MORPHOPHYSIOLOGICAL ANALYSIS OF GROWTH AND YIELD IN CASHEW

(Anacardium occidentale L.)

By

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THESIS

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requirements for the degree

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Kerala, India

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DECLARATION

I here by declare that the thesis entitled **'Morphophysiological analysis of growth and yield in cashew (*Anacardium occidentale L.*)** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certificate

Certified that the thesis entitled '**Morphophysiological analysis of growth and yield in cashew (*Anacardium occidentale L.*)**' is a record of research work done independently by **Smt. P. B. Pushpalatha**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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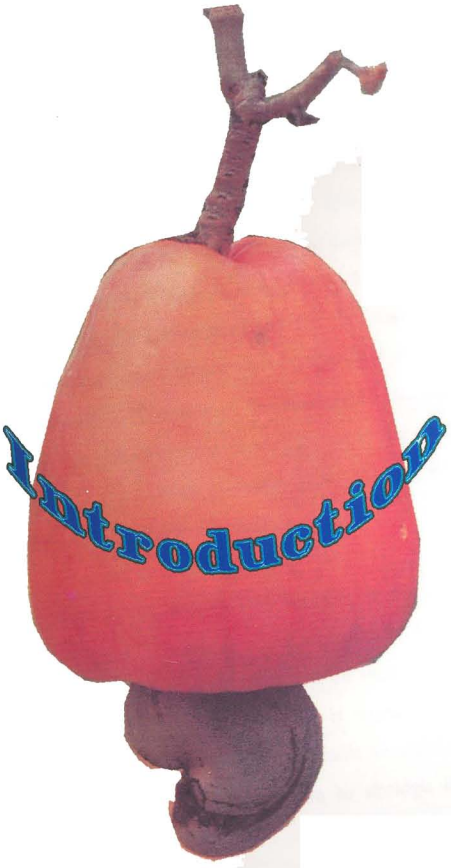

Introduction

INTRODUCTION

Cashew (*Anacardium occidentale L.*) is a major tree crop widely cultivated in the tropical countries of the world, mainly for its nutritious nuts. It is a native of Brazil and introduced to India by Portuguese in the 16th century and was grown for checking soil erosion. Henceforth, cashew flourished to the status of one of the most important commercial crops of our country.

India is the world's largest producer of raw cashew nuts producing 4.30 lakh tonnes of raw nuts from an area of 6.59 lakh hectares (Balasubramanian,1998) and accounts for 43.80 per cent of the total world production. The importance of cashew in Indian economy is due to its vital position in agricultural exports and also its employment generating capacity in the processing sector. Among the horticultural commodities exported from India, cashew ranks first and contribute 1.10 per cent of the total export earnings of the country (Rao *et al.,* 1998). Eventhough the production and export statistics are remarkable, India has a well known history in importing raw nuts. In the year 1998, the country earned foreign exchange to the tune of Rs. 1391 crores through export of kernel and cashew nut shell liquid (CNSL). At the same time, an amount of Rs. 744 crores was spent for importing raw cashew nuts (about 2.25 lakh tonnes). This is because of the fact that our internal production (835 kg ha^{-1}) is not sufficient to meet the requirement (eight lakh tonnes) of our processing units. The industrial demand is also at an increasing trend and it is estimated that around 10 lakh tonnes of raw nuts is required by the processing industries during the year 2000. The situation warrants an urgent need for taking up efforts to boost up our national production to abridge the gap between demand and production.

One of the options available for increasing the productivity of cashew plantations is to evolve location specific strategies for cashew cultivation with special reference to variety and management practices (Salam, 1999). The varieties recommended for cultivation are expected to have superior quality with respect to growth, flowering, nut and yield characters (Rao *et al.*, 1998).

To achieve this objective, the strategy being adopted at present is a thorough evaluation of the germplasm (clonal accessions) conserved at different research centres. This will help to identify the mother plants with desirable quality attributes viz., compact canopy, intensive flowering behaviour with production of more hermaphrodite flowers, cluster bearing habit, good kernel weight (above 2g) and shelling percentage (above 30) apart from possessing high yield potential. The evaluation of the genotypes will help to identify the lacunae for realising good yield from cashew plantations. This in turn will help to formulate research programmes to overcome the factors limiting exploitation of yield potential. The study on variability among the genotypes conserved at Cashew Research Station, Madakkathra was taken up in corroboration with this national perspective of strengthening our future crop improvement programmes. Studies on association of different characters with yield and among themselves will be helpful in the improvement of a complex trait like yield for which direct selection is not very effective.

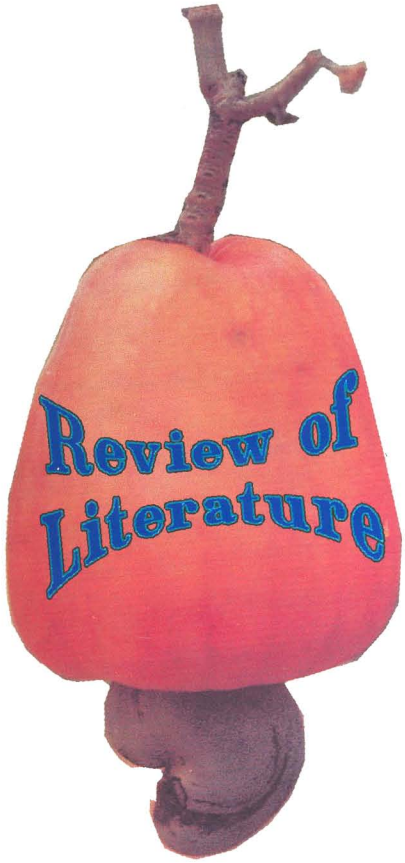
Flushing, flowering and fruit set are essential components of crop production and consist of multistage processes which are temporally and spatially ordered (Kinet, 1993). The morphological, biochemical and anatomical factors involved at different sequential stages may be determining the yield potential of a crop. A fundamental knowledge on these factors is highly essential to elucidate the factors governing as well as limiting yield in a particular situation. This in turn help to formulate specific corrective measures to the problems identified. In cashew, the process of differentiation of reproductive shoots from vegetative shoots, subsequent flowering and fruit set are important physiological stages of reproductive growth (Rao *et al.*, 1998), and as such knowledge available at present is inadequate to explain morphophysiological aspects of sequential differentiation, leading to crop production.

The possibilities of growth regulation to enhance crop production has been of interest to scientists for many years. In cashew, the attempts made in this direction is very little, especially under the situation where partial, intermittent and late flowering characters of many varieties pose problem for realising higher yield from unit area. In this situation, regulation of flowering behaviour of selected varieties will contribute much to augment yield in cashew. The development of a number of highly active growth retardants enhanced the potential of crop production through chemical regulation of growth and yield in many temperate and tropical fruit species. This breakthrough has motivated to undertake a new venture to tackle the problems associated with reproductive phase of the crop.

The use of dwarfing root stocks and chemical growth retardants has helped the temperate fruit growers to exercise considerable control over tree vigour (Kulkarni, 1988). These two growth controlling practices have made high density orcharding effective, resulting in higher yields. Extensive growth and large tree size pose problem for orchard management in cashew. High density planting will be possible only through developing technology for dwarfing the tree stature.

In this context the research project **"Morphophysiological analysis of growth and yield in cashew"** was proposed with the following objectives:

1. Evaluation of germplasm to analyse the variability in morphological characters among genotypes and to elucidate factors associated with yield
2. To estimate the varietal variation in biochemical and anatomical characters at different physiological stages related to reproductive growth
3. To explore the possibilities of chemical regulation of flowering
4. To develop strategies for induction of dwarfism in cashew grafts


Review of
Literature

REVIEW OF LITERATURE

Cashew is highly cross pollinated and heterozygous in nature and exhibits enormous variability in their performance. Consequently there is ample scope for successful genetic improvement through selection and breeding for superior genotypes (Ascenso, 1986 a; 1986 b). The performance of the genotypes vary from place to place depending on the climate in which the tree is grown (Rao and Gopakumar, 1994). For a systematically planned crop improvement programme, a precise knowledge of the extent of variability present among the genotypes and the association which existsbetween yield and component characters is very important (Rao *et al.*, 1998).

2.1 Morphological variation among cashew types and characters correlated with yield

2.1.1 Grouping of germplasm accessions

Grouping of cashew types based on similarity in characters had been attempted by many scientists. Cashew germplasm consisting of 292 accessions collected by the Central Plantation Crops Research Institute since 1972 was categorised into different groups by Swamy *et al.* (1990) based on characters such as yield, nut size, shelling percentage, apple size, maturity, bearing and plant habit. Nalini *et al.* (1994) selected and grouped 36 F_1 hybrids from a population of 216 F_1 hybrids for having nut size above 8 g. Sheshagiri (1996) grouped 15 cashew types growing in Regional Research Station, Mudigiree on the basis of variation in percentage of hermaphrodite flowers. At NRC for cashew, 153 clonal accessions were grouped to 18 clusters based on certain strongly inherited or key characters by Swamy *et al.* (1998).

2.1.2 *Variation in morphological characters*

Wide variation in vegetative, flowering, nut and yield characters among cashew genotypes had been reported by many scientists (Pavithran and Ravindranathan, 1974; Patnaik *et al.*, 1985; Sapkal *et al.*, 1994; Sena *et al.*, 1995 and Swamy *et al.*, 1998).

2.1.2.1 Vegetative characters

Wide variability in growth characters of cashew trees was reported by Damodaran *et al.* (1978), Falade (1981) and Devi (1981). Observations recorded on height, girth and spread of 100 cashew trees of five and six year old revealed great variation among the population (Nayar *et al.*, 1981). Evaluation of germplasm accessions revealed great variability for tree stature in cashew (Swamy *et al.*, 1990). Out of 161 accessions 11 accessions were found to possess bushy to medium plant habit and compact to medium canopy spread.

Based on a study which involved 56 cashew hybrids and 16 parents, high degree of variation in vegetative characters was reported for the hybrids with respect to canopy spread (Manoj, 1992)

Among 18 cashew varieties tested at Cashew Research Station, Madakkathra the variety V-3 was reported as tallest and M44/3 the shortest. The canopy spread varied widely and ranged between 7.97 and 10.35 m. The highest trunk girth was recorded for the variety H-1610 and lowest for M 44/3 (CRS, 1997)

2.1.2.2 Flowering characters

Maximum variability among F_1 population of cashew genotypes was observed for percentage of hermaphrodite flowers (Devi, 1981). Sriharibabu (1981) reported that average percentage of hermaphrodite flowers in high yielding varieties may go upto 45. Parameswaran *et al.* (1984) investigated the relationship between yield and duration of different phases of flower opening in cashew. The mean duration of flowering in trees above medium yield was 83.70 days and those

below medium yield was 102.70 days. The proportion of male phase in the total duration of flowering was significantly low in trees above medium yield.

Under Orissa conditions, the percentage of hermaphrodite flowers was found to vary between 5.94 and 20.69 percentage (Patnaik *et al.*, 1985). Bapatla varieties are reported to have a hermaphrodite flowers ranging from 8.00 to 15.00 per cent (Reddy and Rao, 1985). Based on a work conducted at Ullal, Hanamashetti *et al.* (1986) reported that total number of flowers per panicle varied from 165 to 837 and sex ratio between 4:1 and 6.1:1. Duration of flowering in different selections was found to vary from 51 to 111 days. Wide variation in the number of perfect flowers depending on the climatic conditions was reported by Das and Sahoo (1987).

The selections Ullal-1 and Ullal-2 are reported to have 2.27 to 6.66 percentage hermaphrodite flowers under humid conditions of Ullal (Khan and Kumar, 1988). Wide variation (9.57 to 23.25) in the number of panicles recorded from different directions of tree canopy was reported by Krishnappa *et al.* (1991 a). In another study Krishnappa *et al.* (1991 b) noted a variability to the extent of 231.40 to 835.80 in different varieties with respect to number of flowers per panicle. The number of staminate flowers ranged from 115.40 to 302.00 and number of nuts per panicle from 4,50 to 8.00. Hallad and Sullikeri (1992) reported that the duration of flowering in cashew varied from 116 to 129 days.

Floral biology of different cashew types under Jhargram conditions was studied by Chattopadhyay and Ghosh (1993). Period of flower opening was found to vary from 46.50 to 66.10 days. Floral characters of four cashew cultivar in Northern Australia was studied by Foltan and Ludders (1994). Ullal-1 was observed to be the only cultivars with an early short period of hermaphrodite flowers production.

Krishnappa *et al.* (1994) studied sex ratio in 16 cashew selections in Eastern tracts of Karnataka. The total number of flowers per panicle observed

was between 156.80 and 1027.40 in different selections. Seven selections had more than 45 per cent hermaphrodite flowers and the rest had 10.30 to 44.70 per cent.

Sapkal *et al.* (1994) reported that duration of flowering ranged from 95.08 to 119.83 days and number of flowers per panicle ranged from 335.04 to 990.78 and sex ratio between 2.06:1 to 30.19:1 among different cashew selections.

Floral characters of 17 clonally propagated cashew types were tabulated by Sena *et al.* (1995). They identified Vengurla-2 as the variety having highest number of panicles per m^2. Greatest panicle length was observed in H-1608 and sex ratio found to vary between 0.093 to 1.038. Variability in flowering duration was observed among cashew genotypes under Vridhachalam conditions (Subramanian *et al.*,1996). Shortest flowering period (52 days) was observed with a Mysore type,ME 15/4 and longest flowering period with a Madras type, A-5/2 (88 days). Sex ratio among different types was found to vary between 1.25:1 and 0.20:1 Sheshagiri (1996) evaluated 15 cashew types growing at Regional Research Station, Mudigiree for flowering period, number of staminate and perfect flowers. Flowering was found to occur from mid-December to late May in major selections and synchronised flowering types were not observed in the population.

Investigations carried out under All India Co-ordinated cashew Improvement Project at Bhubaneswar during 1995-'96 in 13 clonally propagated cashew types revealed that the flowering period continued upto 14 weeks in certain varieties (Lenka, *et al.*, 1999). Maximum perfect flowers were recorded upto five and six weeks while high sex ratio was observed within the first week of flower opening. Studies on floral characters of 14 clones were carried out at CRS, Bapatla by Dorajeerao *et al.* (1999). Duration of flowering was found to vary among clones from 57 to 72 days. Panicle length ranged between 15.83 and 23.79 cm while breadth varied from 20.61 and 29.59 cm.

2.1.2.3 Nut and yield characters

Among the nut characters in cashew, maximum variability was observed for nut weight and shelling percentage (Devi, 1981). A high degree of variability in nut yield per tree had been reported by Falade (1981), Devi (1981) and Ramadas and Thatham (1982).

Variation in nut size of 16 promising cashew selections was found to range between 5.21 to 9.40 g and shelling percentage from 22.37 to 28.71 (Nandini and James, 1984). Ghosh and Chatterjee(1987) reported variation in nut weight (4.25 to 6.73 g) and shelling percentage (18.00 to 34.70) among different cashew selections. Mohan *et al.* (1987) developed an index score method for identifying elite cashew types. Size of nuts and number of nuts per panicle were the characters found to vary greatly among cashew genotypes studied. Six varieties released from Andhra Pradesh Agricultural University showed variation in nut size from 4.00 to 6.00 g and shelling percentage from 23.00 to 28.10 (Reddy *et al.*, 1989). Based on evaluation of 292 seedling accessions collected at CPCRI, Vittal, Swamy *et al.* (1990) identified the trees having high yield potential ranging from 4.98 to 9.84 kg and good shelling percentage (30.00 to 35.10).

A study on the performance of selected cashew types at Cashew Research Station, Anakkayam showed that nut size ranged from 5.10 to 8.90g and shelling percentage from 25.80 to 27.99 (Nalini and Santhakumari, 1991).

Manoj (1992) reported highest degree of variation for nut yield followed by number of nuts per panicle.

2.1.3 Correlation of morphological traits with yield

Many workers had reported the relation between components like vegetative, flowering and nut characters with yield.

Percentage of hermaphrodite flowers and number of nuts reaching maturity was found to have a strong correlation with yield in cashew (Rao, 1974). Nayar *et al.* (1981) reported that canopy spread had maximum positive correlation with yield, followed by trunk girth and height of the tree.

Spread of plant, number of laterals per shoot and panicles per unit area and fruit set per panicle are highly correlated with yield of cashew (Nawale, 1983).

A strong correlation was observed between tree yield with percentage of flowering shoots per unit area of tree canopy followed by total canopy area by Parameswaran, *et al.* (1984). No significant correlation was noted between yield and tree height. A weak positive correlation was found between yield and percentage of open hermaphrodite flowers. A significant inverse relationship was found between yield and percentage of fruit drop.

Correlation coefficient worked out in cashew for eight characters with yield suggested that selections could be based on nut weight per tree since this is highly correlated with yield (Mohan *et al.*, 1987).

George *et al.* (1989) studied seven biometric characters to predict yield and revealed that yield could be forecasted with precision R^2= 0.64 by a single spot observation at peak flowering phase. The number of variables could be brought down to three viz., number of nuts per tree, condition of flowering (grouped 0 to 5) and canopy area, without affecting the estimate.

Nut yield had high significant positive correlation with nuts per panicle and mean number of perfect flowers per panicle (Anitha *et al.*, 1991). Mean nut weight and nut length had negative correlation with number of nuts per panicle that reached maturity.

Strong correlation of nut yield with girth, canopy spread, number of nuts per panicle weight of kernel, leaf area, height of tree and individual nut weight was observed by Manoj *et al.*(1994).

Kumar and Uduppa (1996) studied the association between nut yield and yield attributing characters in cashew and reported that nut yield per tree was influenced by genetic factors, cultural practices and climatic factors. Among 26 characters studied they calculated that 99.7 to 99.9 percentage of total variability in nut yield was controlled by five characters viz., number of reproductive shoots, number of bisexual flowers per panicle, fruit set, fruit retention and the total number of nuts produced per tree. Total number of nuts produced per tree was found as the most important character correlated with yield.

Correlation studies in cashew conducted by Reddy *et al.* (1996) showed that out of 19 characters studied nut yield had positive correlation with number of nuts per panicle, height, canopy spread, panicle length and stem girth, both at phenotypic and genotypic levels, where as days taken for 50 percentage flowering and per cent hermaphrodite flowers had positive correlation with nut yield only at phenotypic level.

Systematic crop improvement programme requires precise knowledge of the relationship between yield and yield attributing components for selection programme. (Rao *et al.*,1998).

2.2 Variation in biochemical constituents at different physiological stages of reproductive growth

Changes in biochemical constituents in relation to growth and reproduction is not well studied in cashew. Hence the related works in mango are mainly reviewed here under.

The nutritional status of a plant system plays an important role in determining its production potential. With the ageing of the canopy, shuffling of the nutrients from older to younger leaves was observed to a greater extent by many works in crops like guava, citrus and mango (Chadha, 1973 and Singh, 1978). Suryanarayana (1977) recorded a decline in protein content of mango shoots from September to January and it was found coincided with increased enzyme activity.

At the time of flower bud formation in mango shoots, carbohydrate content was found to attain a peak (Veera and Rao, 1977). They could not work out a correlation between nitrogen content, C:N ratio and flower bud formation. The changes in the chemical composition of mango leaves during different stages of flowering and fruit growth were studied by Pathak and Pandey (1978). The levels of all the nutrients were found higher before flowering and lower during flowering and fruit growth. A tendency to recoup the nitrogen level by rapid uptake prior to onset of different phases were also observed.

Amino acid content was found much higher in the shoots of mango cv Alphonso with differentiating flower buds than those with vegetative buds (Ravishankar, 1978). Glucose, fructose and starch contents decreased in shoots of all mango cultivars studied at the time of flower bud formation, but during infloresence development and flower emergence the content of these constituents rose sharply. Suryanarayana (1978) could not observe any relation between nitrogen content and the C:N ratio with flower bud formation or the number of flowers. Koochareonpisal and Subhadrabandu (1980) reported that carbohydrate levels in terminal stems before flowering and after harvesting differed significantly.

Kumar *et al.* (1982) studied the variation in mineral composition of leaves of cashew as affected by season, position and age and reported that fruiting had a depressive effect on the major nutrient contents of cashew. They recorded higher contents of nitrogen, phosphorus and potassium after fruiting season.

Considerably greater accumulation of carbohydrates, proteins, aminoacids and enhancement of enzyme activities in mature mango trees compared to juvenile and non flowering trees was observed by Chacko and Ananthanarayanan (1982).

Changes in the biochemical constituents viz., carbohydrates, nitrogen, calcium, magnesium and potassium in relation to flowering was studied by Ravishankar and Rao (1982) in mango. The level of insoluble carbon and non-reducing sugars was found decreased during bud differentiation while the level

of reducing sugars increased. Calcium rose markedly during differentiation where as magnesium and potassium declined slightly. Carbohydrate contents in the terminal stems, before flowering and after harvesting differed among mango clones and it was possible to group them into two viz., clones having high and low carbohydrate content. Rao *et al.* (1982) observed higher aminoacid content in mango shoot terminals before fruit bud differentiation and the level was found declined after emergence of panicles. They reported that the process of fruit bud differentiation was especially associated with the metabolism of argenine and glutamic acid.

Chadha *et al.*(1984) reported a decline in leaf nutrient status at postharvest stage in all mango cultivars and attributed this phenomenon to translocation of nutrients to developing fruits. The leaf N, P, K, Ca, Mg and S contents were found decreased from flowering to postharvest stages. This was attributed to earlier translocation to developing buds.

Paulas and Shanmughavelu (1988) analysed leaf samples at quiescent, bud burst, flowering and fruiting stages for protein, starch, ascorbic acid, RNA and DNA in three mango cultivars. Starch, ascorbic acid, RNA and DNA contents were higher and protein content was lower at flowering than at the quiscent and fruiting stage.

Variation in leaf nitrogen concentration ranging from 1.20 to 3.24 per cent was reported by Gopikumar and Aravindakshan (1989) in cashew seedlings.

Leaf nitrogen content of cashew leaves varied with physiological phases. It was highest (2.76%) in flowering phase and lowest (1.24%)in preflushing phase (Mathew, 1990).

In mango leaf non-reducing sugar, total soluble sugar, alcohol, insoluble nitrogen, total nitrogen content and nitrate reductase activity was found to be higher in branches which flowered where as leaf reducing sugar, starch, alcohol, soluble nitrogen and C:N ratio was higher in non-flowered branches. (Devi and Tyogi, 1991). This indicated greater accumulation of carbohydrates ready for flowering in next season.

Anakaiah and Rao (1991) noted that chlorophyll content in cashew leaves ranged between 8.58 and 11.71 (mean 9.83) in the case of high yielders, where as it ranged from 6.61 to 8.46 mg l^{-1} (mean 7.90) in the case of poor yielders. Average starch percentage recorded in the high yielders was 7.19 and in poor yielders 6.90 per cent. According to Latha (1992) leaf nitrogen content was highest (3.02%) at flowering and lowest (1.93%) at flushing phase.The chlorophyll 'a', 'b' and total chlorophyll content recorded were 0.39, 0.48 and 0.76 mg g^{-1} leaf tissue respectively. Bhaskar (1993) reported that the chlorophyll 'a', 'b' and total chlorophyll contents of cashew leaves (five years old tree) were 0.50, 0.49 and 0.93 mg g-1 leaf tissue respectively. Highest leaf N concentration was found at flushing and flowering phase and lowest at fruiting and maturity phases.

Nitrate Reductase Activity in leaves of four cashew varieties (Anakkayam-1, H-1600, H-1610 and Kanaka) ranged from 0.13 (Kanaka) to 0.21 (Anakkayam-1) mmol No_2 g^{-1} fresh weight h-1 (Salam *et al.*, 1993).

Sherlija and Unnikrishnan (1996) studied the changes in profiles of protein, free aminoacids, sugars, starch and phenols during transition from the vegetative to reproductive phases in cashew shoot apex. The quantitative values of total protein did not differ much between the reproductive and vegetative phases. Total aminoacid decreased during the transition while sugar and starch contents increased. Total starch slightly decreased while the phenolic content increased markedly in the reproductive phase.

2.3 Chemical regulation of flowering

An array of chemicals effective in regulating flowering behaviour of fruit crops had been evolved in the recent past. Among them the bud breaking agent potassium nitrate and the growth retardants viz., Alar, Cycocel and Paclobutrazol seemed to be widely used in temperate and tropical fruit crops.

2.3.1 *Effect of Potassium nitrate*

Bondad and Apostol (1979) studied the effect of spraying mango shoots with KNO_3 at 10 to 40 gl^{-1}. They reported that flowering was induced at various intensities in treated plants while none of the unsprayed shoots flowered.

Profound influence of KNO_3 on flowering of fruit trees was reported by Bondad and Linsangan (1979). Mango shoots five to eight months old required only seven days from spraying 10 to 160 g l^{-1} of KNO_3, to attain 100 per cent flowering. Pahutan shoots four to eight months old showed 100 per cent flowering within 14 days when sprayed with 10 to 80 g l^{-1} of KNO_3 and Pico trees within eight days after spraying with 10 g l^{-1} KNO_3.

Mango trees flowered approximately one month earlier when sprayed with KNO_3 two per cent once in October or twice in October and December (Vasquez, 1982). This treatment had no effect on fruit number, fruit weight or soluble solids.

Early flowering and hence early harvesting occurred in mango trees sprayed with KNO_3 two per cent (Vasquez and Rosendiz, 1985). They studied the possible role of KNO_3 on ethylene biosyntheis by spraying two inhibitors of ethylene biosynthesis viz., $AgNO_3$ and $CoCl_2$. Application of $AgNO_3$ at 250 ppm two and four hours after KNO_3 spray and $CoCl_2$ at 200 ppm one hour after KNO_3 spray inhibited flowering. From this they concluded that KNO_3 promotes ethylene biosynthesis.

Winston and Wright (1986) tried KNO_3 and ethephon together with cincturing to induce flowering in several cultivars of mango and reported that only the cultivar "Carabo" produced flowering in response to this treatment.

Spraying KNO_3 (10 to 160 g l^{-1}) to mango shoots in September to October advanced flowering by 21 days (Sergent and Leal, 1989). Heavy flowering was noted with the best treatment viz., spraying KNO_3 at 10g l^{-1}.

Sharma *et al.* (1990) reported heavy flowering and fruiting in mango trees sprayed with KNO_3 at various concentrations at flowering time. Compared to urea four per cent and ethrel 1 g l^{-1}, KNO_3 six per cent significantly increased the percentage of flowering shoots and the number of mixed panicles and vegetative shoots (Rojas *et al.*, 1993).

Based on a trial carried out at the Central Plantation Crops Research Institute at Karnataka, Mohan and Rao (1995) reported increased number of laterals per leader, percentage of perfect flowers (per panicle), fruit set and nuts carried to maturity when cashew trees were sprayed with KNO_3 at two per cent level.

Oosthuyse *et al.* (1996) studied the effect of KNO_3 spray on flowering, fruit retention fruit size and tree yield on three mango cultivars and reported that KNO_3 applied at two to four per cent concentrations increased the fruit retention. Fruit quality was not affected by KNO_3 application.

Heavy flowering and fruiting occurred in mango trees in response to spray with potassium nitrate at the rate of 12 g per tree (Ferrari and Sergent,1996).

Effect of off season application of KNO_3 six per cent, on flowering of mango trees was reported by Shongwe *et al.* (1997). When KNO_3 was sprayed in May, off season flowering was noticed and the number of panicles produced was more than control.

Increase in fruit number in response to spray application of KNO_3 was reported by Mossak (1997). Rojas (1997) studied the effect of pruning and KNO_3 spray and their combination on promotion of early flowering in mango trees. Pruning was found to inhibit flowering while KNO_3 caused heavier flowering in unpruned trees. Pruning and application of KNO_3 was also found to induce flowering. Effect of KNO_3 on induction of flowering and yield of mango at Venezuela was also reported by Sergent *et al.* (1997). KNO_3 application at the rate of 36 or 48 g per tree advanced flowering and harvest date, increased yield and reduced alternate bearing compared to control.

2.3.2 *Effect of growth retardants*

Recent investigation suggest that new growth retardants have potential to induce early uniform and profuse flowering in orchard trees through controlling vegetative growth (Quinlan, 1980). The effectiveness of growth retardants viz., Alar (daminozide), cycocel (chlormequat) and cultar (paclobutrazol) in orchard management of temperate fruit crops especially in apple had adequately been reviewed in literature. Among the tropical fruit crops, a major part of the research work for regulation of flowering using growth retardants is seemed to be undertaken in mango trees.

2.3.2.1 *Alar (daminozide) and Cycocel (chlormequat)*

Foliar sprays of alar applied early in the spring on young apple trees reduced extension growth and increased flowering (Veinbrants, 1972). Similarly Erasmus and Zyl (1974) observed that alar at 1000 to 3000 ppm applied 25 or 48 days after full bloom greatly reduced the rate of shoot elongation and 1000 or 2000 ppm applied 25 days after flowering reduced the shoot numbers. Alar at 2000 ppm applied after full bloom significantly reduced shoot growth, increased flower bud differentiation and yield (Dimitrovski *et al.*1976). Chlormequat at 0.50 per cent was found to reduce the shoot growth and induce heavy flowering when applied as spray to young strongly growing trees of pear (Hussabue, 1976). The effect was found significantly more than alar.

On the basis of the studies conducted in mango, Das and Pandey (1976) reported that both daminozide and maleic hydrazide applied to shoots during September increased shoot diameter and delayed the appearance of subsequent flushes. Daminozide at 7000 ppm and MH at 5000 ppm increased flowering shoots to 66 per cent and 60 per cent respectively as against 27 per cent in control.

In studies with the cultivars Langra (juvenile phase) and Baramasi (bearing phase), Mukhopadhyay (1976) found that chlormequat significantly increased the production of panicles, and size of panicles and hermaphrodite flowers per panicle.

Suryanaryana (1977) observed higher percentage of flowering in mango trees when sprayed with cycocel and Alar each at 5000 ppm at monthly intervals from May to December.

Daulta *et al.* (1981) studied the effect of cycocel sprays on flowering, fruiting and physico-chemical composition of fruits in mango cv Dashehari and reported that fruit set was greatly increased in response to 500 or 1000 ppm cycocel.

Suryanarayana (1981) reported that cycocel and alar each at 5000 ppm increased flowering shoots from 25 per cent in control to 85 and 47 per cent respectively. Both retardants significantly lowered the respiration rate at all stages. The levels of chlorophyll and carotenoids were consistently higher in treated leaves.

Rath *et al.* (1982) reported higher percentage of flowering in mango cv Langra, when the ringed main branches were treated with cycocel at 3000 ppm during off year in mid-October and again in early November.

Spraying apple trees with 2000 ppm daminozide two years after full bloom increased flowering in the following year (Ramirez and Hoad, 1984).

The apple trees treated with 0.30 per cent alar (daminozide) four weeks after flowering increased the yield and decreased the fruit weight (Kirillova and Toma, 1985). The Alar was found to shift the endogenous growth regulator levels in different parts.

Pruning in May and spraying with chlormequat retarded the growth of pear trees over four years. Chlormequat was not found to affect the fruiting (Indenko and Smagin, 1986).

Treatment with alar at 2000 or 3000 ppm did not produce any marked effect on number of flower buds and fruiting intensity in pear (Piper and Sadowaski,1987).

Two sprays of alar at 500 ppm at fortnightly interval upto middle October was reported to produce highest mean number of panicles per shoot in apple (Rao and Ravishankar,1992).

Kurien and Iyer (1993) reported that the growth retarding effect of alar and cycocel persist only for one season in mango trees. Hence repeated application of these chemicals was found necessary to control vegetative growth.

Effect of spraying growth retardants alar and cycocel each at 1000 or 2000 ppm at two times viz., mid May and full bloom was studied by Atawia and Hassan (1995) in apple. Spraying at mid-May showed the effect of reducing growth and enhancing flowering in the following year. Spraying at full bloom caused the greatest reduction in growth.

2.3.2.2 Effect of Paclobutrazol

International research with paclobutrazol since 1979 had demonstrated its effectiveness in various crops in relation to soil and foliar methods of application. Shearing and Jones (1986) stated that paclobutrazol is readily taken up by roots and by young stems. This offered the option to apply the chemical either as foliar spray or through soil. The authors reported excellent results in peaches to soil as well as foliar application of paclobutrazol.

2.3.2.2.1 Foliar application

Foliar application of paclobutrazol was found to reduce growth of shoots and leaf, darken the leaf colour and enhance fruit set in apple (Stinchcombe *et al.*(1984).

Miller and Swietlik (1986) reported that foliar sprays of paclobutrazol was effective in inhibiting the vegetative growth in apple and peach trees of

different age. Quinlan and Richardson (1986) studied the translocation of foliar applied paclobutrazol and reported that the most effectively utilised chemical is that deposited on the apical bud or stem tissues immediately behind it. Due to easy translocation in the case of foliar application it takes only one week to produce the effect. Edgerton (1986) studied the effect of foliar and soil method of application in apple trees of different age groups and found that for older trees foliar method of application is more effective than soil method.

Increased flowering in mango trees in response to foliar application of 1000 ppm paclobutrazol was reported by Tromp (1987). Spraying of young apple trees with paclobutrazol was reported to reduce the shoot growth, total number of flowers per tree and fruit set in apple trees (Wanichkul and Lenz,1988).

In apple trees single or double sprays of paclobutrazol at 100 mgl^{-1} was reported to reduce vegetative growth, increase in number of flower cluster per tree, initial and final fruit set (Hodairi and Canham,1990). Increased fruit set in response to foliar application of paclobutrazol to apple trees was reported by Jones *et al.* (1991).

In young pear trees spray application of paclobutrazol was found to reduce shoot and flower bud formation (Mei *et al.*, 1995).

In a trial to induce off season flowering in mango at Thailand, Tongumpai *et al.* (1997) sprayed paclobutrazol at 1000 or 2000 ppm to three year old mango trees. Flowering was found to initiate 29 to 41 days earlier in paclobutrazol treated trees. Two applications of either 1000 or 2000 ppm paclobutrazol resulted in largest number of flowering panicle and most uniform flowering.

2.3.2.2.2 Soil application

Significant reduction in vegetative growth in young apple, peach and sweet cherries due to soil application of paclobutrazol was reported by Edgerton

(1986). Soil application was found effective only for young trees compared to old trees. According to Miller and Swietlik (1986) paclobutrazol treatment to the soil under the trees generally inhibited vegetative growth in apple and peach trees of different ages. Effect of soil application of paclobutrazol on one to eight year old veneer grafted mango trees was reported by Kulkarni (1988). The treatment was found to reduce internodal length, shoot length and height increment. Precocious flowering, axillary flowering and cauliflory was also noted in treated plants. Sergent and Leal (1989) opined that soil drenching of paclobutrazol ranging from 1 to 6 g ha^{-1} could control over vigorous growth in apple trees, when applied twice at one year interval.

Tongumpai *et al.* (1989) reported that paclobutrazol applied as collar drench in soil at the rate of 1 g *a.i* m^{-1} of canopy diameter, induced flowering three to five months after treatment in easy to flower cultivars. Soil application of paclobutrazol to apple trees reduced the vegetative growth but had no effect on fruit set, flowering, fruit yield and percentage of fruits. The application of paclobutrazol at higher dose to the soil was found to have a negative effect on fruit shape in apple (Comai,1990).

Application of paclobutrazol at high concentration to the soil was reported to inhibit shoot growth, increase leaf thickness and leaf area (Hao *et al.*, 1991). Winston (1992) reported that soil application of paclobutrazol to apple trees as collar drench was more effective than foliar spray. Early and profuse flowering in mango trees in response to soil application of paclobutrazol was reported by Kurien and Iyer (1993). Higher doses were found to have detrimental effect both on fruit set and retention. The effect of soil application of paclobutrazol to young mango trees was studied by Werner and Schaffer (1993). Soil application was found effective in reducing shoot growth, plant height and internodal length. The treatments also increased flowering. Tongumpai *et al.* (1993) suggested drenching the mango tree basins with paclobutrazol at the rate of 6 g per tree to induce early flowering. Urruntia and Campbell (1994)

treated six year old mango trees with paclobutrazol. Early and profuse flowering was observed in response to soil application of paclobutrazol.

Trace studies with paclobutrazol after soil application to apple trees showed that paclobutrazol was transported through xylem and accumulated in phloem and distributed to leaves (Gang *et al.*,1994)

Mango trees treated with 5 g paclobutrazol per tree were reported to have increased per cent of flowering shoots and yield compared to control (Miao *et al.*, 1994). Soil application of paclobutrazol treatments was found to reduce shoots and stimulate flower bud formation in young pear trees (Mei *et al.*, 1995). Spray application at 500 mgl^{-1} in combination with soil application at 5 g per tree was reported to produce most favourable effect.

In a trial at Venezuela on five year old mango trees, paclobutrazol applied to the soil at 2.5, 5, 10 or 15 g *a.i* per tree was found to accelerate flowering, extend flowering period and improve total fruit weight (Ferrari and Sergant, 1996). Mossak (1996) reported increased yield in mango trees in response to soil application of paclobutrazol (cultar).

The combined effect of pruning and soil application of paclobutrazol on the productivity of mango was investigated by Burondkar *et al.* (1997). Application of paclobutrazol at 2.50, 5.00, 7.50 and 10.00 g per tree during July 1992 after pruning was found to advance flowering by 11.40, 19.20, 26.80 and 28.80 days respectively. Significant improvement in yield was also noted in treated plants.

2.3.3 *Variation in response to paclobutrazol application among different varieties of fruit crops*

Variation in response with respect to vegetative flowering, and yield characters to paclobutrazol application among mango varieties had been reported by Kulkarni (1988).

A clear difference in response among apple varieties to soil or foliar application of paclobutrazol was reported by Ogata *et al.* (1989). Single application of 1,000 or 2,000 ppm paclobutrazol by foliar spray to 'Tsugare' apple and soil application of paclobutrazol to Fuji and Goldern delicious apple significantly reduced the extension growth, while in starkling delicious and Jonathan, the foliar or soil application failed to control tree grwoth.

Varietal variation in response to paclobutrazol application in six mango cultivars was studied by Tongumpai, *et al.* (1989). The variety Khilewsawoey was found to respond least to paclobutrazol application. In apple Hodairi and Canham (1990) reported that paclobutrazol evoked response varied depending on varieties.

Varietal variation in response to soil application of paclobutrazol (15g per tree) in mango was studied by Vuillaume (1991). The treatment was found to be effective in advancing flowering but the intensity varied among different cultivars.

Struklec and Modic (1994) compared the influence of paclobutrazol on two apple cultivars, Jonagold and Gloster. The response of the cultivar Janagold was not found to be in an acceptable manner compared to Gloster.

In S. Africa, greatest increase in fruit number occurred to Tommy atkin mangoes in response to application of KNO_3 at four per cent (Oosthuyse *et al.*, 1996). In Hudi variety two applications at four per cent and in Kent, two applications at two per cent produced the best response.

2.3.4 *Variation in biochemical constituents in relation to paclobutrazol application*

Paclobutrazol treated plants are reported to appear dark greeen and this has been correlated with increased chlorophyll content by many scientists (Jaggard *et al.*, 1982 and Sankhla *et al.*, 1985). The scientists opined that the increased chlorophyll content could be due to enhanced chlorophyll biosynthesis or simply a concentrating effect due to reduced leaf expansion.

Increased carbohydrate content in leaf tissues of apple in response to paclobutrazol application was reported by Steffens *et al.* (1983). They also reported that the increase in chlorophyll content in response to paclobutrazol application was more evident with leaves that developed after paclobutrazol appliction.

Paclobutrazol treatment was reported to increase soluble protein in leaves of apple seedlings and alterations in protein content seemed to parallel chlorophyll content (Wang *et al.*, 1985). In general the effect of paclobutrazol is reported to shift assimilate partitioning from leaves to roots (Upadhyaya *et al.*, 1986).

Increased chlorophyll content in response to application of paclobutrazol at higher concentration was reported by Hao, *et al.* (1991). Paclobutrazol application was found to increase the N, Ca, Mn, Zn and B content in mango leaves while P,K and Ca contents were decreased (Werner and Schaffer, 1993).

2.4 Induction of dwarfism in plants at nursery stage

At present, research efforts are gaining momentum to evolve new technologies for increasing productivity of cashew. In this context the concept of high density planting using dwarf genotypes with compact canopy would be a very good option. The use of dwarfing root stocks and chemical growth retardants had allowed considerable control over tree vigour in many fruit species. However little progress had been made in this direction in cashew.

2.4.1 Effect of irradiation

Effect of gamma irradiation of cashew seeds on growth and vigour of seedlings was studied by Salam *et al.* (1992). Irradiation of seeds upto 10 Gy stimulated the growth of seedlings and above 20 Gy suppressed the growth and encouraged branching. Dwarfism was observed in seedlings produced from nuts irradiated at doses of 40 to 60 Gy. The LD_{50} value for cashew nuts was fixed between 40 and 50 Gy and irradiation beyond 60 Gy was found to arrest seed germination.

Nagatomi *et al.* (1993) reported that irradiated seeds of genus Cytisus on regeneration produced dwarf plants. The number of dwarf plants were found to increase with increased irradiation dose. In banana Nagatomi *et al.* (1996) reported that irradiation of shoot masses produced variants with altered leaf shape and long stalks.

Mutagenesis in pear seedlings through irradiation of seeds produced plant habit suitable for high density planting (Predieri, 1997). Out of 7,000 plants obtained from irradiation treatment, only few with reduced internode length could be obtained.

2.4.2 Effect of growth retardants

Possibility of using growth retardants in inducing dwarfism in young pear trees was studied by Hussabue (1972). CCC (chlormequat) applied at 0.25 to 0.50 per cent to one year old potted plants was found to be more effective growth retardant than alar. It shortened the shoot internodes. Chemical control of tree vigour in mango was reported by Iyer (1973). Effect of growth retardants on two year old grafted pear plants was studied by Singh and Sharma (1973). Alar (daminozide) at 2000, 4000 or 6000 ppm or cycocel (chlormequat) at 1,500, 3,000 or 4,500 ppm was found to reduce shoot growth and internodal length but did not affect shoot diameter or internode number.The release of M & B 25-105 (n-propyl 3 t butyl phenoxy acetate) in U.K for use in commercial nurseries was reported to control growth of apples and pears inducing production of more lateral shoots(Duckworth *et al.*, 1979)

Development of new chemical branching agents which control tree growth at nursery stage itself was reported by Quinlan (1980). He suggested that new growth regulators have potential for use at all stages of tree development, to improve nursery tree quality and orchard establishment, to induce early flowering and cropping and to control the growth of orchard trees. Grausland (1983) found that growth retardation of young pear trees using cycocel was effective

only under reduced planting distances. Paclobutrazol is reported to modify the pattern of endogenous plant hormone biosynthesis enabling it to alter the plant vigour (Bruinsma, 1985).

Indenko and Smagin (1986) observed that pruning pear trees in May together with spraying chlormequat retarded growth over four years when two seasonal applications at 0.40 per cent were made one at the year of pruning and again two years later. Kwon and Lee (1986) reported that soil application of paclobutrazol is effective in reducing over vigorous growth of apple seedlings. The treatment was found to increase the chlorophyll content and advance terminal bud formation.

Kulkarni (1988) studied the effect of soil and foliar application of paclobutrazol on young container grown mango grafts. Soil application at the rate of 1.25 g *a.i* per plant controlled the growth, while 2.5 g *a.i* per plant produced delayed toxicity symptoms of epinasty and leaf scorching . Foliar sprays had no effect.

Paclobutrazol applied as foliar spray on two year old grafted mango plants at the rate of 2000 mg l^{-1} per plant in the month of September every year caused significant reduction in plant height, trunk girth and shoot girth (Khader,1991).

Kurien *et al.* (1991) recorded lower levels of abscisic acid in shoot tips of paclobutrazol treated trees compared to control. Treatment with paclobutrazol was found to enhance total phenol content in buds and alter the phloem to xylem ratio of the stem (Kurien and Iyer, 1992).

Soil drenching of paclobutrazol (2.5, 5.0 or 10.0 g per tree) and foliar sprays of cycocel 4000 or 8000 mg l^{-1} or alar (daminozide) at 1,500 or 3,000 mg per tree suppressed the flushing, shoot length, leaf number and area. Among the three chemicals tried paclobutrazol was found most effective (Kurien

Paclobutrazol applied at the rate of 20, 60 and 240 mg *a.i* per plant to two year old grafted and non-grafted mango and peach cultivars caused inhibition of growth (Salomon and Reuveni, 1994). Severe inhibition of growth occurred at higher levels especially in the grafted plants.

2.4.3 Anatomical characters in relation to plant vigour

In a trial for screening mango seedlings for use as dwarfing root stocks Mukherjee and Das (1976) concluded that dwarfing root stocks possess short stature, smaller number of secondary roots, lower root dry weight, smaller number of root vessels, higher percentage of root bark and lower respiration.

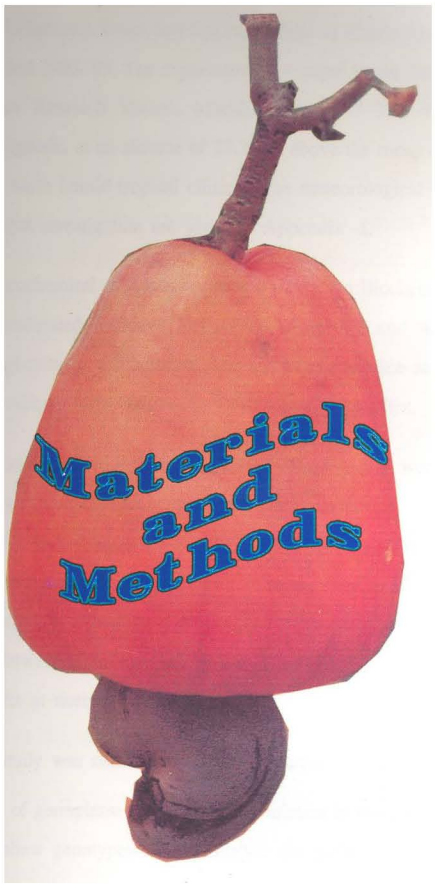
Anatomical characters viz., percentage of stem and root bark, number of vessels per unit area in stems and roots, area of vessels, average plant height, area of metaxylem (stems) and average area covered by tree canopy (m^{-2}) were used by Mukherjee and Das (1980) for screening of mango seedlings for use as dwarf root stocks. The varieties having high bark percentage were recorded as less vigorous types.

Singh et.al. (1986) screened dwarfing root stocks of mango at nursery stage on the basis of anatomical characters. They reported that bark percentage determined from cross sections of stem, root and petiole were negatively correlated with height, girth and tree volume.

Higher phenolic levels and higher xylem, phloem ratio were shown to be associated with dwarfing in mango seedlings (Iyer *et al.*, 1992). They suggested that these characters could be used for screening dwarf mango cultivars.

Studies conducted by Kurien and Iyer (1993) with 24 mango cultivars of widely varying vigour indicated that low tree vigour was associated with a higher primary phloem to xylem ratio in young shoots. Width of cortex did not show any relation to tree vigour. There was no significant difference among mango cultivars with respect to the number of xylem vessels or the size of metaxylem vessels. Higher phloem to xylem ratio was observed in the case of trees dwarfened by external application of 10 g paclobutrazol per tree.

Usha *et al.* (1996) compared morophological, biochemical and anatomical characters of cashew seedlings grown from vigorous and less vigorous trees. Height, girth, and internodal length of seedlings of less vigorous trees were found less compared to vigorous types. Number of stomata were more in vigorous types. Bark percentage in stem and roots were higher in less vigorous types than vigorous types.


Materials
and
Methods

MATERIALS AND METHODS

The present investigation " Morphophysiological analysis of growth and yield in cashew (*Anacardium occidentale L.*)" was carried out in the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during the period 1995-'99. The experiments envisaged in the field were carried out at Cashew Research Station, Madakkathra (10 ^{0} 32 ' N latitude and 76 ^{0} 13 ' E longitude, at an altitude of 22.25 m above the mean sea level.). The area enjoys a warm humid tropical climate. The meteorological data during the period of present investigation are given in Appendix -I.

The biochemical studies were carried out in the Biochemistry laboratory, All India Co-ordinated Research Project on Medicinal and Aromatic Plants, College of Horticulture, Vellanikkara. The facilities available at the College of Forestry, Vellanikkara were utilised for the anatomical studies.

The main objectives of the present investigation were to study the variability in morphological characters among the genotypes of cashew germplasm, to elucidate the factors associated with yield, to analyse the variability in biochemical and anatomical characters among the varieties at different physiological stages of reproductive growth, to explore the possibilities of chemical regulation of flowering and controlling tree size through induction of dwarfism in cashew grafts at nursery stage.

The study was conducted in four different experiments

1. Evaluation of germplasm to estimate the variation in morphological characters among cashew genotypes and to analyse the yield components
2. Variation in biochemical and anatomical characters among varieties at different physiological stages of reproductive growth
3. Chemical regulation of flowering behaviour of cashew varieties
4. Induction of dwarfism in cashew grafts at nursery stage

The details regarding the experiments, materials and methodology adopted for conducting various aspects of the study are presented in this chapter.

3.1 Evaluation of germplasm to estimate the variation in morphological characters among cashew genotypes and to analyse the yield components

Sixty seven clonal accessions planted during the years 1988 and 1989 (at a spacing of 4 m x 4 m) in the germplasm conservation block of Cashew Research Station, Madakkathra were selected for the study.The source of collection of these accessions and available information about their parent trees are given in Appentix-II. Preliminary grouping of these accessions based on the variation in their flowering behaviour (Early, mid and late) and yield performance (High, medium and low) was done. For convenience, accessions selected are invariably referred as varieties in the present study.

3.1.1 Grouping of germplasm

(i) Based on flowering behaviour

The time of flushing and flowering in all the 67 accessions selected were noted during 1996- '97 and 1997 - '98 season. For this, trees were observed on alternate days and the date on which 50 per cent of dormant shoots in an unit area showed flush emergence was taken as the date of flushing. Similarly the date on which panicle emergence was observed in 50 per cent of flushes was taken as the date of flowering.

Based on date of flowering each variety was assigned with a character separately for the two seasons. The character was assigned as numbers, calculating the days between October first and the date on which a variety attained 50 per cent flowering. Average of the character for both years were worked out for each variety. Based on this mean character and standard deviation (SD) of the population were worked out. Those varieties having the character below mean-SD were grouped as early, above mean + SD were grouped as late and between mean - SD and mean + SD were grouped as mid season.

