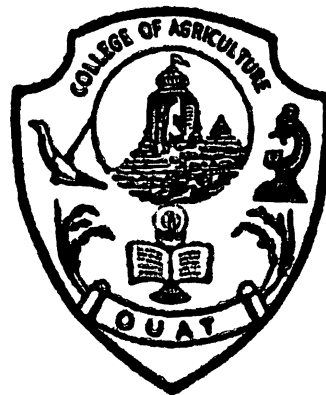


EVALUATION OF CASHEW HYBRIDS

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(HORTICULTURE)

By
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Orissa University of Agriculture and Technology
BHUBANESWAR, ORISSA
2000

THESIS ADVISOR

Dr. K. C. MOHAPATRA

DEDICATED
TO
MY BELOVED PARENTS
&
THE PEOPLE WHO
SELFLESSLY SERVE
THE GREEN ENVIRONMENT

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Dated, Nov., 2000

CERTIFICATE I

This is to certify that the thesis entitled "**EVALUATION OF CASHEW HYBRIDS**" submitted by **Chinmayee Mohanty** to the Orissa University of Agriculture and Technology, Bhubaneswar, in partial fulfilment of the requirement for the degree of **Master of Science in Agriculture (Horticulture)** is a faithful record of *bonafide* research carried out by her under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation has been duly acknowledged.


30-11-2000

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forwarded to Dean, CA.




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CERTIFICATE - II


This is to certify that the thesis entitled " **EVALUATION OF CASHEW HYBRIDS**" submitted by **Chinmayee Mohanty** to Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Horticulture)** has been approved by the Student's Advisory Committee after an Oral examination on the same in collaboration with an External Examiner.


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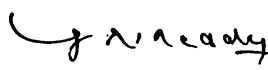
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Bhubaneswar
Dated 30th Nov. 2000

Chinmayee Mohanty
(CHINMAYEE MOHANTY)

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ABSTRACT

An investigation was carried out during the year 1999-2000 to determine extent of variability, degree of association of quantitative characters and to evaluate F₁ hybrids of cashew for important characters with an experimental material comprised of 17 F₁ hybrids of 3 years old, 13 F₁ hybrids of 5 years old and 6 parent cashew plants belonging to 7 parental combinations grown in Ranasinghpur Cashew Research Station, Orissa University of Agriculture and Technology, under agro-climatic conditions of Bhubaneswar.

Variability studies showed that a good amount of variability in terms of range, mean and coefficient of variation existed in the hybrids as well as in the parents for all the characters studied. Hybrids of 3 years old exhibited maximum variability for the character nut yield whereas in 5 years old hybrid population, the character found was inflorescence size.

The correlation and path coefficient analysis studies from both age group hybrids exhibited that yield attributing characters like number of flowering laterals/m², number of nuts/panicle and individual nut-weight contributed highly towards nut-yield. Heterosis study were made for all these hybrids and they were found to exhibit different extent of heterosis in different aspects. Export kernel grade study over these hybrids showed that all the hybrids were of highest export grade kernel (W 180) except A₁₀ (W 280).

Out of the 30 hybrids studied from both age groups, 11 hybrids were identified as superior hybrids. Those were B'₄, B'₃₁, B'₃₄ and C'₁₃ among the 3 years old hybrids and A₄, A₆, A₉, A₁₀, D₄, D₆ and D₇ among the 5 years old hybrids.

CHAPTER - 1

INTRODUCTION

INTRODUCTION

The 'Gold mine in waste land', the cashew (*Anacardium occidentale L.*) family Anacardiaceae, from its humble beginning as a crop intended to check soil erosion has later on emerged as one of the most important dollar earning crops of the country. Cashew is traditionally grown in the states like Orissa, Andhra Pradesh, Tamilnadu and West-Bengal in the east-coast; Kerala, Karnataka, Goa and Maharashtra in the west coast; in the plains, ghats and hill regions. It is also grown in Madhyapradesh and has spread to other nontraditional areas of West Bengal in the lower Gangetic plains and Tripura in the eastern Himalayas in recent years.

Cashew is a versatile nut with many health advantages. It has a zero cholesterol kernel, as 82% of the fat content in cashew is in the form of unsaturated fatty acids. It has 21% proteins and 22% carbohydrates with a right combination of aminoacids, minerals and vitamins and is nutritionally at par with milk, egg, and meat without the disadvantages of the food of animal origin. The soluble sugar in cashew is less than 1% and as such diabetic patients can also take cashew kernel without any problem.

Bakhru (1987) reported that all genuine nuts are high in protein, fat and carbohydrate content, rich in many minerals and some of them contain multivitamins. Nuts specially in the form of milkdrinks are highly beneficial in the treatment of several common disease. Ailments like loss of appetite, general depression, nervous weakness, anemia cough, urinary and liver disorders are believed to respond favorably to the use of cashewnut.

Besides the kernel, the apple, the cardanol and the bark are also put into various industrial uses.

The apple is a good source of fermentable sugar (10.4%) and vit-C (261.5 mg) per 100g of edible portion and is used for preparation of various types of fermented beverages like feni, nonfermented beverages like chutney, pickle, nectar and squash, Unfortunately cashew apple and its products are not yet commercialised in India.

The cashewnut shell liquid (CNSL), the cardanol is a by product of cashew industry. It has innumerable applications in polymer based industries such as for friction lining, paints, varnishes, laminary resin etc.

The tree provides fuel wood with good calorific value, the bark of the plant yields an acid sap that is used for indelible ink making. The gummy exudate has good binding property. Young leaves are also used as salad in some parts of the world.

Due to these good number of usefulness, the demand of the crop is increasing all over the world. The export of cashew kernels from India touched a height of 92.461 MT valued at Rs. 2451.45 crores in 1999-2000 against 77,076 MT valued at Rs. 1630.08 crores during 1998-99. The increase attained was 50% in value and 20% in quantity. (Pillai. 2000).

Viewing towards area and productivity of this crop it is found that the estimated area under cashew in India is 7.32 lakh hectares and the production has ranged between 3.5 - 4.3 lakh tones per annum in the recent past. The present installed processing capacity is over 8 lakh tones resorting to import

of raw cashew nuts. The average import of rawnuts during last 5 years was 2.18 lakh tones valued at Rs. 720 crores. (Nayar, 2000). So any effort in increasing the production of raw cashewnuts in India would not only generate high levels of employment in farms and factories but also save foreign exchange out flow.

Searching for reasons of abysmally low cashew productivity of India, one major reason comes to mind is that the existing plantations have been established from seedling progenies of poor genetic stock. By using clonal planting material of improved genotypes, productivity of cashew can be increased manifold. Hence the breeding programme for cashew is formulated with the objectives of effecting crosses involving as many parental combinations as possible having the desired characters, making a rigorous screening of the F_1 hybrids and multiplying the selected superior progenies by vegetative means (Damodaran et al. 1979).

Proper evaluation of F_1 hybrids is as important as the production of hybrids. In this context the present investigation was under taken. This will help to identify superior F_1 hybrids of cashew having increased production potential and desirable horticultural attributes. The information on variability and association of characters obtained through this study will be useful in rendering the selection of hybrids more effectively.

As a whole the objectives of the present experiment can be represented as follows.

1. To estimate the variability existing in the hybrid populations with respect to important biometric characters.

2. To study the degree of association between important biometric characters and their correlation with nut yield.
3. To study degree of contribution of major yield attributing characters like number of flowering laterals/m², number of nuts/panicle and nut weight towards the nut yield.
4. To have a heterosis study for the above mentioned major yield attributing characters.
5. To identify superior hybrids combining important yield attributing characters.

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CHAPTER - 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A precise knowledge on the extent of variability present among the genotypes and the association which exists between yield and different biometrical character is essential for a systematically planned crop-improvement programme. Research works performed by different scientists over different time and different agroecological situations provides a good guideline for conducting an experiment. So literature pertaining to the aspects investigated in this study which source and authors have been fully acknowledged is reviewed here under the following heads.

- 2.1. Vegetative growth pattern.
- 2.2. Floral traits.
- 2.3. Fruit set, development and retention.
- 2.4. Apple characters.
- 2.5. Yield attributes.
- 2.6. Crop improvement through hybridisation.
- 2.7. Genetic variability and correlation of characters.

2.1. VEGETATIVE GROWTH PATTERN :

Rao(1955) in a study on growth and fruiting in cashew, reported that bearing in cashew commences in third or fourth year, attains a full bearing by the tenth year and lives upto thirty to forty years. Sometimes it may live upto seventy years.

Mukherjee(1956) recorded 6 variations in growth, flowering and fruiting behaviour of cashew growing in West-Bengal. Rao and Hassan(1957) noted two main active growth phases. One beginning in October and lasting until January prior to the flowering stage and the other between March and May. Shoot growth during the active phase beginning in October varied from 2.5 to 21.5 cm per shoot, with a mean of 10.7 cm. The extension growth ceased with the flowering of shoots. The subsequent growth of these shoots at the beginning of March comprised only the lateral shoots arising from buds below inflorescence.

Dasarathy (1958) after conducting a study of growth features and blossom biology of cashew, observed two types of branching in cashew namely extensive and intensive. The extensive shoot grew to a length of 20 to 30cm and became dormant for sometime. This kind of growth pattern resulted in a spreading canopy. In the intensive type, shoot grew to a length of about 25 to 30 cm and terminated in a panicle. Simultaneously 7-8 lateral branches also arose within 10-15 cm of the apex of the main branch. Some of these lateral shoots also terminated in panicles in the same flowering season, repeating the same growth pattern and giving a bushy appearance to the tree. In high yielding trees, more than 60% shoots constituted the intensive type of branching as against 20% only in low yielders.

Bigger(1960) studying young trees in Southern Tanzania observed that maximum growth took place during the rains from January to April, while there was evidence of two lesser periods of increased growth in the middle of dry season and in November at the beginning of rainy season following fruiting.

Maity(1960) reported 3 growth flushes in a year. The winter and spring season flushes are more vigorous than the rainy flush. Argles(1969) recorded two or three periods of growth in cashew types, eventhough, under favourable conditions the stray growth may occur almost every month. He also reported that the pattern of growth of a bearing tree consists of a generative flower flush and a vegetative flush in the same year. The vegetative flush consists of lateral shoots, which always develops soon after the main crop has matured. Flowering is terminal and is always preceded by vegetative flush.

Chakravarty *et al.* (1980) in their studies on growth and flowering in cashew observed that the terminal shoots which emerged in spring showed continuous and steady linear extension and diametric thickening upto 6 months after emergence and thereafter the rate of growth slowed down considerably. Emergence of laterals took place mainly during summer rains. Although lateral branches developed on recent growth as well as in one or two years old terminal shoots, maximum branching usually occurred on one year old shoots. Both vegetative and flowering shoots produced laterals, but maximum number of laterals appeared from the later category of shoots. He also reported that vegetative shoots appeared in April-May, developed panicles in about 92% cases. During the next flowering season while that produced in December-January bore flowers in about 10% shoots in the same year.

Reddy *et al.* (1986b) found that the canopy spread varied from 2.5m(in1/26 Nileswar) to 4.5 m (in 4/62 Alangudi) in East-West direction. Minimum spread in North South direction was seen in 5/23 Coondapur(6.1m)

in 3 years old plantation. It was also recorded that a variation in leaf size from 88.48 mm in 3/108 Gobbi to 167.78 mm in 9/43.

Reddy and Rama Rao (1986) while studying the nature and extent of growth in Bapatla reported that maximum flush in cashew over 70% was from 15th December to 15th January while about 15% was in January second fortnight and February. A second growth flush of marginal importance would occur in May-June. He also recorded that, on an average a shoot made an extension of 11.8 cm in about 37 days. From the time of bud break the panicle completed flowering in about 62-72 days.

Reddy *et al.* (1989a) reported that the plant height varied from 4.40m to 7.5m. Stem growth from 92 to 290 cm. Spread of plant from 8.1 to 23.85 m among 20 varieties of cashew at Bapatla including released ones.

Uthaih *et al.* (1989) evaluated 35 three year old cashew types with regard to vegetative growth performance. Type 9/23 was superior in most of the characters studied. Types 7/108 and 9/78 were vigorous. Ullal cashew 1 and Ullal cashew 2 were less vigorous, but they produced fairly large numbers of shoots per tree. Among the exotic ones, Mozambique was more vigorous than Australia.

Chattopadhyay *et al.* (1992) investigated with 11 clonal types of cashew grown on laterite soil in West-Bengal over 2 years and reported that H-1610 and TN-129 were the highest ranking for all characters namely height, basal girth and canopy spread.

Harris *et al.* (1994) recorded a variation in the height, girth, East-West and North-South spread of the plant ranging from 1.85 to 3.93 mt, 1.9 to

5.0cm, 2.15 to 5.30mt and 11.72 to 20.62 mt with a mean of 2.91 mt, 3.5 cm, 3.74 mt and 16.54 mt. respectively.

Abraham and Abdulsalam (1995) studied the leaf area of cashew and reported that during preharvest flushing phase the leaf area accounted for 54.15 sq. mt with leaf area index less than one. The preharvest flushes that occurs during November accounted for 79.2% of the total leaf area of crown.

Naik *et al.* (1997) studied the growth performance of 14 cashew genotypes and found a significant difference for biometrical characters like growth at collar, production of secondary branches, spread of the branches etc.

2.2. FLORAL TRAITS :

Galang and Lazo (1936) observed that the peak flowering in central America and West Africa was January and February and in Malagasy March-April.

Rao (1955) recorded that the flowering commences in the month of November, extends upto February and the fruits ripen from March to May. He also marked two to three distinct waves of flower appearance and the flowers appearing at the intermediate phase were the most productive ones. The duration of harvest extended from 40-70 days.

Dasarathi (1958) under Bapatla condition registered the peak flowering time to be mid January to mid February.

Bigger(1960) in Tanzania observed a considerable variation in the date at which the trees reached their flowering peak. On the average, this peak was about 2.5 months after appearance of the first flower.

Damodaran *et al.* (1965) conducted a detailed study on flowering behaviour in cashew, flowers were borne on the past seasons growth either terminally or laterally. Both vegetative and floral parts emerged from the same bud. The initial growth that emerged from the growing bud gave rise to normal vegetative leaves which became smaller as the extension growth developed into the floral panicle. They also reported that the emergence of flower bud extended over a period of nearly five and a half months. In some trees, the emergence period was continuous while in some others there were distinct flushes. The period of flower opening varied from a minimum of 25 days to a maximum of 168 days. The peak period of flowering in most trees was from December to the middle of February.

According to Northwood (1966) in Jamaica condition, there was no consistency in early, mid-season or late flowering in any individual tree.

^{and Thankamma}
Nambiar(1985) reported that the duration and season of flowering varied from one region to another depending on altitude, temperature, humidity and rainfall.

Thimaraju *et al.* (1980) under Bangalore condition, registered the occurrence of flowering in the months from March to July with maximum and long duration flowering in the month of April and May.

Veeraraghavathatham and Paniswamy (1985) found to put forth flowers in month of January-February at Vridhachalam, though the flowering

is found to start from early December and extends upto late March in different places around it. The inflorescence is a compound panicle and flowers are biomorphic, Neutral and pistillate flowers were not observed.

Hanamashetti *et al.* (1986) observed that duration of flowering extended for about four months from last week of November to the last week of March. The duration ranged from 51 to 111 days.

Reddy *et al.* (1986) found that the flowering season was between November and February with its peak in December and January. The number of panicles per tree varied from 100.0 in 2/97 kottarakara to 470 in 1/11 Ullal.

Chandre Gauwda *et al.* (1989) observed highest panicle length of 19.9 cm in 4/62 Allangudi and lowest in 1/61 Allangudi (14 cm).

Krishnappa *et al.* (1991a) experimented at Karnataka eastern dry tract and found out longest panicle(20-30cm) in M-44/3. The highest number of panicles per m² are in M-44/3 i.e. (23.25) and lowest in Vengrula-4 i.e. (9.57).

Hallad and Sulikeri (1992) reported at Dharwad condition that the duration of flowering varied from 115.66 days (2/77 Tuni Andhra) to 128.66 days (2/64 Madhuranthakam Madras).

Chattophdhaya and Ghose (1993) reported at Jhargram condition that duration of flower opening ranged from 46.5 days in TN-16 to 66.1 days in Redhazari, while total number of flowers/panicle ranged from 161.9 in BLA-39.4 to 328.2 in Red Hazari.

Harris *et al.* (1994) at Vridhachalam found that the panicle length, spread and number of branches per panicle varied in the range of 11.72 to 20.82 cm, 11.72 to 18.12 cm and 3.40 to 6.90 with mean values of 16.54 cm, 15.78 cm and 5.29 numbers respectively.

Sapkal *et al.* (1994) found that the duration of flowering extended for about 4 months from first week of November to last week of February which in different selections ranged from 95.08 to 119.83 days.

Sena *et al.* (1995a) reported that duration of flowering ranged from 53.26 days to 90 days in different cashew types under Bhubaneswar condition. They also recorded a wide variation in flowering panicle per m² ranging from 8.8 in TN 129 to 26.4 in Vengrula-2. In the study highest panicle length and breadth was observed in H-1608 while the lowest length of 10.82 cm in M 26/2 and lowest breadth of 14.91 cm was recorded in Bhubaneswar cluster-1.

Shesagiri (1996) evaluated 15 elite cashew selection for flowering period, number of staminate and perfect flowers at Mudigere, Karnataka during 1993-94. The flowering occurred from mid-December to late May in majority of selections. Short synchronized flowering was not observed in any of the selections; 13 required > 100 days to complete flowering.

2.3. FRUIT SET, DEVELOPMENT AND RETENTION :

Rao (1956) observed only 3% fruit set in cashew. They also reported that wind was the main pollinating agent and so breeding for shorter style length and a lower ratio of style to stamen length was suggested to help in securing a better fruitset by open pollination.

Pillai and Pillai (1975) conducted a study on the shedding of immature fruits in cashew. According to them nearly 85% of the fruits shed were fertilized at different stages of development while the remaining 15% were unfertilised. Out of the 85% of fertilised fruits. Only 4% reached maturity, the remaining 81% being shed away at various stages of development. Of this 20% was caused by insect attack and the remaining 61% could be attributed to any factor ranging from nutritional imbalance to defective metabolism.

Mohankumar (1984) reported that the development of the cashewnut and the apple (the swollen receptacle) are followed from fruit set until the harvest 70 days later.

Sahu (1984) reported that the fruitset in cashew varies from 5.66% (V-36/3) to 2.6% (TN-40) under the agroclimatic zones of Bhubaneswar. Pattanik *et al.* (1985) observed 11.92 to 54.50% fruitset under Orissa conditions. About 44.5 to 88.08% of the hermaphrodite flowers dropped off without setting in fruits. The total fruits drop varied from 50.61 to 100% in different cashew types. On an average only about 23.26% of the flowers that had set fruit reached maturity.

Chacko *et al.* (1991) reported that 15.5% fruitset obtained in Australian condition by open pollination which in due to the presence of beehives in cashew orchard. They also reported that the 15.5% fruit set obtained in their condition is much less than the 98% of open pollinated flowers that possess pollengrains on their stigmas.

Krishnappa *et al.* (1991b) reported that the number of fruits per panicle varied from 4.5 to 8.0. Nalini and Santhakumari (1991) reported number of

nuts per panicle as high as 16.0 and 13.5. In another study Krishnappa *et al.* (1992) observed only 4.6 to 6.6 fruits per panicle.

Foltan and Ludders(1995) reported that less than 41% of the perfect flowers showed initial fruitset was attained within the first (3-4) weeks of the fruiting period. Fruits deriving from flowering opening later are usually shed. Competitive advantage of the first fertilised and most advanced fruits is suggested.

Mishra(1995) from Bhubaneswar reported that the fruit set in red and yellow cultivars varied from 8.5% to 10.4% respectively. He also reported that apples took 40 days to achieve the maximum size in girth where as nuts took 33 days. During the subsequent 10-12 days, nuts were hardened and from fruitset to ripening of fruit it took 50-52 days.

Alves *et al.* (1999) separated the harvested cashew (nut + apples) of clone CCP-76 at Pacajus, Brazil, into 7 development stages on basis of apple skin colour. 1-green with green nut. 2-green with ripen dry nut. 3-light green 4- some yellow colour 5-yellow changing to orange. 6-light orange 7-deep orange and evaluated different apple characteristics. He reported that after full development of nut, the apple increased significantly in size. But eating quality highest SS and reducing sugar contents, lowest TA and highest (SS:TA ratio)was associated with stage 7.

2.4. APPLE CHARACTERS :

Aiyadurai and Koyamu (1957) in a population of thousand bearing cashew trees found a considerable differences in growth habit, size, colour

and shape of cashew apples. Uthaman and Koyamu (1957) also reported similar variations.

Albuquerque *et al.* (1960) observed the apple characters of cashew and found that yellow apples tended to be heavier, softer and less astringent than red apples. They also noticed wide variation in weight and size of cashew apple.

Aiyadurai (1966) also reported the existence of cashew apple in varying intensities of yellow, red and mixed shades of these two characters.

Damodaran (1977) reported that along with other economic characters, considerable variation existed in mean weight, size, shape and colour of apples of the F₁ -progenies of four cross combination.

Chandran and Damodaran (1985) found that K-19/2 ranked first with regard to mean weight, length, diameter, length : diameter ratio and apple juice content. Haldankar *et al.* (1986) found out that Vengrula -3 had the largest and heaviest apples.

Ghosh (1990) reported that the apple of the best variety TN-16 of West-Bengal was medium in size, yellow in colour and the juice recovery was 63.5%.

Nalini and Santhakumari(1991) reported from Anakkayam that the apple weight varied form 27g to 80g and the juice % varied from 60 to 80% in some selected cashew types.

Hallad *et al.* (1993) observed the apples which were either yellow or red and their shape was round, oblong or pyriform. Fruit weight ranged form

10.9 to 35.5g per 25 apples and was greatest in 9/78 Ullal. Manoj *et al.* (1994a) observed weight of apple varied from 32 to 126g.

Sena *et al.* (1995) recorded maximum apple weight of 87.28g in VTH-30/4, maximum apple length 7.85 cm in VTH-30/4 and highest specific gravity of 0.980 in H-1608 and minimum weight, length, specific gravity of 18.14g, 7.03cm and 0.823 in Bhubaneswar cluster-1 respectively.

