrutha(2.20g), Vridhachalam-3(2.17g), Damodar(2.0g), Anakkayam-1(1.66g), Madakkathara-1 (1.63g), K-22-1(1.62g) included in this group. But none of parents or hybrids recorded a kernel weight below 1.2g.

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 (30.05), Vridhachalam-3 (29.73), 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). Out of 19 hybrids, 12 showed shelling percentage of more than 28%. Among the parents, six varieties showed good shelling percentage of more than 28 %. None of the parents or hybrids were in the category low shelling percentage of below 18.

Export grades of cashew hybrids are represented in Table14. Hybrids, H03-52/7, H03-52/5, H03-21/10, H03-95/4, H03-18/17, H03-110/1 and H03 97/2 and parent, Priyanka were having high export grade of W180. One hybrid (H03-110/2) and 2 parents (Dharasree and Damodar) have export kernel grade of W240. Ten hybrids and 5 parents have export grade of W210. Hybrid H03-55/10 and parents, K-22-1, Anakayam-1, Madakathara-1 falls under lowest export grade of W280.

Table 14. Quantitative kernel characters of cashew hybrids and its parents

Hybrids/ Parents	Kernel length (cm)	Kernel width (cm)	Kernel thickness (cm)	Shell thickness (mm)	Kernel weight(g)	Shelling percentage	Export grade
H03 - 36/8	2.75^{fg}	1.93^{bc}	1.32^{ghij}	0.18^{ij}	2.9^{ef}	28.35	W210
H0 - 55/11	2.58^{klm}	1.66^{hij}	1.39^{fgh}	0.19^{hi}	2.22^{kl}	26.43	W210
H0 - 55/10	2.23^{p}	1.25^{o}	1.26^{hijkl}	0.19^{hi}	1.83^{n}	36.44	W280
H03-53/9	2.65^{hijk}	1.67^{hi}	1.12^{i}	0.20^{ghi}	2.29^{ijk}	29.10	W210
H03 - 57/4	2.56^{lmn}	1.67^{hij}	1.26^{hijk}	0.20^{ghi}	2.15^{l}	23.12	W210
H03 - 92/3	2.91^{e}	1.52^{mn}	1.36^{fghi}	0.19^{hi}	2.27^{ijkl}	28.77	W210
H03 - 95/8	2.622^{jkl}	1.77^{efg}	1.34^{fghij}	0.20^{hi}	2.54^{g}	24.49	W210
H03 - 97/2	3.00^{d}	1.96^{b}	1.24^{hijkl}	0.20^{ghi}	3.12^{c}	30.89	W180
H03- 110/1	3.17^{ab}	1.64^{hijk}	1.74^{bc}	0.30^{a}	3.44^{b}	30.77	W180
H03- 110/2	2.54^{mn}	1.72^{fgh}	1.15^{kl}	0.20^{ghi}	1.92^{mn}	30.14	W240
H03 - 110/3	2.76^{f}	1.46^{n}	1.34^{fghij}	0.20^{hi}	2.38^{hi}	30.36	W210
H03 - 111/2	2.84^{e}	1.85^{cde}	1.35^{fghi}	0.29^{ab}	2.50^{gh}	29.45	W210
H03 - 113/1	3.12^{bc}	1.70^{ghi}	1.26^{hijkl}	0.20^{ghi}	2.80^{e}	29.63	W210
H03 - 95/4	3.07^{cd}	2.12^{a}	2.12^{a}	0.28^{cd}	4.19^{a}	33.68	W180
H03 - 18/17	3.20^{a}	1.81^{def}	1.81^{b}	0.27^{d}	2.94^{d}	23.54	W180
H03 - 52/7	2.74^{fg}	2.07^{a}	2.07^{a}	0.21^{g}	3.02^{cd}	29.58	W180
H03 - 52/6	2.32^{o}	1.54^{lmn}	1.54^{de}	0.23^{f}	2.62^{fg}	25.76	W210
H03 - 52/5	3.10^{bc}	1.79^{defg}	1.79^{bc}	0.24^{e}	3.07^{c}	29.52	W180
H03-21/10	3.16^{b}	2.09^{a}	1.64^{cd}	0.19^{hi}	3.66^{b}	29.16	W180
Dhana	2.63^{ijkl}	1.88^{bcd}	1.48^{ef}	0.23^{ef}	2.36^{ij}	28.09	W210
Madak-1	2.19^{p}	1.51^{mn}	1.20^{jkl}	0.10^{l}	1.63^{o}	25.83	W280
Priyanka	3.19^{a}	1.77^{efg}	1.59^{de}	0.29^{bc}	2.79^{e}	25.14	W180
Anak-1	2.49^{n}	1.58^{jklm}	1.24^{hijkl}	0.10^{l}	1.66^{o}	28.09	W280
Amrutha	2.58^{klm}	1.26^{o}	1.32^{ghij}	0.18^{j}	2.20^{kl}	30.05	W210
Vri- 3	2.71^{fgh}	1.55^{klmn}	1.39^{fgh}	0.20^{ghi}	2.17^{kl}	29.73	W210
Sulabha	2.54^{mn}	1.62^{ijkl}	1.27^{hijk}	0.20^{ghi}	2.62^{fg}	26.46	W210
Poornima	2.71^{fghi}	1.56^{klm}	1.46^{efg}	0.19^{hi}	2.50^{gh}	31.65	W210
K-22-1	2.85^{e}	1.84^{de}	1.22^{ijkl}	0.19^{hi}	1.62^{o}	25.31	W280
Dharasree	2.61^{klm}	1.83^{de}	1.31^{ghij}	0.16^{k}	2.25^{jkl}	29.92	W240
Damodar	2.68^{ghij}	1.80^{def}	1.19^{jkl}	0.20^{ghi}	2.00^{m}	25.91	W240
C.V(%)	1.912	3.898	7.532	3.90	3.475		
SE(m)_	0.003	0.004	0.012	0	0.008		
SE(d)	0.037	0.047	0.076	0.006	0.044		

4.2. CORRELATION STUDIES

Correlation studied for 18 component characters of cashew genotypes have been presented in Table 15. In the present investigation, yield of the tree was significantly positively correlated 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).

Among the yield attributing traits, number of nuts per panicle exhibited significant positive correlation with apple weight (0.48), nut length (0.66), nut width (0.64), nut thickness (0.58) and kernel thickness (0.07) and significant negative correlation with kernel width (-0.51) and Number of nuts per kilogram (-0.71). Nut weight was significantly positively correlated with kernel weight (0.84), nuts per panicle (0.70), apple weight (0.73) and number of male flowers (0.52), nut length (0.94), nut width (0.74), nut thickness (0.76), kernel length (0.67), kernel width (0.71) and kernel thickness (0.69).

Kernel weight recorded significant positive correlation with nuts per panicle (0.72), nut thickness (0.81), kernel length (0.74), kernel width (0.72) and kernel thickness (0.76) and significant negative correlation with number of nuts per panicle. Number of nuts per kilogram showed significant negative correlation with nut weight, kernel weight, number of nuts per panicle, apple weight, number of male flowers per panicle, nut length, nut width, kernel length, kernel width, kernel thickness.

Apple weight recorded significant and positive correlation with nut length (0.67), nut width (0.54), nut thickness (0.55), kernel width (0.49) and kernel thickness (0.48). Number of bisexual flowers per panicle had significant positive correlation with sex ratio (0.73) while exhibited non-significant positive correlation with male flowers (0.36). Male flowers recorded significantly positive correlation with nut length (0.62) and nut width (0.64). Panicles per m^2 had highly significant positive correlation with number of laterals per m^2 (0.86).

Table 15: Correlation coefficients for 18 quantitative characters of cashew hybrids

	NW	KW	SP	NP	AW	AN	BF	MF	SR	PM	LM	NL	NW	NT	KL	KW	KT	NK
TY	**0.16***	**0.08***	**0.11***	-0.36	**0.9****	-0.05	***0.42**	0.29	0.229	0.18	0.25	-0.03	0.12	-0.09	-0.09	-0.12	-0.29	0.02
NW		**0.84****	-0.43	**0.70*****	**0.73*****	0.19	0.12	**0.52***	-0.27	-0.01	0.04	**0.94*****	**0.79*****	**0.76*****	**0.67****	**0.71*****	**0.69****	**-0.94*****
KW			0.09	**0.72*****	**0.54***	0.01	0.12	**0.62****	-0.30	-0.04	-0.01	**0.87*****	**0.74*****	**0.81*****	**0.74*****	**0.72*****	**0.76*****	**-0.82*****
SP				-0.04	-0.43	-0.38	-0.07	-0.01	0.01	-0.14	-0.12	-0.32	-0.24	-0.07	-0.05	-0.18	0.04	0.36
NP					**0.48***	-0.13	0.27	0.39	0.03	-0.17	-0.20	**0.66****	**0.64****	**0.58****	0.42	**-0.51***	**0.97*****	**-0.71*****
AW						0.19	0.09	0.28	-0.08	0.33	0.22	**0.67***	**0.54***	**0.55***	0.67**	**0.49***	**0.48***	**-0.76*****
AN							-0.20	0.22	-0.47	0.07	0.27	0.15	-0.06	-0.01	0.21	0.16	-0.14	-0.29
BF								0.36	**0.73*****	-0.31	-0.34	0.21	0.24	0.06	-0.07	0.24	0.43	-0.25
MF									-0.37	0.04	0.01	**0.62****	**0.64****	0.30	0.45	0.39	0.06	**-0.55***
SR										-0.28	-0.35	-0.24	-0.18	-0.14	-0.36	-0.10	-0.14	0.15
PM											**0.86*****	0.07	0.15	0.04	0.37	-0.01	-0.16	0.07
LM												0.08	0.12	0.13	0.42	-0.04	-0.16	-0.01
NL													**0.86*****	**0.75*****	**0.75*****	**0.81*****	**0.67****	**-0.89*****
NW														**0.50***	**0.59****	**0.59****	**0.64****	**-0.73*****
NT															**0.79*****	**0.59****	**0.6****	**-0.71*****
KL																**0.54***	**0.46***	**-0.66****
KW																	**0.51***	**-0.63****
KT																		**-0.72*****

AN: Apple nut ratio; BF: No. of bisexual flowers per panicle; MF: No. of male flowers per panicle; SR: Sex ratio; PM: No. of panicle per m^2; LM: No. of laterals per m^2; NL: Nut length; NW: Nut width; NT; Nut thickness, KL: Kernel length; KW: Kernel width; KT: Kernel thickness; NK: No. of nuts per kilogram

4.3. PRINCIPLE COMPONENT ANALYSIS

Principle component analysis was carried out using five yield contributing characters to transform the dependent variables into a set of independent variables (Hottling, 1993; Mardia *et al*., 1971). The identification of principle component is based on the correlation among different characters, their eigen values, and eigen vectors of principal components. The characters in the principal components were identified on the basis of eigen vectors. The values of the eigen vectors and their contribution to total variation are presented in Table 16.

The principal component analysis revealed that the first three components having eigen value above one explained 85.92 per cent of the total variability (Fig 2). The first principal component (PC1) comprised of nut weight and kernel weight and explained 41.96 per cent of the total variation, whereas the PC2 comprised of yield per tree and apple weight and explained 27.32 per cent of total variation. The PC3 accounted for 16.63 per cent of variability and included number of bisexual flowers per panicle and shelling percentage (Table 16).

The score plot obtained after PCA is given as figure 3. The hybrids namely, H03-21/10, H03-110/1, H03-36/8, H03-97/2, H03-52/5, H03-52/6 and H03-52/7 were fallen in the first quadrant of the graph and can be grouped along with the check variety, Poornima. These hybrids having comparable nut yield per tree (kg), nut weight (g), kernel weight (g), number of bisexual flowers, shelling percentage and apple weight as that of the check variety, Poornima can be identified as promising hybrids for further evaluation. The hybrid, H03-18/17 possess same character as that of bold nut type variety, Priyanka. The characters like nut yield per tree, nut weight(g), kernel weight and number of bisexual flowers showed same range in these genotypes.

Table 16. Eigen value and eigen vectors of the first three principal components

Variables	**PC1**	**PC2**	**PC3**
Eigen value	2.518	1.639	1.022
Proportion	41.966	27.323	16.633
Cumulative	41.966	69.289	85.922
Tree yield	0.207	0.471	0.429
Nut weight	0.573	-0.415	0.011
Kernel weight	0.663	-0.176	-0.256
Apple Weight	0.108	-0.520	0.282
No. of bisexual flowers per panicle	0.373	0.296	0.582
Shelling percentage	0.195	0.466	-0.576

Fig.2. Scree plot of selected quantitative characters

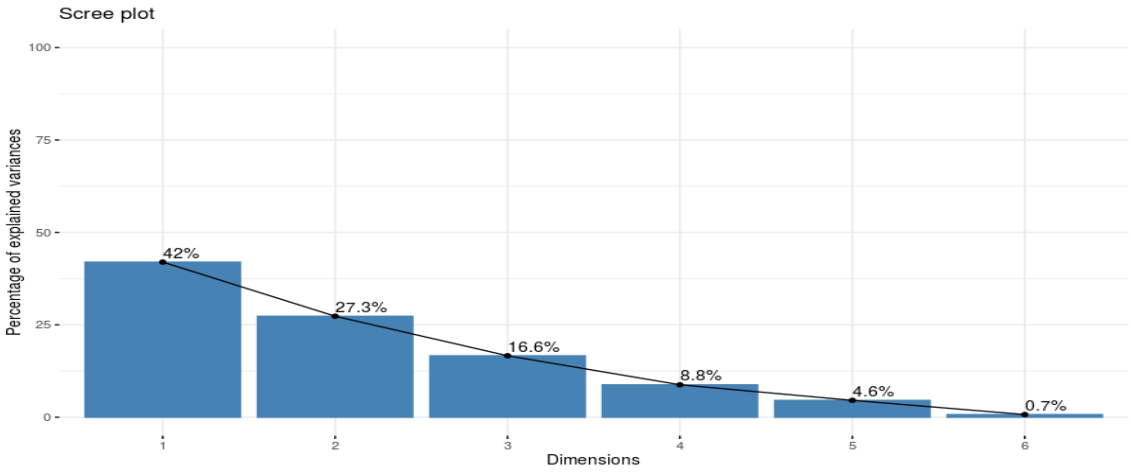
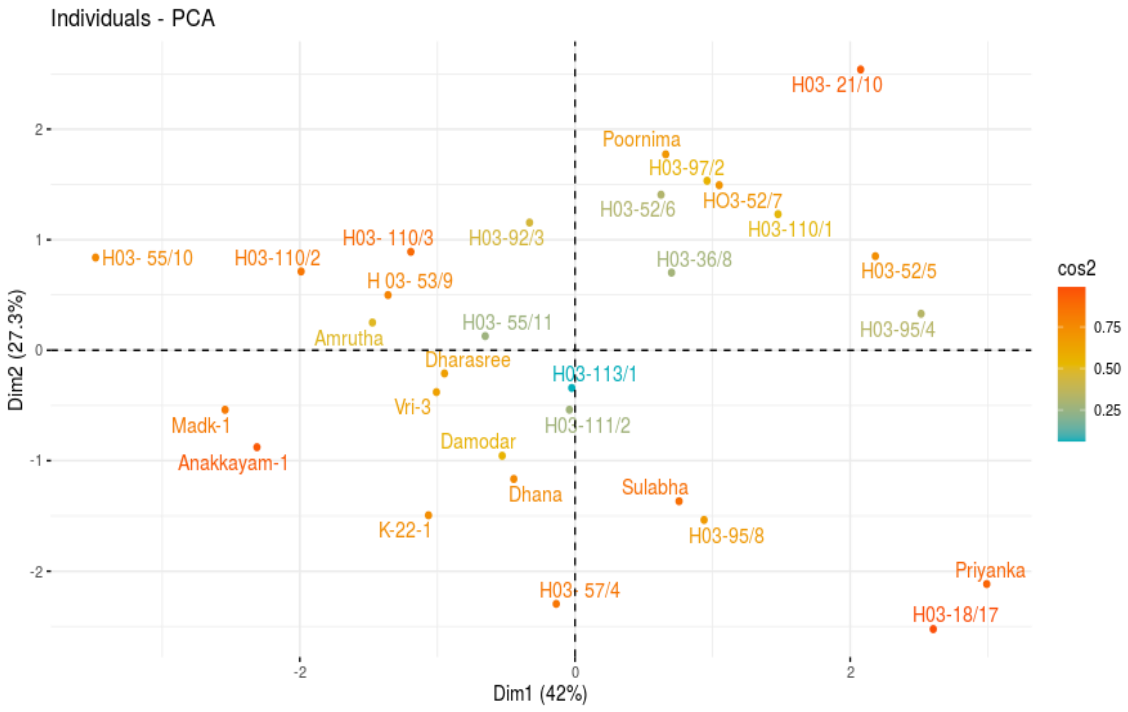


Fig.3. Score plot of selected quantitative character



4.4. BIOCHEMICAL EVALUATION

Biochemical characters of 19 hybrids and their parents *viz*. TSS, Acidity, Vitamin C, Total sugar and Tannin content are mentioned in Table (17) and described as follows.

4.4.1. Total Soluble Solid (TSS)

A perusal of table17 revealed a significant variation in the content of total soluble solids (TSS) of cashew apple of hybrids and their parents. The TSS ranged from 13.15^0Brix to 17.4^0Brix. The hybrid H03-53/9 recorded the highest TSS of 17.4^0 Brix followed by parent Damodar (16.26^0Brix) and K-22-1 (16.25^0Brix). The hybrid H03-18/17 recorded the lowest TSS (13.15^0Brix) among the tested hybrids and parents.

4.4.2. Titratable Acidity (%)

The results on titratable acidity (%) of cashew apple (Table 17) revealed significant variations among the hybrids and parents. Among the 19 cashew hybrids and 11 cashew varieties evaluated the acidity ranged from 0.33 to 0.13%. Parents, Dhana, Madakkathara-1, Priyanka and Anakayam-1, Poornima, Sulabha and Dharasree showed highest acidity (0.33%). The lowest acidity content was recorded for hybrid H03-21/10, H03-18/17, H03-95/4, H03-55/11, H03-55/10 and variety Amrutha (0.133%).