(ii) Based on yield performance

All the varieties selected for the study were assessed for their performance based on the yield data for 1996 -'97 and 1997 - '98 seasons. For each variety average yield for these two years were worked out. Based on this mean yield of the population and standard deviation (SD) were calculated. Those varieties having an average yield above mean +SD were grouped as high yielders, between mean and mean +SD as medium yielders and below mean as low yielders.

(iii) Based on flowering behaviour and yield

A final grouping of the 67 genotypes was again done based on their flowering behaviour and yield performance as follows:

Flowering behaviour	Yield performance	Group
Early season	High Yielders	EH
	Medium yielders	EM
	Low yielders	EL
Mid season	High Yielders	MH
	Medium yielders	MM
	Low yielders	ML
Late season	High Yielders	LH
	Medium yielders	LM
	Low yielders	LL

3.1.2 Analysis of variation in morphological characters

Three varieties from each group (as shown in 3.1.1, iii) were selected for analysing the variation in morphological characters. Thus there were all together 27 varieties. With four trees in each variety, 108 trees were marked for the study.

Observations on different vegetative, flowering, nut and yield characters (as detailed below) were recorded for each tree separately and the data were interpreted statistically (as given in 3.1.4)

3.1.2.1 Vegetative characters

The vegetative characters recorded were height of the tree, trunk girth, spread, number of flushes per m^2, flush length, shoot girth and number of leaves per flush with the following specifications.

Character	Method adopted
Height of the tree	Measured from ground level to the tip of the topmost leaf and expressed in metre (m)
Trunk girth	Measured at 50 cm above the ground level and expressed in centimetre (cm)
Spread	Average of the East-West and North- South spread expressed in metre (m)
Number of flushes (m^{-2})	Average of the number of flushes observed from ten randomly selected quadrants of 1 m^2
Shoot girth	Recorded at one cm apart from the base of ten randomly selected flush shoots after cessation of leaf emergence and expressed in centimetre (cm)
Flush length	Average length of ten flushes recorded on four sides of the canopy after panicle differentiation started on the flushes.
Number of leaves ($flush^{-1}$)	Counted on ten randomly selected flushes and average worked out.

3.1.2.2 Flowering characters

Observations were recorded on flowering characters such as number of panicles per unit area, panicle length, panicle breadth, percentage of hermaphrodite flowers and number of nuts per panicle with the following specifications for each tree separately.

Character	Method adopted
Number of panicles (m^{-2})	Average of the number of panicles observed at ten randomly selected quadrants of 1 m^2 in the canopy
Panicle length.	Recorded on ten randomly selected fully developed panicles,average worked out and expressed in centimetre (cm).
Panicle breadth	Recorded on ten randomly selected fully developed panicles, average worked out and expressed in centimetre (cm).
Percentage of hermaphrodite flowers	Average of number of hermaphrodite flowers to total number of flowers produced on five randomly selected panicles expressed as percentage. For this five panicles per tree were tagged separately and observed for flower opening . Opened flowers were removed daily after recording the counts as hermaphrodite and male separately. This process was continued till no new flowers appeared.
Number of nuts (panicle^{-1})	Recorded on ten randomly selected panicles after the nuts attained maturity and average worked out.

3.1.2.3 Nut and yield characters.

Nut characters such as length, breadth, hundred nut weight, shelling percentage, kernel weight and yield were recorded as follows for each tree separately.

Character	Method adopted
Nut length	Length of ten nuts were recorded, average worked out and expressed in centimetre (cm)
Nut breadth	Breadth of ten mature nuts were recorded, average worked out and expressed in centimetre (cm).
Hundred nut weight	Weight of two lots consisting of hundred nuts each were recorded separately, average worked out and expressed in grams (g)
Shelling percentage	This was worked out as the ratio of weight of kernels to the weight of raw nuts expressed in percentage.
Kernel weight	Average weight of twenty five kernels was recorded as kernel weight and expressed in grams (g).

3.1.3 Analysis of growth and yield components

The morphological characters viz., vegetative, flowering, nut and yield characters were statistically analysed (as given in 3.1.4) to find out the components closely related with yield, interrelation among the characters and direct and indirect effects of the component characters on yield.

3.1.4 Statistical analysis

The data generated on morphological characters of the 27 varieties were analysed using MSTAT-C package available at CCF, College of Horticulture, Vellanikkara and SPAR-1 package developed by IASRI, New Delhi. Analysis of variance was performed on morphological characters and whenever the treatments were found significantly different their means were compared using DMRT (Duncan's Multiple Range Test). Genotypic and phenotypic coefficient of variation, heritability and genetic advance were worked out for each character separately.

Morphological characters associated with yield were identified through genotypic and phenotypic correlation coefficient and path coefficient analysis.

(i) Phenotypic and genotypic variance

Variance components were estimated using the formula suggested by Burton (1952).

Genotypic variance (Vg) = (VT-VE)/N

Where VT = mean sum of squares due to treatments

VE = mean sum of squares due to error

N = Number of replications

Phenotypic variance (Vp) = Vg +Ve where Vg is the genotypic variance and Ve is the environmental variance

(ii) Phenotypic and genotypic coefficients of variation

The phenotypic and genotypic coefficients of variation were calculated as follows :

Phenotypic coefficient of variation (PCV) = $(Vp^{1/2} / \bar{x}) \times 100$

Genotpic coefficient of variation (GCV) = $(Vg^{1/2} / \bar{x}) \times 100$, where $\bar{x}$ is the overall mean.

(iii) Heritability

Heritability in the broad sense was estimated as follows:

Heritability in broad sense = (Vg/Vp) x100.

(iv) Expected genetic advance

The genetic advance expected under five per cent selection pressure was calculated using the formula suggested by Lush (1949) and Johnson *et al.* (1955).

Expected genetic advance, $GA = K \times (Vg/Vp) \times Vp^{1/2}$

Vg = Genotypic variance

Vp = Phenotypic variance

K = Selection intensity which is equal to 2.06 for selection of five per cent individuals.

(v) Phenotypic and genotypic correlation coefficients

Phenotypic and genotypic correlation coefficients were worked out to study the extent of association between characters. The phenotypic and genotypic covariance were worked out for calculating the variance.

(vi) Path coefficient analysis

The principles and techniques suggested by Wright (1921) and Li (1955) were employed for the analysis. In path coefficient analysis the correlation among causes and effects were partitioned into direct and indirect effects of causal factors on effect factors.

(vii) Evolving selection index using discriminant function

Estimation of the discriminant function based on most reliable and effective characters was made and ideal selection index was constructed as reported by Hazel (1943).

3.2 Variation in biochemical and anatomical characters among varieties at different physiological stages of reproductive growth

3.2.1 *Analysis of biochemical characters*

(i) Selection of plants

One high yielding and one low yielding variety coming under each of early , mid and late season groups were selected for analysis of biochemical characters.

Flowering behaviour	Yield performance	Group
Early season	High yielder	EH
	Low yielder	EL
Mid season	High Yielder	MH
	Low yielder	ML
Late season	High yielder	LH
	Low yielder	LL

Two plants were marked under each variety. Thus 12 trees were identified for drawing samples for the analysis.

(ii) Samples for analysis

Leaf samples were taken from the shoots at different stages of physiological maturity from the identified plants (Plate 1).

Details of samples taken are given below:

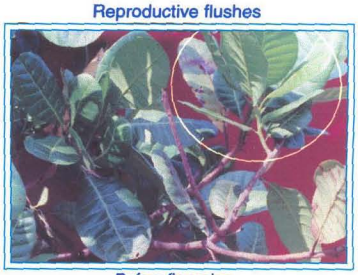
Mature shoots : Third or fourth leaf was collected from the top of the shoot for analysing the biochemical constituents at different physiological phases of reproducitve development as detailed below:

Plate 1. ***Sampling stages for biochemical analysis***

Mature lateral shoots

Before flushing

Reproductive flushes

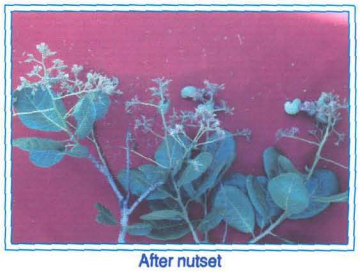


Before flowering

After flushing

After flowering

After flowering



After nutset

Vegetative flush

Stage at which samples were collected	Identity of the shoot
Before flushing	Dark brown shoots with dark green leaves. Well bulged terminal bud protected by a rosette of leaves
After flushing	Mature shoots, tip turned greenish bearing grown up flush / flushes terminated in a bud
After flowering	Flushes on mature shoots terminated in a well developed panicle

Reproductive flushes : First fully maturied leaf was collected from the top of the flushes at different phases of reproductive development as given below:

Stage at which samples were collected	Identity of the shoot
Before flowering	A well developed reproductive bud visible at the tip of the flush protected by a rosette of light green or purple leaves.
After flowering	Flushes terminated in a well developed panicle. Leaves dark green in colour.
After nut set	No live flowers remained on the panicle. Nuts are at the various stages of development. Leaves, light green in colour

Vegetative flushes : Simultaneous with sampling of reproductive flushes, samples (first fully matured leaf from the top) were drawn from vegetative flushes as well. Here the stages are referred as before flowering, after flowering and after nut set and denote the various physiological stage of the tree.

Stage at which samples were collected	Identity of the shoot
Before flowering	Flushes without rosette of leaves and with vegetative bud at the tip. Leaves are green or purple in colour
After flowering	Flushes with dark green leaves, vegetative bud at the tip
After nut set	Light brown shoots with dark green leaves, vegetative bud at the tip.

These leaf samples were oven dried (70^0 C), ground well and passed through 40 mesh sieve and stored in air tight containers. Fresh samples were taken as and when required according to the components analysed.

(iii) Biochemical constituents analysed

The details of biochemical components analysed with different samples prepared are given below:

Sample	Biochemical component analysed
Dried leaves	Total carbohydrate, total nitrogen and total phenols
Fresh leaves	Chlorophyll, Nitrate Reductase Activity (NRA)

Total carbohydrate, nitrogen, phenols, and chlorophyll were estimated as suggested by Sadasivam and Manickam (1996). Nitrogen was estimated by microkjeldahl method (Jackson, 1958) using the instrument 'Titrimetric' available at KHDP, Vellanikkara. Nitrate Reductase Activity (NRA) was analysed as detailed by Klepper *et al.* (1971).

The fresh leaf samples were made into discs of approximately 0.5 mm diameter and 0.3 g of samples were taken in an injection bottle containing 5 ml of infiltration medium (0.2 M KNO_3 and 1 mM potassium phosphate at pH 7.5). The injection bottle containing the media and leaf were evacuated at 6 mm mercury pressure for 30 seconds, the vacuum released and the process repeated. The bottles were incubated at a BOD for one hour at 33^0 C, with shaking at 30 minutes interval. After one hour, the bottles were placed in a hot water bath for five minutes to arrest the reaction. After cooling, 0.4 ml of the colouring agent (one per cent sulphanilamide in 3 M HCL and 0.2 per cent naphthyl ethylene diamine dihydrochloride in equal volume) was added to this medium and made up to 6 ml. The absorbance of the supernatant was read at 540 nm in spectrophotometer. Enzyme activity was expressed as mmol NO_2^- produced g^{-1} fresh leaf h^{-1}.

3.2.2 Analysis of anatomical characters

(i) Selection of plants

One high yielding and one low yielding variety each from the early and late group was selected for studying the anatomical characters.

Flowering behaviour	Yield performance	Group
Early season	High yielder	EH
	Low yielder	EL
Late season	High yielder	LH
	Low yielder	LL

(ii) Samples for the study

Three different type of shoots as detailed below were collected from the selected varieties for the study of anatomical characters.

Type of shoot	Stage at which shoots were collected
Mature lateral shoots	Before flushing
Reproductive flushes	Before flowering
Vegetative flushes	Simultaneous with collection of samples from reproductive flushes

Physiological identity of the above types of shoots at various stages of sampling are given in 3.2 (ii)

(iii) Sectioning and preparation of section

Sections were taken from the terminal one centimetre portion of the three different type of shoots. Sections from the mature shoots were taken with the help of microtome available at the College of Forestry, Vellanikkara. Hand sections were taken from the reproductive and vegetative flushes.

Thin sections were separately washed in distilled water, stained in one percentage saffranin and mounted on the slide in glycerine for taking observations.

The anatomical characters of these shoots were observed with the help of CETI binocular research microscope and photographs were taken using NIKON trinocular research microscope attached with camera available at CCF, Vellanikkara.

3.3 Chemical regulation of flowering

The investigations on chemical regulation of flowering were conducted at the Cashew Research Station, Madakkathra. The different varieties maintained as per the package of practices recommendation of Kerala Agricultural University were utilised for the study. Five different experiments as detailed below were carried out consecutively for four seasons to identify suitable chemical for regulation of flowering in cashew.

3.3.1 *Observational trial on chemical regulation of flowering*

To study the effect of different chemicals on regulation of flowering in cashew, an observational trial was conducted during 1995-'96 season including the following chemicals at different concentration as specified below:

T_1 Cultar (paclobutrazol) 250 mg l^{-1}

T_2 Cultar (paclobutrazol) 500 mg l^{-1}

T_3 Cultar (paclobutrazol) 1000 mg l^{-1}

T_4 KNO_3 1%

T_5 KNO_3 3%

T_6 KNO_3 5%

T_7 Cultar 250 mg l^{-1}+ KNO_3 1%

T_8 Cultar 250 mg l^{-1} + KNO_3 3%

T_9 Cultar 250 mg l^{-1} + KNO_3 5%

T_{10} Cultar 500 mg l^{-1} + KNO_3 1%

T_{11} Cultar 500 mg l^{-1} + KNO_3 3%

T_{12} Cultar 500 mg l^{-1} + KNO_3 5%

T_{13} Cultar 1000 mg l^{-1} + KNO_3 1%

T_{14} Cultar 1000 mg l^{-1} + KNO_3 3%

T_{15} Cultar 1000 mgl^{-1} + KNO_3 5%

T_{16} Alar (Daminozide) 250 mg l^{-1}

T_{17} Alar (Daminozide) 500 mg l^{-1}

T_{18} Alar (Daminozide) 1000 mg l^{-1}

T_{19} Cycocel (Chlormequat) 250 mg l^{-1}

T_{20} Cycocel (Chlormequat) 500 mg l^{-1}

T_{21} Cycocel (Chlormequat) 1000 mg l^{-1}

T_0 Control.

The trial was conducted in a late high yielding variety, Madakkathra-2 (eight years old, planted at a spacing of 6 m x 6 m). Each treatment was given to a single tree separately as spray to the lateral shoots (three to four months old) with dormant buds before preblossom flushing. Five litre spray solution was used for imposing soaking spray to the entire canopy.

The trees were observed closely for the vegetative, flowering nut and yield characters as specified below.

Character	Specification
3.3.1.1 Vegetative character	
(a) Days to flushing	Days taken for initiation of flushes in 50 per cent of lateral shoots after imposing the treatment
(b) Number of flushes (m^{-2})	Recorded as specified in 3.1.2.1
(c) Length of flushes (cm)	
(d)Number of leaves ($flush^{-1}$)	
(e) Flushing span (days)	Number of days between flushing of 10 per cent lateral shoots to complete flushing of the tree.
3.3.1.2 Flowering Character	
(a) Days to flowering	Days taken for emergence of panicles in 50 per cent of reproductive flushes on lateral shoots
(b) Number of panicles (m^{-2})	Recorded as specifeid in 3.1.2.2
(c) Number of nuts ($panicle^{-1}$)	
(d) Number of hermaphrodite flowers ($panicle^{-1}$)	Average number of hermaphrodite flowers produced on five randomly selected panicles

(e) Duration of flowering (days)	Average number of days between the date of first flower opening to that of last flower opening, recorded on five randomly selected panicles

3.3.1.3 Nut and Yield character

(a) Nut length (cm)	Recorded as specified in 3.1.2.3
(b) Nut breadth (cm)	
(c) Hundred nut weight (g)	
(d) Kernel weight (g)	
(e) Yield (Kg)	
(f) Fruit weight (g)	Average weight of 10 fruits expressed in grams (g)

3.3.2. Second screening trial for selecting suitable chemical for regulation of flowering

The two effective chemical combinations selected suitable for flowering regulation based on the results of the observational trial were further tested on more number of plants during 1996-'97 season for confirming the results. These treatments were also imposed together with carbaryl 0.10 per cent (used widely in cashew for controlling tea mosquito attack). Thus there were five treatments including control (water spray) as given below:

T1 Cultar 1000 mg l^{-1} + KNO_3 1%

T2 Cultar 500 mg l^{-1} + KNO_3 1%

T3 Cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10 %

T4 Cultar 500 mg l^{-1} + KNO_3 1% + carbaryl 0.10 %

To Control

The variety selected was Madakkathra-2 (a late high yielder) six years old, planted at a spacing of 7.5 m x 7.5 m.

The trial was conducted in RBD with four replications. Considering single tree as one replication, there were four trees under each treatment. Five litre of the solution prepared at specified concentration was sprayed to each tree canopy during late September (before preblossom flush emergence) with a rocker sprayer.

The trees were observed for the vegetative, flowering, nut and yield characters as specified for the observational trial (3.3.1.1, 3.3.1.2 and 3.3.1.3). The data were analysed in RBD and the best combination was selected for further studies.

3.3.3. Varietal response to spray application of selected chemical combination (cultar 1000 mg l^{-1} +KNO_3 1% + carbaryl 0.10%)

The best chemical treatment identified in the observational and second screening trial was further tested by applying it as spray to the following seven varieties during 1997-'98 season.

Early high yielders	Anakkayam-1 and Madakkathra-1
Mid season high yielders	Dhana, Kanaka and Dharasree
Late high yielders	Madakkathra-2 and Sulabha

Six year old grafts planted at a spacing of 7.5 m x 7.5 m were used for the study. Four trees under each variety received the chemical treatment while the control plants were given water spray. Five litre of the solution was used for giving soaking spray to each tree canopy.

Observations recorded were same as that described for the observational trial (3.3.1.1, 3.3.1.2 and 3.3.1.3).

The data were analysed in RBD, computing the mean deviation of each character recorded in treated plants that from control. When the coefficient of variation for a particular character exceeded 30, the data were subjected to logarithmic transformation and analysis of variance was performed. The values were then transformed to original scale , computing antilogarithms. The intensity of deviation was compared using Duncans's Multiple Range Test (DMRT).

3.3.4 *Effect of selected chemical combination (cultar 1000 mgl^{-1} + KNO_3 1% + carbaryl 0.10 %) in large plot trial*

The effect of best chemical treatment selected viz., cultar 1000 mgl^{-1} combined with KNO_3 at one per cent level and carbaryl 0.10 per cent for flowering regulation in previous trials was further tested during 1998-'99 season on more number of trees (at a spacing of 7.5 m x 7.5 m) in compact block (large plot). Treatments were imposed on 15 trees (six year old) of the variety Madakkathra-1 (early high yielder) and 15 trees of the variety Madakkathra-2 (late high yielder) in separate blocks. Five trees in each plot served as the control.

Observations on vegetative, flowering, nut and yield characters were recorded as detailed in the observational trial (3.3.1). Data were analysed statistically for the extent of variation in each character expressed among treated plants and control.

3.3.5 *Changes in biochemical constituents in response to spray application of the selected chemical combination*

Samples were drawn from two plants of the variety Madakkathra-2 and analysed separately for different biochemical constituents. Leaf samples from mature lateral shoots were collected three days before and after chemical application and immediately after flushing.

Samples could not be collected from mature shoots after flowering, since no standard leaves were left on them due to heavy leaf fall after chemical application. Leaf samples were also collected from reproductive flushes at three

stages viz., before flowering, after flowering and after nut set from treated as well as control plants.

The biochemical components analysed were total nitrogen, carbohydrates, starch, total phenols and chlorophyll. The procedures suggested by Sadasivam and Manickam (1996) were adopted for the analysis.

3.3.6 *Variation in varietal characters in response to foliar application of the selected chemical combination (pooled analysis)*

The data generated on vegetative, flowering, nut and yield characters in the former trials pertaining to the variety Madakkathra-1 (3.3.3 and 3.3.4) and Madakkathra-2 (3.3.2, 3.3.3 and 3.3.4) were subjected to pooled analysis to estimate the over all effect of the chemical on these two varieties.

3.3.7 *Varietal response to soil application of cultar*

The effect of soil application of cultar at the rate of 3 ml per plant in regulation of flowering was studied in the following varieties during 1998-'99 season.

Early high yielders	Anakkayam-1 and Madakkathra-1
Mid season high yielders	Dhana and Kanaka
Late high yielders	Madakkathra -2 and Sulabha

Six year old grafts planted at a spacing of 7.5 m x 7.5 m were given the treatment. Four trees under each variety received the chemical treatment and was compared with the control.

Cultar, 3 ml was dissolved in three litres of water and poured to pits of size 0.2 m x 0.2 m with 20 cm depth taken 30 cm away from the tree trunk. Application of three litres water served as the control. Five litres of water was further applied in alternate days for two weeks to the treated plants (to enhance the absorption of chemical) as well as to control.

Observations recorded were same as that taken for the observational trial (3.3.1.1, 3.3.1.2 and 3.3.1.3). The data were analysed using Duncan's Multiple Range Test (DMRT) after analysis of variance.

3.4 Induction of dwarfism in cashew grafts at nursery stage

The possibility to induce dwarfism in planting materials of cashew (grafts) at nursery stage was studied by adopting two methods

(i) Irradiation of seeds used to raise root stocks

(ii) Application of cultar (paclobutrazol) to cashew grafts

3.4.1 Irradiation of seeds, raising root stocks and grafting

Hundred seeds of uniform weight each of the variety Madakkathra-1 were subjected to irradiation at doses 5, 10, 15, 20, 25, 30, 40, 50, 60 and 70 Gy, using cobalt 60 source at the Radio Tracer Laborotory, Kerala Agricultural University,Vellanikkara, Thrissur. The treated seeds were sown separately in polybags of size 9" x 6" filled with potting mixure 1:1:1 (cowdug:sand:soil).

Germination percentage of seeds at different levels of irradiation was recorded at five days interval upto one month and survival of the seedlings recorded two months after germination.

Growth parameters viz., height, girth and number of leaves of the seedlings were recorded at 15 days after germination and those seedlings which recorded a height of 5 cm less than that of control were selected and kept separately denoting as apparent dwarfs. Biometric characters of the selected dwarf root stocks viz. height, girth, number of leaves per plant were recorded at 15 days interval upto 60 days after germination.

Twenty seedlings each belonging to the different irradiation doses were grafted two months after germination with scions of the variety Madakkathra-1, adopting soft-wood grafting technique.

The success of grafting was assessed based on the sprouting recorded one month after grafting and subsequent survival was recorded when the grafts attained two and three months old.

Five grafts were selected randomly from each group and their growth parameters such as height, girth and number of leaves were recorded at three months interval upto one year (growth in polybags) and compared with that of control.

Based on the observations for one year, the apparent dwarfs were transplanted to the pots of size 20" x 18" filled with potting mixture and their growth parameters were recorded for another one year.

3.4.2 Application of cultar (paclobutrazol) to cashew grafts at nursery stage

Possibility of inducing dwarfism in young cashew grafts through chemical means was tried by applying cultar to grafts grown in polybags (size 15" x 10") filled with potting mixture. One month old cashew grafts (of uniform size) of the variety Sulabha were used for the purpose .

The different doses of the chemicals applied were cultar at the rate of 1, 2, 3, 4, 6, 8 and 10 ml per plant. There were four grafts under each treatment with five replications.

The irrigation was withheld for two days for the selected plants and the specified quantity of chemical diluted to one litre with water was then applied around the plants 3 cm away from the base. Treatments were imposed twice to the same graft, first at one month age and then at three months age.

The grafts were not irrigated for three days and irrigated slightly for next three days and then irrigated as usual.

Observations on height, girth and number of leaves per plant of the treated grafts were recorded at three months interval retaining them in polybags upto 12 months age and compared with that of control.

Based on the observations on growth parameters, apparent dwarfs (those measured a height 10 cm less than control plants) were transplanted to the mud pots (holding 25 to 30 kg soil) together with control for comparison. Their growth performance was evaluated for another one year. Data were tabulated and analysed in CRD.

3.4.3 Variation in biochemical and anatomical characters

3.4.3.1 Biochemical characters

Biochemical constituents in the leaves of the selected dwarf grafts were recorded when they attained two year old. For this third or fourth leaf from the top of the mature shoots were drawn from grafts belonging to cultar treatment (1 and 2 ml per plant) and irradiation treatment (20, 30 and 40 Gy) and compared with respective control.

The samples were analysed for the carbohydrate, nitrogen, chlorophyll, phenols and Nitrate Reductase Activity (NRA). The method adopted for analysing the specified constituents were as given in 3.2.1.

3.4.3 Anatomical characters

Observations on stomatal index, leaf thickness, cuticle thickness, bark thickness and number of xylem vessels per unit area of the selected dwarf grafts (in both the treatments viz., irradiation (20, 30 and 40 Gy) and cultar application (1 and 2 ml per plant) were recorded when the grafts were two year old and compared with respective control.

(i) Stomatal Index (SI)

The stomatal index was recorded following the method suggested by Johansen (1940). Leaf peelings of the youngest fully matured leaf (third or fourth leaf from top) were taken from upper and lower surface of one year old seedlings. The peelings were dipped in 10 per cent acetone for 24 hours and were made chlorophyll free. The peelings were then washed in water and stained with saffranine for one minute. The stained samples were washed with water

and mounted on a slide with glycerol. Stomatal count per unit leaf area was taken from 20 spots from upper and lower surfaces with the help of Leitz Dialux-20 microscope at 25 x magnification and mean worked out.

(ii) Leaf thickness (mm)

The thickness of youngest fully matured leaf (third or fourth leaf from the top) was measured in mm using a vernier caliper. The measurements were taken from 10 samples per treatment and the mean worked out.

(iii) Cuticle thickness (µm)

Thin transverse sections were prepared from the youngest fully matured leaf (third or fourth leaf from the top) and were stained by Sudan IV prepared by dissolving 0.5 g of the dye in 100 ml of 70 per cent alcohol (Loequin and Langerson, 1978). The sections were stained for 20 minutes and mounted on a slide with glycerol (Johansen,1940). The measurements on cuticle thickness were made at 25 x magnification (with calibrated eye piece micrometer attached to CETI binocular research microscope) in the region of intense red stained cuticle, overlying the epidermal cell wall. Twenty measurements were taken from different spots of every section both on upper and lower surfaces and mean worked out.

(iv) Bark thickness (mm)

Sections from the stem portion adjacent to the youngest fully matured leaf (third or fourth leaf from the top) were taken and bark thickness was measured using calibrated eye piece micrometer and expressed in millimetre (mm). Ten measurements were taken for every treatment and the mean worked out.

(v) Number of xylem vessels (mm^{-2})

Cross sections of the stem portion adjacent to the youngest fully matured leaf (third or fourth leaf from the top) were taken and number of xylem vessels per unit area were counted separately using a CETI binocular research microscope

fitted with calibrated eye piece micrometre. For different treatments, observations were recorded from ten locations and mean worked out. Photographs were taken with the help of NIKON trinocular research microscope attached with camera.

3.4.4 Evaluation of selected dwarfs in the field

Two dwarf grafts each selected from irradiation (20, 30 and 40 Gy) and cultar treatments (1 and 2 ml per plant) were transplanted to the field at a spacing of 7.5 m x 7.5 m. The growth performance viz., height, girth and number of leaves per plant were recorded for six months at an interval of three months.


Results

RESULTS

The results of the present investigation "**Morphophysiological analysis of growth and yield in cashew**" are presented under four major heads.

1. Evaluation of germplasm to estimate the variation in morphological characters among cashew genotypes and analysis of yield components
2. Variation in biochemical and anatomical characters among varieties at different physiological stages of reproductive growth
3. Chemical regulation of flowering
4. Induction of dwarfism in cashew grafts at nursery stage.

4.1 Evaluation of germplasm to estimate the variation in morphological characters among cashew genotypes and analysis of yield components

4.1.1 Grouping of germplasm

The varieties classified into different categories based on their flowering behaviour and yield performance are presented below:

(i)Based on flowering behaviour

The early, mid and late season varieties identified based on their date of flowering during 1996-'97 and 1997-'98 season are given in Table 1. Twelve varieties which attained the flowering stage before mid November of each year was grouped as early, 38 varieties which flowered between mid November and December were grouped as mid season and those flowered after mid December were grouped as late season. Accordingly there were 12 early varieties, 38 mid season varieties and 17 late varieties. The variety Anakkayam-1 which recorded 50 per cent flowering by first fortnight of October was identified as the earliest among 67 varieties studied. Another variety which came into flowering during

Table 1. Grouping of genotypes based on flowering behaviour (1996-'97 and 1997-'98)

Early season			
Sl No	Variety	Date of flowering	
		1996-' 97	1997-' 98
1	2	3	4
1	Anakkayam-1	11-10-'96 (11)	14-10-'97(14)
2	BRZ-248(s)	28-10-'96 (28)	21-10-'97(21)
3	Madakkathra-1	03-11-'96 (34)	12-11-'97(43)
4	H-1588	02-11-96 (33)	12-11-'97(43)
5	H-1589	02-11-'96 (33)	12-11-'97 (43)
6	BRZ-239	02-11-'96 (33)	13-11-'97 (44)
7	BRZ-120	10-11-'96 (41)	14-11-'97(45)
8	Paruthiyara	12-11-'96 (43)	14-11-'97 (45)
9	H-3-13	10-11-'69 (41)	14-11-'97 (45)
10	BRZ-2	17-11-'96 (48)	13-11-'97(44)
11	BRZ-3	15-11-'96 (46)	13-11-'97(44)
12	PU-8	02-11-'96 (33)	14-11-'97(44)
Mid season			
Sl No	Variety	Date of flowering	
		1996-' 97	1997-' 98
1	Kanaka	12-11-'96 (43)	18-11-'97(49)
2	BRZ-241	25-11-'96 (56)	18-11-'97(49)
3	BRZ-244	25-11-'96 (56)	18-11-'97(49)
4	H-3-4	20.11'96 (51)	18-11-'97(49)
5	H-1600	30-11-'96 (61)	20-11-'97(51)
6	H-1610	28-11-'96 (59)	20-11-'97(51)
7	Dharasree	28-11-'96 (59)	20-11-'97(51)
8	Pu-7	08-12-'96 (69)	26-11-'97(57)

Contd

Table

Table 1. Continued

1	2	3	4
9	H-8-7	20-11-'96 (51)	27-11-'97(58)
10	H-8-6	04-12-'96 (65)	27-11-'97(58)
11	UL-12-2	02-12-'96 (63)	27-11-'97(58)
12	BRZ-248(m)	21-11-'96 (52)	27-11-'97(58)
13	H-3-9	24-11-'96 (55)	02-12-'97 (63)
14	Dhana	29-11-'96 (60)	02-12-'97 (63)
15	BRZ-18	12-12-'96 (73)	02-12-'97 (63)
16	K-10-1	10-12-'96 (71)	02-12-'97 (63)
17	H-1593	12-12-'96 (73)	03-12-'97(64)
18	H-1602	12-12-'96 (73)	04-12-'97(65)
19	Akshaya	10-12-'96 (71)	04-12-'97(65)
20	H-8-15	10-12-'96 (71)	04-12-'97(65)
21	Pu-2	18-12-'96 (79)	05-12-'97(66)
22	Pu-6	28-11-'96 (59)	05-12-'97(66)
23	Pu-4	28-11-'96 (59)	06-12-'97 (67)
24	K-22-1	14-12-'96 (75)	06-12-'97 (67)
25	K-3-1	4-12-'96 (65)	07-12-'97 (68)
26	K-3-2	11-12-'96 (72)	08-12-'97(69)
27	Rajmundry	02-12-'96 (63)	08-12-'97(69)
28	K-4-1	07-12-'96 (68)	08-12-'97(69)
29	Amrutha	02-12-'96 (63)	10-12-'97(71)
30	A-26-2	02-12-'96 (63)	10-12-'97(71)
31	K-4-2	07-12-'96 (68)	10-12-'97(71)
32	H-680	02-12-'96 (63)	10-12-'97(71)

Contd.

Table 1. Continued

1	2	3	4
33.	A-6-1	02-12-'96 (63)	12-12-'97(73)
34	H-9-3	02-12-'96 (63)	12-12-'97(73)
35	H-682	03-12-'96 (64)	12-12-'97(73)
36	Pu-1	03-12-'96 (64)	12-12-'97(74)
37	Vapala	11-12-'96 (72)	12-12-'97(74)
	Late season		
Sl No	Variety	Date of flowering	
		1996-' 97	1997-' 98
1	Priyanka	31-12-'96 (92)	18-12-'97(79)
2	H-718	02-01-'97 (94)	18-12-'97(79)
3	H-719	02-01-'97 (94)	18-12-'97(79)
4	H-856	02-01-'97 (94)	18-12-'97(79)
5	K-30-1	29-01-'97 (121)	19-12-'97(80)
6	H-8-8	02-02-'97 (125)	19-12-'97(80)
7	Anagha	02-01-'97 (94)	20-12-'97(81)
8	KTR-27	27-12-'96 (88)	20-12-'97(81)
9	K-18-2	21-01-'97 (113)	26-12-'97(87)
10	M-1-2	14-01-'97 (106)	04-1-'98 (96)
11	K-19-1	29-01-'97 (121)	04-1-'98 (96)
12	K-19-2	20-01-'97 (112)	05-1-'98 (97)
13	Sulabha	27-01-'97 (119)	07-1-'98(99)
14	H-8-10	18-01-'97 (110)	08-1-'98 (100)
15	K-16-1	17-01-'97 (109)	08-1-'98 (100)
16	PTR-1-1	08-02-'97 (131)	12-1-'98 (104)
17	Madakkathra-2	28-01-'97 (120)	18-1-'98(110)

Values in the parenthesis denote the character assigned to each variety based on its date of flowering

Mean of the character of total population = 66.20

Standard deviation (SD) = 21.13

October was BRZ-248(s). All other early varieties identified in the study flowered in the first fortnight of November.

Among the 38 mid season varieties studied, flowering time of 13 varieties were in the second fortnight of November and for the remaining in the first fortnight of December.Among the mid season varieties H-1596 was the earliest.

Seventeen varieties were grouped as late. Among these, PTR-1-1 was identified as the most late, which flowered during first week of February in 1996-'97 and late January in 1997-'98 season.

(ii) Based on yield performance

The 67 varieties grouped as high, medium and low yielding, based on the mean yield for 1996-'97 and 1997-'98 season are given in Table 2. The yield data of the varieties for these two seasons are separately given in Appendix-III.

Ten varieties were identified as high yielders with yield above 3.75 kg.The variety Madakkathra-2 was the highest yielder (5.35 kg) followed by BRZ-248(s) (5.17 kg). The other varieties with high yield were Anakkayam-1 and Priyanka which recorded a yield of 4.98 kg and 4.93 kg respectively.

Nineteen medium yielding varieties were identified with a yield status between 2.25 kg and 3.75 kg. Among them H-1588 which recorded a yield of 3.64 kg ranked first followed by BRZ-120 (3.58 kg).In this yield group, the variety Akshaya recorded the lowest yield (2.69 kg.)

It was observed that 38 varieties (56.71%) in the germplasm were low yielders.(yield < 2.25 kg). Twelve varieties which recorded an yield below 1kg were designated as very poor yielders.

Table 2. Grouping of cashew germplasm based on yield performance (1996-'97 and 1997-'98)

High yielders (yield > 3.75 kg)		Medium yielders. (yield 2.25 to 3.5 kg)		Low yielders. (Yield < 2.25 kg)			
Variety	Yield (kg)	Variety	Yield (kg)	Variety	Yield (kg)	Variety	Yield (kg)
BRZ-248(s)	5.17	BRZ-120	3.58	H-680	1.87	K-10-1	1.12
Priyanka	4.93	H-1588	3.64	M-1-2	1.74	A-6-1	1.25
Anagha	4.79	K-22-1	3.38	BRZ-244	1.94	Pu-6	1.14
Madakkathra-2	5.35	H-1600	3.43	H-8-8	1.44	H-3-4	1.29
Anakkayam-1	4.98	Amrutha	3.45	H-682	1.59	BRZ-241	1.18
H-1596	4.41	Vapala	3.30	H-8-7	1.47	PTR-1-1	1.45
Dharasree	4.67	Sulabha	3.51	K-3-2	1.68	A-26-2	1.15
H-1593	3.91	H-1610	3.16	Paruthiyara	1.78	K-16-1	0.77
Madakkathra-1	4.30	H-856	3.29	K-18-2	1.19	H-8-10	0.73
Kanaka	3.87	KTR-27	3.19	K-3-1	1.09	Pu-8	0.87
		H-1589	3.66	H-9-3	1.34	K-4-2	0.92
		H-1602	3.08	Pu-1	1.22	H-8-15	0.79
		H-8-6	3.21	K-19-2	1.02	UL-12-2	0.31
		K-19-1	3.03	K-30-1	1.40	H-718	1.02
		H-3-13	3.13	BRZ-18	0.80	Pu-2	1.13
		BRZ-248(m)	2.99	BRZ-2	1.15	K-4-1	0.98
		Akshaya	2.69	BRZ-3	1.46	Pu-7	0.59
		H-3-9	2.74	BRZ-239	1.08	Rajmundry	0.62
		Dhana	2.77	H-719	1.36	Pu-4	0.73

Mean yield of the population = 2.27 kg Standard Deviation (SD) = 1.50

(iii) Based on flowering behaviour and yield

The list of varieties coming under each group formed based on flowering behaviour and yield performance are given in Table 3. Among the 10 high yielding varieties, three each were grouped under early and late season and four under mid-season. Out of 19 medium yielders, four were early, 11 midseason and four late varieties.

Among the low yielders, five were early, 23 mid season and 10 late varieties. Major percentage (39.48%)of low yielders were identified as mid season varieties.

4.1.2 Variation in morphological characters

The varieties selected (Plate 2) for analysing the variability in vegetative, flowering, nut and yield characters are presented below

Group	Variety
Early high yielders(EH)	Madakkathra-1, Anakkayam-1 BRZ-248(s)
Mid season high yielders (M.H)	H-1596 H-1593, Dharasree
Late high yielders (L.H)	Priyanka, Anagha, Madakkathra-2
Early medium yielders (E.M)	BRZ-120, H-1589, H-1588
Mid season medium yielders (M.M)	H-1610 Amrutha H-1600
Late medium yielders (L.M)	K-19-1, H-856, KTR-27
Early low yielders (E.L)	BRZ-2, BRZ-3, Pu-8
Mid season low yielders (M.L)	A-6-1, A-26-2, Pu-1
Late low yielders (L.L)	H-719, H-718, K-30-1

Plate 2. *Cashew varieties chosen for the study*

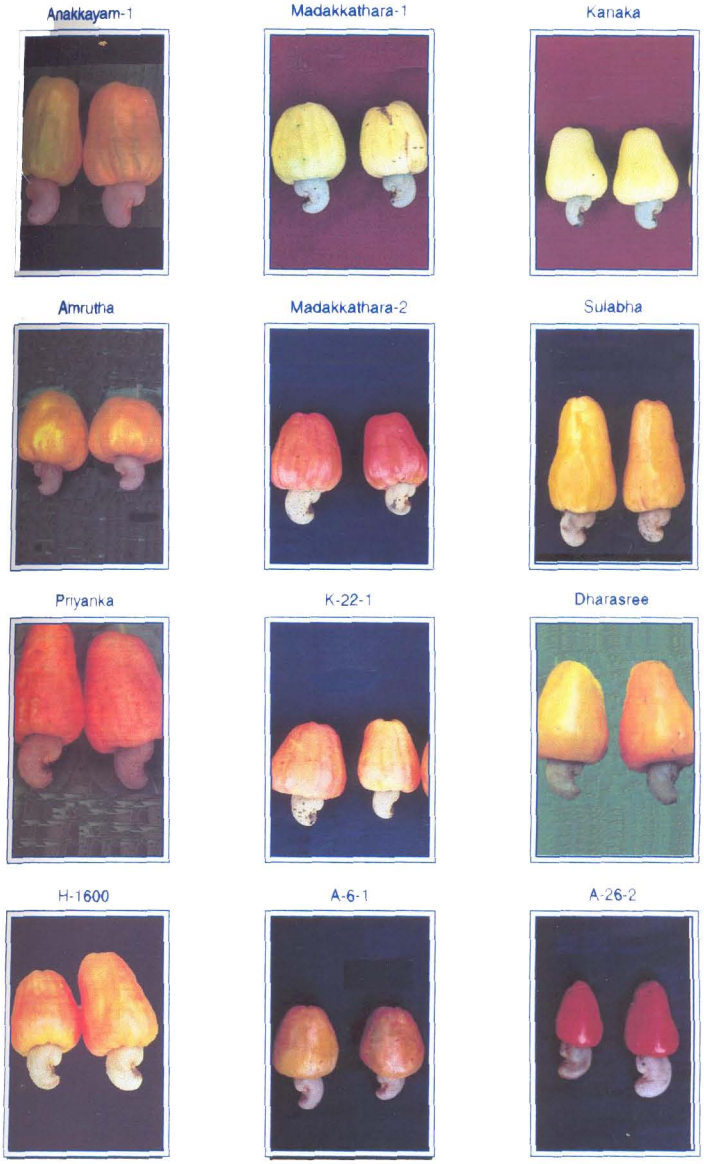


Table 3. Grouping of cashew germplasm based on flowering behaviour and yield performance

Early season			Mid season				Late season		
Yield group			Yield group				Yield group		
High	Medium	Low	High	Medium	Low		High	Medium	Low
Anakkayam-1	H-1588	BRZ-239	Kanaka	H-1600	BR-241	Pu-4	Priyanka	H-856	H-718
Madakkathra-1	H-1589	Paruthiyara	H-1596	H-8-6	BR-244	K-3-1	Anagha	KTR-27	H-719
BRZ-248(s)	BRZ-120	BRZ-2	H-1593	BRZ-248(m)	H-3-4	K-3-2	Madakkathra-2	K-19-1	K-30-1
	H-3-13	BRZ-3	Dharasree	H-3-9	Pu-7	Rajmundry		Sulabha	H-8-8
		Pu-8		Dhana	H-8-7	K-4-1			K-18-2
				H-1602	UL-12-2	K-4-2			M-1-2
				H-7-6	BRZ-18	H-680			K-19-2
				K-22-1	K-10-1	H-9-3			H-8-10
				Amrutha	H-8-15	H-682			PTR-1-1
				Vapala	Pu-2	A-6-1			K-16-1
				H-1610	Pu-6	Pu-1			
						A-26-2			

The selected varieties were analysed for the variation expressed among them for 18 morphological characters (Appendix-IV, Plate 3) and the results are presented as vegetative, flowering, nut and yield characters.

4.1.2.1 Vegetative characters

The mean values for the characters viz., height, trunk girth, spread, flushes per unit area, shoot girth, flush length and number of leaves pertaining to each variety are given in Table 4.

(i) Height (m)

The height recorded for the selected 27 varieties varied considerably (Table 4). However significant difference was not observed among the varieties A-6-1, Anagha, A-26-2, Madakkathra-2, BRZ-248(s),Madakkathra-1, H-1610, Pu-1, BRZ-3, Priyanka, BRZ-2 and K-30-1. They were found superior with respect to plant height. Lowest height was recorded for H-1600, which was on par with H-1589, H-719, K-19-1, H-1593, H-1588 and H-1600.

(ii) Trunk girth(cm)

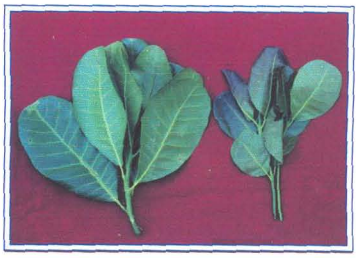
Variation was observed among the varieties for trunk girth. Significantly high girth was recorded by the varieties H-1600 and KTR-27. The girth recorded for BRZ-248(s) (43.50 cm), H-1593 (45.75 cm), Dharasree (47.75 cm) and H-856 (46.75 cm) were significantly inferior to rest of the varieties studied.

(iii) Spread (m)

Considerable variation with respect to spread was observed among the varieties studied.(Table 4) Maximum spread was recorded with BRZ-120 (6.15 m) which was significantly superior to rest of the varieties. The high yielding varieties BRZ-248(s), Anakkayam-1, Anagha and Madakkathra-2 and medium yielding varieties KTR-27, K-19-1, H-1589 and Amrutha recorded more or less same spread.The variety Pu-8 (3.63 m) ranked inferior for this character.

Plate 3. ***Variability in morphological characters***

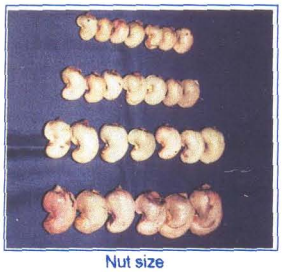
Flush length



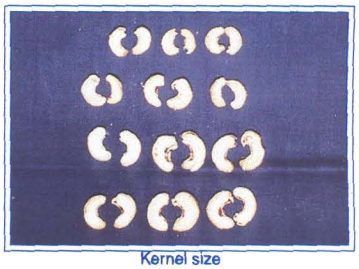
Shoot girth

Panicle length

Nutset



Nut size



Kernel size

Table 4. Variability in vegetative characters of 27 selected cashew varieties

	Sl.No	Variety	Height (m)	Trunk girth (cm)	Spread (m)	No: of flushes (m^{-2})	flush length (cm)	No: of leaves ($flush^{-1}$)	Shoot girth (cm)
1	2	3	4	5	6	7	8	9	10
	1	Madakkathra-1	5.45^{ab}	53.50^{bcdef}	4.75^{cde}	13.75^{cde}	9.82^{efg}	4.45^{defghij}	1.96^{bcdefghi}
E.H	2	Anakkayam-1	4.80^{efghi}	55.50^{bcdef}	5.25^{bcd}	15.95^{ab}	9.62^{efg}	4.43^{defghij}	2.07^{bcde}
	3	BRZ-248(s)	5.45^{ab}	43.50^{g}	5.28^{bcd}	16.38^{a}	8.48^{fghij}	4.62^{cdefghi}	1.78^{hi}
	4	H-1596	4.7^{ghi}	52.25^{cdefg}	4.38^{efgh}	13.5^{cde}	8.70^{fghi}	6.23^{b}	1.85^{efghi}
M.H	5	H-1593	4.35^{ilk}	45.75^{fg}	3.80^{hij}	14.55^{bcd}	9.00^{efghi}	4.75^{cdefghi}	1.87^{efghi}
	6	Dharasree	5.07^{bcdefg}	47.75^{fg}	4.10^{ghij}	13.35^{cde}	8.45^{fghij}	4.75^{cdefghi}	1.98^{bcdefghi}
	7	Priyanka	5.28^{abcde}	53.25^{bcdf}	4.43^{efg}	15.10^{abc}	9.07^{efghi}	4.32^{efghij}	1.97^{bcdefghi}
L.H	8	Anagha	5.67^{a}	56.75^{bcde}	5.18^{bc}	13.75^{cde}	8.98^{efghi}	5.88^{abc}	1.93^{bcdefghi}
	9	Madakkathra-2	5.50^{ab}	54.00^{bcdef}	4.98^{bcd}	13.65^{cde}	7.82^{ghij}	4.28^{fghij}	2.05^{bcdef}
	10	BRZ-120	4.68^{ghij}	59.00^{bcd}	6.15^{a}	12.65^{def}	6.42^{j}	3.15^{j}	2.13^{abcd}
E.M	11	H-1589	4.55^{hijk}	50.25^{defg}	5.13^{abc}	13.15^{cde}	9.50^{efgh}	4.35^{efghij}	2.15^{abc}
	12	H-1588	4.20^{jk}	52.75^{cdefg}	5.00^{cdef}	12.05^{efg}	9.73^{efg}	5.43^{bcdefg}	1.91^{defghi}
	13	H-1610	5.43^{abc}	56.75^{bcd}	4.50^{defg}	14.50^{bcd}	8.38^{fghij}	4.20^{ghij}	2.03^{bcdefg}
M.M	14	Amrutha	4.88^{defgh}	53.25^{bcdef}	5.10^{bc}	13.85^{cde}	8.25^{fghij}	5.48^{bcdef}	1.99^{bcdefgh}
	15	H-1600	4.07^{k}	72.25^{a}	4.20^{efghij}	12.90^{def}	7.35^{hij}	3.95^{hij}	1.76^{I}

Contd.

Table 4. Continued

1	2	3	4	5	6	7	8	9	10
	16	K19-1	4.50 ^{hijk}	54.00 ^{bcdef}	5.15 ^{bc}	12.60 ^{def}	8.15 ^{ghij}	4.38 ^{defghij}	1.85 ^{efghi}
L.M	17	H-856	4.75 ^{ghi}	46.75 ^{fg}	4.20 ^{efghij}	13.80 ^{cde}	8.90 ^{efghi}	4.85 ^{cdefghi}	2.02 ^{bcdef}
	18	KTR.27	4.57 ^{hij}	71.00 ^{a}	5.65 ^{b}	12.25 ^{efg}	7.20 ^{ij}	3.63 ^{ij}	1.88 ^{efghi}
	19	BRZ-2	5.27 ^{abcde}	61.00 ^{bcd}	4.05 ^{fghij}	9.75 ^{hi}	12.90 ^{bc}	5.60 ^{bcdef}	2.32 ^{a}
E.L	20	BRZ-3	5.30 ^{abcd}	49.25 ^{efg}	4.08 ^{fghij}	12.10 ^{efg}	13.68 ^{abc}	6.50 ^{b}	1.54 ^{j}
	21	Pu-8	4.95 ^{cdefgh}	58.25 ^{bcd}	3.63 ^{j}	9.70 ^{hi}	15.25 ^{a}	9.08 ^{a}	1.83 ^{fghi}
	22	A-6-1	5.72 ^{a}	58.25 ^{bcd}	3.88 ^{ghij}	11.00 ^{fgh}	10.90 ^{de}	4.88 ^{cdefghi}	1.92 ^{cdefghi}
M.L	23	A-26-2	5.53 ^{ab}	51.75 ^{cdefg}	3.75 ^{ij}	10.65 ^{gh}	10.38 ^{def}	4.45 ^{cdefghi}	1.84 ^{efghi}
	24	Pu-1	5.40 ^{abc}	61.25 ^{bc}	4.08 ^{fghij}	8.00 ^{I}	10.92 ^{de}	5.75 ^{bcd}	1.81 ^{ghi}
	25	H-719	4.52 ^{hijk}	55.25 ^{bcdef}	3.70 ^{ij}	9.40 ^{hi}	13.27 ^{bc}	5.70 ^{bcde}	1.98 ^{bcdefghi}
L.L	26	H-718	4.78 ^{fghi}	54.75 ^{bcdef}	3.85 ^{ghij}	10.05 ^{b}	12.15 ^{cd}	5.27 ^{bcdefgh}	2.15 ^{ab}
	27	K-30-1	5.25 ^{abcdef}	62.75 ^{b}	4.33 ^{efghi}	10.50 ^{gb}	14.63 ^{ab}	8.13 ^{a}	1.95 ^{bcdefghi}

Values having any common superscript are not significantly different from one another

E.H - Early season high yielders
E.M - Early season medium yielders
E.L - Early season low yielders
M.H- Mid season high yielders
M.M - Mid season medium yielders
M.L- Mid season low yielders
L.H - Late season high yielders
L.M - Late season medium yielders
L.L -Late season low yielders

(iv) Number of flushes (m^{-2})

Number of flushes produced varied significantly among the 27 selected varieties. Variation in flush number among the early high yielding varieties BRZ-248(s), Anakkayam-1 and the high yielding variety Priyanka was not significant, but superior to rest of the varieties. The low yielding varieties were significantly inferior to all high yielding varieties with respect to flush production and were ascribed with low ranks.