Owaiye (1996) reported from a pooled yield data of 4 years that the yellow pseudo apple colour types was significantly higher yielding than pink across sites from 29.1% higher in 1990 to 153.1% in 1987. These preliminary results indicate that separation of varieties by pseudo-apple colour is possible.

Attri and Singh (1997) reported maximum length in Bapatla Tree No.273 (7.6cm) whereas diameter was highest (5.9cm) in Ansur Early. Apple weight (90.7g) in Bapatla Tree No.273. The apple weight and nut weight ratio was highest in Bapatla Tree No. 273 i.e. (15.1:1).

2.5. YIELD ATTRIBUTES:

Rao and Hassan (1957) studied seed characters of cashew and found considerable variation in weight and shelling % of 100 samples, collected from India and other countries.

Peixoto (1960) mentioned nuts of 30g in Brazil. Correia (1963) estimated the average weight of a nut in Mozambique to be about 5g. Lafeebvre(1963) in Madagascar, found average weight for samples of 100 nuts from different regions ranging from 395 to 467 g.

Rocchetti and Moselle (1967) studying Tanzanian nuts reported an average weight of 4.8 g per nuts.

Giuliano and Agnoloni (1975) investigated samples of cashew nuts from different countries and found the individual nut weight varying from 3.6 to 5.4 g. They found that nuts from Mozambique were not only the largest but also most variable in shape among the nuts from Kenya, Madagascar and Mozambique.

Kumar *et al.* (1984) reported that the pericarp and Kernel reached their maximum size in about 30 days after fruitset. He also stated that optimum fruit development occurred at 70 days after fruit set.

Nandini and James (1984) in an yield trial reported that nut size of 16 promising types varied from 5.21 to 9.40 g and the shelling % from 22.37 to 28.71. Nambier and Pillai (1985) recorded that the yield of nuts per tree varied enormously i.e. 1 to 45 kg per year.

Aravindakshan *et al.* (1986) reported that BLA-139-1 with mean tree yield of 32.67kg, shelling % of 32.85 and Kernel size of 1.84 g is ideal for large scale cultivation. In areas where both nut and apple are of equal demand as in Goa the hybrid H-3-17 and BLA-139-1 are ideal.

Reddy *et al.* (1986) reported in Chintamani condition that the yield of nuts per tree varied with selections with a maximum of 2.419 kg in 4/62 Alangudi and minimum 0.253 kg in 1/11 Ullal.

Antarkar and Joshi (1987) reported that the physical parameters viz. weight, length, volume and diameter could be considered as the physical

indices of maturity of cashew fruit and nut while specific gravity could be only be considered as physical index of maturity of nut. He also declared that nut matured earlier than the apple of the cashew fruit.

Chadre Gowda *et al.* (1989) reported that the 100 nut weight ranged from 360g in 1/61 Alangudi to 255 in 4/62. Alangudi 3 and the shelling % showed a variation between 29% in 1/63 chrompet to 33% in 1/64 Madhurathakam.

Reddy *et al.* (1989) studied 6 varieties released from Andhra Pradesh Agricultural University. These varieties showed a variation in nut size from 4.0 to 6.0 g, shelling % from 23.0 to 28.1 and protein content of Kernel from 18.06 to 21.30%.

Nalini and Santhakumari (1991) at CRS, Anakkayam showed that nut size ranged from 5.1 to 8.9 g and shelling % from 25.80 to 27.99.

Manoj *et al.* (1993) recorded variation in yield ranging from 13.13 kg (H-402) to 23.48 kg (H-342) per plant, nuts per panicle from 3.0 to 6.5 and shelling % (31.56%) and yield per tree (21.43 kg of nut) was recorded in H-419.

Attri and Singh (1997) reported that maximum nut weight from Ansur Early (8.2g) and minimum in Bapatla Tree No. 273 (6.0g). Abdul Salam (1998) noted that the nut weight of varieties H-2/16, H-1610, H-1608 were above 8 g. The nut weight ranged from 5g to 9.25g. The shelling % of varieties ranged from 28.1 (VTH-59/2) to 37.0 (Anakkayam-1). The 3 varieties VTH-30/4, M-44/3 and Anakkayam-1 had shelling % above 35. The variety H-2/16 gave the highest % W-80 Kernel followed by H-2/15.

2.6. CROP IMPROVEMENT THROUGH HYBRIDISATION :

Genetic improvement in cashew through hybridisation was initiated in the country during early sixties. Work on this line is in progress in different research stations and several superior hybrids suitable for cultivation in different agro-climatic zones have been identified and released for large scale cultivation in the respective zones.

Damodaran *et al.* (1978) conducted hybridisation work at the cashew Research Station at Kottarakkara and Anakkayam in Kerala, during the period from 1963 to 1973 which resulted in the development of 216 hybrid progenies from 28 parental combinations. Among these hybrids H-3-17 and H-4-7 were selected as promising for large scale cultivation under Kerala conditions.

Damodaran *et al.* (1979) observed that whenever an exotic parent was involved in the hybridisation programme, the progeny showed better performance than cross between local types. This was in conformity with the established concept that hybrid vigour is best manifested in crosses involving parents with greater genetic diversity.

Salam *et al.* (1988) developed a new high yielding cashew hybrid Amrutha derived from a cross between BLA-139-1 and H3-13 at CRS, Madakkathara, Kerala. It has a spreading canopy with extensive branching. Flowering takes place during Dec.-Jan(Mid season) and lasts 2 months. The inflorescence has a sex ratio of 1 bisexual : 10 male flowers. Mean yield of mature trees is 18.35 kg/tree at a spacing of 7.5 x 7.5 m (mean of 11 years)

mean nut weight is 7.18 g with a kernel weight of 2.24g and a shelling % of 31.58%.

Manivannan *et al.* (1989) studied 5 parental types and their ten F1 cross combinations. Positive heterosis was observed for nut yield and number of nuts only with one in each cross combination. Two cross combination exhibited heterobeltiosis for nut weight and one of there parents was an exotic genotypes.

Nawale (1990) studied the inheritance pattern in F1 hybrids and the study revealed that the improvement of cashew in respect of yield of nuts, size of nuts, shelling % and other desirable tree growth, flowering and fruiting characters could be possible through hybridisation by proper selection of the parental combination. The result of parent studies clearly shows that the parent (Ansur early) having small nut size when crossed with the parent (Mysore Kolekar 1/61) also having small nut size, the hybrid progeny(H-24) obtained was of small nut size, indicating that such small nut sized parental combination required to be eliminated form cashew hybridisation.

Evaluation of 163 F₁- hybrids developed during 1973-1979 conducted at CRS, Madakkathara resulted in the identification of 14 superior hybrids (Veeraraghavan, 1990). The highest mean yield per tree for 12 years (1977-88) of 12.83 kg was recorded by H-1598 followed by H-1608, H-1610, H-1602 and H-1591 had the boldest nut followed by H - 1602 and H-1608. H-1602 had the highest Kernel followed by H-1596 and H-856.

George (1991) found out four promising selections and 5 promising hybrids of cashew suited for the agroclimatic conditions of Kerala were developed at CRS; Madakkathara of which one selection has been officially released and 3 have been recommended for release.

Manoj (1993) derived information on heterosis from data on nut yield per tree, individual nut weight and Kernel weight in six 10 year old fl hybrids selected for their superior performance and grown at Vellanikkara. All 6 hybrids exhibited heterosis over their respective better parents as well as the standard variety Madakkathara-1 for nut yield per plant indicating the effectiveness of hybridisation for improvement in cashew. He also evaluated 56,10 year old F1 hybrids from 12 parental combinations for 4 growth parameters, 5 floral traits, 6 yield components and 7 apple traits during 1990-92. H-342 had the highest nut yield per tree (23.4kg) while, H-402 with a mean nut yield per tree of 23.1 kg. had the highest protein content (35.6%). The highest individual nut weight (9.6g), Kernel weight (3.03g) and shelling % (31.6%) were observed in H-419 which yielded 21.4kg of nuts per tree.

Gunjate(1994) evaluated cashew hybrids at Vengrula, Maharashtra. Hybrid No.68 was identified as a promising type with high yielding potential (16.67kg/tree) bolder nuts (7.9g) fitting into the international Kernel grade of 216, good shelling % (28), compact canopy (68laterals/m²) with big apple (70g). Due to its superior traits over existing types, it has been released for cultivation in Maharashtra and Goa. 4 more new hybrids viz. no. 255 (Vengrula-3 x M10/4)No.303 (Vengruala-4 x M - 10/4) No. 320 (M44/3 Vetore-56) and hybrid 367 (Vengrula-4 x M-10/4) are promising.

Subramanian *et al.* (1994) studied heterosis over eight 6 year old F1 hybrids of cashew at RRS, Vridhachalam. Relative heterosis, heterobeltiosis and standard heterosis were worked out over mid parent, better parent and standard variety for nut yield per tree, individual nut weight and shelling % in these hybrids.

Sapkal *et al.* (1998) reported vegetative, floral, nut and apple characteristics for cashew cultivar Vengrula-7, based on 12 years of observations. It is derived from a cross between Vengrual 3 and M 10/4 (VR 11). Vengrula 7 gives mean yield of 14.5kg /tree/yr and is suitable for cultivation in Maharashtra, Goa, N.Karnataka, Orissa and Madhya Pradesh. Kernel grade (count) is 180/lb, shelling % is 30.5 and mean Kernel weight is 2.5g.

2.7. GENETIC VARIABILITY AND CORRELATION OF CHARACTERS :

Damodaran (1977) studied variability in the F1 population of cashew and observed considerable variation for mean yield, weight of 100 nuts, mean weight of apple, shelling %, size, colour and shape of apples. It was also noted that a large number of productive hybrid progenies were derived from the crosses in which one of the parent was an exotic type.

Devi (1981) studied the variability in F₁ population of cashew and found that the variability was maximum for nut weight followed by shelling %, % of hermaphrodite flowers and mean nut yield.

Falade(1981) studied varietal differences in tree size and yield of cashew in Nigeria condition. Cashew trees in 2 selected plots of comparable

ages were grouped into varieties on the basis of colours and shapes of their apples. The variation in the size of the tree was found to be comparatively narrower than that in the yield. Varieties also greatly differed in their yield potentials which in turn depended on the location.

Nayar *et al.* (1981) reported that canopy spread has maximum positive correlation with yield followed by trunk girth and height of tree.

Ramdas and Thatham (1982) studied the variability and 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.

Nawale (1983) reported that spread of plant , a large number of lateral shoots and panicles per unit area and high fruitset per panicle are correlated with higher yield of cashew and he further painted out that these characters need to be considered in cashew breeding for its improvement. Besides high yield and desirable tree characters, size of nuts, Kernel size and shelling % are also important in view point of processing of cashew nuts for kernels in trades.

George *et al.* (1984) conducted studies for 3 years to standardise a technique for forecasting cashew yield based on 7 biometrical characters recorded at weekly intervals revealed that yield could be forecasted with reasonable precision ($R^2 = 0.64$) by a single spot observation made during the peak flowering period (Feb.-March). The number of variable could be brought down to 3 viz. the number of nuts on the tree, condition of flowering

(graded 0 to 5) and canopy area, without substantially affecting the accuracy of the estimate ($R^2 = 0.61$).

Factors influencing yield in cashew were studied by Parameswaran *et al.* (1984a). A strong correlation was observed between tree yield and the % of flowering shoots per unit area of tree canopy followed by total canopy area. No significant correlation was noted between yield and tree height.

Parameswaran *et al.* (1984b) investigated the relationship between yield and duration of different phases in flower opening in cashew. The mean duration of flowering in trees above medium yield was 83.7 days and in those below medium yield it was 102.7 days.

Arabindakshan *et al.* (1986) registered a significant variation in the characters like apple weight ranging from 31.33g (K-28-2) to 132.67g (H-3-13).

Faluyi (1987) studied genetic variability among nut yield traits and found out that variation was greatest for nuts per tree and nut weight per tree. Study of correlation coefficients suggested that selection should be based on nut weight per tree.

Mohan *et al.* (1987) had developed an index score method using yield component for classifying cashew types. Individual trees with high scores and high yield were identified and treated as elite. These were characterised by medium sized nuts and more number of nuts per panicle.

George *et al.* (1989) developed and field tested a method to forecast the cashew yield from large plantations based on biometrical characters and yield attributes. The yield estimates arrived at were found to be reasonably

precise with an average deviation of 6.7 to 17.9% with the actual yield at different locations.

Anitha *et al.* (1991) made correlation and regression studies of 11 yield contributing characters. The nut yield had a positive and highly significant correlation with number of nuts per panicle that reached maturity (0.961) and mean number of perfect flowers per panicle (0.564). Mean nut weight had negative correlation with the number of nuts per panicle that reached maturity.

Manoj *et al.* (1994b) carried out an experiment with 56 ten year old F1 hybrids of cashew belonging to 12 parental combinations. The correlation studies and path coefficient analysis identified the important biometric characters which contribute towards nut yield per tree in cashew as weight of kernel, mean canopy spread, number of nuts per panicle, girth of tree, leaf area, duration of flowering and height of the tree in that order of priority.

Sena *et al.* (1994) derived information on yield correlations from data on 12 yield components in 17 cultivars grown during 1993 in Bhubaneswar. Fruitset per panicle and single nut weight had the greatest effect 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 % was significant and positively correlated.

Neto and Caligiri (1998) reported that in correlation analysis use of 2 or more consecutive years data might considerably reduce problems imposed by variability.

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CHAPTER - 3

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation envisaged to evaluate F1 hybrids of cashew for growth parameters, floral traits, yield attributes and apple characters and to determine the extent of variability and degree of association of quantitative characters in cashew. The experiment was carried out at the Ranasinghpur cashew Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, which is 7 kms away from university main campus. The place is situated at 20° 15'N latitude, 85° 82'E longitude and at an altitude of 25.5m above MSL, enjoying a warm and moist climate with mild winter and hot summer. The meteorological data for the experimental period is presented in table-1. The soil of the site is sandyloam and acidic in reaction with pH of 5.1.

The experimental material comprised of 30F1 hybrid plants and 6 parent plants which are grown in the Cashew Research Station, Bhubaneswar. Desirable characters accumulation of these parents in their F1 offsprings through breeding is tried by effecting crosses between these parents. Out of 55 F1 hybrid plants which have been evolved and plated in the year 1995, 13 hybrids plants with an age of 5 years were selected on the basis of their vegetative characters and similarly 17 hybrid plants of 3 years old were selected from 171 hybrid plants of 1997.

The cross combinations and the number of F1 hybrids belonging to each parental combinations are furnished in Table - 2.

TABLE 1. METEOROLOGICAL DATA FOR THE PERIOD JULY- 1999 TO JUNE - 2000

Month	Temperature °c		R.H. (%)		Rainfall (mm)	Mean Evaporation (mm)	No. of Rainy days (days)	Sunshine (hr/day)
	MAX.	MIN.	Morning	Afternoon				
1999								
July	32.2	25.0	90	75	262.6	3.7	16	3.1
Aug	31.9	24.9	93	74	445.8	3.4	20	3.9
Sept.	31.6	25.0	93	77	238.6	3.5	20	3.9
Oct.	31.4	23.3	94	74	745.5	3.3	13	6.1
Nov.	30.1	17.6	91	49	19.3	3.5	3	8.5
Dec.	28.9	14.9	87	43	0.0	3.5	-	8.2
2000								
Jan.	29.6	14.4	90	39	0.0	3.9	-	9.0
Feb.	28.9	18.7	91	57	35.8	3.5	6	6.5
Mar.	34.3	21.8	94	46	0.0	5.7	-	8.9
April	35.9	25.1	92	63	52.8	7.5	4	8.6
May	37.2	26.0	89	56	92.8	7.7	7	8.3
June	33.8	25.5	92	73	298.5	5.3	18	4.8

Source : Crop weather observatory, Dept. of Agronomy, OUAT, Bhubaneswar , Orissa.

TABLE 2. CROSS COMBINATIONS AND THEIR RESPECTIVE F₁ HYBRIDS

Sl. No.	Cross combination	Name of the F ₁ hybrids of each combination		Number of F ₁ hybrids
		Planted in year 1997	Planted in year 1995	
1	BBSR-1 X H-2/16	A'35		1
2	BBSR-1 X VTH-711/4	B'4, B'7, B'9 B'11, B'14, B'15 B'18, B'23, B'25 B'30, B'31, B'34		12
3	BBSR -1 X H - 2/15	C'2, C'3, C'13, C'17		4
4	BBSR-1 X Kankadi		A ₃ , A ₄ , A ₆ , A ₉ , A ₁₀	5
5	BBSR-C X VTH-711/4		C ₁₁	1
6	BBSR-C X Kankadi		E ₃	1
7	BBSR-1 x VTH-711/4		D ₄ , D ₆ , D ₇ , D ₈ , D ₁₀ , D ₁₁	6

The hybrids and parents were observed for 11 vegetative characters, 4 floral characters, 5 apple characters and 12 nut and yield attributing characters.

3.1. VEGETATIVE CHARACTERS

- 3.1.1 Height of tree (m).
- 3.1.2. Girth of tree(cm).
- 3.1.3 Mean canopy spread (m).
- 3.1.4. Extension growth of twig(cm).
- 3.1.5. Shoot diameter(cm).
- 3.1.6. Number of leaves per shoot.
- 3.1.7. Leaf area (cm²).
- 3.1.8. Number of laterals per m².
- 3.1.9. Colour of young leaf.
- 3.1.10. Odour of young leaf.
- 3.1.11. Leaf shape.

3.2. FLORAL CHARACTERS

- 3.2.1. Duration of 50% flowering.
- 3.2.2. Number of flowering laterals per m².
- 3.2.3. Inflorescence size (cm²).
- 3.2.4. Inflorescence compactness.

3.3. APPLE CHARACTERS

- 3.3.1. Weight of apple(g).
- 3.3.2. Apple size (cm²).
- 3.3.3. Apple colour.
- 3.3.4. Apple shape.
- 3.3.5. Attachment of nut to apple.

3.4. NUT AND YIELD ATTRIBUTING CHARACTERS

- 3.4.1. Nut dimension (cm³).
- 3.4.2. Individual nut weight(g).
- 3.4.3. Shape of the nut base.
- 3.4.4. Structure of nut.
- 3.4.5. Shape of nut apex.
- 3.4.6. Relative position of suture to apex.
- 3.4.7. Shell thickness.
- 3.4.8. Shelling percentage.
- 3.4.9. Kernel weight (g).
- 3.4.10. Kernel dimension(cm³).
- 3.4.11. Nuts per panicle.
- 3.4.12. Nut yield per tree (kg).

The methodology adopted to study these characters is as follows.

3.1. VEGETATIVE CHARACTERS

3.1.1. Height of Tree

The distance between base and top most point of the tree was measured using a long graduated pole.

3.1.2. Girth of Tree

The circumference of mainstem of plants were measured by a measuring mater tape leaving 15cm from the ground level.

3.1.3. Mean Canopy Spread

Mean spread^{of} the tree canopy was worked out by measuring the spread in North-South and East-West direction using the long graduated pole and averaging these two.

3.1.4. Extension Growth of Twig

Current season growth of 10 twigs were measured and averaged out.

3.1.5. Shoot Diameter

The circumference was measured at middle portion of current seasons twig by help of a slide caliper and dividing the value with π , the diameter of shoot was calculated.

3.1.6. Number of Functional Leaves per Shoot

Total number of functional leaves present in current season growth in 10 shoots selected at random were counted and number of leaves present per shoot was calculated.

3.1.7. Leaf Area

8 fully matured leaves (6th leaf counting from the top of the twig) were collected, 2 from each direction and the leaf area was measured using a leaf area meter and their average values were worked out.

3.1.8. Number of Laterals per m²

A square meter frame which covers an area of 1 m² was taken. Four different locations one in each direction on the canopy of the tree were selected randomly. Number of laterals covered by the square meter frame in these locations were counted and recorded separately. Then the average value was worked out.

3.1.9. Colour of Young Leaf

The colour of young leaf was visually observed and described as red, yellow red, green yellow or purple as per the specification of International Plant breeding and Genetic Resource Institute (IPGRI).

3.1.10. Odour of Young Leaf

Young leaves were inhaled and the smell was described as mango like or turpentine like.

3.1.11. Leaf Shape

Shape of fully expanded leaves were visually observed and described as club shape, oblong, circular or oval.

3.2. FLORAL CHARACTERS

3.2.1 Duration of 50% Flowering

The panicle initiation date and the date of 50% flowering were observed and the difference between the two dates was described as duration of 50% flowering.

3.2.2. Number of Flowering Laterals per square meter

During the peak flowering period, an iron frame covering 1 m² area was placed on each tree at 4 different locations on canopy, one in each direction. The

number of flowering laterals covered within the frame were counted and average value was determined.

3.2.3. Inflorescence Size

Length and breadth of 10 selected inflorescence were taken and multiplied. The average value was worked out and expressed as inflorescence size.

3.2.4. Inflorescence Compactness.

The compactness of the inflorescence was visually observed and expressed as loose or compact.

3.3. APPLE CHARACTERS

3.3.1 Weight of Individual Apple

Weight of 10 matured apples were taken by a weighing balance and the average value was worked out.

3.3.2. Apple Size

Ten matured apples were collected from each plant and length and breadth were measured by a slide caliper. The values were multiplied and the average value was calculated to express individual apple size.

3.3.3. Apple Colour

Colour of matured apples was determined by eye estimation and expressed as yellow or red or yellow red or red purple.

3.3.4. Apple Shape

Shape of apple was observed visually and expressed as cylindrical or conical to obovate or round or pyriform.

3.3.5. Attachment of Nut to Apple.

Attachment of nut to apple observed manually and expressed as intermediate or loose or tight.

3.4. NUT, KERNEL AND YIELD ATTRIBUTING CHARACTERS

3.4.1. Nut Dimension

Length, Breadth, and thickness of 25 nuts were taken by help of slide caliper and multiplied value was calculated which was then averaged out.

3.4.2. Individual Nut Weight

Weight of 100 well sundried nuts were taken and the average value was worked out.

3.4.3. Shape of Nut Base

Shape of nut base was observed visually and expressed in terms of round or flattened or obliquely flattened or angular.

3.4.4. Suture of Nut

Nut sutures observed visually and expressed as round or angular.

3.4.5. Shape of Nut Apex

Apex of nuts were observed by eye estimation and declared as round or intermediate or pointed.

3.4.6. Relative Position of Suture to Apex

Relative position of suture to apex was determined by eye estimation and expressed in terms of suture projection in front of apex or inline with apex or behind apex.