4.4.3. Vitamin C (mg/100ml)

Table 15 summarizes the vitamin C contents of 19 cashew hybrids and 11 parents. Significant difference was observed among the genotypes based on the analysis of variance. The average Vitamin C content ranged from 107.50.to 220.16 mg/100ml. The parent Dharasree and Poornima (220.15 each) recorded the highest Vitamin C content. The lowest Vitamin C content (107.50 mg/100ml) was recorded by hybrid H03-53/9.

4.4.4. Total sugar (%)

The results on total sugar content of cashew apple revealed significant variation among the hybrids and parent varieties. Among the 30 cashew genotypes evaluated the total sugar ranged from 13.44 to 21.21%. Hybrid H03-57/4 and H03-97/2 showed highest sugar content (21.21%). The lowest sugar content was shown by hybrid H03 110/3 (13.44 %).

4.4.5. Tannin (%)

The results on tannin content of cashew apple revealed significant variation among the hybrids and cross parent varieties. Tannin content ranged from 0.09% to 0.29%. The highest tannin content was recorded in hybrid H03-113/1 (0.29%.). Lowest tannin content was shown by hybrid H03-55/11, H03-92/3 and H03-55/10 (0.09% each).

Table 17. Biochemical characters of cashew hybrids and its parents

Hybrids/ parents	TSS (^{0} Brix)	Acidity (%)	Vitamin C(mg/100ml)	Total Sugar (%)	Tannin (%)
H03 - 36/8	15.40^{f}	0.27^{b}	138.46^{k}	19.44^{b}	0.24^{c}
H03 - 55/11	16.00^{cd}	0.13^{d}	158.96^{e}	19.44^{b}	0.09^{i}
H03 - 55/10	16.10^{bc}	0.13^{d}	138.46^{k}	16.60^{d}	0.09^{i}
H03 - 53/9	17.40^{a}	0.20^{c}	107.50^{n}	19.44^{b}	0.24^{cd}
H03 - 57/4	15.40^{f}	0.20^{c}	153.58^{g}	21.21^{a}	0.24^{c}
H03 - 92/3	15.20^{g}	0.27^{b}	174.35^{b}	19.44^{b}	0.09^{i}
H03 - 95/8	14.60^{jk}	0.20^{c}	158.73^{f}	16.52^{d}	0.15^{f}
H03 - 97/2	14.47^{k}	0.27^{b}	174.35^{b}	21.21^{a}	0.11^{jk}
H03 - 110/1	15.20^{g}	0.27^{b}	123.15^{m}	16.52^{d}	0.22^{e}
H03 - 110/2	15.00^{h}	0.27^{b}	158.72^{f}	19.44^{b}	0.27^{b}
H03 - 110/3	14.75^{h}	0.13^{d}	168.96^{c}	13.44^{i}	0.12^{ghi}
H03 - 111/2	15.00^{h}	0.27^{b}	174.35^{b}	19.44^{b}	0.11^{ijk}
H03 - 113/1	16.15^{bc}	0.27^{b}	148.60^{h}	17.94^{c}	0.29^{a}
H03 - 95/4	14.70^{j}	0.13^{d}	148.60^{h}	19.44^{b}	0.11^{k}
H03 - 18/17	13.15^{o}	0.13^{d}	168.96^{c}	19.44^{b}	0.27^{b}
H03 - 52/7	13.37^{n}	0.27^{b}	158.72^{f}	17.94^{c}	0.15^{f}
H03 - 52/6	15.20^{g}	0.27^{b}	163.54^{d}	16.32^{e}	0.14^{fg}
H03 - 52/5	15.20^{g}	0.27^{b}	158.72^{f}	14.75^{g}	0.21^{e}
H03 -21/10	15.90^{d}	0.13^{d}	158.72^{f}	17.94^{c}	0.21^{e}
Dhana	14.05^{l}	0.33^{a}	148.48^{i}	13.70^{h}	0.11^{ijk}
Madk-1	15.07^{gh}	0.33^{a}	148.71^{h}	17.94^{c}	0.12^{hij}
Priyanka	16.17^{bc}	0.33^{a}	174.35^{b}	19.44^{b}	0.22^{e}
Anak-1	15.67^{e}	0.27^{b}	143.36^{j}	16.32^{e}	0.12^{hij}
Amrutha	14.50^{k}	0.13^{d}	133.12^{l}	17.94^{c}	0.13^{gh}
VRI- 3	14.90^{hi}	0.27^{b}	143.36^{j}	15.54^{f}	0.24^{c}
Sulabha	13.75^{m}	0.33^{a}	148.71^{h}	15.54^{f}	0.25^{c}
Poornima	13.47^{n}	0.33^{a}	220.15^{a}	17.94^{c}	0.22^{e}
K-22-1	16.25^{b}	0.27^{b}	153.55^{g}	16.32^{e}	0.24^{c}
Dharasree	15.67^{e}	0.33^{a}	220.15^{a}	15.55^{f}	0.22^{de}
Damodar	16.26^{b}	0.27^{b}	153.55^{g}	16.32^{e}	0.22^{de}
CV (%)	0.86	0.051	0.051	0.728	6.024
SE(m)	0.017	0.006	0.04	0.016	0.006
SE(d)	0.092	0.057	0.057	0.091	0.008

4.5. PEST AND DISEASE INCIDENCE

The following pest and diseases were observed in the sample population during the year 2020-2021

4.5.1 TMB (*Helopeltis antonii*) F: Miridae, O: Hemiptera

Tea mosquito bug was the most important limiting factor of cashew. Both nymph and adults suck sap from the tender shoots, young leaves, inflorescence, apples and nuts. The damage of TMB was observed from October to January in flushing, flowering and fruiting stages of cashew.

4.5.2. Cashew stem and root borer (*Procaederus ferrugineus* L.) F: Cerambydae, O: Coleoptera

The occurrence of Cashew stem and root borer, was observed on hybrid H03-57/4, H03-110/2 and H03-113/1 (Plate 11). They bored the sap wood of the tree as a result of which resinous substances oozed out from the wounds along with a thick reddish mass of chewed fibers.

4.5.3. Leaf miner (*Acrocercopssyn gramma* M.) F: Gracillariidae, O: Lepidoptera

The mining injury by caterpillars occurs both on tender leaves causing extensive leaf blisters, which later dry up resulting on distortion, browning and curling of the leaves. As the attacked leaf, holes develop due to drying out of the damaged portion (Plate 12).

4.5.4. Leaf and blossom webber (*Lamida moncusalis* Wlk) F: Pyralidae, O: Lepidoptera

The caterpillar feed on the terminal leaves of new shoots and blossoms after webbing them. Presence of webbing on terminal portions, with clumped appearance, and drying of webbed shoots/ inflorescence are noticed. (Plate 13) They also feed externally the developing apples and nuts. The attack was found severe in hybrids H03-97/2, H03-53/9, H03-95/4 and H03-95/8.

4.5.5. Apple and nut borer (*Thylacoptila paurosema*) F: Pyralidae, O: Lepidoptera

Apple and nut borer infestation observed on hybrids like H03-97/2, H03-110/1, H03-92/3. (Plate 14) Initially damage the flowering panicles by webbing and feeding on unopened flower, Later stage it bore inside the tender nuts and apples and nuts resulting in shriveling and pre mature fall. In the developed green nuts and apples, larvae tunnel near the junction of apple and nut, and the bore holes are plugged with frass and excreta.

4.5.6. Leaf folders (*Hypotima haligramma). F:* Gelihiidae, O: Lepidoptera

Lepidopterous leaf folders were observed feeding on tender foliage in hybrids like H03-97/2, H03-95/4, H03-18/17 and H03-92/3. Leaf folder rolls up the margin and larvae feeds on the leaf margin, and the infected leaves dried up. (Plate 15)

4.5.7. Mealy bug, (*Ferrisia virgata* Cockrell) F: Pseudococcidae, O: Hemiptera

Mealybug colonies develop on young vegetative shoots, leaves, inflorescence and tender nuts. Damaged flowers wither and dry (Plate 16).

Plate 11. Stem and root borer (*Procaederus ferrugineus* L.)

Plate 12. Leaf miner (*Acrocercopssyn gramma* M.)

Plate 13. Leaf and blossom Webber (*Lamida moncusalis* Wlk)

Plate 14. Apple and nut borer (*Thylacoptila paurosema*)

Plate 15. Leaf folder *(Hypotima haligramma)*

Plate 16. Mealy bug (*Ferrisia virgata* Cockrell)

Plate17. Aphid (*Aphis gossypii*)

4.6. TMB SCORING

The score for Tea mosquito damage at flush and panicle emergence for the year 2020-2021 on 19 cashew hybrids and 11 parents were pooled and the mean values calculated for shoots and panicles are presented in the Table 18. (Plate18) The hybrids were grouped according to the mean TMB damage score to shoots/panicles as less susceptible (LS), moderately susceptible (MS) and highly susceptible (HS) as suggested Ambika *et al*., (1979).

The damage score for TMB infection in hybrids and parents ranged from 0.02 (H03-21/10) to 0.62 (H03-95/4). Out of 19 hybrids, five entries were less susceptible, 13 entries were moderately susceptible and one hybrid H03-95/4 was susceptible to TMB. The hybrids, H03-57/4, H03-110/1, H03-113/1, H03-52/5 and H03-21/10 and parents, Dhana, Madakkathara-1, Vridhachalam-3, and K-22-1 were less susceptible to TMB. Among the parents, Sulabha was susceptible to TMB and Anakayam-1, Damodar, Priyanka and Dharasree were moderately susceptible to TMB.

Table 18. Mean values of TMB damage score on cashew hybrids and its parents

Hybrids / parents	Damage count on 52 leader shoots			
	Shoots	Panicles	Mean TMB Population	Intensity of TMB Population*
H03-36/8	0.41	0.45	0.43	MS
H03-55/11	0.25	0.35	0.30	MS
H03-55/10	0.34	0.33	0.33	MS
H03-53/9	0.44	0.44	0.44	MS
H03-57/4	0.15	0.24	0.19	LS
H03-92/3	0.32	0.35	0.33	MS
H03-95/8	0.28	0.31	0.29	MS
H03-97/2	0.31	0.35	0.33	MS
H03-110/1	0.11	0.14	0.12	LS
H03-110/2	0.32	0.34	0.33	MS
H03-110/3	0.23	0.29	0.26	MS
H03-111/2	0.31	0.43	0.37	MS
H03-113/1	0.22	0.24	0.23	LS
H03-95/4	0.61	0.63	0.62	S
H03-18/17	0.49	0.46	0.47	MS
HO3-52/7	0.43	0.40	0.41	MS
H03-52/6	0.31	0.29	0.30	MS
H03-52/5	0.21	0.23	0.22	LS
H03-21/10	0.01	0.03	0.02	LS
Dhana	0.13	0.14	0.13	LS
Madak-1	0.21	0.11	0.16	LS
Priyanka	0.24	0.15	0.19	MS
Anak-1	0.21	0.31	0.26	MS
Amrutha	0.32	0.32	0.32	MS
Vri-3	0.10	0.29	0.19	LS
Sulabha	0.43	0.61	0.52	S
Poornima	0.20	0.25	0.22	LS
K-22-1	0.23	0.19	0.21	LS
Dharasree	0.39	0.23	0.31	MS
Damodar	0.49	0.32	0.40	MS

***LS – Less susceptible, MS- Medium susceptible, S- Susceptibl**

On shoots

On panicle

On nut

Plate 18. Tea mosquito bug (*Helopeltis antonii*)

4.7. ESTIMATION OF HETEROSIS

In the current study, magnitude of heterosis was calculated for individual nut weight, kernel weight, no. of bisexual flowers, apple weight, nut length, nut width, nut thickness, kernel length, kernel width and kernel thickness in the hybrid population. Relative heterosis, heterobeltiosis and standard heterosis were worked out and presented in table 19 a, b and c.

4.7.1. Nut weight

Table 19a. indicated that among 19 hybrids, H03-18/17 showed highest positive significant relative heterosis (75.88%), heterobeltiosis (60.10%) and standard heterosis (58.07%) in case of individual nut weight. This was followed by H03-36/8, relative heterosis of 44.19%, heterobeltiosis of 26.25% and standard heterosis of 34.24%. Out of the 19 hybrids, fourteen showed significant positive relative heterosis, 10 hybrids showed heterobeltiosis and 14 showed standard heterosis. The hybrid 55/10 showed lowest negative non-significant relative heterosis (-45.40%), heterobeltiosis (-58.16%) and standard heterosis (-41.22%). Three hybrids namely H03-95/4, H03-21/10 and H03-18/17 showed positive significant standard heterosis of more than 50%.

4.7.2. Kernel weight

So far as kernel weight is concerned, it is clear from table that, highest significant positive relative heterosis (68.97%), heterobeltiosis(50.20%) and standard heterosis(67.80%) was projected by H03-95/4 followed by H03-18/17, relative heterosis, heterobeltiosis and standard heterosis of 62.59%, 47.25% and 17.80%. The hybrid H03- 110/2 showed lowest negative non-significant relative heterosis (-27.36%), heterobeltiosis (-31.17%) and standard heterosis (-23.10%). Out of the 19 hybrids 13 showed positive significant relative heterosis, 11 showed heterobeltiosis and 10 hybrids shows standard heterosis.

4.7.3. Apple weight

For the apple weight, out of 19 hybrids 3 hybrids (H03-95/8, H03-97/2 and H03-11/2) showed positive significant relative heterosis, 3 hybrids (H03-53/9, H03-113/1 and H03-52/7) showed negative significant relative heterosis. Two hybrids (H03-53/9 and H03-113/1) showed signifcant negative heterobeltiosis and five hybrids namely H03-57/4, H03-92/3, H03-53/9 and H03-113/1 showed negative significant standard heterosis.

4.7.4. No. of bisexual flowers

No.of bisexual flowers, out of 19 hybrids, 11 hybrids shower significant positive relative heterosis, 4 of them showed positive significant heterobeltiosis and hybrids namely H03-57/4 and H03-18/17 showed negative significant heterobeltiosis. None of them showed positive significant standard heterosis for Number of bisexual flowers.

4.7.5. Nut length

For the nut length, 13 hybrids over the mid parent, 4 over the better parent and 10 over the standard check showed positive and significant heterosis. The hybrids namely H03-36/8, H03-97/2 and H03-18/17 showed positive significant relative heterosis, heterobeltiosis and standard heterosis for the character nut length.

4.7.6. Nut width

For the nut width, 14 hybrids showed positive significant relative heterosis and 5 hybrids showed positive significant heterobeltiosis. The hybrids namely, H03-36/8, H03-53/9, H03-97/2, H03-18/17 and H03-21/10 showed positive significant relative heterosis and heterobeltiosis for the character nut width.

4.7.7. Nut thickness

Thirteen hybrids showed positive significant relative heterosis, 8 hybrids showed heterobeltiosis and standard heterosis each. The hybrids namely, H03-21/10, H03-110/1, H03-95/4 and H03-52/5 showed positive significant relative heterosis, heterobeltiosis and standard heterosis for the character of nut thickness.

4.7.8. Kernel length

For the kernel length, 12 hybrids over the mid parent, 5 over the better parent and 9 over the standard check showed positive and significant heterosis. The hybrids namely H03-97/2, H03-113/1 and H03-18/17 showed positive significant relative heterosis, heterobeltiosis and standard heterosis for the character kernel length.

4.7.9. Kernel width

For the nut width, 9 hybrids showed positive significant relative heterosis, 7 hybrids showed heterobeltiosis and 15 showed standard heterosis. The hybrids namely, H03-95/8, H03-53/9, H03-110/2, H03-95/4, h03-52/7 and H03-21/10 showed positive significant relative heterosis and heterobeltiosis for the character nut width.

4.7.10. Kernel thickness

Seven hybrids showed positive significant relative heterosis, 5 hybrids showed heterobeltiosis and 6 hybrids showed standard heterosis each. The hybrids namely, H03-52/5, H03-52/7, H03-95/4, H03-110/1 and H03-18/17 showed positive significant relative heterosis, heterobeltiosis and standard heterosis for the character of kernel thickness.