(v) Flush length (cm)

Length of flushes varied considerably among the varieties studied. All the nine low yielding varieties were superior with respect to flush length (10.38 to 15.25 cm). All the high and medium yielding varieties were ranked inferior. Flush length was minimum in an early season medium yielding type BRZ-120 (6.42 cm)

(vi) Number of leaves ($flush^{-1}$)

Considerable variation for the number of leaves produced per flush was evident (3.15 to 9.08), with an early low yielding type Pu-8 recorded the maximum and an early medium yielding type BRZ-120 recorded the minimum leaf number per flush.

(vii) Shoot girth (cm)

The varieties varied significantly with respect to girth of flushes after full emergence. Maximum girth was recorded by BRZ-2 (2.32 cm) followed by H-1589 (2.15 cm), H-718 (2.15 cm) and BRZ-120 (2.13 cm) and minimum by BRZ-3 (1.54 cm). This character did not show any relation between the flowering behaviour or yield status of the varieties.

4.1.2.2 Flowering characters

The results of the flowering characters of different varieties studied are given in Table 5.

(i) Number of panicles (m^{-2})

Variation in panicle number was significant (4.90 to 13.30) among the varieties studied. Anakkayam-1 was the top scorer and was on par with the rest of high yielders included in the study viz., BRZ-248(s), Priyanka, H-1593, Dharasree, Anagha, Madakkathra-2, Madakkathra-1 and H-1596.All the low yielders were significantly inferior to the high yielders with respect to this character and the minimum was observed for K-30-1(4.90 m^{-2}). The medium yielders ranked in between.

(ii) Hermaphrodite flowers (%)

Significantly high variation was observed among the varieties for the percentage of hermaphrodite flowers. This character recorded high values for the early high yielder BRZ-248(s) (34.63%), early medium yielder H-1589 (32.56%) and a mid season medium yielder Amrutha (32.46%). Production of hermaphrodite flowers was more or less in the same range (30.83 to 31.77%) among the varieties Madakkathra-1. Madakkathra-2 and H-1588

All the low yielders included in the study ranked low with respect to this character and the values ranged between 6.43 to 16.44 percentage.

(iii) Panicle length (cm)

Length of panicles varied greatly among the varieties studied. Two early, medium yielding varieties H-1588 and H-1589 recorded maximum panicle length (20.50 cm and 20.10 cm respectively) which was on par with KTR-27, H-1593, Anagha, Madakkathra-1, BRZ-120, Amrutha, and H-1610 and H-856. All the low yielders ranked low with respect to this character.

(iv) Panicle breadth (cm)

Panicle breadth varied considerably within the yield groups and ranged between 14.48 cm and 24.57 cm. Maximum panicle breadth was recorded for KTR-27 and minimum for H-719.

Table 5. Variability in flowering characters of 27 selected cashew varieties

	Sl. No	Variety	No: of panicles (m^{-2})	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	No: of nuts (panicle^{-1})
1	2	3	4	5	6	7	8
	1	Madakkathra-1	12.02^{abcde}	30.97^{bcd}	19.09^{abc}	17.92^{ef}	14.69^{a}
E.H	2	Anakkayam-1	13.30^{a}	28.60^{d}	14.77^{g}	16.40^{ef}	13.46^{ab}
	3	BRZ-248(s)	12.90^{ab}	34.63^{a}	14.52^{g}	18.08^{fg}	12.44^{bc}
	4	H-1596	11.85^{abcdef}	21.83^{h}	18.30^{bcde}	17.02^{ef}	9.30^{fg}
M.H	5	H-1593	12.45^{abcd}	22.35^{gh}	19.30^{abc}	17.95^{fg}	9.25^{fg}
	6	Dharasree	12.40^{abcd}	25.51^{ef}	17.33^{cde}	23.55^{ef}	10.19^{efg}
	7	Priyanka	$12.85.^{abc}$	23.53^{fgh}	16.73^{def}	22.45^{ab}	10.81^{def}
L.H	8	Anagha	$12.35.^{abcd}$	25.27^{ef}	19.18^{abc}	24.37^{a}	9.82^{efg}
	9	Madakkathra-2	12.20^{abcd}	30.83^{bcd}	16.20^{efg}	17.33^{ef}	12.06^{bcd}
	10	BRZ-120	$10.85.^{defg}$	26.08^{e}	18.58^{abcd}	18.0^{def}	10.19^{efg}
E.M	11	H-1589	$9.35.^{ghi}$	32.56^{ab}	20.1^{ab}	22.95^{abc}	9.44^{fg}
	12	H-1588	11.20^{bcde}	31.77^{bc}	20.50^{a}	24.20^{a}	8.94^{g}
	13	H-1610	$10.95.^{cdefg}$	23.78^{efgh}	18.38^{abcd}	18.10^{ef}	9.06^{g}
M.M	14	Amrutha	$11.45.^{abcdef}$	32.46^{ab}	18.40^{abcd}	18.02^{ef}	9.75^{fg}
	15	H-1600	$10.05.^{fgh}$	29.74^{cd}	16.92^{de}	23.03^{ab}	11.44^{cde}

Contd.

Table 5. Continued

1	2	3	4	5	6	7	8
	16	K19-1	10.25^{efgh}	26.25^{e}	18.10^{bcde}	17.85^{ef}	12.50^{bc}
L.M	17	H-856	11.85.^{abcdef}	24.37^{efg}	17.98^{abcde}	21.10^{bcd}	9.85^{efg}
	18	KTR.27	8.65^{hij}	22.25^{h}	19.38^{abc}	24.57^{a}	13.13^{b}
	19	BRZ-2	6.25.^{akl}	9.91^{kl}	14.75^{fg}	22.80^{ab}	4.25^{hi}
E.L	20	BRZ-3	8.15^{ij}	9.73^{kl}	12.62^{h}	21.90^{abc}	5.50^{h}
	21	Pu-8	5.60.^{kla}	8.91^{l}	9.65^{ij}	23.08^{ab}	3.69^{I}
	22	A-6-1	6.35.^{kl}	6.43^{h}	9.85^{ij}	18.15^{ef}	5.69^{h}
M.L	23	A-26-2	7.15.^{lk}	12.13^{jk}	11.77^{hi}	18.23^{ef}	2.94 i
	24	Pu-1	6.25.^{kl}	13.30^{j}	11.12^{hij}	17.85^{ef}	4.31^{hil}
	25	H-719	5.50.^{kl}	10.12^{kl}	11.01^{hij}	14.48^{g}	5.88^{h}
L.L	26	H-718	5.93.^{kl}	16.44^{i}	11.08^{hij}	19.00^{def}	4.50^{hi}
	27	K-30-1	4.90^{l}	12.89^{j}	12.33h^{h}	20.02^{cde}	3.56^{I}

Values having any common superscript are not significantly different from one another .

E.H - Early season high yielders E.M - Early season medium yielders E.L - Early season low yielders
M.H- Mid season high yielders M.M - Mid season medium yielders M.L- Mid season low yielders
L.H - Late season high yielders L.M - Late season medium yielders L.L -Late season low yielders

(v) Number of nuts (panicle^{-1})

The cashew varieties exhibited significant variation for number of nuts per panicle. The early high yielders Madakkathra-1 (14.69) and Anakkayam-1 (13.46) were superior to rest of the varieties with respect to this character. The varieties KTR-27, K-19-1, BRZ-248(s) and Madakkathra-2 were on par with Anakkayam-1. All the low yielders were inferior to the high and medium yielders for number of nuts produced per panicle and the values ranged between 2.94 and 5.88.

4.1.2.3 Nut and yield characters

The results of the studies on nut and yield characters of the varieties are given in Table 6.

(i) Hundred nut weight (g)

Variation in hundred nut weight was prominent (320 to 1420 g) among the different varieties studied. The low yielding variety K-30-1 (1420 g) and high yielding variety H-1596 (1405 g) recorded the maximum nut weight. Lowest nut weight was recorded for the low yielding variety H-719.

(ii) Nut length (cm)

Nut length differed significantly among different varieties. This character was maximum for K-30-1 (4.30 cm) which was on par with H-1589 (4.03 cm) and Priyanka (4.00 cm). Nut length was minimum for H-719 (2.50 cm) and on par with Madakkathra-1 (2.56 cm) and H-1600 (2.60 cm)

(iii) Nut breadth (cm)

Considerable variation was noticed among varieties studied with respect to nut breadth. However, variation was insignificant among 13 varieties viz., H-1589, K-30-1, Pu-1, Priyanka, H-1596, BRZ-120, BRZ-248(S), Pu-8, Madakkathra-2 H-1588, BRZ-3, A-26-2 and BRZ-2. Nut breadth was minimum for the variety Dharasree (2 cm)

Table 6. Nut and yield characters of 27 selected cashew varieties

	Sl. No.	Variety	100 nut weight (g)	Nut length (cm)	Nut breadth (cm)	Shelling percentage	Kernel weight (g)	Yield (kg)
1	2	3	4	5	6	7	8	9
	1	Madakkathra-1	614.3^{mno}	2.56^{jk}	2.28^{efgh}	27.00^{hi}	1.63^{ghij}	4.66^{cd}
E.H	2	Anakkayam-1	595.00^{no}	2.95^{ghi}	2.23^{fgh}	28.55^{efg}	1.78^{g}	5.55^{abc}
	3	BRZ-248 (s)	716.00^{kl}	3.03^{gh}	2.85^{abc}	29.33^{def}	1.15^{k}	6.06^{a}
	4	H-1596	1405.00^{a}	3.60^{cde}	2.90^{abc}	32.22^{c}	2.25^{ef}	5.28^{abc}
M.H	5	H-1593	869.25^{fghi}	3.10^{gh}	2.65^{bcde}	31.55^{c}	2.08^{f}	5.10^{bc}
	6	Dharasree	678.75^{lmno}	3.06^{gh}	2.00^{b}	28.63^{efg}	1.68^{ghi}	5.25^{abc}
	7	Priyanka	12500.00^{b}	4.00^{ab}	3.00^{abc}	28.23^{fg}	2.90^{a}	5.88^{ab}
L.H	8	Anagha	1008.75^{de}	2.95^{ghi}	2.30^{efgh}	30.25^{d}	2.93^{a}	5.73^{ab}
	9	Madakkathra-2	900.00^{fgh}	3.50^{cdef}	2.78^{abcd}	29.20^{def}	2.78^{ab}	5.68^{ab}
	10	BRZ-120	764.50^{jkl}	3.60^{cde}	2.90^{abc}	26.30^{I}	1.50^{hij}	4.10^{de}
E.M	11	H-1589	917.50^{efg}	4.03^{ab}	3.08^{a}	36.25^{a}	2.65^{bc}	3.53^{c}
	12	H-1588	1118.75^{c}	3.85^{bc}	2.78^{abcd}	34.15^{b}	2.53^{cd}	3.96^{de}

Contd.

(iv) Shelling percentage

The varieties varied significantly with respect to shelling percentage. This was significantly higher for an early medium yielding variety H-1589 (36.25%) followed by H-1588 (34.15%). The varieties H-1596, Amrutha and H-1593 were on par and were ranked second. Shelling percentage was minimum for the varieties K-30-1 (19.33) and BRZ-2 (18.38)

(v) Kernel weight (g)

Kernel weight per nut differed significantly among the varieties. This character was high for the varieties Anagha (2.93 g) and Priyanka (2.90 g). Kernel weight of K-30-1 (2.80 g) and Madakkathra-2 (2.78 g) were also good.

4.1.2.4 Coefficient of variation, heritability and genetic advance

The selected 27 varieties were analysed for the genotypic and phenotypic coefficients of variation and the results are presented in Table 7. Phenotypic coefficient of variation (PCV) ranged between 10 and 53 per cent and genotypic coefficient of variation (GCV) between seven and 56 per cent. The characters production of hermaphrodite flowers, number of nuts per panicle hundred nut weight and nut yield recorded high genotypic and phenotypic coefficient of variation (GCV ranged between 30.69 and 55.47 per cent while PCV ranged between 31.52 and 52.84 per cent). All other characters recorded low GCV and PCV.

All the characters except tree height, trunk girth, shoot girth and nut breadth recorded high values (>70%) for heritabilty (Table 7). Heritability was high for the characters shelling percentage (97.26%), hermaphrodite flowers (96.83%) and hundred nut weight (94.84%).

Genetic advance (Table 7) recorded for the characters showed wide variation ranging between 0.20 and 514.36 per cent. Maximum genetic advance was observed for hundred nut weight.

Table 7. Coefficient of variation, heritability and genetic advance for 18 characters among 27 selected cashew varieties

Character	Range	Mean	GCV (%)	PCV (%)	Heritability (%)	Genetic Advance
1	2	3	4	5	6	7
Tree height (m)	4.07 -5.72	4.99	8.90	10.74	67.32	0.76
Trunk girth (cm)	43.50 -72.25	55.21	10.92	15.06	52.64	9.01
Tree spread (m)	3.63 -6.15	4.54	14.17	16.16	76.75	1.16
Number of flushes (m^{-2})	8.00 -16.38	12.55	15.95	18.56	73.76	3.55
Flush length (cm)	6.43 -15.25	9.92	22.53	25.91	76.30	4.00
Number of leaves ($flush^{-1}$)	3.15 -9.08	5.13	23.63	28.41	69.84	2.08
Shoot girth (cm)	1.54 -2.32	1.95	7.02	9.87	49.89	0.20
Number of panicles (m^{-2})	4.90 -13.30	9.74	27.97	30.30	85.21	5.18
Hermaphrodite flowers (%)	6.43 - 34.63	21.94	39.24	39.89	96.83	17.46

Contd.

Table 7. Continued

1	2	3	4	5	6	7
Panicle length (cm)	9.65 -20.50	15.85	21.47	23.01	87.48	6.54
Panicle breadth (cm)	14.48 -24.58	19.94	13.78	16.33	71.86	4.78
No: of nuts (panicle^{-1})	2.94 -14.69	8.76	38.82	40.58	91.12	6.70
100 nut weight (g)	320.0-1420.00	835.47	30.69	31.52	94.84	514.36
Nut length (cm)	2.50 -4.30	3.25	14.15	15.82	78.76	0.85
Nut breadth (cm)	2.00 -3.08	2.59	11.06	14.35	59.20	0.46
Shelling percentage	18.38 -36.25	26.92	16.95	17.19	97.26	9.26
Kernel weight (g)	1.13 -2.93	2.02	26.31	27.50	91.70	1.05
Nut yield (kg)	0.73 -6.06	3.41	55.47	52.84	90.63	3.54

4.1.3 Analysis of growth and yield components

4.1.3.1 Correlation of morphological traits with yield

The genotypic and phenotypic correlations of vegetative,flowering and nut characters with nut yield were worked out and the results are presented in Tables 8 and 9 respectively.

The characters showing high positive correlation with nut yield were flushes per unit area, panicles per unit area, number of nuts per panicle, percentage of hermaphrodite flowers, panicle length and shelling percentage. The genotypic correlation (rg) for these characters ranged between 0.73 and 0.96 while phenotypic correlation (rp) ranged between 0.69 and 0.92. The genotypic and phenotypic correlations recorded were the highest for number of panicles per unit area (rg = 0.96 and rp= 0.92).

Maximum negative correlation was observed for flush length (rg= - 0.77 and rp= - 0.63).

4.1.3.2 Interrelation among characters

The tree height recorded significantly negative correlation with panicle length (rg = -0.41) at genotypic level and insignificant correlation with all the characters at phenotypic level (Table 9).

Trunk girth recorded negative correlation with tree height, spread, flushes per unit area, number of panicles per m^2, hermaprodite flowers (%), panicle length number of nuts per panicle, 100 nut weight, shelling percentage, kernel weight and yield. It had positive correlation in low magnitude with rest of the characters. Tree spread registered highest positive genotypic association with percentage of hermaphrodite flowers (0.72) and the number of nuts per panicle (0.69), while flush length recorded highest negative correlation (rg = - 0.70 and rp = -0.50).

Table 8 Genotypic correlation coefficients (rg) among different characters in cashew

	Characters	Tree height (cm)	Trunk girth (cm)	Tree spread (m)	No. of flushes (m^{-2})	Flush length (cm)	No. of leaves ($flush^{-1}$)	Shoot girth (cm)	No. of panicles (m^{-2})	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	Number of nuts ($panicle^{-1}$)	100 nut weight (g)	Nut length (cm)	Nut breadth (cm)	Shelling percentage	Kernel weight (g)
Vegetative characters	Trunk girth (cm)	-0.179																
	Tree spread (m)	-0.196	-0.091															
	No. of flushes (m^{-2})	-0.081	-0.476 **	0.494 **														
	Flush length (cm)	0.232	0.024	-0.700 **	-0.708 **													
	No. of leaves ($flush^{-1}$)	0.164	0.000	0.543 **	-0.515 **	0.836 **												
	Shoot girth (cm)	-0.022	0.056	0.214	-0.024	-0.089	0.292											
Flowering characters	No. of panicles (m^{-2})	-0.121	-0.476 **	0.524 **	0.928 **	-0.806 **	-0.557 **	0.001										
	Hermaphrodite flowers (%)	-0.312	-0.248	0.720 **	0.792 **	-0.787 **	-0.563 **	0.144	0.843 **									
	Panicle length (cm)	-0.410 *	-0.128	0.655 **	0.669 **	-0.784 **	-0.537 **	0.194	0.772 **	0.761 **								
	Panicle breadth (cm)	-0.178	0.278	0.019	-0.077	0.014	0.145	-0.075	-0.024	-0.034	0.293							
	Number of nuts ($panicle^{-1}$)	-0.265	-0.100	0.691 **	0.813 **	-0.820 **	-0.675 **	0.031	0.837 **	0.861 **	0.740 **	-0.037						
Nut and yield characters	100 nut weight (g)	0.039	-0.099	0.181	0.258	-0.169	0.146	-0.019	0.274	0.144	0.413 *	0.191	0.056					
	Nut length (cm)	0.012	0.005	0.083	-0.158	0.334	0.447 **	0.165	-0.188	-0.168	0.021	0.371 *	-0.321	0.597 **				
	Nut breadth (cm)	0.123	0.108	0.159	-0.117	0.094	0.181	-0.052	-0.169	-0.104	-0.021	0.122	-0.270	0.545 **	0.850 **			
	Shelling percentage	-0.323	-0.434 *	0.441 **	0.708 **	-0.668 **	-0.354	-0.010	0.775 **	0.741 **	0.729 **	0.123	0.612 **	0.327	0.036	0.045		
	Kernel weight (g)	-0.024	-0.064	0.196	0.341	-0.208	-0.022	0.163	0.352 *	0.311	0.504 **	0.272	0.200	0.768 **	0.390 *	0.181	0.458 **	
	Yield (kg)	-0.099	-0.360	0.555 **	0.896 **	-0.768 **	-0.491 **	0.035	0.960 **	0.845 **	0.728 **	-0.008	0.834 **	0.313	-0.080	-0.049	0.735 **	0.368 *

Table 9. Phenotypic correlation coefficients (rp) among different characters in cashew

	Characters	Tree height (cm)	Trunk girth (cm)	Tree spread (m)	No. of flushes (m^{-2})	Flush length (cm)	No. of leaves ($flush^{-1}$)	Shoot girth (cm)	No. of panicles (m^{-2})	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	Number of nuts ($panicle^{-1}$)	100 nut weight (g)	Nut length (cm)	Nut breadth (cm)	Shelling percentage	Kernel weight (g)
egetative haracters	Trunk girth (cm)	-0.047																
	Tree spread (m)	0.025	0.108															
	No. of flushes (m^{-2})	0.074	0.304	0.519 *														
	Flush length (cm)	0.183	0.029	-0.503 *	-0.506 *													
	No. of leaves ($flush^{-1}$)	0.123	0.015	-0.358 *	-0.362 *	0.779 *												
	Shoot girth (cm)	-0.003	0.005	0.119	0.006	-0.004	-0.144											
owering haracters	No. of panicles (m^{-2})	-0.018	-0.337	0.503 *	0.883 *	-0.626 *	-0.396 *	-0.014										
	Hermaphrodite flowers (%)	-0.240	-0.180	0.625 *	0.677 *	-0.686 *	-0.470 *	0.096	0.759 *									
	Panicle length (cm)	-0.300	-0.102	0.535 *	0.529 *	-0.621 *	-0.433 *	0.139	0.657 *	0.689 *								
	Panicle breadth (cm)	0.026	0.167	0.155	0.067	0.004	0.105	-0.009	-0.067	-0.032	0.237							
	Number of nuts ($panicle^{-1}$)	-0.132	-0.050	0.666 *	0.751 *	-0.655 *	-0.512 *	0.002	0.802 *	0.804 *	0.669 *	0.004						
ld aracters	100 nut weight (g)	0.021	-0.010	0.138	0.224	-0.146	0.118	-0.009	0.265	0.140	0.305	0.149	0.004					
	Nut length (cm)	0.000	-0.051	0.041	-0.120	0.236	0.329	0.071	-0.145	-0.138	-0.028	0.308	-0.277	0.538 *				
	Nut breadth (cm)	0.059	0.010	0.147	-0.064	0.081	0.145	-0.144	-0.103	-0.080	0.006	0.069	-0.172	0.392 *	0.611 *			
	Shelling percentage	-0.269	-0.311	0.369	0.590 *	-0.587	-0.304	-0.005	0.695 *	0.715 *	0.685 *	0.094	0.573 *	0.317	0.028	0.005		
	Kernel weihght (g)	-0.024	-0.050	0.148	0.292	-0.182 *	0.006 *	0.135	0.323	0.285	0.473 *	0.203	0.182	0.719 *	0.338	0.159	0.424 *	
	Yield (kg)	0.003	-0.230	0.563 *	0.843 *	-0.629 *	-0.380 *	0.024	0.919 **	0.785 *	0.648 *	0.094	0.823 *	0.289	-0.073	-0.024	0.683 *	0.338

The flushes per unit area was positively correlated with panicles per unit area (rg = 0.93 and rp = 0.88) followed by nut yield (rg = 0.90 and rp= 0.84), number of nuts per panicle (rg = 0.81 and rp = 0.75) and percentage of hermaphrodite flowers (rg = 0.79 and rp = 0.68). Flush length recorded high positive correlation with number of leaves (rg = 0.84 and rp = 0.78) and highest negative correlation with number of nuts per panicle (rg = - 0.82 and rp = - 0.67).

Number of leaves per flush was negatively associated with seven characters and highest negative association was observed for number of nuts per panicle (rg = - 0.68 and rp = - 0.51). The magnitude of association of shoot girth with the characters studied was relatively low .

Panicles per unit area registered high positive correlation with flushes per unit area (rg = 0.93 and rp = 0.88) number of nuts per panicle (rg = 0.84 and rp = 0.80) and percentage of hermaphrodite flowers (rg = 0.84 and rp = 0.76) apart from its high correlation with yield. Similar relation was observed between the percentage of hermaphrodite flowers and the characters under study.

Panicle length was positively associated with nut yield and many important yield attributes viz., panicles per unit area (rg = 0.77) percentage of hermaphrodite flowers (rg = 0.76) and number of nuts per panicle (rg = 0.74). The genotypic correlation coefficient for panicle breadth with nut length was significant (rg = 0.37) and the magnitude was very low with rest of the characters studied.

Percentage of hermaphrodite flowers registered high positive correlation with number of nuts per panicle (rg = 0.86 and rp = 0.80) and high negative correlation with flush length (rg = - 0.79 and rp = - 0.69).

Number nuts per panicle exhibited positive association with shelling percentage (rg = 0.61), besides yield.

Hundred nut weight showed high positive association with kernel weight (rg = 0.77 and rp = 0.72). All the nut characters were positively correlated with this character. Both nut length and nut breadth were highly and positively correlated with each other (rg = 0.85 and rp = 0.61)

Among the nut characters, shelling percentage recorded relatively high positive association with kernel weight (rg = 0.46 and rp = 0.42) and hundred nut weight (rg = 0.33 and rp = 0.32). Kernel weight was found to be positively correlated with hundred nut weight (rg = 0.77 and rp = 0.72).

4.1.3.3 Path coefficient analysis

The direct and indirect effects of the component characters on nut yield derived through phenotypic and genotypic path coefficient analysis are furnished in Tables 10 and 11 respectively and the results presented with special reference to genotypic path.

Highest positive direct effect on nut yield was exhibited by panicles per unit area (0.98) and it registered highest positve correlation with yield (0.92). The other characters showing high magnitude were number of leaves ($flush^{-1}$) (0.28), nut length (0.26) and number of nuts per panicle (0.20)

The character which exhibited highest negative direct effect was flush length (-0.35)

Correlation coefficient of flushes per unit area, percentage of hermaphrodite flowers and number of nuts per panicle with nut yield was mainly due to their high positive effect through number of panicles per unit area (0.91, 0.84 and 0.82 respectively) eventhough their direct effects were of low magnitude.

Direct effect of tree height and trunk girth on yield were positive and low (0.05 and 0.12 respectively) while that of spread was negative (-0.19), However spread registered positive correlation with yield (0.56) due to its positive indirect effect through panicles per unit area (0.51)

Table 10 Genotypic path coefficient analysis of yield in cashew

	Characters	Tree height (cm)	Trunk girth (cm)	Tree spread (m)	No. of flushes (m^{-2})	Flush length (cm)	No. of leaves ($flush^{-1}$)	Shoot girth (cm)	No. of panicles (m^{-2})	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	Number of nuts ($panicle^{-1}$)	100 nut weight (g)	Nut length (cm)	Nut breadth (cm)	Shelling percentage	Kernel weight (g)
Vegetative characters	Tree height (cm)	**0.046**	-0.022	0.038	0.003	-0.08	0.046	-0.001	-0.12	-0.034	0.017	0.017	-0.054	-0.007	0.003	0.007	0.042	-0.001
	Trunk girth (cm)	-0.008	**0.122**	-0.017	0.019	-0.008	0.000	0.002	-0.469	-0.037	0.005	-0.027	-0.020	0.017	0.001	0.006	0.056	-0.003
	Tree spread (m)	-0.009	0.011	**-0.190**	-0.019	0.243	-0.152	0.008	0.514	0.085	-0.027	-0.002	0.140	-0.032	0.022	0.009	-0.057	0.009
	No. of flushes (m^{-2})	-0.004	-0.058	-0.094	**-0.039**	0.246	-0.144	-0.001	0.911	0.103	-0.028	0.008	0.165	-0.045	-0.041	-0.007	-0.091	0.016
	Flush length (cm)	0.011	0.003	0.133	0.028	**-0.346**	0.233	-0.004	-0.793	-0.099	0.033	-0.001	-0.166	0.029	0.088	0.005	0.086	-0.010
	No. of leaves ($flush^{-1}$)	0.008	0.000	0.103	0.020	-0.289	**0.279**	-0.011	-0.547	-0.075	0.022	-0.014	-0.137	-0.025	0.117	0.010	0.045	0.001
	Shoot girth (cm)	-0.001	0.007	-0.041	0.001	0.031	-0.082	**0.039**	0.001	-0.021	-0.008	0.007	0.006	0.003	0.044	-0.003	0.001	0.008
Flowering characters	No. of panicles (m^{-2})	-0.006	-0.058	-0.010	-0.036	0.28	-0.155	0.000	**0.981**	0.105	-0.032	0.002	0.170	-0.048	-0.049	-0.010	-0.100	0.016
	Hermaphrodite flowers (%)	-0.013	-0.037	-0.131	-0.033	0.278	-0.168	0.007	0.835	**0.124**	-0.032	-0.003	0.175	-0.025	-0.044	-0.006	-0.095	0.014
	Panicle length (cm)	-0.019	-0.016	-0.125	-0.026	0.272	-0.150	0.008	0.759	0.094	**-0.042**	-0.028	0.150	-0.072	-0.005	-0.001	-0.094	0.023
	Panicle breadth (cm)	-0.008	0.034	-0.003	0.003	-0.005	0.041	-0.003	-0.025	0.004	-0.012	**0.095**	-0.008	-0.033	0.097	0.007	-0.016	0.013
	Number of nuts ($panicle^{-1}$)	-0.012	-0.012	-0.131	-0.032	0.284	-0.189	0.001	0.821	0.107	-0.031	0.004	**0.203**	-0.010	-0.084	-0.015	-0.079	0.009
Nut and yield characters	100 nut weight (g)	0.002	-0.012	-0.034	-0.010	0.059	0.041	-0.001	0.269	0.018	-0.017	-0.018	0.011	**-0.174**	0.157	0.031	-0.042	0.035
	Nut length (cm)	0.001	0.001	-0.016	0.006	-0.116	0.125	0.006	-0.185	-0.021	0.001	-0.035	-0.065	-0.104	**0.262**	0.048	-0.005	0.018
	Nut breadth (cm)	0.006	0.013	-0.030	0.005	-0.033	0.051	-0.002	-0.167	-0.013	0.001	-0.012	-0.055	-0.095	0.224	**0.056**	-0.006	0.008
	Shelling percentage	-0.015	-0.053	-0.084	-0.028	0.231	-0.099	0.000	0.761	0.092	-0.030	-0.012	0.124	-0.057	0.009	0.003	**-0.128**	0.021
	Kernel weight (g)	-0.001	-0.008	-0.037	-0.013	0.072	0.006	0.006	0.345	0.039	-0.021	-0.026	0.041	-0.134	0.102	0.010	-0.059	**0.046**

Residual = 0.0275

Diagonal values (in bold) indicate direct effects

Table 11. Phenotypic path coefficient analysis of yield in cashew

	Characters	Tree height (cm)	Trunk girth (cm)	Tree spread (m)	No. of flushes (m^{-2})	Flush length (cm)	No. of leaves ($flush^{-1}$)	Shoot girth (cm)	No. of panicles (m^{-2})	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	Number of nuts ($panicle^{-1}$)	100 nut weight (g)	Nut length (cm)	Nut breadth (cm)	Shelling percentage	Kernel weight (g)
Vegetative characters	Tree height (cm)	**0.121**	-0.003	-0.002	0.005	-0.017	0.01	0.000	-0.009	-0.028	0.005	0.000	-0.035	0.001	0.000	0.003	-0.018	0.001
	Trunk girth (cm)	-0.007	**0.054**	-0.006	-0.019	-0.003	0.001	0.000	-0.182	-0.028	0.002	0.001	-0.013	-0.004	-0.003	0.000	-0.021	0.001
	Tree spread (m)	0.004	0.006	**-0.058**	0.033	0.048	-0.030	0.004	0.274	0.075	-0.009	0.001	0.180	0.005	0.002	0.007	0.025	-0.003
	No. of flushes (m^{-2})	0.009	-0.016	-0.030	**0.063**	0.048	-0.030	0.000	0.481	0.090	-0.009	0.000	0.203	0.009	-0.007	-0.003	0.040	-0.007
	Flush length (cm)	0.022	0.002	0.029	-0.032	**-0.096**	0.065	-0.001	-0.339	-0.086	0.011	0.000	-0.176	-0.006	0.013	0.004	-0.040	0.004
	No. of leaves ($flush^{-1}$)	0.015	0.001	0.021	-0.023	-0.075	**0.083**	-0.005	-0.214	-0.060	0.008	0.000	-0.138	0.005	0.018	0.007	-0.021	0.000
	Shoot girth (cm)	0.000	0.000	-0.007	0.000	0.004	-0.012	**0.034**	-0.001	0.015	-0.002	0.000	0.000	0.000	0.004	-0.007	0.000	-0.003
Flowering characters	No. of panicles (m^{-2})	-0.002	-0.018	-0.029	0.056	0.060	-0.033	0.000	**0.545**	0.097	-0.012	0.000	0.217	0.010	-0.008	-0.005	0.047	-0.008
	Hermaphrodite flowers (%)	-0.026	-0.012	-0.034	0.044	0.064	-0.039	0.004	0.413	**0.128**	-0.012	0.000	0.218	0.005	-0.007	-0.004	0.049	-0.004
	Panicle length (cm)	-0.036	-0.006	-0.031	0.033	0.059	-0.036	0.005	0.357	0.088	**-0.018**	0.001	0.181	0.014	0.002	0.000	0.047	-0.011
	Panicle breadth (cm)	0.004	0.009	-0.009	0.004	-0.004	0.009	0.000	0.038	0.004	-0.004	**0.004**	0.014	0.006	0.017	0.003	0.006	-0.005
	Number of nuts ($panicle^{-1}$)	-0.016	-0.003	-0.039	0.047	0.062	-0.042	0.000	0.437	0.103	-0.012	0.000	**0.271**	0.002	-0.016	-0.008	0.039	-0.007
Nut and yield	100 nut weight (g)	0.002	-0.005	-0.008	0.014	0.014	0.010	0.000	0.144	0.018	-0.006	0.000	0.013	**0.039**	0.030	0.019	0.022	-0.018
	Nut length (cm)	0.000	-0.003	-0.002	-0.008	-0.022	0.027	0.002	-0.079	-0.017	0.001	0.001	-0.075	0.021	**0.057**	0.030	0.002	-0.008
	Nut breadth (cm)	0.007	0.000	-0.009	-0.004	-0.008	0.012	-0.005	-0.056	-0.011	0.000	0.000	-0.046	0.015	0.034	**0.049**	0.000	-0.004
	Shelling percentage	-0.032	-0.017	-0.021	0.037	0.056	-0.025	0.000	0.378	0.092	-0.012	0.000	0.155	0.012	0.002	0.000	**0.068**	-0.010
	Kernel weight (g)	-0.005	-0.003	-0.009	0.018	0.017	0.000	0.005	0.176	0.036	-0.008	0.001	0.049	0.028	0.019	0.008	0.029	**0.024**

Residual = 0.1012

Diagonal values (in bold) indicate direct effects

The direct effects of vegetative characters viz, shoot girth and number of leaves per flush were positive (0.04 and 0.28 respectively) while that of flush length was negative (- 0.35). Flush length recorded maximum negative correlation with yield among the characters studied and high negative indirect effect through panicles per unit area (- 0.79)

Panicle length showed negative direct effect (- 0.04) but positive correlation with yield, influencing indirectly through panicles per unit area (0.76). Panicle breadth had direct positive effect (0.10) but had negative correlation with yield.

Among the nut characters, nut length and nut breadth had negative correlation, while 100 nut weight, shelling percentage and kernel weight exhibited positive correlation with yield. Shelling percentage and kernel weight influenced yield through maximum indirect positive effect (0.76 and 0.35 respectively) through panicles per unit area.

4.1.3.4 Selecton index

Construction of selection indices using discriminant function technique is immensly helpful to discriminate genotypes on the basis of their phenotypic performance. Out of 18 predictor traits studied, the attributes which exhibited significant genotypic correlation with yield were chosen. Selection indices were constructed using these traits in different combinations and efficiency index worked out.

The selection index constructed including characters like yield, number of panicles per m^2, number of nuts per panicle, percentage of hermaphrodite flowers, panicle length and flush length recorded maximum efficiency of E = i 1.74 as follows:

Character	Coefficient of selection index
Yield	0.766
Number of panicles per m^2	0.112
Number of nuts per panicle	-0.049
Hermaphrodite flowers (%)	0.021
Panicle length	0.024
Flush length	-0.049

Further selection indices were constructed excluding the character sequentially to identify the selection models which had selection efficency more or less equal to that constructed with maximum efficiency.

Finally, excluding the characters percentage of hermaphrodite flowers and panicle length from the selection scenario, a selection index could be constructed as follows:

Character	Coefficient of selection index
Yield	0.814
Flush length	0.083
Number of panicle per m^2	0.258
Number of nuts per panicle	-0.007

$$E = i\ 1.73$$

With minimum phenotypic characters this selection index has efficiency more or less equal to that constructed with maximum efficiency (i 1.74). Thus a selection index based on yield, flush length, number of panicles per m^2 and number of nuts per panicle was identified for selecting superior genotypes in

cashew.

4.2 Variation in biochemical and anatomical characters among varieties at different physiological stages of reproductive growth

4.2.1 Analysis of biochemical constituents

The varieties selected for analysing the variation in biochemical constituents at different physiological stages of reproductive growth in cashew are given below:

Group	Variety
Early high yielder (EH)	Madakkathra-1
Early low yielder (EL)	BRZ-2
Medium high yielder (MH)	Dharasree
Medium low yielder (ML)	A-6-1
Late high yielder (LH)	Madakkathra-2
Late low yielder (LL)	H-718

4.2.1.1 Carbohydrate (%)

(i) Mature shoots

The carbohydrate content in the varieties with respect to different phases of development are presented in Table 12. The content in mature shoots was significantly high in high yielding varieties at all the three phases analysed viz., before flushing, after flushing and after flowering compared to low yielding varieties. Before flushing, maximum carbohydrate was recorded with Madakkathra-2 (9.80%) and the minimum with BRZ-2 (2.61%). After flushing and flowering the carbohydrate content in these shoots decreased in all the varieties studied. The content ranged between 2.92 and 4.46 per cent in high yielders after

Table 12. Varietal variation in carbohydrate (%), nitrogen (%), and C:N ratio at different stages of reproductive growth

Variety	Mature shoots			Reproductive flushes			Vegetative flushes		
	Before flushing	After flushing	After flowering	Before flowering	After flowering	After nut set	Before flowering	After flowering	After nut set
Carbohydrate (%)									
Madakkathra-1	8.06	2.92	1.57	2.19	9.76	3.30	1.59	10.58	10.64
BRZ-2	2.61	1.64	1.60	1.46	3.95	3.38	1.09	6.37	7.64
Dharasree	7.01	3.44	1.78	2.42	6.47	4.52	2.54	8.36	10.67
A-6-1	3.48	1.71	1.67	1.23	2.79	4.03	1.18	5.21	5.83
Madakkathra-2	9.80	4.46	1.70	2.28	8.56	2.84	1.79	6.35	10.43
H-718	3.30	1.93	1.61	1.15	4.30	1.98	1.37	2.92	4.36
CD (P = 0.05)	1.14	1.25	0.10	0.76	2.25	NS	1.59	1.70	3.15
SEm±	0.33	0.36	0.03	0.23	0.65		0.09	0.49	0.91
Nitrogen (%)									
Madakkathra-1	2.78	1.10	0.76	0.45	2.77	1.01	0.42	3.17	3.67
BRZ-2	2.55	1.69	0.99	0.42	2.71	1.99	0.33	2.83	2.96
Dharasree	2.89	0.87	0.70	0.37	2.75	0.87	0.48	3.06	3.55
A-6-1	2.42	1.55	1.04	0.34	2.63	1.67	0.42	2.78	2.96
Madakkathra-2	3.17	0.93	0.87	0.37	2.80	0.87	0.48	3.14	3.47
H-718	2.95	1.85	1.24	0.48	2.55	1.60	0.38	2.50	2.67
CD (P=0.05)	NS	0.38	0.17	NS	0.10	0.35	NS	0.28	0.14
SEm±		0.11	0.05		0.03	0.01		0.08	0.04
C:N ratio									
Madakkathra-1	2.92	2.65	2.07	4.90	3.52	3.27	3.79	3.34	2.90
BRZ-2	1.02	0.99	1.62	3.48	1.46	1.70	3.40	2.25	2.58
Dharasree	2.43	4.08	2.54	6.54	2.35	5.23	5.29	2.73	3.00
A-6-1	1.43	1.11	1.61	3.62	1.06	2.41	2.82	1.88	1.97
Madakkathra-2	3.10	4.83	1.95	6.16	3.06	3.26	3.73	2.02	3.00
H-718	1.12	1.05	1.30	2.40	1.68	1.24	3.61	1.17	1.63
CD (P=0.05)	0.48	1.25	0.07	3.36	0.10	1.42	NS	0.48	0.28
SEm±	0.14	0.36	0.02	0.97	0.03	0.41		0.14	0.08

NS – Non significant

flushing as against 1.64 to 1.93 per cent in low yielders. After flowering it was further reduced to 1.57 to 1.78 per cent in high yielders and 1.60 to 1.67per cent in low yielders.

(ii) Reproductive flushes

Carbohydrate content in the reproductive flushes of high yielders were comparatively higher than that in low yielders, before and after flowering (Table 12). Before flowering carbohydrate content in the high yielders ranged from 2.19 to 2.42 per cent while the range in low yielders was 1.15 to 1.46 per cent. In all the varieties after flowering, there was an increase in the level of carbohydrates. At this stage maximum content was recorded with Madakkathra-1 (9.76%) and minimum with A-6-1 (2.79%).

After nut set the carbohydrate content in the high yielding varieties decreased drastically compared to low yielding varieties.The decline was maximum in Madakkathra-1.

(iii) Vegetative flushes

The difference in carbohydrate content in the vegetative flushes of high and low yielding varieties was insignificant when analysed before flowering. After flowering and nut set comparatively high accumulation of carbohydrates was recorded for the high yielding varieties.

Before flowering, the content was maximum in the mid season high yielding variety Dharasree (2.54%), followed by the other two high yielders viz., Madakkathra-1 (1.59%) and Madakkathra-2 (1.79%). Minimum carbohydrate content was recorded with the early low yielding variety BRZ-2 (1.09%). After flowering, the carboydrate content in these flushes showed pronounced increase in all the varieties studied. The accumulation was high in high yielding varieties with the maximum recorded in Madakkathra-1 (10.58%) and minimum in the late low yielding variety H-718 (2.92%).

After nut set the increase in the carbohydrate content in the high yielding varieties varied between 10.43 to 10.67 per cent while the range in low yielders was only 4.36 to 7.64 per cent.

4.2.1.2 Nitrogen (%)

(i) Mature shoots

The nitrogen content recorded for mature shoots of selected varieties at different stages of reproductive growth is presented in Table 12. The mature lateral shoots of all the varieties irrespective of their flowering behaviour and yield performance did not vary significantly with respect to nitrogen content. The nitrogen in the leaves prior to flushing varied between 2.42 and 3.17 per cent among the varieties studied. However after flushing, the nitrogen level in these leaves was found reduced. At this stage the nitrogen level was significantly high in low yielding varieties (1.55 to 1.85%) compared to high yielding ones (0.87 to 1.10%). After panicle emergence nitrogen in these past season shoots was further decreased in all the varieties analysed and at this stage the content was relatively high in all the low yielding varieties.

(ii) Reproductive flushes

The nitrogen level in the reproductive flushes was low (0.34 to 0.48%) before panicle emergence and it did not vary significantly among the varieties studied.After panicle development the nitrogen content rose suddenly in all the varieties and it ranged between 2.55 and 2.80 per cent. The content was relatively high in high yielders at this stage (2.75 to 2.80 %). After nut set the nitrogen content was decreased in high yielding varieties studied, compared to low yielding varieties.

(iii) Vegetative flushes

The nitrogen level analysed for the vegetative flushes at three stages viz., preflowering, flowering and post nut set are presented in Table 12.

The nitrogen content did not vary considerably among the varieties during the preflowering phase and ranged between 0.33 to 0.48 per cent. During flowering season, the conent in these flushes increased and it was comparatively high in high yielding varieties viz., Madakkathra-1 (3.17%), Dharasree (3.06%) and Madakkathra-2 (3.14%) The nitrogen level was further increased in these flushes after nut set and the accumulation was relatively high in high yielders (3.47 to 3.67%) as against 2.67 to 2.96 per cent in low yielders.

4.2.1.3 C:N ratio

(i) Mature shoots

The C:N ratio of mature shoots was found to be at higher levels in all the high yielding varieties studied compared to low yielding varieties when analysed at the three stages viz., before flushing, after flushing and after panicle development. Before and after flushing C:N ratio was maximum in the late high yielding variety Madakkathra-2 (3.10 and 4.83 respectively) while it was very low in the early low yielding variety BRZ-2 (1.02 and 0.99 % respectively).

After flowering the C:N ratio in these shoots was significantly reduced (1.30 to 2.54) in high yielding varieties. The ratio was found maximum with the variety Dharasree (2.54) and minimum with the variety H-718 (1.30) at this stage.

(ii) Reproductive flushes

The varietal variation with respect to C:N ratio at different phases of development of the reproductive flushes are presnted in Table 12.The ratio was high in high yielding varieties compared to low yielding varieties at all the three stages studied. Before flowering C:N ratio did not vary greatly among the high yieders (4.90 to 6.54%) and low yielders (2.40 to 3.62%). After fowering the ratio was decreased in all the varieties. The reduction was more in the mid season variety Dharasree which registered the maximum decrease between first

and second stage of analysis. After nut set maximum C:N ratio was noted with the midseason highyielding variety Dharasree (5.23) and minimum with the late low yielding variety H-718 (1.24).

(iii) Vegetative flushes

The C:N ratio in vegetative flushes of the selected varieties did not vary greatly when analysed before flowering (Table 12). After flowering the ratio decreased in all the varieties studied . At this stage, maximum ratio was recorded for the variety Madakkathra-1 (3.34). After nut set the ratio in vegetative flushes of all the varieties showed an increase, except in the variety Madakkathra-1 which showed a slight decrease.

4.2.1.4 Chlorophyll (mg g^{-1})

The chlorophyll 'a' , chlorophyll 'b' and total chlorophyll content in the leaves of mature shoots, reproductive and vegetative flushes with respect to three different phases of growth are presented in Table 13.

(a) Mature shoots

The contents of chlorophyll 'a', chlorophyll 'b' and total chlorophyll were high in mature shoots of the high yielding varieties, when analysed before flushing (Table 13). The difference in content among the three high yielding and three low yielding varieties was insignificant. The chlorophyll 'a' at this stage ranged between 1.53 and 1.56 mg g^{-1} in the three high yielding varieties. The chlorophyll 'b' ranged between 1.48 and 1.58 mg g^{-1} in high yielding varieties and was 1.22 to 1.32 mg g^{-1} in low yielding varieties.

When analysed after flushing, the chlorophyll 'a', 'b'and total chlorophyll content in the mature shoot decreased drastically in all the varieties. At this stage, chlorophyll 'a' was maximum in low yielders (0.69 to 0.95 mg g^{-1}) as compared to high yielders (0.47 to 0.70 mg g^{-1}). The total chlorophyll

Table 13.Varietal variation in chlorophyll content (mg g^{-1}) at different stages of reproductive growth

Variety	Before flushing			After flushing			After flowering		
	Chl 'a'	Chl 'b'	Total chl'	Chl 'a'	Chl 'b'	Total chl'	Chl 'a'	Chl 'b'	Total chl'
a) Mature shoots.									
Madakkathra-1	1.53	1.58	3.11	0.47	0.15	0.62	0.14	0.09	0.23
BRZ-2	1.34	1.32	2.66	0.87	0.62	1.49	0.16	0.06	0.22
Dharasree	1.53	1.49	3.02	0.49	0.20	0.69	0.14	0.11	0.25
A-6-1	1.25	1.25	2.50	0.69	0.13	0.82	0.22	0.11	0.33
Madakkathra-2	1.56	1.48	3.04	0.70	0.16	0.86	0.11	0.08	0.19
H-718	1.27	1.22	2.49	0.95	0.15	1.10	0.14	0.47	0.61
CD (P = 0.05)	0.14	010	0.21	0.28	0.14	0.38	NS	NS	NS
SEm±	.04	0.03	0.06	0.08	0.04	0.11			
B) Reproductive flushes	Before flowering			After flowering			After nut set		
Madakkathra-1	0.17	0.14	0.31	0.47	1.53	2.00	0.27	0.18	0.45
BRZ-2	0.16	0.05	0.21	0.32	0.87	1.19	0.21	0.18	0.39
Dharasree	0.19	0.13	0.32	0.44	1.70	2.14	0.24	0.09	0.32
A-6-1	0.17	0.12	0.29	0.25	1.03	1.28	0.30	0.13	0.43
Madakkathra-2	0.17	0.08	0.25	0.51	1.78	2.29	0.29	0.18	0.47
H-718	0.16	0.09	0.24	0.31	0.95	1.26	0.19	0.19	0.38
CD (P = 0.05)	NS	NS	NS	0.07	0.31	0.35	0.03	0.04	0.07
SEm±				0.02	0.09	0.10	0.01	0.01	0.02
c) Vegetative flushes.									
Madakkathra-1	0.24	0.23	0.47	0.50	0.26	0.76	0.53	0.30	0.83
BRZ-2	0.24	0.16	0.40	0.36	0.31	0.67	0.41	0.21	0.62
Dharasree	0.27	0.29	0.56	0.47	0.23	0.70	0.44	0.22	0.66
A-6-1	0.23	0.15	0.38	0.33	0.23	0.56	0.30	0.19	0.49
Madakkathra-2	0.26	0.27	0.53	0.51	0.17	0.68	0.40	0.11	0.51
H-718	0.20	0.19	0.39	0.17	0.20	0.37	0.25	0.16	0.41
CD (P = 0.05)	NS	NS	NS	0.07	NS	0.14	0.07	0.07	0.14
SEm±				0.02	0.03	0.04	0.02	0.02	0.04

Chl - Chlorophyll

content recorded for the low yielders was also high (0.82 to 1.49 mg g^{-1}) compared to high yielders (0.62 to 0.86 mg g^{-1}). The chlorophyll 'b' level did not show any distinct pattern with respect to high and low yielders.