3.4.7. Shell Thickness

Thickness of shell at 5 different points were measured randomly with help of the slide-caliper and average value was calculated.

3.4.8. Shelling Percentage

Shelling percentage was calculated for individual nut by using the following formula.

$$\text{Shelling percentage} = \frac{\text{Average Kernel weight}}{\text{Average nut weight}} \times 100$$

3.4.9 Kernel Weight

Weight of 100 whole kernels were taken and the average is worked out. This observation was also used for working out export grades of kernels of selected hybrids. Export grades of cashew kernels were calculated on the basis of the number of kernels per pound as notified by the Government of India.

3.4.10. Kernel Dimension

Length, breadth and thickness of 25 kernels were measured by slide caliper and multiplied. Then the average value was calculated.

3.4.11. Nuts per Panicle

The nuts per panicle retained on the 10 randomly selected panicles were counted and the average was worked out.

3.4.12. Nut Yield per Tree

Tree wise yield was recorded at each harvest taking the weight of matured and well dried nuts and the values were added to get the nut yield per tree for the concerned year.

3.5. STATISTICAL ANALYSIS

Different statistical analysis followed in the present study are as follows.

3.5.1. Estimation of variability.

3.5.2. Estimation of correlation.

3.5.3 Estimation of path coefficient analysis.

3.5.4. Estimation of heterosis.

3.5.1. Estimation of Variability

Variability existing in different characters was estimated as suggested by Burton (1952). The formula used in the estimation of variability is given below.

$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Mean of the character under study}} \times 100$$

3.5.2 Estimation of Correlation

Correlation coefficient is used to measure the association between the variables. Correlations between yield and 20 characters by the method advocated by Karl Pearson (1887-1936)

$$\text{Correlation between characters X and Y, } r_{xy} = \frac{\text{Cov}(X, Y)}{\sqrt{V(X) \cdot V(Y)}}$$

where,

r_{xy} = correlation coefficient between X and Y

$\text{Cov}(X, Y)$ = Covariance between X and Y

$V(x)$ = Variance of X

$V(y)$ = Variance of Y

3.5.3. Estimation of Path Coefficient Analysis

If the cause and effect relationship is well defined, it is possible to represent the whole system of variables in the form of a diagram. A set of simultaneous equations can be written directly and a solution of these equations provide information on the direct and indirect contribution of these causal factors to the effect. Thus path coefficient analysis was used to partition the correlation coefficients into direct and indirect effects (Wright, 1921 and Li, 1956).

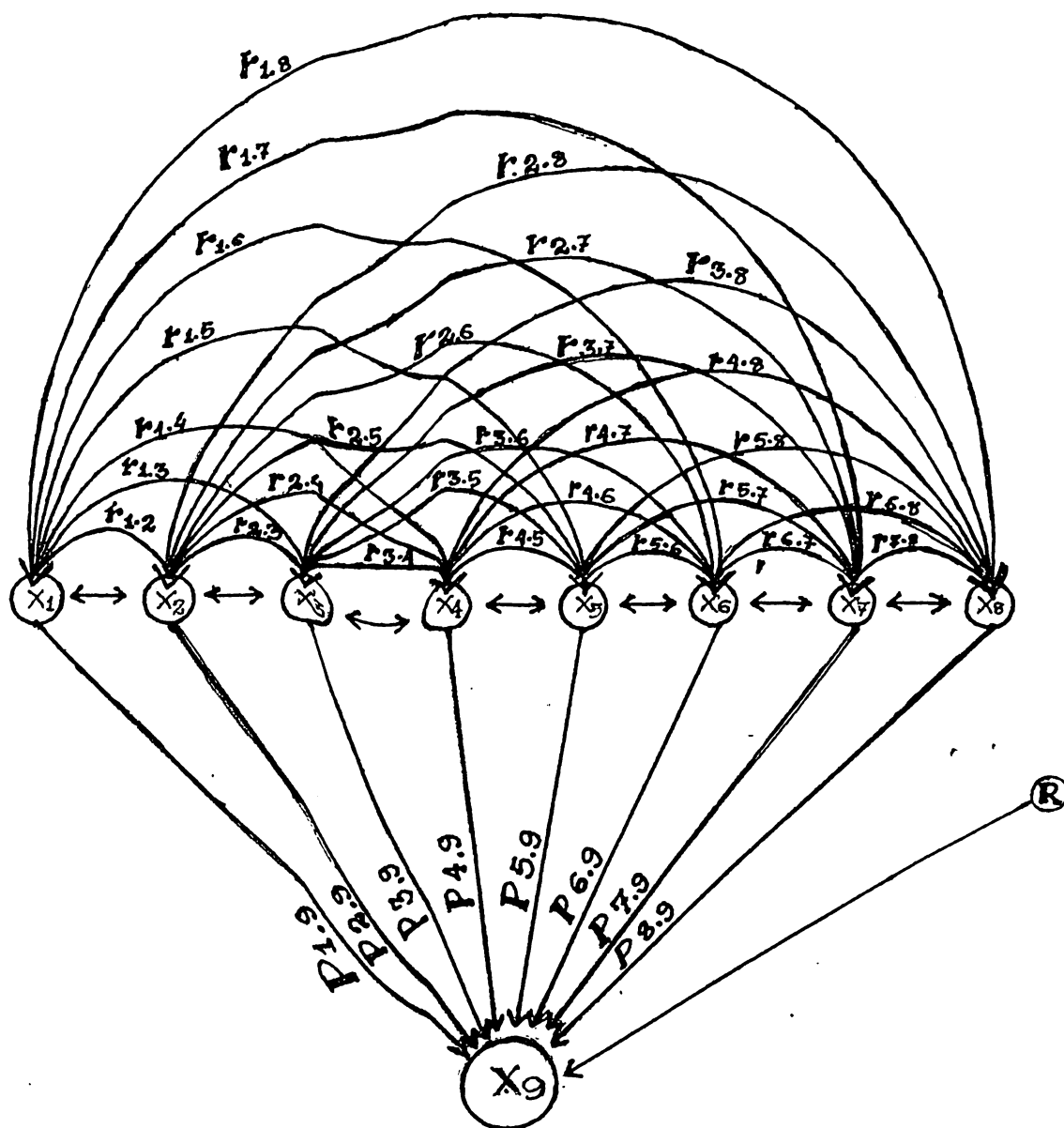
The following set of simultaneous equations were formed and solved for estimating the various direct and indirect effects.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13} P_{4y} + r_{14}P_{4y} + \dots + r_{1k}P_{ky}$$

$$r_{2y} = P_{2y} + r_{21}P_{1y} + r_{23} P_{3y} + r_{24}P_{4y} + \dots + r_{2k}P_{ky}$$

$$r_{3y} = P_{3y} + r_{31}P_{1y} + r_{32} P_{2y} + r_{34}P_{4y} + \dots + r_{3k}P_{ky}$$

G-1 PATH DIAGRAM OF THE FACTORS
INFLUENCING NUT YIELD IN CASHEW.



X1 = Height of tree (m)

X2 = Canopy spread (m)

X3 = No. of leaves/shoot

X4 = Leaves area (cm²)

X5 = No. of laterals/m²

X6 = No. of flowering laterals/m²

X7 = No. of nuts/panicle

X8 = Nut weight (g)

X9 = Nut yield (kg/tree)

R = Residual value

$$r_{ky} = P_{ky} + r_{k1}P_{1y} + r_{k2}P_{2y} + r_{k3}P_{3y} + \dots + r_{k(k-1)}P_{(k-1)y}$$

Where,

r_{1y} to r_{ky} denote coefficient of correlation between independent characters 1 to k and dependent character Y. r_{12} to $r_{k(k-1)}$ denote coefficient of correlation between all possible combinations of independent characters and p_{1y} to p_{ky} denote direct effects of characters 1 to k on character Y.

3.5.4. Estimation of Heterosis

Heterosis over mid-parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis) was worked out for characters like flowering laterals per m², nut weight, number of nuts per panicle, nut weight, nut yield per tree and shelling percentage using the formulae suggested by Briggles (1963) and Hayes *et al.* (1965).

$$\text{Relative heterosis} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Heterobeltiosis} = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Standard heterosis} = \frac{F_1 - CV}{CV} \times 100$$

Where,

F_1 = performance of F_1 hybrids

BP = Better parent value

MP = Mid parent value.

CV = Check or standard variety.

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CHAPTER - 4

RESULTS

RESULTS

The present experiment entitled "Evaluation of cashew hybrids" was conducted during the year 1999-2000. The experimental results obtained in the investigation are presented under the following heads.

- 4.1. Estimation of variability.
- 4.2. Estimation of correlation among characters.
- 4.3. Estimation of path coefficient analysis.
- 4.4. Estimation of heterosis for important yield attributing characters.

4.1. ESTIMATION OF VARIABILITY

4.1.1. GROWTH PARAMETERS

The range, mean and coefficient of variation of growth parameters of 3 years and 5 years old hybrids and their parents were worked out and are presented in the table 3. The individual values for hybrids and parents for each parameter are presented in table 4 and table 5.

4.1.1.1. Height of Tree

From the tables it is evident that for the height of tree, a higher range from 3.50 m to 8.00 m, higher mean (5.37 m) and a higher coefficient of variation (30.25) was obtained in case of parents in comparison to both age groups of hybrids. Among the 3 years old hybrid plants the maximum height was obtained in B'₁₄ (4.00 m) followed by B'₄, B'₃₁ and B'₃₄ (3.75 m each) and minimum in C'₁₇ (2.15 m). Whereas in case of 5 years old hybrid

TABLE 3. VARIATION IN GROWTH PARAMETERS OF HYBRIDS AND PARENTS

Sl. No.	Characters	RANGE			MEAN			COEFFICIENT OF VARIATION		
		Hybrids (3 years old)	Hybrids (5 years old)	Parents	Hybrids (3 years old)	Hybrids (5 years old)	Parents	Hybrids (3 years old)	Hybrids (5 years old)	Parents
1	HEIGHT OF TREE(m)	2.15-4.00 (1.85)	3.00-4.75 (1.75)	3.50-8.00 (4.50)	3.29	3.98	5.37	13.57	12.15	30.25
2	CANOPY SPREAD (m)	1.50 - 4.38 (2.88)	3.00-5.00 (2.00)	4.37-9.25 (4.88)	3.28	3.98	7.14	19.91	15.74	23.21
3	EXTENSION GRWOTH OF TWIG(cm)	4.5 - 12.00 (7.50)	4.00-10.50 (6.50)	8.50-21.00 (12.50)	9.15	7.11	14.88	24.24	32.27	31.23
4	GIRTH OF TREE (cm)	19 - 33 (14)	28.00-63.00 (35.00)	60.00-115.00 (55.00)	28.47	42.31	20.28	10.90	24.66	25.14
5	SHOOT DIAMETER (cm)	0.32 - 0.54 (0.22)	0.38-0.60 (0.22)	0.35-0.64 (0.29)	0.47	0.49	0.48	13.11	13.32	24.81
6	NUMBER OF LEAVES PER SHOOT	6-10 (4)	7-11 (4)	7-17 (10)	7.40	8.46	10.33	20.26	15.72	36.49
7	LEAF AREA (cm ²)	65.80-120.50 (54.7)	57.60-120.20 (62.60)	90-121.65 (31.65)	96.11	85.91	104.02	15.15	20.15	11.72
8	NUMBER OF LATERALS PER m ² CANOPY AREA	20-41 (21)	21-34 (13)	26.35 (9)	26.18	26.92	29.50	19.63	18.16	11.89

NB : Figures in parenthesis indicate range.

TABLE 4. GROWTH PARAMETERS FOR INDIVIDUAL HYBRID AND THEIR PARENTS FOR 3 YEARS OLD HYBRIDS

	HEIGHT OF TREE (m)	CANOPY SPREAD (m)	EXTENSION ON GROWTH OF TWIG (cm)	GIRTH OF TREE (cm)	SHOOT DIAMETER (cm)	NUMBER OF LEAVES PER SHOOT	LEAF AREA (cm ²)	NUMBER OF LATERALS PER m ² CANOPY AREA
PARENTS								
BBSR-1	8.00	9.25	13.40	76	0.45	9	99.87	26
VTH-711/4	4.00	6.50	14.50	60	0.57	7	121.65	26
H-2/16	3.50	7.25	21.00	75	0.35	17	112.62	29
H-2/15	5.00	8.25	12.40	93	0.35	12	90.00	29
HYBRIDS								
A' ₃₅	3.50	4.00	8.50	31	0.38	10	19.25	35
B' ₄	3.75	3.75	8.20	31	0.32	7	104.30	24
B' ₇	3.50	3.75	12.00	28	0.48	10	101.75	27
B' ₉	2.75	3.25	12.00	29	0.54	6	120.50	25
B' ₁₁	3.50	3.12	5.70	28	0.51	7	98.50	23
B' ₁₄	4.00	3.75	7.00	30	0.51	6	79.80	22
B' ₁₅	3.10	3.37	9.90	30	0.44	7	110.50	20
B' ₁₈	3.25	1.50	9.50	19	0.48	6	98.40	25
B' ₂₃	3.25	3.50	9.80	29	0.48	6	110.20	22
B' ₂₅	3.00	3.13	11.50	30	0.54	6	85.20	29
B' ₃₀	3.25	4.38	3.00	33	0.44	6	99.10	25
B' ₃₁	3.75	3.63	9.00	30	0.44	7	104.32	25
B' ₃₄	3.75	3.25	12.00	29	0.54	8	96.30	41
C' ₂	3.50	2.50	4.50	25	0.41	8	65.80	27
C' ₃	3.00	2.75	7.20	26	0.51	7	68.30	22
C' ₁₃	3.00	3.25	10.30	27	0.54	10	103.50	25
C' ₁₇	2.15	2.88	10.50	29	0.48	9	88.20	28

TABLE 5. GROWTH PARAMETERS FOR INDIVIDUAL HYBRID AND THEIR PARENTS FOR 5 YEARS OLD HYBRIDS

	HEIGHT OF TREE (m)	CANOPY SPREAD (m)	EXTENSION GROWTH OF TVMG (cm)	GIRTH OF TREE (cm)	SHOOT DIAMETER (cm)	NUMBER OF LEAVES PER SHOOT	LEAF AREA (cm ²)	NUMBER OF LATERALS PER m ² CANOPY AREA
PARENTS								
BBSR-1	8.00	9.25	13.40	76	0.45	9	99.87	26
BBSR-C	6.25	4.38	8.50	115	0.54	7	92.50	32
KANKADI	5.50	7.25	19.50	65	0.64	10	107.50	35
VTH-711/4	4.00	6.50	14.50	60	0.57	7	121.65	26
HYBRIDS								
A ₃	4.50	5.00	4.00	63	0.44	7	78.15	25
A ₄	4.00	3.75	4.10	37	0.44	8	89.60	32
A ₆	4.25	4.50	9.00	43	0.60	7	95.15	34
A ₉	4.00	4.50	4.20	43	0.47	8	65.80	32
A ₁₀	3.75	3.75	7.50	36	0.48	8	67.80	33
C ₁₁	4.50	4.00	7.00	50	0.48	10	105.40	26
E ₃	4.25	4.38	9.00	51	0.48	9	90.75	32
D ₄	4.00	3.25	10.50	30	0.38	10	120.20	21
D ₆	4.75	4.75	6.00	51	0.60	9	98.40	22
D ₇	3.50	4.13	5.50	51	0.41	11	82.10	23
D ₈	3.50	3.50	6.40	36	0.51	7	91.20	22
D ₁₀	3.75	3.00	9.80	31	0.51	7	74.75	23
D ₁₁	3.00	3.25	9.50	28	0.54	9	57.60	25

population the maximum value was obtained in D₆ (4.75 m) followed by A₃ and C₁₁ (4.50 m each) and minimum in D₁₁ (3.00 m)

4.1.1.2. Canopy Spread

Canopy spread of parents showed the highest range (4.88 m), mean (7.14 m) and coefficient of variation 23.21. But mean values observed for 3 years and 5 years old hybrid population were 3.28 m and 3.98 m respectively. In case of 3 years old hybrid population, the highest canopy spread was obtained in B'₃₀ (4.38 m) followed by A'₃₅ (4.00 m) and the lowest was in B'₁₈ (1.50 m). But among the 5 years old hybrids highest canopy spread was seen in A₃ (5.00 m) followed by D₆ (4.75 m) and the lowest was in D₁₀ (3.00 m).

4.1.1.3. Extension Growth of Twig

Extension growth of twig ranged with the highest value of 12.50 cm (from 8.50 cm to 21.00 cm) and highest mean value of 14.88 cm in case of parents but the highest coefficient of variation was observed in 5 years old hybrids (32.27). Among the 3 years old hybrids highest individual value in this aspect was obtained by B'₇ and B'₉ (12.00 cm each) followed by B'₂₅ (11.50 cm) and the lowest value by C'₂ (4.50 cm) where as in 5 years old hybrid population highest value was obtained in D₄ (10.50 cm) followed by D₁₀ (9.80 cm) and the lowest value in A₃ (4.00 cm).

4.1.1.4. Girth of Tree

In case of girth of tree, the highest range from (60.00 cm to 115.00 cm) and the highest coefficient of variation (25.14) was observed in parental

group but the 5 years old hybrids also showed a coefficient of variation of 24.66 which was close to the parental value of 25.14. The highest mean of 42.31 cm was also seen in case of 5 years old hybrid group. In the 3 year old hybrid population, maximum girth was obtained in B'₃₀ (33.00 cm) followed by A'₃₅ and B'₄ (31.00 cm) each and the minimum was in B'₁₈ (19.00 cm). The maximum girth in 5 year old hybrid population was obtained by A₃ (63.00 cm) followed by E₃, D₆ and D₇ (51.00cm) each and the minimum is D₁₁ (28.00 cm).

4.1.1.5. Shoot Diameter :

In the aspect of shoot diameter the hybrids of both age group showed a similar range (0.22 cm), which is also closer to the parental value (0.29 cm). The mean values of 3 years old hybrids, 5 years old hybrids, and parents are also very close and almost similar to each other i.e. 0.47 cm, 0.49cm and 0.48 cm respectively. The highest coefficient of variation was seen in case of parents (24.81). Among the 3 years old hybrids the maximum shoot diameter was observed in case of B'₉ , B'₂₅, B'₃₄ and C'₁₃ (0.54cm each) followed by B'₁₁, B'₁₄ and C'₃ (0.51cm each) and with the minimum value in B'₄ (0.32 cm). The maximum value in case of 5 years old hybrids was seen in A₆ and B₆ (0.60 cm each) followed by D₁₁(0.54cm) and minimum value in D₄ (0.38cm).

4.1.1.6 Number of Leaves per shoot

A higher range (10.00) mean (10.33) and co-efficient of variation value (36.49) was seen in parents in comparison to the plants of both the hybrid age groups with regard to the number of leaves per shoot. Among the 3 years old

hybrids the maximum number was obtained in A'₃₅, B'₇ and C'₁₃ (10.00) each followed by C'₁₇ (9.00) and the minimum value in B'₉, B'₁₄, B'₁₈, B'₂₃, B'₂₅ and B'₃₀ (6.00 each) whereas, in 5 years old hybrid population maximum value was obtained in D₇ (11.00) followed by D₄ and C₁₁ (10.00 each) and the minimum value in A₆, D₈ and D₁₀ (7.00 each).

4.1.1.7. Leaf Area

The highest mean in the aspect of leaf area was seen in parents (104.02cm²). In the 5 years old hybrids leaf area was ranging from 57.60cm² to 120.20 cm² showing the highest range 62.60 cm² and the highest coefficient of variation (20.15). In the population of 3 years old hybrids, the maximum leaf area was observed in B'₉ (120.50 cm²) followed by B'₁₅ (110.50 cm²) and the minimum value in C'₂ (65.80 cm²). Among the 5 years old hybrids D₄ showed maximum value (120.20 cm²) followed by C₁₁ (105.40 cm²) and the minimum value in D₁₁ (57.60 cm²)

4.1.1.8. Number of Laterals per square meter canopy area

With regard to the number of laterals per m² canopy area, the highest range value from 20.00 to 41.00 and co-efficient of variation of 19.63 in case of 3 years old hybrids was observed. But the highest mean was recorded in case of parents (29.50). Among the 3 years old hybrids B'₃₄ showed maximum number of laterals (41.00) followed by A'₃₅ (35.00) where as B'₁₅ showed the minimum number (20.00). In case of 5 years old hybrid population highest value in this character was obtained in the hybrid A₆ (34.00) followed by A₁₀ (33.00) and the lowest value in D₄ (21.00).

4.1.2. FLORAL AND APPLE TRAITS

The range of variability in the floral and apple traits like duration of 50% flowering, number of flowering laterals per m², inflorescence size, apple size and apple weight, their means and co-efficient of variation are presented in table 6. The individual values of both the hybrid groups and parents for each trait are presented in the table 7 and table 8.

4.1.2.1. Duration of 50% Flowering

With reference to the duration of 50% flowering, the data showed the highest range of 12 days to 22 days and the highest mean value of 19.82 days in case of 3 years old hybrids. However, the co-efficient of variation was highest in case of parents (15.27). In the hybrid population of 3 years old the maximum duration was seen in case of B'₇, B'₁₁ and B'₁₄ (22 days each), followed by B'₄, B'₉, B'₁₅, B'₁₈, B'₂₃, B'₃₀, B'₃₁ and B'₃₄ (21 days each), and the minimum value was seen in A'₃₅ (12 days). Similarly in case of 5 years old hybrids maximum duration was observed in C₁₁ (19 days) followed by A₆, D₄, D₈, D₁₀ and D₁₁ (18 days each) where as minimum duration was recorded in A₄ (14 days).