Table. 19a. Magnitude of heterosis (%) over mid parent, better parent and standard check for various characters f hybrids

	Nut weight			Kernel weight			Apple weight			No.of bisexual flowers		
	R.H (%)	**H.B. (%)**	**S.H(%)**	**R.H. (%)**	**H.B. (%)**	**S.H. (%)**	**R.H.(%)**	**H.B.(%)**	**S.H.(%)**	**R.H.(%)**	**H.B.(%)**	**S.H.(%)**
H03-36/8	44.19*	26.25*	34.24*	36.48*	15.33*	9.10*	16.55	0.35	-18.083	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	-26.9446	20.698*	17.47	-9.19
H03-55/10	-45.40	-58.16	-41.22	-17.71	-34.39	-26.70	-74.72	-0.82	-78.4046	-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*	-52.1078	16.712*	3.398	-8.78
H03-57/4	6.86*	-16.19	17.75*	-2.71	-22.93	-13.90	-24.32	-0.28	-20.3325*	-11.36	-19.06*	-1.709
H03-92/3	-8.20	-20.25	-0.06	-4.65	-12.50	-9.00	5.32*	0.08	-4.61134*	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	15.54643	-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	10.60865	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	1.468702	-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	-51.8702	5.420*	-17.05	-6.54
H03-110/3	-17.44	-29.34	-0.72	-9.88	-14.61	-4.60	-65.79	-0.61	-46.2061	-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	-4.32594	-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*	-27.947*	-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	-15.338	19.47*	16.410	-8.90
H03-18/17	75.88*	60.10*	58.07*	62.57*	47.25*	17.80*	47.59	0.79	38.27925	-16.55	-18.53*	0.05
HO3-52/7	12.28*	-6.94	30.76*	21.74*	8.22*	20.90*	-27.29*	-0.29	-13.3241*	79.47*	74.871*	1.47
H03-52/6	10.54*	-8.38	28.73*	5.53*	-6.19	4.80*	-33.61	-0.35	-21.4212	92.10*	87.179*	-2.47
H03-52/5	13.07*	-6.28	31.68*	23.96*	10.19*	23.10*	25.96	0.27	54.98012	56.84*	52.820*	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

Table. 19b. Magnitude of heterosis(%) over mid parent, better parent and standard check for various characters hybrids

	Nut length			Nut width			Nut thickness		
	R.H (%)	**H.B. (%)**	**S.H(%)**	**R.H. (%)**	**H.B. (%)**	**S.H. (%)**	**R.H.(%)**	**H.B.(%)**	**S.H.(%)**
H03-36/8	33.46*	25.26*	8.51*	19.83*	16.87*	9.55	24.33*	15.75*	2.20
H03-55/11	-2.82	-17.51	-2.96	2.12*	-6.69	-15.61	4.95	-2.29	-3.24
H03-55/10	-26.07	-37.24	-26.18	-18.99	-25.98	-33.05	-10.34	-16.53	-17.34
H03-53/9	16.13*	11.39*	-0.46	34.77*	30.48*	4.30	84.08*	71.78*	69.27*
H03-57/4	2.75	-14.83	-1.63	4.46*	-5.29	-14.34	4.03	-3.14	-4.09
H03-92/3	9.18*	-3.02	-2.43	1.57*	-0.39	-17.83	11.86*	1.78	-9.15
H03-95/8	15.73*	2.79	3.42*	4.28*	2.27	-15.65	14.56*	4.23	-6.95
H03-97/2	38.07*	36.19*	6.38*	22.45*	15.83*	4.46	17.99*	9.29*	-2.44
H03-110/1	3.42*	-4.33	12.54*	5.94*	0.88	0.88	10.54*	10.00*	10.00*
H03-110/2	-15.64	-21.96	-8.21	-21.24	-25.00	-25.00	-15.20	-15.61	-15.61
H03-110/3	-4.75	-11.89	3.65*	-11.04	-15.29	-15.29	-2.82	-3.29	-3.29
H03-111/2	8.95*	2.10	-3.80	-13.44	-15.44	-30.25	1.65	-11.85	7.07*
H03-113/1	2.87*	1.47	1.47	-11.68	-21.11	-21.11	9.13*	-0.51	20.84*
H03-95/4	21.97*	1.49	19.3*	17.07*	9.86	0.64	39.35*	21.16*	19.98*
H03-18/17	36.55*	27.74*	20.6*	25.84*	22.68*	1.19	16.20*	13.57*	10.24*
HO3-52/7	12.81*	-6.14	10.41*	17.64*	10.39	-0.16	16.74*	1.50	0.51
H03-52/6	0.93	-16.02	-1.22	2.06*	-4.23	13.38	14.73*	-0.25	-1.22
H03-52/5	10.17*	-8.33	7.3*	13.41*	6.43	3.74	32.66*	15.34*	14.22*
H03-21/10	8.36*	0.52	18.24*	17.86*	12.68*	1.91	28.52*	22.19*	21.00*

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

Table. 19c. Magnitude of heterosis(%) over mid parent, better parent and standard check for various characters F1 hybrids

	Kernel length			Kernel width			Kernel thickness		
	R.H (%)	**H.B. (%)**	**S.H(%)**	**R.H. (%)**	**H.B. (%)**	**S.H. (%)**	**R.H.(%)**	**H.B.(%)**	**S.H.(%)**
H03-36/8	14.79*	4.75*	1.29	14.16*	2.93	24.04*	0.37	-9.40	7.53
H03-55/11	-9.77	-18.97	-4.96	-0.75	-6.07	6.57*	-1.77	-12.58	-4.79
H03-55/10	-22.25	-30.17	-18.11	-25.07	-29.10	-19.55	-11.13	-20.91	-13.87
H03-53/9	2.82*	1.44	-2.67	17.96*	6.01*	7.37*	-13.09	-15.72	-23.80
H03-57/4	-4.01	-19.36	-5.42	1.83	-5.65	7.05*	10.22*	-3.30	5.31
H03-92/3	14.22*	11.59*	7.08*	-4.26	-6.33	-2.72	2.06	-1.98	-6.68
H03-95/8	2.84*	0.48	-3.58	18.85*	14.81*	19.23*	0.19	-3.78	-8.39
H03-97/2	25.52*	14.94*	10.29*	25.56*	21.30*	25.96*	0.20	-2.93	14.90
H03-110/1	7.28*	-0.63	16.54*	-1.50	-7.34	5.13*	14.43*	9.75*	19.52*
H03-110/2	-14.04	-20.38	-6.62	25.23*	17.80*	33.65*	-24.75	-27.83	-21.40
H03-110/3	-6.94	-13.79	1.10	-12.16	-17.37	-6.25	-12.13	-15.72	-8.22
H03-111/2	3.09*	-0.70	4.41*	0.68	0.41	18.43*	6.92	3.24	-7.36
H03-113/1	16.20*	14.71*	14.71*	0.15	-7.24	8.81*	-8.84	-13.53	-13.53
H03-95/4	8.10*	-3.76	12.87*	27.86*	19.92*	36.06*	42.45*	33.49*	45.38*
H03-18/17	15.79*	12.15*	17.92*	-0.27	-1.36	16.35*	50.62*	48.77*	24.32*
HO3-52/7	-1.85	-12.62	2.48	25.00*	17.23*	33.01*	39.26*	30.50*	42.12*
H03-52/6	-18.93	-27.82	-15.35	-7.08	-12.85	1.12	3.52	-2.99	5.65
H03-52/5	9.15*	-2.82	13.97*	7.83*	1.13	14.74*	20.13*	12.58*	22.60*
H03-21/10	9.05*	-0.86	16.27*	23.30*	18.08*	33.97*	14.29*	3.14	12.33*