After panicle development, the chlorophyl 'a', 'b' and total chlorophyll content in the mature shoots of all the varieites studied decreased further to very low level and relatively high status was recorded for the late low yielding variety H-718.

(c) Reproductive flushes

The chlorophyll 'a', chlorophyll 'b' and total chlorophyll content did not vary considerably among the varieties studied before flowering (Table 13).

When analysed after panicle development the chlorophyll 'a' , 'b' and total chlorophyll contents were found to be increased considerably in all the varieties. The content was high in all the high yielders studied and the difference among them was insignificant. Similarly, the content among the low yielders did not vary considerably. The chlorophyll 'a' content at this stage ranged between 0.44 and 0.51 mg g^{-1} among the high yielders. The chlorophyll 'b'content recorded for the high yielders ranged from 1.53 to 1.78 mg g^{-1} while it was 0.87 to 1.03 mg g^{-1} among the low yielders.

After nut set, the chlorophyll content again decreased drastically in all the varieties and it ranged from 0.32 to 0.47 mg g^{-1} in high yielders and 0.38 to 0.43 mg g^{-1} in low yielders.

(c) Vegetative flushes

At first stage of analysis the chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents in vegetative flushes did not vary among the varieties studied (Table 13). After flowering stage, the chlorophyll content was found increased in all the varieties. At this stage chlorophyll 'a' and total chlorophyll were

significantly high in high yielders compared to the low yielders. The total chlorophyll ranged between 0.68 and 0.76 mg g^{-1} among the high yielding varieties and 0.37 to 0.67 mg g^{-1} in low yielding varieties.

When analysed after nut set, chlorophyll 'a' (0.53 mg g^{-1}), chlorophyll 'b' (0.30 mg g^{-1}) and toal chlorophyll (0.83 mg g^{-1}) were maximum for the early high yielding variety Madakkathra-1. Total chlorophyll was minimum with the late low yielding variety H-718 (0.41 mg g^{-1}).

4.2.1.5 Total phenol (%)

(a) Mature shoots

The data recorded for phenol content in shoots of different varieties at different growth stages are presented in Table 14.

Total phenol content in leaves of mature shoots of the high yielders was significantly high (2.50 to 2.80%) compared to low yielders (1.40 to 1.60%) before flushing. Variation among the high yielders and low yielders was not significant. The phenol level decreased further after the development of flushes. At this stage also it was significantly high in leaves of the high yielding varieties (1.10 to 1.60%). The phenol content in leaves decreased further after panicle development and the values recorded varied from 0.28 to 0.53% in high yielders and 0.37to 0.47 per cent in low yielders.

(ii) Reproductive flushes

Phenol content before flowering was found to be considerably high in leaves of high yielding varieties (2.60 to 3.10%) compared to the low yielding varieties (1.50 to 1.60%) and the maximum was registered by the variety Madakkathra-1.

After development of panicle, the phenol content was considerably reduced to the range of 1.40 to 1.85% in high yielding varieties. The magnitude of reduction in low yielding varieties was comparativiely low. After nut set the phenol content in leaves of all the varieties decreased.

Table 14. varietal variation in Phenolic content (%) at different stages of reproductive growth

Variety	Mature shoots			Reproductive flushes			Vegetative flushes		
	Before flushing	After flushing	After flowering	Before flowering	After flowering	After nut set	Before flowering	After flowering	After nut set
Madakkathra-1	2.5	1.10	0.28	3.10	1.85	0.63	2.05	1.70	1.46
BRZ-2	1.5	0.72	0.37	1.60	0.95	0.60	1.25	1.25	1.05
Dharasree	2.8	1.60	0.47	2.90	1.65	0.56	1.85	1.45	1.25
A-6-1	1.6	0.72	0.47	1.50	1.55	0.56	1.40	1.30	1.30
Madakkathra-2	2.8	1.40	0.53	2.60	1.40	0.21	1.90	1.65	1.50
H-718	1.4	0.46	0.42	1.55	1.35	0.57	1.27	1.25	1.00
CD (P = 0.05)	0.87	0.31	NS	0.10	0.03	0.21	0.04	0.03	0.35
SEm ±	0.25	0.09		0.03	0.01	0.06	0.01	0.01	0.10

Table 15 Varietal variation in Nitrate Reductase Activity (mmol of NO_2 g^{-1} h^{-1}) at different stages of reproductive growth

Variety	Mature shoots			Reproductive flushes			Vegetative flushes		
	Before flushing	After flushing	After flowering	Before flowering	After flowering	After nut set	Before flowering	After flowering	After nut set
Madakkathra-1	0.48	0.38	0.30	0.47	0.71	0.32	0.37	0.37	0.39
BRZ-2	0.30	0.37	0.30	0.40	0.52	0.28	0.45	0.18	0.35
Dharasree	0.77	0.83	0.37	0.49	0.58	0.43	0.36	0.33	0.45
A-6-1	0.30	0.30	0.28	0.44	0.56	0.40	0.18	0.17	0.05
Madakkathra-2	0.80	0.89	0.40	0.49	0.68	0.58	0.39	0.32	0.62
H-718	0.23	0.34	0.28	0.41	0.67	0.25	0.16	0.15	0.17
CD (P=0.05)	0.17	0.17	0.10	NS	0.10	0.13	0.07	0.13	0.07
SEm ±	0.05	0.05	0.03		0.03	0.04	0.02	0.04	0.02

(ii) Vegetative flushes

Data generated with respect to phenol content in vegetative flushes of different varieties at various phases of development are presented in Table 14. When analysed at the first stage (before flowering) phenol conent in flushes varied significantly among the varieties studied. The content was maximum in the early high yielding variety Madakkathra-1 (2.05%) and minimum in the early low yielding variety BRZ-2 (1.25%) and H-718 (1.27%).

The phenol content at second stage of analysis (after flowering) decreased (0.35 to 0.40%) in high yielders. The magnitude of reduction was considerably low in low yielders. However, the content was significantly high (1.45 to 1.70%) in high yielders compared to low yielders (1.25 to 1.30%). The phenol content was further decreased at the third stage of analysis (after nut set) and the content was comparatively high in high yielders (1.25 to 1.50%).

4.2.1.6 Nirate reductase activity (NRA)

(a) Mature shoots

Nitrate reductase activity in leaves of mature shoots before and after flushing was comparatively high in high yielding varieties (Table 15) with the maximum in Madakkathra-2 (0.80 and 0.89 mmol of NO_2 g^{-1} h^{-1} respectively) followed by Dharasree (0.77 and 0.83 mmol of NO_2 g^{-1} h^{-1} respectively). The activity was of low magnitude in low yielding varieties at both the stages.

After panicle development the nitrate reductase activity was found reduced in all the varieties studied. The varieties Madakkathra-2 and Dharasree recorded a high nitrate reductase activity of 0.37 and 0.40 mmol of NO_2 g^{-1} h^{-1} respectively at this stage.

(b) Reproductive flushes

Nitrate reductase activity in reproductive flushes before flowering did not vary significantly among the different varieties studied. After flowering the

NRA was found increased in all the varieties and the maximum was recorded by the variety Madakkathra-1 (0.71 mmol of NO_2 g^{-1} h^{-1}). After nut set the NRA further decreased in all the varieties and was significantly high in the variety Madakkathra-2 (0.58 mmol of NO_2 g^{-1} h^{-1})

(c) Vegetative flushes

The NRA did not vary significantly among the high yielding varieties studied and ranged between 0.36 and 0.39 mmol of NO_2 g^{-1} h^{-1} before flowering (Table 15). After flowering the content was significantly high (0.32 to 0.37 mmol of NO_2 g^{-1} h^{-1}) in high yielders compared to low yielders (0.15 to 0.18 mmol of NO_2 g^{-1} h^{-1}). After nut set, the NRA in these flushes was significantly high in high yielding variety Madakkathra-2 (0.62 mmol of NO_2 g^{-1} h^{-1}) and the minimum in the variety H-718 (0.17 mmol of NO_2 g^{-1} h^{-1})

4.2.2 Variation in anatomical characters of different shoots

The varieties selected for studying the anatomical characters of shoots (that emerge at different stages of reproductive growth) are given below.

Group	Variety
Early high yielder (EH)	Madakkathra-1
Early low yielder (EL)	BRZ-2
Late high yielder (LH)	Madakkathra-2
Late low yielder (LL)	H-718

(i) Mature shoots

Anatomical features of the mature shoots before flushing was studied. All the mature shoots irrespective of the varieties studied were in the secondary growth phase (growth of tissues in the stelar region). The cork cambium originated in the outer layer of collenchyma. Beneath this secondary cortex embedded with resinous pits connected by resinous canals were present.

Well developed secondary xylem (Plate 4) and phloem could be observed in all such shoots. The number of phloem was innumerable and difficult to count. Observations recorded for the xylem vessels are given Table 16.

The number of xylem vessels per unit area was more in high yielding varieties Madakkathra-1 and Madakkathra-2 (12.20 and 13.90 mm^{-2} respectively) compared to low yielding varieties studied (9.20 to 10 .00 mm^{-2})

The cambium and primary phloem in the primary cortex seemed to be pushed outwards. However, the primary xylem remained more or less intact around the centre.

Secondary medullary rays passing through secondary xylem and phloem was also observed irrespective of the varieties studied.

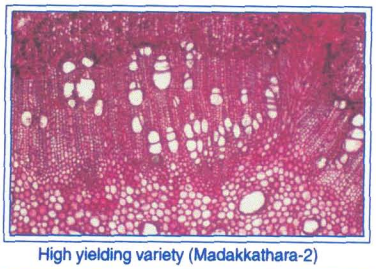
The bark thickness of the varieties measured with the help of CETI binocular research microscope fitted with ocular micrometer are as given in Table 16. The varieties differed significantly in bark thickness of mature shoots. Highest bark thickness (3.06 mm) was recorded for the variety Madakkathra-2 and lowest for the variety BRZ-2 (2.67 mm).

(ii) Flushes

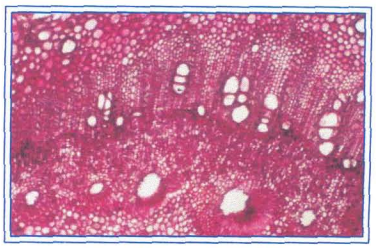
Many of the anatomical features observed for the reproductive and vegetative flushes were common irrespective of the varieties studied .

The outermost layers of cutinised epidermis with epidermal hairs was observed. Lying below the epidermis a zone consisting three or four layers of sclerenchymatous cells were present. Below this was a continous mass of undifferentiated thin walled parenchymatous cells extending to the centre. The cells of ground tissue enclosed numerous resinous cavities connected by resinous canals. The resinous cavities were surrounded by three or four layers of thick walled cells.

Plate 4. ***Pattern of secondary xylem vessels***

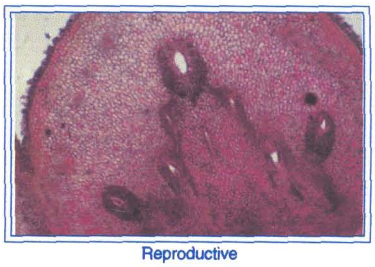


High yielding variety (Madakkathara-2)

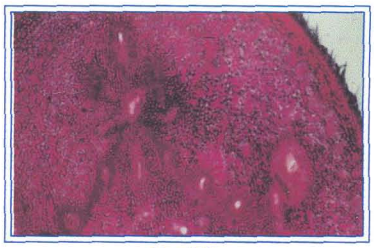


Low yielding variety (A-6-1)

Plate 5. ***Anatomy of flushes***



Reproductive



Vegetative

Table 16. Bark thickness and number of xylem vessels in mature shoots of cashew varieties

Variety	Bark thickness (mm)	Number of xylem vessels (mm^{-2})
Madakkathra-1	2.89	12.20
BRZ-2	2.67	10.00
Madakkathra-2	3.06	13.90
H-718	2.98	9.20
CD (P = 0.05)	0.40	1.80
SEm±	0.04	0.52

The only feature found differentiating reproductive flushes from vegetative flsuhes was the presence of flowering primordia in the reproductive flushes (Plate 5). In the vegetative flushes flowering primordia was absent and ground tissue started differentiating into different regions.

4.3 Chemical regulation of flowering

4.3.1 Response of the variety Madakkathra-2 to spray application of different chemicals in observational trial

Data generated on vegetative, flowering, nut and yield characters in the observational trial are presented in Table 17, 18 and 19 respectively.

4.3.1.1 Vegetative characters

The important vegetative parameters studied were days taken for flushing after chemical application, number of flushes per m^2, length of flushes, number of leaves per flush and flushing span.

(i) Days to flushing

Number of days taken for flushing after chemical application varied considerably among the treatments (Table 17) Early flushing was induced in plants treated with cultar 1000 mg l^{-1} together with KNO_3 at varying concentrations (one to five per cent). Flushing was observed in these plants 30 days earlier than control. Cultar 500 mg l^{-1} combined with KNO_3 at two concentrations viz., three and five per cent also recorded early flushing.

(ii) Number of flushes(m^{-2})

Effect of different treatments on production of flushes were prominent (Table 17) . In general application of cultar 1000 mg l^{-1} along with KNO_3 one to five per cent produced more number of flushes (>50) with the maximum registered for cultar 1000 mg l^{-1} with KNO_3 one per cent (58.60 m^{-2}). The two lower levels of cultar 250 and 500 mg l^{-1} or varying levels of KNO_3 tried did not favour flush production. Potassium nitrate alone tried at varying concentrations

Table 17. Influence of chemical treatments on vegetative characters of the variety "Madakkathra-2" (observational trial)

	Treatments	Days to flushing	No: of flushes (m^{-2})	Length of flush (cm)	No:of leaves ($flush^{-1}$)	Flushing span (days)
T_1	Cultar 250 mg l^{-1} (Paclobutrazol)	22	36.4	8.60	7.40	31
T_2	" 500 mg l^{-1}	28	33.80	8.70	8.20	34
T_3	" 1000 mg l^{-1}	20	48.00	7.70	6.90	28
T_4	KNO_3 1%	12	36.80	9.90	8.80	34
T_5	KNO_3 3%	10	36.20	9.00	8.60	38
T_6	KNO_3 5%	14	32.40	10.50	9.20	40
T7	Cultar 250 mg l^{-1} + KNO_3 %	12	34.50	9.50	8.40	28
T_8	" + KNO_3 1%	10	38.26	9.60	8.60	28
T_9	" + KNO_3 5%	10	34.60	9.30	8.60	31
T_{10}	Cultar 500 mg l^{-1} + KNO_3 1%	10	48.90	7.20	7.00	25
T_{11}	" + KNO_3 1%	7	43.20	8.40	7.40	26
T_{12}	" + KNO_3 5%	7	38.40	9.40	8.20	27
T_{13}	Cultar 1000 mg l^{-1} + KNO_3 1%	5	58.60	6.90	5.00	26
T_{14}	" + KNO_3 1%	6	56.20	7.40	6.20	28
T_{15}	" + KNO_3 5%	5	53.40	7.60	6.40	28
T_{16}	Alar 250 mg l^{-1} (Daminozide)	29	44.90	8.20	7.20	21
T_{17}	" 500 mg l^{-1}	28	45.60	8.50	7.00	32
T_{18}	" 1000 mg l^{-1}	26	45.40	8.00	6.90	34
T_{19}	Cycocel 250 mg l^{-1} (Chlormequat)	22	44.30	10.00	8.90	32
T_{20}	" 500 mg l^{-1}	19	46.20	10.80	8.60	28
T_{21}	" 1000 mg l^{-1}	19	47.20	9.70	8.40	24
T_0	Control	36	46.10	9.70	8.40	40

Table18. Influence of chemical treatments on flowering characters of the variety "Madakkathra-2" (Observational trial)

	Treatments	Days to flowering	Number of panicles (m^{-2})	Number of hermaphr-odite flowers ($panicle^{-1}$)	Duration of flowering (days)	Number of nuts ($panicle^{-1}$)
T1	Cultar 250 mgl^{-1} (Paclobutrazol)	27	27.40	142.82	40.40	12.80
T2	" 500mgl^{-1}	22	25.20	121.21	44.20	10.40
T3	" 1000mgl^{-1}	18	25.80	192.62	44.20	14.20
T4	KNO_3 1%	41	24.30	182.22	44.00	10.60
T5	KNO_3 3%	41	27.40	164.82	44.80	9.80
T6	KNO_3 5%	49	25.20	124.14	46.00	9.60
T7	Cultar 250 mgl^{-1}+KNO_3 1%	40	26.30	142.62	42.80	12.60
T8	" + KNO_3 3%	35	26.10	140.44	47.00	10.20
T9	" + KNO_3 5%	35	27.20	146.60	48.80	14.80
T10	Cultar500 mgl^{-1}+KNO_3 1%	20	47.40	146.64	50.20	16.40
T11	" + KNO_3 3%	29	37.30	142.21	42.40	14.20
T12	" + KNO_3 5%	43	30.20	108.58	42.00	10.20
T13	Cultar1000 mgl^{-1}+KNO_3 1%	12	48.60	193.39	44.40	18.20
T14	" + KNO_3 3%	14	42.70	108.82	36.60	8.40
T15	" + KNO_3 5%	20	41.40	123.63	39.40	8.20
T16	Alar 250 mgl^{-1} (Daminozide)	48	37.20	128.24	39.00	8.80
T17	" 500mgl^{-1}	51	26.20	164.42	35.60	8.20
T18	" 1000mgl^{-1}	47	38.30	146.56	33.60	7.40
T19	Cycocel 250mgl^{-1} (Chlormequat)	52	20.00	128.48	34.80	8.60
T20	" 500mgl^{-1}	43	28.20	148.28	42.40	7.80
T21	" 1000mgl^{-1}	38	28.80	124.40	53.80	6.80
T0	Control	59	27.40	148.42	52.60	8.40

Table 19. Influence of chemical treatments on nut and yield characters of the variety "Madakkathra-2" (observational trial)

	Treatments	Nut length (cm)	Nut breadth (cm)	100 nut weight (g)	Kernel weight. (g)	Yield (kg)	Fruit weight (g)
T1	Cultar 250 mg l^{-1} (Paclobutrazol)	3.56	2.92	802	2.26	7.40	67.4
T2	" 500 mg l^{-1}	3.60	2.92	808	2.27	7.20	69.16
T3	" 1000 mg l^{-1}	3.60	3.00	808	2.24	6.90	70.12
T4	KNO_3 1%	3.58	2.92	758	2.29	5.60	70.58
T5	KNO_3 3%	3.56	3.00	788	2.28	6.90	73.20
T6	KNO_3 5%	3.60	2.66	764	2.26	5.90	69.00
T7	Cultar 250 mg l^{-1} + KNO_3 1%	3.64	2.78	768	2.27	6.20	63.98
T8	" + KNO_3 3%	3.60	2.66	782	2.25	6.90	71.34
T9	" + KNO_3 5%	3.60	2.80	810	2.28	4.20	70.40
T10	Cultar 500 mg l^{-1} + KNO_3 1%	3.76	2.92	806	2.26	8.20	65.60
T11	" + KNO_3 3%	3.58	2.92	768	2.28	7.80	67.50
T12	" + KNO_3 5%	3.60	2.94	798	2.30	4.80	67.60
T13	Cultar 1000 mg l^{-1} + KNO_3 1%	3.60	2.72	816	2.32	8.40	67.31
T14	" + KNO_3 3%	3.68	3.00	810	2.31	4.90	66.75
T15	" + KNO_3 5%	3.64	2.94	812	2.26	4.80	67.98
T16	Alar 250 mg l^{-1} (Daminozide)	3.58	2.84	760	2.25	5.60	68.25
T17	" 500 mg l^{-1}	3.66	2.82	764	2.26	5.50	69.72
T18	" 1000 mg l^{-1}	3.60	2.84	780	2.27	4.90	70.08
T19	Cycocel 250 mg l^{-1} (Chlormequat)	3.62	2.82	770	2.30	4.80	69.72
T20	" 500 mg l^{-1}	3.70	2.80	700	2.28	3.20	68.68
T21	" 1000 mg l^{-1}	3.64	2.68	690	2.26	3.00	69.90
T0	Control	3.74	2.78	782	2.25	6.70	68.00

reduced the flush number (35 to 38 m^{-2}) compared to control (46 m^{-2}). Plants treated with varying concentration of alar and cycocel behaved more or less same as that of control with respect to this character.

(iii) Length of flush (cm)

Flush length ranged between 6.90 and 10.80 cm among the treatments. Shortest flushes were produced in plants treated with cultar 1000 mg l^{-1} along with KNO_3 one per cent while the longest flushes were produced in plants treated with cycocel 500 mg l^{-1}. The different levels of KNO_3 tried alone or in combination with cultar 250 mg l^{-1} did not induce much reduction in flush length. Similarly the higher doses KNO_3 together with cultar 500 and 1000 mgl^{-1} evoked a favourable influence in increasing the length compared to cultar at same concentrations with KNO_3 one per cent level.

(iv) Number of leaves ($flush^{-1}$)

The mean number of leaves produced per flush was decreased considerably due to treatment with cultar 1000 mg l^{-1} together with KNO_3 at varying concentrations (one to five per cent). It was very low in plants treated with cultar 1000 mg l^{-1} combined with KNO_3 at one per cent. Treatment with KNO_3 alone at all levels tried increased the number of leaves per flush. Compared to its lowest level tried, KNO_3 at two higher levels viz., three and five per cent in combination with cultar at different concentrations tried (250 to 1000 mg l^{-1}) had a tendency to increase leaf production. Alar, irrespective of the levels tried reduced the leaf number compared to control while cycocel treated plants produced leaves more or less same as that of control.

(v) Flushing span (days)

Flush emergence ceased much earlier in plants treated with alar 250 mg l^{-1} and cycocel 1000 mg l^{-1}. The flushing span of the trees received these treatments were 21 and 24 days respectively. Plants treated with cultar 500 and

1000 mg l^{-1} in combination with KNO_3 at different concentrations tried, also registered short flushing span (25 to 28 days). Treatments with KNO_3 alone increased the span compared to treatment in combination with cultar. Control plants as well as plants received treatment with KNO_3 alone at five per cent level remained in flushing stage upto 40 days (Table 17).

4.3.1.2 Flowering characters

The data on flowering characters as influenced by various chemical treatments are presented in Table 18.

(i) Days to flowering

Days taken for flowering after chemical application was found reduced in response to spray application to differenct chemicals and showed wide variation (12 to 52 days) among the different treatments (Table 18). Plants treated with cultar 1000 mg l^{-1} together with KNO_3 at two lower doses viz., one and three per cent showed flowering, 12 to 14 dasy after chemical application.

(ii) Number of panicles (m^{-2})

Plants treated with cultar 1000 mg l^{-1} combined with KNO_3 at one per cent induced production of more number of panicles. Number of panicles per m^2 registered for this treatment was 48.60. Treatment with cultar or KNO_3 alone at different levels tried or cultar 250 mg l^{-1} with varying levels of KNO_3 did not alter the panicle production on flushes.

(iii) Number of hemaphrodite flowers (panicle^{-1})

Number of hermaphrodite flowers varied considerably among the treatments. Highest number (193.39 per panicle) was observed for the plants treated with cultar 1000 mg l^{-1} along with KNO_3 at one per cent followed by cultar 1000 mg l^{-1} (Table 18). Hermaphrodite flowers appeared in very low frequency in plants treated with cultar 500 mg l^{-1} combined with KNO_3 at five per cent (108.58 per panicle).

(iv) Duration of flowering (days)

Duration of flowering varied from 34 to 53 days among different treatments. It was much reduced in plants treated with alar at varying levels (34 to 39 days). Cultar 1000 mg l^{-1} in combination with KNO_3 at different levels also had a tendency to reduce the flowering span (37 to 44 days). The highest level of cycocel tried extended the flowering duration to 53 days which was more or less equal to that of control (52 days).

(v) Number of nuts (panicle^{-1})

Number of nuts produced per panicle registered variation among treatments. Highest number of nuts per panicle was noted in plants treated with cultar 1000 mg l^{-1} with KNO_3 at one per cent (18.20) followed by cultar 500 mg l^{-1} with KNO_3 one per cent (16.40). However the higher levels of KNO_3 along with cultar 1000 mg l^{-1} had no favourable effect on production of nuts.

4.3.1.3 Nut and yield characters

The influence of various chemical treatments on nut and yield characters of the variety Madakkathra-2 are presented in Table 19.

(i) Nut length (cm)

Nut length was not found to differ much in response to various treatments imposed. However nuts from trees treated with cultar 500 mg l^{-1} with KNO_3 at one per cent recorded maximum length of 3.76 cm.

(ii) Nut breadth (cm)

Variation for nut breadth was not much pronounced among various treatments. However plants treated with cultar 1000 mg l^{-1} with KNO_3 at three per cent level produced nuts with maximum breadth (3 cm).

(iii) Hundred nut weight (g)

Treatments differed considerably with respect to this character. Nut weight was maximum in plants treated with cultar 1000 mg l^{-1} in combination with KNO_3 at one per cent (816 g), which was followed by cultar 1000 mg l^{-1} combined with KNO_3 at five per cent level (812 g). Nut weight recorded in plants treated with alar and cycocel alone (690 to 780 g) at varying concentrations was low compared to control (782 g)

(iv) Kernel weight (g)

Kernel weight did not show much variation among the treatments. However slight improvement in this character was observed in plants treated with cultar 1000 mg l^{-1} in combination with KNO_3 at one per cent and three per cent (2.32 and 2.31 g per kernel respectively).

(v) Yield (kg)

Influence of treatments on yield was evident and it varied from 3.00 to 8.40 kg among different treatments. Maximum yield per tree (8.40 kg) was recorded for the treatment, cultar 1000 mg l^{-1} together with KNO_3 at one per cent level followed by cultar 500 mg l^{-1} and KNO_3 at one per cent level (8.20 kg).

Yield was found reduced in plants treated with all levels of alar and cycocel.

(vi) Fruit weight (g)

Much variation was not observed in fruit weight due to different treatments. However treatment with KNO_3 at three per cent resulted in an increase in fruit weight (73.20 g) compared to other treatments.

Based on the observations made on the influence of different chemicals on vegetative, flowering, nut and yield characters, two treatments viz., cultar 1000 mg l^{-1} combined with KNO_3 at one per cent and cultar 500 mg l^{-1} with KNO_3 at one per cent were selected as apparently superior for flowering regulation in cashew. The characters which are highly and positively correlated with yield (Expt.I) viz., number of panicles per m^2, number of hermaphrodite flowers, number of nuts per panicle were considerably increased due to these two treatments. Further, these treatments induced early flushing , flowering and reduced flushing and flowering span. Ultimately yield was also increased. Hence these two treatments were selected out for further studies.

4.3.2. *Response of the variety Madakkathra-2 to spray application of the selected chemical combinations in second screening trial*

Response of the late season variety Madakkathra-2 to the chemical combinations selected on the basis of observational trial was assessed in a second screening trial applying each chemical combination alone or together with carbaryl 0.10 per cent. Data generated on vegetative, flowering, nut and yield characters were statistically analysed (Appendix - V) and are presented in Table 20, 21 and 22 respectively.

4.3.2.1 Vegetative characters

(i) Days to flushing

All the chemical treatments induced early flushing. However earliest flushing was observed in plants treated with cultar 500 and 1000 mg l^{-1} combined with KNO_3 at one per cent. Flush emergence was observed within five to six days in response to these two treatments.

Table 20. Influence of selected chemical combinations on vegetative characters of the variety "Madakkathra-2" (Second screening trial).

Treatments		Days to flushing	Number of flushes (m^{-2})	Length of flush (cm)	No: of leaves ($flush^{-1}$)	Flushing span (days)
T_1	Cultar 1000 mg l^{-1} + $KNO_3$1%	6.00^{c}	38.40^{a}	4.03^{b}	3.55^{bc}	24.00^{b}
T_2	Cultar 500 mg l^{-1} + $KNO_3$1%	5.75^{c}	35.45^{a}	4.50^{b}	4.20^{b}	22.50^{b}
T_3	Cultar 1000 mg l^{-1} + $KNO_3$1% + Carbaryl 0.10%	6.75^{b}	39.64^{a}	3.93^{b}	3.33^{c}	25.00^{b}
T_4	Cultar 500 mg l^{-1} + $KNO_3$1%+ Carbaryl 0.10 %	6.75^{b}	35.23^{a}	4.10^{b}	3.78^{bc}	23.75^{b}
T_0	Control	40.25^{a}	27.23^{b}	6.40^{a}	5.30^{a}	32.25^{a}

Values having any common superscript are not significantly different from one another

Table 21. Influence of selected chemical combinations on flowering characters of the variety "Madakkathra-2" (second screening trial)

Treatments		Days to flowering	Number of panicles (m^{-2})	Number of hermaphrodite flowers ($panicle^{-1}$)	Duration of flowering (days)	Number of nuts ($panicle^{-1}$)
T1	Cultar 1000 mg l^{-1} + KNO_3 1 %	24.00^{b}	34.75^{a}	136.00^{b}	42.25^{b}	13.45^{a}
T2	Cultar 500 mg l^{-1} + KNO_3 1 %	24.75^{b}	28.95^{ab}	184.00^{a}	45.25^{b}	12.52^{a}
T3	Cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10 %	21.00^{c}	33.28^{a}	206.75^{a}	43.50^{b}	14.32^{a}
T4	Cultar 500 mg l^{-1} + KNO_3 1% + carbaryl 0.10 %	22.75^{bc}	25.95^{bc}	149.50^{b}	41.00^{b}	12.07^{a}
T0	Control	56.50^{a}	21.95^{c}	154.75^{b}	65.50^{a}	8.28^{b}

Values having any common superscript are not significantly different from one another

Table 22. Influence of selected chemical combinations on nut and yield characters of the variety "Madakkathra-2" (second screening trial)

Treatments		Nut length (cm)	Nut breadth (cm)	100 nut weight (g)	Kernel weight (g)	Yield (kg)	Fruit weight (g)
T_1	Cultar 1000 mg l^{-1} + $KN0_3$ 1 %	2.93^{a}	2.73^{ab}	863.50^{a}	2.03^{ab}	5.75^{b}	73.72^{a}
T_2	Cultar 500 mg l^{-1} + $KNO_3$1 %	2.93^{a}	2.65^{bc}	860.80^{a}	2.10^{a}	6.18^{ab}	75.50^{a}
T_3	Cultar 1000 mg l^{-1} + $KNO_3$1 % + Carbaryl 0.10 %	2.98^{a}	2.80^{a}	865.50^{a}	2.10^{a}	6.93^{a}	73.23^{a}
T_4	Cultar 500 mg l^{-1} + $KNO_3$1% + Carbaryl 0.10 %	2.95^{a}	2.75^{ab}	847.00^{ab}	2.05^{ab}	5.75^{b}	75.00^{a}
T_0	Control	2.80^{b}	2.60^{c}	827.30^{b}	2.03^{ab}	3.33^{c}	74.70^{a}

Values having any common superscript are not significantly different from one another.

(ii) Number of flushes (m^{-2})

All the chemical treatments improved the production of flushes but did not differ significantly among themselves. The number of flushes per m^2 varied between 35 and 40 among the treatments as against 27.23 in control plants.

(iii) Length of flush (cm)

The preblossom flushes that emerged on lateral shoots after chemical treatment was much reduced in their length. However the length of flushes did not vary significantly among the treatments (3.93 to 4.50 cm). The length of flushes was found comparatively more in control plants (6.40 cm).

(iv) Number of leaves (flush $^{-1}$)

Leaf production per flush was also reduced in response to chemical application. Number of leaves varied considerably among the chemical treatments (3.33 to 4.20) and significantly more leaves per flush were observed in control plants (5.30). Leaves were minimum in plants treated with cultar 1000 mg l^{-1} combined with KNO_3 at one per cent and carbaryl 0.10 per cent.

(v) Flushing span (days)

Flushing span was reduced considerably and varied from 22 to 25 days among different treatments. Control plants recorded significantly high flushing span (32.25 days) compared to other treatments.

4.3.2.2 Flowering characters

(i) Days to flowering

Panicles emerged sufficiently earlier in plants treated with chemicals than in control. Significant reduction in time taken for flowering was observed in plants treated with cultar 1000 mg l^{-1} along with KNO_3 one per cent and carbaryl 0.10 per cent. They flowered within 21 days after treatment. The other

three chemical treatments did not register significant difference. Flowering was much delayed in control plants and they flowered only 56 days after imposing treatments.

(ii) Number of panicles (m^{-2})

The chemical treatments T_1, T_2 and T_3 had superior effect with respect to panicle production and number of panicles ranged between 26 to 35 among these treatments. Panicle production in control plants were low and was on par with T_4

(iii) Number of hermaphrodite flowers ($panicle^{-1}$)

The chemical treatments T_1 and T_4 did not have much influence on hermaphrodite flower production and the numbers recorded (136 and 149.50 per panicle respectively) were on par with control (154.75 per panicle). The other two treatments viz., T_2 and T_3 significantly improved the hermaphrodite flower (184 and 206.75 per panicle respectively) production.

(iv) Duration of flowering (days)

An absolute reduction in flowering span was observed in all plants that received chemical treatments compared to that of control. The duration of flowering varied between 41 and 45 days among various treatments. The chemical treatments did not vary significantly among themselves and acquired same rank position. Control plants recorded significantly high flowering duration (66 days) compared to treated plants.

(v) Number of nuts ($panicle^{-1}$)

All the chemical treatments tried significantly increased nut production (12.07 to 14.32 nuts per panicle) compared to control and did not differ significantly among themselves. Nut production in control plants was only 8.28 nuts per panicle.

4.3.2.3 Nut and Yield characters

(i) Nut length (cm)

It was observed that chemical treatments did not vary significantly among themselves with respect to this character but were superior to control. Nut length varied between 2.93 to 2.98 cm among treatments while it was 2.80 cm in control.

(ii) Nut breadth (cm)

Chemical treatments induced variation in nut breadth. Maximum breadth (2.80 cm) was recorded in plants that received treatment with cultar 1000 mg l^{-1} in combination with KNO_3 one per cent and carbaryl 0.10 per cent (T_3) which was on par with T_1 and T_4. Lowest nut breadth was recorded in control plants.

(iii) Hundred nut weight (g)

The chemical treatments improved the nut weight. Weight of hundred nuts in control plants was only 827.30 g which was significantly inferior to T_1, T_2 and T_3. The magnitude of variation among the chemical treatments was insignificant.

(iv) Kernel weight (g)

Variation in kernel weight was insignificant between the treatments.and it ranged between 2.03 to 2.10 g per nut.

(v) Yield (kg)

Nut yield registered significant variation among treatments. The treatment T_3 recorded highest yield (6.93 kg) which was on par with T_2 (6.18 kg). Yield in control was significantly inferior (3.33 kg) to all other treatments.

(vi) Fruit weight (g)

The various chemical tretments tried were not found to alter the weight of cashew apples. The weight recorded for different treatments were on par with control.

Based on the observational and second screening trial, cultar 1000 mg l^{-1} along with KNO_3 one per cent and carbaryl 0.10 per cent was selected as the most sutiable chemical combination for regulation of flowering in cashew.

4.3.3 Response of different varieties to spray application of the chemical combination selected for regulation of flowering

The response of different varieties to spray application of selected chemical combination viz., cultar 1000 mg l^{-1} in combination with KNO_3 one per cent and carbaryl 0.10 per cent was studied with respect to vegetative flowering, nut and yield characters and the data are presented separately in Tables 23, 25 and 27.

The improvement in vegetative, flowering, nut and yield characters was worked out by calculating the mean deviation of each character expressed in treated plants from that of control. The data with statistical interpretation after DMRT analysis (Appendix - VI) are given in Tables 24, 26 and 28.

4.3.3.1 Vegetative characters

(i) Days to flushing

All the varieties irrespective of their flowering nature responded positively to the chemical treatment and time taken for flushing was reduced by 15 to 30 days among the varieties (Table 23). The reduction was much pronounced in variety Madakkathra-2 in which the flushing occurred in treated plants one month earlier than control. The variety Sulabha stood next to Madakkathra-2 in which the chemical treatment induced flushing 22.50 days earlier than control.

Table 23. Varietal response to spray application of selected chemical combination (cultar 1000 mg l^{-1}+KNO_3 1 % + carbaryl 0.10 %) in relation to vegetative characters

Variety	Days to flushing		Number of flushes (m^{-2})		Length of flush (cm)		Number of leaves ($flush^{-1}$)		Flushing span (days)	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Anakkayam-1	6.75	22.00	37.90	32.30	3.50	4.70	3.80	5.00	20.50	36.00
Madakkathra-1	7.00	24.00	35.40	28.20	5.60	6.40	6.00	7.00	20.80	29.00
Dhana	7.25	28.00	37.30	30.40	6.00	7.90	6.50	8.00	17.00	32.00
Kanaka	7.75	26.00	35.70	29.60	7.50	8.90	8.00	9.00	20.00	34.00
Dharasree	10.75	28.00	28.50	30.60	6.80	5.90	7.30	7.00	22.80	24.00
Madakkathra-2	8.00	38.00	35.50	26.80	5.60	7.40	6.30	8.00	23.30	35.00
Sulabha	13.50	36.00	40.50	34.20	7.10	7.80	8.00	9.00	13.50	35.00

Table 24. Improvement in vegetative characters of the varieties in response to spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 % + carbaryl 0.10 %)

Variety	Days to flushing	Number of flushes (m^{-2})	Length of flush (cm)	Number leaves ($flush^{-1}$)	Flushing span (days)
Anakkayam-1	-15.250[a]	(1.551 [a]) 5.227	(1.459 [c]) -1.257	(1.458 [bc]) -1.262	-15.500 [d]
Madakkathra-1	-17.000 [b]	(1.570 0 [a]) 7.120	(1.465 [b]) -0.804	(1.462 [b]) -1.009	-8.200 [b]
Dhana	-20.750 [c]	(1.566 [a]) 6.812	(1.449 [d]) -1.902	(1.455 [cd]) -1.504	-15.000 [cd]
Kanaka	-18.250[b]	(1.557 [a]) 6.017	(1.456 [c]) -1.426	(1.462[b]) -1.000	-14.000 [cd]
Dharasree	-17.250[b]	(1.444 [b]) -2.225	(1.489 [a]) 0.845	(1.481 [a]) 0.239	-1.200 [a]
Madakkathra-2	-30.000 [e]	(1.588 [a]) 8.682	(1.451 [d]) -1.777	(1.451 [d]) -1.753	-11.700 [c]
Sulabha	-22.500 [d]	(1.558 [a]) 6.178	(1.467 [b]) -0.705	(1.462 [b]) -1.000	-21.500 [e]

Values having any common superscript are not significantly different from one another
Logarithmic transformed values are given in parenthesis and values given below to them are in the original scale
Data on days to flushing and flushing span were not subjected to transformation

Table 25. Varietal response to spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10 %) in relation to flowering characters

	Days to flowering		Number of panicles (m^{-2})		No: of hermaphrodite flowers (panicle^{-1})		Duration of flowering (days)		Number of nuts (panicle^{-1})	
Variety	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Anakkayam-1	10.75	29.00	34.20	29.30	140.50	102.20	29.30	44.00	14.43	12.00
Madakkathra-1	14.00	36.00	33.30	27.40	169.75	117.20	30.50	41.00	19.40	16.80
Dhana	12.25	38.00	32.60	25.40	162.50	119.40	27.30	45.00	17.88	14.50
Kanaka	14.25	36.00	32.80	24.50	100.75	83.20	28.50	43.00	19.65	16.40
Dharasree	22.25	36.00	23.40	24.60	120.25	116.00	20.00	26.00	10.00	8.00
Madakkathra-2	21.75	47.00	30.70	18.40	133.25	108.00	35.00	52.00	12.68	6.20
Sulabha	24.50	45.00	35.50	26.40	125.00	123.80	28.00	42.00	16.45	9.80

Table 26. Improvement in flowering characters of the varieties in response to spray application of selected chemical combination (cultar1000 mg l^{-1} + KNO_3 1 % + carbaryl 0.10 %)

Variety	Days to flowering	Number of panicles (m^{-2})	No: of hermaphrodite flowers (panicle $^{-1}$)	Duration of flowering (days)	Number of nuts (panicle^{-1})
Anakkayam-1	-18.250^{b}	(1.541^{b}) 4.780	(2.167^{ab}) 37.160	-14.700^{bc}	(1.511^{bc}) 2.401
Madakkathra-1	-22.000^{c}	(1.554^{b}) 5.828	(2.181^{a}) 49.070	-10.500^{b}	(1.512^{bc}) 2.32
Dhana	25.750^{d}	(1.570^{b}) 7.128	(2.160^{ab}) 42.680	-17.700^{c}	(1.523^{abc}) 3.368
Kanaka	-21.750^{c}	(1.583^{ab}) 8.289	(2.062^{bc}) 16.350	-14.500^{bc}	(1.522^{abc}) 3.235
Dharasree	-13.750^{a}	(1.458^{c}) -1.300	(2.041^{c}) 1.060	-6.000^{a}	(1.505^{c}) 1.961
Madakkathra-2	-25.250^{d}	(1.626^{a}) 12.296	(2.100^{b}) 23.620	-17.000^{c}	(1.561^{ab}) 6.429
Sulabha	-20.500^{bc}	(1.592^{ab}) 9.069	(2.043^{c}) 3.860	-14.000^{bc}	(1.563^{a}) 6.570

Values having any common superscript are not significantly different from one another
Logarithmic transformed values are given in the parenthesis and values given below to them are in the original scale
Data on days to flowering and duration of flowering were not subjected to transformation

Table 27. Varietal response to spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 % +carbaryl 0.10 %) in relation to nut and yield characters

Variety	Nut length (cm)		Nut breadth (cm)		100 nut weight (g)		Kernel weight (g)		Yield (kg)		Fruit weight (g)	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Anakkayam-1	2.90	2.80	1.80	2.20	603.30	598.00	1.80	1.60	8.30	5.40	38.30	38.00
Madakkathra-1	2.40	2.30	2.30	2.20	616.80	621.00	1.60	1.70	7.80	3.30	42.90	42.40
Dhana	3.20	3.20	2.70	2.80	1034.20	1014.50	2.20	2.40	5.70	3.20	76.40	78.60
Kanaka	2.70	2.70	1.90	1.70	698.80	687.00	1.90	1.80	4.10	2.80	62.90	62.80
Dharasree	3.50	3.60	2.90	2.60	830.00	829.00	2.00	2.00	6.60	4.20	75.10	77.80
Madakkathra-2	2.90	2.90	3.00	2.90	874.30	868.50	2.20	2.20	4.20	2.10	72.80	72.80
Sulabha	3.10	3.10	3.00	2.90	921.50	906.00	2.40	2.50	2.60	0.80	74.30	74.80

Table 28. Improvement in nut and yield characters of the varieties in response to spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 %+ carbaryl 0.10 %)

Variety	Nut length (cm)	Nut breadth (cm)	100nut weight (g)	Kernel weight (g)	Yield (kg)	Fruit weight (g)
Anakkayam-1	(1.479 ^{a}) 0.099	(1.472 ^{b}) -0.351	(1.535 ^{a}) 4.256	(1.480 ^{a}) 0.175	2.900 ^{b}	(1.481 ^{ab}) 0.272
Madakkathra-1	(1.478 ^{a}) 0.075	(1.479 ^{a}) 0.125	(1.410 ^{a}) -4.323	1.476 ^{a}) -0.075	4.500 ^{a}	(1.484 ^{a}) 0.511
Madakkathra-2	(1.477 ^{a}) 0.025	(1.478 ^{a}) 0.050	(1.542 ^{a}) 4.845	(1.471 ^{a}) 0.025	2.100 ^{bc}	(1.476 ^{b}) -0.542
Dhana	(1.477 ^{a}) -0.000	(-1.476 $^{a\,b}$) -0.075	(1.531 ^{a}) 3.995	(1.475 ^{a}) -0.175	2.500 ^{bc}	(1.444 ^{d}) -2.221
Kanaka	(1.477 ^{a}) -0.000	(1.480 ^{a}) 0.174	(1.612 ^{a}) 10.958	(1.479 ^{a}) 0.010	1.300 ^{c}	(1.478 ^{b}) 0.067
Dharasree	(1.475 ^{a}) -0.125	(1.481 ^{a}) 0.250	(1.209 ^{a}) -13.807	(1.477 ^{a}) -0.025	2.400 ^{bc}	(1.435 ^{a}) -2.762
Sulabha	(1.477 ^{a}) -0.000	(1.478 ^{a}) 0.075	(1.603 ^{a}) 10.110	(1.478 ^{a}) 0.075	1.800 ^{bc}	(1.470 ^{c}) -0.481

Values having any common superscript are not significantly different from one another
Logarithmic transformed values are given in parenthesis and values given below to them are in the original scale
Data on yield were not subjected to transformation

(ii) Number of flushes (m^{-2})

In all the varieties except Dharasree chemical application favoured production of more flushes per m^2. (Table 23). In Dharasree more or less same number of flushes per m^2 was produced in treated plants and control.

The improvement in flush production among the varieties in response to chemical application was not significant except for the variety Dharasree. In Dharasree, the treatment did not favour flush production.

(iii) Length of flush (cm)

The length of flushes emerged after chemical application was considerably reduced in all the varieties except in Dharasree (Table 23). Among the varieties, maximum reduction for flush length was noticed for Dhana (Table 24), where the length was reduced to the extent of 1.90 cm per flush. The variety Dharasree recorded longer flushes than control.

(iv) Number of leaves ($flush^{-1}$)

Leaf production per flush was found to be reduced in all the varieties in response to chemical application (Table 23) except for Dharasree, in which the number of leaves per flush recorded was more or less same for treated plants and control. The magnitude of reduction was significantly high in Madakkathra-2 (-1.75 leaves per flush)and Dhana (-1.50 leaves per flush) compared to other varieties (Table 24)

(v) Flushing span (days)

The vegetative phase of treated plants was short compared to control (Table 23). Maximum reduction in flushing span was noticed in the variety Anakkayam-1 (- 15.50 days), Dhana (-15.00 days) and Kanaka (-14.00 days). The treatment was not effective in imparting a compact flushing phase in the variety Dharasree and it behaved more or less same as that of control.

4.3.3.2 Flowering characters

(i) Days to flowering (days)

In all the varieties studied the chemical application induced earliness in flowering (Table 25). However the magnitude of earliness induced varied among the varieties (Table 26). The treated plants of the varieties Madakkathra-2 and Dhana entered to the flowering stage 25 to 26 days earlier compared to their control. However in the variety Dharasree, chemical application induced only 13.75 days earliness, which was significantly low compared to other varieties.

(ii) Number of panicles (m^{-2})

Panicle production was increased in all the varieties (Plate 6) except Dharasree (Table 25 and 26). Maximum improvement of panicles per m^2 was recorded in the variety Madakkathra-2 (12.30) . The variety Dharasree did not show much response for the chemical treatment with respect to panicle production.

(iii) Number of hermaphrodite flowers ($panicle^{-1}$)

In all the varieties studied hermaphrodite flower production was accelerated in response to chemical application (Table 25). The variety Madakkathra-1 ranked superior with respect to the improvement in this character. In this variety number of hermaphrodite flowers was improved by 49 per panicle (Table 26).

(iv) Duration of flowering (days)

Chemical application had a tendency to induce compact flowering phase in all the varieties studied (Table 25). The varieties Madakkathra-2 and Dhana were superior in their response and the span was reduced to the extent of 17 to18 days compared to their control (Table 26). Response of the variety Dharasree was poor when compared to all other varieties.

Plate 6. ***Effect of chemical treatments*** *(Cultar 1000 mg l^{-1}+KNO_3 1% + Carbaryl 0.10%) on flowering*

Anakkayam-1

Madakkathra-1

Kanaka

Dhana

Madakkathra-2

Sulabha

(v) Number of nuts (panicle^{-1})

The mean number of nuts produced per panicle was increased in treated plants (Plate 7) of all the seven varieties compared to control (Table 25). On an average nut production per panicle in treated plants ranged between 10 and 20 among different varieties while in the control plants it ranged between 6 to 17. Significant improvement in nut production was observed in the variety Sulabha (6.57 nuts more per panicle) in response to the treatment (Table 28). The favourable response observed in other varieties such as Madakkathra-2, Dhana and Kanaka were on par with the variety Sulabha. Response of the variety Dharasree was low compared to other varieties.

4.3.3.3.Nut and yield characters

(i) Nut length (cm)

The average length of nuts produced in treated plants was not altered due to the chemical application irrespective of the varieties studied (Tables 27 and 28)

(ii) Nut breadth (cm)

Average breadth of nuts from treated plants of different varieties recorded a slight increase than that from control (Table 27). However, the change recorded for this character among varieties was insignificant (Table 28), except for Anakkayam-1. In this variety the nut breadth was 0.35 cm less than control.

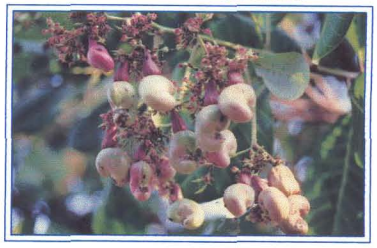
(iii) Hundred nut weight (g)

Influence of chemical treatment in altering the nut weight among different varieties was statistically insignificant. (Table 28)

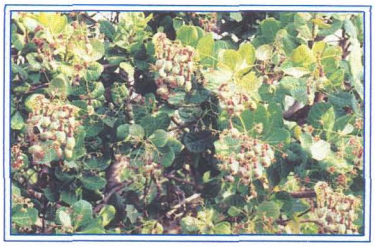
(iv) Kernel weight (g)

The improvement in kernel weight among the varieties studied in response to chemical application (Table 28) was statistically insignificant.

Plate 7. ***Effect of chemical treatments*** *(Cultar 1000 mg l^{-1}+KNO_3 1% + Carbaryl 0.10%) on nutset*



Treated



Control

(v) Yield (kg)

Foliar application of chemical had profound influence in increasing the nut yield character in all the varieties studied. The mean yield per tree ranged between 2.60 kg to 8.30 kg in treated plants of different varieties while it was 0.80 kg to 5.40 kg in control plants (Table27). Maximum improvement in yield (4.50 kg per tree) was recorded for the variety Madakkathra-1 (Table 28), whereas improvement was less in the variety Kanaka (1.30 kg per tree). The response of rest of the varieties studied was more or less of the same magnitude.