4.1.2.2. Number of Flowering Laterals per meter square Canopy Area

In the aspect of number of flowering laterals per m², a similar mean (20.13 and 20.44) and co-efficient of variation (19.55 and 19.37) were calculated respectively in case of hybrids of 3 years and 5 years old age groups. However a higher mean (22.28) and lower co-efficient of variation (11.02) were calculated for parents in comparison to both the hybrid groups. In the hybrid population of 3 years old the maximum number was counted for

TABLE 6 . VARIATION IN FLORAL AND APPLE TRAITS OF HYBRIDS AND PARENTS

SI. No.	CHARACTERS	RANGE			MEAN			COEFFICIENT OF VARIATION		
		Hybrids (3 years old)	Hybrids (5 years old)	Parents	Hybrids (3 years old)	Hybrids (5 years old)	Parents	Hybrids (3 years old)	Hybrids (5 years old)	Parents
1	DURATION OF 50% FLOWERING (DAY)	12-22 (10)	14-19 (5)	12-18 (6)	19.82	16.92	15.17	13.13	8.85	15.27
2	NUMBER OF FLOWERING LATERALS PER m ² CANOPY AREA	15.00-31.57 (16.57)	16.28-25.84 (9.56)	19.50-26.60 (17.10)	20.13	20.44	22.28	19.55	19.37	11.02
3	INFLORESCENCE SIZE (cm ²)	113.5-584.1 (470.60)	157.30-782.00 (624.70)	224.75-768.00 (543.25)	357.00	394.96	414.05	41.68	40.06	53.71
4	APPLE SIZE (cm ²)	14.72-36.00 (21.28)	12.80-39.76 (26.96)	19.25-36.72 (17.47)	23.15	23.59	27.51	25.39	29.58	23.69
5	APPLE WEIGHT (g)	30.00-110.00 (80.00)	26.00-80.00 (54.00)	50.00-94.00 (44)	50.24	57.35	65.00	36.13	26.62	25.75

N.B. Figures in parenthesis indicate range

TABLE 7. FLORAL AND APPLE TRAITS FOR INDIVIDUAL HYBRIDS AND THEIR PARENTS FOR 3 YEARS OLD HYBRIDS

	DURATION OF 50% FLOWERING (DAYS)	NUMBER OF FLOWERING LATERALS /m ² CANOPY AREA	INFLORESCENCE SIZE (cm ²)	APPLE SIZE (cm ²)	APPLE WEIGHT (g)
PARENTS					
BBSR-1	17	19.50	266.00	21.60	50.00
VTH-711/4	13	20.54	768.00	26.00	65.00
H-2/16	12	22.00	277.02	30.00	66.00
H-2/15	16	22.00	224.75	31.50	60.00
HYBRIDS					
A' ₃₅	12	26.25	252.00	36.00	110.00
B' ₄	21	18.24	236.35	27.00	52.60
B' ₇	22	21.60	486.40	24.75	54.00
B' ₉	21	20.00	358.80	27.00	65.00
B' ₁₁	22	17.48	507.50	20.14	45.00
B' ₁₄	22	16.72	303.60	22.04	38.50
B' ₁₅	21	15.00	481.90	19.25	48.50
B' ₁₈	21	19.00	200.00	14.72	30.00
B' ₂₃	21	16.50	558.78	24.75	51.00
B' ₂₅	20	22.62	411.60	27.84	50.00
B' ₃₀	21	19.00	441.60	21.00	43.30
B' ₃₁	21	19.25	584.10	16.00	32.00
B' ₃₄	21	31.57	500.00	33.75	60.00
C' ₂	19	20.52	113.50	17.50	50.00
C' ₃	19	18.25	216.59	21.50	52.00
C' ₁₃	19	19.00	201.16	22.80	37.20
C' ₁₇	15	21.28	216.00	17.50	35.00

TABLE 8. FLORAL AND APPLE TRAITS FOR INDIVIDUAL HYBRID AND THEIR PARENTS FOR 5 YEARS OLD HYBRIDS

	DURATION OF 50% FLOWERING (DAYS)	NUMBER OF FLOWRING LATERALS /m ² CANOPY AREA	INFLORESENCE SIZE (cm ²)	APPLE SIZE (cm ²)	APPLE WEIGHT (g)
PARENTS					
BBSR-1	17	19.50	226.00	21.60	50.00
BBSR-C	18	23.04	336.00	19.25	55.00
KANKADI	15	26.60	612.50	36.72	94.00
VTH-711/4	13	20.54	768.00	26.00	65.00
HYBRIDS					
A ₃	16	18.75	412.80	31.20	65.00
A ₄	14	23.68	265.95	39.76	80.00
A ₆	18	25.84	282.80	22.50	69.60
A ₉	17	25.12	157.30	20.00	56.80
A ₁₀	17	25.74	270.68	12.80	55.00
C ₁₁	19	19.50	385.00	24.96	62.00
E ₃	15	24.96	302.40	29.25	47.20
D ₄	18	16.38	229.50	24.00	33.00
D ₆	17	16.28	782.00	26.00	60.00
D ₇	15	17.48	605.64	19.25	74.00
D ₈	18	16.28	367.35	22.00	52.00
D ₁₀	18	17.02	647.52	17.50	65.00
D ₁₁	18	18.75	425.50	17.50	26.00

B'₃₄ (31.57) followed by A'₃₅ (26.25) and the minimum value was in B'₁₅ (15.00). In 5 year old hybrid population the hybrid A₆ got the highest number (25.84) followed by A₁₀ (25.74) and D₆ and D₈ got the lowest number (16.28 each).

4.1.2.3. Inflorescence Size

Inflorescence size showed the highest range in 5 years old hybrid population which was ranging from 157.30 cm² to 782.00 cm². However the highest mean and co-efficient of variation calculated for parents were 414.05 cm² and 53.71 respectively. Among the 3 years old hybrids, maximum inflorescence size was seen in B'₃₁ (584.10 cm²) followed by B'₂₃ (558.78 cm²) and the lowest value in C'₂ (113.50 cm²). In the hybrid population of 5 years old the maximum value was obtained in D₆ (782.00 cm²) followed by D₁₀ (647.52 cm²) and the minimum value was in A₉ (157.30 cm²).

4.1.2.4. Apple Size

From the table, it can be seen that in case of apple size, lowest range is observed in parents, ranging from 19.25 cm² to 36.72 cm² and showing the highest mean of 27.51 cm² whereas 5 years old hybrids are with the highest range of 26.96 cm² having the highest co-efficient of variation value of 29.58. Among the 3 year old hybrids, maximum size apple was obtained from A'₃₅ (36cm²) followed by B'₃₄ (33.75 cm²) and the minimum size apple from B'₁₈ (14.72cm²). In 5 years old hybrid population, the maximum apple size was seen in A₄ (39.76 cm²) followed by A₃ (31.20 cm²) and the minimum size in A₁₀ (12.80cm²).

4.1.2.5. Apple Weight

Data showed for apple weight that the highest range and the highest coefficient of variation was obtained in case of 3 years old hybrids (80 g and 36.13 respectively). But the highest mean was obtained in case of parents (65.00 g). Among the hybrids of 3 years old age in A'₃₅, the maximum individual apple weight (110.00 g) was recorded followed by B'₉ (65.00 g) and the hybrid B'₁₈ was with the minimum apple weight (30.00 g). Similarly A₄ had the maximum apple weight (80.00 g) followed by D₇ (74.00 g) and D₁₁ had the minimum apple weight (26.00 g) in the hybrid population of 5 years age.

4.1.3. NUT, KERNEL AND YIELD ATTRIBUTES

The range mean and coefficient of variation for nut, kernel and yield attributing characters were worked out and presented in table 9. The individual hybrid as well as parental value for each character are presented in table 10 and table 11.

4.1.3.1. Number of Nuts per Panicle

From the table, it is evident that, regarding number of nuts per panicle, the parents had the highest co-efficient of variation (56.01), mean (4.03) and range from 1.50 to 6.50. Within 3 years old hybrid group, maximum number of nuts per panicle was observed in B'₁₄ (4.30) followed by C'₁₃ (4.20) and the minimum number was in B'₂₃ (1.10). Similarly the maximum value in this aspect was observed in A₉ (5.10) followed by D₄ (4.80) and the minimum value was in A₃ and D₁₀ (2.40 each) in 5 years old hybrid group.

TABLE 9. VARIATION IN NUT, KERNEL AND YIELD ATTRIBUTES OF HYBRIDS AND PARENTS

SI. No.	CHARACTERS	RANGE			MEAN			COEFFICIENT OF VARIATION		
		Hybrids (3 years old)	Hybrids (5 years old)	Parents	Hybrids (3 years old)	Hybrids (5 years old)	Parents	Hybrids (3 years old)	Hybrids (5 years old)	Parents
1	NUMBER OF NUTS PER PANICLE	1.10-4.30 (3.20)	2.40-5.10 (2.70)	1.5-6.50 (5.00)	2.25	3.39	4.03	45.78	26.26	56.01
2	NUT DIMENSION (cm ³)	7.50-22.87 (15.37)	10.08-22.54 (12.46)	9.00-36.22 (27.22)	16.19	16.89	19.59	22.89	21.73	55.99
3	NUT WEIGHT (g)	422-10.44 (6.22)	4.94-13.20 (8.26)	4.60-15.80 (11.20)	7.77	8.45	8.96	20.45	24.66	45.87
4	SHELLING PERCENTAGE (%)	16.66-32.46 (15.80)	26.00-33.92 (7.92)	22.78-32.60 (9.82)	27.44	30.96	28.28	15.63	7.50	13.83
5	SHELL THICKNESS (mm)	3.00-4.50 (1.50)	3.00-4.00 (1.0)	2.50-4.00 (1.50)	3.69	3.48	3.17	11.60	12.65	16.29
6	KERNEL WEIGHT (g)	1.12 - 2.86 (1.74)	1.61-2.90 (1.29)	1.50-3.60 (2.10)	2.14	2.47	2.42	23.35	15.69	33.91
7	KERNEL DIMENSION (cm ³)	2.00-12.37 (10.37)	4.19-10.80 (6.61)	3.86-14.58 (10.72)	6.35	7.12	7.60	38.42	27.92	58.55
8	NUT YIELD (kg/tree)	0.14-0.68 (0.54)	0.25-0.73 (0.48)	0.60-14.23 (13.63)	0.34	0.47	4.95	48.82	34.55	94.86

N.B. Figures in parenthesis indicate range

TABLE 10. NUT, KERNEL AND YIELD ATTRIBUTES FOR INDIVIDUAL HYBRID AND THEIR PARENTS FOR 3 YEARS OLD HYBRIDS

	NUMBER OF NUTS PER PANICLE	NUT DIMENSION (cm ³)	NUT WEIGHT (g)	SHELLING PERCENTAGE (%)	SHELL THICKNESS (mm)	KERNEL WEIGHT (g)	KERNEL DIMENSION (cm ³)	NUT YIELD (kg/tree)
PARENTS								
BBSR-1	5.20	10.80	4.60	32.60	3.00	1.50	3.86	3.50
VTH-711/4	1.50	29.92	11.24	28.47	4.00	3.20	14.58	0.60
H-2/16	6.20	16.50	8.10	28.00	3.00	2.27	5.19	14.23
H-2/15	3.30	15.12	8.64	25.27	3.00	2.18	6.05	5.68
HYBRIDS								
A' ₃₅	1.50	15.96	8.10	30.86	4.00	2.50	6.96	0.52
B' ₄	3.10	14.87	8.80	24.54	3.50	2.56	4.48	0.40
B' ₇	2.30	17.25	7.30	31.00	4.00	2.26	8.26	0.30
B' ₉	2.40	15.98	9.10	27.47	3.70	2.50	5.10	0.35
B' ₁₁	1.50	20.52	10.44	20.11	4.00	2.10	5.40	0.23
B' ₁₄	4.30	15.67	5.40	31.11	3.00	1.68	5.64	0.32
B' ₁₅	1.40	22.87	7.50	31.46	3.00	2.36	10.11	0.17
B' ₁₈	1.30	10.72	9.90	28.88	3.50	2.86	12.37	0.22
B' ₂₃	1.10	19.60	8.20	26.83	4.50	2.20	6.55	0.15
B' ₂₅	1.50	16.85	8.20	24.39	4.00	2.00	4.50	0.28
B' ₃₀	1.40	19.60	7.80	16.66	3.50	1.30	6.16	0.21
B' ₃₁	3.20	16.85	9.00	30.66	4.00	2.76	7.54	0.55
B' ₃₄	2.50	13.46	8.10	28.39	4.00	2.30	5.42	0.68
C' ₂	2.10	14.28	6.00	25.00	3.00	1.50	5.52	0.25
C' ₃	1.30	7.50	4.22	26.54	3.50	1.12	2.00	0.14
C' ₁₃	4.20	19.04	7.70	32.46	4.00	2.50	8.10	0.63
C' ₁₇	3.30	14.14	6.30	30.16	3.50	1.90	3.90	0.33

TABLE 11. NUT, KERNEL AND YIELD ATTRIBUTES FOR INDIVIDUAL HYBRID AND THEIR PARENTS FOR 5 YEARS OLD HYBRIDS

	NUMBER OF NUTS PER PANICLE	NUT DIMENSION (cm ³)	NUT WEIGHT (g)	SHELLING PERCENTAGE (%)	SHELL THICKNESS (mm)	KERNEL WEIGHT (g)	KERNEL DIMENSION (cm ³)	NUT YIELD (kg/tree)
PARENTS								
BBSR-1	5.20	10.80	4.60	32.60	3.00	1.50	3.86	3.50
BBSR-C	6.50	9.00	5.40	32.59	2.50	1.76	4.22	3.80
KANKADI	1.50	36.22	15.80	22.78	3.50	3.60	11.70	1.00
VTH-711/4	1.50	29.92	11.24	28.47	4.00	3.20	14.58	0.60
HYBRIDS								
A ₃	2.40	16.18	9.90	26.00	4.00	2.60	7.20	0.35
A ₄	3.40	22.54	9.10	31.90	4.00	2.90	6.92	0.65
A ₆	3.10	15.30	8.50	32.47	3.00	2.76	10.80	0.62
A ₉	5.10	10.08	4.94	32.61	3.00	1.61	4.19	0.58
A ₁₀	3.50	20.88	13.20	33.00	3.00	2.56	7.98	0.73
C ₁₁	2.50	16.30	7.66	32.37	3.80	2.48	4.87	0.32
E ₃	4.30	14.79	5.60	33.92	3.00	1.90	6.50	0.56
D ₄	4.80	16.63	8.30	32.53	4.00	2.70	10.26	0.60
D ₆	3.50	22.17	9.64	29.05	3.00	2.80	8.96	0.38
D ₇	3.40	15.68	9.64	28.00	3.50	2.70	4.99	0.40
D ₈	2.50	16.68	7.90	31.64	3.50	2.50	7.02	0.25
D ₁₀	2.40	19.48	8.60	29.53	3.50	2.54	6.72	0.28
D ₁₁	3.10	12.34	6.80	29.41	4.00	2.00	6.09	0.34

4.1.3.2. Nut Dimension

In the aspect of nut dimension, a similar mean of 16.19 cm³ and 16.89 cm³ were obtained in 3 years and 5 years old hybrid groups respectively. But a higher mean(19.59 cm³) and a much higher coefficient of variation (55.99) was observed in case of parent group in comparison to both the hybrid groups. Among the 3 years old hybrid group, highest nut dimension was observed in B'₁₅ (22.87cm³) followed by B'₁₁ (20.52cm³) and the lowest value was in C'₃(7.50 cm³). Among the 5 years old hybrid group highest value was obtained in A₄(22.54 cm³) followed by D₆ (22.17 cm³) and the lowest value in the hybrid A₉(10.08 cm³).

4.1.3.3. Nut Weight

Individual nut weight showed a wider variation among parents (4.60 g to 15.80g) with a range of 11.20g while the hybrid had comparatively narrower range i.e. 4.22 g to 10.44g in 3 years age group hybrids and 4.94 g to 13.20g in 5 years age group hybrids. Parents are also with a higher mean (8.96g) and much higher co-efficient of variation (45.87) in comparison to both age group hybrids. In case of 3 years old hybrid population, highest nut weight was observed in B'₁₁(10.44g) followed by B'₁₈(9.90g) and the lowest nut weight in C'₃(4.22 g). In case of 5 years old hybrid population the highest nut weight was observed in A₁₀(13.20g) followed by A₃(9.90g) and the lowest nut weight in A₉(4.94g).

4.1.3.4. Shelling Percentage

In case of shelling percentage, 3 years old hybrids showed the highest range (16.66% to 32.46%) and the highest coefficient of variation (15.63) but the highest mean was obtained in case of 5 years old hybrids (30.96%) followed by the parents (28.28%). In case of 3 years age group hybrids, highest shelling percentage was observed in C'₁₃ (32.46%) followed B'₁₅(31.46%) and lowest value is B'₃₀(16.66%). In 5 years old hybrid group, highest value was obtained in E₃ (33.92%) followed by A₁₀(33.00%) but the lowest value was obtain in A₃(26.00%).

4.1.3.5. Shell Thickness

It can be seen from the table that a similar range (1.5 mm each) was obtained in case of parents as well as 3 years old age group hybrids so far as shell thickness is concerned. But highest mean (3.69mm) was recorded in 3 years old hybrid group. However, the highest co-efficient of variation was obtained in parents (16.29mm) in this aspect. Among the hybrids of 3 years old age group, highest shell thickness was obtained in B'₂₃(4.50mm) followed by A'₃₅, B'₇, B'₁₁, B'₂₅, B'₃₁, B'₃₄, C'₁₃, (4.00mm each) and the lowest in C'₂, B'₁₄, B'₁₅(3.00mm each). Among the hybrids of 5 years of age, highest value obtained in A₃, A₄ and D₄ (4.00 mm each) followed by C₁₁ (3.80mm) and the lowest value in A₆, A₉, A₁₀, E₃, D₆ (3.00 mm).

4.1.3.6. Kernel Weight

With respect to kernel weight higher range (2.10g) was recorded in case of parents than both the hybrid groups and so far as mean value is concerned, closer values of 2.42g, 2.47g and 2.14g were obtained in parents,

5 years old and 3 years old hybrid respectively. However, parents showed the highest co-efficient of variation (33.91). In case of hybrids of 3 years age group maximum kernel weight was observed in B'₁₈(2.86g) followed by B'₃₁ (2.76g) and the minimum kernel weight in C'₃ (1.12g). Among the hybrids of 5 years old, maximum kernel weight was obtained in A₄(2.90g) followed by D₆(2.80g) and the lowest weight in A₉ (1.61g).

4.1.3.7. Kernel Dimension

In the aspect like kernel dimension 3 years old hybrids showed a closer range (10.37cm³) with parents (10.72 cm³) while 5 years old hybrids showed closer value of mean (7.12 cm³) with parents (7.60 cm³) but the coefficient of variation was highest in parents (58.55) . Among the hybrids of 3 years old age group, highest kernel dimension was observed in B'₁₈ (12.37 cm³) followed by B'₁₅ (10.11 cm³) and the lowest in C'₃ (2.00 cm³). In case of 5 years old hybrid population the highest kernel dimension was observed in A₆ (10.80 cm³) followed by D₄ (10.26 cm³) and the lowest dimension in A₉ (4.19 g).

4.1.3.8. Nut Yield

Nut yield per tree showed a very wide range (13.63 kg/tree) in case of parents as compared to hybrids of both age group. Highest mean (4.95 kg/tree) and the highest co-efficient of variation (94.86) was observed in case of parents.

Among the 3 years old hybrid population, highest nut yield value was obtained in B'₃₄(0.68 kg/tree) followed by C'₁₃(0.63kg/tree) and the lowest value in C'₃ (0.14 kg/tree) whereas, in 5 years old hybrid population, the

highest nut yield was obtained in A₁₀ (0.73 kg/tree) followed by A₄ (0.65 kg/tree) and lowest in D₈ (0.25 kg/tree).

4.2. ESTIMATION OF CORRELATION AMONG CHARACTERS

In the present investigation correlation studies were undertaken using 20 selected characters and nut yield in case of hybrids of both age group separately to determine the degree of association between yield and different characters (table 12 and table 13).

In the table 12 correlation coefficient values between characters of 3 years old hybrids had been presented.

The table indicated that, number of laterals/m² showed maximum positive correlation with yield (0.659) followed by number of flowering laterals/m² (0.639), number of nuts per panicle (0.594), number of leaves per shoot (0.513) , kernel weight (0.479) and apple size (0.456).

There was a weak negative relationship was observed when yield was compared with leaf area (-0.101) nut dimension (-0.028) and duration of 50% flowering (-0.246).

Besides the factors mentioned earlier, yield was found to have a non-significant positive correlation with extension growth of twig, shoot diameter, inflorescence size, apple weight, nut weight, shelling %, shell thickness, kernel dimension, canopy spread, plant height and plant girth.