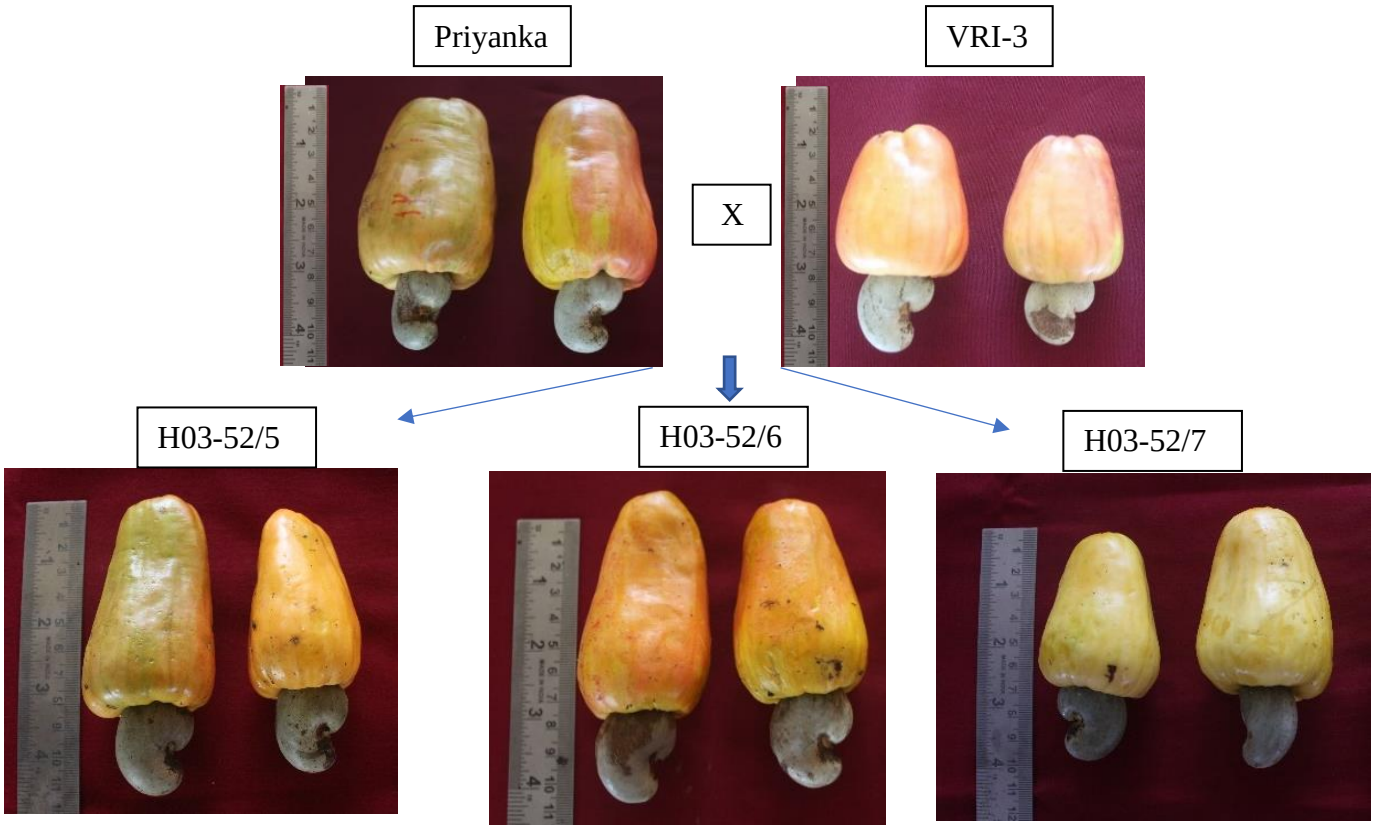


Plate 19. Hybrids between Priyanka and VRI-3

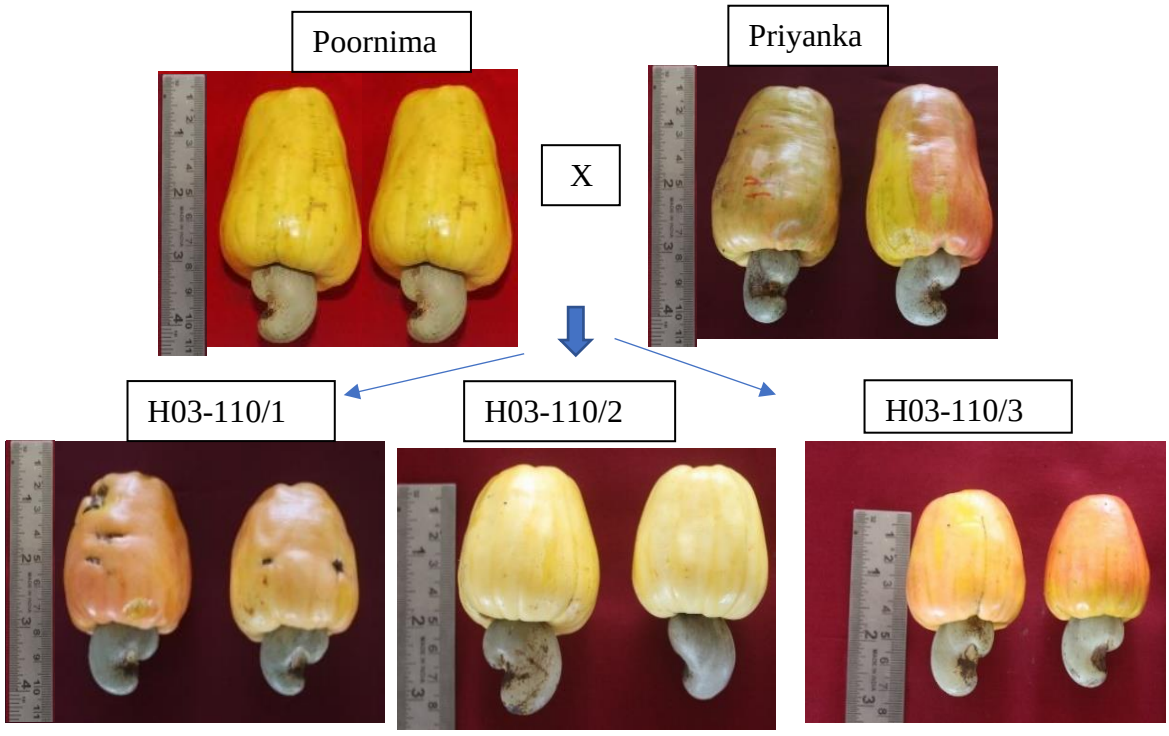


Plate 20. Hybrids between Poornima and Priyanka

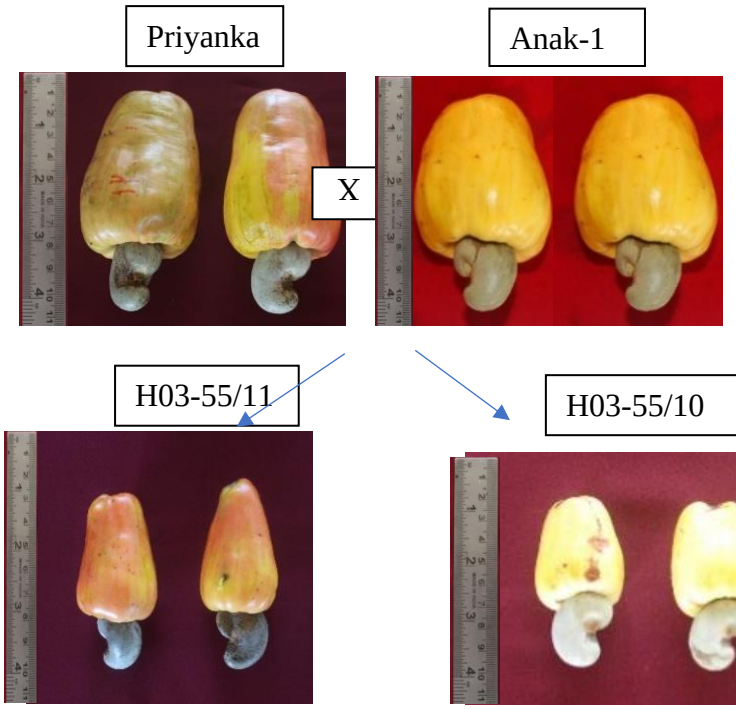


Plate 21. Hybrids between Priyanka and Anak-1

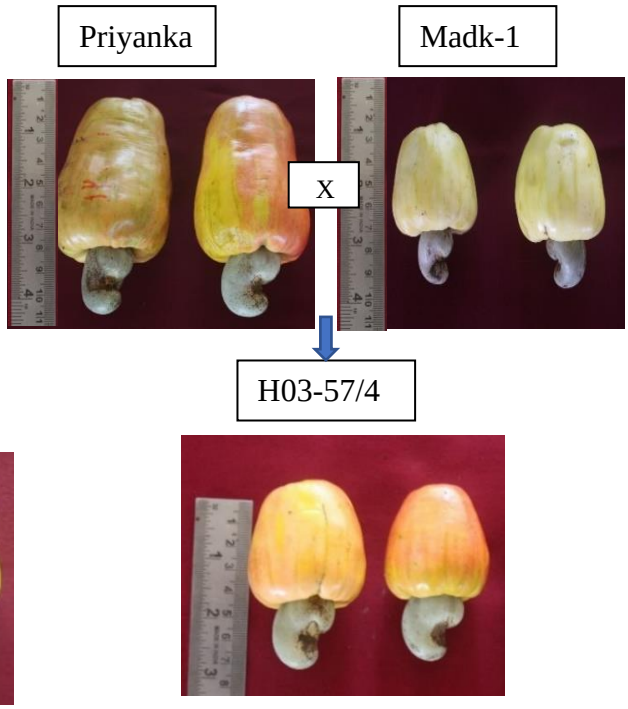


Plate 22. Hybrids between Priyanka and Madk-1

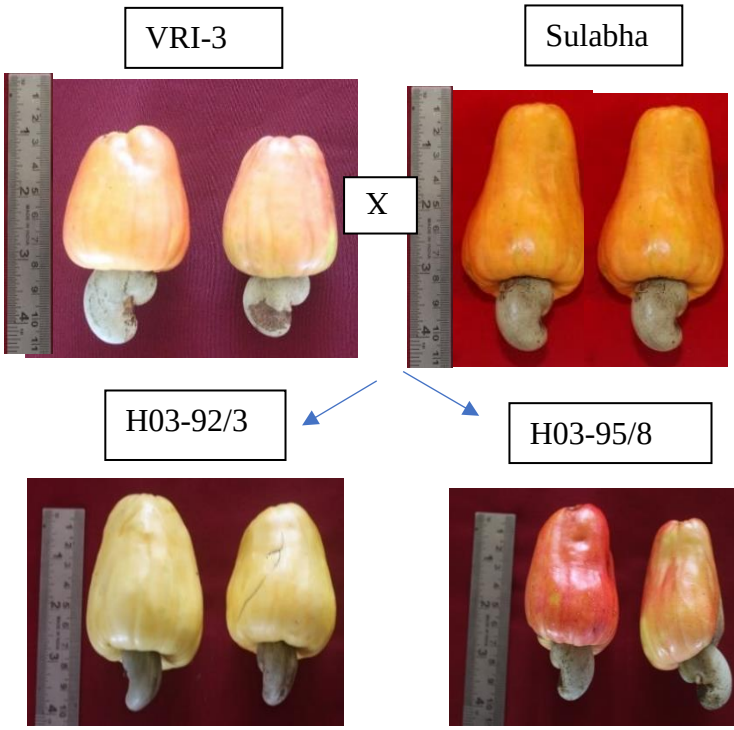


Plate 23. Hybrids between VRI-3 and Sulabha

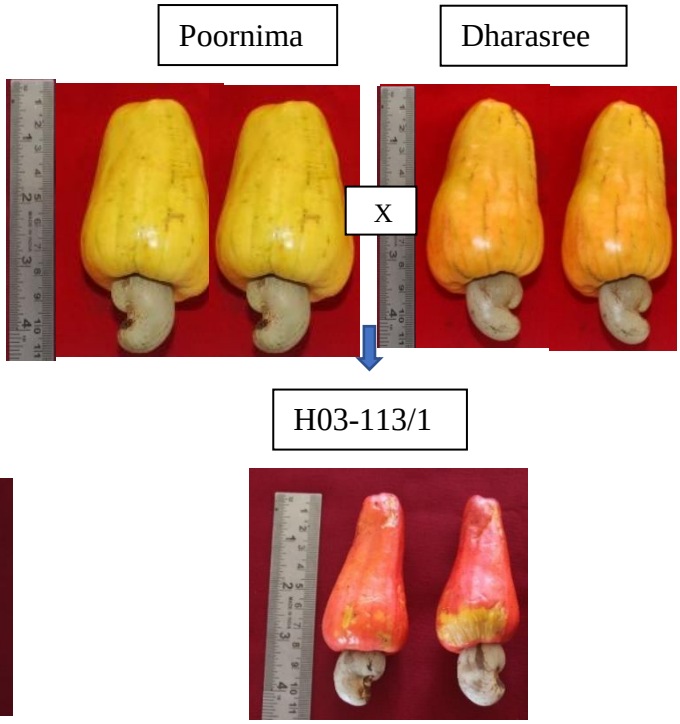


Plate 24. Hybrids between Poornima and Dharasree

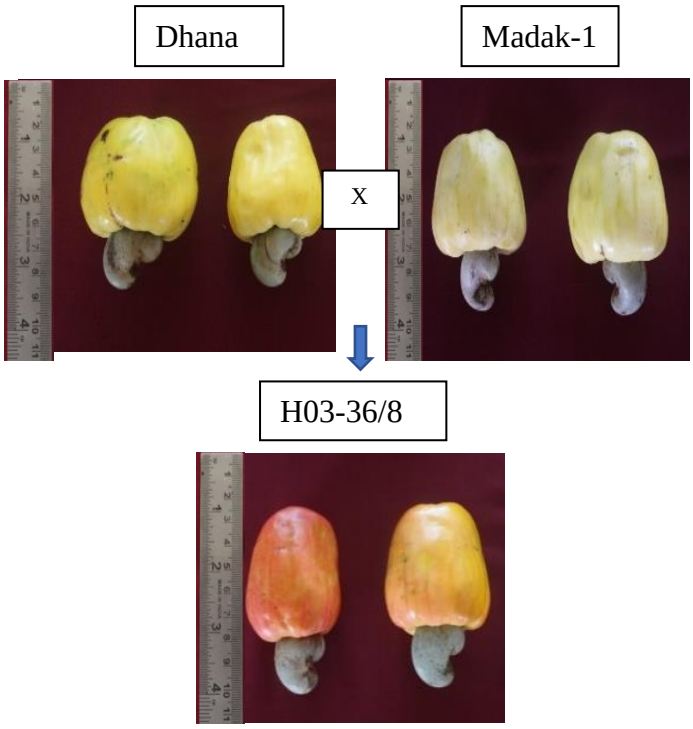


Plate 25. Hybrids between Dhana and Madk-1

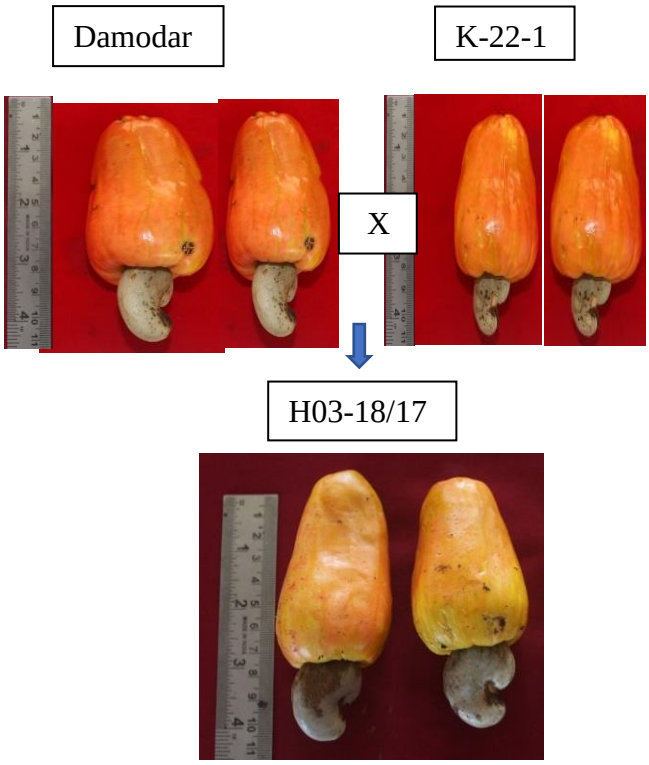


Plate 26. Hybrids between Damodar and K-22-1

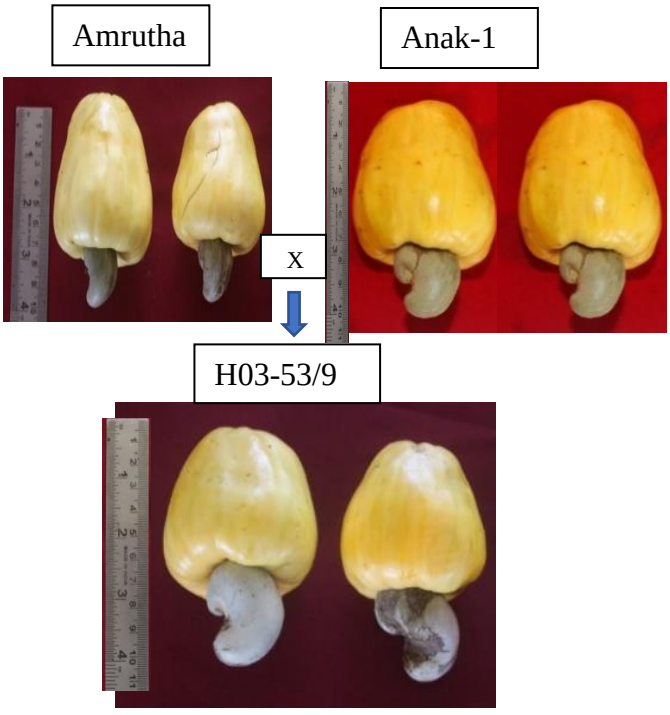


Plate 27. Hybrids between Amrutha and Anak-1

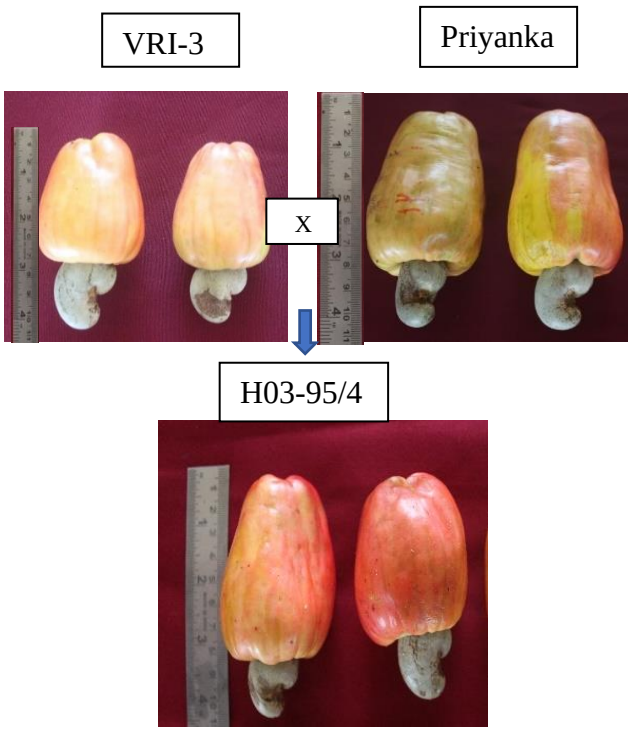


Plate 28. Hybrids between VRI-3 and Priyanka

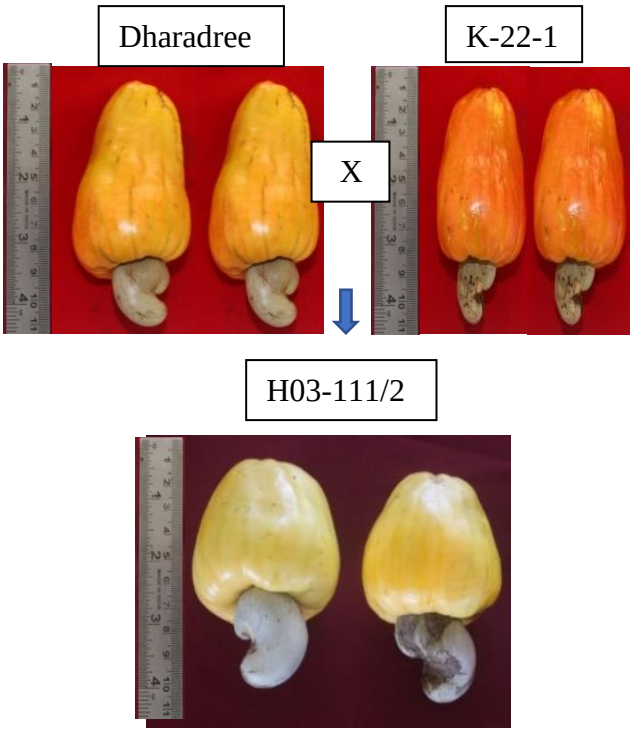


Plate 29. Hybrids between Dharasree and K-22-1

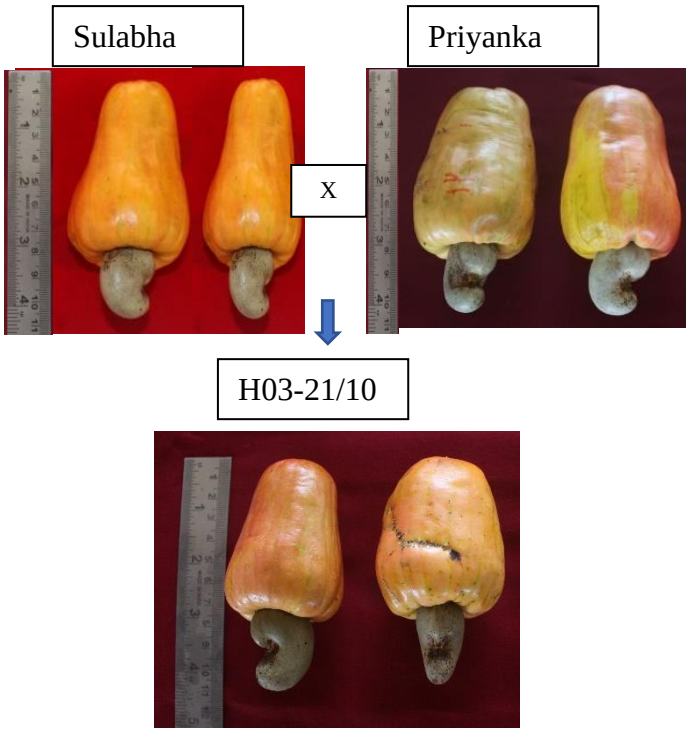


Plate 30. Hybrids between Sulabha and Priyanka

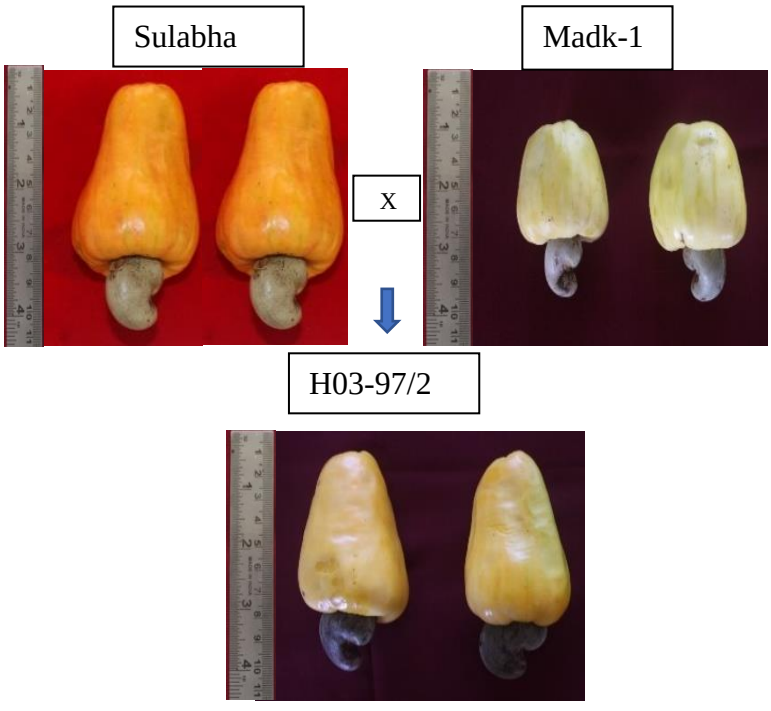


Plate 31. Hybrids between Sulabha and Madk-1

Discussion

5. DISCUSSION

Observations recorded during the course of investigation were statistically analysed and presented in the previous chapter with appropriate tables and figures. In the present chapter the findings obtained are briefly narrated and discussed under different headings.

5.1. Variability in morphological characters

Morphological variation among hybrid population gives an indication of genetic diversity in the studied genotypes. Growth pattern of any perennial tree decides the subsequent architecture in the tree. In case of cashew, volume of tree canopy is very important as it indicates the bearing area and determines the tree spacing as well as population density per unit area (Ona *et al*., 2017). The growth and canopy expansion rate also have the influence on pruning practices (Mangal, 2016). Canopy structures can be classified as compact, open, upright and open, upright and compact, spreading, semi-spreading and highly spreading (Salam and Peter, 2010). Upright and compact tree habit was noticed in 58 per cent of hybrids and 82 per cent of parents. This canopy shape is generally suitable for high density planting (Haripriya, 2014) as a greater number of trees can be accommodated per unit area. But five genotypes have spreading canopy and may cause interlocking of canopies of adjacent trees over the years, hence not suitable for this intensive cultivation. On a per tree basis, the productivity may be high in spreading type, but on per hectare basis it may be high in upright and compact canopy (Salam and Peter, 2010). Upright and open canopy in H03-55/10, H03-111/2, H03-95/4, Priyanka and Sulabha facilitates better penetration of solar radiation within the canopy.

Branching pattern in cashew trees can be extensive or intensive (Damodaran *et al.,* 1965). More than 60 per cent intensive branches are seen in high-yielding trees whereas low-yielders possess less than 20 per cent intensive branches (Masawe, 1996). Even though, both types of branching were observed in all trees in the present study, intensive type dominated in 63 per cent of hybrids and 90 per cent of parents. Generally, intensive type of growth pattern tends to give bushy appearance to trees

whereas extensive type results in spreading tree habit. But in the present study, only two spreading hybrids (H03-52/6 and H03-52/7) showed extensive branching pattern. This shows the influence of genetic composition of a particular cultivar on the canopy shape (Kapinga *et al*., 2017).

Cashew flushes may vary in shape, size and colour depending on the genotype (Masawe, 1996). Some cashew varieties can be easily identified by the type of leaves or flushes. Leaves may be red, yellow red, green yellow or purple coloured. But young leaves were yellow red and mature leaves were green in most of the hybrids evaluated. Leaf shape is a varietal character and can be broadly classified as oblong, obovate or oval. In the present study, the most frequently observed leaf shape was obovate with smooth margin and round apex. Leaf cross section was level in 84.21 per cent of hybrids.

Cashew flowers occur in large inflorescences termed panicles (Purseglove, 1968). Among hybrids evaluated, the panicle shape varied from pyramidal to broadly pyramidal. Ninety per cent of hybrids and parents were having loose and pyramidal inflorescence. Only one hybrid, H03-97/2, produced compact and broadly pyramidal inflorescence. Sena *et al*., (1995); Mangal, (2016) and Ona *et al*., (2017) also observed two types of inflorescences in cashew cultivars. Unlike mango, which bears its crop on the past season's shoot, the cashew produces flowers on the current season's flushes (Roe, 1994), after the growth flush at the end of the rainy season. In cashew, flower colour may develop or change during anthesis period (Weevers, 1952). All the hybrids, except H03-52/6 and H03-52/5, developed cream-coloured flowers.

The flowering duration of cashew genotypes has special importance in the state of Kerala, where monsoon is staggered with a high annual rainfall of 300cm. As per the descriptor for cashew, genotypes in which flowering commenced from October are represented as early flowering types (Nayak *et al*., 2014). In the present study, 68.42 per cent of hybrids and 45 per cent of parents showed early flowering nature. It was also noted that hybrids having long flowering duration have medium to

long harvesting period. Early bearing with long flowering (>90 days) and harvesting duration was observed only in two hybrids, H03- 97/2 and H03-21/10. It is interesting to note that these hybrids having early flowering nature with long flowering duration also tend to yield more per tree (>24 kg). This result is in conformity with the findings of Mohapatra *et al.*, (2000), who observed that the hybrid, BH-85, having long flowering duration of 92.67 days have high nut yield per tree of 14.68 kg among the tested hybrids under Bhubaneswar condition. Majority of the hybrids and parents exhibited medium flowering duration (60-90 days) that has advantage of completion of flowering before the commencement of monsoon in Kerala. Rao (1995) and Samal *et al.,* (2006) also reported similar facts about flowering in cashew. The harvesting period of hybrid population under study lasted for 30 to 95 days as reported by Dasarathi (1958) under Bapatla conditions. But Mohapathra *et al*., (2017) recorded short harvesting duration ranging from 20.67 to 33 days in Bhubaneswar regions.

The cashew apple is an accessory fruit (sometimes called a pseudo or false fruit), a hypocarpium, that develops from the pedicel and the receptacle of the cashew flower (Varghese and Pundir, 1964). The cashew apple has a base at the point of attachment to the peduncle, ridges on its body and a cavity attached to the nut. Apples can be of cylindrical, conical obovate, round or pyriform in shape depending on the variety. The base, apex, ridges, grooves, cavity and skin of cashew apple also showed great variation among the hybrids. In the current study, it was observed that when either of parents had conical shaped apples, hybrids also produced conical shaped fruits, indicating the dominance of conical shape as it is passed from parents to their progeny. A study by Sethi *et al*., (2015c) also reported that conical shape of cashew apples dominates in hybrids.

Tree height is one of the indicators of the growth and development of cashew trees and is determined by plant genetics (Ona *et al.,* 2017). It always increases with the increase in age of the tree and irreversible (Salam and Peter, 2010). Response of cashew genotypes to different cultural practices followed during the crop growth also influences the growth habit. It is evident that the tree height in hybrids ranged from 6.25m to 10.53m, the tree girth ranged from 1.0m to 2.75m and the canopy spread

ranged from 6.6m to 14.35m. It supports the findings of Sreenivas *et al*., (2016), who found substantial differences in growth characteristics such as tree height, stem girth, and mean canopy spread among genotypes. All hybrids evaluated were tall (> 4m) and have high spread of canopy (>6.0 m). Two hybrids, H03-55/10 (6.25m) and H03-55/11 (6.45m) having lowest tree height can be considered for high density planting system. In the present study, variety K-22-1, recorded a tree height of 5.80m and grouped as tall. But, Chandrasekhar *et al*., (2012) and Mohapatra *et al*., (2017) suggested this variety as semi tall (2.5-4 m) with intensive compact tree habit and recommended for high density planting under Bhubaneswar conditions. The differential growth rates of cashew varieties or hybrids with respect to tree height, girth and canopy spread were also reported by Manivannan *et al*., (1989), Uthaiah *et al*., (1989), Reddy *et al*., (1996), Naik *et al*., (1997), Swamy *et al*., (1990), Dorajeerao *et al*., (2002), Reddy *et al*., (2002), Samal *et al*., (2006), Sharma *et al*., (2011), Dasmohapatra and Pattnaik, (2012), Dadzie *et al*., (2014), Tripathy *et al*., (2015), Sethi *et al.,* (2015) and Anindita *et al*., (2018).