(vi) Fruit weight (g)

A slight increase in fruit weight was recorded for treated plants of Anakkayam-1, Madakkathra-1 and Kanaka (Table 27). No change in fruit weight was observed in the variety Madakkathra-2 and in the remaining varieties slight decrease in fruit weight was noticed in response to chemical application.

Statistical analysis revealed that the positive improvement in fruit weight recorded for the varieties Madakkathra-1 and Anakkayam-1 was on par and superior to other varieties (Table 28)

4.3.4 Effect of spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10 per cent) in large plot trial

4.3.4.1 Response of the early high yielding variety Madakkathra-1

The data on vegetative flowering, nut and yield characters recorded for the variety Madakkathra-1 in response to application of cultar 1000 mg l^{-1} combined with KNO_3 at one per cent and carbaryl 0.10 per cent in a large plot trial are presented in Table 29.

(i) Vegetative characters

Application of the chemical resulted in considerable variation in vegetative characters. Flushing was observed in treated plants 18 days earlier than control.

Table 29. Influence of spray application of the selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 %+ carbaryl 0.10 %) on the variety "Madakkathra-1" (large plot trial)

Characters	Mean		t value
	Treated	Control	
(i) **Vegetative characters**			
Days to flushing	5.42	23.00	-38.24*
Number of flushes (m^{-2})	37.09	28.20	4.93*
Length of flush (cm)	6.56	7.73	-4.01*
Number of leaves ($flush^{-1}$)	7.00	8.67	-3.58*
Flushing span (days)	21.80	34.00	8.95*
(ii) Flowering characters			
Days to flowering	12.83	36.67	-44.43*
Number of panicles (m^{-2})	31.88	23.78	4.42*
Number of hermaphrodite flowers ($panicle^{-1}$)	126.53	112.00	0.97
Duration of flowering (days)	40.67	52.67	-8.09*
Number of nuts ($panicle^{-1}$)	13.49	9.17	7.37*
(iii)Nut and yield characters			
Nut length (cm)	2.60	2.74	1.14
Nut breadth (cm)	2.28	2.36	1.12
Hundred nut weight (g)	698.27	689.33	1.29
Kernel weight (g)	1.92	1.86	0.98
Yield (kg)	3.89	1.17	6.60*
Fruit weight (g)	45.37	44.43	1.66

Number of flushes recorded an increase by 8.89 per m^2 than control and was highly significant. Length of flushes produced after chemical application (preblossom) was shorter and measured only 6.56 cm per flush compared to 7.73 cm in control.Number of leaves was also reduced significantly. In treated plants flushing period was shortened and completed within 22 days which was 12 days less than control.

(ii) Flowering characters

Flowering process was hastened in response to chemical application resulting in a marked deviation with respect to days taken for flowering after chemical application. Treated plants flowered within 12.83 days which was 23.84 days earlier than control. Chemical treatment influenced panicle production favourably. Number of panicles was 31.88 per m^2 in treated plants where as corresponding figure in control was 23.78. Hermaphrodite flower production was not much affected by the treatment and was more or less same as that of control. Chemical application was effective by inducing compactness in flowering duration. In treated plants duration of flowering phase was only 40.67 days as against 52.67 days in control. Significant improvement in nut production per panicle was also recorded in response to chemical application. Number of nuts per panicle was 13.49 in treated plants compared to 9.17 in control.

(iii) Nut and yield characters

Plants which received chemical treatment recorded a significant improvement in yield by 2.72 kg per plant. The other nut characters under consideration viz., length, breadth,nut weight and kernel weight did not register significant difference. Variation in fruit weight was also negligible among treated plants and control.

4.3.4.2 Response of the late high yielding variety Madakkathra-2

The response of the variety Madakkathra-2 (in a compact block consisting of 15 trees) to foliar application of chemical combination selected for flowering regulation is presented in Table 30.

(i) Vegetative characters

Among the vegetative characters studied, days to flushing, number of flushes per m^2 and flushing span varied significantly in treated plants compared to control (Table 30).Plants that received chemical application attained the flushing phase nine days after treatment where as the process was further delayed by 40 days in the control. Production of flushes was also improved in response to the treatment. Average number of flushes observed was 30.65 in treated plants as against 25.17 in control.Similarly the treated plants remained in flushing phase for 23.71 days where as the flushing phase was extended to 34 days in control.

The effect of chemical application on flush length and number of leaves was statistically insignificant.

(ii) Flowering characters

Foliar application of the chemical evoked profound influence on flowering characters studied. The chemical application preponed the time of flowering and induced one month earliness compared to that of control. Panicle production per unit area was accelerated in response to the chemical application. Number of panicles per m^2 was 26.99 in treated plants as against 18.73 in control. Tendency to produce hermaphrodite flowers was more in treated plants and on an average they recorded an improvement by 29.33 per panicle for this character. The treatment also excelled by inducing compact flowering span. The duration was reduced by 22 days in response to the treatment. Nut production was found to be improved to the extent of six nuts per panicle in this variety.

Table 30. Influence of spray application of the selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 % + carbaryl 0.10 %) on the variety "Madakkathra-2" (large plot trial)

Characters	Mean		t value
	Treated	Control	
(i)Vegetative characters			
Days to flushing	8.59	48.60	-84.00*
Number of flushes (m^{-2})	30.65	25.17	3.25*
Length of flush (cm)	5.49	6.60	-1.78
Number of leaves ($flush^{-1}$)	6.71	7.33	-0.90
Flushing span (days)	23.71	34.00	-4.08*
(ii) Flowering characters			
Days to flowering	29.59	60.67	3.26*
Number of panicles (m^{-2})	26.99	18.73	4.70*
Number of hermaphrodite flowers ($panicle^{-1}$)	137.33	108.00	1.72
Duration of flowering (days)	25.35	47.33	-4.00*
Number of nuts ($panicle^{-1}$)	16.42	10.10	2.47*
(iii)Nut and yield characters			
Nut length (cm)	2.72	2.80	-1.30
Nut breadth (cm)	2.80	2.90	-0.84
Hundred nut weight (g)	869.00	847.82	-1.42
Kernel weight (g)	2.15	2.13	0.21
Yield (kg)	4.30	1.70	2.90*
Fruit weight (g)	69.98	72.60	-1.13

(iii) Nut and yield characters

Among the nut and yield characters studied, yield was found to be significantly improved in response to chemical application. Treated plants registered an average yield of 4.30 kg as against 1.70 kg per tree in control.

The other nut characters studied viz., the length, breadth and weight of nuts did not register significant difference over control. The fruit weight also did not register any significant variation.

4.3.5 Change in biochemical constituents in response to spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1%+carbaryl 0.10 per cent)

Variation in biochemical constituents viz., nitrogen, carbohydrate, starch, total phenol and chlorophyll in response to spraying cultar 1000 mg l^{-1} with KNO_3 one per cent and carbaryl 0.10 per cent to the variety Madakkathra-2 are presented in Table 31.

(i) Nitrogen (%)

The nitrogen content in the leaves of mature shoots increased by 0.18% within three days after chemical application. The content remained unaltered in control trees. The flush emergence resulted in depletion of nitrogen and the content in sprayed trees and unsprayed trees was decreased by two and 1.53 per cent respectively.

Nitrogen level in the reproductive flushes before flowering was not changed due to cbemical application. After flowering the nitrogen status increased in these flushes comparatively to a higher level (3.18%) than in control (2.18%). After fruit set the nitrogen content decreased and the difference was insignificant between the sprayed and unsprayed trees.

Table 31. Variation in biochemical constituents in response to spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1% + carbaryal 0.10 %)

Treatment	Nitrogen (%)	Carbo-hydrates (%)	C:N ratio	Starch (%)	Total phenol (%)	Chlorophyll		
						'a' (mg g^{-1})	'b' (mg g^{-1})	Total (mg g^{-1})
1	2	3	4	5	6	7	8	9
Mature shoots								
Before spraying	3.80	9.86	2.59	4.16	1.62	1.76	1.98	3.74
Control	3.58	9.83	2.75	4.28	1.48	1.71	1.92	3.63
After spraying	3.98	9.84	2.61	4.12	1.48	1.65	1.90	3.55
Control	3.54	9.46	2.47	3.24	1.44	1.72	1.89	3.61
After flushing (sprayed)	1.98	2.18	1.10	1.65	0.18	0.31	0.11	0.42
Control	2.01	3.42	1.68	1.90	0.29	0.61	0.23	0.84
CD (P = 0.05)	0.10	0.31	0.42	0.17	0.21	0.14	0.07	0.17
SEm±	0.03	0.09	0.12	0.05	0.06	0.04	0.02	0.05
Reproductive flushes								
Before flowering	0.46	2.84	6.17	1.28	3.14	0.49	0.94	1.43
Control	0.42	4.56	10.86	1.12	2.94	0.83	0.91	1.74
After flowering (sprayed)	3.18	12.48	3.92	6.21	2.66	1.21	2.38	3.59
Control	2.18	9.62	4.41	3.33	2.54	1.12	1.98	3.10
After nut set (sprayed)	1.02	6.48	6.35	2.37	0.98	1.21	1.47	2.68
Control	0.92	3.29	3.58	0.92	1.21	0.92	1.12	2.04
CD (P = 0.05)	0.83	0.21	4.05	0.69	0.10	0.07	0.07	0.10
SEm±	0.24	0.06	1.17	0.20	0.03	0.02	0.02	0.03

(ii) Carbohydrate (%)

The chemical application did not cause immediate change in the carbohydrate level (Table 31) in leaves of mature shoots. Flushing resulted in drastic decrease in carbohydrate in the shoots of treated plants (2.18%) than in control (3.42%).

The carbohydrate content in reproductive flushes of sprayed trees before flowering was considerably low (2.84%) compared to control (4.56%). After flowering the content increased to a higher level of 12.48 per cent in these flushes of sprayed trees compared to 9.62 per cent in unsprayed trees. The nut set decreased the carbohydrate in both cases and the intensity was more in sprayed trees.

(iii) C:N ratio

The C:N ratio in mature shoots did not register immediate change due to foliar application of chemical. The flushing resulted in reduction in this ratio and the intensity of reduction was more in treated plants (1.10 in sprayed trees as against 1.68 in control).

Before flowering C:N ratio was more in control (10.86) compared to sprayed trees (6.17). After flowering the C:N ratio was found decreased to a substantial level both in treated and control plants. After nut set the C:N ratio recorded an increase by 2.43 in treated plants where as in control the ratio was decreased slightly by 0.83.

(iv) Starch (%)

The starch content in mature shoots was not found improved immediately in reponse to foliar application of the chemical. The content in leaves of these shoots registered a steady decline when analysed after flushing. The intensity of depletion was almost same both in treated and control plants. Before flowering the starch in reproductive flushes of sprayed and unsprayed trees did not vary considerably (1.28 and 1.12%). After flowering the starch content in these flushes

registered a sudden increase which was comparatively high in sprayed trees (6.21%). Nut set decreased the starch content both in sprayed and unsprayed trees.

(v) Total phenols (%)

Spraying with selected chemical combination reduced the phenol content in leaves of mature shoots, where as the quantity remained unaltered in control (Table 31). Flushing reduced the phenols in these leaves and the intensity of depletion was comparatively more in treated plants. The quantity recorded at this stage was 0.18 per cent in treated plants as against 0.29 per cent in control.

Flowering and nut set resulted in reduction of phenol content in the reproductive flushes. The intensity of reduction was found to be more in treated plants compared to control when analysed at both the stages viz., after flowering and nutset.

(vi) Chlorophyll (mg g^{-1})

Foliar application of the chemical was not found to alter significantly the chlorophyll 'a', 'b' and total chlorophyll content in the leaves of mature shoots when analysed three days after treament (Table 31). Flushing resulted in drastic reduction in chlorophyll and the intensity was more in treated plants compared to control.

In the reproductive flushes the chlorophyll conent was low before flowering in control and treated plants. It was raised to a very high level after panicle development . It can be seen that the increase in the treated plants was more compared to control (1.21 mg g^{-1} chlorophyll 'a', 2.38 mg g^{-1} chlorophyll 'b' and 3,59 mg g^{-1} total chlorophyll in treated plants as against 1.12 mg g^{-1} chlorophyll 'a', 1.98 mg g^{-1} chlorophyll 'b' and 3.10 mg g^{-1} total chlorophyll in control).

After nut set the chlorophyll content in control and treated plants was found reduced. However the chlorophyll 'a', 'b' and total chlorophyll was found retained relatively at higher levels in treated plants compared to control.

4.3.6 Changes in varietal characters (pooled effect) in response to spray application of the selected chemical combination

4.3.6.1 Response of the variety Madakkathra-1

Observations on the vegetative,flowering, nut and yield characters of the variety Madakkathra-1 recorded during 1997-'98 and 1998-'99 season in response to spray application of cultar 1000 mg l^{-1} combined with KNO_3 one per cent and carbaryl 0.10 per cent were pooled and the mean values with statistical interpretations are given in Table 32.

(i) Vegetative characters

All the vegetative characters under study varied significantly among the treated plants and control. Flushing was observed in treated plants within six days after chemical application while control plants entered in flushing stage only 23 days after the date of treatment. In treated plants number of flushes was increased by 8 m^{-2} while the flush length and number of leaves were decreased. Flushing span was shortened to 22 days while it was extended further to approximately by 11 days in control.

(ii) Flowering characters

The characters studied in relation to flowering were found modified favourably by chemical application. Time taken for flowering registered significant reduction by 24 days in treated plants. More number of panicles per m^2 was produced (32.18 m^{-2}) with more number of hermaphrodite flowers per panicle. Chemical application also had the effect of inducing synchronised flowering and the span was reduced by 11 days in treated plants. Significant improvement in nut production was also recorded in response to application of chemical. Number of nuts per panicle was 14.73 in treated plants as against 11.08 in control.

Table 32. Influence of spray application of the selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 %+ carbaryl 0.10 %) on the variety "Madakkathra-1" (Pooled analysis)

Characters	Mean		t value
	Treated	Control	
i) Vegetative characters			
Days to flushing	6.21	23.50	-50.42*
Number of flushes (m^{-2})	36.74	28.20	5.57
Length of flushes (cm)	6.79	8.25	-3.05*
Number of leaves ($flush^{-1}$)	6.36	7.40	-2.97*
Flushing span (days)	21.58	32.75	-9.06*
(ii) Flowering characters			
Days to flowering	12.68	36.50	-33.48*
Number of panicles (m^{-2})	32.18	24.68	4.77*
Number of hermaphrodite flowers ($panicle^{-1}$)	131.68	112.50	2.79*
Duration of flowering (days)	35.59	46.84	-9.92*
Number of nuts ($panicle^{-1}$)	14.73	11.08	2.24*
(iii) Nut and yield characters			
Nut length (cm)	2.50	2.52	0.92
Nut breadth (cm)	2.29	2.28	0.30
Hundred nut weight (g)	681.12	672.25	0.48
Kernel weight (g)	1.76	1.78	-0.20
Yield (kg)	4.71	1.70	3.26*
Fruit weight (g)	44.85	43.98	1.25

(iii) Nut and yield characters

Significant improvement (3 kg per tree) in yield (Table 32) was recorded in response to spray application of the chemical. Nut length, nut breadth, nut weight, kernel weight and fruit weight are the characters in which chemical application did not bring any significant change.

4.3.6.2 Response of the variety Madakkathra-2

The results of the pooled analysis of the data generated on vegetative, flowering, nut and yield characters during 1996-'97, 1997-'98 and 1998-'99 seasons, in response to application of cultar 1000 mg l^{-1} combined with KNO_3 one per cent and carbaryl 0.10 per cent to the late high yielding variety Madakkathra-2 are presented in Table 33.

(i) Vegetative characters

All the vegetative characters varied significantly among the treated and control plants. Flushing was observed in treated plants 34 days earlier compared to control.

Chemical application induced more flushes per m^2 (33.34). Flush length as well as leaf production was reduced. Treatment also induced compact flushing phase and registered a reduction in flushing span by 10 days compared to control.

(ii) Flowering characters

Significant variation in flowering characters was observed in treated plants compared to control. The plants that received chemical treatment entered in flowering stage within 22 days after treatment while flowering in control plants occurred only 57 days after the date of treatment.

Significantly high panicle production per m^2 was recorded in the treated plants. The improvement registered was as high as 8.72 per m^2. Production of hermaphrodite flowers was accelerated by 20 per panicle due to the chemical application.

Table 33 Influence of spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1 %+ carbaryl 0.10 %) on the variety "Madakkathra-2" (Pooled analysis)

Characters	Mean		t value
	Treated	Control	
(i) Vegetative characters			
Time taken for flushing (days)	7.78	42.25	-16.10*
Number of flushes (m^{-2})	33.34	26.40	4.30*
Length of flushes (cm)	5.85	6.40	-1.03
Number of leaves ($flush^{-1}$)	5.03	6.60	-5.40*
Flushing span (days)	22.96	32.25	-13.90*
(ii) Flowering characters			
Days to flowering	22.13	56.88	-14.00*
Number of panicles (m^{-2})	29.08	20.30	5.40*
Number of hermaphrodite flowers ($panicle^{-1}$)	151.37	131.38	1.23*
Duration of flowering (days)	38.12	58.27	-3.36*
Number of nuts ($panicle^{-1}$)	16.08	8.70	5.73*
(iii) Nut and yield characters			
Nut length (cm)	2.70	2.71	1.11
Nut breadth (cm)	2.90	2.85	1.34
Hundred nut weight (g)	869.30	848.00	2.29*
Kernel weight (g)	2.19	2.06	3.30*
Yield (kg)	4.02	2.56	2.44*
Fruit weight (g)	73.19	73.38	-0.72

The treatment also had a favourable effect on synchronising the panicle production and the flowering phase was reduced to 38 days as against 58 days in control plants. Number of nuts per panicle was found doubled in response to chemical application. Number of nuts per panicle recorded in treated plants was 16.08 as against 8.70 recorded for the control.

(iii) Nut and yield characters

Nut weight, kernel weight and yield were the important characters in which chemical application induced significant positive improvement in the pooled analysis. Nut weight was increased by 21.30 g per hundred nut (Table 33) Kernel produced in treated plants were bolder and recorded a mean kernel weight of 2.19 g. The mean yield per tree was also increased to 4.02 kg per plant compared to 2.56 kg in control.

4.3.7 Response of different varieties to soil application of cultar

Varietal response to soil application of cultar (paclobutrazol) was analysed on the basis of observations on vegetative, flowering nut and yield characters in treated and control plants (Appendix - VII). The mean values for each character is presented in Tables 34,36 and 38 and mean deviation of each character in treated plants from that of control is presented in Tables 35, 37 and 39.

4.3.7.1 Vegetative characters

(i) Days to flushing

In all the six varieties studied time taken for flushing was reduced (Table 34) in response to soil application of the chemical.

Analysis of the magnitude in reduction (Table 35) revealed that induction of flushing occured much earlier in the variety Sulabha in which treated plants entered into flushing 34 days earlier than control. Response was low for the variety Madakkathra-1. In this variety flushing was observed only seven days earlier compared to control.

Table 34. Varietal response to soil application of cultar (3.0 ml plant^{-1}) in relation to vegetative characters

Variety	Days to flushing		No: of flushes (m^{-2})		Length of flush (cm)		Number of leaves (flush^{-1})		Flushing span (days)	
	Treated	control	Treated	control	Treated	control	Treated	control	Treated	Control
Anakkayam-1	17.25	29.00	31.20	30.20	5.90	6.90	6.50	8.00	26.30	35.00
Madakkathra-1	19.00	26.00	26.30	20.10	6.40	6.40	7.00	7.00	28.50	26.00
Dhana	15.75	34.00	29.60	28.20	5.90	7.10	6.50	8.00	25.30	26.00
Kanaka	15.50	29.00	30.60	28.20	6.70	7.90	7.50	8.00	26.50	39.00
Madakkathra-2	21.75	41.00	31.70	26.50	6.60	7.80	7.30	9.00	21.80	28.00
Sulabha	18.75	53.00	42.50	46.40	6.30	7.90	6.80	9.00	15.00	30.00

Table 35. Improvement in vegetative characters of the varieties in response to soil application of cultar (3.0 ml plant^{-1})

Variety	Days to flushing	Number of flushes (m^{-2})	Length of flush (cm)	Number of leaves (flush^{-1})	Flushing span (days)
Anakkayam-1	1.522^{b} (-11.768)	1.662^{a} (0.919)	1.643^{b} (-1.05)	1.638^{c} (-1.502)	1.559^{bc} (-8.794)
Madakkathra-1	1.580^{a} (-7.00)	1.709^{a} (6.126)	1.654^{a} (0.05)	1.653^{a} (0.000)	1.676^{a} (2.451)
Madakkathra-2	1.409^{c} (-19.360)	1.701^{a} (5.184)	1.641^{bc} (-1.225)	1.636^{c} (-1.750)	1.588^{b} (-6.278)
Dhana	1.426^{c} (-18.355)	1.665^{a} (1.280)	1.642^{bc} (-1.175)	1.638^{c} (-1.503)	1.532^{c} (-10.964)
Kanaka	1.497^{b} (-13.565)	1.675^{a} (1.675)	1.641^{bc} (-1.200)	1.648^{b} (-0.503)	1.510^{cd} (-12.674)
Sulabha	1.029^{d} (-34.308)	1.612^{a} (1.512)	1.638^{c} (-1.575)	1.631^{d} (-2.252)	1.476^{d} (-15.084)

Values having any common superscript are not significantly different from one another.
Values in the parenthesis are in the original scale and logarithmic transformed values are given above to them.

Table 36. Varietal response to soil application of cultar (3.0 ml plant^{-1}) in relation to flowering characters

Variety	Days to flowering		No: of panicles (m^{-2})		No. of hermaphrodite flowers (panilce^{-1})		Duration of flowering (days)		No:of nuts (panicle^{-1})	
	Treated	Treated	Treated	control	Treated	Control	control	control	Treated	Control
Anakkayam-1	18.75	29.00	28.10	24.60	141.00	106.00	36.50	46.00	17.85	10.60
Madakkathra-1	22.50	32.00	21.50	18.40	151.00	135.20	34.50	41.00	21.88	20.50
Dhana	17.00	40.00	21.70	18.60	161.00	123.40	29.50	41.00	16.83	12.80
Kanaka	18.75	36.00	25.70	24.50	171.50	140.00	34.00	48.00	17.50	10.20
Madakkathra-2	26.50	48.00	27.30	22.40	178.00	140.00	37.30	34.00	11.30	9.60
Sulabha	22.00	56.00	33.50	22.20	135.00	108.80	24.50	40.00	12.23	9.80

Table 37. Improvement in flowering characters of the varieties in response to soil application of cultar (3.0 ml plant^{-1})

Variety	Days to flowering	Number of panicles (m^{-2})	No: of hermaphrodite flowers (panicle^{-1})	Duration of flowering (days)	Number of nuts (panicle^{-1})
Anakkayam-1	-10.250 ^{a}	1.686 ^{b} (3.486)	1.759 ^{b} (34.89)	-9.500 ^{bc}	1.717 ^{a} (7.139)
Madakkathra-1	-9.500 ^{a}	1.682 ^{b} (3.118)	1.570 ^{d} (14.14)	-6.500 ^{b}	1.666 ^{d} (1.304)
Dhana	-23.000 ^{c}	1.682 ^{b} (3.097)	1.846 ^{a} (36.48)	-11.50 ^{c}	1.690 ^{b} (4.021)
Kanaka	-17.250 ^{b}	1.665 ^{c} (1.200)	1.709 ^{bc} (31.18)	-14.000 ^{de}	1.718 ^{a} (7.294)
Madakkathra-2	-21.500 ^{c}	1.698 ^{a} (4.844)	1.849 ^{a} (37.40)	-3.250 ^{a}	1.669 ^{d} (1.691)
Sulabha	-34.000 ^{d}	1.701 ^{a} (5.227)	1.699 ^{c} (24.16)	-15.500 ^{e}	1.676 ^{c} (2.422)

Values having any common superscript are not significantly different from one another
Data in the parenthesis are in the original scale and logarithmic transformed values are given above to them
Data on days to flowering and duration of flowering were not subjected to transformation

Table 38. Varietal response to soil application of cultar (3.0 ml plant^{-1}) in relation to nut and yield characters

Variety	Nut length (cm)		Nut breadth (cm)		100 nut weight (g)		Kernel weight (g)		Yield (kg)		Fruit weight (g)	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Anakkayam-1	2.90	2.90	1.80	1.80	599.30	600.00	1.80	1.70	4.80	4.20	37.20	36.80
Madakkathra-1	2.40	2.40	1.70	1.60	613.30	610.00	1.70	1.80	3.20	2.20	43.30	42.50
Dhana	3.10	3.00	2.90	2.90	1089.50	1059.00	2.30	2.20	4.60	2.80	75.40	74.50
Kanaka	2.90	2.90	1.80	1.90	612.00	608.00	2.00	2.00	3.60	2.00	39.70	40.50
Madakkathra-2	2.90	2.80	2.90	2.90	879.00	869.00	2.30	2.20	3.30	1.80	73.80	72.80
Sulabha	3.20	3.20	3.10	2.90	951.00	912.00	2.30	2.40	4.40	3.40	75.20	75.00

Table 39. Improvement in nut and yield characters of the varieties in response to soil application of cultar (3.0 ml plant^{-1})

Variety	Nut length (cm)	Nut breadth (cm)	100 nut weight (g)	Kernel weight (g)	Yield (kg)	Fruit weight (g)
Anakkayam-1	1.653^{a} (-0.050)	1.653^{a} (-0.001)	1.643^{b} (-1.031)	1.654^{a} (0.049)	1.659^{d} (0.649)	1.657^{bc} (0.365)
Madakkathra-1	1.653^{a} (-0.000)	1.654^{a} (0.125)	1.683^{ab} (3.140)	1.652^{a} (-0.075)	1.681^{a} (2.935)	1.660^{ab} (0.744)
Dhana	1.654^{a} (0.125)	1.653^{a} (-0.025)	1.861^{a} (27.650)	1.654^{a} (0.075)	1.670^{b} (1.773)	1.662^{a} (0.891)
Kanaka	1.653^{a} (-0.025)	1.652^{a} (-0.075)	1.689^{ab} (3.862)	1.653^{a} (-0.001)	1.668^{b} (1.574)	1.645^{d} (-0.839)
Madakkathra-2	1.654^{a} (0.0750	1.653^{a} (-0.001)	1.732^{ab} (8.994)	1.654^{a} (0.075)	1.667^{bc} (1.500)	1.663^{a} (0.994)
Sulabha	1.653^{a} (0.025)	1.655^{a} (0.149)	1.877^{a} (13.376)	1.652^{a} (-0.075)	1.663^{cd} (1.049)	1.655^{c} (0.170)

Values having any common superscript are not significantly different from one another
Values in the parenthesis are in the original scale and logarithmic transformed values are given above to them

(ii) Number of flushes (m^{-2})

Eventhough number of flushes m^{-2} registered slight decrease for the variety Sulabha (Table 34), the response of the varieties in terms of improvement in flush number was on par (Table 35).

(iii) Length of flushes (cm)

Length of flushes emerged after chemical application was reduced except in the variety Madakkathra-1 (Table 34). For this variety flush length was same in treated plants and control.

The response was high for the variety Sulabha (Table 35) in which the length on an average was reduced by 1.58 cm per flush. This reduction was on par with the varieties Madakkathra-2, Dhana and Kanaka.

(iv) Number of leaves ($flush^{-1}$)

Reduction in leaf number per flush was noticed in all the varieties studied except in Madakkathra-1 (Table 34). In this variety the leaf number was not changed in response to chemical application. Maximum reduction in number of leaves (2.25 per flush) was recorded by the variety Sulabha (Table 35).

(v) Flushing span (days)

Flushing span was reduced in all the varieties except in Madakkathra-1 in response to chemical application (Table 34). The magnitude of reduction was more for the variety Sulabha in which flushing was completed in treated plants, 15 days earlier compared to control.

4.3.7.2 Flowering characters

(i) Days to flowering

In all the varieties chemical application augmented the panicle intiation and the treated plants flowered much earlier compared to control (Table 36).

Treated plants of the variety Sulabha flowered 34 days earlier and was superior in response to all other varieties. The earliness induced (9 to 10 days) was comparatively less in the early season varieties Madakkathra-1 and Anakkayam-1 (Table 37).

(ii) Number of panicles (m^{-2})

Improvement in number of panicles per m^2 was also noticed in treated plants of all the varieties. The magnitude was high (five panicles per m^2) for the varieties Madakkathra-2 and Sulabha, whereas the response of the variety Kanaka was inferior.

(iii) Number of hermaphrodite flowers (panicle^{-1})

All the varieties studied responded positively to chemical application and the production of hermaphrodite flowers was increased (Table 36).

The improvement in this character varied among the varieties analysed (Table 37). The varieties Madakkathra-2 and Dhana recorded the maximum improvemt (37.40 and 36.48 per panicle respectively), while the improvement was minimum (14.14 per panicle) for the variety Madakkathra-1.

(iv) Duration of flowering (days)

Chemical application resulted in synchronised flowering in all the varieties studied and duration of flowerig was reduced (Table 36). The response of the varieties varied significantly and was high for the variety Sulabha. In this variety flowering was completed 16 days earlier in treated plants compared to control (Table 37). The response of the variety Madakkathra-2 was low and the duration of flowering was found reduced only by three days.

(v) Number of nuts (panicle^{-1})

Production of nuts per panicle was increased in treated plants of all the varieties (Table 36). The variety Anakkayam-1 showed more positive response

to chemical application and the number of nuts was increased by seven nuts per panicle. In the varieties Madakkathra-1 and Madakkathra-2 the improvement was low compared to other varieties.

4.3.7.3 Nut and yield characters

(i) Nut length (cm)

The average length of nuts of all the varieties studied were not changed considerably in response to soil application of chemical (Table 38). The analysis on variation revealed the insignificant influence of the chemical in altering nut length among varieties (Table 39)

(ii) Nut breadth (cm)

Chemical applcation did not casuse much variation in breadth of nuts of all the vrieties studied (Table 38 and 39).

(iii) Hundred nut weight (g)

Nut weight in treated plants of all the varieties studied was better than that in control except for the variety Anakkayam-1 (Table 38). In this variety nut weight recorded in treated plants and control were on par. The improvement in nut weight of the varieties Madakkathra-1, Madakkathra-2, Dhana, Kanaka and Sulabha were on par (Table 39).

(iv) Kernel weight (g)

The chemical appplication did not influence the kernel weight of the varieties studied. The variation analysed among the varieties was also found insignificant.

(v) Yield (kg)

Irrespective of the varieties studied improvement in yield was noted in treated plants (Table 38). Maximum improvement was recorded for the variety

Madakkathra-1 in which yield per plant was improved by 3 kg compared to control.

(vi) Fruit weight (g)

Fruit weight was found not much influenced by soil application of the chemical.

4.4 Induction of dwarfism in cashew grafts at nursery stage

The results of the experiment conducted to induce dwarfism in cashew grafts through irradiation of seeds and soil application of chemical (cultar) are presented below

4.4.1 Effect of irradiation of seeds

4.4.1.1. Germination

The germination percentage of seedlings at different levels of irradiation recorded at 15 days interval upto one month and survival of seedlings two months after germination are given in Table 40. The different levels of irradiation caused significant variation in germination and survival of seedlings. The lowest level of irradiation (5 Gy) augmented the process of germination resulting in maximum number of seedlings at 15 and 20 days after sowing (81 and 88 per cent respectively).This superiority was maintained as observed at 25 and 30 days after sowing. All the other levels of irradiation had a negative effect on germination (%) and no seeds germinated at the initial stage of observation (15 days after sowing) at levels of 60 Gy and 70 Gy. In these treatments the final germination percentage was also low (15 and 2 per cent respectively). However survival of the seedlings was not improved due to irradiation. Survival recorded in the treated seeds at a dose of 5 Gy was only 72 per cent as against 80 per cent in control. The survival rate was low in all other treatments and none of the seedlings of 70 Gy irradiation level survived two months after germination.

Table 40. Effect of irradiation on germination of cashew seeds and survival of seedlings

Irradiation dose (Gy)	Germination (%)				Survival (%) of seedlings (2 months after germination)
	Days after sowing				
	15	**20**	**25**	**30**	
5	81	88	88	88	72
10	57	73	73	73	61
15	56	68	74	74	64
20	48	79	79	79	58
25	52	76	76	76	57
30	49	69	71	71	46
40	37	67	70	70	44
50	12	33	33	33	18
60	0	12	15	15	11
70	0	0	2	2	0
Control	64	81	82	82	80
χ^2	16.60	2.30	2.70	2.70	5.89

4.4.1.2 Growth of root stocks

The growth parameters of cashew seedlings (raised from irradiated seeds) viz., height, girth and number of leaves recorded from 15 days to 60 days after germination are presented in Table 41, together with statistical interpretations (Appendix - VIII).

(i) Height (cm)

Irradiation of seeds at higher level viz., beyond 20 Gy had a tendency to reduce the root stock height while the lower doses (5 to 20 Gy) had no effect.

Eventhough variability with respect to height existed among treatments it was not wide at initial stage (15 days after germination). In the treatments 5 to 20 Gy and control, the seedling height was on par and significantly superior to rest of the treatments. The irradiation dose 60 Gy produced shortest seedlings.

The variation in seedling height among different irradiation levels became wide at one month after germination. Seedlings at 5 Gy irradiation and control registred maximum height (17.62 to 17.93 cm) while seedlings at 50 and 60 Gy was far inferior (6.01 to 6.55 cm)

At 45 and 60 days after germination the superiority of seedlings at 5 Gy irradiation and control was maintained. The seedlings at the 60 Gy irradiation level recorded the lowest height (8.53 cm) after two months.

(ii) Girth (cm)

The different doses of irradiation given to the seeds produced variability in girth of root stocks. Maximum girth was recorded with root stocks at 50 and 60 Gy irradiation level at all stages of observation. Girth of seedlings varied irratically among rest of the treatments and when observed at the final stage (60 days after germination), girth of seedlings at 40 Gy irradiation was found improved and became on par with seedlings at 50 and 60 Gy irradiation dose.

Table 41. Growth parameters of root stocks influenced by irradiation of cashew seeds

Irradiation dose (Gy)	Height (cm)				Girth (cm)				Number of leaves (plant^{-1})			
	Days after germination				Days after germination				Days after germination			
	15	30	45	60	15	30	45	60	15	30	45	60
5.0	11.140^{a}	17.620^{a}	19.890^{a}	21.540^{a}	1.510^{c}	2.110^{b}	2.660^{cd}	2.990^{b}	8.000^{ab}	9.400^{abc}	10.800^{bc}	12.800^{b}
10.0	11.470^{a}	15.710^{b}	16.460^{b}	18.450^{b}	1.360^{d}	2.060^{b}	2.580^{d}	2.960^{b}	8.000^{ab}	9.600^{ab}	11.200^{b}	12.600^{bc}
15.0	11.070^{a}	14.620^{bc}	16.180^{b}	18.990^{b}	0.880^{f}	1.550^{d}	2.230^{e}	2.620^{d}	8.200^{ab}	9.600^{ab}	11.100^{bc}	12.700^{b}
20.0	12.390^{a}	13.870^{c}	15.630^{b}	17.070^{b}	1.110^{e}	1.570^{d}	2.110^{e}	2.770^{cd}	7.800^{b}	8.900^{bc}	10.500^{bc}	12.200^{bc}
25.0	6.830^{b}	9.070^{d}	10.840^{c}	13.930^{c}	1.340^{d}	2.070^{b}	2.560^{d}	2.960^{b}	7.108^{c}	8.800^{c}	10.300^{c}	11.800^{c}
30.0	6.640^{b}	9.120^{d}	11.740^{c}	13.000^{c}	1.520^{c}	1.900^{c}	2.590^{d}	2.920^{bc}	6.100^{d}	7.300^{d}	8.600^{d}	9.900^{d}
40.0	5.870^{b}	7.730^{de}	9.310^{cd}	12.110^{c}	1.610^{b}	2.180^{b}	2.770^{bc}	3.360^{a}	4.900^{e}	6.500^{e}	7.800^{e}	9.00^{e}
50.0	5.420^{bc}	6.550^{ef}	9.880^{c}	10.870^{cd}	1.810^{a}	2.380^{a}	2.900^{ab}	3.262^{a}	3.900^{f}	4.900^{f}	5.700^{f}	6.80^{f}
60.0	3.960^{c}	6.010^{f}	7.410^{d}	8.530^{d}	1.860^{a}	2.390^{a}	2.930^{a}	3.270^{a}	3.200^{g}	4.500^{f}	5.000^{f}	5.50^{gf}
Control	11.940^{a}	17.930^{a}	20.120^{a}	23.670^{a}	1.380^{d}	2.100^{b}	2.590^{d}	3.070^{b}	8.500^{a}	9.900^{a}	12.000^{a}	13.60^{a}

Values having any common superscript are not significantly different from one another.

(iii) Number of leaves (plant^{-1})

The different levels of irradiation given to the seeds affected the production of leaves on root stocks. At initial stages of observation (15and 30 days after germination) leaf number per plant recorded was significantly high for the seedlings at 5, 10 and 15 Gy irradiation level and was on par with control. In subsequent stages of growth, leaf production was reduced irrespective of the treatment levels and the leaves per plant became significantly low compared to control.

Lowest number of leaves was recorded with seedlings at 50 and 60 Gy irradiation level when observed at all the stages of growth.

4.4.1.3 Succes of grafting on root stocks of irradiated seeds

4.4.1.3.1 Sprouting and survival of grafts

Sprouting (%) of grafts observed at one month after grafting and survival observed two and three months after grafting are presented in Table 42. The initial success as observed by sprouting (65 to 80%) did not show any significant variation upto the treatment level 30 Gy.Grafting on root stocks from treated seeds at the next two higher levels viz., 40 and 50 Gy showed only low initial success (50 and 30 percentage respectively). Seedlings raised from seeds at 60 Gy irradiation level were extreme dwarfs, that grafting could not be done on them.

The highest survival of grafts was registered in control (70%) when observed two months after grafting .Higher the irradiation dose lower was the survival of grafts and it was reduced to the extent of 20 per cent on root stocks raised from seeds irradiated at 50 Gy (Table 42)

After three months, the grafts in all the treatments (5 to 40 Gy) survived except in 50 Gy level where slow death of grafts occurred due to leaf curling and subsequent wilting.

Table 42. Success of grafting on root stocks of irradiated seeds

Irradiation dose (Gy)	Sprouting (%)	Survival (%)	
	(One month after grafting)	(2 Months after grafting)	(3 Months after grafting)
5	80	60	60
10	75	55	55
15	75	50	50
20	80	55	55
25	65	45	45
30	70	40	40
40	50	35	35
50	30	20	0
Control	75	70	70
χ^2	7.14	2.74	14.32

4.4.1.3.2 Growth parameters of grafts as influenced by root stocks from irradiated seeds

When root stocks were raised from irradiated seeds immense variability (Appendix-IX) were shown by the grafted plants (Plate 8) at nursery stage. The details are presented in Table 43.

(i) Height (cm)

Data recorded on height of grafts at three months interval (maintained initially for one year in polybags and next year in pots) are presented in Table 43. Analysis of the data revealed that maximum retardation of growth was observed for the grafts with root stocks from seeds irradiated at 40 Gy level. Capability of this treatment to reduce height was pronounced upto 12 months growth in polybags. When observed after 15 months, the height of grafts at 25, 30 and 40 Gy irradiation level were on par. The effect of lower levels of irradiation to control growth of grafts became pronounced during subsequent growth periods and at 24 months age, height of grafts at 20, 25, 30 and 40 Gy were more or less on par.

Throughout the period of observation grafts on root stocks raised from 5 Gy and 10 Gy showed better growth in terms of height even better than the control plants (Plate).

(ii) Girth (cm)

Girth during the initial stage of growth (observed at three months age) was not much influenced by irradiation at different levels. Eventhough the response was observed to be erratic during subsequent stages of growth with different treatments, the superiority of lower doses (5 and 10 Gy) was maintained throughout the period of observation.

Plate 8. ***Effect of seed irradiation on graft growth***

5Gy

25Gy

Control

30Gy

40Gy

Table 43. Growth parameters of cashew grafts on root stocks raised from irradiated seeds

Irradiation dose (Gy)	Growth in poly bags				Growth in pots			
	Age of grafts							
	3 months	6 months	9 months	12 months	15 months	18 months	21 months	24 months
1	2	3	4	5	6	7	8	9
(i) Height								
5.0	24.24 [a]	27.32 [a]	32.00 [a]	36.36 [a]	42.42 [a]	48.52 [a]	57.32 [a]	68.30 [a]
10.0	24.62 [a]	27.60 [a]	32.48 [a]	37.88 [a]	43.32 [a]	48.14 [a]	55.64 [a]	65.74 [a]
15.0	20.64 [e]	23.96 [b]	27.22 [bc]	31.06 [c]	35.22 [c]	38.04 [cd]	41.74 [cd]	46.04 [cd]
20.0	19.44 [bc]	22.64 [b]	26.38 [b]	28.62 [bc]	31.72 [b]	33.96 [b]	36.32 [b]	39.18 [b]
25.0	21.54 [b]	22.54 [b]	23.82 [d]	25.84 [d]	27.92 [d]	30.04 [e]	33.02 [d]	36.06 [d]
30.0	21.76 [b]	22.88 [b]	24.80 [cd]	26.02 [d]	27.54 [d]	30.94 [de]	34.46 [cd]	37.06 [d]
40.0	14.52 [d]	19.50 [c]	20.06 [e]	22.90 [e]	25.78 [ad]	28.80 [e]	31.96 [d]	34.50 [d]
Control	21.94 [b]	23.96 [b]	27.50 [b]	31.88 [b]	34.00 [bc]	36.92 [bc]	39.62 [bc]	42.32 [bc]
(ii) Girth (cm)								
5.0	2.16 [a]	2.34 [a]	3.14 [a]	3.84 [a]	4.68 [a]	5.58 [a]	6.20 [a]	7.22 [a]
10.0	2.18 [a]	2.28 [ab]	3.08 [a]	3.86 [a]	4.30 [b]	5.38 [ab]	6.34 [a]	7.26 [a]

Contd.

Table 43. *Continued*

1	2	3	4	5	6	7	8	9
15.0	2.10 ^{b}	2.28 ^{ab}	2.72 ^{b}	3.44 ^{b}	4.32 ^{b}	4.92 ^{c}	5.62 ^{b}	6.32 ^{b}
20.0	2.06 ^{ab}	2.10 ^{b}	2.46 ^{abc}	3.04 ^{c}	3.72 ^{a}	4.30 ^{dc}	5.00 ^{c}	5.60 ^{c}
25.0	2.06 ^{ab}	2.16 ^{b}	2.52 ^{bc}	3.26 ^{bc}	3.68 ^{c}	4.46 ^{d}	4.96 ^{cd}	5.20 ^{d}
30.0	2.08 ^{ab}	2.14 ^{b}	2.68 ^{b}	3.30 ^{bc}	3.92 ^{c}	4.98 ^{abc}	5.52 ^{b}	5.92 ^{c}
40.0	2.18 ^{a}	2.40 ^{a}	2.60 ^{b}	3.22 ^{bc}	3.66 ^{c}	3.96 ^{e}	4.58 ^{bc}	4.86 ^{d}
Control	1.88 ^{b}	1.68 ^{c}	2.28 ^{e}	3.10 ^{c}	3.72 ^{c}	3.98 ^{e}	4.22 ^{c}	4.88 ^{d}
(iii) Number of leaves (plant^{-1})								
5.0	11.00 ^{d}	16.00 ^{c}	21.80 ^{d}	25.20 ^{ef}	30.60 ^{f}	40.20 ^{cd}	45.80 ^{cd}	53.20 ^{cd}
10.0	12.40 ^{bcd}	18.60 ^{bc}	24.00 ^{bcd}	31.00 ^{bc}	37.00 ^{bc}	44.00 ^{bc}	55.60 ^{b}	62.00 ^{ab}
15.0	12.20 ^{bcd}	17.60 ^{c}	22.80 ^{cd}	27.80 ^{de}	33.00 ^{def}	37.80 ^{d}	43.60 ^{d}	49.00 ^{d}
20.0	14.00 ^{ab}	17.60 ^{c}	23.60 ^{cd}	30.80 ^{bc}	35.60 ^{cd}	42.60 ^{bc}	49.40 ^{c}	58.40 ^{b}
25.0	15.20 ^{a}	21.40 ^{a}	27.40 ^{ab}	33.40 ^{b}	39.20 ^{b}	47.40 ^{b}	56.00 ^{b}	62.20 ^{b}
30.0	13.60 ^{abc}	21.20 ^{ab}	30.00 ^{a}	38.20 ^{a}	46.60 ^{a}	54.00 ^{a}	62.40 ^{a}	71.20 ^{a}
40.0	11.40 ^{cd}	17.00 ^{c}	22.60 ^{cd}	25.00 ^{f}	31.00 ^{ef}	36.40 ^{d}	39.40 ^{e}	44.40 ^{e}
Control	12.20 ^{bcd}	18.40 ^{c}	26.00 ^{bc}	28.60 ^{cd}	33.60 ^{de}	44.80 ^{bc}	54.40 ^{b}	57.60 ^{bc}

Values having any common superscript are not significantly different from one another.

(iii) Number of leaves (plant^{-1})

Number of leaves on grafts at 20 to 30 Gy irradiation treatments were significantly high at earlier stage of growth (Table 43). However during later stage (after 12 months) the leaf number was found significantly higher only in grafts at 30 Gy irradiation level. When observed after transplanting to pots the number of leaves per plant was significantly low in grafts at 40 Gy irradiation level at all stages of observation.

4.4.2. Response of cashew grafts to soil application of cultar (paclobutrazol) in nursery

Application of cultar to the grafts at nursery stage resulted in drastic change in their survival and growth behaviour. When cultar was applied at 4 and 6 ml per plant,they showed symptoms of wilting. Defoliation occurred gradually and the plants died within one week. Plants applied with cultar at 8 and 10 ml per plant dried completely within three days after application. Only those plants which received the lower two doses (one and 2 ml per plant) were survived. They were applied with the same dose of chemical for the second time at three months age.

Observations on the growth parameters viz., height, girth and number of leaves per plant were recorded after application of the second dose (six months age) up to two years, at three months interval and are given in Table 44 with statistical interpretations (Appendix-X).

(i) Height of the grafts (cm)

Observations recorded on height at three months interval upto two years revealed that soil application of cultar at one and 2 ml per plant reduced the height of grafts to a substantial level (Table 44). This was true at all stages of observation (Plate 9). When observed two years after treatment,grafts were much reduced in their size (33.76 to 33.89 cm).

Plate 9. ***Effects of soil application of cultar on graft growth***

0.25 g *a.i* (plant^{-1})

Nursery

0.50 g *a.i* (plant^{-1})

0.25 g *a.i* (plant^{-1})

0.50 g *a.i* (plant^{-1})

Field

Control

Table 44. Growth parameters of cashew grafts treated with cultar

Character	Dose of cultar (plant^{-1})	Growth in polybags			Growth in pots			
		Age of grafts (months)						
		6	9	12	15	18	21	24
(i) Height (cm)								
	1 ml	18.50^{b}	21.48^{b}	24.83^{b}	29.16^{b}	30.95^{b}	32.47^{b}	33.76^{b}
	2 ml	18.61^{b}	21.16^{b}	24.26^{b}	30.06^{b}	31.07^{b}	32.19^{b}	33.89^{b}
	Control	20.53^{a}	25.06^{a}	30.09^{a}	35.56^{a}	41.17^{a}	47.76^{a}	52.49^{a}
(ii) Girth (cm)								
	1 ml	2.28^{ab}	2.61^{b}	3.15^{b}	4.01^{b}	4.56^{a}	5.20^{a}	6.03^{b}
	2 ml	2.35^{a}	2.88^{a}	3.59^{a}	4.41^{a}	4.63^{a}	5.21^{a}	6.93^{a}
	Control	2.19^{b}	2.44^{b}	2.84^{c}	3.25^{c}	3.64^{b}	4.06^{b}	4.69^{c}
(iii) Number of leaves (plant^{-1})								
	1 ml	7.00^{b}	9.10^{b}	12.00^{b}	14.80^{b}	24.30^{b}	29.70^{a}	35.60^{a}
	2 ml	8.00^{ab}	9.50^{b}	11.10^{b}	16.10^{b}	23.50^{b}	29.80^{a}	34.20^{a}
	Control	9.80^{a}	17.30^{a}	17.68^{a}	24.90^{a}	29.60^{a}	32.30^{a}	34.00^{a}

Values having any common superscript are not significantly different from one another.

(ii) Girth (cm)

Girth of grafts was improved significantly in response to soil application of cultar. This response was evident when observed at three months after the application of second dose (when grafts were at six months age). The plants treated with cultar at one and 2 ml per plant at this age attained a girth of 2.28 and 2.35 cm respectively which was significantly superior to control plants. Girth increment was rapid in plants treated with cultar at 2 ml per plant and excelled the other treatments at all stages of observation. On an average the grafts in this group attained girth of 6.93 cm, two years after treatment compared to 4.69 cm in control plants.

(iii) Number of leaves (plant^{-1})

Leaf production was reduced drastically in response to application of chemical during early stages of growth. Thus leaf number in treated plants was significantly low compared to control plants till the grafts attained 18 months. When observed at 21 and 24 months age, number of leaves were statistically on par in treated and control plants.

4.4.3 Variation in biochemical and anatomical characters of selected dwarfs

4.4.3.1 Variation in biochemical constituents

The data on biochemical constituents viz., chlorophyll, carbohydrates, nitrogen, phenol content and the activity of enzyme Nitrate Reductase recorded for the selected dwarf grafts in cultar (1 and 2 ml per plant) and irradiation treatment (25, 30 and 40 Gy) are presented in Table 45.