It was also observed from the table that, there was a positive and highly significant relationship maintained between number of flowering laterals/m² and number of laterals per m² (0.991), apple size and number of laterals/m²

TABLE 12. CORRELATION COEFFICIENTS BETWEEN YIELD AND DIFFERENT CHARACTERS (3 YEARS OLD HYBRIDS)

	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃	X ₁₄	X ₁₅	X ₁₆	X ₁₇	X ₁₈	X ₁₉	X ₂₀	
X ₂	0.398																				
X ₃	0.235	-0.128																			
X ₄	0.298	0.295	-0.389																		
X ₅	0.316	0.063	0.435	-0.403																	
X ₆	0.352	0.121	0.427	-0.384	0.991**																
X ₇	0.211	0.208	-0.254	0.466*	-0.002	0.002															
X ₈	0.353	-0.004	0.266	-0.347	0.656**	0.662**	0.114														
X ₉	0.106	-0.280	0.353	-0.621*	0.508*	0.504*	-0.057	0.811**													
X ₁₀	-0.036	-0.048	0.012	0.359	-0.244	-0.306	0.567*	0.011	-0.013												
X ₁₁	0.188	-0.065	-0.155	0.395	0.113	0.072	0.459*	0.136	0.063	0.452*											
X ₁₂	0.629**	0.112	0.477*	-0.091	0.109	0.109	-0.132	0.055	0.071	-0.110	-0.241										
X ₁₃	0.419	0.258	0.193	0.112	0.319	0.327	0.499*	0.430	0.232	0.179	0.506*	-0.012									
X ₁₄	0.589*	-0.120	0.154	0.290	0.161	0.125	0.197	0.140	0.085	0.197	0.707**	0.472*	0.375								
X ₁₅	0.175	-0.087	0.067	0.224	-0.109	-0.160	0.133	-0.279	-0.164	0.308	0.373	0.364	-0.018	0.611*							
X ₁₆	0.159	0.085	0.297	0.138	0.016	0.005	-0.232	-0.064	-0.309	-0.019	-0.181	0.461*	-0.169	0.152	-0.111						
X ₁₇	-0.133	-0.270	0.130	-0.033	0.059	0.042	0.450*	0.461*	0.361	0.535*	0.067	-0.129	0.202	-0.099	-0.219	0.181					
X ₁₈	-0.283	-0.313	-0.094	-0.136	0.124	0.099	0.247	0.202	0.117	0.052	0.141	-0.039	-0.013	0.127	0.155	0.134	0.307				
X ₁₉	-0.078	-0.225	0.010	-0.011	0.100	0.081	0.438	0.449*	0.322	0.518*	0.063	0.199	0.126	-0.158	-0.405	0.156	0.917**	0.112			
X ₂₀	-0.018	0.277	-0.569*	0.755**	-0.417	-0.383	0.484*	-0.296	-0.569*	0.217	0.231	-0.262	-0.051	0.027	0.177	0.023	-0.016	0.380	-0.092		
X ₂₁	0.364	0.042	0.513*	-0.101	0.659**	0.639**	0.002	0.456*	0.222	-0.028	0.230	0.412	0.322	0.479*	0.027	0.594*	0.232	0.253	0.196	-0.246	

* significant at 5% level

** significant at 1% level

X₁ = extension growth of twig X₂ = Shoot diameter X₃ = Number of leaves per shoot X₄ = Leaf area X₅ = Number of laterals/m² canopy area
 X₆ = Number of flowering laterals/m² canopy area X₇ = Inflorescence size X₈ = Apple size X₉ = Apple weight X₁₀ = Nut dimension X₁₁ = Nut weight
 X₁₂ = Shelling percentage X₁₃ = Shell thickness X₁₄ = Kernel weight X₁₅ = Kernel dimension X₁₆ = Number of nuts per panicle
 X₁₇ = Canopy spread X₁₈ = Height of tree X₁₉ = Plant girth X₂₀ = Duration of 50% flowering X₂₁ = Nut yield

TABLE 13. CORRELATION COEFFICIENTS BETWEEN YIELD AND DIFFERENT CHARACTERS (5 YEARS OLD HYBRIDS)

	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃	X ₁₄	X ₁₅	X ₁₆	X ₁₇	X ₁₈	X ₁₉	X ₂₀
X ₂	0.190																			
X ₃	0.112	-0.397																		
X ₄	0.201	-0.152	0.324																	
X ₅	-0.138	0.147	-0.302	-0.280																
X ₆	-0.109	0.104	-0.259	-0.277	0.994**															
X ₇	0.006	0.350	0.164	-0.019	-0.616*	-0.647*														
X ₈	-0.425	-0.198	-0.057	0.417	0.121	0.069	-0.125													
X ₉	-0.596*	0.003	-0.207	0.044	0.264	0.205	0.205	0.363												
X ₁₀	-0.074	0.082	-0.123	0.274	-0.109	-0.163	0.404	0.272	0.422											
X ₁₁	-0.113	-0.048	-0.081	-0.013	-0.051	-0.068	0.262	-0.153	0.327	0.707**										
X ₁₂	0.328	0.017	0.022	0.273	0.559*	0.588*	-0.661*	-0.038	-0.201	-0.080	-0.278									
X ₁₃	-0.023	-0.499	0.169	0.138	-0.456	-0.489	0.038	0.356	-0.151	0.026	0.009	-0.381								
X ₁₄	-0.057	-0.011	-0.005	0.499	-0.270	-0.323	0.356	0.271	0.487	0.764**	0.718**	0.278	0.255							
X ₁₅	0.435	0.291	-0.241	0.487	-0.009	-0.014	-0.024	0.071	-0.112	0.388	0.382	0.121	-0.104	0.564*						
X ₁₆	0.053	-0.307	0.352	0.108	0.280	0.356	-0.466	-0.006	-0.326	-0.324	-0.363	0.491	-0.313	-0.434	0.036					
X ₁₇	-0.577*	0.189	-0.063	0.040	0.309	0.310	0.037	0.351	0.396	-0.132	-0.012	-0.214	-0.397	-0.044	0.003	0.106				
X ₁₈	-0.262	0.143	-0.050	0.534	0.131	0.123	0.084	0.511	0.373	0.277	0.052	0.033	-0.236	0.243	0.268	0.048	0.694*			
X ₁₉	-0.561*	-0.032	0.097	0.124	0.064	0.062	0.212	0.389	0.456	-0.061	0.867**	-0.375	-0.173	0.048	-0.186	-0.131	0.886**	0.670*		
X ₂₀	0.509	0.380	-0.106	0.138	-0.308	-0.294	0.028	-0.561*	-0.439	-0.218	-0.102	0.137	0.011	-0.083	0.191	-0.233	-0.335	-0.060	-0.361	
X ₂₁	0.016	-0.190	0.009	0.054	0.738**	0.768**	-0.639*	0.102	0.066	0.097	0.189	0.592*	-0.324	0.009	0.342	0.643*	0.129	0.122	-0.142	-0.354

* significant at 5% level

** significant at 1% level

X₁ = extension growth of twig X₂ = Shoot diameter X₃ = Number of leaves per shoot X₄ = Leaf area X₅ = Number of laterals/m² canopy area
 X₆ = Number of flowering laterals/m² canopy area X₇ = Inflorescence size X₈ = Apple size X₉ = Apple weight X₁₀ = Nut dimension X₁₁ = Nut weight
 X₁₂ = Shelling percentage X₁₃ = Shell thickness X₁₄ = Kernel weight X₁₅ = Kernel dimension X₁₆ = Number of nuts per panicle
 X₁₇ = Canopy spread X₁₈ = Height of tree X₁₉ = Plant girth X₂₀ = Duration of 50% flowering X₂₁ = Nut yield

(0.656), apple size and number of flowering laterals (0.662) . apple weight and apple size (0.811) , shelling % and extension growth of twig (0.629) , plant girth and canopy spread (0.917) as well as duration of 50% flowering and leaf area (0.755).

A significant positive correlation was observed between leaf area and inflorescence size (0.466), apple weight and number of laterals/m² (0.508), apple weight and number of flowering laterals/m² (0.508), apple weight and number of flowering laterals/m² (0.504), nut dimension and inflorescence size (0.567), nut weight and inflorescence size (0.459), nut weight and nut dimension (0.452), shelling % and number of leaves per shoot (0.477), shell thickness and inflorescence size (0.499), shell thickness and nut weight (0.506), kernel weight and extension growth of twig (0.589), kernel weight and shelling % (0.472), number of nuts/panicle and shelling % (0.461) , canopy spread and nut dimension (0.535), plant girth and apple size (0.449), plant girth and nut dimension (0.518) and between duration of 50% flowering and inflorescence size (0.484).

For the hybrid population of 5 years old trees correlation study was presented in table 13.

The table revealed that number of flowering laterals per m² has the maximum positive correlation with yield (0.768). Yield had also a statistically highly significant positive correlation with number of laterals per m² (0.738), shelling %(0.592) and number of nuts per panicle (0.643). A significantly negative relationship was found between yield and inflorescence size (-0.639). Where as a weak positive correlation was noted when yield was

compared with extension growth of twig , number of leaves per shoot, leaf area, apple size, apple weight, nut dimension, nut weight, kernel weight, kernel dimension, canopy spread and plant height.

The study in table 13 also revealed that there was positive and highly significant correlation existed between number of flowering laterals/m² and number of laterals/m² (0.994), nut weight and nut dimension (0.707), kernel weight and nut dimension (0.764) , kernel weight and nut weight (0.718), plant girth and nut weight (0.867) and between plant girth and canopy spread (0.886).

The table also indicated that there was a statistically significant positive correlation was maintained between height of tree and canopy spread (0.694), plant girth and height of tree (0.670), shelling % and number of flowering laterals/m² (0.588), kernel dimension and kernel weight (0.564) and shelling percentage and number of laterals per m² (0.559).

It was also observed from the table that there was a significant negative correlation maintained between inflorescence size and number of laterals/m² canopy area (-0.616), inflorescence size and number of flowering laterals/m² (-0.647), canopy spread and extension growth of twig (-0.577) and between plant girth and extension growth of twig (-0.561).

There was a weak negative relationship observed when yield was compared with shoot diameter (-0.190). Shell thickness (-0.324), plant girth (-0.142) and duration for 50% flowering (-0.354).

4.3 ESTIMATION OF PATH COEFFICIENT ANALYSIS

In the present experiment with an objective of finding out their importance as causal factors for yield, 8 parameters were selected for path coefficient analysis. Those parameters were 1. Number of laterals/m² 2. Number of flowering laterals/m² 3. Number of nuts per panicle 4. Number of leaves per shoot 5. Canopy spread 6. Plant height 7. Nut weight 8. Leaf area. The table 14 and table 15 showed direct and indirect effect of these parameters on yield in population of 3 years old hybrids and 5 years old hybrids respectively. The values in main diagonal were considered as direct effect and off diagonal values were considered as indirect effect.

Table 14 indicated the direct and indirect effect of selected characters in 3 years old hybrid population with a residual value of 0.1285. Among the 8 characters studied number of nuts per panicle showed maximum positive direct effect on yield (0.5947) followed by number of flowering lateral/m² (0.4674) and nut weight (0.3225). Leaf area showed a negative direct effect on yield (-0.0378) however, it contributes to yield positively mainly through the indirect effect of nut weight (0.1272).

The study revealed that plant height showed a positive direct effect on yield (0.0716) and a positive indirect effect mainly through number of nuts per panicle (0.0797). Canopy spread showed a positive direct effect on yield (0.0371) and positive indirect effect on yield (0.1078) mainly through number of nuts per panicle.

TABLE 14. DIRECT EFFECTS, INDIRECT EFFECTS AND CORRELATION COEFFICIENTS OF DIFFERENT CHARACTERS ON YIELD (FOR 3 YEARS OLD HYBRIDS)

	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	Y(r)
X ₁	<u>0.0716</u>	0.0114	-0.0139	0.0052	0.0075	0.0466	0.0797	0.0454	0.253
X ₂	0.0220	<u>0.0371</u>	0.0193	0.0012	0.0035	0.0197	0.1078	0.0213	0.232
X ₃	-0.0067	0.0048	<u>0.1479</u>	0.0147	0.0262	0.1996	0.1768	-0.0501	0.513*
X ₄	-0.0098	-0.0012	-0.0576	<u>-0.0378</u>	-0.0243	-0.1796	0.0822	0.1272	-0.1008
X ₅	0.0089	0.0022	0.0644	0.0153	<u>0.0602</u>	0.4633	0.0093	0.0358	0.659**
X ₆	0.0071	0.0016	0.0632	0.0145	0.0597	<u>0.4674</u>	0.0028	0.0226	0.639**
X ₇	0.0096	0.0067	0.0440	-0.0052	0.0009	0.0022	<u>0.5947</u>	-0.0590	0.594*
X ₈	0.0101	0.0024	-0.0230	-0.0149	0.0067	0.0328	-0.1088	<u>0.3225</u>	0.2301

RESIDUAL = 0.1285

NOTE : The diagonal values (underlined) show the direct effects and the off-diagonal values indicate the indirect effects.

Y(r) : Correlation coefficient values of each parameter with nut yield.

* Significant at 5% level

** Significant at 1% level

X₁ = Height of tree

X₂ = Canopy spread

X₃ = Number of leaves per shoot

X₄ = Leaf area

X₅ = Number of laterals/m² canopy area

X₆ = Number of flowering laterals/m² canopy area

X₇ = Number of nuts per panicle

X₈ = Nut weight

TABLE 15. DIRECT EFFECTS, INDIRECT EFFECTS AND CORRELATION COEFFICIENTS OF DIFFERENT CHARACTERS ON YIELD (FOR 5 YEARS.) OLD HYBRIDS)

	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	Y(r)
X ₁	<u>-0.1155</u>	-0.0508	-0.0030	0.1355	0.1909	-0.0984	0.0333	0.0240	0.122
X ₂	-0.0802	<u>-0.0731</u>	0.0039	0.0100	0.4484	-0.2482	0.0740	-0.0054	0.129
X ₃	0.0058	0.0046	<u>-0.0610</u>	0.0822	-0.4380	0.2073	0.2455	-0.0375	0.009
X ₄	-0.0617	-0.0029	-0.0198	<u>0.2538</u>	-0.4061	0.2214	0.0754	-0.0061	0.054
X ₅	-0.0152	-0.0226	0.0184	-0.0710	<u>1.4523</u>	-0.7958	0.1951	-0.0234	0.738**
X ₆	-0.0142	-0.0227	0.0158	-0.0702	1.4435	<u>-0.8007</u>	0.2484	-0.0317	0.768**
X ₇	-0.0055	-0.0078	-0.0215	0.0274	0.4062	-0.2852	<u>0.6976</u>	-0.1684	0.643*
X ₈	-0.0060	0.0009	0.0049	-0.0033	-0.0734	0.0547	-0.2532	<u>0.4640</u>	0.189

RESIDUAL = 0.0180

NOTE : The diagonal values (underlined) show the direct effects and the off-diagonal values indicate the indirect effects.

Y(r) : Correlation coefficient values of each parameter with nut yield.

* Significant at 5% level

** Significant at 1% level

X₁ = Height of tree

X₂ = Canopy spread

X₃ = Number of leaves per shoot

X₄ = Leaf area

X₅ = Number of laterals/m² canopy area

X₆ = Number of flowering laterals/m² canopy area

X₇ = Number of nuts per panicle

X₈ = Nut weight

Number of leaves per shoot also exhibited a positive direct effect on yield (0.1479) with a positive indirect effect on yield through number of flowering lateral/m² (0.1996) and number of nuts per panicle (0.1768).

Even though leaf area projected a negative direct effect on yield (-0.0378) it had a positive indirect effect on yield mainly through nut weight (0.1272).

the study also revealed that the number of lateral/m² had a positive direct effect on yield (0.0602) and its highest positive indirect effect on yield was mainly through number of flowering laterals per m² canopy area (0.4633) while the number of flowering lateral/m² canopy area showed a positive direct effect (0.4674) on yield and positive indirect effect mainly through number of leaves per twig (0.0632) followed by number of laterals per m² (0.0597).

Number of nuts per panicle with maximum positive direct effect on yield (0.5947) exhibited a positive indirect effect mainly through number of leaves per shoot (0.0440) and nut weight with a positive direct effect on yield (0.3225) showed a positive indirect effect mainly through number of flowering lateral per m²(0.0328).

The path coefficient analysis for the 5 years old hybrid population was presented in table 15 with a residual value of 0.0180.

Among the 8 characters studied for this age group number of lateral/m² showed a maximum positive direct effect on yield (1.4523), followed by number of nuts per panicle (0.6976) and nut weight (0.4640). Negative direct

effect on yield was exhibited by plant height (-0.1155), canopy spread (-0.0731), number of leaves per shoot (-0.0610) and number of flowering lateral/m² (-0.8007). The study also revealed that even though plant height and canopy spread exhibited negative direct effect on yield, their positive indirect effect was mainly through number of lateral/m² (0.1909 and 0.4484 respectively). Similarly number of leaves per shoot with a negative direct effect on yield exhibited a positive indirect effect mainly through number of nuts/panicle (0.2455) and number of flowering lateral/m² (0.2073).

Leaf area showed a positive direct effect (0.2538) on yield with a positive indirect effect mainly through number of flowering lateral/m² canopy area (0.2214).

Number of lateral/m² canopy area which showed maximum positive direct effect (1.4523) on yield in the 5 years old hybrid population, also contributed towards yield with a positive indirect effect mainly through number of nuts/panicle (0.1951). While number of flowering laterals which exhibited a negative direct effect (-0.8007) on yield sowed a high positive indirect effect through number of lateral/m² canopy area (1.4435).

The study also revealed that number of nuts per panicle with a positive direct effect of 0.6976 on yield exhibited a positive indirect effect on yield mainly through number of lateral/m² canopy area (0.4062) and nut weight contributed directly with a positive value (0.4640) on yield and indirectly with a positive value mainly through number of flowering laterals/m²(0.0547).

4.4. ESTIMATION OF HETEROSIS

Developing hybrid varieties exhibiting heterosis for important economic characters and their popularization among farmers will make considerable headway in enhancing the productivity of cashew to a satisfactory level (Manoj and George, 1993). In the current study magnitude of heterosis was calculated for nut yield per tree, individual nut weight, number of flowering laterals per m², number of nuts per panicle and shelling % in certain better performing F1 hybrids. Relative heterosis, heterobeltiosis and standard heterosis were worked out and presented in table 16 to table 21.

4.4.1. Number of Flowering Laterals per m² Canopy Area

With respect to number of flowering laterals/m², it was evident from table 16 that among the 3 years old hybrids, B'₃₄ exhibited heterosis over its mid parent value, over the better parent value and over the standard variety i.e. Bhubaneswar-1, with values of 57.69%, 53.70% and 61.89% respectively. Among the 5 years old hybrids highest relative heterosis and standard heterosis was achieved by A₆ with values of 12.10% and 32.51% respectively. Next to A₆, A₁₀ showed a relative heterosis of 11.67% and a standard heterosis of 32.0% so far as number of flowering laterals per m² is concerned. Only one hybrid of 3 years old i.e. B'₃₄ and 4 hybrids of 5 years old i.e. A₄, A₆, A₉ and A₁₀ could show standard heterosis in this aspect over the standard variety Bhubaneswar-1.

4.4.2. Number of Nuts per Panicle

So far as number of nuts per panicle is concerned, it is clear from table 17 that, highest relative heterosis value was projected by A₉ (52.24%)

TABLE 16. HETEROSIS FOR NUMBER OF FLOWRING LATERALS/m²

SL. NO.	HYBRID	NUMBER OF FLOWERING LATERALS PER m ²					RELATIVE HETEROSIS (%)	HETEROBEL-TIOSIS (%)	STANDARD HETEROSIS (%)
		HYBRID	PARENT-1	PARENT-2	MID PARENT	STANDARD VARIETY			
3 YEARS OLD									
1	B' ₄	18.24	19.50	20.54	20.02	19.50	-	-	-
2	B' ₃₁	19.25	19.50	20.54	20.02	19.50	-	-	-
3	B' ₃₄	31.57	19.50	20.54	20.02	19.50	57.69	53.70	61.89
4	C' ₁₃	19.00	19.50	22.00	20.75	19.50	-	-	-
5 YEARS OLD									
5	A ₄	23.68	19.50	26.60	23.05	19.50	2.73	-	21.43
6	A ₆	25.84	19.50	26.60	23.05	19.50	12.10	-	32.51
7	A ₉	25.12	19.50	26.60	23.05	19.50	8.98	-	28.82
8	A ₁₀	25.74	19.50	26.60	23.05	19.50	11.67	-	32.00
9	D ₄	16.38	19.50	20.54	20.02	19.50	-	-	-
10	D ₆	16.28	19.50	20.54	20.02	19.50	-	-	-
11	D ₇	17.48	19.50	20.54	20.02	19.50	-	-	-

TABLE 17. HETEROSIS FOR NUMBER OF NUTS PER PANICLE

SL. NO.	HYBRID	NUMBER OF NUTS PER PANICLE					RELATIVE HETEROSIS (%)	HETEROBELTIOSIS (%)	STANDARD HETEROSIS (%)
		HYBRID	PARENT-1	PARENT-2	MID PARENT	STANDARD VARIETY			
3 YEARS OLD									
1	B' ₄	3.10	5.20	1.50	3.35	5.20	-	-	-
2	B' ₃₁	3.20	5.20	1.50	3.35	5.20	-	-	-
3	B' ₃₄	2.50	5.20	1.50	3.35	5.20	-	-	-
4	C' ₁₃	4.20	5.20	3.30	4.25	5.20	-	-	-
5 YEARS OLD									
5	A ₄	3.40	5.20	1.50	3.35	5.20	1.49	-	-
6	A ₆	3.10	5.20	1.50	3.35	5.20	-	-	-
7	A ₉	5.10	5.20	1.50	3.35	5.20	52.24	-	-
8	A ₁₀	3.50	5.20	1.50	3.35	5.20	4.48	-	-
9	D ₄	4.80	5.20	1.50	3.35	5.20	43.28	-	-
10	D ₆	3.50	5.20	1.50	3.35	5.20	4.48	-	-
11	D ₇	3.40	5.20	1.50	3.35	5.20	1.49	-	-

followed by D₄ (43.28%) where both of these hybrids belong to 5 years old hybrid population. None of the 3 years old hybrids can shows heterosis for number of nuts/panicle.

4.4.3. Nut Weight

Table 18 indicated that among the 3 years old hybrids in case of individual nut weight C'₁₃ showed maximum relative heterosis of (16.31%) followed by B'₃₁ (13.64%) where as maximum standard heterosis was obtained in case of B'₃₁ (95.65%) followed by B'₄ (91.30%). Similarly in case of population of 5 years old hybrids highest relative heterosis (29.41%) and highest standard-heterosis (186.96%) were projected by A₁₀ followed by D₆ and D₇. In case of hybrids D₆ and D₇ same relative heterosis (21.72%) and same standard heterosis (109.56%) was recorded. All the 11 selected hybrids showed standard heterosis in this aspect.