Plant leaf area is an important determinant of light interception and consequently of transpiration, photosynthesis and plant productivity (Ghatge *et al*.,2009). The highest leaf size (>160 cm^2) was recorded in the bold nut types, H03-18/17 and Priyanka indicating the role of leaf area in productivity.

In terms of phenological characters, the hybrids and parents exhibited high variance in number of laterals per square metre (20.76) and number of panicles per square metre (17.37). Distribution of number of flowering laterals and panicles per meter square among 19 cashew hybrids and 11 parents are depicted in Fig 4. A positive linear relationship was found between the number of flowering laterals and panicles per meter square. As the number of flowering laterals per meter square increased, the number of panicles produced per meter square also increased. Both these yield contributing characters were found to be the highest in the hybrid, H03-97/2. This also reflected in its yield (24.5 kg/tree/year). Among the hybrids, the flowering laterals per metre square ranged from 8.00 to 13.75. Aliyu *et al*., (2011),

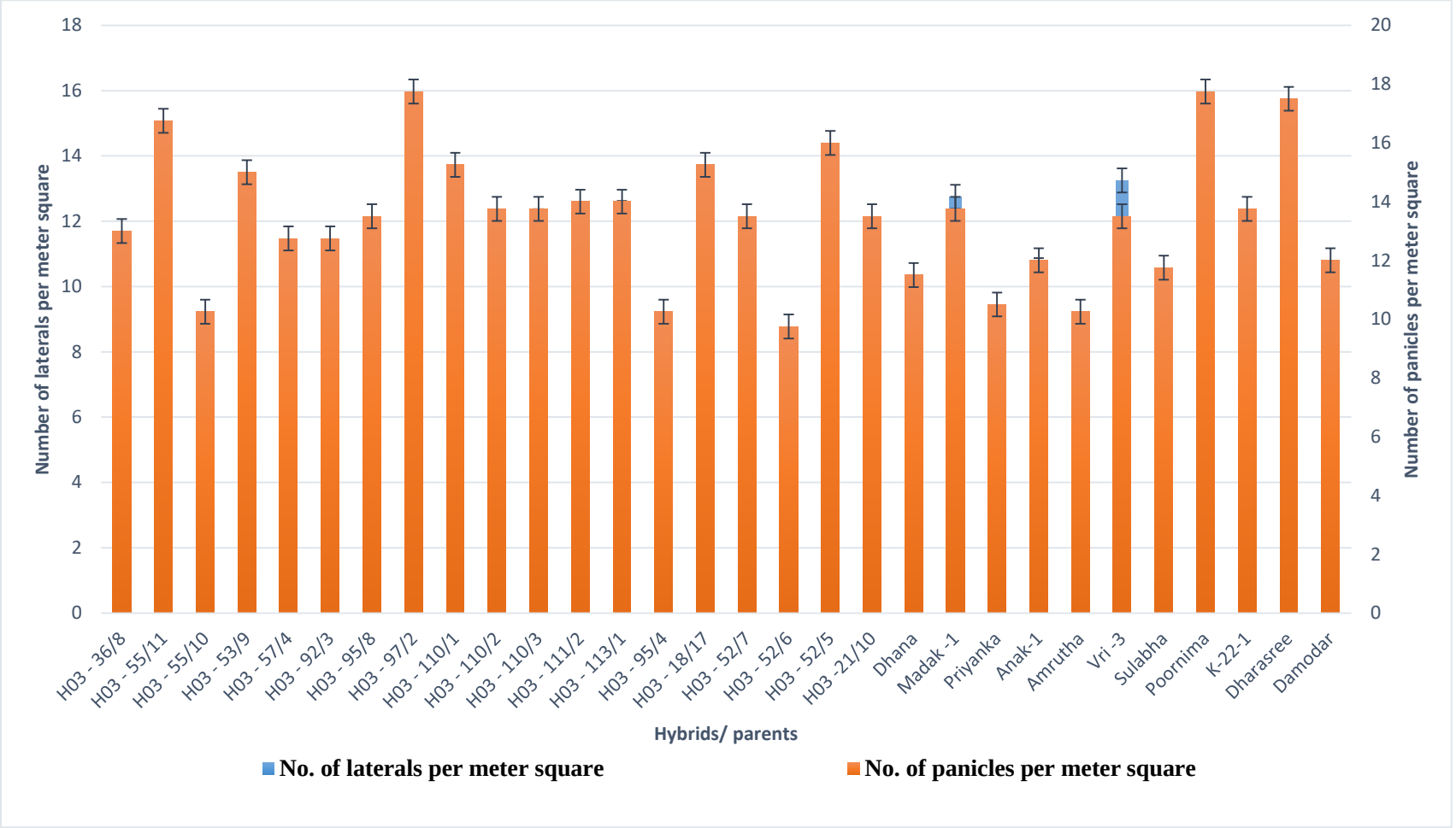
Dorajeerao *et al*., (2002), Sethi *et al*., (2018), Sharma *et al*., (2020) also observed variations in number of laterals per metre square.

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). The cashew 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 12) in contrary to 32.75 number of bisexual flowers under Bhubaneswar conditions (Mohapatra *et al*., 2017).

The sex ratio is closely associated with the number of hermaphrodite flowers in all hybrids. Varietal character is responsible for the differences in panicle and floral parameters. Singh *et al*., (2008), Samal *et al*., (2006), Reddy *et al*., (2002) and Sena *et al*., (1994) also discovered significant differences in panicle and flower characteristics.

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 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 clustering bearing nature. Number of nuts per panicle in cashew is highly a 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). Sharma *et al.,* (2020) recorded nuts per panicle ranging from 15.65 (RP-1) to 1.0 (Kankadi-1).

Fig 4. Distribution of number of flowering laterals and panicles per meter square among 19 cashew hybrids and 11 parents



The distribution of number of bisexual flowers and nuts per panicle among hybrids and varieties is depicted as figure 5. Though, a clear-cut positive relationship was lacking between number of bisexual flowers and final nut set per panicle, number of bisexual flowers showed a significant positive correlation with total nut yield per tree. Fruit set can vary between different ecologies or locations. Rao and Hassan (1957) reported only 3 per cent nut set on the west coast of India, and 6- 12 per cent on the east coast (Murthy *et al*., 1984). In reality, the number of fruits that attained maturity in cashew was often very low compared to initial fruit set. This indicates the need of assuring successful pollination in cashew field to get more nut set per panicle.

5.2.3. Variability in Yield characters

Yield is the ultimate target of any varietal evaluation. In cashew, nut is the produce of commerce. The average nut yield plant^{-1}(kg) in the hybrid population ranged from 2.1 kg to 25.20 kg during 2020 at 10 years of stabilized yield. Nayak *et al*., (2014) suggested that cashew genotypes yielding more than 18 kg of nut per tree per year can be considered as high yielders. During the evaluation period, the hybrids, H03-21/10, H03-97/2, H03-110/1, H03-36/8, H03-52/5, H03-92/3 and parent Poornima and Amrutha were recorded as high yielders. Genotypes with yield between 9-18 kg are referred as medium yielders and 7 hybrids and 9 parents included in this category. The parent, Priyanka and hybrid, H03-95/4 were low yielders with bold sized nut (11.10 and 12.44g, respectively). This indicates the strong effect of nut size-number trade off on nut yield (Aliyu and Awopetu, 2011). 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, Nalini *et al*., (1991); Hedge *et al*., 2000).

The poor nut yield of some of the hybrids in this study were mostly due to alternate bearing habit, of the genotype, which may eventually show an increased productivity over the years.

Significant differences were observed among the cashew hybrids with respect to apple, nut and kernel weight (Fig 6.). 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 Pereira *et al*. (2011), Desai (2009), Lenka *et al*., (2003), Raquel *et al*., (2003), Reddy *et al*., (2002b), Reddy *et al*., (2001) and Narayana reddy *et al.*, (1986), Sahoo *et al*., (2020), Gajbhiye *et al.*, (2018), Sapkal *et al*., (1992). Because of the larger apple weight, hybrids, H03-52/5 and H03-18/17, can be selected as better types for 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 17 hybrids having high nut weight (>7g), 12 hybrids were categorized under high kernel weight group (>2.5g). The kernel of cashew nut is edible, economical and processed part. According to Manoj *et al*., (1994) and Sethi *et al*., (2015) kernel weight has the greatest beneficial direct effect on nut yield in cashew. Significant differences among the values of kernel weight were also reported by Desai (2011) and Desai (2009).

The distribution of apple, nut and kernel weight among cashew hybrids and cross parents is depicted as Fig 6. 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 also were found to bear larger nuts in some of the hybrids (for example H03-53/9).

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 therefor nut weight could not 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), Mahesha *et al*., (2005), Haldankar *et al*., (2004), Vishnuvardhana *et al*., (2003), Reddy *et al*., (2002) and Manoj *et al*., (1993).

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, H03-52/5 and H03-97/2 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). According to Aliyu and Awopetu (2011), cashew trees with nut weight greater than 15g are represented as jumbo nut, not suitable for commercial planting, because of their poor yield per tree. But, none of the hybrids showed jumbo nut character in this study.

They also opined that cashew genotypes having nut weight between 9-12g are better suitable for commercial cultivation. Thus, hybrids H03-36/8 (10.23g), H03-21/10 (12.55g), H03-18/17 (12.44g), H03-95/4 (12.44g), H03-110/1 (11.18g), H03-52/5 (10.40g), H03-95/8 (10.37g), H03-52/7 (10.21g), H03-52/6 (10.17g), H03-97/2 (10.10g), H03-113/1 (9.45g) and H03-57/4 (9.30g) can be suggested for commercial cultivation after considering the tree yield. Of these, H03-36/8, H03-97/2, H03-110/1, H03-52/5 and H03-21/10 were high yielders with nut yield above 18 kg per tree indicating the direct impact of nut weight on nut yield (Krishnappa *et al*., 1998).

The variability in nut and kernel dimensions is represented as figure 7. This shows a linear and positive relation between nut and kernel traits. As the nut dimensions increases, the kernel length, width and thickness also increase accordingly. The length, width and thickness of nut and kernel have a direct impact on nut and kernel weight. All these traits showed a significant positive correlation with each other and negative correlation with number of nuts per kilogram (Table 15).

Fig 5. Distribution of number of bisexual flowers and nuts per panicle among the cashew hybrids and parents

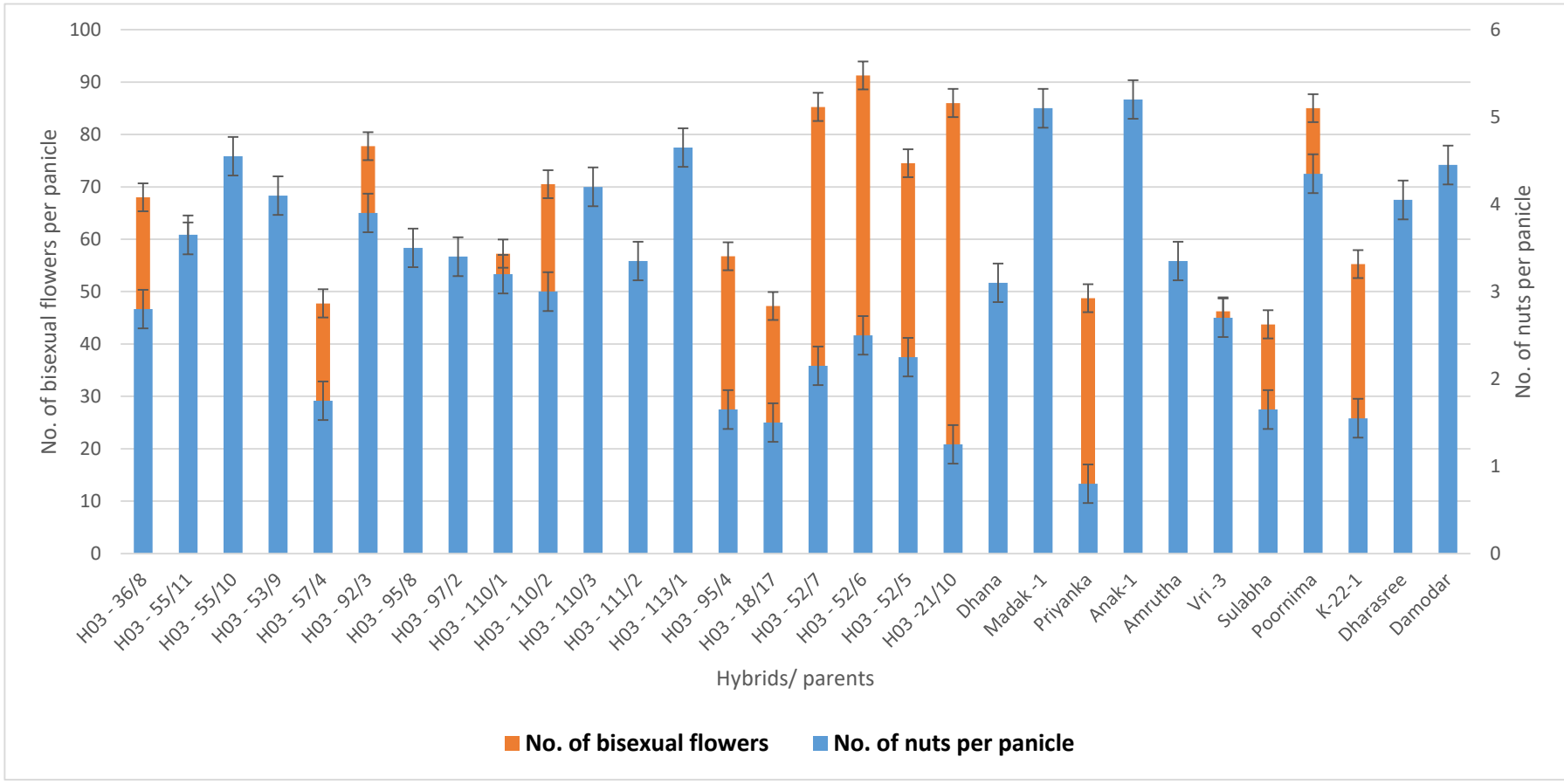
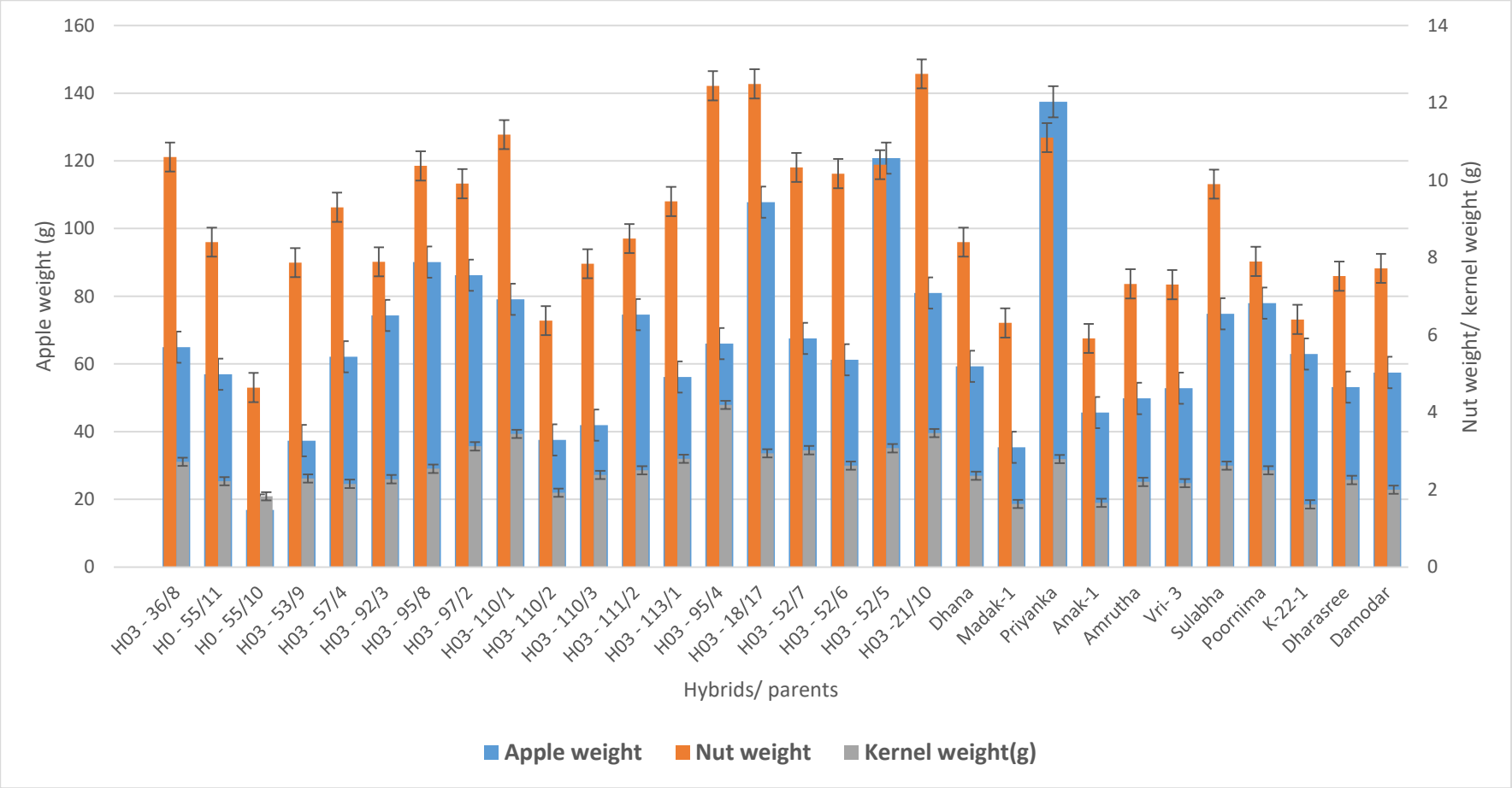