(i) Effect of cultar

The chloropyll 'a' (0.81 mg g $^{-1}$), chlorophyll 'b' (0.22 mg g^{-1}), total chlorophyll (1.03 mg g^{-1}), carbohydrates (8.74 %)and nitrogen (3.56 %) in grafts treated with cultar at 2 ml per plant were significantly superior to the grafts in

Table 45. Biochemical characters of selected dwarf grafts in irradiation and cultar treatments

Treatments	Treatment dose ($plant^{-1}$)	Chlorophyll 'a'($mg\ g^{-1}$)	Chlorophyll 'b'($mg\ g^{-1}$)	Total chlorophyll ($mg\ g^{-1}$)	Carbohydrate (%)	Nitrogen (%)	Phenols (%)	NRA (mmol of $NO_2\ g^{-1}\ h^{-1}$)
Cultar	1 ml	0.81	0.22	1.03	8.74	3.56	1.06	0.92
	2 ml	0.66	0.15	0.82	8.35	3.39	0.89	0.83
	Control	0.63	0.13	0.76	7.78	3.08	0.55	0.79
	CD (P = 0.05)	0.12	0.06	0.18	0.85	0.06	0.91	0.30
	SEm±	0.02	0.01	0.03	0.14	0.01	0.15	0.05
Irradiation	Irradiation dose (Gy)							
	25	0.55	0.15	0.70	7.24	3.08	0.54	0.71
	30	0.60	0.21	0.81	6.89	2.83	0.89	0.71
	40	0.50	0.10	0.60	7.23	2.80	0.88	0.74
	Control	0.58	0.18	0.76	7.41	3.25	0.71	0.73
	CD (P = 0.05)	0.14	0.14	0.23	0.77	0.23	0.72	0.05
	SEm±	0.03	0.03	0.05	0.17	0.05	0.16	0.01

control. The phenol content and the Nitrate Reductase Activity (NRA) recorded for the grafts treated with cultar (1 and 2 ml per plant) did not differ significantly from that recorded for the control.

(ii) Effect of irradiation

There was no significant difference in chlorophyll 'a', 'b', total chlorophyll and the activity of the enzyme Nitrate Reductase recorded for the grafts at different irradiation level and that recorded for the control (Table 45). The carbohydrate content (7.41%) registered was significantly high in control compared to grafts at different irradiation levels. Similarly the nitrogen content was also signficantly high in control (3.25%) compared to 30 Gy and 40 Gy (2.83% and 2.80% respectively) irradiation level.

The phenol content (0.54%) at 25 Gy irradiation level was significantly inferior compared to control. Phenol content recorded in grafts at 30 Gy (0.85%) , 40 Gy (0.88%) and control was on par.

4.4.3.2 Variation in anatomical characters

Observations on anatomical characters viz., number of stomata (mm^{-2}), leaf thickness (mm), cuticle thickness (μm), bark thickness (mm) and number of xylem vessels (mm^{-2}) recorded for the grafts treated with cultar at two different levels (1 and 2 ml per plant) and irradiation at three levels (25, 30 and 40 Gy) are given in Table 46.

(i) Effect of cultar

Number of stomata (mm^{-2}) was not found increased in response to application of cultar. The difference in stomatal count for the grafts that received soil application of cultar one and 2 ml per plant (46.59 and 49.86 mm^{-2} respectively) and control (41.96 mm^{-2}) was statistically insignificant.

Both the treatments of cultar resulted in increase in leaf thickness (1.60 to 1.63 mm respectively) compared to control (1.54 mm).

Table 46. Anatomical characters of selected dwarf grafts in irradiation and cultar treatments

Treatments	Treatment dose ($plant^{-1}$)	Number of stomata (mm^{-2})	Leaf thickness (mm)	Cuticle thickness (µm)	Bark thickness (mm)	Number of xylem vessels (mm^{-2})
Cultar	1 ml	46.59	1.60	5.24	2.95	16.80
	2 ml	49.86	1.63	5.94	3.02	18.90
	Control	41.96	1.54	4.94	2.87	15.30
	CD (P = 0.05)	11.00	0.03	0.28	0.10	1.80
	SEm±	3.18	0.01	0.08	0.03	0.53
Irradiation	Irradiation dose (Gy)					
	25	38.41	1.48	4.38	2.40	11.90
	30	31.88	1.47	4.50	2.51	13.20
	40	35.69	1.46	3.92	2.48	10.50
	Control	35.42	1.50	4.10	2.54	12.10
	CD (P = 0.05)	2.27	0.05	0.25	0.16	2.18
	SEm±	0.79	0.02	0.11	0.07	0.76

Cuticle thickness of leaves increased due to application of cultar. Thickest cuticle (5.94 μm) was noticed in grafts applied with cultar at the rate of 2 ml per plant and cuticle was thin (4.94 μm) in control plants.

Chemical application also had a tendency to increase the bark thickness. As the quantity of cultar applied was increased to 2 ml per plant, thickness of bark increased by 0.15 mm compared to control plants .

Cultar applied at 2 ml per grafts significantly improved the number of xylem vessels (18.90 mm^{-2}) of shoots (Plate 10) compared to the grafts at lowest level of treatment (16.80 mm^{-2}) and control (15.30 mm^{-2}).

(ii) Effect of irradiation

Highest number of stomata (mm^{-2}) was observed for the plants at 25 Gy (38.41 mm^{-2}) compared to that in control (35.42 mm^{-2}). Stomata was lowest (31.88 mm^{-2}) in plants at 30 Gy irradiation level.

The influence of different irradiation levels on leaf thickness (1.46 to 1.48 mm), bark thickness (2.40 to 2.51 mm) and number of xylem vessels (10.50 to 13.20 mm^{-2}) was insignificant compared to control.

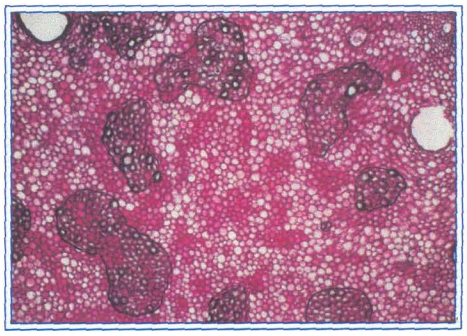
When the grafts in different irradiation levels were compared thickest cuticle (4.50 μm) was recorded for grafts at 30 Gy irradiation level.

4.4.4 Growth performance of selected dwarf grafts in the field

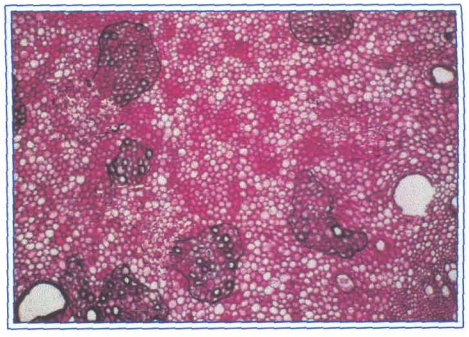
The average height, girth and number of leaves per plant recorded for the selected dwarfs after planting in the field are presented in Table 47.

The height increment acquired by the grafts of different irradiation treatments was significantly high compared to the grafts of cultar treatment. The grafts applied with cultar at the rate of one and 2 ml per plant recorded a height of 69.68 and 58.26 cm respectively, six months after planting in the field as

Plate 10. ***Pattern of xylem vessels in cultar applied grafts***



Treated



Control

Table 47. Growth parameters of selected dwarf grafts in the field

Treatments	Height (cm)		Girth (cm)		Number of leaves (plant^{-1})	
	Months after planting					
	3	6	3	6	3	6
Dose of cultar (plant^{-1})						
1ml	37.96	69.68	7.34	9.82	43.50	61.00
2 ml	34.42	58.26	7.93	10.26	45.50	63.00
Control	65.63	93.40	6.69	10.84	36.50	65.00
CD (P = 0.05)	16.16	13.77	3.36	3.64	4.31	4.49
SEm±	3.60	3.06	0.75	0.81	0.96	1.00
(ii) Dose of irradiation (Gy)						
25	48.28	86.20	7.28	10.28	45.00	75.00
30	51.28	96.48	8.20	10.40	52.50	103.00
40	56.53	94.56	9.32	12.32	63.00	108.50
control	62.20	98.38	8.42	12.48	69.00	113.00
CD (P = 0.05)	7.22	10.11	1.48	4.43	4.02	2.89
SEm±	2.25	3.15	0.46	1.38	1.25	0.90

against 93.40 cm for the respective control plants (Plate 9). The height recorded for the grafts (96.48 cm and 94.56 cm) at two higher irradiation levels did not differ significantly from control (98.38 cm), six months after planting in the field.

Much difference was not observed in girth and number of leaves among cultar treated plants and control, when observed six months after planting.

Even though the irradiation treatments did not result significant reduction in girth, number of leaves per plant was decreased compared to control.


Discussion

DISCUSSION

Cashew (*Anacardium occidentale L.*) is widely cultivated throughout the tropics for its nut and apple. Eventhough cashew has a long history as a useful plant, only in recent years a systematic research effort, realising its commercial importance was started. A major part of the research devoted in the last three decades was to increase productivity of cashew orchards.

The present investigations on " *Morphophysiological analysis of growth and yield in cashew* " was aimed to pave a path for realising higher yield from cashew plantations through chalking out strategies to overcome the existing production constraints which were hitherto unattempted.

Yield being a complex structure involving integrated set of morphophysiological characters, attempt to delineate the influence of these parameters on growth and yield was done preceeding to other research efforts. Attempts were made in the present study to overcome the influence of yield limiting characters viz., erratic, intermittent and late flowering associated with the reproductive phase of cashew.

Another area of investigation was to analyse the ways and means to induce dwarf stature in the existing genotypes which may fit for high density orcharding. The major results of the present investigations are being discussed in this chapter with the help of available literature.

5.1 Evaluation of germplasm to study the variation in morphological characters among genotypes and to analyse the components associated with yield

5.1.1 Grouping of germplasm based on flowering behaviour and yield . performance

The cashew gene bank which has been established at the Cashew Research Station, Madakkathra is exclusively of clonal accessions. In the current

research programme, efforts were made to study the performance of these accessions due to their domestication in this agroecological region, since a fundamental knowledge on the flushing and flowering cycles in the existing environmental condition is essential for efficient utilisation of crop management systems. Similar type of works were undertaken at the National Research Centre for Cashew (Swamy *et al.*, 1990; 1998).

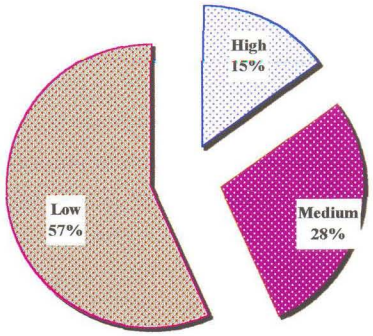
The timing and intensity of flushing and flowering was found to vary greatly as reported by Pavithran and Ravindranathan (1974). There are early season varieties, flowering between October and November, mid season varieties, flowering in November and December and late season varieties flowering after December under Madakkathra conditions as observed in the present study when grouping of germplasm was done based on flowering behaviour (Table1).

Accordingly, out of the germplasm of 67 varieties, 12 varieties were grouped as early, 38 as mid season and 17 as late ones. Majority of the varieties started flowering in November-December (mid season), the major flowering period of cashew (Fig. 1). Earlier workers have also made similar observations.(Chakrabortiy *et al.*, 1980 and Sheshagiri, 1996).

Study on the yield performance of the 67 varieties had revealed that the proportion of high yielders in the germplasm was very low (Fig. 2) and majority were low yielders (Table.2). Usually the varieties conserved in a germplasm may also comprise low yielders since the selection is based on various qualitative and quantitative characters. It was evident that many of the varieties collected for their high yield performance behaved as low yielders. The varieties released by NRCC Puttur for Karnataka state such as Pu-1, Pu-2, Pu-4, Pu-6, Pu-7 and Pu-8 yielded extremely low under the agroecological situation of Madakkathra. This signifies the phenotypic variability in cashew and the need for choosing location specific varieties for their best performance as opined by Sheshagiri (1996), Rao *et al.* (1998) and Salam (1999).

Fig.1. Genotypes grouped based on flowering behaviour

Fig.2. Genotypes grouped based on yield performance



The early season high and medium yielders (Table 3) identified in the present study are useful in the breeding programme. In places where early monsoon is expected only the varieties which can complete the total harvest before the onset of monsoon can be planted as suggested by Rao (1989). Among such varieties Anakkayam-1 and Madakkathra-1 are the early season high yielding selections of KAU, released in the National Workshop on Cashew in 1987. However, all the three early high yielders selected in the study have poor nut size (below eight grams) and is to be improved further to catch up the export market. The present strategy is selection of varieties having good yield with nut size above eight grams (Rao *et al.*, 1998). The early high yielders at present recommended have low acceptance due to their small nut size. Developing a variety with early high yield and good nut size is the immediate task of a cashew breeder.

All the four mid season high yielders were hybrids of which Kanaka and Dharasree were already released by KAU in 1995 and 1997 respectively. The late high yielders selected, Priyanka, Anagha and Madakkathra-2 are the released varieties of KAU. The late high yielders were found to possess good nut size (Table 6). The small nut size of early high yielders and bold nut size of late high yielders as observed in the present study necessitates recombination of desirable of character between these two groups, that early high yileders with bold nut size could be evolved. Such research programmes had already been taken up as a mandate of All India Co-ordinated cashew improvement programme.

The late season varieties are disadvantageous, since there is a chance for the loss of a part of the crop in the South West monsoon.This necessitates the evolution of strategies for preponing flowering towards early or mid season especially for high and medium yielders. However, these varieties can be recommended to places where onset of South West monsoon is very late.

The medium yielders selected among the three flowering groups are of great economic significance. Since they possess good yield and nut size, they could be recommended for large scale cultivation. The varieties such as Dhana, Amrutha and Sulabha had already been released by KAU, after confirming their potentiality.

The present study was effective in selection of varieties based on season of flowering and yield performance and identification of parents for future breeding programme. The improvement of the existing genotypes are envisaged through understanding of the yield and yield related characters. Though the low yielders are not economically viable and could not be accepted as such, they could not be neglected as they may be possessing some unique characters like bigger nut size, resistance to pest and diseases, short stature etc. This is evident from the fact that K-30-1 a low yielder is a parent of many hybrids as it possesses extremely big nut size (11.80 g) and PTR-1-1 which is devoid of cardanol in CNSL (Nalini *et al.*, 1994) will be helpful in developing fascinating varieties. Dwarf stature is another favourable trait in cashew (eg.UL-12-2) especially where land is a limiting factor and high density orcharding is an economic proposition.

5.1.2 Variation in morphological characters among the genotypes

Studies were carried out to determine the extent of variability and degree of association of quantitative characters with yield and flowering in cashew. The association of different morphological, biochemical and anatomical characters were worked out. To broaden the spectrum of variability and to obtain a reliable estimate of association of characters with flowering and yield, three varieties from each class with respect to flowering nature and yield (4.1.2) were selected for the study.

Wide variability in terms of range and coefficient of variation existed in the population with respect to many of the vegetative, flowering, nut and yield characters. Damodaran *et al.* (1978), Falade (1981), Devi (1981), Parameswaran *et al.* (1984), Manoj (1992) Reddy *et al.* (1996) and Swamy *et al.* (1998) reported high variability for different parameters of cashew.

Among the vegetative characters, maximum variability was displayed for flush length (6.43 to 15.25 cm) and number of leaves per shoot (3.15 to 9.08). This variability observed is of considerable importance since high and medium yielders irrespective of their flowering season had short flushes (Table 4). The association of short flushes with the high or medium yielders can be attributed to the presence of high frequency of reproductive flushes per unit area. The reproductive flushes were observed to be short and they terminated in panicles soon. On the other hand, the poor yielders display an extended growth of flushes that terminate in weak panicle.

The variability for tree height among the selected population ranged from 4.07 m to 5.72 m with a mean of 4.99 m. The genotypic and phenotypic coefficients of variation was of lower magnitude for these characters (<11.0) indicating low variability among this clonal population. Falade (1981) also reported narrow variability for tree size among cashew trees of same age. This is of high significance in the present study where dwarfing was attempted to modify the tree stature, where scope for selection is limited.

The variability for other growth parameters like tree girth and spread among the varieties was also very low in the present study. Earlier workers had observed great variability with respect to trunk girth and tree spread in cashew (Damodaran *et al.*,1978; Falade, 1981; Devi,1981). The earlier cashew plantations were established from unselected planting materials especially seeds. Also they might not have been maintained as per specific package of practices recommendation. Contrary to this the present study was conducted in a clonal population of same age maintained according to a uniform package of practices recommendation. This may be the reason for narrow variability noticed with respect to girth, spread etc, the characters which are likely to be modified with respect to management practices.

When flowering characters of differential yielding varieties were subjected to variability analysis, percentage of hermaphrodite flowers and number of nuts per panicle were observed to vary much among the varieties studied (Table7). Devi (1981), Patnaik *et al.* (1985), Reddy and Rao (1985), Krishnappa *et al.* (1994) Subrahmanian *et al.* (1996) and Swamy *et al.* (1998) also reported high variability for percentage of hermaphrodite flowers among different cashew varieties. The broad spectrum of variability observed for this character is also of considerable importance since high yielders were found to possess exceptionally high percentage of hermaphrodite flowers (Table 5). Since fruit set is directly related to the hermaphrodite flower production, necessity for its exploitation for realising higher yield is evident from this study.

Variability for number of nuts per panicle was observed at a range of 2.94 to 14.69 in the present study . Existence of genotypes with more number of nuts per panicle as high as 16 was reported by Nalini and Santhakumari (1991). Rao and Swamy (1994) reported that variability recorded for this particular character among the genotypes in the germplasm of seedling progenies ranged between one and eight. The high variability with respect to this character observed may be due to the inclusion of some genotypes like Madakkathra-1 having cluster bearing habit resulting in more number of nuts per panicle. Here again the association of this character with yield was in the same pattern as observed for the hermaphrodite flowers and this can be utilised in the yield improvement programme. More number of nuts per panicle and earliness were the superior characters identified with the released varieties Anakkayam-1 and Madakkathra-1.

The low variability observed in the present study for the number of panicles per m^2 of canopy area is a matter of concern as this is an important character deciding yield. In a study comprising 56 cashew hybrids and their 16 parents, Manoj (1992) observed only low variability for the number of panicles

per unit area, while Krishnappa *et al.* (1991a) could observe high variability for this character when 17 varieties were analysed. This emphasized the need for further exploration and collection of genotypes to enrich the germplasm if an improvement for this particular character is to be achieved.

Among flowering characters, the panicle length and breadth exhibited least variability. Selection for this trait had minimum scope among the types evaluated.

Maximum variability was observed for nut yield (GCV = 55.47%) and nut weight (GCV = 30.69%) among the nut and yield characters (Table 7). This indicated a higher contribution of these traits towards the total genetic divergence.High variability for nut yield per tree had been reported by Damodaran *et al.* (1978), Falade (1981), Ramadas and Thatham (1982), Nalini and Santhakumari (1991) and Manoj (1992). The high variability with respect to yield of the varieties tested provide ample scope for selection and further improvement in this character. The character nut weight was not found associated with specific yield group but found scattered among them. This once again emphasises the need for incorporating the bold nut character with many of the high yielders. Based on the germplasm evaluation at NRCC Puttur, Swamy *et al.* (1990) identified ten trees with high yield potential with medium sized nuts.

Since the national perspective of the breeding programme in cashew is for evolving varieties having more nut weight , the varieties identified in the present study with high nut weight viz., H-1596, Priyanka, Anagha, H-1588, H-856 and K-30-1 (Table 6) are valuable in breeding programmes. Considerable variability among the genotypes with respect to nut weight was observed by Devi (1981), Nandini and James (1984), Reddy *et al.* (1989) and Nalini *et al.* (1994).

Kernel weight was another character that had high variability (26.31) among the genotypes. Rao and Swamy (1994) could observe great variability in kernel weight (0.5 to 4.50 g) among the genotypes studied resulting in kernel

count per pound ranging between 100 and 900. Since export grade of a variety is determined based on kernel weight (number of kernels per pound), this character is invariably used to describe a variety. The varieties having prime export grade are preferred and in the selection programme kernel weight is to be given importance rather than nut weight. At present varieties with kernel weight above 2 g are preferred for cultivation. The varieties identified for good kernel weight in the present study thus have great importance and it is high time to select and perpetuate such varieties if other economically important characters are satisfactory. Two varieties Anakkayam-1 and Madakkathra-1 are early high yielders with low kernel weight and export grade. BRZ-248(s) is another high yielder that possesses low kernel weight. The poor yielder K-30-1 has good kernel weight and is a late variety. Varieties with poor yield and kernel weight have no economic value. The recently released varieties of cashew viz., Sulabha, Priyanka, Amrutha and Anagha are ranked superior (W-180) with respect to kernel weight and yield. Varieties with desirable shelling percentage (>30) were low in the germplasm. This points to the limited scope for selection for this character in the population studied. To strengthen the varieties with regard to this most important economic character, intensive survey and collection of varieties possessing this character in maximum tune is required.

5.1.2.1 Heritability and genetic advance

Estimates of heritability are useful to a plant breeder as they provide basis for selection based on phenotypic performance. In the present study shelling percentage recorded the highest magnitude (97.26%) of heritability followed by percentage of hermaphrodite flowers (96.83) and hundred nut weight (94.84). All the characters studied registered moderate to high heritability. The earlier objective for cashew breeding was mainly higher productivity but in recent years with the increasing concern for quality (Rao *et al.*, 1998) emphasis is given for identification of varieties with good shelling percentage and kernel weight. High heritability can aid in effective selection based on phenotypic performance. The other character with high heritability was number of panicles

per square metre which is also directly related to yield. The high heritability observed for yield indicates that improvement for yield could be obtained through direct selection.

The genetic advance for all the characters were moderate to low except hundred nut weight, which expressed a high genetic advance of 514.36. High heritability coupled with higher magnitude of genetic advance indicated the role of additive genes and suggest a very good scope for faster improvement through selection (Burton,1952; Panse,1957). Percentage of hermaphrodite flowers and shelling percentage had moderate genetic advance coupled with high heritability. Those characters which expressed low genetic advance and high heritability can be improved through hybridization.

5.1.3 Morphological characters asssociated with yield

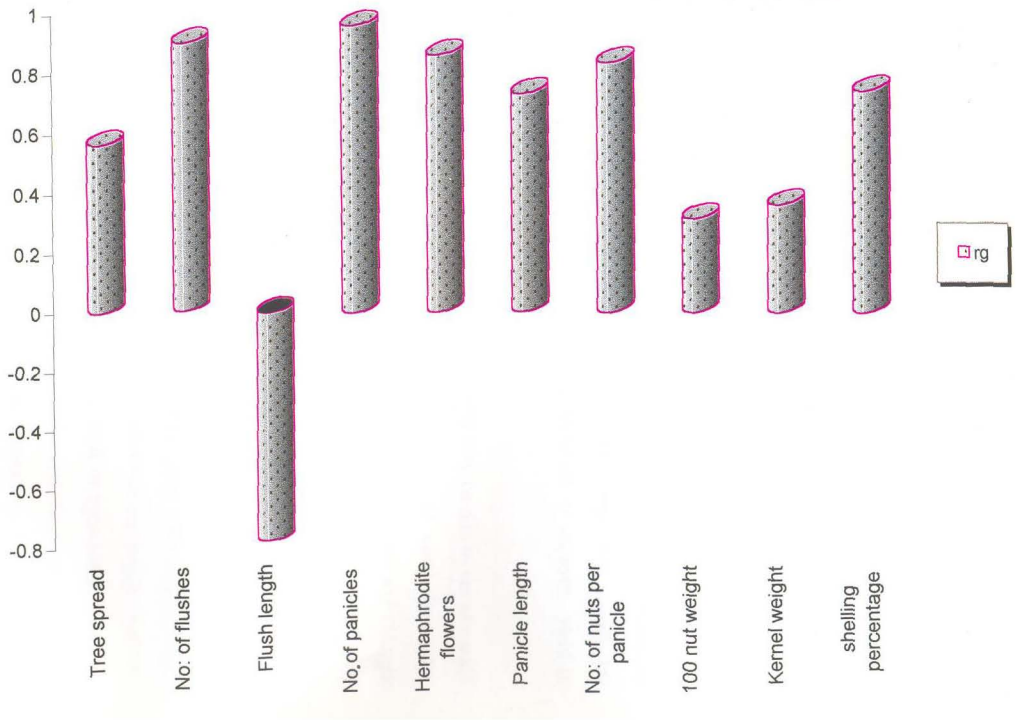
5.1.3.1 Correlation of the specific traits with yield

Since variability is contributed both by genotype and environment, the correlation observed between two characters in a genetically variable population is phenotypic in nature. Phenotypic correlation is the net result of genotypic and environmental correlation and hence its magnitude is intermediate. In the present study phenotypic correlation coefficients (Table 9) were found to be less than genotypic correlation (Table 8). The correlation of some of the characters with yield are depicted in Fig. 3.

Negative association was observed for certain vegetative characters with yield and the maximum was observed for flush length. This emphasises that shorter flush length and higher yield are highly correlated and a direct selection can be done on this basis.

The intensity of correlation observed for the plant yield with tree spread and number of flush was of high magnitude and the same is in corroboration with the earlier findings of Nayar *et al.* (1981), Nawale (1983), George *et al.*(1989), Parameswaran *et al.* (1984),Mohan *et al.* (1987), Manoj *et al.* (1994)

Fig. 3. Genotypic correlation (rg) of morphological characters with yield



and Reddy *et al.* (1996). Abraham (1994) highlighted the importance of number of flushes in relation to productivity in cashew on the basis of observation that preharvest flushes accounted for 79.2 per cent of total leaf area in the crown while previous season flushes accounted only 19.62 per cent leaf area.

In contrast to the feeble association of most of the vegetative characters studied with yield, almost all flowering characters except panicle breadth had positive correlation. Among them, number of panicles per m^2, percentage of hermaphrodite flowers and number of nuts per panicle were the most prominent. These results are in agreement with reports of Anitha *et al.* (1991) and Kumar and Uduppa (1996) that yield was highly correlated with number of reproductive flushes,number of hermaphrodite flowers and number of nuts produced per panicle. Since lengthy flushes had shown negative correlation and production of panicles had positive correlation with yield, methods to control vegetative growth and induce maximum flowering will be a better preposition to improve yield in cashew.

Association of lengthy panicles with yield may be due to the aforesaid reason of short flushes resulting in better partitioning of metabolites for reproductive phase occurring in the high yielding varieties. Kumar and Uduppa (1996) also observed high correlation of panicle length with yield. Thus this character serve as a criterion for direct selection of high yielding varieties.

All the nut and yield characters except shelling percentage, exhibited either low positive or negative correlation with yield. Since shelling percentage is the percentage recovery of kernels from raw nuts, good shelling percentage is an indication of good kernel weight. Varieties with more nut weight need not express good shelling percentage owing to thick shell or light kernel and vice versa.. This results are in consonance with Ramadas and Thatham (1982) and Manoj *et al.* (1994). Kanaka is a cashew variety released by KAU having low nut weight (6.80 g) but having maximum shelling percentage (36.80) among the released varieties of KAU (Usha *et al.*, 1995) owing to good kernel weight

(2.08 g). Thus shelling percentage or kernel weight are to be given prime consideration in future, while screening varieties to catch export scenario. Swamy *et al.* (1990) have identified ten varieties at CPCRI, having good shelling percentage (30 to 35.10 per cent) and possessing good yield potential (4.98 to 9.84 kg per tree).

The nut weight recorded a weak positive correlation (0.31) with yield. This can be true in the sense that varieties having more nut weight alone can not be considered as high yielders if they fail to lead more number of nuts to maturity. Anitha *et al.* (1991) reported maximum regression coefficient ('b' values) of the yield to number of nuts reached to maturity. Higher nut weight may cause greater competition among the nuts elevating the intensity of nut fall. Varieties with high ratio of hermaphrodite flowers with better nut weight are to be screened further providing management practices so as to exploit the yield potential of desirable varieties in full.

Nut length and nut breadth exhibited a negative correlation with yield since nut length and nut breadth simply contribute to nut weight and hence the negative association of these characters with yield is justifiable. A best example is the nuts of variety K-30-1 which possesses big nuts in terms of length and breadth but it is not a high yielder. The results are in conformity with the findings of Rao (1974) and Anitha *et al.* (1991). They opined that the increase in length, breadth and nut weight lead to decrease in panicle yield.

Based on the extent of relation between vegetative, flowering and nut characters with yield, a selection index with an efficiency of E= i.1.73 could be constructed. The characters proposed that will aid indirect selection for superior genotypes based on the present study are short prebloom flushes, more number of panicles per m^2 and more number of nuts per panicle,

5.1.3.2 Direct and indirect effects of specific traits on yield

Correlation coefficients observed between complex and component characters are the ultimate reflection of direct and indirect effects of the latter on the former. Path analysis is a technique to partition the total correlation in terms of direct and indirect effects so that direct influence of component characters confounded by other characters can be understood. In cashew, yield structure involves integrated set of complex characters eventhough each one of them appears to be important on its own. Specific partitioning of these variable is to be done (Rao *et al.*, 1998)

The present study examined the effects of seven vegetative, five flowering and five nut and yield characters on yield, the ultimate economic character.

In the present study the direct effects of component characters on yield were affected by other component characters as evidenced by correlation coefficients. Both direct effects and correlation coefficients were generally in the same direction. For example highest positive direct effect on nut yield was exhibited by panicles per unit area (0.98), the character which had highest positive correlation with yield. This is in agreement with the reports of Parameswaran, *et al.* (1984) who reported a strong correlation between tree yield and percentage of flowering shoots per unit area of tree canopy. The flush length exhibited highest direct negative effect, which was highly and negatively correlated with yield.

The most interesting factor observed was that the high positive correlation coefficient with yield observed for many component characters was through their positive indirect effect through single component character viz., panicles per unit area (Table 10) which is highly correlated with the economic character yield, rather than their direct effects. The high correlation coefficients observed for flushes per unit area, percentage of hermaphrodite flowers, number of nuts per panicle on nut yield were due to their indirect effects through number of

panicles per unit area. Same was the reason for the high positive correlation of spread and panicle length with nut yield. Similarly, the negative correlation of flush length with yield was through high negative indirect effect through panicles per unit area (-0.79). This highlights the usefulness of this character in the selection programme. The results are in conformity with Anitha *et al.* (1991) and Manoj (1992). In the present study all the high yielders studied had high number of panicles per unit area at a very high tune (>12).

More number of panicles per unit area originate from spreaded canopy having more number of short flushes per unit area as evidenced through genotypic path analysis (Table 10).

More number of panicles per unit area also resulted in production of more hermaphrodite flowers and number of nuts per panicle, thus influencing yield positively. However proportion of male flowers below a particular level in a panicle may affect fruit set. Manoj (1992) also observed high fruit set per panicle when percentage of hermaphrodite flowers was more.

Short flowering phase with an ability to produce high percentage of hermaphrodite flowers is one of the important characteristics of high yielders in cashew (Reddy and Rao,1985). The direct effect of nut characters on yield was negligible. This observation was in contradiction to the finding of Manoj *et al*, (1994) who observed high positive direct effect of kernel weight on yield. In this study the nut weight, shelling percentage and kernel weight had positive correlation with yield influencing a number of indirect positive effect through many other component characters especially flowering characters.

Owing to the high correlation exhibited by flowering characters with yield, selection for higher yield from a population would be more effective when programmed during flowering time.

5.2 Variation in biochemical and anatomical characters at different physiological stages of growth and reproduction

5.2 1 Variation in biochemical constituents

The growth of cashew tree is in a rhythmic cyclic fashion. The flushes that emerge after harvest (postharvest flushes) continue to grow approximately for one month and enter into a quiescent stage. When these shoots mature after three to four months, revive their growth activity to produce prebloom flushes which consist of both vegetative and reproductive flushes. Panicles emerge on reproductive flushes and this leads the tree to the reproductive phase. Some of the prebloom flushes remain vegetative without differentiating to panicles (vegetative flushes). The postharvest flushes are developed from the harvested shoots and this cycle is continued.

The changes occurring in these different types of shoots at different physiological stages of growth may be the governing tool in modelling flowering and yield. The biochemical changes studied are discussed here under.

5.2.1.1 Carbohydrates

A high carbohydrate reserve in the leaves of mature shoots before flushing was noticed in the present study. Flushing and flowering were found to deplete carbohydrate reserve (Fig. 4 a) This may be due to the storing of carbohydrates during the previous quiescent phase of the shoots (after harvest till prebloom flushing) and subsequent utilisation for flushing and flowering. Reports of starch accumulation during extended periods of canopy rest prior to flowering in mango is supportive to the present study (Chacko and Ananthanarayanan, 1982; Robert and Wolstenholme, 1992; Shivashankara and Mathai, 1995). Ravishankar and Rao (1982) recorded a depletion of carbohydrates after flushing and panicle development in mango. The high carbohydrate reserves recorded for the high yielding varieties in the present study may be the reason for their better flushing and flowering efficiency. The continuous depletion of carbohydrates in the mature shoots and failure of its further enrichment in the shoots result in leaf fall. Heavy leaf fall as observed in high yielders further support this statement.

Fig. 4 a. Carbohydrate content (%) in mature lateral shoots of high and low yielding varieties at different stages of growth

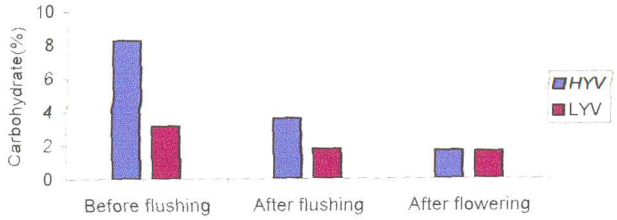


Fig. 4 b. Carbohydrate content (%) in reproductive flushes of high and low yielding varieties at different stages of growth

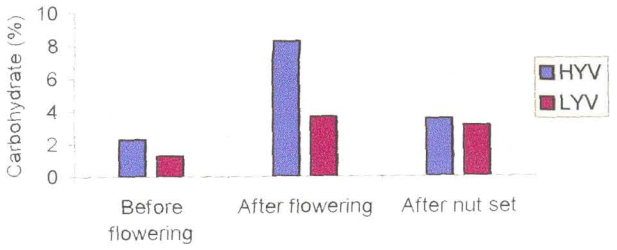
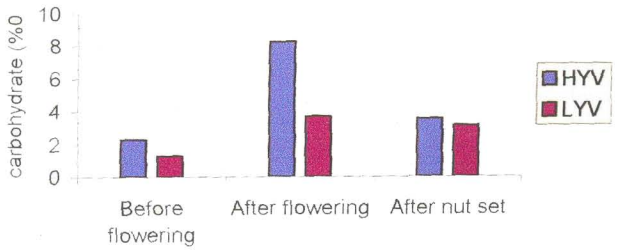


Fig. 4 c. Carbohydrate content (%) in vegetative flushes of high and low yielding varieties at different stages of growth



In the present study, carbohydrates in reproductive shoots was low before flowering and found increased after panicle development (Fig. 4 b)

As stated earlier, due to the continous growth and differentiation, carbohydrates may not be getting stored in young reproductive flushes before flowering. The results are in conformity with the findings of Sherlija and Unnikrishnan (1996). They also observed low carbohydrate reserve in the young shoots before transition to reproductive phase. After panicle development, the carbohydrate content in the flushes was found increased. By this time the leaves in past season growth (mature shoots) fall off and the leaves on these current season shoots mature and start to perform photosynthetic activity. Also a repumping of carbohydrates which were stored in stem and bark during quiscence and subsequent leaf fall might have occurred to the newly developed frame work for the ensuing physiological activities. Greater accumulation of metabolites at the time of flower initiation was noticed in mature mango tree barks by Chacko and Anathanarayananan (1982). Translocation of nutrients from old to younger leaves has also been reported in mango (Chacko *et al.*, 1972) in response to renewal of growth. Presence of sufficient reserves of carbohydrates before fruit set was found very crucial by Pathak and Pandey (1978) ; Suryanarayana and Rao (1978) and Paulas and Shanmugavelu (1988). They opined that leaves act as the storage organ for carbohydrates and suppliers of these stored nutrients for developing fruits. High carbohydrate reserve in reproductive flushes as observed by Veera and Rao (1977) in mango and great depletion after nut set in high yielders amplifies the fact that carbohydrates play an important role in fruit set. The high carbohydrate content in leaves before fruit set and depletion due to utilisation in the ensuing growth phases was reported in cashew by Sherlija and Unnikrishnan (1996). This result also suggest that there should be sufficient storage of these metabolites in leaves before fruit bud differentiation to complete reproductive cycle. The large scale loss of flowers and fruits at various development phases in low yielding varieties may be due to the low carbohydrate reserve and failure in efficient utilisation of the available quantity.

It is interesting to note that the depletion of carbohydrates is at a very low level in the low yielding varieties owing to their less flowering and fruit set. The results of the study support the fundamental principle proposed by Davenport and Elisea (1997) that yield is a product of photoassimilate (carbohydrate) accumulation and subsequent distribution during the growth cycle.

In vegetative flushes, the carbohydrate content was found steadily increasing throughout the different phase of analysis (Fig.4 c). Since the carbohydrate content of these flushes after nut set was increased the role of supplying nutrients to the current activities during that time is doubtful. Their function can be storing the carbohydrates. The view expressed on the basis of the present study is in conformity with the reports of Devi and Tyogi (1991) in mango. They recorded higher levels of carbohydrates in non flowered shoots of mango and opined that the storage in vegetative shoots is for utilisation during the coming season.

5.2.1.2 Nitrogen (%)

Foliar nitrogen level in the mature shoots of high yielding and low yielding varieties did not show any specific pattern and it ranged between 2.55 and 3.17 per cent (Table 12). This shows that the absorption and accumulation of nitrogen before the reproductive event is almost the same in all the varieties, irrespective of their yield performance.

The nitrogen accumulated in these shoots might have been utilised for prebloom flushing and development of flushes as evidenced by reduction in nitrogen content after flushing (Fig. 5 a). The utilisation was more in high yielding varieties since more number of flushes per m^2 was found in high yielders (Table 5). Due to the less number of flushes per unit area in low yielders, the depletion of nitrogen was at a low rate. After flowering, the nitrogen content was further reduced in these mature shoots. Since the frequency of reproductive flushes are less in low yielders and they support the growth of more vegetative flushes, the intensity of depletion of nitrogen in these varieties at this stage was

Fig.5 a. Nitrogen content (%) in mature lateral shoots of high and low yielding varieties at different stages of growth

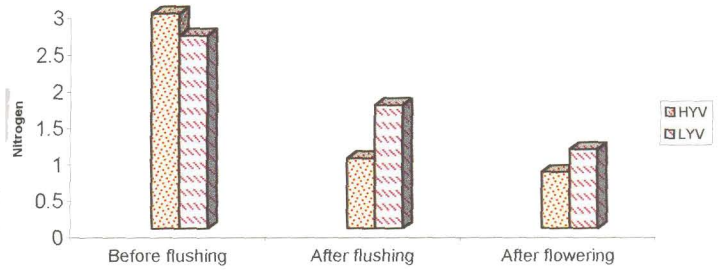


Fig.5 b. Nitrogen content (%) in reproductive flushes of high and low yielding varieties at different stages of growth

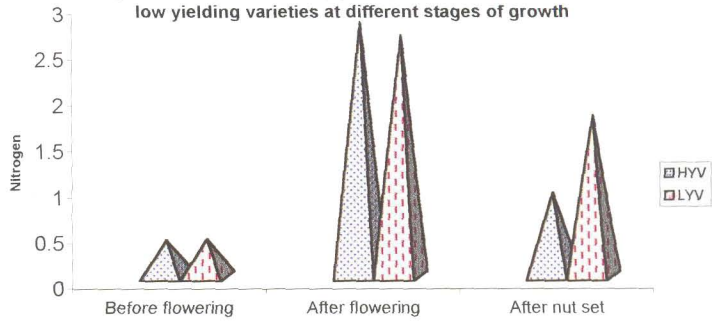
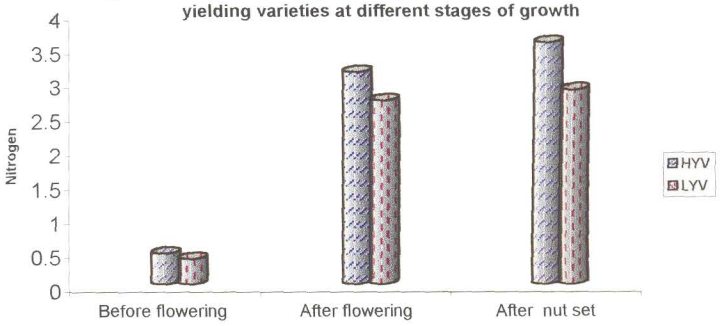


Fig. 5 c. Nitrogen content (%) in vegetative flushes of high and low yielding varieties at different stages of growth



more compared to high yielders. The nitrogen accumulation and utilisation pattern by the mature shoots delineated in the present study conforms with Mathew (1990) who reported minimum nitrogen content in cashew leaves during senescence stage. Here also minimum nitrogen level in leaves of mature shoots was observed after panicle formation, the stage at which leaves on mature shoots turn yellow enter to senile stage and start to fall.

The nitrogen in the reproductive flushes was very low before flowering and increased to a maximum level after panicle development and reduced to a low status after nut set in all the varieties studied (Fig. 5 b). Mathew (1990) also observed a similar nitrogen status at these different physiological phases of reproductive flushes in cashew. Low nitrogen content in the flowering shoots of mango was reported by Devi and Tyogi (1991). Flowering closely follow flushing in cashew and thus nitrogen might have been mobilised from mature shoots to these new growths, without getting accumulated in them. It may be continuosly utilised for panicle formation substantiating low nitrogen status in reproductive flushes before panicle development as reported by Mathew (1990). Simultaneous with panicle development, the leaves on reproductive shoots mature and nitrogen mobilised from past season growth may be stored in these current season growths for the ensuing nut set and development, which occur after a time lag of three to four weeks after panicle development. This might be the reason for maximum nitrogen content observed after panicle development. Chadha *et al.* (1984) also noted higher nitrogen content in leaves of mango cultivars at flowering stage compared to postharvest stage. Pathak and Pandey (1978) were of the opinion that there was a tendency to recoup the nitrogen level at depleted condition as evident by the higher nitrogen level prior to fruit set observed in mango cultivars. As reported by Pandey (1989), growing organs would require nitrogen to form protein bodies which resulted in the maximum depletion of this element from leaves noted after nut set. More nut set in high yielding varieties may be the reason for the greater depletion of nitrogen after nutset.

The vegetative flushes also store nitrogen in course of development and the quantity was high in high yielders (Fig. 5 c). As noted in the case of reproductive flushes, maximum accumulation of nitrogen in these flushes was recorded after panicle development phase of the tree. Since they enter into a quiescent stage during panicle development and nutset phase, depletion of nitrogen was not noticed at third stage of analysis (Table 12). Further, this give rise to another school of thought that the current season vegetative flushes may not be having contributory role in present season but may act as source in the ensuing development phases. However, the function of vegetative flushes on growth and reproduction of cashew tree requires further detailed investigation before a conclusion is arrived at .

5.2.1.3 C:N ratio

The C:N ratio followed the trend of carbohydrate and nitrogen in the shoots at different physiological phases analysed. The high C:N ratio in the leaves of mature shoots at the first stage of analysis may be conducive for flushing and flowering as observed by Shivasankara and Mathai (1995) in mango.

Due to the very low nitrogen level in mature shoots of high yielders before flowering, the C:N ratio was found comparatively very high. Suryanarayana (1980) opined that high C:N ratio is a prerequisite for flowering mango shoots. However, Veera and Rao (1977) could not draw definite relationship between C:N ratio and flowering in mango. The high C:N ratio observed in mature shoots of high yielders before flowering in the present study give a possible biochemical basis of heavy flowering and yield.

As opined by Veera and Rao (1977) in mango, definite relationship could not be drawn between C:N ratio of reproductive and vegetative flushes and flowering in the present study. However, the ratio of both the flushes was observed to be maintained at a comparatively higher level in high yielders at all the three stages of analysis. This was due to the higher levels of carbohydrate reserve in such varieties and low nitrogen status.

5.2.1.4 Chlorophyll (mg g^{-1})

High chlorophyll 'a' and 'b' were recorded in the leaves of mature shoots before flushing. The high carbohydrate content in the leaves of these shoots at this stage (Table 12) and the physiological necessity of the food material for further growth and development amply substantiate the high chlorophyll content at this stage. Varietal variation was observed for the chlorophyll content and the values were high for the high yielders. Earlier reports in cashew also indicated varietal variation for chlorophyll content and the better photosynthetic efficiency of high yielders (Anakaiah and Rao, 1991; Bhaskar, 1993).

Flushing and flowering resulted in low chlorophyll content in mature shoots and the reduction was at a faster rate in high yielders (Fig.6 a) This may be due to the chlorophyll degradation associated with leaf senescence and leaf fall.

In the reproductive flushes, the total chlorophyll content before flowering was almost the same in all the varieties studied. Since these flushes are too immature and physiologically more active (Mathew,1990), the biochemical constituents especially chlorophyll might not get stabilised.

After panicle development, the chlorophyll content in the leaves of reproductive shoots was found to increase (Fig.6 b). In appearance also these leaves were dark green in colour and may be photosynthetically more active as evidenced by accumulation of more carbohydrates . Sherlija and Unnikrishnan (1996) also recorded more chlorophyll content in the leaves of reproductive flushes at flowering stage in cashew.

During nut set and development, the carbohydrates might have translocated as discussed earlier and the associated chlorophyll degradation might be the reason for low chlorophyll content after nut set phase. This result is in conformity with the reports of Sherlija and Unnikrishnan (1996) in cashew.

Fig.6 a. **Total chlorophyll** content (mg g^{-1}) in mature lateral shoots of high and low yielding varieties at different stages of growth

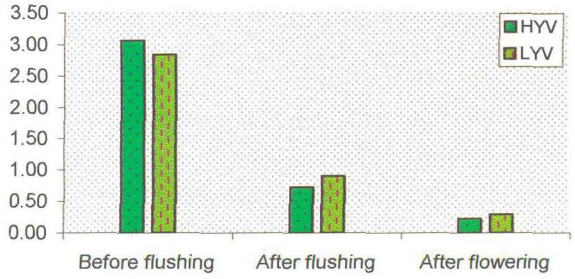
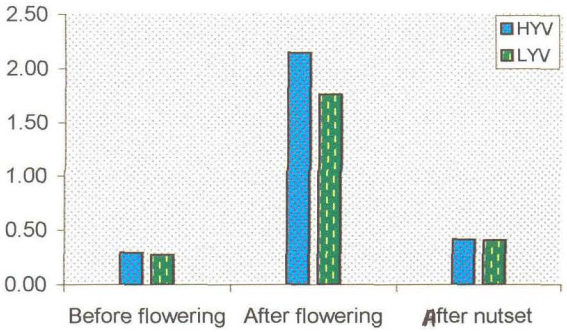


Fig.6 b. Total chloropyll content (mg g^{-1}) in reproductive flushes of high and low yielding varieties at different stages of growth



The authors opined that the integrity of chlorophyll is dependent on the photosynthates and when substrate concentration decrease in the leaves degradation of chlorophyll result.In vegetative flushes a definite pattern of variation with respect to chlorophyll content was not observed among varieties.

5.2.1.5 Total phenols

Total phenol content in leaves of mature shoots were high before flushing. After flushing and flowering, the phenol content was decreased to a very low level (Fig. 7 a). Among stored metabolites, the carbohydrates are reported to be the prime reserve and phenolic compounds are second only to carbohydrates. Conversion of phenolic compounds to carbohydrates, aminoacids, aromatic derivatives etc. has also been reported in higher plants by Sherlija and Unnikrishnan (1996). The abundance of carbohydrates in the leaves recorded before flushing strengthens this opinion that the high phenolics in such shoots may be serving as the intermediary compounds in the pathway of synthesising more carbohydrates and other food reserves. The low phenolics during the senile stage noted in the other two stages of analysis is self explanatory.

The phenolic content in the reproductive flushes also showed a decreasing trend during the different stages of analysis (Fig. 7 b). This observation is in conformity with the findings of Sherlija and Unnikrishnan (1996) in cashew, where higher phenolics was noted in the leaves of flushes before the transition phase. After panicle development, the content in the leaves decreased.

Synthesis of more carbohydrates after panicle development (as recorded earlier) might be the reason for the reduction of this intermediary compound at this stage. Further decrease in phenolic content after nut set in leaves may be due to a redistributed synthesis of these compounds in young appendages viz., developing panicles, nuts etc. This can be further supported by the fact that the purplish phenolic compounds are more evident in young appendages rather than the old parts.

Fig. 8 a. Nitrate Reductase Activity (NO_2 g^{-1} h^{-1}) in mature lateral shoots at different stages of growth

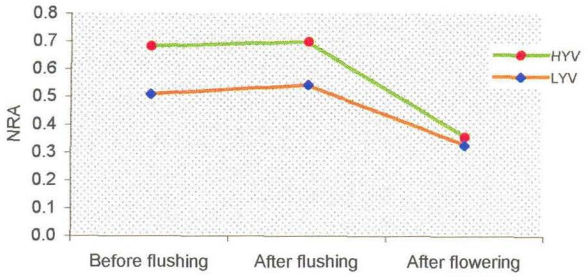
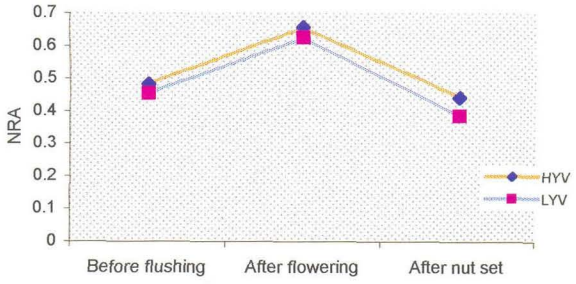


Fig. 8 b. Nitrate Reductase Activity (NO_2 g^{-1} h^{-1}) in reproductive flushes at different stages of growth



The amount of this particular constituent was high in vegetative flushes of high yielders (Fig. 7 c) throught all the three different stages analysed. This may be one of the reasons for high metabolite status in vegetative flushes of high yielders at all the three stages ananlysed.

5.2.1.6 Nitrate Reductase Activity (NRA)

High Nitrate Reductase Activity (NRA) was recorded in the leaves of mature shoots before flushing. This can be attributed to the great accumulation of nitrogen in the quiescent phase and requirement of synthesis of nitrogen based compounds during the ensuing reproductive phase. Comparatively high NRA was recorded for the high yielders. This might be the reason for better nitrogen use efficiency of high yielders as evidenced by more depletion of nitrogen after flushing (Table 13). Nitrate Reductase is a substrate dependent enzyme and the nitrogen content of the tissues is a major factor controlling the enzyme activity . High NRA has been reported in the leaves of mature shoots of mango before onset of reproductive phase (Devi and Tyogi, 1991). The present results agree with the findings of Thomas (1990) who reported high nitrate content and NRA in leaves of black pepper coinciding with the period of February where growth is low. Similar reports are also there in forest species where an increase in proportion of nitrate resulted in an increase in NRA (Adams and Attivil,1982).