4.4.4. Nut Yield

It was revealed from table 19 that for the character of nut yield per plant in the 3 years old hybrid population B'₃₄ showed highest relative heterosis (257.89%), highest heterobeltiosis and highest standard heterosis (142.86% each). Next to this hybrid B'₃₁ showed a relative heterosis of 189.47%. In C'₁₃ standard heterosis value was recorded 125.0% with the least relative heterosis value (7.69%) where as in case of 5 years old hybrid population for the same character A₁₀ hybrid showed highest relative heterosis (102.78%), highest heterobeltiosis (30.36%) and highest standard heterosis (30.36%) followed by A₄ with a relative heterosis of 80.55%, heterobeltiosis of 16.07% and standard heterosis of 16.07%. It is interesting

TABLE 18. HETEROSIS FOR INDIVIDUAL NUT WEIGHT

SL. NO.	HYBRID	INDIVIDUAL NUT WEIGHT (g)					RELATIVE HETEROSIS (%)	HETEROBELTIOSIS (%)	STANDARD HETEROSIS (%)
		HYBRID	PARENT-1	PARENT-2	MID PARENT	STANDARD VARIETY			
3 YEARS OLD									
1	B ₄ '	3.10	4.60	11.24	7.92	4.60	11.11	-	91.30
2	B ₃₁ '	3.20	4.60	11.24	7.92	4.60	13.64	-	95.65
3	B ₃₄ '	2.50	4.60	11.24	7.92	4.60	2.27	-	76.08
4	C ₁₃ '	4.20	4.60	8.64	6.62	4.60	16.31	-	67.39
5 YEARS OLD									
5	A ₄	9.10	4.60	15.80	10.20	4.60	-	-	97.83
6	A ₆	8.50	4.60	15.80	10.20	4.60	-	-	84.78
7	A ₉	4.94	4.60	15.80	10.20	4.60	-	-	7.39
8	A ₁₀	13.20	4.60	15.80	10.20	4.60	29.41	-	186.96
9	D ₄	8.30	4.60	11.24	7.92	4.60	4.79	-	80.43
10	D ₆	9.64	4.60	11.24	7.92	4.60	21.72	-	109.56
11	D ₇	9.64	4.60	11.24	7.92	4.60	21.72	-	109.56

TABLE 19. HETEROSIS FOR NUT YIELD

SL. NO.	HYBRID	NUT YIELD (kg/tree)					RELATIVE HETEROSIS (%)	HETEROBEL-TIOSIS (%)	STANDARD HETEROSIS (%)
		HYBRID	PARENT-1	PARENT-2	MID PARENT	STANDARD VARIETY			
3 YEARS OLD									
1	B ₄ '	0.40	0.28	0.10	0.19	0.28	110.53	42.86	42.86
2	B ₃₁ '	0.55	0.28	0.10	0.19	0.28	189.47	96.43	96.43
3	B ₃₄ '	0.68	0.28	0.10	0.19	0.28	257.89	142.86	142.86
4	C ₁₃ '	0.63	0.28	0.89	0.59	0.28	7.69	-	125.00
5 YEARS OLD									
5	A ₄	0.65	0.56	0.16	0.36	0.56	80.55	16.07	16.07
6	A ₆	0.62	0.56	0.16	0.36	0.56	72.22	10.71	10.71
7	A ₉	0.58	0.56	0.16	0.36	0.56	61.11	3.57	3.57
8	A ₁₀	0.73	0.56	0.16	0.36	0.56	102.78	30.36	30.36
9	D ₄	0.60	0.56	0.19	0.38	0.56	60.00	7.14	7.14
10	D ₆	0.38	0.56	0.19	0.38	0.56	1.33	-	-
11	D ₇	0.40	0.56	0.19	0.38	0.56	6.67	-	-

TABLE 20. HETEROSIS FOR SHELLING PERCENTAGE

SL. NO.	HYBRID	SHELLING PERCENTAGE (%)					RELATIVE HETEROSIS (%)	HETEROBEL-TIOSIS (%)	STANDARD HETEROSIS (%)
		HYBRID	PARENT-1	PARENT-2	MID PARENT	STANDARD VARIETY			
3 YEARS OLD									
1	B' ₄	24.54	32.6	28.47	30.53	32.6	-	-	-
2	B' ₃₁	30.66	32.6	28.47	30.53	32.6	0.43	-	-
3	B' ₃₄	28.39	32.6	28.47	30.53	32.6	-	-	-
4	C' ₁₃	32.46	32.6	25.27	28.93	32.6	12.20	-	-
5 YEARS OLD									
5	A ₄	31.9	32.6	22.78	27.69	32.6	15.20	-	-
6	A ₆	32.47	32.6	22.78	27.69	32.6	17.26	-	-
7	A ₉	32.61	32.6	22.78	27.69	32.6	17.77	0.03	0.03
8	A ₁₀	33.0	32.6	22.78	27.69	32.6	19.18	1.23	1.23
9	D ₄	32.53	32.6	28.47	30.53	32.6	6.55	-	-
10	D ₆	29.05	32.6	28.47	30.53	32.6	-	-	-
11	D ₇	28.0	32.6	28.47	30.53	32.6	-	-	-

to note that, with respect to the character nut yield, out of 11 selected hybrids 8 hybrids showed heterobeltiosis except D₆, D₄ and C'₁₃ and 9 hybrids showed standard heterosis except the hybrids D₆ and D₇.

4.4.5. Shelling Percentage

Going through the table 20, it was observed that among the 3 years old hybrids only 2 hybrids could show relative heterosis for shelling % and among these two hybrids, highest value was projected by C'₁₃ (12.20%) followed by B'₃₁ (0.43%). In 5 years old hybrid population only 2 hybrids, A₉ and A₁₀ showed heterobeltiosis as well as standard heterosis. In these 2 hybrids maximum relative heterosis, heterobeltiosis and standard heterosis have been observed in A₁₀(19.18%, 1.23%, & 1.23% respectively) followed by A₉(17.77%, 0.03%, and 0.03% respectively).

EXPORT GRADE OF SUPERIOR HYBRIDS

Out of the 8 export grades in terms of the number of whole kernels per pound W 180 grade ranks the best grade followed by W 210, W 240, W 280, W 320, W 400, W 450 and W 500, fixed as per the international standard. The export grades of whole kernels per pound of all the selected hybrids have been worked out and presented in Table 21. It is observed from the table that, 10 out of 11 selected hybrids of both the age group possess the highest export grade kernel (W 180) except A₉ (W 280).

In most of these hybrids, highest export grade of W 180 was observed because of the contribution of the character "More kernel weight" by the male parents having the higher nut weight as well as kernel weight taken all through this experiment.

Table 21. Export Grade of Superior Hybrids

Hybrids	Kernel weight (g)	Number of whole kernels per pound	Export grade
3 years old			
B'₄	2.56	177.34	W 180
B'₃₁	2.76	164.49	W 180
B'₃₄	2.30	197.39	W 180
B'₁₃	2.50	181.60	W 180
5 years old			
A₄	2.90	156.55	W 180
A₆	2.76	164.49	W 180
A₉	1.61	281.98	W 280
A₁₀	2.56	177.34	W 180
D₄	2.70	168.15	W 180
D₆	2.80	162.14	W 180
D₇	2.70	168.15	W 180

Besides all these quantitative characters some other characters were observed visually, those were presented in table 22.

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TABLE 22. VISUAL CHARACTERISATION OF PARENTS AND F₁- HYBRIDS

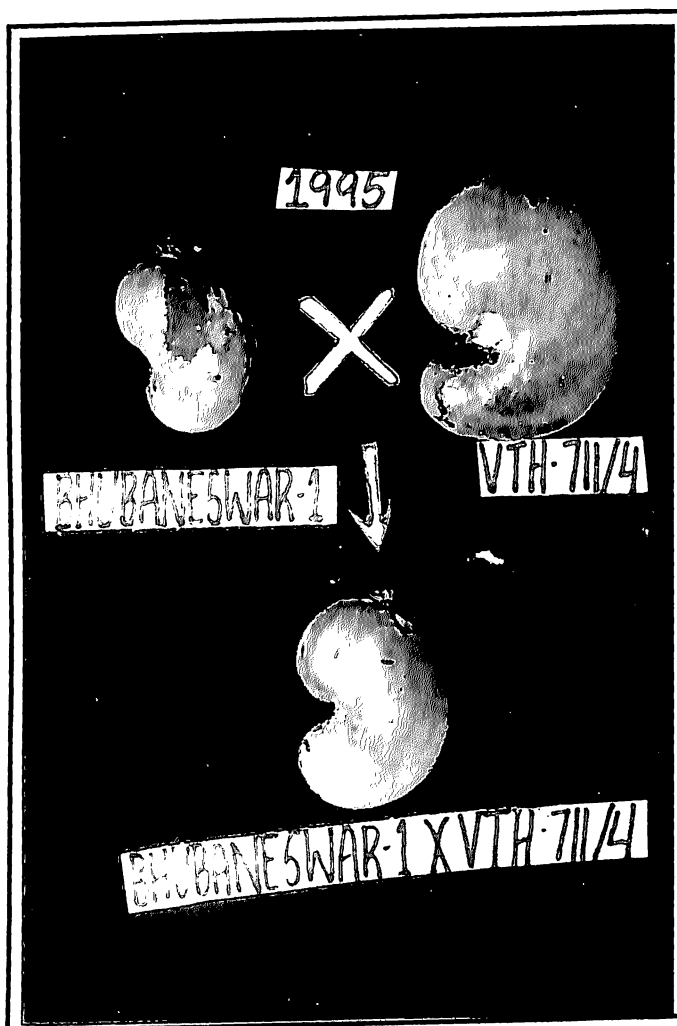
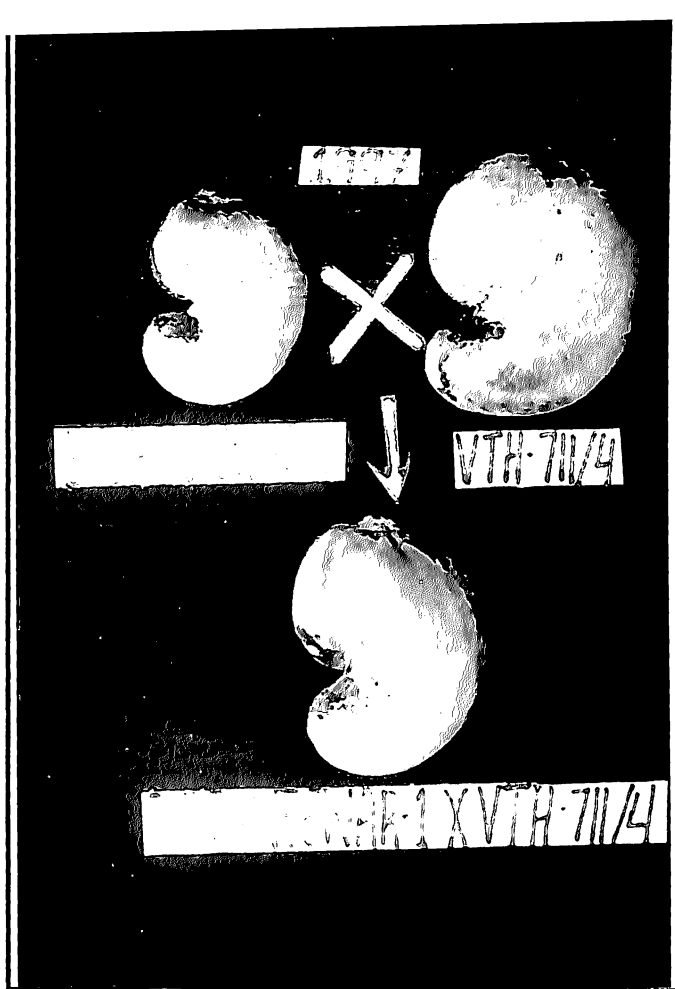
PARENTS / HYBRIDS	1	2	3	4	5	6	7	8	9	10	11	12
PARENTS												
BBSR-1	YR	TL	CL	L	YR	CO	T	OF	RD	RD	RD	IL
BBSR-C	GY	TL	CL	C	YR	CO	I	OF	ANG	BD	RD	IF
KANKADI	GY	TL	OV	L	Y	CY	L	OF	ANG	FL	I	IL
VTH - 711/4	GY	TL	OV	L	Y	P	I	OF	ANG	FL	I	IF
H-2/16	YR	TL	CL	L	Y	CO	L	RD	ANG	BD	RD	IF
H-2/15	YR	TL	OV	C	Y	CO	L	OF	ANG	BD	RD	IF
3 YEARS OLD H YBRIDS												
A ₃₅	YR	TL	CL	L	YR	CO	L	RD	ANG	RD	I	IF
B ₄	GY	TL	CL	L	Y	CO	I	OF	ANG	RD	RD	IL
B ₇	GY	TL	CL	L	Y	CO	L	OF	ANG	RD	RD	IL
B ₉	R	TL	CL	L	Y	CO	L	OF	ANG	RD	I	IL
B ₁₁	GY	TL	OV	L	YR	CO	L	OF	RD	RD	I	IF
B ₁₄	GY	TL	CL	L	Y	CO	I	OF	ANG	RD	RD	IF
B ₁₅	YR	TL	OV	L	YR	CO	I	OF	ANG	RD	RD	BH
B ₁₈	YR	TL	CL	L	YR	CO	I	OF	RD	RD	RD	IL
B ₂₃	GY	TL	OV	L	YR	CO	I	OF	ANG	RD	I	IF
B ₂₅	GY	TL	OV	L	YR	CO	I	OF	ANG	RD	I	IF
B ₃₀	GY	TL	CL	L	YR	CO	I	OF	ANG	RD	I	IF
B ₃₁	GY	TL	CL	L	Y	CO	I	OF	ANG	RD	I	IF
B ₃₄	GY	TL	OV	L	Y	CY	L	OF	ANG	FL	I	IL
C ₂	YR	TL	OV	C	Y	P	T	OF	RD	RD	RD	IF
C ₃	YR	TL	OV	C	Y	CO	I	RD	RD	RD	RD	IF
C ₁₃	GY	TL	OV	C	YR	CO	L	OF	RD	BD	RD	IF
C ₁₇	GY	TL	CL	C	Y	CO	I	OF	RD	RD	RD	IF
5 YEARS OLD HYBRIDS												
A ₃	GY	TL	CL	L	Y	CY	I	OF	ANG	RD	I	IF
A ₄	YR	TL	CL	L	Y	CO	L	OF	ANG	RD	I	IF
A ₆	YR	TL	CL	L	Y	CO	I	OF	ANG	RD	RD	IF
A ₉	YR	TL	CL	L	Y	CO	I	OF	ANG	RD	RD	IF
A ₁₀	YR	ML	CL	L	Y	CO	I	OF	ANG	RD	RD	IF
C ₁₁	YR	TL	OV	C	YR	CY	I	OF	RD	BD	I	IF
E ₃	YR	TL	OV	L	R	CY	I	RD	ANG	RD	I	IL
D ₄	PR	TL	CL	L	R	CO	L	OF	ANG	RD	I	IF
D ₆	R	TL	CL	L	YR	CO	L	OF	ANG	RD	I	IF
D ₇	GY	TL	OV	L	YR	CY	L	OF	ANG	RD	I	IL
D ₈	GY	TL	OV	L	YR	CY	I	OF	ANG	FL	I	IF
D ₁₀	GY	TL	CL	L	YR	CO	I	OF	ANG	RD	I	IF
D ₁₁	GY	TL	CL	L	R	CO	I	OF	ANG	RD	I	IF

1. Colour of young leaf - Red (R) / Yellow Red (YR) /Green yellow (GY)/ Purple (PR)
2. Odour of young leaf - Mango like (ML)/ Terpentine like (TL)
3. Leaf shape - Oblong (OB)/ Club shape(CL)/ oval (OV)
4. Inflorescence compactness - Loose (L)/ compact (C)
5. Colour of matured apple - Red (R)/ Yellow (Y)/ Yellow red (YR)/ Red purple (RP)
6. Apple shape - Cylindrical (CY)/Conical Obovate(CO)/ Round (RD)/ Pyriform (P)
7. Attachment of nut to apple - Loose (L)/ Intermediate (I) / Tight (T)
8. Shape of nut base - Round (RD)/ Flattened (FL)/ Obliquely flattened (OF)
9. Suture of nut - Round (RD)/Angular (ANG)
10. Flank of nut - Flattened (FL)/ Round (RD)/ Buldging (BD)
11. Shape of nut apex - Round (RD)/Intermediate (I)/ Pointed (PT)
12. Relative position of suture to apex - Suture projection in front of apex (IF)/ inline with apex (IL)/ behind apex. (BH).



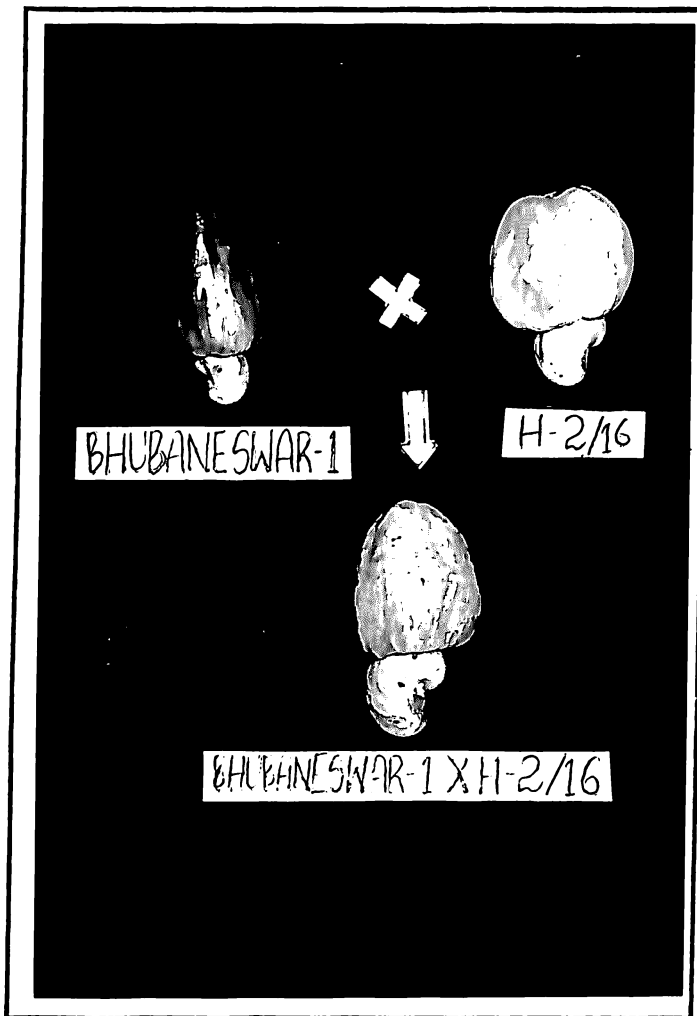
Plate-1 : Promising standard variety "Bhubaneswar-1" of the locality.

F₁ Hybrid
(B₄)

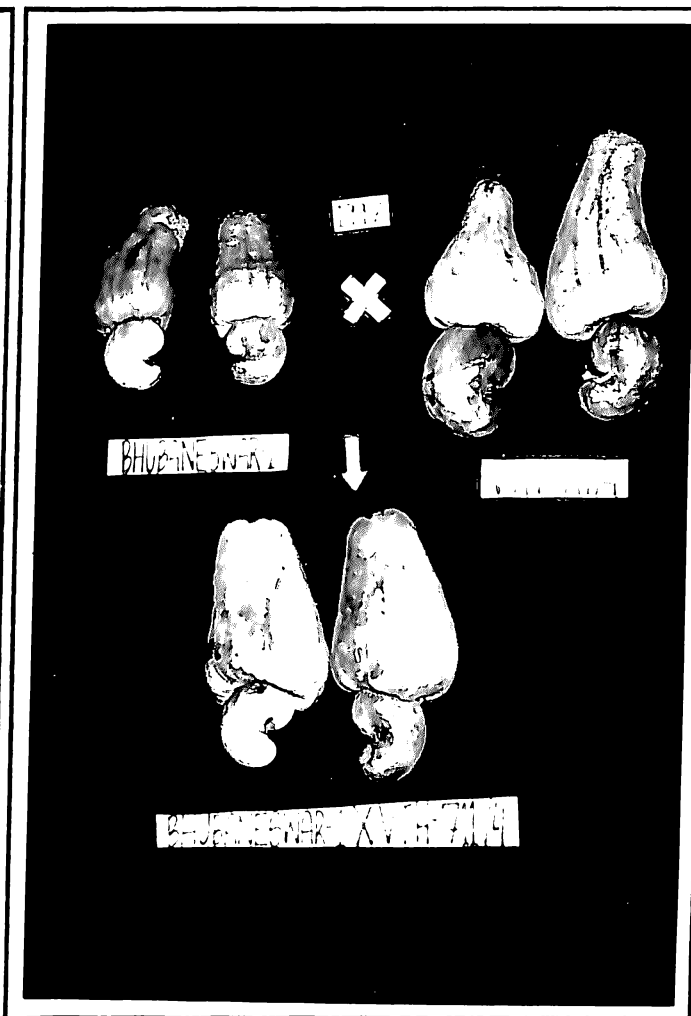


F₁ Hybrid
(D₄)

Plate-2 & 3 : F₁ Hybrid nuts of common parents Bhubaneswar-1 and VTH- 711/4 for both age groups.