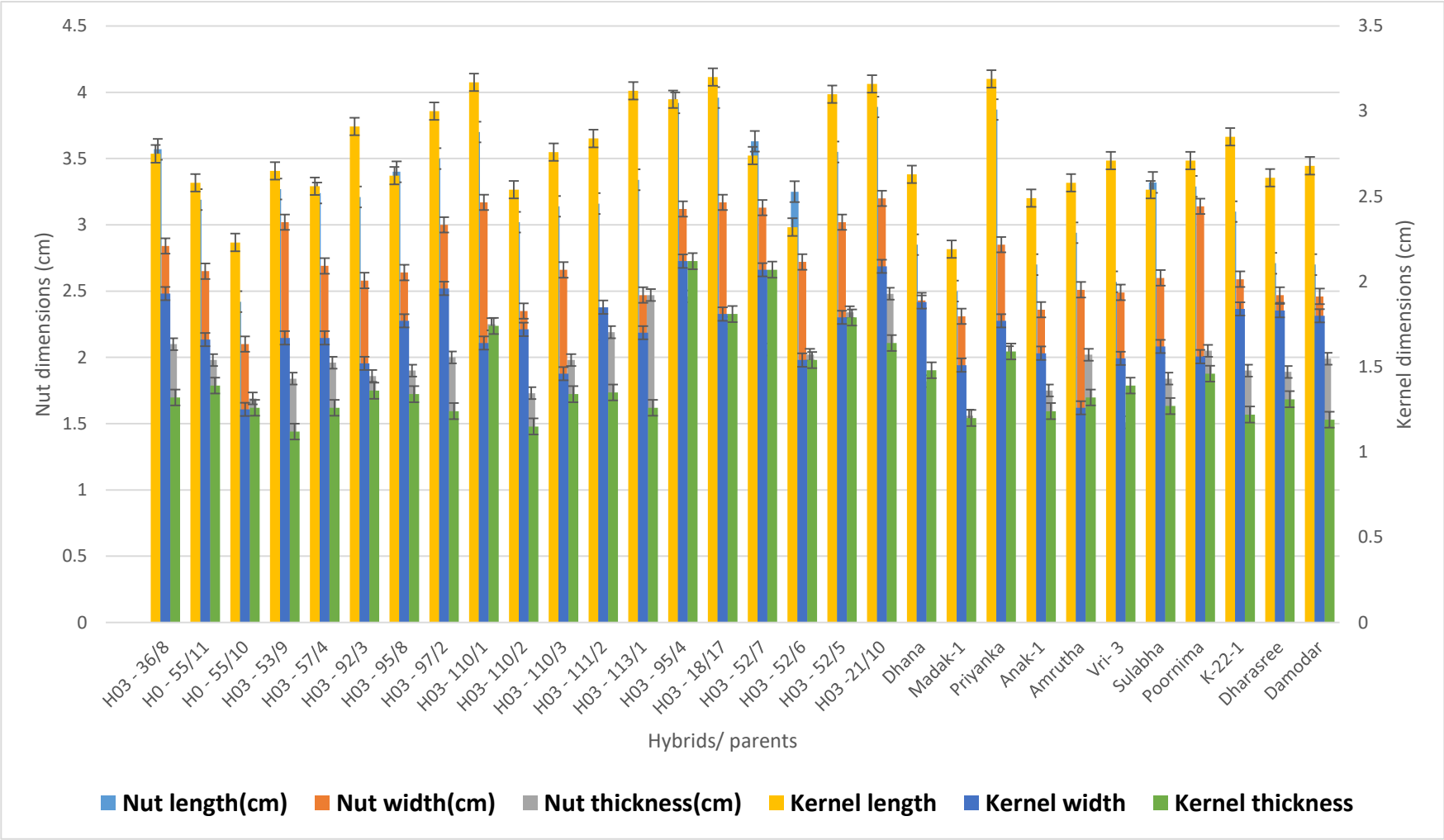
Fig 6. Variability in apple weight, nut weight and kernel weight among the cashew hybrids and parents



Shelling percent has 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. The shelling percentage in the present study ranged from 23.14 to 36.44. Similar variations on the shelling percentage were reported by Sethi *et al*., (2018), Hedge *et al*., (2018) 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*., (2015) and recommend that both nut weight and shelling percentage need to be taken into account while selecting.

The high heritability of kernel weight and shelling percentage also revealed significant scope for the improvement of these traits in the cashew breeding programme (Blaikie *et al*., 2003). Selection of nut and kernel weight was regarded as valuable source of variations in the cashew development programme, according to Chijojola *et al*., (2009).

Fig7. Variability in nut and kernel characters among the cashew hybrids and its parent



5.2. Correlation among yield related traits

Without respect to cause or effect relationships, correlation analysis exposes the duration and amount of any given pair of traits association. A thorough understanding of the relationship between yield and the potential component characters to be considered in selection programmes. Even though, cashew is a major foreign exchange earner, such research has been limited, and as a result, the information accessible is limited (Newale and Selvi, 1990).

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) among 19 cashew hybrids and 11 parents. simple correlation analysis by Parameswaran (1979), Kumar *et al*., (1996), Lenka *et al*., (2001) indicated a positive correlation between yield and percentage of bisexual flowers. However, a weak negative link was observed between yield and apple weight, apple to nut ratio, and internodal length. Sena *et al.,* (1994) found a strong positive association between yield and nut weight. Salam (1998) discovered a strong link between yield, kernel weight, and nuts per panicle. A favorable association between yield and kernel weight was shown by Manoj *et al.,* (1984).

As indicated by the strength of substantial positive correlation between nut production per plant and nut weight, nut weight might be considered as a major yield contributing elements. This backed up the findings of Nayar *et al*., (1981), Reddy *et al*., (1996), and Rao *et al*. (2002). The nut weight and the number of hermaphrodite flowers per panicle were highly significant in the current study, confounding the results of Aliyu (2006), who reported that nut weight, number of nuts per tree, and number of hermaphrodite flowers per panicle were positively correlated with nut yield and could be used as primary components for improving yield.

In this study, nut weight was found to have a positive association with apple weight, indicating that selecting for larger nut and apple sizes may provide an advantage for genetic improvement and nut yield.

A strong positive significant correlation between nut and kernel characters implies that when nut dimensions increase the kernel characters also increases. This implies that nut size should be an important selection index for crop improvement programmes of cashew as suggested by Aliyu *et al*., (2011) and Aliyu *et al.,* (2006). The association between nut weight, kernel weight, number of nuts per panicle, and number of laterals per square metre was very strong, indicating that selecting for one of the features would automatically result in a positive shift in the mean of the other linked yield component traits.

5.3. Identification of promising cashew hybrids

In cashew improvement programmes, selection for nut size, kernel weight and shelling percentage were considered as the valuable source of variations (Sethi *et al*., 2015a). Today, the main product driving cashew industry is the kernel from the drupaceous nut, which is typically graded into 26 different classes based on size and colour and prices are paid accordingly. Processors usually looking forward to bigger sized nuts as that will give kernels of higher grade (Aliyu and Awopetu, 2011). This necessitated the development of varieties or hybrids that combine desirable nut characteristics, i.e., capable of producing high premium kernels and high yield.

Based on the correlation study conducted, traits like nut weight, kernel weight, shelling percentage, apple weight and number of bisexual flowers having significantly positive correlation with tree yield can the boost nut yield. The principal component analysis based on this yield contributing characters reflected the genetic diversity present in the hybrid population by distributing the hybrids into four quadrants of loading plot (Fig.2). Eight hybrids, H03-36/8, H03-21/10, H03-110/1, H03-97/2, H03-95/4, H03-52/5, H03-52/6, H03-52/7, were placed in the first quadrant along with check variety, Poornima. All these hybrids were having bold sized nuts and premium kernels. Since high nut yield and more than 28 shelling percentage are considered as ideal for kernel recovery, hybrid H03-55/6 with a shelling percentage of 25.76 and H03-95/4 with a nut yield of 2.10, cannot be suggested for commercial cultivation, but can be conserved as a repository of genes for bolder nut and kernels of higher grade.

In order to attract profitable investments in cashew industry, high yielding cultivars combining prolific fruiting with nut sizes in the range of 9.0 to 12.0 g, kernel weight more than 2.5 and shelling percentage above 28 can be recommended to farmers. Thus hybrids, H03-36/8, H03-21/10, H03-110/1, H03-97/2, H03-52/5, H03-52/7 were identified as candidate hybrids with good yield, capable of producing high premium kernels (W180-W240). This indicates a good opportunity for nut yield and kernel size improvement through heterosis breeding programmes in cashew. The hybrid H03-18/17, possessing bold nut characters as that of variety, Priyanka can be used for future breeding programmes in cashew.

The study provided the data for determining the genetic relatedness of cashew hybrids, which will aid in tree enhancement programmes. A population with a wide range of genetic diversity would be ideal for collecting germplasm that could be utilised to make valuable clones after vegetative propagation. The hybrids showing good nut and kernel weight, nut yield, and shelling percentage can be selected and vegetatively propagated for orchard establishment for evaluation and further selection. The research revealed the existence of a potential genetic base that can be leveraged to boost cashew generation. To determine whether the variance is genetic, molecular markers such as amplified fragment length polymorphism (AFLP) DNA markers, simple sequence repeats (SSRs), or microsatellites must be used to characterise the cashew populations.

5.4. Variation in Biochemical characters

Cashew apples of selected hybrids and their cross parents showed significant variations for T.S.S., Titratable acidity, Total sugar, Vitamin C and Tannin.

The total soluble solid (TSS) content of a cashew apple indicates its suitability for consumption as well as the manufacture of alcoholic beverages. The TSS content of cashew hybrids ranged from 13.15 ^{0}Brix to 17.4 ^{0}Brix (Fig. 8). The TSS content of the cross parent has no effect on the TSS content of the corresponding hybrids.

Variations in TSS content of cashew apple was also studied by Sethi *et al*. (2015a) and Mirdha *et al.*, (2019).

In the current investigation, the ascorbic acid content of hybrids ranged from 107.50 to 220.15 mg/100ml (Fig 9.) and cross parents have higher Vitamin C than the corresponding hybrids. The amounts of ascorbic acid (vitamin C) in cashew apple juices support the trend in vitamin C in cashew apple juice that has been documented by various researchers (Morton, 1987; Akinwale, 2000; Azam and Judge, 2001). Unlike research that indicated the effect of apple colour on vitamin C levels, that is yellow coloured cashew apple produces more Vitamin C than red coloured (Assunço and Mercadante, 2003), the current investigation found that colour has no effect on this level. Furthermore, the vitamin C levels in this study are much lower than those recorded by Morton (1987), who found 372 mg/100 g. Mirdha *et al*., (2019) also studied the variations in vitamin C content of cashew apples.

The results on cashew apple acidity (%) revealed significant variations among the hybrids. Among the 19 cashew hybrids and 11 cashew varieties evaluated the acidity ranged from 0.13 to 0.33% (Fig 8). Mirdha *et al*., (2019) and Yahaya *et al*., (2016) found similar variations on titratable acidity. The acidity content of the cashew apple in the present investigation was lower than that reported by Ramteke *et al*., (2020).

Fig **8. Variation in TSS content of cashew apple of hybrids**

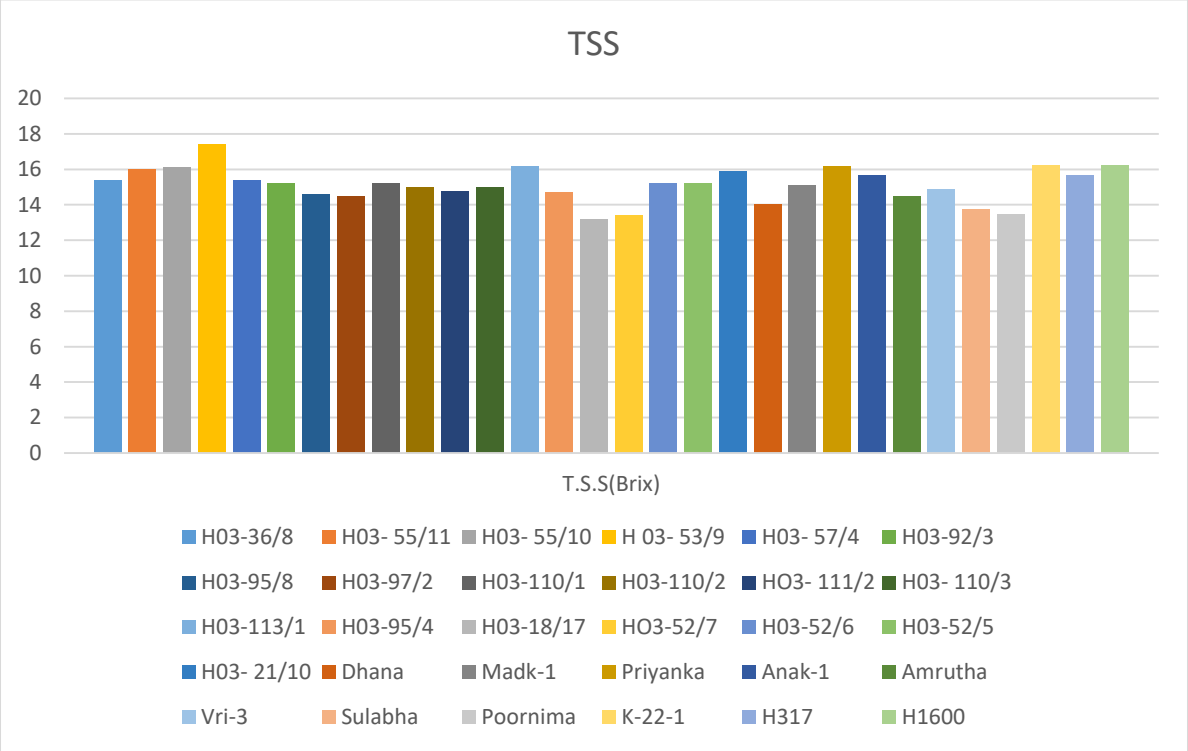
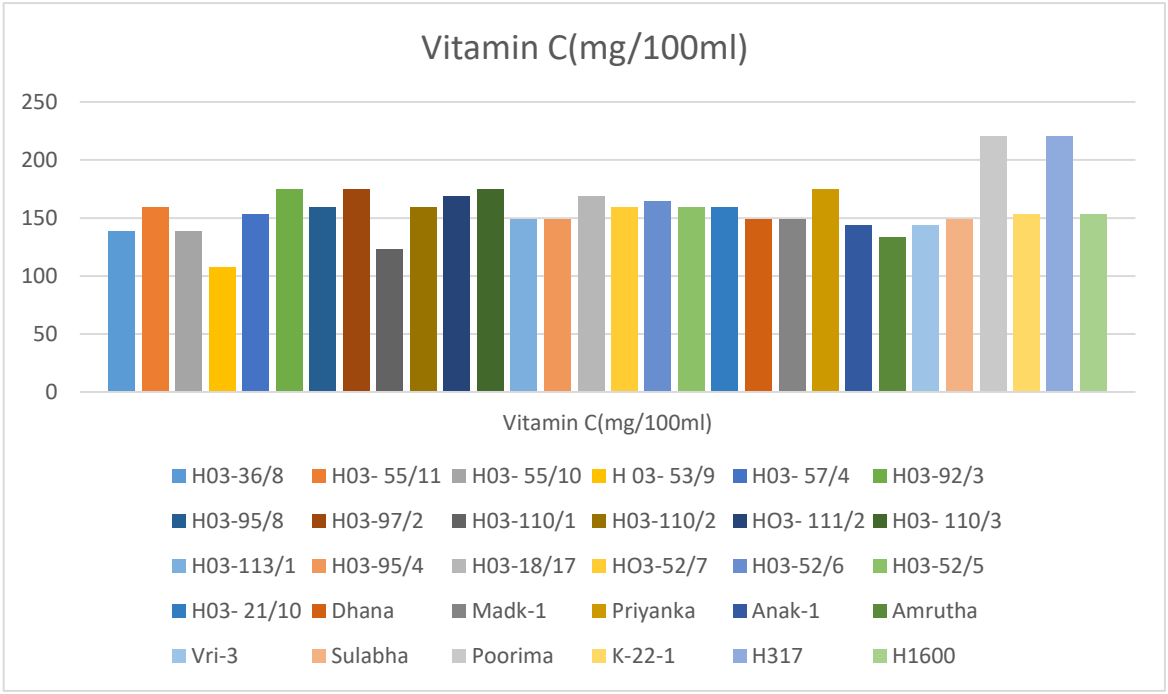


Fig **9. Variation in Vitamin C content of cashew apple of hybrids and parents**



The distribution of total sugar content of cashew apple among 19 hybrids is depicted as Figure 10. Among the 30 cashew genotypes evaluated the total sugar ranged from 13.44 to 21.21% (Fig 11). Mirdha *et al.,* (2019) found similar variations on Total sugar. reported that the sugar content of hybrids ranged from 10.22% to 19.22%, which is less than our studies.

The astringent taste of cashew apple due to the tannin content. Genotypes with lesser tannin content was preferred for cashew apple processing. In the current investigation, the hybrid's tannin content ranged from 0.09% to 0.29%. The similar variations in content of tannin content shown by Ramteke *et al*., (2020) and Mirdha *et al*., (2019).

In the present investigation H03-53/9, HO3-55/10, H03-113/1 and H03-55/11 have high TSS content. Hybrid H03-113/1 have high TSS, Hybrid H03-55/11 have less acidity, high sugar and minimum tannin content. H03-92/3, H03-55/10 also shows minimum tannin content. So these can be recommended as hybrids with better biochemical characteristics and these can be used in cashew apple processing.