Flushing did not cause much alteration in NRA It can be assumed that the nitrogen status in leaf tissues at this stage does not become a limiting factor for NRA.

The translocation of nitrates in huge quantity for fruit bud differentiation and depletion of nitrogen in leaves of mature shoots may be the reason for low nitrate reductase activity after panicle development. The finding is in conformity to that of Adams and Attivil (1982) in forest species and Thomas (1990) in black pepper, where on set of reproductive phase was reported to cause reduction in NRA.

The NRA in reproductive and vegetative flushes was also in accordance with the nitrogen requirement of the shoots. It was observed that the phases requiring more nitrogen compounds were preceeded by high NRA activity (Fig. 8 a; 8 b). Since the requirement of synthesis of nitrogen based compounds are more in high yielders as discussed earlier, comparatively high NRA can be expected in such varieties as evidenced in the present study. Such genotypic difference in NRA levels had been reported by earlier workers (Deckard *et al.*, 1973 in maize, Goodman *et al.*, 1974 in wheat and Chatterjee *et al.*, 1977 in barley).

According to Farooqi and Sirohi (1976), NRA is indirectly associated with the flowering response in plants. They have reported high positive correlation between NRA and yield. Deckard *et al.* (1973) also noted high correlation between NRA and yield of grains in maize during ear initiation and development. Ramadevi (1986) observed peak activity values for NRA at flowering stage in rice.

High phenolic content recorded in the shoots at immature stages were found coinciding with low NRA activity. Accumulation of phenols, the secondary metabolites may be inhibiting the activity of the particular enzyme.

The present study indicated the significance of the enzyme Nitrate Reductase and its substrate on growth and yield in cashew. Significant variation in NRA observed at critical stages in vegetative and reproductive phases highlights the importance of nitrogen management practices for better exploitation of yield potential.

5.2.2 *Variation in anatomical characters of shoots in relation to yield*

The anatomical features of the mature shoots were not found to vary greatly in relation to flowering behaviour and yield. However, distinct variation was observed with respect to number of xylem vessels per unit area and bark thickness among varieties (Table 16). Number of xylem vessels per unit area was significantly more in high yielders. The abundance of xylem vessels associated with high yielders may be helping to enrich the source in a better way. This in turn may favour better sink strength resulting in high yield (Kurien

Fig. 8 a. Nitrate Reductase Activity (NO_2 g^{-1} h^{-1}) in mature lateral shoots at different stages of growth

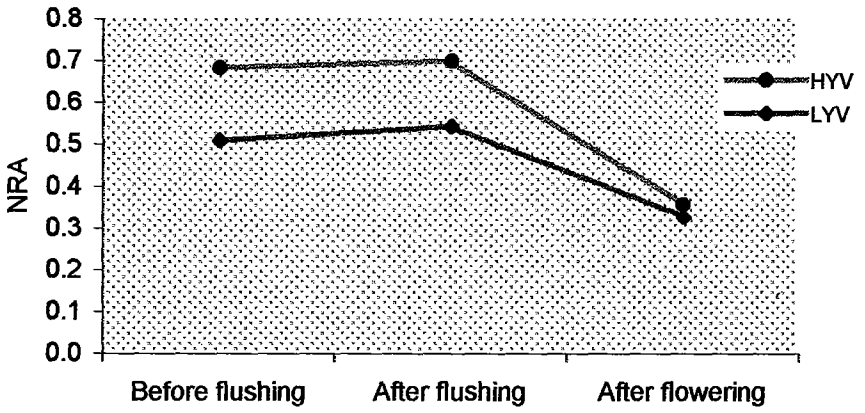
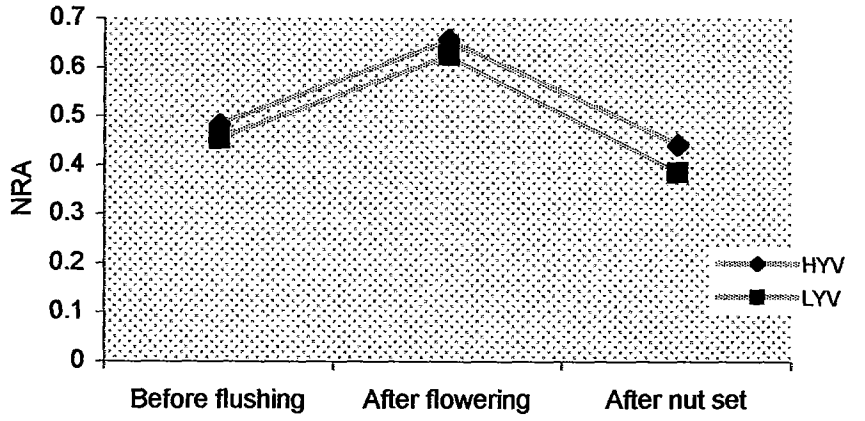


Fig. 8 b. Nitrate Reductase Activity (NO_2 g^{-1} h^{-1}) in reproductive flushes at different stages of growth



and Iyer, 1993). The high yielding varieties also recorded a comparatively thicker bark in the mature shoots. This may be due to the physiological necessity of the high yielders to store more assimilates during the rest period. High carbohydrate reserves recorded in the mature shoots of high yielders is supportive of this view. Chacko and Ananthanarayanan (1982) observed storage of metabolites in bark and roots during canopy rest period.

The results indicated that the characters viz., bark thickness and number of xylem vessels can be used as a tool for anatomical screening of high yielding varieties.

Studies on anatomical characters of the flushes established the faliure of a portion of prebloom flushes to differentiate to panicle. A well differentiated floral primordium was present in reproductive flush as against the absence of the same in vegetative flushes (Plate 5). Whether the vegetative flushes arise as the physiological necessity of the plant or due to some factors limiting differentiation need further investigation. In the former case they may be supporting growth and reproduction, where as in the latter context, they may be masking yield expression in full potential.

5.3 Chemical regulation of flowering in cashew

The reproductive phase in cashew faces serious problems related with flushing and flowering processes. Primarily the mature lateral shoots may fail to express a bud break and subsequent flushing and secondly the flushes produced may remain vegetative without differentiating to panicles. Since panicles are produced on current season flushes (prebloom flushes), the problems hitherto stated are manifested as a two step process in the same year in cashew. Though the tree is not completely left barren due to this partial expression in the ability to differentitate, flowering intensity greatly varies.This result in erratic flowering and yield behaviour with many cashew varieties. The delay in bud break and differentiation associated with many varieties result in late flowering character. More over intermittent bud break resulting in protracted flushing and flowering is an existing phenomenon observed with same variety itself.

In mango also these problems are being reported (Chadha, 1985; Pandey and Narwadkar, 1984 ; Burondkar and Gunjate, 1994 and Ram *et al.*, 1996). Here panilces are produced on past season shoots. If sufficient flushes are not produced during postharvest period (postharvest flushing) itself flowering will be greatly reduced in the current season. This leaves the tree barren without crop referred as "off" year, the year followed by heavy crop known as "on" year , the phenomenon being called alternate bearing. Therefore inducing production of more postharvest flushes for getting regular and heavy flowering was thought to be a better preposition in mango whereas in cashew it is being done aiming at prebloom flushes. Thus inorder to have high regular uniform bearing in cashew induction and manipulation of preblooom flushes seems to be the best target for exploitation of yield potential.

Prebloom flushes appear in cahew by late September and hence treatments for regulating flowering are to be imposed prior to this. The present work undertaken at Cashew Research Station, Madakkathra to regulate flowering in cashew was first of its kind and the valuable results obtained are discussed herewith.

Trials were conducted during 1995-'96 (observational trial) and 1996-'97 season (second stage screening) for identifying suitable chemical combination for regulation of flowering in cashew.

5.3.1 Observational trial for screening of chemical

The fact that gibberellins are antagonistic to flowering as reported in mango (Burondkar and Gunjate,1994) lead to a newer approach of using antigibberellin compounds (plant growth retardants) viz., alar (daminozide) and cycocel (chlormeqat) for overcoming the problems associated with flowering. Another approach adopted in tackling the problem was the use of paclobutrazol (2RS, 3RS)-1-(4-chlorophenyl)-4,-4-dimethyl 1-2 (1,2,4-triazol-1.yl) pentan-3-01). It is commercially available in the market in the trade name, Cultar (containing 25 per cent concentration of paclobutrazol in suspension), Bonzi, Sudabakar,

Parlay, Clipper etc. (Ram *et al.*,1996). Paclobutrazol is reported to be a broad spectrum gibberellin biosynthesis retardant. Reduced level of gibberellic acid have been detected as result of paclobutrazol treatment in fruit crops (Hedden and Graebe, 1985 and Lever, 1986). It is a promising new triazol plant growth regulator, reported to be 1,000 times more effective than the growth retardant chlormequat (Davis *et al*; 1986), previously available for use in India in many fruit species. It was developed and now manufactured in bulk by the Imperial Chemical Industries (ICI), UK.

Another chemical included in the study was potassium nitrate (KNO_3) which is reported to be successful not only to break the biennial fruit bearing habit of mango but also for advancing the flowering and fruiting periods several months ahead (Beuno and Valmayer, 1974; Bondad and Linsangan, 1979; Elisea, 1986 and Rojas *et al.*, 1993).

Based on the reports on effectiveness of the aforesaid chemicals on various perennial crops, especially in mango, in the observational trial three growth retardants viz., paclobutrazol, alar and cycocel and the flowering regulator KNO_3 were tried alone at specified concentrations and as combination sprays (3.3.1). The treatments were imposed as foliar spray during last week of September (before bud break commence in all the varieties) to the late season variety Madakkathra-2.

Among the chemicals tried, the growth retardant alar and cycocel failed to manipulate the vegetative, flowering or nut and yield characters of the tree in a favourable direction. This may be due to the necessity of still higher levels of alar and cycocel than that tried in the present study. To evoke a response in the same magnitude as that of paclobutrazol the requirement of these growth retardants are reported to be 1000 times more than paclobutrazol (Davis *et al.*, 1986). The other chemicals, paclobutrazol and KNO_3 tried independently evoked only a partial or moderate response compared to the combination treatments tried. For example the cultar tried independently at different concentrations induced

early flushing , flowering and improved the number of nuts per panicle compared to control. The other effects were not remarkable. The various levels tried failed to influence favourably the factors which are highly correlated with yield viz., flush length, number of panicles per m^2, hermaphrodite flower production and number of nuts per panicle (discussed in 5.1.3.1). Similar was the effect of KNO_3 alone at various levels tried. Eventhough early flushing and flowering were observed, the components associated with higher yield were not found improved. It can be concluded that the effect of growth retardants and KNO_3 tried individually at different concentrations was not encouraging in the context of present investigation.

Among the combination treatments the two higher concentrations of cultar together with KNO_3 at lowest level was found to positively influence the yield contributing factors (Table 17,18 and 19). On the contrary, the higher levels of KNO_3 in association with different levels of cultar had a negative or no effect. This may be due to the higher concentration of NO_3^- anions in the active component of KNO_3 (Bueno and Valmayer, 1974) that induced vegetative response. The length of flushes and number of leaves per flush were maintained almost equal as that of control plants even when applied along with the most effective growth retardant cultar at 250 mg l^{-1}. Earlier reports in mango suggested four per cent KNO_3 as optimum for inducing flowering (Elisea, 1986 and Elise and Caldeire, 1988). They proposed that the temporal timing and physiological state of the tree are the important factors determining the dose of application of KNO_3. In mango the chemical being applied to relatively mature shoots might have necessitated higher dose than cashew for inducing bud break.

Lowest concentration of cultar tried together with KNO_3 at varying levels induced earliness in flushing and flowering but was not effective in improving the other flowering and yield characters of the variety. Earlier reports suggest that a threshold level of paclobutrazol is required at the shoot apices and continous supply to the growing points is to be ensured for retardation of

growth and enhancing flowering (Dalziel and Lawrence,1984; Quinlan ,1985 and Lever, 1986). This could be the reason for limited effect of lowest level of cultar tried.

The most favourable chemical that influenced vegetative flowering nut and yield characters studied along with their merit compared to control is given in Table 48.

The results of the observational trial for screening chemical thus drew some valuable information. Potassium nitrate at one per cent level is sufficient for breaking the dormancy of lateral buds resulting in early onset of flushing in combination with cultar at 500 mg l^{-1} or 1000 mg l^{-1}. The favourable response was also reflected in flowering and yield attributes. The effect of these two chemicals on vegetative, flowering and yield characters had been discussed elsewhere (5.3.2.1) in this chapter.

5.3.2 *Second stage screening for ideal chemical for regulation of flowering*

The chemical combinations selected on the basis of their effect in the observational trial were further tested along with the insecticide carbaryl. Carbaryl, the systemic insecticide is being recommended at 0.10 per cent level to control tea mosquito in cashew (KAU 1996). This is usually given as foliar spray during flushing, flowering and nut set stages. Since the newly imposed treatments induce flushing and flowering early and in close succession, carbaryl 0.10 per cent supplemented with the chemical is expected to provide protection to the new growths. Moreover the combination spray would be highly economical and labour saving.

The study was aimed to identify the most effective chemical combination for regulation of flowering in cashew.

The chemical combination which manipulated different characters most favourably and the effect displayed are summarized in Table 49. Out of the four

Table 48. Summarised results of the observational trial

Characters	Treatment that evoked most favourable response	Response	
1	2	3	4
I Vegetative characters		Treatment	Control (water spray)
(i) Days to flushing	Cultar 1000 mg l^{-1} + KNO_3 1% Cultar 1000 mg l^{-1} + KNO_3 3% Cultar 1000 mg l^{-1} + KNO_3 5%	Induced flushing within five to six days after chemical application	Flushing was observed only after 36 days from the date of chemical application
(ii) Number of flushes (m^{-2})	Cultar 1000 mg l^{-1} + KNO_3 1%	Induced profuse flushing as high as 58.60 flushes m^{-2}	Flushing to the extent of 46.10 flushes m^{-2}
(iii) length of flush (cm)	Cultar 1000 mg l^{-1} + KNO_3 1%	Flush length was reduced to an average length of 6.90 cm $flush^{-1}$	Flushes were larger with an average length of 9.70 cm $flush^{-1}$
(iv) Number of leaves ($flush^{-1}$)	Cultar 1000 mg l^{-1} + KNO_3 1%	Average number of leaves on each flush was five	Average number of leaves ($flush^{-1}$) was 8.40
(v) Flushing span (days)	Alar 250 mg l^{-1}	Flushing span was reduced and was confined to a period of 21 days	Flushing was extended to a period of 40 days
II Flowering characters			
(i) Days to flowering	Cultar 1000 mg l^{-1} + KNO_3 1%	Early onset of flowering. Attained flowering stage 12 days after chemical application	Entered into flowering stage only after 59 days from the date of chemical application

Contd.

Table 48. Continued

1		2	3	4
(ii)	Number of panicle (m^{-2})	Cultar 1000 mg l^{-1} + KNO_3 1% Cultar 500 mg l^{-1} + KNO_3 1%	Induced profuse flowering. Number of panicles was as high as 47 to 49 per m^2	Number of panicles per m^2 was only 27
(iii)	Number of hermaphrodite flowers (panicle^{-1})	Cultar 1000 mg l^{-1} + KNO_3 1%	Number of hermaphrodite flowers was to the extent of 193.39 (panicle^{-1})	Number of hermaphrodite flowers per panicle was only 148.42
(iv)	Duration of flowering (days)	Alar 1000 mg l^{-1}	Induced synchronised flowering. Flowering was over within 34 days from the date of flowering.	On an average flowering period was extended to 53 days
(v)	Number of nuts (panicle^{-1})	Cultar 1000 mg l^{-1} + KNO_3 1%	Increased the nut set to the extent of 18.20 nuts per panicle.	Nut set was to the tune of 8.40 nuts per panicle
III Nut and yield characters				
(i) (ii) (iii)	Nut length Nut breadth Kernel weight	Not altered due to treatment		
(iv)	Nut weight	Cultar 1000 mg l^{-1} + KNO_3 1%	Nut weight was increased to 816 g per 100 nut	Hundred nut weight was 782 g
(v)	Yield	Cultar 1000 mg l^{-1} + KNO_3 1% Cultar 500 mg l^{-1} + KNO_3 1%	Yield was increased to 8.20 to 8.40 kg per tree.	Yield was 6.70 kg per tree.
(vi)	Fruit size	Not altered due to treatment		

Table 49. Summarised results of the second screening trial

Characters	Treatment that evoked most favourable response	Response	
1	2	3	4
I Vegetative characters		**Treatment**	**Control (water spray)**
(i) Days to flushing	All the chemical combination tried	Induced flushing with in five to seven after chemical application	Flushing occurred only after 40 days from the date of chemical application
(ii) Number of flushes (m^{-2})	All the chemical combination had more or less same effect	Induced profuse flushing. Number of flushes :35 to 40 m^{-2}	Number of flushes was only 27 per m^2
(iii) Length of flush (cm)	All the chemical combination reduced the flush length	Flush length was reduced to the extent of 3 to 4.5 cm per flush.	On an average the flush length was six centimeter.
(iv) Number of leaves ($flush^{-1}$).	Cultar 1000 mg l^{-1} + KNO_3 1%+ carbaryl 0.10%	Number of leaves was reduced to three per flush.	Number of leaves was five per flush
(v) Flushing span (days)	All the chemical treatments had same effect.	Flushing span was reduced to 23 to 25 days.	Flushing span extended to 32 days
II Flowering characters			
(i) Days to flowering.	Cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10%	Attained flowering stage 21 days after application of chemical	Flowering occurred only 57 days after the date of chemical application
(ii) Number of panicles (m^{-2})	Cultar 1000 mg l^{-1} + KNO_3 1% and cultar 1000 mg l^{-1} + KNO_3 1%+ carbaryl 0.10%	Induced production of more panicles which was as high as 33 to 35 numbers m^{-2}	Number of panicle per m^2 only 22

Contd.

Table 49. Continued

1		2	3	4
(iii)	Number of hermaphrodite flowers (panicle^{-1})	Cultar 1000 mg l^{-1} + KNO_3 1%+ carbaryl 0.10 %	Improved the number of hermaphrodite flowers to 207 per panicle	Number of hermaphrodite flowers was only 155 per panicle
(iv)	Duration of flowering	All the chemical combinations	Induced synchronised flowering and duration of flowering was reduced to 41 to 45 days	Duration of flowering was extended to 66 days
(v)	Number of nuts (panicle^{-1})	All the chemical combinations	Number of nuts per panicle was improved to 12 to 14 nuts	Number of nuts per panicle was only eight
III Nut and yield characters				
(i)	Nut length	All the chemical combination improved nut length slightly	Length per nut was 2.93 to 2.98 cm	Length per nut was 2.80 cm
(ii)	Nut breadth	Cultar 1000 mg l^{-1} + KNO_3 1%+ carbaryl 0.10%	Nut breadth was 2.80 cm	Nut breadth was 2.60 cm
(ii)	100 nut weight	All the chemicals tried improved the nut weight	Weight of hundred nuts was 847 to 866 g for different treatments.	Weight of hundred nuts was 827 g
(iii)	Kernel weight	Kernel weight was not altered significantly		
(iv)	Yield	Cultar 1000 mg l^{-1} + KNO_3 1%+ carbaryl 0.10%	Yield was increased to the level of 6.93 kg per tree.	Yield per tree was 3.33 kg
(v)	Fruit size	Fruit size was not altered significantly		

chemical combinations tried, the superiority of foliar application of the combination, cultar 1000 mg l^{-1} with KNO_3 at one per cent level and Carbaryl at 0.10 per cent is evident from the table and Fig. 9.

The effect of these chemicals on vegetative; flowering, nut and yield characters are discussed based on results of the two trials conducted to screen the most ideal chemical for regulation of flowering in cashew. The sequential changes observed from spraying the most favourable chemical combination till nut set are given in Plate 12.

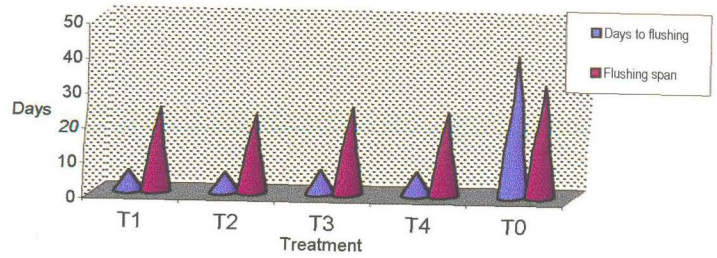
5.3.2.1 Influence of paclobutrazol, potassium nitrate and carbaryl on flowering regulation

5.3.2.1.1 Vegetative characters

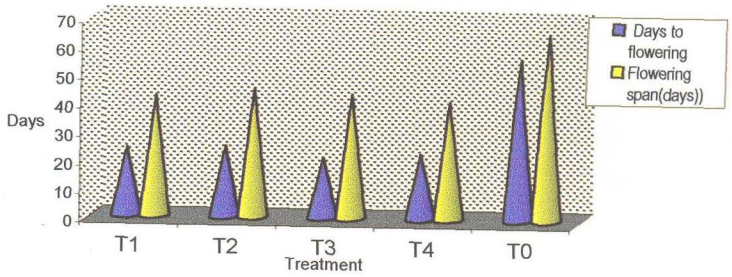
In the observational trial it was found that cultar 1000 mg l^{-1} together with KNO_3 at one per cent level exerted profound influence on all vegetative characters studied. In the second stage of screening all the chemical combinations tried induced almost similar positive effects on vegetative characters except on the number of leaves produced (Table 20). Here cultar 1000mg l^{-1} with KNO_3 one per cent and carbaryl 0.10 per cent were found superior in effect.

The chemical treatments were found effective in advancing the prebloom flushing by one month. This could be mostly attributed to the effect of KNO_3 in the combination. The possible role of KNO_3 in breaking dormancy of shoots had been discussed by many scientists. Tongumpai *et al.* (1989) and Davenport and Elisea (1990) explained that the role of KNO_3 is to initiate shoot growth in mango, but do not determine the course of bud morphogenesis. It has been proposed due to the evolution of ethylene and increasing ethylene content of tissues (Vazquez and Rosendiz, 1985). They confirmed this view by applying $COCl_2$ or $AgNO_3$, two ethylene synthesis inhibitors to KNO_3 treated plants and found that the effect of KNO_3 was negated. The observations of the present study are also supportive to the possible role of KNO_3 through evolving ethylene. Within five days after application of the chemical the leaves of mature shoots

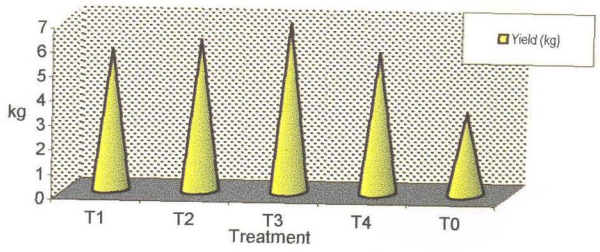
Fig.9. Influence of chemical treatments on morphological characters of the variety Madakkathra-2



Vegetative characters



Flowering characters



Nut characters

Plate 11. ***Sequential changes in cashew trees as affected by chemical treatment***

Before spraying

Rapid leaf yellowing

Intensive leaf fall

Synchronised flushing

Synchronised flowering

Uniform nutsets

turned yellow and exhibited a typical symptom of ripening similar to that induced by ethylene. Followed by this heavy leaf fall and bud break occurred in mature shoots resulting in production of flushes. Davenport and Elisea (1990) suggested that the defoliation of trees stimulate flushing possibly by altering the cytokinin to auxin ratio in buds. They opined that the leaves being the primary source of auxin their removal result in an increased cytokinin to auxin ratio conducive for the production of more shoots. More number of flushes per unit area observed in the present study was supportive to the view expressed by the authors.

The bud forcing by application of the specified chemical combination might have enhanced the nitrogen status of the shoots resulting in increased flushing. Better supply of metabolites at the onset of reproductive phase might have also taken place, as evidenced through biochemical studies (4.3.5). The capacity of paclobutrazol to mobilise more metabolites for reproductive events had been discussed elsewhere in this chapter.

Consequent to the flushing great depletion of carbohydrate reserves and nitrogen status in the mature shoots were recorded in the treated plants compared to control (Table 31) in the present study. It can be assumed that the exhaurstion of intermediary compounds in the pathway of carbohydrate synthesis might have taken place as the phenol content also recorded comparative low values at this stage. The great depletion of chlorophyll status in leaves of mature shoots of treated plants could be taken as an indication of mobilisation of more assimilates from these shoots and subsequent degradation of chlorophyll. Partitioning of assimilates from source to sink in response to paclobutrazol application had been reported by Balamani and Poovaiah (1985).

Another important observation of the present study was the reduction in flush length and number of leaves on the flushes induced through chemical treatment. Here the paclobutrazol might have imposed its profound influence by way of retarding the vegetative growth. Similar observations had been made in mango in response to paclobutrazol application by Khader (1991), Kurien and

Iyer (1993), Ram *et al.* (1996) and Burondkar *et al.* (1997). Paclobutrazol apparently acts at least in part by suppressing the synthesis of gibberellin. Accordingly the effect of paclobutrazol in plants are found to be reversed by gibberellin and is found effective in inhibiting the extension growth in a wide range of species (Davis *et al.*, 1986).

The impact of paclobutrazol on gibberellin biosynthesis had been studied well. Gibberellins are synthesised from mevalonic acid via. isoprenoid pathway and the triazoles specifically inhibit the microsomal oxidation of kaurene, kaurenal and kaurenol which are catalysed by kaurene oxidase (cytochrome p^{450} oxidase), inhibiting gibberellin biosynthesis (Dalziel and Lawrence, 1984; Hedden and Graebe, 1985). According to Lever (1986), paclobutrazol is not blocking the activity of either existing endogenous or exogenous GA_3 but primarily reduce gibberellin biosynthesis. Gibberellins being the hormones associated with cell elongation, the check or suppression in their production result in reduced extension of growth.

The reduction in number of leaves per flush observed due to the most effective treatment corroborate with the reports of Jones *et al.* (1991) in apple, Ogata *et al.* (1989) in peach and Ram *et al.* (1996) in mango. The authors opined that paclobutrazol reduced the number of nodes per shoot and thus the leaf number.

The short flushing span noted in the present study might be the result of flushing and rapid differentiation of reproductive buds at the terminals in response to chemical application. Paclobutrazol is reported to bring three to sixty days early flowering depending upon the cultivars and other climatic conditions (Vuillume, 1991).

Paclobutrazol is found effective in inhibiting the vegetative growth in a wide range of temperate, subtropical and tropical species (Kurien and Iyer,1993).

Quinlan (1985), Richardsan and Quinlan (1986) and Jones *et al.* (1991) reported that the target site for practically useful biochemical effects for paclobutrazol is the active sub-apical meristemes. It can be assumed that the foliar applied paclobutrazol in cashew might have been taken up through young sub-apical shoots and evoked favourable response. Quinlan and Richardson (1986) stated that the paclobutrazol move acropetally when applied to young active stems that immediate effects can be expected.

The mature lateral shoots are physiologically very active as evidenced in the anatomical studies (5.2.2). This might have resulted in better absorption and translocation of chemicals applied as foliar spray.

5.3.2.1.2 Flowering characters

The effect of cultar 1000 mg l^{-1} and KNO_3 at one per cent was significant in altering the flowering characters in cashew. Time taken for flowering was reduced,number of panicles per m^2 was improved, percentage of hermaphrodite flowers was increased, the flowering span was reduced and number of nuts per panicle was found inrcreased both in observational and second screening trials.

Early flowering has been reported in response to application of paclobutrazol in crops like peach, apricot and cherry by Proebsting and Mills (1985) and in mango by Burondkar and Gunjate (1994) and Tongumpai *et al.* (1997). Early flowering in mango has been reported by Vazquez and Rosendiz (1985), Sergent and Leal (1989) and Rojas (1997) due to foliar application of KNO_3. There is a contradictory report by Stinchcombe *et al.* (1984), who observed delayed flowering in cider apple due to paclobutrazol application. The early flushing and simultaneous check imposed to the growth of these flushes due to application of the chemical may be a reason for early flowering observed in the present study. The growth retardants are known to divert metabolites to the buds and promote flower initiation (Monselise and Luckwill, 1974). Due to this effect the paclobutrazol in the chemical combination might have altered the

sink strength within the plant allowing greater partition of assimilates for reproductive phenomenon. The KNO_3 might have improved the metabolite status of the flushes. Thus the variety Madakkathra-2 which normally flowers in January entered into flowering by the month of October.

Number of panicles per m^2 was found improved (Table 18 and 21) in response to application of the chemical. Tongumpai *et al.* (1997) explained the combined effect of paclobutrazol and KNO_3 in altering the flowering physiology of mango. They found that when KNO_3 2.5 per cent was applied eight to ten weeks after cultar application (2.0 to 8.0 g. *a. i* per tree) to the mango variety KSW (a difficult to flower variety) flowered profusely about a week earlier. They attributed this effect to the bud breaking capacity of KNO_3 and induction of flower bud formation by cultar by lowering gibberellin levels. The pooled effect obtained due to combined application of these two chemicals in the present study might have resulted in early and profuse flowering of the late season variety.

The beneficial effect of cultar in increasing flowering was also reported by many workers in different fruit species. Reports of Quinlan (1985), Lever (1986), Webster *et al.* (1986), Edgerton (1986) and Hodairi and Canham (1990) in apple, Kulkarni (1988), Khader (1991) Kurien and Iyer, (1993) Urruntia and Campbell (1994) and Tongumpai *et al.* (1997) in mango are few examples. Improvement in this character can be considered as a significant milestone in yield improvement programme of cashew since high positive correlation was observed for the number of panicles per m^2 with yield through indirectly influencing a number of yield contributing factors.

The number of hermaphrodite flowers was found increased through the chemical treatment and this was another favourable result of the study. Better light penetration to the canopy due to leaf fall might have augmented their production. According to the general physiology of cashew, the onset of flowering is with the production of male flowers (male phase) followed by mixed phase

with the production of more number of bisexual flowers and end with a male phase (Parameswaran *et al.*, 1984). Thus the duration of flowering usually extend to 45 to 60 days depending on the varieties. Sena *et al.* (1995) and Dorajeerao *et al.*(1999) reported wide variation in flowering duration in cashew varieties. Due to chemical induction, duration of flowering was found confined to a short period and the tree might have stimulated to express its reproductive potential within that period. The emergence of more number of flowers per panicle per day observed in the treated plants might be due to this consequence. Production of hermaphrodi te flowers was also noticed during the initial phase of flowering in the present study. Mariappan *et al*, (1995) observed increase in hermaphrodite flower production due to application of ethrel 100 ppm in cashew. They opined that ethrel spray might have exerted its effect on sex expression by the manipulation of endogenous auxin corresponding to the reduction in male flowers. The KNO_3 regulated ethylene biosynthesis might have played a similar role resulting in production of more hermaphrodite flowers. The early setting of nuts in treated plants might have paved path for their escape from devastating tea mosquito bug.

Synchronised flowering resulting in a short flowering phase was another major response to chemical application. Davenport and Elisea (1997) opined that a flowering stimulus was synthesised in the leaves during the fall that flower formation occurs if a bud undergoes cell division in the presence of such stimulus. Bud growth in the absence of such stimulus result in the formation of vegetative shoots. It can be assumed that a stimulus favourable for flowering might have originated at the time of leaf fall in cashew and the associated cell division resulted in the differentiation of reproductive shoots. Since they emerged more or less at the same period (as observed in the present study) the differentiation might have been in a synchronised manner. Thus flowering span might have reduced.

Number of nuts per panicle was also significantly improved in response to chemical application. This can be attributed to the increase in source strength facilitating better utilisation for nut set. The KNO_3 in the treatment and capacity of the paclobutrazol to divert metabolites might have played their own role to enrich the source strength. This was evident when biochemical characters of the flush leaves were studied before nut set (Table 31). More quantity of nitrogen was found to be accumulated in treated plants after panicle emergence. This might have made possible the synthesis of more protein bodies for increased nut set. The findings of Wang *et al.* (1985) is supportive to this view. He reported increased soluble protein levels in the leaves of plants treated with cultar. The carbohydrate reserves in the reproductive flushes of treated plants was also found enriched after panicle development than control in the present study. Steffens *et al.* (1985) and Wang *et al.* (1985) also reported an increase in carbohydrate levels in young shoots of apple seedlings in response to paclobutrazol application. The high chlorophyll status recorded in leaves of such shoots amply substantiate the accumulation of photosynthates. Increased chlorophyll content in apple seedlings treated with paclobutrazol had been reported by Hao *et al.* (1991). The leaves on the newly emerged flushes after paclobutrazol application appeared more green than that on control in the study. This effect of paclobutrazol had been reported in many fruit crops by Ram *et al.* (1996). A reduction in the phenol content of these flushes (Table 31) indicate the conversion of intermediary metabolites to stable assimilates.

Apart from the effect of cultar 1000 mg l^{-1} with KNO_3 at one per cent level on flowering characters, the advantage of adding carbaryl 0.10 per cent together with this combination was evident in the second srceening trial. Better yield without any additional investment on chemical application was observed (Table 22). Carbaryl, the systemic insecticide might have provided protection to young flushes and panicles which are most vulnerable to tea mosquito attack as reported by Sundararaju and Bhaktavathsalam (1990). The pest infestation statrts

when new shoots emerge on trees and the attack get aggregated when the adults and nymphs suck sap from tender succulent shoots, floral branches and immature nuts,resulting in shoot dieback and blossom blight respectively.

The tea mosquito attack in cashew completely shatters the healthy phenological events of the tree. The protection given due to applying carbaryl just before flushing might have played profound role in overcoming these negative effects of tea mosquito attack related with flushing and flowering.

5.3.2.1.3 Nut and yield characters

Significant improvement in yield was recorded in treated plants compared to control. Improvement in yield due to paclobutrazol application had already been reported with many fruit species (Ram *et al.*, 1996), Reports in mango by Ram and Tripathi (1993), Miao *et al.* (1994) Mossak (1997) and Burondkar *et al.* (1997) need emphasis in this context. The ultimate effect of potassium nitrate sprays was also found to enhance the yield as reported in mango by Oosthuyse *et al.* (1996), Mossak (1997) and Sergent *et al.* (1997).

Hodairi and Canham (1990) opined that the diversion of more metabolites by growth retardants might have increased the carrying capacity of the tree and thus yield. Mohan and Rao (1995) reported that the number of nuts carried to maturity was increased when cashew trees were sprayed with growth retardants or two per cent potassium nitrate. Favourable alteration of the source strength and better partitioning of metabolites might have also reduced the competition among fruitlets resulting in control of preharvest fruit drop. Relatively more chlorophyll 'a', 'b' and total chlorophyll recorded in the present study (Table 31) in flushes of treated plants after nut set reveal their relative efficiency to carry on more photosynthesis and capability to lead more nuts and fruits to maturity.

An yield improvement by 25 per cent in response to chemical application was recorded in the observational trial and in second screening trial yield was

doubled. The increased yield may be linked to the favourable response evoked by the chemical on vegetative and flowering characters. Davenport and Elisea (1997) stated that yield is a product of photoassimilate accumulation and subsequent redistribution during the annual growth cycle.

The role of carbaryl in imparting better nut and yield characters cannot be under estimated. The protection given to the flushes at the right stage might have paved a path for exploitation of source strength in full. This might have reflected ultimately on nut and yield characters.

The quality attributes of the nuts viz., length, breadth, nut and kernel weight were not found altered significantly due to chemical application in the present study. The apple weight also remained without much variation.

The reports on the effect of triazoles on fruit quality seems to be somewhat inconsistent. Paclobutrazol application is reported to increase fruit weight (Ferrari and Sergant, 1996), fruit quality,external appearance and firmness (Kulkarni *et al.*, 1997) in mango. Potassium nitrate sprays were not found to affect fruit quality of mango fruits (Vazquez, 1982 and Oosthuyse *et al.* 1996). Contrary to these reports Kurien and Iyer (1993) reported reduction in fruit weight, volume, total soluble solids and sugar acid ratio in mango fruits in response to high dose of paclobutrazol treatment. Curry and Williams, (1983) and Stinchcombe *et al.* (1984) indicated small decrease in weight and size of apples from paclobutrazol treated trees. Williams (1984) reported deformation and Quinlan and Richardson (1986) reported russetting of apple fruits in response to paclobutrazol application.

The vegetative, flowering, nut and yield characters and biochemical characters in relation to chemical application, highlights the efficiency of cultar 1000 mg l^{-1} combined with KNO_3 one per cent and carbaryl 0.10 per cent for flowering regulation and yield manipulation in cashew. This chemical combination can be recommended for realising higher yields from cashew plantations.

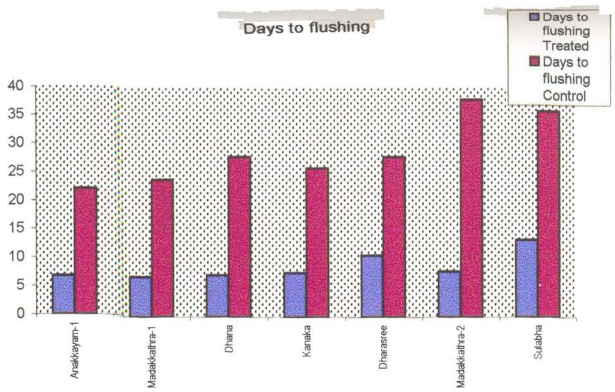
However, the postharvest implications of chemical application in cashew orchards is to be assertained in detail in terms of produce quality and safety. The internationally permissible limit of paclobutrazol in fruit tissues is below 0.50 mg kg^{-1} of fruit (Srivastava and Ram, 1999). This signifies the need on studies pertaining to residual status and its effect on cashew apple and kernel in relation to different methods and dose of paclobutrazol application.

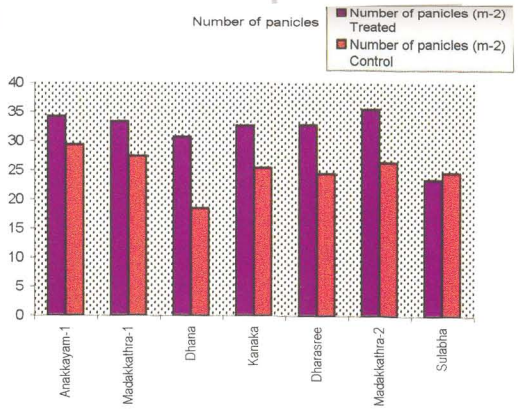
5.3.3 Varietal response to chemical regulation of flowering

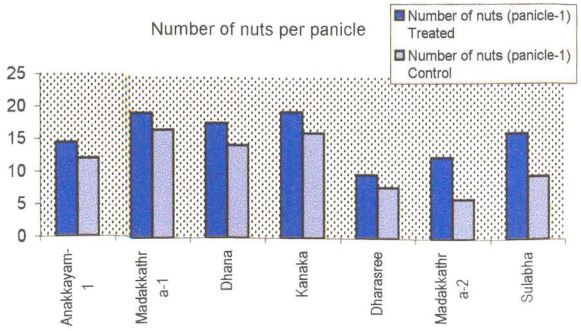
In the present study, varietal variation in response to regulation of flowering was observed. The effects of the ingredients paclobutrazol, potassium nitrate and carbaryl in the chemical combination were evident among different varieties. However, the effect was found manifested at varying intensities in different varieties (Fig. 10). The variety Dharasree included in the study showed an indifferent response compared to other varieties. Varietal variation in vegetative, flowering and yield characters in response to application of paclobutrazol has been reported by Kulkarni (1988) in mango and Hodairi and Canham (1990) in apple. They attributed this phenomenon of variation among varieties to the difference in genetic make up and biochemical factors.

The response observed among different cashew varieties are summarised in Table 50. The table clearly shows that several characters were shifted due to chemical application. Several such shifted characters viz., short flushes, more number of panicle per m^2, number of nuts per panicle have already been established to have strong positive correlation with yield. Most of these characters were found assembled in the late season variety Madakkathra-2. Hence this can be ranked as the variety which can be manipulated in the most favourable manner for improving yield through chemical application. An increase in yield by 50 per cent was recorded with this variety.

It was evident from the present study that favourable response was exhibited by all the varieties irrespective of their flowering season to chemical


Days to flushing
Days to flushing Treated
Days to flushing Control
40
35
30
25
20
15
10
5
0
Anakkayam-1
Madakkathra-1
Dhana
Kanaka
Dharasree
Madakkathra-2
Sulabha


Number of panicles
Number of panicles (m-2) Treated
Number of panicles (m-2) Control
40
35
30
25
20
15
10
5
0
Anakkayam-1
Madakkathra-1
Dhana
Kanaka
Dharasree
Madakkathra-2
Sulabha


Number of nuts per panicle
Number of nuts (panicle-1) Treated
Number of nuts (panicle-1) Control
25
20
15
10
5
0
Anakkayam-1
Madakkathra-1
Dhana
Kanaka
Dharasree
Madakkathra-2
Sulabha

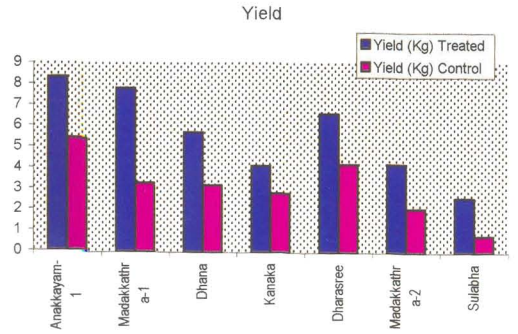

Yield
Yield (Kg) Treated
Yield (Kg) Control
9
8
7
6
5
4
3
2
1
0
Anakkayam-1
Madakkathra-1
Dhana
Kanaka
Dharasree
Madakkathra-2
Sulabha

Table 50. Significant response among cashew varieties to chemical regulation of flowering

Characters		Response	Variety which showed most favourable response
I Vegetative characters			
(i)	Days to flushing	Reduced by one month	Madakkathra-2
(ii)	Number of flushes (m^{-2}).	Increased by five to nine	All the varieties except Dharasree
(iii)	Length of flush (cm)	Reduced by two centimeter	Dhana and Madakkathra-2
(iv)	Number of leaves ($flush^{-1}$)	Reduced by two	Madakkathra-2
(v)	Flushing span (days)	Reduced by three weeks.	Sulabha.
II Flowering characters			
(i)	Days to flowering.	Reduced by 25 to 26 days	Madakkathra-2 and Dhana
(ii)	Number of panicles (m^{-2})	Increased by 12.00	Madakkathra-2
(ii)	Number of hermaphrodite flowers ($panicle^{-1}$)	Increased by 49 per panicle	Madakkathra-1
(iii)	Duration of flowering (days)	Reduced by 17 to 18 days	Madakkathra –2 and Dhana
(iv)	Number of nuts ($panicle^{-1}$)	Increased by six to seven	Madakkathra-2 and Sulabha
III Nut and yield characters			
(i)	Nut length	Insignificant response among varieties	
(ii)	Nut breadth		
(iii)	Nut weight.		
(iv)	Kernel weight		
(v)	Yield	Yield improvement was 4.50 kg per tree	Madakkathra-1
(vi)	Fruit size	Not consistent among varieties	

regulation of flowering. The response of almost all the varieties were intermediate between high reponse of Madakkathra-2 and least response of Dharasree. Maximum yield improvement (58 per cent) was registered by the variety Madakkathra-1 (Table 28). It can be presumed that yield manipulation is better possible when attempted during natural flowering time of that variety. However, expression of better yield potential even after remarkable shift in yield time observed with late season varieties amplifies the significant influence of the chemical combination identified in the present study.

5.3.4 *Effect of selected chemical combination (Cultar 1000 mg l^{-1} + KNO_3 1% + Carbaryl 0.10%) in large plot trial*

The favourable effects of the chemical combination was once again demonstrated through two large plot trials laid out with varieties Madakkathra-1 and Madakkathra-2. (4.4.1 and 4.4.2). An average yield improvement of 2.75 kg per tree for the early variety Madakkathra-1 and 2.50 kg per tree for the late variety Madakkathra-2 could be realised when the treatment was imposed on more number of trees in a compact block. This prooves the efficiency of the chemical combination selcted through present study for flowering regulation in cashew.

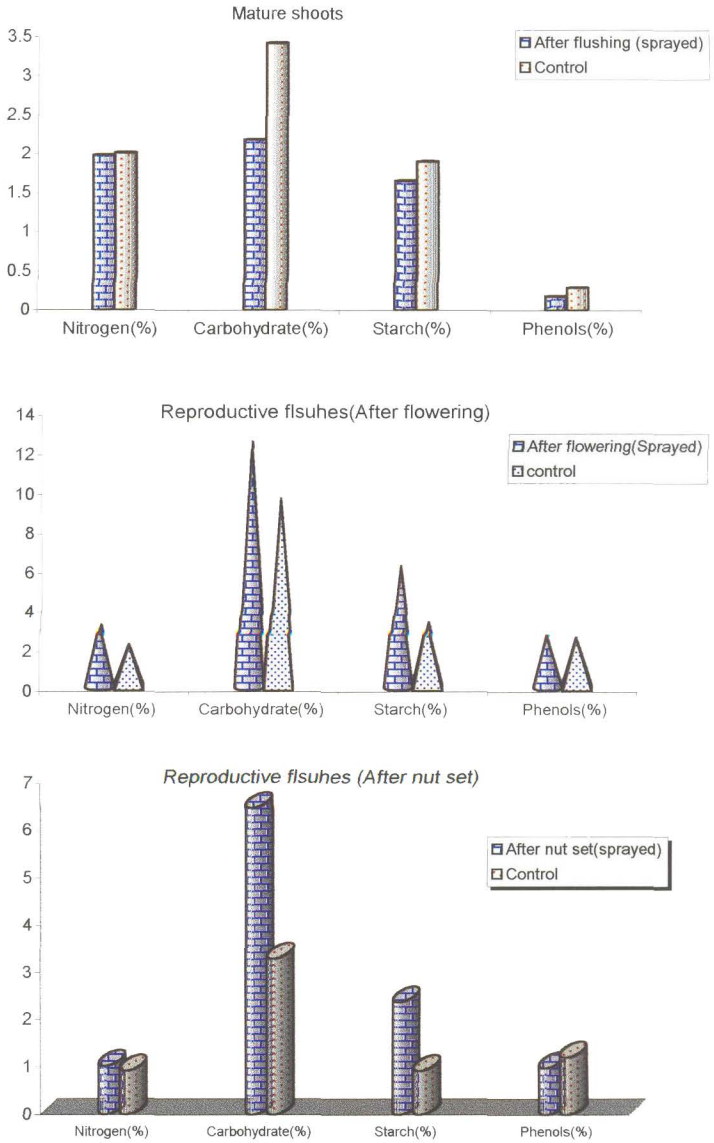
5.3.5 *Variation in biochemical constituents in response to application of selected chemical combination*

The influence of spray application of the selected chemical combination on biochemical constituents viz., nitrogen, carbohydrates, starch and total phenols of the variety Madakkathra-2 (Fig. 11) had already been discussed elsewhere (5.3.2.1) in this chapter.

5.3.6 *Effect of the selected chemical combination over years (pooled effect)*

The overall effect of the chemical combination on early season variety Madakkathra-1 and late season variety Madakkathra-2 was profound in checking the vegetative growth and inducing early profuse flowering. The better response of the variety Madakkathra-1 (as discussed earlier) was once again evident

Fig.11. Influence of spray application of the selected chemical combination on biochemical constituents of the variety 'Madakkathra-2'



when the effect of two seasons (1997-'98 and 1998-'99) were pooled and analysed. This variety registered an overall yield improvement by 3.00 kg per tree.

The yield improvement over three years (1996-'97, 1997-'98 and 1998-'99) for the variety Madakkathra-2 was only 1.50 kg per tree. However, expression of better yield potential even after remarkable shift in yielding time observed with this late variety amplifies the significant influence of the selected chemical combination.

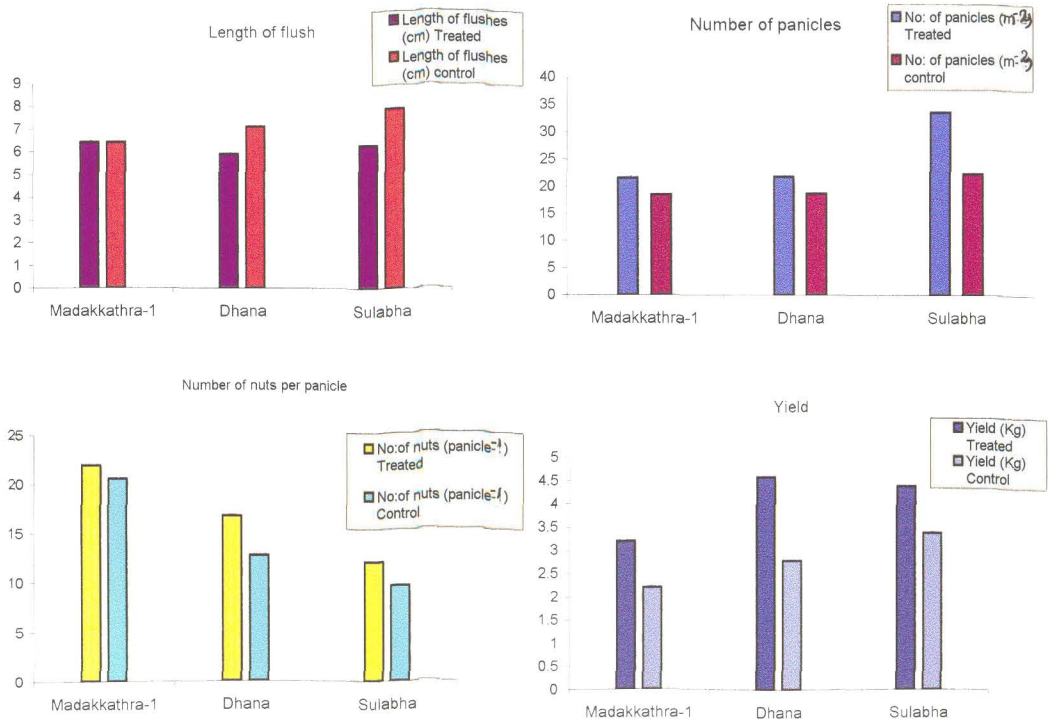
The economics of cashew orchard management through application of the selected chemical combination, worked out on the basis of this results are given in Appendix - XI.