F₁ Hybrid (A'₃₅)

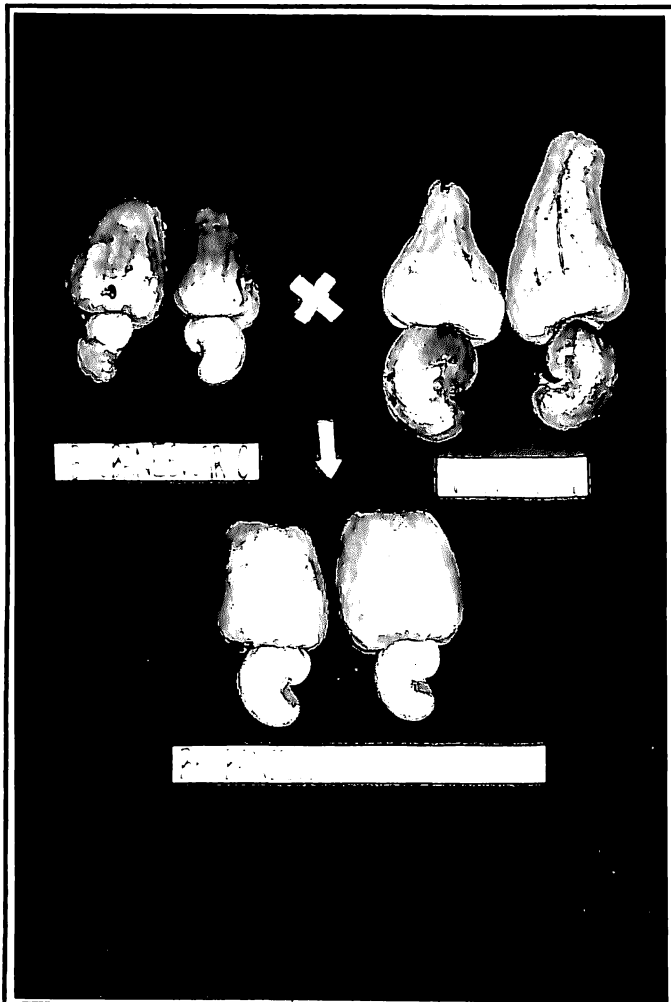
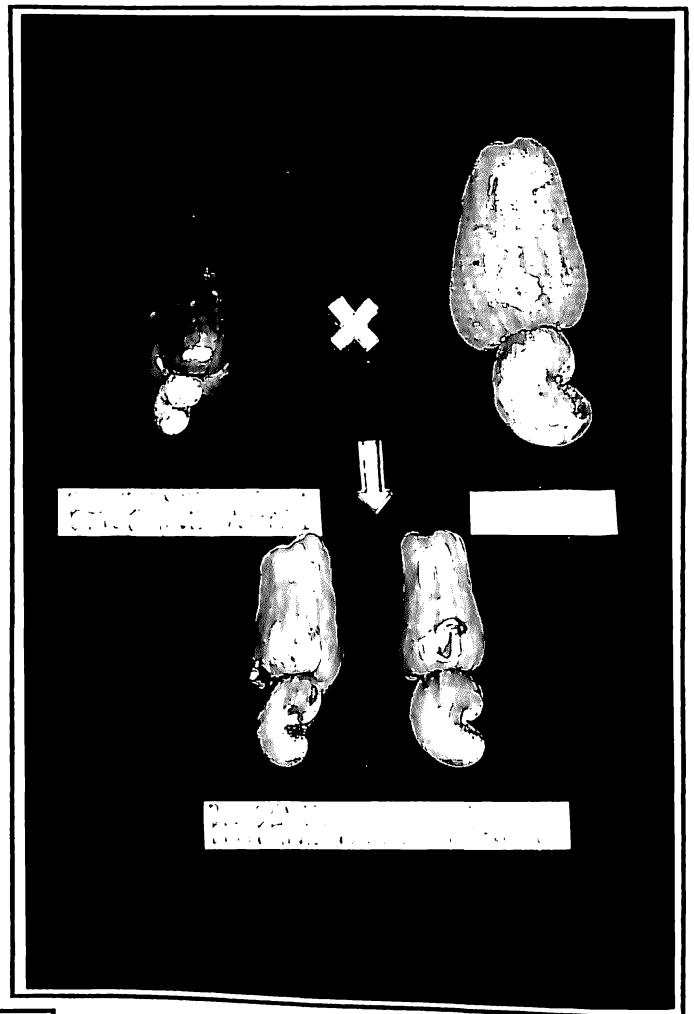


F₁ Hybrid (B'₃₁)



F₁ Hybrid (C'₁₃)

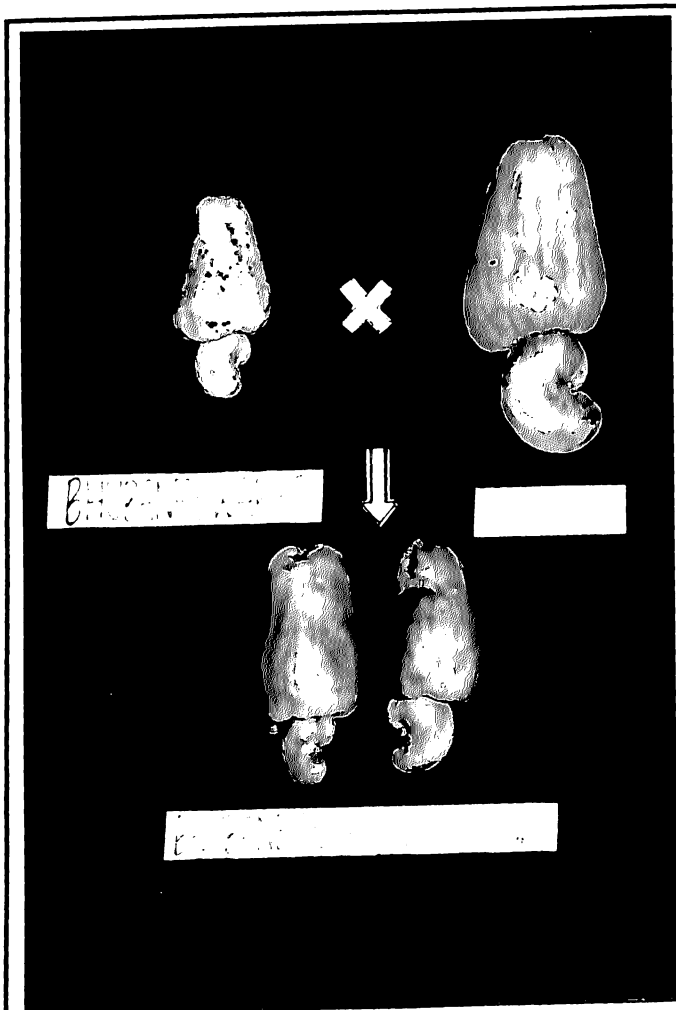
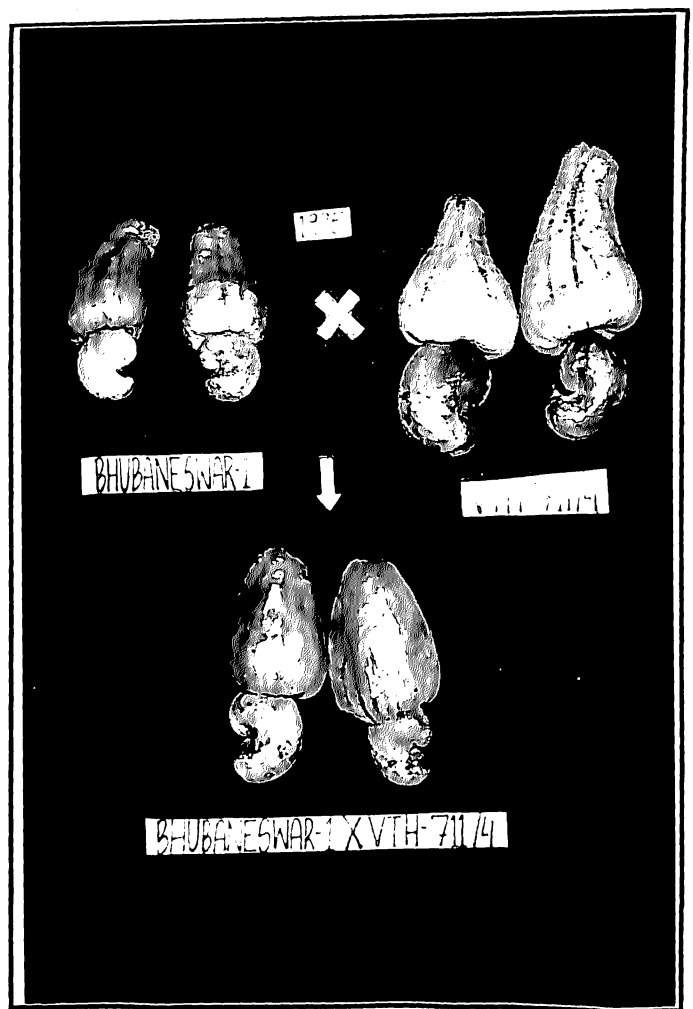
**F₁ Hybrid
(A₁₀)**



**F₁ Hybrid
(C₁₁)**

Plate-7 & 8 : Whole Fruits of different cross combinations and their respective F₁ Hybrids for five years age group.

F₁ Hybrid
(D₆)



F₁ Hybrid
(E₃)

Plate-9 & 10 : Whole Fruits of different cross combinations and their respective F₁ Hybrids for five years age group.

CHAPTER - 5

DISCUSSION

DISCUSSION

One of the obvious reasons for the low level of productivity of cashew is the fact that most of the existing cashew plantations have been raised from seedling progenies of non-descriptive, genetically inferior seed material. So, as suggested by Devi (1981) and Nawale *et al.* (1990) potentiality of crop improvement through breeding programme are now well recognised by the research workers in this field. Developing genotypes with increased production potentiality without sacrificing the desirable horticultural attributes is the challenge faced by the breeder. A planned programme of hybridization between selected types possessing one or more of the desirable characters and a comprehensive evaluation of F1 hybrids will result in the identification of superior hybrids. As cashew can be successfully propagated by vegetative methods, the superior genotypes thus developed can easily be multiplied and maintained.

Information on variability of quantitative characters and on the association among yield and its component characters are of vital importance in any plant breeding program. This is more so in a crop like cashew where a higher variability can be used to improve the genetic potential.

The present investigation was basically envisaged to determine the extent of variability and degree of association of quantitative characters. The results obtained are discussed in the ensuing pages.

5.1 VARIABILITY

In spite of lower age, a good extent of variability in terms of range and coefficient of variation exist in the hybrid population of both the age groups discussed in the experiment.

5.1.1 Growth Parameters

Among the 3 years old hybrids maximum extent of variation was observed for extension growth of twig (24.24cm) followed by number of leaves per twig (20.26), canopy spread (19.91m) and number of laterals per m² (19.63), where as in the population of 5 years old hybrids maximum variation was also observed in extension growth of twig (32.27cm) followed by girth of tree (24.66cm) and leaf area (20.15m²). Falade (1981) also reported the presence of high variability for tree size in cashew.

Hybrids showed a higher degree of variability than parents in case of leaf area and number of laterals per m². This finding shows that, the spectrum of variability has been broadened as a result of hybridization in case of these two particular characters, which can be exploited in further study. But in all other growth parameters, though variability was there still hybridization could not result in enhanced variability indicating that the extent of variability available in the parental population was it self high.

5.1.2 Floral and Apple Traits

Among the floral traits maximum variation was observed in both the hybrid groups with respect to inflorescence size, i.e. 41.68 and 40.06 for 3 years old and 5 years old hybrids respectively.

In the aspect of number of flowering laterals per m² a higher variability as compared to parents was also observed by both the hybrid groups in 19.55 and 19.37 in 3 years old and 5 years old hybrid groups respectively. A similar finding was also reported by Krishnappa *et al.* (1991a) and Sena *et al.* (1995a). It is an encouraging finding as flowering laterals is an important yield attributing character.

In case of apple weight greater variability was observed in 3 year old hybrids (36.13) as well as 5 years old hybrids (26.62) than the parents (25.75) which corroborates the findings of Aravindakshan (1986) and Sena *et al.* (1994). In apple size 3 years old hybrids and 5 years old hybrids obtained coefficient of variability of 25.39 and 29.58 respectively which are higher than the parent (23.69).

5.1.3 Nut, Kernel and Yield Attributes

Both the hybrid groups showed a lower variability than parents with regard to most of the nut, kernel and other yield attributing characters (table 9). However, in the 3 years old hybrid population, maximum variation was observed in nut yield (48.82) followed by number of nuts/panicle (45.78), kernel dimension (38.42) and kernel weight (23.35) whereas in case of 5 years old hybrids maximum variation was observed in nut yield (34.55) followed by kernel dimension (27.92), number of nuts per panicle (26.26) and nut weight (24.66).

A higher variability in case of number of nuts per panicle was reported by Nalini and Santhakumari (1991). However, a wider variability in case of yield was reported by Aiyadurai and Koyamu (1957), Damodaran *et al.*

(1977), Falade (1981), Ramdas and Thatham (1982) and Nalini and Santhakumari (1991).

One of the significant finding is higher variability in shelling percentage (15.63) in 3 years old hybrids in comparison to parent group (13.83). Similar result for shelling percentage was obtained by Nalini and Santhakumari (1991).

5.2 CORRELATION AMONG CHARACTERS

A precise knowledge on the association which exists between yield and the possible component characters is very important and it helps in deciding the characters to be considered in selection programs. However, such studies carried out in cashew is an important foreign exchange earning crop', so far are only limited and consequently the information available is rather meager (Newale and Salvi, 1990).

In 3 years old hybrid population nut yield was found to possess highly significant and positive correlation with number of laterals per m² (0.659), number of flowering laterals per m² (0.639), number of nuts per panicle (0.594), number of leaves per shoot (0.513), kernel weight and apple size (0.456). The characters like extension growth of twig, shoot diameter, inflorescence size, apple weight, nut weight, shelling %, shell thickness, kernel dimension, canopy spread, plant height and plant girth had non significant and positive co-relation with yield. However, leaf area, nut dimension and duration of 50% flowering showed weak negative correlation (-0.101, -0.028 and -0.246 respectively) with yield.

In 5 years old hybrid population, nut yield maintained a highly significant positive correlation with number of flowering laterals/m² (0.768), number of laterals/m² (0.738), number of nuts per panicle (0.643) and shelling % (0.592) whereas characters like extension growth of twig, number of leaves per shot, leaf area, apple size, apple weight, nut dimension, nut weight, kernel weight, kernel dimension, canopy spread and plant height have weak positive correlation with yield.

However, a strong positive correlation between yield and canopy area was reported by Nayar *et al.* (1981) and Parameswaran *et al.* (1984a) whereas a highly significant correlation between yield and nuts per panicle was reported by Parameswaran *et al.* (1984a) between yield and % of flowering shoot per m². He also reported a positive correlation between yield and plant height which was not significant whereas Manoj *et al.* (1994b) reported this relationship to be significant in his own study.

A high positive correlation between yield and nut weight as well as apple weight was reported by Sena *et al.* (1994) and significant positive correlation was reported between yield and shelling % by Abdul Salam (1998). Manoj *et al.* (1994b) reported a positive correlation between yield and kernel weight, canopy spread, nuts per panicle and leaf area.

In the present study a negative correlation was observed between yield and duration of 50% flowering in hybrid populations of both the age group but Manoj *et al.* (1994b) reported a positive correlation between yield and duration of flowering.

In both the table of 3 years and 5 years age group hybrids, a negative association between duration of 50% flowering and yield was observed which may be due to the fact that, a lengthy flowering duration approaches hot summer at Bhubaneswar which ceases nut setting and nut retention and ultimately decreasing the yield (table 1).

5 years old hybrids showed a negative correlation between number of flowering laterals and inflorescence size while inflorescence size is negatively correlated with yield which ultimately confirms the positive correlation between number of flowering laterals and yield which had been observed highly significant in this study, which corroborates the findings of Parameswaran *et al.* (1984a). A negative correlation between inflorescence size and nuts per panicle indicated that an increase in yield in this case was due to an increase in number of nuts per panicle; Anitha *et al.* (1991) and Manoj *et al.* (1994b).

The important observations of this study for both the age group hybrids were the existence of positive correlation of each of the individual characters nut weight, shelling % and kernel weight with yield. Similar results have also been reported by Manoj *et al.* (1994b), Abdul salam (1998) and Sena *et al.* (1994). Besides this, in this experiment also there was a finding of strong positive association between individual nut weight and kernel weight. However, Ohler (1979) and Damodaran *et al.* (1979) recommended selection of trees producing medium sized nuts as they were reported to be more productive.

Hybrids of both age group showed a positive association of individual nut weight and kernel weight with the weight of apple which clearly indicates

that the development of apple in no way hampers the development of nut. The report of Damodaran *et al.* (1966) indicated that the enlargement of cashew apples takes place when the development of nut ceases and this result substantiates the above finding.

In this experiment there was a positive correlation of apple size as well as apple weight with nut yield, thus confirming the result of Sena *et al.* (1994).

Also there was an existence of a negative correlation between nut weight and nuts per panicle which clearly indicated the existence of competition among the nuts present in panicle for nutrients and assimilates. This confirmed the findings of Anitha *et al.* (1991). An important finding in this experiment was the existence of comparatively highly positive correlation between number of nuts per panicle and yield in case of 5 years old hybrids in comparison to that of 3 years old hybrids. This may be due to juvenility of the 3 years old hybrids for which the plants may not be able to express the characters fully.

A highly significant positive correlation of yield with number of laterals/m², number of flowering laterals/m² and number of nuts per panicle indicated the importance of these characters for direct selection. This result is in conformity with Parameswaran *et al.* (1994a) and Anitha *et al.* (1991) and Kumar *et al.* (1996). A significant positive correlation between yield and number of leaves per twig observed in both the age group of hybrids also and confirms the findings of Kumar *et al.* (1996).

A positive correlation was observed between mean canopy area and nut yield is of great importance since yield per tree is influenced by the shape of the canopy. Nayar *et al.* (1981), Parameswaran *et al.* (1984a) and Manoj *et al.* (1994b) also reported regarding the positive correlation between yield and canopy area conforming the present investigation. Cashew trees bear fruits at the periphery and fruit production becomes almost nil on branches of trees those intermingle with branches of neighbouring trees thus limiting the availability of sunlight. So higher yield can be expected from trees with higher canopy area at the same time having an intensive branching habit.

5.3. PATH COEFFICIENT ANALYSIS

The result of path coefficient analysis in case of 3 years old hybrids were presented in the table 14.

The result indicated that number of nuts per panicle showed the maximum positive direct effect on yield (0.5947) followed by number of flowering laterals/m² (0.4674) and nut weight (0.3225). These characters also showed high positive correlation with nut yield.

The high positive direct effect of number of nuts/panicle and number of flowering laterals/m² and their significant positive correlation (0.594 and 0.6389 respectively) with yield indicated that these two are important characters to be considered for selection of superior plants for nut yield. Nut weight also exhibited a high positive direct effect on yield.

The plant height showed a direct effect and positive indirect effect (0.0716 and 0.0797 respectively) and indirect contribution was through number of nuts per panicle, whereas leaf area with a negative direct effect

(-0.0378) contributed to yield indirectly mainly through nut weight. Number of laterals found to contribute to yield mainly with a positive indirect effect (0.4633) through number of flowering laterals/m².

The table 15 indicating path coefficient analysis in 5 years old hybrids revealed that maximum positive direct effect towards yield was contributed by number of laterals/m² (1.4523) followed by number of nuts per panicle (0.6976) and nut weight (0.4640). A positive direct effect of nuts per panicle on yield was also reported by Manoj *et al.* (1994). Plant height and number of leaves per shoot contributed indirectly to yield mainly through number of laterals/m² and number of nuts/panicle (0.1909, 0.2455 respectively) in spite of their negative direct effect on yield (-0.1155), -0.0610 respectively).

This table indicated a negative direct effect of canopy spread on yield, however, a positive direct effect in this character was reported by Manoj *et al.* (1994). Leaf area contributed directly (0.2538) to yield and indirectly mainly through number of flowering laterals/m² (0.2214). The number of laterals/m² showed positive direct effect (1.4523) and indirect effect through number of nuts/panicle (0.1951).

With an overall view on both the tables it was found that the characters like number of laterals/m², number of flowering laterals/m² and to some extent individual nut weight had higher contribution for nut yield either directly or indirectly. Therefore, these characters are to be considered as important causal factors for nut yield and due emphasis should be given on these characters while evaluating the hybrids.

5.4. HETEROSIS

The heterosis study was made on selected hybrids from both the hybrid populations, and results were described in table 16 to table 21.

5.4.1. Number of Flowering Laterals per meter square Canopy Area

In 5 years old population, with respect to the number of flowering laterals/m² A₄, A₆, A₉ and A₁₀ showed relative heterosis and standard heterosis and among 3 years old hybrids B'₃₄ showed relative heterosis, heterobeltiosis and standard heterosis which indicated the extent of success of hybridization in these hybrids. It is observed that the parents Bhubaneswar-1 and VTH-711/4 are heterotic to each other with respect to number of flowering laterals/m² which is manifested in their F₁ hybrid B'₃₄ (Heterobeltiosis 53.70%) in the 3 years old hybrid population.

5.4.2. Number of Nuts per Panicle

With regard to number of nuts per panicle none of the hybrids could exceed the standard variety Bhubaneswar-1 which is also the better parent in this aspect. However, a maximum, relative heterosis of 52.24% was achieved in the hybrid A₉ followed by D₄ (43.28%) of 5 years old hybrid plants. As it is an important character for enhancement of yield, further study should be carried out in this area. Overall, a positive heterosis was achieved by 5 hybrids i.e. A₉, A₁₀, D₄, D₆, and D₇ of 5 years old age group out of the 11 selected hybrids of both the age group. A positive heterosis for number of nuts/panicle was also recorded by Manivannan *et al.*(1989).

Fig. 2 : Comparison of the promising hybrids with their respective parents for number of flowering laterals/m² canopy area.