Fig 10. Variation in Titrable acidity and Tannin of cashew apple for hybrids

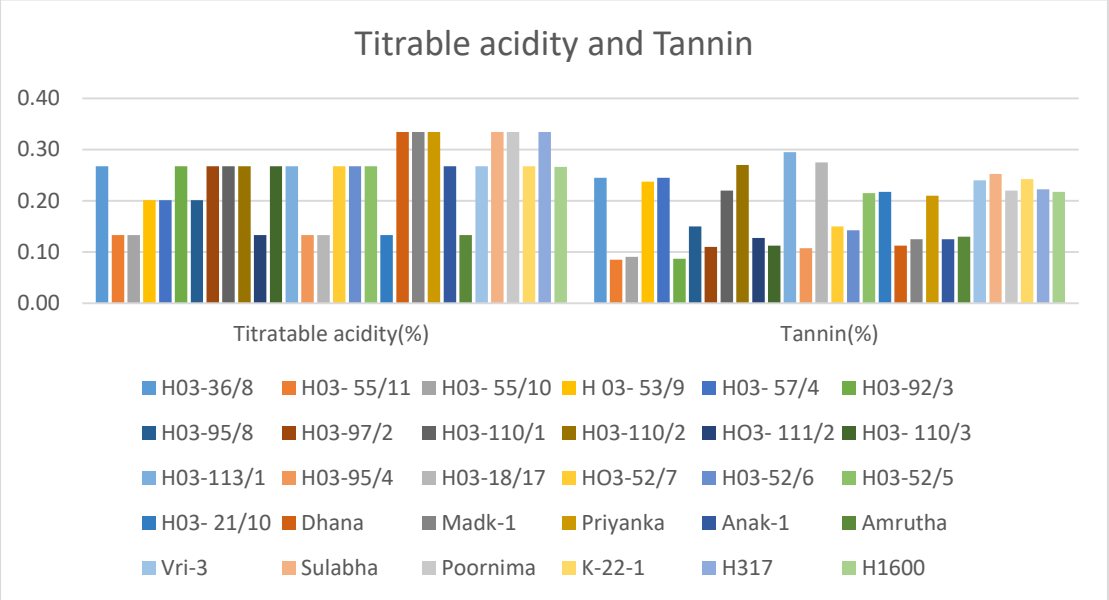
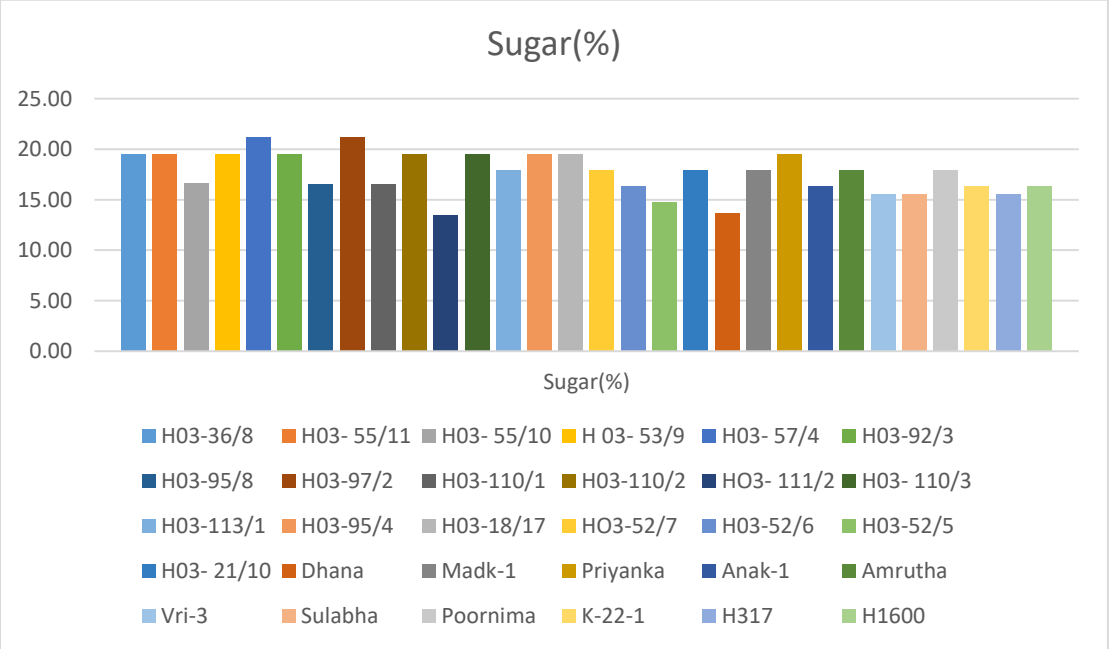


Fig 11. Variation in Total Sugar (%) of cashew apple for hybrids



5.5. Heterosis studies and performance of hybrids

The genetic divergence between the parental varieties usually determines how heterosis manifests. If the heterosis in the offspring of a cross between two parental varieties is quite high, it is concluded that these progenies are genetically different from their cross parents (Hallauer and Filho, 1981).

Since cashew is a highly cross-pollinated crop, it is very difficult to obtain a single plant with all desirable traits. A tree which produces large number of nuts often has small nuts which are not suitable for cashew industry. Hence, the strategy on breeding programme for cashew is to make crosses involving as many parental combinations as possible through selection and heterosis breeding approaches. The parents to be used in hybridization need to be selected for nut quality aspects with yield potential as the centre of focus. The heterosis, called as hybrid vigour, is defined as the superior performance of hybrids over its parents (Shull, 1914). The hybrid vigour obtained in cashew can be capitalized and utilized directly through clonal propagation at any stage of the breeding programme, which is an added advantage (Eradasappa *et al*., 2020).

Meredith and Bridge (1972) used the term ‘useful heterosis’ for the ‘standard heterosis’. it is also called economic heterosis as it has direct practical value in plant breeding. The importance of estimating it was advocated by Swaminathan *et al*. (1972). The high degree of relative heterosis, heterobeltiosis, and standard heterosis for yield contributing traits obtained in this study, indicates the effectiveness and potential enhancement of the character, which could lead to an increase in crop yield (Manoj and George, 1993; Shankarnarayan, 1996). This result can be compared to those obtained by Sethi *et al*., (2015), who investigated the extent of heterosis exhibited by some promising hybrids at the All India Coordinated Research Project on Cashew, Bhubaneswar, Odisha, India. Manivannan *et al.* (1989) and Manoj and George (1989) also found positive heterosis in nut yield. For the cashew development initiative, a higher magnitude of heterosis for nut weight and kernel weight has also been suggested (Chipojola *et al*., 2009).

In terms of nut weight (g), kernel weight (g), number of bisexual flowers, apple weight, nut length, nut width, nut thickness, kernel length, kernel width, and kernel thickness, the hybrids H03-21/10, H03-36/8, HO3-110/1, H03-97/2, H03-52/7, H02-52/6, H03-52/5, H03-18/17 and H03-95/4 showed better heterosis. These findings suggest that hybridization, influences nut weight, kernel weight, number of bisexual flowers, apple weight allowing for considerable genetic improvements in the selection process. Through the direct study of heterotic effects in clonal selection processes, as well as the establishment of base populations for the cashew population enhancement programme, this method makes it feasible to generate commercial clones with suitable features.

Other research stations, such as Vengurla (Maharashtra) and Bapatla (Andhra Pradesh), reported that when prolific bearer is crossed with bold nut type, the chances of producing a hybrid with better nut weight are increased (Salvi, 1979). In this study, the cross parents of H03-110/1, H03-110/2, and H03-110/3 are Poornima and Priyanka are; the cross parents of H03-52/7, H03-52/6, and H03-52/5 are Priyanka and Vridhachalm 3; and one of the parentages of the hybrid H03-21/10 and H03-95/4 is Priyanka. When a prolific bearer is crossed with Priyanka, the nut weight and kernel weight increase**.** Nawale and Selvi (1990) found a similar report of transmission of nut weight parameters from parents to F1 hybrids in cashew. They believe that in order to generate good cashew hybrids, parents with tiny nut sizes should be discarded from the hybridization programme and parents with medium nut sizes should be chosen. They also discovered that when cashew parents with large nut sizes are crossed as a male parent in a crossing, the nut size improves significantly.

H03-36/8 has Dhana and Madakkathara-2 as cross parents, while H03-97/2 has Sulabha and Madakkathara-1 cross parents. The yield per tree is higher in these hybrids than in other hybrids. This indicates that when Madakkathara-1 is used as one of the parents in hybridisation, a high yielding variety tree is produced. The fruit colour of the cashew apple has no resemblance to the cross parents employed in hybridization.

Poornima and Madakkatahara-1 have the longest flowering time among the parents. H03-36/8 and H03-97/2 were among the hybrids with the longest flowering period, and the Madakkathar-1 was used as the male parent in these hybrids. When we employ Madakkathara-1 as a male parent, we have a better probability of obtaining hybrids with longer flowering times.

In the present study cluster bearing habit is observed in hybrids H03-55/10, H03-113/1, H03-53/9. In two hybrids H03-55/10 and H03-55/10 male parent is Anakkayam-1, which is one of the best cluster bearers in cross parents. Hybrid H03-113/1, the male parent is variety Dharasree, which is also a cluster bearer. This discovered that when cashew parents with cluster bearer is crossed as a male parent in a crossing, the progenies are also reported to be cluster bearer.

The Fig. (12a, b, c,) describes the relative heterosis, heterobeltiosis and standard heterosis of nineteen cashew hybrids with respect to nut weight, kernel weight, apple weight, no.of bisexual flowers, apple weight, nut length. Nut width, nut thickness, kernel length, kernel width and kernel thickness of 9 cashew hybrids H03-21/10, H03-110/1, H03-97/2, H03-36/8, H03-52/7, H03-52/6, H03-52/5, H03-18/17 and H03-95/4.

From the figure (12), all the hybrids exhibit 50% more hybrid vigour than their parents and 30% more hybrid vigour than their better parent. Hybrids H03-52/6, H03-52/5 and H03-52/7 have relatively less hybrid vigour than their standard variety Poornima for characters like nut weight, kernel weight, no.of bisexual flowers and apple weight.

All the 9 hybrids have positive significant standard heterosis for nut weight, exceptionally H03-21/10, H03-110/1, H03-36/8, H03-52/5, H03-52/7, H03-18/17 and H03-95/4 have 30% more standard heterosis than others (Figure 12.) All the hybrids exhibit positive significant relative heterosis.

All the hybrids shows positive relative heterosis, H03-21/10, H03-110/1, H03-97/2, H03-36/8, H03-52/7 for kernel weight (Figure 12a). H03-52/5 shows more than 25% relative heterosis. H03-52/6 shows negative heterobeltiosis. All the hybrids have positive standard heterosis for kernel weight.

Thy hybrid H03-95/4 have high nut weight and kernel weight than other hybrids. This hybrid can be represented as a bold nut hybrid. The yield of the hybrid is very less compared to other hybrids, this may due to the susceptible nature of these hybrids to TMB. The hybrid H03-95/4 can be used as one of the cross parent in future crop improvement programmes.

The salient features of H03-21/10, H03-110/1, H03-97/2, H03-36/8, H03-52/7, H03-52/6, H03-52/5 and H03-95/4 are summarized in Table (20,21,22,23,24,25,26,27 and 28).

In terms of yield per tree(kg), nut weight(g), kernel weight(g), and shelling percentage, hybrids H03-21/10, H03-36/8, HO3-110/1, H03-97/2and H03-52/5 can be considered as an elite bold nut hybrid with good yield potential and can be further evaluated under Kerala conditions. Hybrids H03-95/4, H03-52/6, H03-52/7 and H03-18/17 with good quality traits like bold nut, high kernel weight and shelling percent can be uses as parent for future breeding programme.

These findings suggest that heterosis, or hybrid vigour, as a result of hybridizations, influences cashew nut yield, nut weight, kernel weight, and shelling percentage, allowing for considerable genetic improvements in the selection process. Through the direct study of heterotic effects in clonal selection processes, as well as the establishment of base populations for the cashew population enhancement programme, this method makes it feasible to generate commercial clones with suitable features.

Fig 12a. Percentage performance and magnitude of heterosis on nut weight and kernel weight

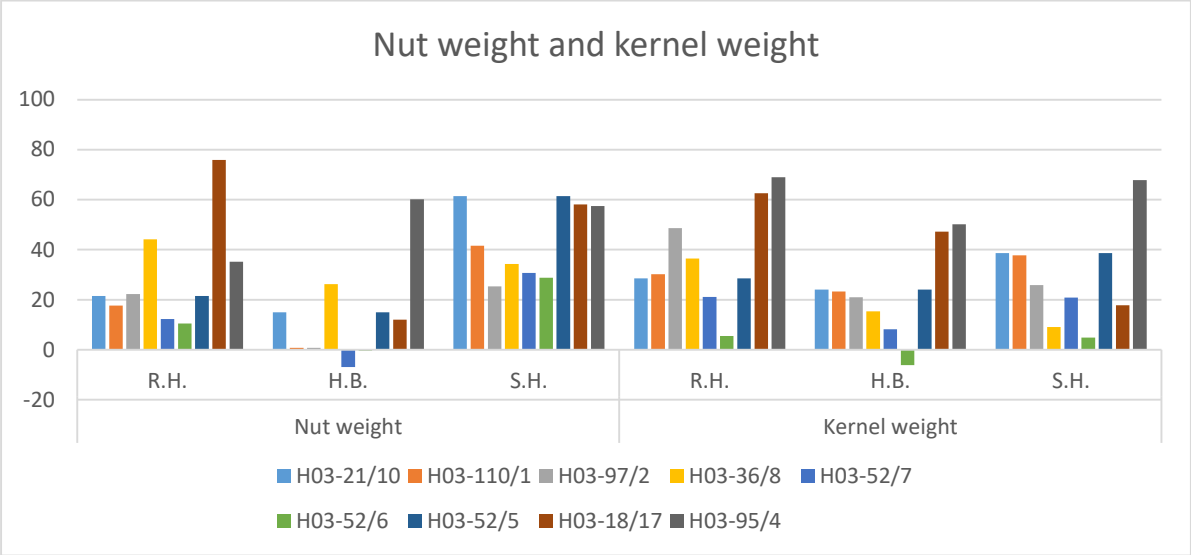


Fig12b. Percentage performance and magnitude of heterosis on apple weight and no.of bisexual flowers

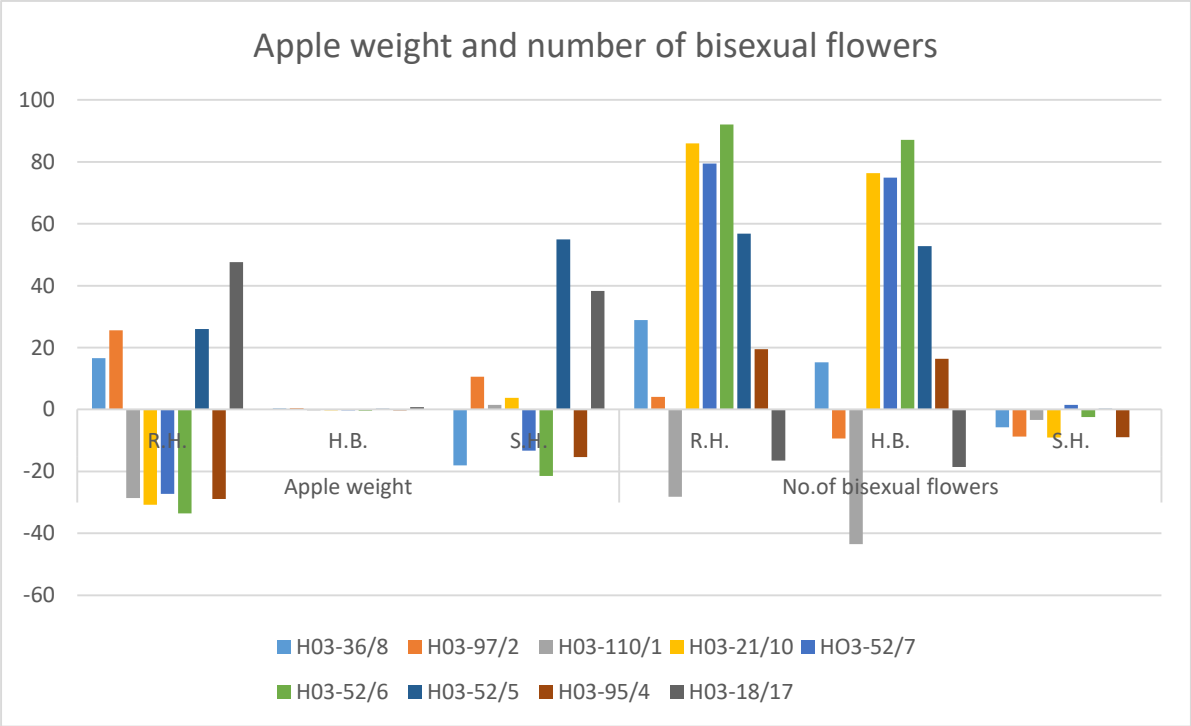


Fig12c. Percentage performance and magnitude of heterosis on nut characters

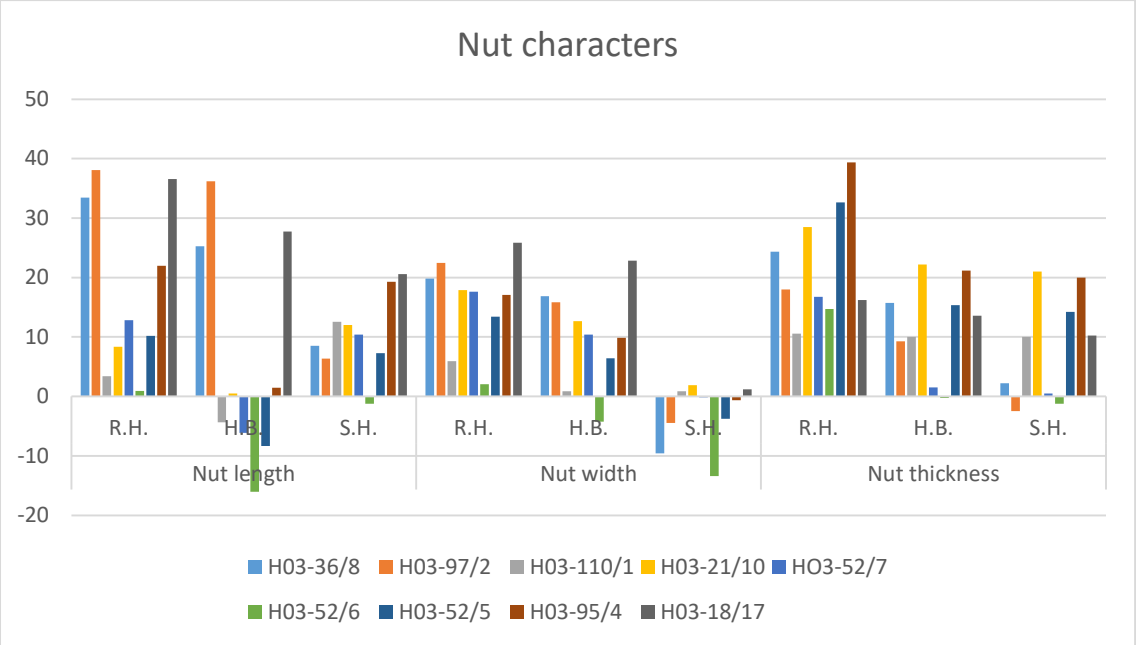


Fig12d. Percentage performance and magnitude of heterosis on kernel characters

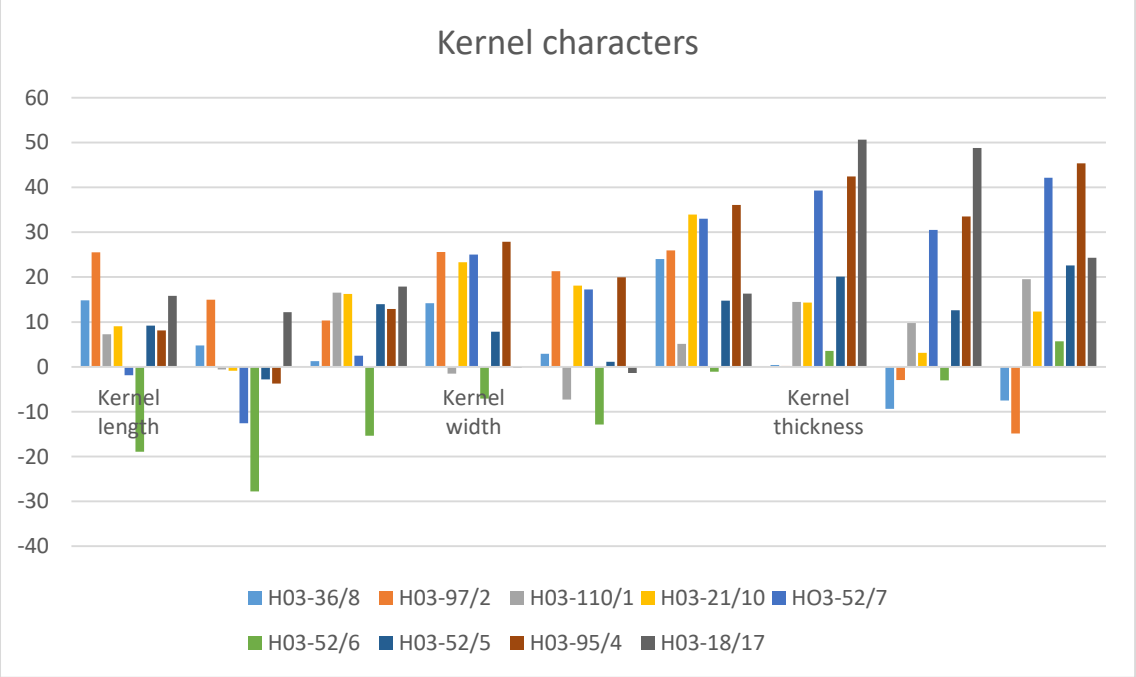


Table 20. Salient features of H03-21/10

Characters	Female parent Sulabha	Male parent Priyanka	Hybrid H03-21/10
Flowering	Late	Mid	Early
Sex ratio	0.088	0.088	0.108
Canopy type	Compact	Open	Compact
Nut weight(g)	9.44	12.43	12.55
No.of nuts/kg	111	98	90
Kernel weight(g)	2.28	3.32	3.66
Shelling percentage	24.23	26.75	29.16
Export grade	W210	W180	W180
Nut yield/tree(kg)	10.6	6.4	25.20

Table 21 . Salient features of H03-110/1

Characters	Female Parent Poornima	Male Parent Priyanka	Hybrid H03-110/1
Flowering season	Early	Mid	Mid
Sex ratio	0.111	0.088	0.048
Canopy type	Compact	Open	Compact
Nut weight(g)	9.55	12.43	11.18
No.of nuts/kg	139	98	101
Kernel weight(g)	2.742	3.32	3.44
Shelling percentage	28.70	26.75	30.77
Export grade	W210	W180	W180
Nut yield/tree(kg)	17.05	6.4	23.40

Table 22. Salient features of H03-97/2

Characters	Female parent Sulabha	Male Parent Madk-1	Hybrid H03-97/2
Flowering	Late	Early	Early
Sex ratio	0.088	0.105	0.063
Canopy type	Compact	Compact	Spreading
Nut weigh(g)	9.44	5.35	10.10
No.of nuts/kg	111	149	128
Kernel weight(g)	2.28	1.66	3.12
Shelling percentage	24.23	30.98	30.89
Export grade	W210	W280	W180
Nut yield/tree(Kg)	10.6	15.6	24.5

Table 23. Salient features of H03-36/8

Characters	Female Parent Dhana	1st Parent Madakkathara-1	Hybrid H03-36/8
Flowering season	Mid	Early	Early
Sex ratio	0.090	0.105	0.093
Canopy type	Compact	Compact	Compact
Nut weight(g)	8.61	5.35	10.23
No.of nuts/kg	128	149	121
Kernel weight(g)	2.365	1.66	2.90
Shelling percentage	27.46	30.98	28.35
Export grade	W210	W280	W210
Nut yield/tree(kg)	8.2	15.6	22.10

Table 24. Salient features of H03-52/7

Characters	Female Parent Priyanka	Male parent Vridhachalam-3	Hybrid H03-52/7
Flowering season	Mid	Early	Mid
Sex ratio	0.088	0.077	0.113
Canopy type	Open	Compact	Spreading
Nut weight(g)	12.43	7.30	10.21
No.of nuts/kg	98	142	110
Kernel weight(g)	3.32	2.17	3.02
Shelling percentage	26.75	29.76	29.58
Export grade	W180	W210	W180
Nut yield/tree(kg)	6.4	13.69	16.5

Table 25. Salient features of H03-52/6

Characters	Female Parent Priyanka	Male parent VRI-3	Hybrid H03-52/6
Flowering	Mid	Early	Mid
Sex ratio	0.088	0.077	0.109
Canopy type	Open	Compact	Spreading
Nut weight(g)	12.43	7.30	10.17
No.of nuts/kg	98	142	119
Kernel weight(g)	3.32	2.17	2.62
Shelling percentage	26.75	29.76	25.76
Export grade	W180	210	W210
Nut yield/tree(kg)	6.4	13.69	16.5

Table26. Salient features of H03-52/5

Characters	Female Parent Priyanka	Male parent Vridhachalam-3	Hybrid H03-52/5
Flowering season	Mid	Early	Mid
Sex ratio	0.088	0.077	0.116
Canopy type	Open	Compact	Spreading
Nut weight(g)	12.43	7.30	10.40
No.of nuts/kg	98	142	119
Kernel weigh(g)	3.32	2.17	3.07
Shelling percentage	26.75	29.76	29.52
Export grade	W180	W210	W180
Nut yield/tree(kg)	6.4	13.69	21.60

Table 27. Salient features of H03-95/4

Characters	Female parent Vridhachalam-3	Male parent Priyanka	Hybrid H03-95/4
Flowering	Early	Mid	Early
Sex ratio	0.077	0.088	0.067
Canopy type	Compact	Open	Open
Nut weight(g)	7.30	12.43	12.44
No.of nuts/kg	142	98	95
Kernel weight(g)	2.17	3.32	4.19
Shelling percentage	29.76	26.75	33.72
Export grade	W210	W180	W180
Nut yield/tree(kg)	13.69	6.4	2.10

Table 28. Salient features of H03-18/17

Characters	Female parent Damodar	Male parent K-22-1	Hybrid H03-18/17
Flowering	Mid	Mid	Early
Sex ratio	0.101	0.097	0.070
Canopy type	Compact	Compact	Compact
Nut weight(g)	7.72	6.40	12.49
No.of nuts/kg	125	165	93
Kernel weight(g)	2.0	1.62	2.94
Shelling percentage	25.64	25.36	23.58
Export grade	W210	W280	W180
Nut yield/tree(kg)	10.10	10.20	3.10

Summary

6. SUMMARY

The present study entitled ‘Evaluation of cashew (*Anacardium occidentale* L.) hybrids for yield and quality’ was carried out in the Cashew Research Station, Madakkathara and Department of Plantation Crops and Spices, College of Agriculture, Vellanikkara during the period of 2020-2021. The objective is to evaluate the cashew hybrids for yield and quality characters.

As a part of hybridization and selection programme, 335 hybrids were planted in three blocks during 2003. These hybrids have not been evaluated after 2009 and now they are in stabilized yield. Hybrids of known parentage, planted in the block II were be utilized for the study. The experiment comprised of morphological characterisation of 19 cashew hybrids and 11 cross parents for selected growth and yield attributes. The latest released cashew variety Poornima was used as a standard variety.

For morphological evaluation of these hybrids 30 qualitative and 31quantitative characters were considered. The descriptor list developed by DCRS, Puttur (Nayak *et al*., 2014) was used for recording the observations. All the quantitative characters showed significant differences among 19 cashew hybrids.

Majority of cashew hybrids and parents were having upright and compact canopy with intensive branching habit. Colour of flush are yellowish red in colour, pyramidal shaped loose inflorescence. Early flowering from October was recorded in 13 cashew hybrids and four parents. Secondary flowering was observed in the hybrids, H03-55/11, H03-97/2, H03-21/10 and parents Madakkathara-1, Anakkayam-1, Poornima. Long flowering of more than 90 days was recorded in H03-97/2, H03-21/10 and Poornima.

Apple colour of nine hybrids were yellow, five were yellow-red and 4 were red. The cashew apple of hybrid, H03-95/8, was red purple in colour. The apple

colour of five parents were yellow, four were yellow-red and two (Vri-3, K-22-1) were red coloured. Apple shape was conical obovate in 16 hybrids and seven parents, while apples of hybrids, H03-36/8, H03-95/4, H03-18/17 and variety, Priyanka were cylindrical. Varieties, Dhana, Vridhachalam-3 and K-22-1 produced round shaped cashew apples

Considerable variation was observed with respect to tree characters like, tree height, trunk girth and canopy spread among the hybrids and parents studied. Tree height of hybrids ranged from 6.25 m in H03-55/10 to 10.53 m in H03-52/5 and parents from 5.80 m (K-22-1) to 9.90 m (Damodar). In the hybrid population, maximum tree girth was observed for H03-36/8 (2.75m) and minimum in H03-55/10 (1.0m). Maximum spread was recorded in H03-111/2 (14.35m) and minimum in H03-55/10(6.80m). Among the cross parents, maximum canopy spread was exhibited by Dharasree (10.7m) and minimum in Anakayam-1 (4.75m).

The internodal length of twig ranged from 1.31 (H03 -18/17) to 2.35 cm (K22-1). All the hybrids and parents were having intermediate internode diameter ranging from 5.21 mm (H03-36/8) to 8.40 mm (H03-53/9). All the hybrids and parents were having medium number of leaves per twig (9-19). Leaf area ranged from 103.68 cm^2 (H03-55/10 and Dharasree) to 167.71cm^2 (H03-36/8, H03-18/17).

Significant variation was observed among the Parents and hybrids for the inflorescence characters. The highest number of flowering laterals per square metre was produced by variety, Poornima (15.25) and Dharasree (15.25). Number of bisexual flowers ranged from 39.75 (H03-95/8 and Amrutha) to 91.25 (H03-52/6). The sex ratio ranged from 0.048 (H03-55/10) to 0.113 (H03-52/5).

The apple weight was the highest in Priyanka (137.49g) followed by hybrid, H03 52/5 (120.82g). The apple to nut ratio was the highest in hybrid, H03-52/5(11.36) followed by parent, Priyanka (11.07). The lowest apple to nut ratio of 3.63 was recorded by hybrid, H03-55/10. The number of nuts per panicle, varied from 1.25(H03-21/10) to 5.20(Anakkayam-1). The hybrid H03-21/10 recorded significantly

the heaviest nut weight of (12.55g) followed by H03-18/17(12.49). The hybrid, recorded significantly the lightest nut weight of H03-55/10(4.64). The average kernel weight varied from 1.62g(H03-55/10) to 4.19g(H03-95/4). 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). Hybrids, H03-95/4, H03-21/10, H03-110/1, H03-18/17, H03-52/5, H03-52/7 and H03-97/2 had the best export grade of W180.

Nut yield above 18 kg tree^{-1} was recorded in six hybrids, H03-21/10 (25.20 kg), H03-97/2 (24.50 kg), H03-110/1 (23.40 kg), H03-36/8 (22.10 kg), H03-92/3 (20.2 kg), H03-52/5(21.60 kg) and parent, Amrutha(21.3kg) and check variety, Poornima (20.0 kg).

TSS ranged from 13.15^{0}Brix (H03-18/17) to 17.4^{0}Brix (H03-53/9). The average Vitamin C content ranged from 133.5 to 267.5 mg/100ml. The hybrids H03-36/8, H03-92/3, H03-97/2, H03-113/1 and H03-111/2 shows same amount of vitamin C content(267.5 mg/100ml) and hybrids H03-21/10, H03-55/11, H03-55/10 shows lowest amount of Vitamin C content(133.5 mg/100ml). Total sugar ranged from 13.44 (H03 110/3) to 21.21percent (H03-57/4 and H03-97/2). Lowest tannin content was shown by Hybrid H03-55/11(0.085%), Followed by H03-92/3(0.09%) and H03-55/10(0.09%).

The hybrids H03-57/4, H03-110/1, H03-113/1, H03-52/5 and H03-21/10 and parents, Dhana, Madakkathara-1, Vridhachalam-3, and K-22-1 showed less susceptible to TMB. The hybrid, H03-95/4 susceptible to TMB. The major pest observed are TMB, cashew stem and root borer, leaf folder, leaf and blossom webber, apple and nut borer, leaf miner and mealy bug.

Nut yield per tree was found to possess significant positive correlation with nut weight (0.16), kernel weight (0.08), apple weight (0.9), number of bisexual

flowers (0.42) and shelling percentage (0.11). In the principal component analysis, 85.92% of total variability was explained by the first three principal components with an eigen value greater than one. The characters like yield per plant, apple weight, shelling percentage, kernel weight, nut weight and bisexual flowers contributed more towards diversity. Nine hybrids namely, H03-21/10, H03-97/2, H03-36/8, H03-110/1, H03-52/6, H03-52/5, H03-52/7, HO3-95/4 and H03-18/17 exhibited better heterosis. The hybrid H03-95/4 had a nut weight of 12.44g and kernel weight of 4.19g. It can be used as a cross parent in future breeding programme.

Hybrids H03-36/8, H03-97/2, H03-110/1, H03-21/10 and H03-52/5 exhibited better heterosis with respect to nut weight (g), kernel weight (g) and over all the total nut yield (kg/tree) as compared to the other tested hybrids. Hence, may be recommended for cultivation to increase the production and productivity of cashew. Hybrids H03-95/4, H03-52/6, H03-52/7 and H03-18/17 with good quality traits like bold nut, high kernel weight and shelling percent can be uses as parent for future breeding programme.

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EVALUATION OF CASHEW (*Anacardium occidentale* L) HYBRIDS FOR YIELD AND QUALITY

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ABSTRACT OF THESIS

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ABSRTACT

The demand of cashew (*Anacardium occidentale* L.) for export and local consumption is increasing in the country and there is a gap of 7 lakh tonnes in the production to meet the requirement. Due to pressure on land, the possible way to increase production is to increase productivity by adopting improved varieties. Hybrid vigour was well exploited in cashew. Cashew Research Station, Madakkathara has developed many hybrids through hybridization programmes which are maintained in the farm. In the present study 19 hybrids of stabilized yield along with 11 cross parents and check variety Poornima were evaluated for yield and quality traits during the year 2020-2021.

Qualitative and quantitative parameters including those of growth, inflorescence, apple, nut, yield and biochemical attributes revealed a spectacular array of variations among the tested genotypes. Among hybrid population, upright and compact canopy with intensive branching habit, yellowish red flush colour and pyramid shaped loose inflorescence were predominating. Early flowering from October was recorded in 13 cashew hybrids and four parents. Cluster bearing habit was observed in hybrids H03-113/1 (4.65 fruits), H03-55/10 (4.55 fruits) and H03-53/9 (4.10 fruits). The apple weight varied from16.83 g (H03 55/10) to 137.49g (Priyanka). Nut weight of more than 10g was observed in hybrids H03-21/10, H03-97/2, H03-36/8, H03-110/1, H03-52/6, H03-52/7, H03-52/5, HO3-95/4 and H03-18/17 and these can be represented as bold nut hybrids. The average kernel weight varied from 1.62g (H03-55/10) to 4.19g (H03-95/4). Nut yield above 18 kg/tree was recorded in hybrids, H03-92/3 (20.2 kg), H03-52/5(21.5kg), H03-36/8(22.10 kg), H03-110/1(23.40 kg), H03-97/2 (24.50 kg), H03-21/10 (25.20 kg) and in parent, Amrutha (21.3kg) and check variety, Poornima (20.0 kg).

In biochemical analysis, TSS ranged from 13.15^0Brix (H03-18/17) to 17.4^0Brix (H03-53/9). Vitamin C content ranged from 107.5 to 220.15mg/100ml. Lowest tannin content was shown by hybrid H03-55/11(0.085%), H03-92/3(0.09%) and H03-55/10(0.09%). The hybrids H03-57/4, H03-110/1, H03-113/1, H03-52/5 and

H03-21/10 and parents, Dhana, Madakkathara-1, Vridhachalam-3, and K-22-1 were less susceptible to TMB.

Nut yield per tree was found to possess significant positive correlation with nut weight, kernel weight, apple weight, number of bisexual flowers and shelling percentage. In the principal component analysis 85.92% of total variability was explained by the first three components with an eigen value greater than one. The characters like yield per plant, apple weight, shelling percentage, kernel weight, nut weight and bisexual flowers contributed more towards diversity. Eight hybrids *viz*., H03-21/10, H03-97/2, H03-36/8, H03-110/1, H03-52/6, H03-52/7, H03-52/5 and H03-95/4 were placed in the first quadrant along with check variety Poornima. Magnitude of heterosis was calculated for 19 hybrids over mid parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis). The above eight hybrids along with H03-18/17 exhibited better heterosis.

The hybrids, H03-36/8, H03-97/2, H03-110/1, H03-21/10 and H03-52/5 which exhibited heterosis and nut weight above 10g, tree yield above 18kg, kernel weight above 2.5g and shelling per cent above 28 were selected as promising types. Hence these hybrids may be recommended for commercial cultivation. Further studies should be undertaken with different traits for exhaustive evaluation for commercialization. The hybrids H03-52/6, H03 -52/7, H03-95/4 and H03-18/17 having good yield and quality traits can be utilized for crop improvement programmes.