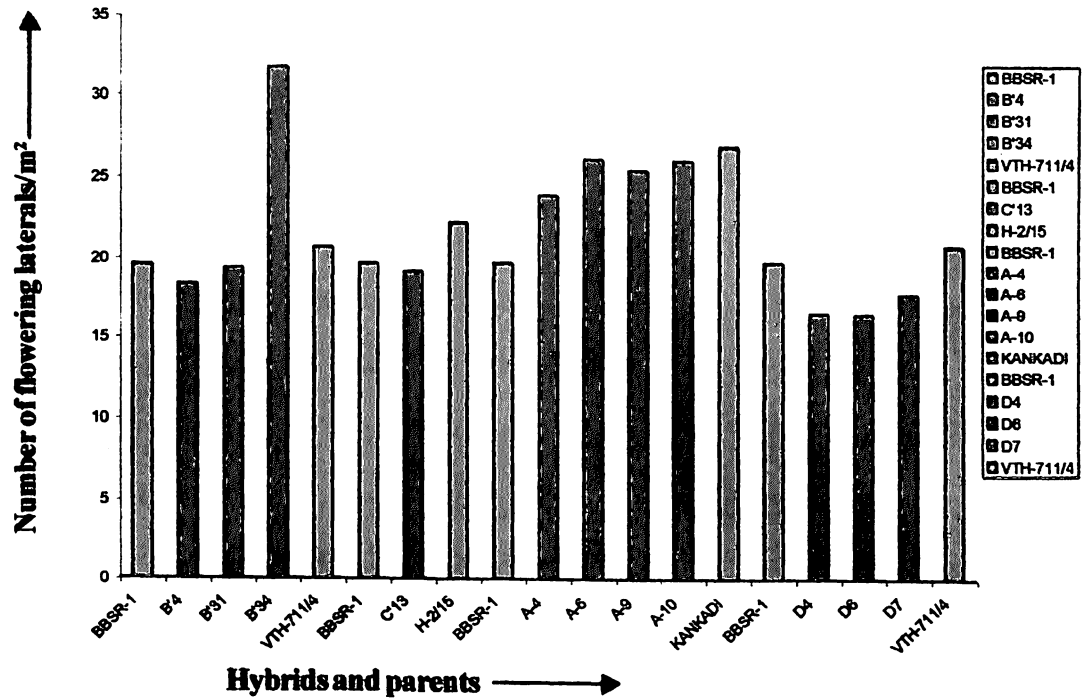
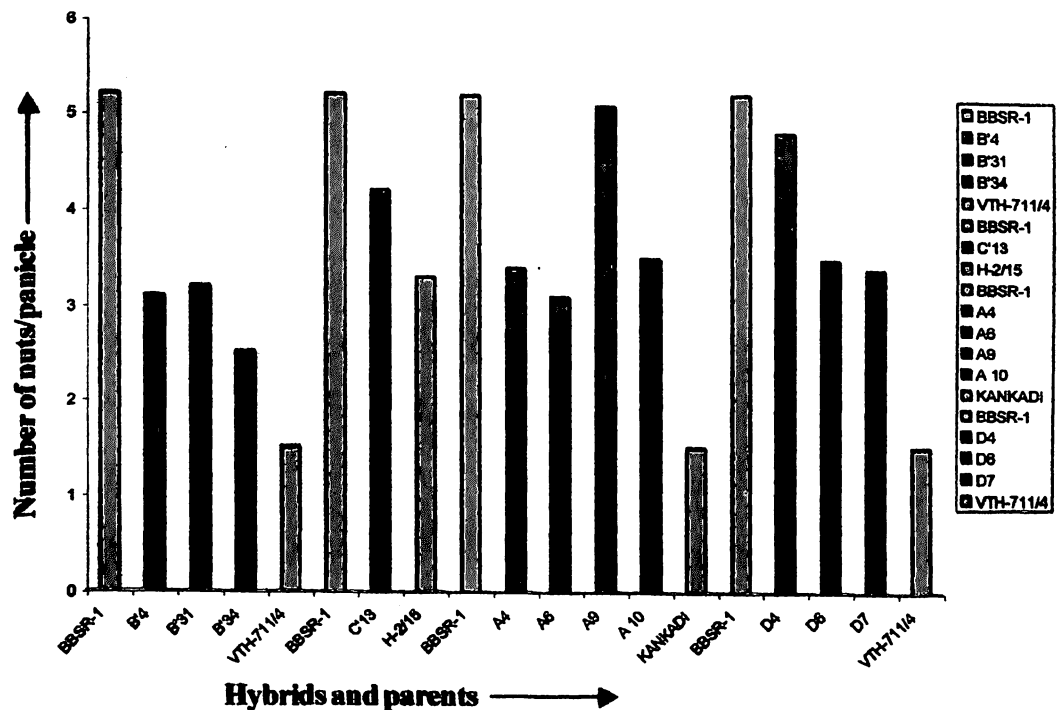


Fig.3 : Comparison of the promising hybrids with their respective parents for number of nuts/panicle



5.4.3. Nut Weight

All the selected hybrids showed standard heterosis in the aspect of individual nut weight, but none could exceed heterosis over better parent. With respect to this character the standard variety (Bhubaneswar -1) was inferior than the other parents. Therefore, relative heterosis is estimated basing on the mid parent value. Out of the 11 hybrids only 8 hybrids exhibited positive relative heterosis with regard to individual nut weight. Among the hybrids of 5 years old age group maximum relative heterosis was achieved by hybrid A₁₀ (29.41%) followed by D₆ and D₇ (21.27% each). Among the hybrids of 3 years old age group hybrid C'₁₃ exhibited maximum relative heterosis i.e. 16.31% followed by B'₃₁ (13.64%). This indicated that Bhubaneswar - 1 combined well with H-2/15, VTH 711/4 and Kankadi. However, relative heterosis, heterobeltiosis, and standard heterosis for nut weight was reported by Subramanian *et al.* (1994).

5.4.4. Nut Yield

With respect to nut yield (kg/tree), 8 out of the 11 selected hybrids showed heterobeltiosis and 9 hybrids showed standard heterosis. Even a standard heterosis of 142.86% could be achieved by B'₃₄, a 3 years old hybrid. It is interesting to note that, though the inheritance of one or more yield attributing characters was poor, but the hybrids were successful for affording a higher level of yield than their parents. Here one thing is worth mentioning that, the hybrids being the under aged trees, the yield value of parents were collected from their previous record when they were 3 years and 5 years old. So the yield value of 3 years old hybrids were compared with

TABLE 23 . CATAGORISATION OF HYBRIDS FOR IMPORTANT YIELD ATTRIBUTES

HYBRIDS	NUMBER OF FLOWERING LATERALS PER m ² CANOPY AREA Range =(16.280-31.571)			NUMBER OF NUTS PER PANICLE Range=(2.500-5.104)			NUT WEIGHT Range =(2.500-13.201)		
	LOW (16.280-21.377)	MEDIUM (21.377-26.474)	HIGH (26.474-31.571)	LOW (2.500-3.367)	MEDIUM (3.367-4.237)	HIGH (4.237-5.104)	LOW (2.500-6.067)	MEDIUM (6.067-9.634)	HIGH (9.634-13.201)
3 YEARS OLD									
B ₄	LOW (18.24)			LOW (3.1)			LOW (3.1)		
B ₃₁	LOW (19.25)			LOW (3.2)			LOW (3.2)		
B ₃₄			HIGH (31.57)	LOW (2.5)			LOW (2.5)		
C ₁₃	LOW (19.0)				MEDIUM (4.2)		LOW (4.2)		
5 YEARS OLD									
A ₄		MEDIUM (23.68)			MEDIUM (3.4)			MEDIUM (9.1)	
A ₆		MEDIUM (25.84)			MEDIUM (3.1)			MEDIUM (8.5)	
A ₉		MEDIUM (25.12)				HIGH (5.1)	LOW (4.94)		
A ₁₀		MEDIUM (25.74)			MEDIUM (3.5)				HIGH (13.2)
D ₄	LOW (16.38)					HIGH (4.8)		MEDIUM (8.3)	
D ₆	LOW (16.28)				MEDIUM (3.5)				HIGH (9.64)
D ₇	LOW (17.48)				MEDIUM (3.4)				HIGH (9.64)

NB : INCLUDED IN UPPER LIMIT, EXCLUDED IN LOWER LIMIT.

Fig.4 : Comparison of the promising hybrids with their respective parents for nut weight(g).

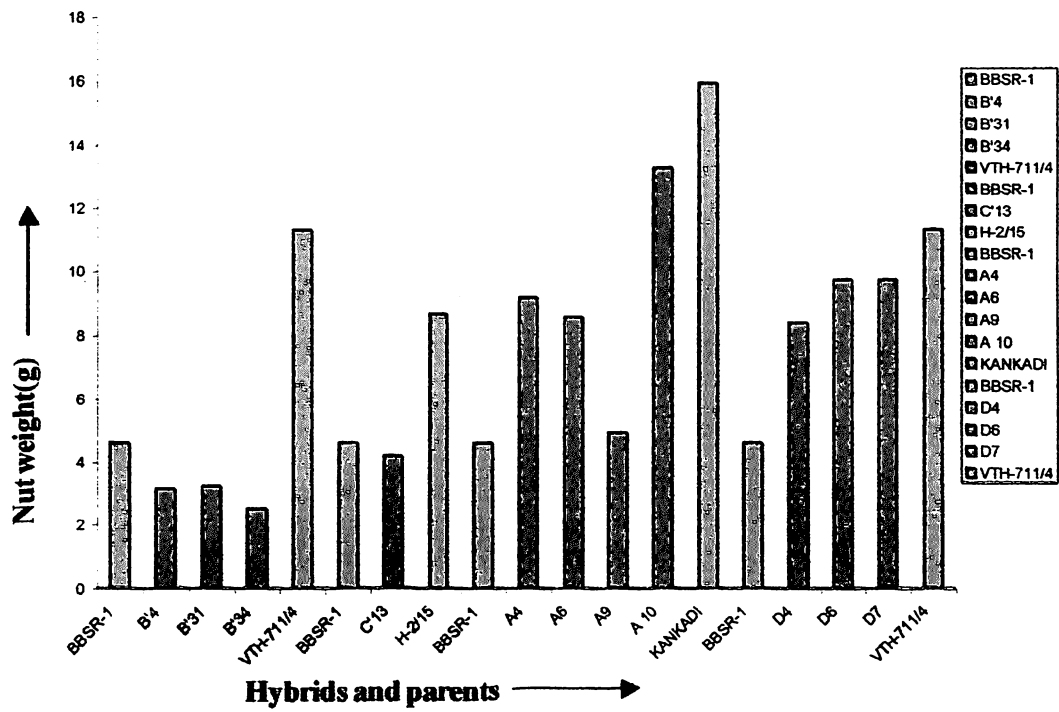
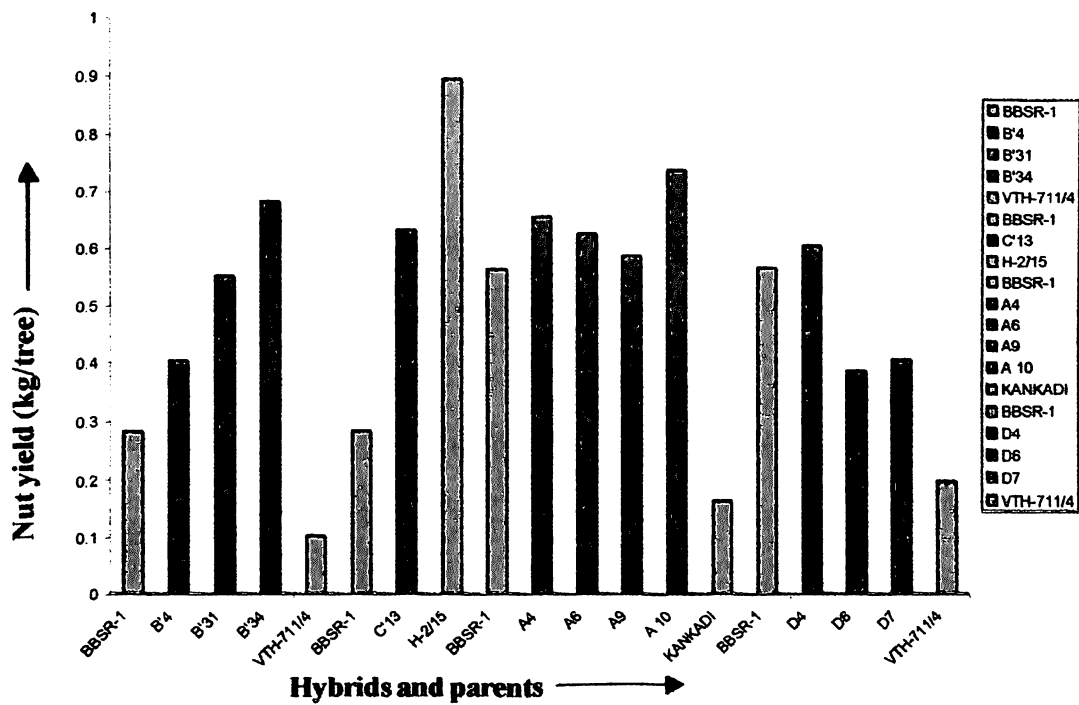


Fig.5 : Comparison of the promising hybrids with their respective parents for nut yield(kg/tree).

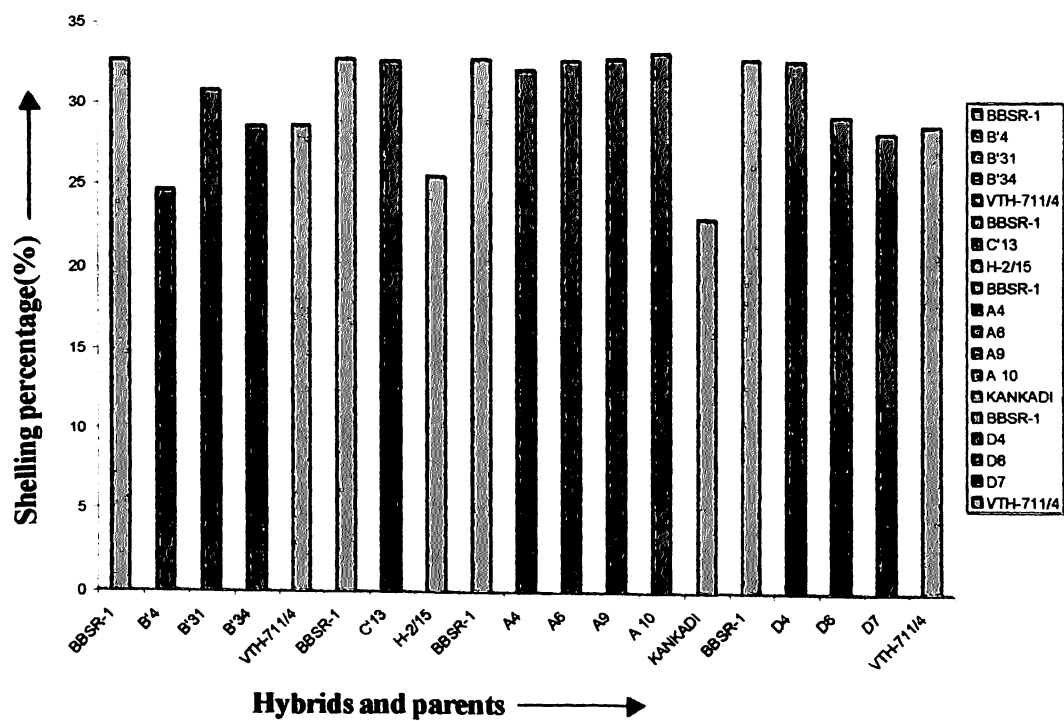


parent value of 3 years old plants and that of 5 years old hybrids were compared with their respective parent value of 5 years old plants. A positive heterosis on yield was also reported by Manivannan *et al.* (1989) and Subramanian *et al.* (1994).

The major objective of hybridization was to achieve higher quantum of nut yield/tree by the hybrids than their respective parents. In the 3 years old age group hybrids B'₃₄ could yield nuts as high as 0.68 kg/tree followed by C'₁₃ (0.63 kg/tree). the comparison study in table 23 showed that the higher yield in case of B'₃₄ may be attributed with higher number of flowering laterals/m² (31.57). In case of C'₁₃ the higher yield may be due to higher number of nuts/panicle (4.2).

In the 5 years old age group hybrids, highest nut yield was recorded by A₁₀ (0.73kg/tree) followed by A₉ (0.65kg/tree) and A₆ (0.62 kg/tree). Moderate number of flowering laterals/m² (25.74) moderate number of nuts per panicle (3.5) and high nut weight (13.2g) contributed to higher nut yield in hybrid A₁₀, where as in case of hybrids A₄ and A₆, moderate number of flowering laterals/m² (23.68 and 25.84 respectively), moderate number of nuts/panicle (3.4 and 3.1 respectively) and medium nut weigh (9.1 and 8.5g respectively) resulted in high yield. In case of hybrids D₆ and D₇ although nut weigh was high (9.64g each) and number of nuts per panicle (3.5 and 3.4 respectively) was medium those could not give high yield because of scary number of flowering laterals/m² (16.28 and 17.48 respectively) in the trees. so for identification of high yielding hybrids more emphasis should be given on number of flowering laterals/m² and number of nuts per panicle the individual nut weight of the tree.

Fig.5 : Comparison of the promising hybrids with their respective parents for shelling percentage(%)



5.4.5 Shelling Percentage

It is revealed from the study that, among the 11 selected hybrids relative heterosis, heterobeltiosis, standard heterosis and shelling percentage was maximum in A₁₀ (19.18%, 1.23% and 1.23% and 33% respectively) followed by A₉ (17.77% , 0.03%, 0.03% and 32.61% respectively). With regard to the shelling percentage of these two hybrids of 5 years age group A₁₀ and A₉ exceeded the shelling percentage value of the better parent Bhubaneswar-1 (32.6%) which is also the standard variety. Standard heterosis for shelling % was reported by Subramanian *et al.* (1994).

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CHAPTER - 6

SUMMARY

SUMMARY

The present study was carried out at the Ranasinghpur Cashew Research Station, Orissa University of Agriculture and Technology during 1999-2000, under agroclimatic conditions of Bhubanewar to determine the extent of variability, degree of association of quantitative characters and to evaluate F₁-hybrids of cashew for growth parameters, floral and apple traits as well as nut, kernel and yield attributes. The experimental material comprised of 17 F₁ hybrids of 3 years old, 13 F₁ hybrids of 5 years old and 6 parents of cashew plants belonging to 7 parental combinations grown in Cashew research Station, Ranasinghpur.

The hybrids and parents were observed for 11 vegetative characters, four floral characters, five apple characters and 14 nut, kernel and yield attributing characters. The salient findings of this study are listed below.

1. Variability studies of different growth parameters indicated that wide variability in terms of range, mean and coefficient of variation existed in parents and hybrids of both age groups. So far as hybrids performance is concerned, maximum variation was found in the extension growth of twig among the 5 years old hybrids (32.27) followed by girth of tree (24.66) and leaf area (20.14). But in case of 3 years old hybrid maximum variation was estimated for extension growth of twig (24.24) followed by number of leaves per twig (20.26) and canopy spread (19.91).

2. Among the different floral and apple traits 3 years old hybrids showed maximum variability for inflorescence size (41.68) followed by apple weight (36.13) and apple size (25.39) and 5 years old hybrids also showed maximum variability in inflorescence size (40.06) followed by apple size (29.58) and apple weight (26.62).
3. So far as nut, kernel and yield attributing characters are concerned 3 years old hybrid population showed maximum variability for nut yield (48.82) followed by number of nuts per panicle (45.78) and kernel dimension (38.42) and 5 years old hybrids also showed maximum variability for nut yield (34.55) followed by kernel dimension (27.92) and number of nuts per panicle (26.26).
4. Correlation studies were undertaken using 21 selected characters to determine degree of association between yield and different characters. Nut yield per tree in case of 3 years old hybrids was found to possess significantly positive correlation with number of nuts per panicle (0.554), number of leaves per shoot (10.513), kernel weight (0.479) and apple size (0.456) whereas number of laterals/m² and number of flowering laterals/m² found to have a highly significant correlation with yield i.e. 0.659 and 0.639 respectively. However, duration of 50% flowering showed maximum negative association with yield (-0.2456).
5. In 5 years old hybrid population nut yield found to possess significantly positive correlation with nuts per panicle (0.643) followed by shelling % (0.592) whereas inflorescence size was with a significant negative correlation with yield (-0.639). And yield was

found to have a highly significant positive correlation with number of flowering laterals/m² (0.768) and number of laterals/m² (0.738).

6. Maximum positive correlation was existed between number of laterals/m² and number of flowering laterals/m² in both the age group (0.991) in 3 years old hybrid group and 0.994 in 5 years old hybrid group.
7. The path coefficient analysis by using 8 selected parameters was carried out to estimate their extent of direct and indirect effects on yield. In case of 3 years old hybrids maximum positive direct effect towards yield was found by number of nuts/panicle (0.5947) followed by number of flowering laterals/m² (0.4674) where as leaf area had a negative direct effect on yield (-0.0378).
8. In case of 5 years old hybrid population the highest positive direct effect was exhibited by number of laterals/m²(1.4523) followed by number of nuts per panicle (0.6976) and nut weight (0.4640). The maximum negative direct effect was exhibited by number of flowering laterals/m² (0.8007).
9. Correlation and path coefficient analysis studies from both age group hybrids revealed that the biometric characters like number of flowering laterals per m², number of nuts per panicle and individual nut weight contributed highly towards yield. So due importance should be given on these characters while evaluating the hybrids.
10. A comparison study was also carried out for important yield attributing characters among the superior hybrids from both the age groups.

In the 3 years old hybrid population B'₃₄ could yield as high as 0.68 kg/tree attributed mainly through higher number of flowering laterals/m² (31.57). The high nut yield value of C'₁₃ (0.63 kg/tree) was found to be mainly attributed by higher number of nuts per panicle. B'₄ and B'₃₁ although were low in comparison to other hybrids regarding the important yield attributing characters, still then they were selected mainly for high yield.

In the 5 years old hybrid population, moderate number of flowering laterals per m² and moderate number of nuts per panicle and high nut weight mainly contributed to higher yield in hybrid A₁₀ whereas, in case of hybrids A₄ and A₆ moderate number of flowering laterals per m², moderate number of nuts per panicle and medium nut weight resulted high yield. In case of A₉ higher yield was mainly contributed through medium number of flowering laterals and high number of nuts per panicle. Higher yield in D₄ was mainly contributed through high number of nuts per panicle and higher nut weight. Although D₆ and D₇ were found lower in yield but both were mainly selected for their higher number of nuts per panicle and higher nut weight. These observations verified that, yield is influenced by the individual or joint association between two or three of the main yield attributing characters like number of flowering laterals/m², number of nuts/panicle and individual nut weight.

11. Magnitude of heterosis was calculated for all these 11 selected hybrids in terms of number of flowering laterals/m², number of nuts/panicle, nut weight, nut yield and shelling % over mid parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis).

12. Most of these selected hybrids showed relative heterosis, heterobeltiosis and standard heterosis for nut yield and nut weight. However, for the number of flowering laterals/m² B'₃₄, for number of nuts/panicle A₉, for individual nut weight A₁₀, for nut yield B'₃₄ and for shelling percentage A₁₀ showed maximum extent of relative heterosis.
13. Export grades were estimated for kernels of these selected hybrids and it was found that all these hybrids showed highest grade (w 180) except A₁₀ (w 280).

Thus the findings of the present investigation pointed towards the superiority of 11 hybrids viz., B'₄, B'₃₁, B'₃₄ and C'₁₃ of 3 years old and A₄, A₆, A₉, A₁₀, D₄, D₆ and D₇ of 5 years old hybrids over the studied hybrid populations.

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CHAPTER - 7

CONCLUSION

CONCLUSION

The present investigation entitled "Evaluation of cashew Hybrids" revealed that, there was a high degree of variability for nut yield, inflorescence size and extension growth of twig in the hybrid population of both age groups. However, the biometric characters like number of flowering laterals/m², number of nuts/ panicle and individual nut weight found to contribute significantly towards nut yield. The whole study indicated some superior hybrids viz. B'₄, B'₃₁, B'₃₄ and C'₁₃ from 3 years old hybrid population as well as A₄, A₆, A₉, A₁₀, D₄, D₆ and D₇ from 5 years old hybrid population. Most of these identified hybrids showed relative heterosis, heterobeltiosis and standard heterosis for nut yield and nut weight. However, for number of flowering laterals/m², B'₃₄, for number of nuts/panicle A₉, for individual nut weight A₁₀, for nut yield B'₃₄ and for shelling % A₁₀ showed maximum extent of relative heterosis.

Recommendation for clonal multiplication of these promising hybrids may be adopted for commercial cultivation. In spite of juvenility of these hybrids their performance are impressive which can be further exploited and evaluated till the hybrids achieve more age of maturity for full expression of their characters with a hope for getting still more stable and encouraging results.

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CHAPTER - 8

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BIBLIOGRAPHY

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