5.3.7 Effect of soil application of paclobutrazol

Observations on the effect of soil application of paclobutrazol to different varieties of cashew yielded some valuable conclusions. The variety Sulabha (a late high yielder) showed significant positive response to soil application (Fig. 12). In this variety the characters which are identified to have high positive correlation with yield especially short flushes and more number of panicles per m^2 were found to be altered in most favourable direction. The response of other varieties can be ranked as medium to low with respect to different characters. Thus the effect of soil applied paclobutrazol cannot be neglected. It was very much evident in suppression of the growth of newly emerged flushes. The length of flushes and number of leaves per flush was reduced (Table 35). Richardson and Quinlan (1986) reported that root applied paclobutrazol is acropetally transported to the leaves primarily via. the xylem and evoke growth retarding responses.

In the present study, eventhough the time taken for flushing was found reduced, the number of flushes per m^2 was not found improved. This shows that the stimulus received for the bud break was not sufficient. This result is

Fig.12. Varietal response to soil application of cultar



supportive to the role of KNO_3 in inducing bud break and initiating flushing as discussed earlier. Potassium nitrate was not included in this experiment. Perhaps this may be the reason for the low effect in reducing the flowering span noted with many varieties compared to foliar application of chemical.

The status of yield improvement achieved in this experiment was also not satisfactory. Even the variety Sulabha which showed maximum response could register only an yield improvement by 1kg per tree. Sterret (1985) suggested that only one fourth of the paclobutrazol is translocated from soil through xylem via absorption through roots. This points to the fact that the level of paclobutrazol applied to the soil in the present study might be quite insufficient. Thus the quantity available in the plant system might be below the required level that its potential was not expressed in full. Moreover soil application may be effective for young trees compared to old trees as observed by Edgerton (1986) in apple. This could be the reason for low yield improvement in response to soil application. More detailed studies on soil application with higher concentrations are necessary to draw further conclusions. In the present study it can be seen that the efficiency of the identified chemical combination was superior in its effect when applied as foliar spray.This can be directly adopted the farmers field for overcoming late, erratic and protracted flowering exhibited by many varieties and to exploit the yield potential to a maximum extent.

Based on the results of foliar and soil application of paclobutrazol it can be concluded that the effect depended on the variety, method of application and concentration of chemical. Earlier reports on the effect of paclobutrazol in tree crops is in agreement with the present study.

The effectiveness of method of application varies depending on location, species, age of the tree etc. Paclobutrazol is reported to be more effective in retarding shoot growth when applied to soil (Burond kar *et al.* 1997) in mango or directly to stems (Bayun and Chang 1986) in apple compared to foliar sprays. Barrett and Bartuska (1982) opined that the soil type is a major factor

determining the effect of soil application. Edgerton (1986) reported better response of old mango trees to foliar application of paclobutrazol at 500 or 1000 mgl^{-1} per tree compared to soil application. Lever (1986) reported that soil applied chemical reaches the active site by transport through xylem in the roots from reservoirs in soil and through young sub-apical shoot tissues following foliar spray. Trace studies with 14^C labelled paclobutrazol (Richardson and Quinlan,1985) have revealed phloem mobility of paclobutrazol.

Soil application of paclobutrazol is to be more judicious. It is of low water solubility (30 ppm in water) and tends to bind reversibly to both soil and to wood as it passes up the vascular system of the tree. Although soil absorption and movement were found to vary with soil type, it is relatively an immobile compound and uptake through roots is critically dependent upon the juxtaposition of chemical and roots. The effect was found more when roots and chemical come in close proximity. Foliage cover and an active transpiration streams are then required to pull the chemical up the tree to growing points. Therefore a delay between time of application and expression of effect could be naturally expected. Contrary to this delivery of the chemical to active sites through foliar sprays are expected to evoke immediate responses.

In the present study soil application of paclobutrazol was not found to shift the flowering time of early varieties. Before the cheimcal reaches to the active site (shoot tips) flower differentiation might have completed in early varieties.Trace studies with paclobutrazol after soil application to apple trees showed that the chemical was transported through xylem and accumulated in phloem and distributed to leaves and the effects were observed about one month after soil application and one week after foliar srpay (Gang *et al.*,1994).

The soil method of application need further refinement on the basis of studies including varying doses, methods and frequency of application. Possibility of application to the soil at manuring time or soil application of paclobutrazol combined with foliar spray of KNO_3 is also to be explored.

5.4 Inducing dwarfism in cashew grafts

5.4.1 Effect of irradiation

5.4.1.1 Germination of seeds and survival of seedlings

Seeds subjected to different doses of irradiation exhibited immense variability with respect to germination and subsequent survival of seedlings (Table 40). Cashew seeds usually start germination 15 days after sowing and complete within one month. In the present study lowest level of irradiation (5 Gy) augmented the germination as evidenced by the high percentage of germination (81 per cent) recorded 15 days after sowing. The other levels of irradiation delayed and reduced the germination which was practically nil at the two higher levels. The stimulatory effects of lower doses of irradiation and suppressing effect of higher doses on cashew seed germination had been reported by Salam, *et al.* (1992) based on a previous trial at the Cashew Research Station, Madakkathra. The authors reported that the seeds failed to germinate at an irradiation level beyond 60 Gy and suggested the lethal dose (LD_{50} %) value between 40 and 50 Gy. The result obtained in the present study supports this view since 70 per cent germination obtained at 40 Gy decreased to 33 per cent when subjected to 50 Gy irradiation. The factors responsible for germination of cashew seeds may be getting momentum when subjected to lower doses of irradiation. Better ability of the irradiated seeds to imbibe water can also be a possible explanation for early germination of irradiated seeds. Some limiting factors inhibiting germination may be developed inside the seeds during storage resulting in delayed germination of stored seeds. Production or expression of such factors might be elevated while irradiation at higher levels and result in poor germination. Detailed biochemical studies are required to substantiate this view.

Eventhough germination of irradiated seeds was satisfactory at lower doses, survival rate was found reduced. Good number of seedlings failed to survive (18 per cent) even at the lowest dose which recorded maximum germination. In the control the loss was only two per cent.

Plate 12. ***Abnormalities in cashew seedlings due to seed irradiation***

Young seedlings

Grown up seedlings

Many of the seedlings derived from irradiated seeds had a brown discolouration at the plumule and dark brown scorches on the cotyledons (Plate 13). Cotyledons were crinkled and leaves had brown spots and scorches at higher dose (50, 60 and 70 Gy). The crinkled cotyledons might have failed to partition its carbohydrate reserves to the growing seedlings which resulted in less vigorous seedlings. This was supported from the observation that such deformed cotyledons were found detached from the growing seedlings much earlier than control plants. These abnormalities might have enhanced the loss. Similar abnormalities were found in the nursery when seeds were germinated and kept in open sunlight generally referred as sunscorching.

5.4.1.2 Growth of root stocks

Observation on growth parameters of the seedlings derived from irradiated seeds up to two months revealed that beyond 20 Gy, seedlings tend to be dwarfs. Such seedlings had less height, less number of leaves and more girth compared to control seedlings (Table 41). Good girth is reported to be an important criterion in screening of ideal root stocks (Pushpalatha *et al.*,1989). The girth increment observed with the seedlings beyond 20 Gy irradiation level is thus expected to give good success in grafting. But seedlings at irradiation level beyond 40 Gy eventhough appeared dwarf produced unhealthy plants with crinkled leaves. As such they were not fit for grafting. Since the seedlings derived from irradiation of seeds at 25 to 40 Gy presented no abnormality and appeared stout they can be considered as ideal dwarf root stocks.Thus an irradiation level of 25 to 40 Gy can be suggested to get dwarf seedling root stocks sacrifycing the ill effects observed in germination and survival of seedlings. The results are in conformity with Salam *et al.*,(1992). They also reported reduced growth of seedlings beyond 20 Gy. Stimulatory effect of lower doses of irradiation on seedling growth reported by the authors were not observed in the present study.

Efficiency of the root stocks could be evaluated only by grafting them using suitable scions and analysing the success in grafting and subsequent performance of grafts. In the present study also the seedlings derived from irradiated seeds were evaluated for their efficiency to use as root stocks.

5.4.1.3 Success in grafting

Sprouting percentage of grafts taken as a measure of initial success of grafting was satisfactory (65 to 80%) with irradiation levels 5 to 30 Gy. The highest irradiation level 40 Gy suggested for getting ideal dwarf root stocks gave only low initial success (50%). Root stocks of 50 Gy level which were extremely dwarf and unhealthy resulted in very poor initial success, 30 per cent as against 75 per cent in control.

All levels of irradiation were found to have a detrimental effect on survival of grafts. Mortality of grafts at varying intensity (20 to 100%) was observed with different doses of irradiation.

Graft take is dependent on the cambial union between root stock and scion. Faster the cell division at the cambium after grafting better will be the graft union. The low cell division as evidenced by the slow growth of irradiated root stocks might be a reason for poor graft take. Subsequently, low differentiation of the conducting tissues might have augmented the failure.

5.4.1.4 Growth performance of grafts

The grafts developed with seedlings derived from irradiated seeds as root stocks were evaluated for growth performance in the nursery for two years. The growth increment curves plotted for height and girth at three months interval clearly revealed the effect of three higher levels of irradiation for suppressing the height without reducing the girth of grafts. The growth of grafts at lower doses of irradiation viz., 5 to 20 Gy were comparatively superior, may be due to the vigorous root stocks.

The effect of the higher levels of irradiation on growth of grafts was more or less same. The grafts at these levels of irradiation remained dwarf and stout during the course of study. It can be presumed that irradiation might have suppressed the activity of some growth promoting factors in the root stocks,which in turn imparted dwarf stature to grafts in nursery.

Among the three higher levels, irradiation at 30 and 40 Gy reduced the germination percentage,survival of seedlings and success in grafting as discussed earlier. There is no advantage of trying these two doses since growth performance of grafts at these two levels were almost equal to grafts at 25 Gy level. So irradiation of cashew seeds at 25 Gy level can be considered ideal for getting grafts with short stature in the nursery. However, a final recommendation could be made only after evaluating the performance of grafts in the field at least for three years.

The growth parameters of the grafts at 25, 30 and 40 Gy level recorded after transplanting to the field indicated the possibility to break the dwarfism in future (Fig. 13). These grafts exhibited a fast growth rate within six months after transplanting to the field (Table 46). The character dwarfism induced through irradiation need not be stable and may not express when taken to a new environment.

5.4.2 Chemical induction of dwarfism in cashew grafts

Designing cashew grafts as dwarfs through chemical application could be much easier and economical to practice. If at all a dwarf root stock could be identified its availability on large scale for commercial nurseries could not be ensured.

Paclobutrazol had been used as a broad spectrum growth retardant in recent years. This has been reported to selectively control tree vigour in many fruit species without markedly affecting the fruit size (Quinlan,1980; Williams, 1984; Erez, 1986; Kulkarni,1988 and Kurien and Iyer, 1992). No previous

Fig. 13. Growth of grafts on root stocks raised from irradiated seeds

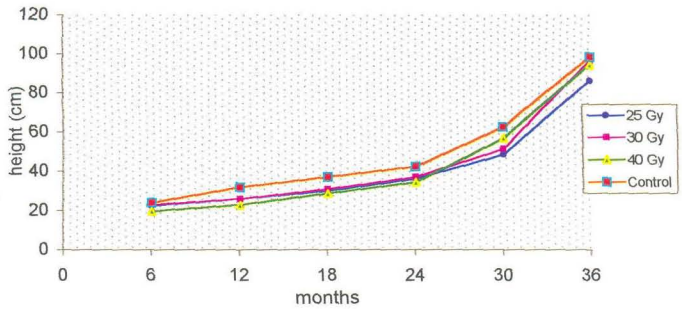
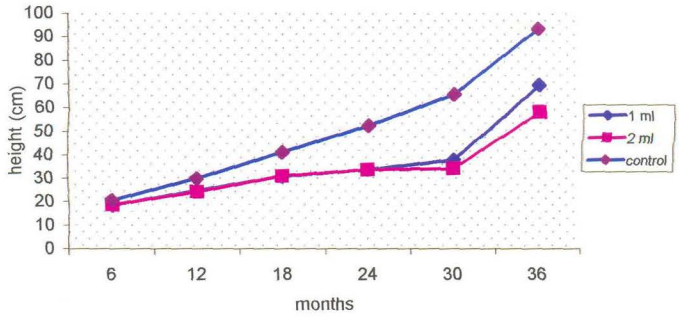


Fig. 14. Influence of soil application of cultar on growth of grafts



attempts were reported in cashew to control tree stature through manipulating seedling growth by chemical application.

In the present investigation, possibility for chemical control of growth was studied by applying paclobutrazol as cultar twice through soil to the grafts in polybags at one month and three months age. The results showed that paclobutrazol at lower doses viz., 0.25 and 0.5 g. *a.i* per plant are effective in controlling the growth of young cashew grafts compared to higher levels. The young grafts were not able to withstand the higher doses of this chemical beyond 0.5 g *a.i* per plant which resulted in leaf scorching, drying and death of grafts. Kulkarni (1988) reported the ill effects of higher levels of paclobutrazol on young mango grafts. Soil application of paclobutrazol at the rate of 2.5 g *a.i* per plant resulted in toxicity symptoms, epinasty and leaf scorching compared to the lower dose 1.25 g *a.i* per plant . Phytotoxicity symptoms in mango due to application of paclobutrazol at high dose was also reported by Kurien and Iyer (1993). The doses upto 0.50 g *a.i* per plant produced healthy dwarf grafts (Table 44). Eventhough occasional leaf fall was there, the grafts that received the chemical at lower two doses retained substantially good number of leaves as that of control plants. The effectiveness of 0.50 g *a i* per plant was found comparatively superior. In general relatively lower rates of paclobutrazol application was found required to inhibit the growth rate as opined by Rademacher and Jung (1981).

The antigibberellin activity of the chemical might have helped to reduce the internodal length as suggested by Steffens *et al.* (1985) thereby dwarfing the plant stature. This chemical may be checking the apical dominance of plants by inhibiting the basipetal movement of auxin as reported with other chemical growth retardants (Quinlan, 1980). Alterations in the plant growth by modifying the biochemical pathways of endogenous plant hormone biosynthesis have been reported by various workers. Bruisma (1985) has reported alteration in the synthesis of endogenous plant hormone due to paclobutrazol application. Kurien

et al. (1991) recorded lower levels of abscisic acid in shoot tips of paclobutrazol treated trees.

The dwarf stature of these grafts were found maintained even after transplanting to field (Fig. 14). This highlights the effectiveness of paclobutrazol to control huge size of cashew which cause serious problem for orchard management.

5.4.3 Variation in biochemical and anatomical characters of the selected dwarf grafts

Studies on biochemical and anatomical characters of the two year old dwarf grafts in irradiation and cultar treatment helped to derive valuable interpretations.

5.4.3.1 Variation in biochemical constituents

The chlorophyll, carbohydrate and nitrogen content in the grafts was found improved in response to soil application of cultar. Increase in chlorophyll content in response to paclobutrazol application in fruit crops had been reported by Jaggard *et al.* (1982) and Sankhla *et al.*(1985). According to them, the increased chorophyll content could be due to enhanced chlorophyll biosynthesis or simply a concentrating effect due to reduced leaf expansion.

Increase in carbohydrate content was observed in plants treated with paclobutrazol. Steffens *et al.* (1985) reported similar effect of paclobutrazol in apple.

Nitrogen content in the leaves were also found increased in response to chemical application. This result is in corroboration with that of Werner and Schaffer (1993) in mango seedlings.

Studies on biochemical characters of the grafts after irradiation treatment revealed its ill effects. The carbohydrate and nitrogen content in grafts of irradiation treatments were low compared to control (Table 45). This shows that the efficiency of the grafts to absorb minerals and synthesise metabolites got

reduced. This might be the reason for the reduced growth exhibited by them in the nursery. If so, the chance for reducing the yield potential of the plants could not be neglected.

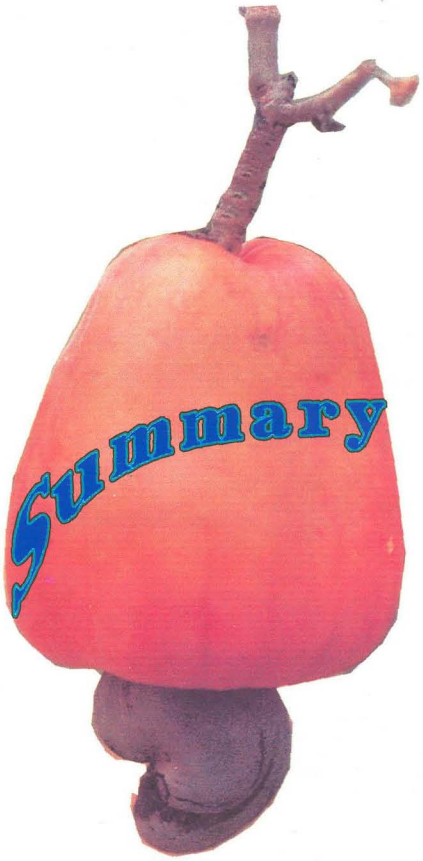
5.4.3.2 Variation in anatomical features of shoots

Mature shoots of dwarf cashew grafts in nursery (induced through irradiation and chemical treatment) were examined for bark thickness, number of xylem vessels per unit area, leaf thickness, cuticle thickness and number of stomata per unit area. Variation was observed in grafts treated with cultar for the different anatomical features observed (Table 46).

Bark thickness and number of xylem vessels per unit area were found increased in response to cultar application. Bark thickness is reported to be an anatomical feature positively correlated with dwarf stature (Mukherjee and Das, 1980., Singh *et al.*1986 and Kurien and Iyer, 1993 in mango and Usha *et al.*, 1996 in cashew). As discussed earlier thick bark may arise as a physiological necessity. The utilisation of photoassimilates by dwarf plants may be low due to the check imposed on growth. This may necessitate storing more assimilates in the stem, root, bark etc. for utilisation during the ensuing physiological events. This might be the reason for thick bark in dwarf grafts. The biochemical and anatomical characters of the dwarf grafts in cultar treatment shows the possiblity of expressing better yield potential by them.

The effect of paclobutrazol in altering the phloem to xylem ratio of mango shoots was reported by Kurien and Iyer, (1993). The number of xylem vessels per unit area was reported to be increased in response to cultar application. This alteration in the proportion of conducting tissues may result in favourable manipulation of source sink relation.

On the contrary, the features reported to be associated with dwarfism viz., bark thickness and number of xylem vessels per unit area were not found altered in the grafts under irradiation treatments.


Summary

Summary

The present investigation "***Morphophysiological analysis of growth and yield in cashew***" was undertaken at the Department of Plantation Crops and Spices, Kerala Agricultural Universtiy, Vellanikkara during the period 1995 to 1999.The objectives were to estimate the variability in morphological characters among cashew genotypes and analyse the yield components, study the variation among varieties with respect to biochemical and anatomical characters at different stages of reproductive growth, explore the possibilities of chemical regulation of flowering and induce dwarfism in grafts at nursery stage.

Results of the experiments are summarised

Grouping of cashew genotypes as early, mid and late season types based on date of flowering, had shown that early and late types are very less and predominance (56.71% of the genotypes) was for mid season types.

When grouping of genotypes was made as high, medium and low yielders based on yield performance, proportion of the high yielders was found very low (14.93% of the genotypes) and about 50 per cent of the genotypes were low yielders.

Variability analysis of 27 varieties (selected from the groups formed based on flowering behaviour and yield performance) revealed significant variation among them with respect to vegetative, flowering, nut and yield characters. Variability was high for certain characters viz., flush length, number of leaves per shoot, percentage of hermaphrodite flowers, number of nuts per panicle, nut weight and yield.

Yield exhibited high positive correlation with number of panicles per unit area (rg = 0.96), percentage of hermaphrodite flowers (rg = 0.85), panicle length (0.73) and number of nuts per panicle (rg = 0.83) and significant negative association with flush length (rg = - 0.77) at genotypic and phenotypic level.

A selection index constructed (efficiency = I 1.73), based on yield, flush length, number of panicles (m^{-2}) and number of nuts per panicle was found effective for identifying superior genotypes.

The total carbohydrate, nitrogen, chlorophyll and phenol content and the activity of the enzyme nitrate reductase in mature lateral shoots of all the varieties studied were high before flushing. A decline in the level of these constituents was observed immediately after flushing and flowering. The extent of accumulation (before flushing) and depletion (for flushing and flowering) of these constituents were high in high yielding varieties.

In reproductive flushes, maximum content of carbohydrates, nitrogen and chlorophyll was observed after the formation of panicles on them. A drastic decline in the level of these constituents were recorded after nut set stage. In high yielders both accumulation and depletion of these constituents were comparatively more than low yielders.

In vegetative flushes, carbohydrates, nitrogen, chlorophyll and NRA had shown a progressive increase throughout the stages analysed.

Studies on variation in anatomical characters of mature lateral shoots had shown that bark thickness and number of xylem vessels per unit area were comparatively high in high yielders. (2.89 to 3.06 mm and 12.20 to 13.90 mm^{-2} respectively) compared to low yielders.

A clear flowering primordium observed in the reproductive flushes before panicle development can be considered as the distinct feature, which distinguish it from vegetative flush. In vegetative flush, only a rudimentary primordium was seen which aborted later.

Spray application of the chemical combination cultar 1000 mg l^{-1} combined with KNO_3 one per cent and carbaryl 0.10 per cent induced early, synchronised and profuse flowering in the late variety Madakkathra-2 and hence selected for regulating of flowering behaviour of late varieties.

The varieties (early, mid and late) evaluated varied considerably in their response to spray application of the selected chemical combination with respect to different biometric characters studied.

The favourable response for spray application of the selected chemical combination was manifested in the morphological and biochemical characters of the varieties, leading to realisation of higher yield from them.

The early, mid season and late season varieties exhibited positive response to soil application of cultar (3 ml per plant), but the intensity was low compared to spray application of the selected chemical combination.

Raising root stocks from irradiated seeds and grafting on them was found ineffective in inducing dwarfism in cashew grafts, whereas, application of cultar through soil to young grafts at the rate of 0.50 g *a.i* per plant twice, was found effective for the purpose.

The grafts treated with cultar exhibited dwarf stature both in the nursery as well as in the field. The biochemical and anatomical characters of the grafts were altered favourably due to the treatment.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Appendices

APPENDIX - I

Meteorological data for the period of investigation

1995	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH-2		
Jan	32.9	22.4	0	0	76	41	9.6	9.1
Feb	35.4	23.4	0.5	0	79	41	10.0	6.4
Mar	37.6	23.5	2.8	0	83	37	9.3	4.4
Apr	36.6	24.9	118.7	5	87	55	9.1	4.0
May	33.5	23.9	370.5	13	91	65	6.5	3.8
June	29.9	23.1	500.4	19	94	77	3.7	10.1
Jul	30.6	23.2	884.7	26	96	81	2.1	1.7
Aug	38.1	23.7	448.7	22	94	78	3.7	2.0
Sep	33.2	23.5	282.5	30	94	70	6.1	2.0
Oct	31.3	23.2	110.4	8	91	65	8.3	1.8
Nov	32.5	22.5	88.4	5	91	69	6.5	1.1
Dec		21.3	0	0	71	43	10.3	6.7

1996	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)		Sunshine (hours)	Wind speed (km h^{1})
	Maximum	Minimum			RH-1	RH-2		
Jan	33.1	22.4	0	0	71	35	9.4	7.1
Feb	34.7	23.4	0	0	72	34	9.9	5.9
Mar	36.4	24.3	0	0	82	37	9.3	3.6
Apr	34.6	25	152	7	87	59	8.3	3.0
May	32.8	25.2	152	7	87	59	8.3	3.0
June	30.5	23.8	400.3	16	94	75	4.7	3.0
Jul	28.8	23.1	588.7	25	96	83	2.7	2.7
Aug	29.6	23.6	310	20	95	78	3.7	3.0
Sep	29.2	23.7	391.6	17	94	74	9.3	2.7
Oct	30.1	22.9	219.3	12	93	70	6.0	2.0
Nov	31.5	23.6	23.1	2	84	59	7.1	3.7
Dec	30.5	21.8	60.8	2	80	55	6.8	6.4

1997	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH-2		
Jan	32	22.9	0	0	78	45	9.6	6.9
Feb	33.9	21.8	0	0	82	39	9.3	3.9
Mar	35.7	24.0	0	0	82	37	9.6	4.0
Apr	352	24.5	8.2	1	83	50	9.4	3.3

Contd.

Appendix-1. Continued .

1	2	3	4	5	6	7	8	9
May	34.4	24.5	63	4	87	57	6.7	3.3
June	31.2	23	720.5	18	93	71	5.9	2.7
Jul	28.6	21.8	979.2	28	95	84	1.9	4.6
Aug	29.0	228	636.8	23	99	78	3.4	2.8
Sep	30.6	23.4	164	73	93	71	6.8	2.5
Oct	32.2	23.6	194.7	12	88	65	73	2.6
Nov	31.6	23.2	211.3	7	8	67	5.3	2.9
Dec	31.7	23.8	66.7	2	83	61	7.5	5.9

1998	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity(%)		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH-2		
Jan	33.1	22.8	0	0	78	49	9.3	6.6
Feb	34.4	23.6	0	0	77	51	9.6	5.2
Mar	36.2	23.6	11	1	86	47	10	3.4
Apr	36.5	25.6	61.4	4	86	50	9	3.1
May	34.1	25.2	203	9	90	63	7.6	2.6
June	30.2	23.3	809.3	24	94	79	3.4	2.7
Jul	29.2	23.6	752.9	28	96	80	3.3	2.8
Aug	29.8	23.9	433.6	18	95	77	3.6	2.5
Sep	30.2	23.3	571.3	24	96	78	4.1	2.0
Oct	32.2	23.6	194.7	12	88	65	7.3	2.1
Nov	31.5	23.1	109.4	9	92	64	7.2	1.7
Dec	30.1	22.9	33	4	79	58	6.6	5.7

1999	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH -2		
Jan	32.4	21.5	0.0	0	76	40	9.3	6.5
Feb	34.5	23.3	22.8	1	77	35	9.1	5.1
Mar	35.5	24.5	0.0	0	88	48	8.8	3.0
Apr	33.4	25.6	39.0	4	88	58	10.3	3.3
May	30.7	24.7	430.5	18	92	72	4.9	3.0
June	29.4	23.0	500.2	23	94	75	5.0	2.5
Jul	28.4	23.0	823.3	28	96	82	2.4	2.5
Aug	29.8	22.9	260.1	12	94	73	5.5	2.3
Sep	31.6	23.4	28.4	3	89	63	7.1	2.1
Oct	30.5	23.2	506.2	15	94	75	4.8	1.6
Nov	31.4	22.7	9.1	1	81	57	8.2	3.6
Dec	30.7	22.7	0.0	0	72	48	8.8	6.6

APPENDIX - I

Meteorological data for the period of investigation

1995	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH-2		
Jan	32.9	22.4	0	0	76	41	9.6	9.1
Feb	35.4	23.4	0.5	0	79	41	10.0	6.4
Mar	37.6	23.5	2.8	0	83	37	9.3	4.4
Apr	36.6	24.9	118.7	5	87	55	9.1	4.0
May	33.5	23.9	370.5	13	91	65	6.5	3.8
June	29.9	23.1	500.4	19	94	77	3.7	10.1
Jul	30.6	23.2	884.7	26	96	81	2.1	1.7
Aug	38.1	23.7	448.7	22	94	78	3.7	2.0
Sep	33.2	23.5	282.5	30	94	70	6.1	2.0
Oct	31.3	23.2	110.4	8	91	65	8.3	1.8
Nov	32.5	22.5	88.4	5	91	69	6.5	1.1
Dec		21.3	0	0	71	43	10.3	6.7

1996	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)		Sunshine (hours)	Wind speed (km h^{1})
	Maximum	Minimum			RH-1	RH-2		
Jan	33.1	22.4	0	0	71	35	9.4	7.1
Feb	34.7	23.4	0	0	72	34	9.9	5.9
Mar	36.4	24.3	0	0	82	37	9.3	3.6
Apr	34.6	25	152	7	87	59	8.3	3.0
May	32.8	25.2	152	7	87	59	8.3	3.0
June	30.5	23.8	400.3	16	94	75	4.7	3.0
Jul	28.8	23.1	588.7	25	96	83	2.7	2.7
Aug	29.6	23.6	310	20	95	78	3.7	3.0
Sep	29.2	23.7	391.6	17	94	74	9.3	2.7
Oct	30.1	22.9	219.3	12	93	70	6.0	2.0
Nov	31.5	23.6	23.1	2	84	59	7.1	3.7
Dec	30.5	21.8	60.8	2	80	55	6.8	6.4

1997	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH-2		
Jan	32	22.9	0	0	78	45	9.6	6.9
Feb	33.9	21.8	0	0	82	39	9.3	3.9
Mar	35.7	24.0	0	0	82	37	9.6	4.0
Apr	352	24.5	8.2	1	83	50	9.4	3.3

Contd.

Appendix-1. Continued .

1	2	3	4	5	6	7	8	9
May	34.4	24.5	63	4	87	57	6.7	3.3
June	31.2	23	720.5	18	93	71	5.9	2.7
Jul	28.6	21.8	979.2	28	95	84	1.9	4.6
Aug	29.0	228	636.8	23	99	78	3.4	2.8
Sep	30.6	23.4	164	73	93	71	6.8	2.5
Oct	32.2	23.6	194.7	12	88	65	73	2.6
Nov	31.6	23.2	211.3	7	8	67	5.3	2.9
Dec	31.7	23.8	66.7	2	83	61	7.5	5.9

1998	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity(%)		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH-2		
Jan	33.1	22.8	0	0	78	49	9.3	6.6
Feb	34.4	23.6	0	0	77	51	9.6	5.2
Mar	36.2	23.6	11	1	86	47	10	3.4
Apr	36.5	25.6	61.4	4	86	50	9	3.1
May	34.1	25.2	203	9	90	63	7.6	2.6
June	30.2	23.3	809.3	24	94	79	3.4	2.7
Jul	29.2	23.6	752.9	28	96	80	3.3	2.8
Aug	29.8	23.9	433.6	18	95	77	3.6	2.5
Sep	30.2	23.3	571.3	24	96	78	4.1	2.0
Oct	32.2	23.6	194.7	12	88	65	7.3	2.1
Nov	31.5	23.1	109.4	9	92	64	7.2	1.7
Dec	30.1	22.9	33	4	79	58	6.6	5.7

1999	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity		Sunshine (hours)	Wind speed (km h^{-1})
	Maximum	Minimum			RH-1	RH -2		
Jan	32.4	21.5	0.0	0	76	40	9.3	6.5
Feb	34.5	23.3	22.8	1	77	35	9.1	5.1
Mar	35.5	24.5	0.0	0	88	48	8.8	3.0
Apr	33.4	25.6	39.0	4	88	58	10.3	3.3
May	30.7	24.7	430.5	18	92	72	4.9	3.0
June	29.4	23.0	500.2	23	94	75	5.0	2.5
Jul	28.4	23.0	823.3	28	96	82	2.4	2.5
Aug	29.8	22.9	260.1	12	94	73	5.5	2.3
Sep	31.6	23.4	28.4	3	89	63	7.1	2.1
Oct	30.5	23.2	506.2	15	94	75	4.8	1.6
Nov	31.4	22.7	9.1	1	81	57	8.2	3.6
Dec	30.7	22.7	0.0	0	72	48	8.8	6.6

APPENDIX – II. Details of clonal germplasm conserved at Cashew Research Station, Madakkathara

Source of collection: Cashew farm, Kottarakkara

Date of planting - 1988

Accession No.	Name of variety	Details of parent tree								
		Year of planting	Planting material/ seedling/ layer/graft	Highest yield in kg. recorded and year of orchard life		Shelling percentage	Nut weight (g)	Kernel weight (g)	Export grade of kernels	Special features if any
1	2	3	4	5	6	7	8	9	10	11
15	Brazil-2	1960	Seedling	Highest yield not available	Between 20-25 yrs	44.0	9	Not recorded		Orange fruits big bunches
16	Brazil-3	1960	Seedling		Between 20-25 yrs	43.7	8			
17	Brazil-120	1973	Seedling		Between 10-12 yrs	42.0	8			
18	Brazil-239	1973	Seedling		Between 10-12 yrs	36.0	14			Biggest nut among the varieties of the farm
19	Brazil-241	1973	Seedling		Between 10-12 yrs	41.0	8			
20	Brazil-244	1973	Seedling		Between 10-12 yrs	38.0	8			
21	Brazil-248 (medium)	1973	Seedling		Between 10-12 yrs	38.0	Not available			
22	Brazil-248 (small)	1963	Seedling		Between 20-25 yrs	44.0	8			
23	KTR-27	1973	Layer		Between 20-25 yrs	43.7	8			Local selection
24	Paruthiyara-1	1963	Seedling		Between 20-25 yrs	43.0	7			Bold nut, High yielding local variety
25	Vapala	1973	Layer		Between 20-25 yrs	43.0	7			Local selection

Contd.

Appendix-II. Continued

Source of collection : Cashew Research Station, Madakkathra — Date of planting 1988

1	2	3	4	5	6	7	8	9	10
26	Anakkayam-1	1978	Layer	11.60 (9th year)	28.00	6.00	1.84	W.240	Early short flowering and harvest phase
27	Madakkathra-1	1978	Layer	5.80 (7th year)	26.80	6.20	1.64	W.280	Early flowering
28	K-22-1	1978	Layer	4.60 (9th year)	22.71	6.20	1.60	W.280	-
29	Madakkathra-2	1978	Layer	19.50 (9th year)	26.20	7.30	2.00	W.240	Medium nuts
30	H-3-13	1978	Layer	11.70 (7th year)	27.80	6.40	1.72	W.280	Cross of tree 30xBrazil-18
31	Dharasree	1978	Layer	17.85 (9th year)	26.20	6.70	1.41	W.320	,,
32	H-680	1973	Seedling	22.30 (12th year)	27.78	6.80	1.42	W.320	Cross of ALGD-1-1xH-3-13
33	H-682	1973	Seedling	19.60 (11th year)	28.57	6.20	1.43	W.320	,,
34	H-718	1973	Seedling	15.56 (7th year)	29.41	6.80	1.70	W.280	,,
35	H-719	1973	Seedling	19.65 (14th year)	31.67	5.80	1.67	W.280	,,
36	H-856	1973	Seedling	16.70 (10th year)	30.73	9.06	2.63	W.180	Cross H-3-13xK-30-1
37	H-1588	1973	Seedling	7.60 (11th year)					Cross K-30-1 xBRZ-9
38	H-1589	1973	Seedling	6.50 (12th year)	27.85	10.80	2.56	W.180	,,
39	Priyanka	1973	Seedling	29.00 (13th year)	28.50	10.85	2.61	W 180	Cross of Anakkayam-1 x K-30-1
40	H-1593	1973	Seedling	19.50 (13th year)	30.95	7.80	2.15	W 240	,,
41	H-1596	1973	Seedling	21.10 (12th year)	27.63	7.40	2.70	W 180	,,
42	Amrutha	1973	Seedling	23.50 (12th year)	31.58	7.10	2.30	W 210	Cross of H-3-13 x Anakkayam-1
43	Kanaka	1973	Seedling	20.85 (13th year)	40.28	6.80	1.76	W 280	Cross of Anakkayam-1 x H-3-13

Contd.

Appendix-II. Continued

44	H-1600	1973	Seedling	21.80 (10th year)	27.27	8.20	1.99	W 240	,,
45	H-1602	1973	Seedling	24.80 (13th year)	23.08	10.20	2.76	W 180	,,
46	Dhana	1973	Seedling	24.50 (12th year)	27.08	9.60	2.22	W 210	Cross of ALGD-1-1 x K-30-1
47	H-1610	1973	Seedling	24.10 (10th year)	26.09	9.20	2.25	W 210	,,
48	M-1-2	1976	Seedling	17.00 (7th year)	27.50	6.35	1.75	W 210	,,
49	A-26-2	1976	Seedling	17.50 (7th year)	26.00	7.25	1.83	W 280	-
50	PTR-1-1	1978	Layer	0.30 (4th year)	41.65	4.00	1.65	W 280	Thin shelled and oil less type
51	A-6-1	1976	Seedling	16.90 (7th year)	25.83	7.75	1.83	W 280	-

Source of collection: NRCC, Puthur Year of planting 1988

52	Pu-1	Details not available
53	Pu-2	
54	Pu-4	
55	Pu-6	
56	Pu-7	
57	Pu-8	
58	Rajamundry	

Source of collection: Cashew Research Station, Anakkayam Year of planting 1988

1	2	3	4	5	6	7	8	9	10
59	UL-12-2	1964	Seedling	0.600 (7th year)			Not available	Not available	A dwarf type
60	Brazil-18	1964	Layer						Commonly used as parent in early crossings
61	K-3-1	1963	Layer	18.900 (19th year)		9.20			
62	K-3-2	1963	Layer	14.300 (18th year)		8.25			
63	K-4-1	1963	Layer	28.400 (23rd year)	30.00	9.85			
64	K-4-2	1963	Layer	19.500 (23rd year)	20.00	9.55			

Contd.

Appendix-II. Continued

65	K-10-1	1964	Layer	19.700 (18th year)	26.14	8.62			
66	K-10-2	1964	Layer	30.500 (22nd year)	26.98	8.50			
67	K-16-1	1963	Layer	20.600 (20th year)	26.08	8.90			
68	K-18-2	1966	Layer	14.700 (12th year)	28.70	7.38			
69	K-19-1	1964	Layer	35.000 (19th year)	26.18	7.80			
70	K-19-2	1964	Layer	21.100 (22nd year)	24.90	7.85			
71	K-30-1	1965	Layer	19.000 (22nd year)	28.90	14.00			
72	H-3-4	1963	Seedling	24.700 (20th year)	27.38	8.10			Cross of tree 30 x Brazil-18
73	H-3-9	1963	Seedling	16.100 (16th year)		8.60			,,
74	H-7-6	1970	Seedling	16.400 (13th year)		12.25			Cross of H-4-7 x K-30-1
75	H-8-1	1969	Seedling	14.500 (10th year)		10.50			Cross of tree20 x K-30-1
76	H-8-6	1970	Seedling	10.300 (13th year)		10.50			,,
77	H-8-7	1970	Seedling	11.200 (13th year)		10.65			,,
78	H-8-8	1970	Seedling	16.400 (16th year)	30.00	10.00			,,
79	H-8-10	1970	Seedling	19.100 (13th year)	26.98	10.75			,,
80	H-8-15	1971	Seedling	10.300 (12th year)		11.50			,,
81	H-9-3	1969	Seedling	18.000 (14th year)		8.70			Cross of tree 20 x Brazil-18

Note : Yield data of 1969 and 1985 not recorded and hence not included in the cumulative yield for all the above types / hybrids. For H-7-6 yield data was recorded from 1976 onwards.

APPENDIX - III

Yield data of 67 cashew varieties (conserved in the germplasm block of CRS, Madakkathra) for 1996 – '97 and 1997 – '98 seasons.

Sl. No.	Accession No.	Name of variety	Yield (kg)	
			1996-97	1997-98
1	15	Brazil-2	1.28	1.98
2	,,	,,	1.10	1.25
3	,,	,,	1.20	1.30
4	,,	,,	0.80	0.30
5	16	Brazil-3	1.10	0.97
6	,,	,,	2.18	1.28
7	,,	,,	1.38	1.45
8	,,	,,	2.12	1.25
9	17	Brazil -120	3.20	4.80
10	,,	,,	3.38	3.12
11	,,	,,	4.20	4.30
12	,,	,,	3.18	4.00
13	18	Brazil-239	0.80	1.40
14	,,	,,	0.70	1.20
15	,,	,,	1.12	0.98
16	,,	,,	1.10	1.30
17	19	Brazil-241	2.20	1.10
18	,,	,,	0.92	1.10
19	,,	,,	1.30	1.28
20	,,	,,	0.70	0.80
21	20	Brazil-244	1.48	1.80
22	,,	,,	0.82	1.70
23	,,	,,	2.20	2.80
24	,,	,,	2.90	1.78
25	21	Brazil-248	3.00	3.20
26	,,	,,	2.80	3.10
27	,,	,,	3.12	2.90
28	,,	,,	2.98	2.80
29	22	Brazil-248 (S)	4.80	6.75
30	,,	,,	3.29	4.80
31	,,	,,	4.12	5.96
32	,,	,,	4.80	6.80
33	23	KTR - 27	2.50	3.80
34	,,	,,	2.28	2.90

Contd.

Appendix-III. Continued

1	2	3	4	5
35	,,	,,	3.12	2.60
36	,,	,,	3.80	4.50
37	24	Paruthiyara	3.20	2.20
38	,,	,,	0.98	1.70
39	,,	,,	2.42	2.40
40	,,	,,	0.80	0.50
41	25	Vapala	3.70	4.20
42	,,	,,	2.80	3.80
43	,,	,,	3.12	3.70
44	,,	,,	2.28	2.80
45	26	Anakkayam-1	4.28	5.80
46	,,	,,	5.12	6.70
47	,,	,,	4.40	4.70
48	,,	,,	3.80	5.00
49	27	Madakkathra-1	4.30	4.20
50	,,	,,	3.80	4.50
51	,,	,,	3.75	5.20
52	,,	,,	3.82	4.750
53	28	K 22-1	2.82	4.20
54	,,	,,	3.43	4.10
55	,,	,,	2.80	2.80
56	,,	,,	3.21	3.70
57	29	Madakkathra-2	4.82	6.20
58	,,	,,	3.89	5.60
59	,,	,,	5.28	5.90
60		,,	6.12	5.00
61	30	H - 3 - 13	2.98	3.80
62	,,	,,	3.82	2.90
63	,,	,,	3.12	3.20
64	,,	,,	2.78	2.40
65	31	Dharasree	3.92	5.40
66	,,	,,	3.80	5.20
67	,,	,,	4.20	3.80
68	,,	,,	3.80	6.20
69	32	H - 680	1.20	2.80
70	,,	,,	1.82	2.60
71	,,	,,	1.12	1.90
72	,,	,,	2.10	1.40

Contd

Appendix-III.Continued

1	2	3	4	5
73	33	H - 682	1.70	2.60
74	,,	,,	0.80	2.30
75	,,	,,	1.82	1.80
76	,,	,,	0.980	0.70
77	34	H - 718	1.20	0.70
78	,,	,,	1.38	0.60
79	,,	,,	1.21	1.20
80	,,	,,	1.48	0.40
81	35	H - 719	1.98	1.34
82	,,	,,	2.12	1.60
83	,,	,,	0.98	0.80
84	,,	,,	0.78	1.25
85	36	H - 856	2.90	2.60
86	,,	,,	2.72	3.40
87	,,	,,	3.18	3.80
88	,,	,,	3.68	4.00
89	37	H - 1588	2.98	3.93
90	,,	,,	3.14	4.10
91	,,	,,	4.00	4.00
92	,,	,,	3.20	3.80
93	38	H - 1589	3.18	4.10
94	,,	,,	3.20	3.20
95	,,	,,	2.40	2.80
96	,,	,,	3.26	4.00
97	39	Priyanka	3.98	5.90
98	,,	,,	4.12	6.10
99	,,	,,	3.54	6.20
100	,,	,,	4.28	5.30
101	40	H - 1593	2.98	5.50
102	,,	,,	3.18	5.40
103	,,	,,	2.76	4.80
104	,,	,,	1.98	4.70
105	41	H - 1596	4.12	6.20
106	,,	,,	3.84	4.80
107	,,	,,	3.28	5.30
108	,,	,,	2.90	4.80
109	42	Amrutha	2.82	3.20
110	,,	,,	2.68	3.80
111	,,	,,	4.12	4.40

Contd.

Appendix-III. Continued

1	2	3	4	5
112	,,	,,	3.20	3.40
113	43	Kanaka	3.80	5.00
114	,,	,,	2.82	3.80
115	,,	,,	1.89	4.60
116	,,	,,	3.40	4.00
117	44	H - 1600	3.28	4.25
118	,,	,,	2.86	3.60
119	,,	,,	3.47	3.93
120	,,	,,	3.12	2.96
121	45	H - 1602	2.00	3.60
122	,,	,,	3.40	3.40
123	,,	,,	2.84	3.70
124	,,	,,	2.90	2.80
125	46	Dhana	2.80	3.70
126	,,	,,	2.78	2.80
127	,,	,,	3.10	1.50
128	,,	,,	3.00	2.40
129	47	H - 1610	2.58	3.18
130	,,	,,	2.69	3.60
131	,,	,,	3.18	4.20
132	,,	,,	2.40	3.40
133	48	M - 1 - 2	1.80	2.20
134	,,	,,	1.70	2.10
135	,,	,,	0.98	2.00
136	,,	,,	0.82	2.30
137	49	A – 26 - 2	1.80	1.80
138	,,	,,	0.89	1.08
139	,,	,,	0.20	1.24
140	,,	,,	1.20	0.95
141	50	PTR - 1-1	1.28	1.90
142	,,	,,	2.30	0.90
143	,,	,,	1.92	0.60
144	,,	,,	1.70	1.00
145	51	A - 6 -1	0.63	0.87
146	,,	,,	2.00	2.10
147	,,	,,	2.21	1.15
148	,,	,,	0.59	0.48
149	52	Pu - 1	0.94	2.00
150	,,	,,	0.80	0.43
151	,,	,,	1.28	1.38

Contd.

Appendix –III. Continued

1	2	3	4	5
152	,,	,,	1.76	1.20
153	53	Pu - 2	1.28	0.80
154	,,	,,	1.56	0.70
155	,,	,,	2.70	0.40
156	,,	,,	0.68	0.90
157	54	Pu - 4	1.30	0.60
158	,,	,,	0.58	0.30
159	,,	,,	0.38	0.20
160	,,	,,	1.98	0.50
161	55	Pu - 6	1.68	1.60
162	,,	,,	1.39	1.40
163	,,	,,	0.82	1.00
164	,,	,,	0.34	0.90
165	56	Pu - 7	0.76	0.30
166	,,	,,	0.62	0.20
167	,,	,,	0.50	1.50
168	,,	,,	0.50	0.30
169	57	Pu - 8	0.70	0.80
170	,,	,,	0.68	1.50
171	,,	,,	0.49	0.90
172	,,	,,	1.38	0.50
173	58	Rajmundry	0.72	0.25
174	,,	,,	0.38	1.00
175	,,	,,	0.69	0.40
176	,,	,,	1.20	0.30
177	59	UL - 12 - 2	0.28	0.80
178	,,	,,	0.39	-
179	,,	,,	0.72	-
180	,,	,,	0.28	-
181	60	Brazil - 18	-	-
182	,,	,,	1.20	1.80
183	,,	,,	1.80	-
184	,,	,,	0.98	0.60
185	61	K - 3 - 1	0.98	1.80
186	,,	,,	0.72	0.60
187	,,	,,	0.69	1.50
188	,,	,,	0.42	2.00
189	62	K - 3 - 2	2.10	2.10
190	,,	,,	2.90	2.20

Contd.

Appendix-III. Continued

1	2	3	4	5
191	,,	,,	0.70	1.80
192	,,	,,	0.69	0.95
193	63	K - 4 -1	1.20	0.50
194	,,	,,	1.92	0.40
195	,,	,,	1.12	1.10
196	,,	,,	0.76	0.80
197	64	K - 4 - 2	1.48	0.86
198	,,	,,	0.79	0.70
199	,,	,,	0.98	0.90
200	,,	,,	0.46	1.20
201	65	K – 10 - 1	0.92	0.95
202	,,	,,	0.78	0.90
203	,,	,,	1.20	1.30
204	,,	,,	1.38	1.50
205	66	K – 10 - 2	3.70	3.80
206	,,	,,	4.28	4.10
207	,,	,,	2.95	30.0
208	,,	,,	2.82	3.40
209	67	K – 16 - 1	0.78	0.58
210	,,	,,	0.62	0.80
211	,,	,,	0.59	1.20
212	,,	,,	0.42	1.30
213	68	K – 18 - 2	1.28	1.70
214	,,	,,	1.30	1.60
215	,,	,,	0.48	1.50
216	,,	,,	0.53	1.20
217	69	K – 19 - 1	2.58	2.90
218	,,	,,	2.63	3.20
219	,,	,,	2.82	3.50
220	,,	,,	3.18	3.40
221	70	K – 19 - 2	1.28	1.80
222	,,	,,	1.30	1.00
223	,,	,,	0.90	-
224	,,	,,	0.68	1.20
225	71	K – 30 - 1	1.29	1.65
226	,,	,,	1.64	1.25
227	,,	,,	0.82	0.98
228	,,	,,	2.18	1.40
229	72	H - 3 - 4	2.10	1.80

Contd.

Appendix-III.Continued

1	2	3	4	5
230	,,	,,	1.38	0.50
231	,,	,,	1.42	1.50
232	,,	,,	0.82	0.80
233	73	H –3 - 9	2.68	3.50
234	,,	,,	3.20	3.10
235	,,	,,	2.32	2.30
236	,,	,,	2.42	2.40
237	74	Akshaya	1.40	3.60
238	,,	,,	3.18	2.80
239	,,	,,	2.80	3.1[illegible]
240	,,	,,	[illegible]	1.90
241	75	Anagha	[illegible]2	6.2[illegible]
242	,,	,,	.69	5.40
243	,,	,,	4.00	6.10
244	,,	,,	3.54	5.20
245	76	H - 8 - 6	3.72	4.1[illegible]
246	,,	,,	2.82	4.00
247	,,	,,	2.90	3.10
248	,,	,,	3.10	1.90
249	77	H - 8 - 7	1.28	2.20
250	,,	,,	1.30	1.80
251	,,	,,	1.30	1.10
252	,,	,,	0.80	2.00
253	78	H - 8 - 8	1.30	2.10
254	,,	,,	0.76	1.50
255	,,	,,	0.68	2.10
256	,,	,,	1.30	1.80
257	79	H – 8 - 10	0.84	1.10
258	,,	,,	0.48	0.80
259	,,	,,	0.20	0.90
260	,,	,,	1.38	1.10
261	80	H - 8 - 15	1.00	1.00
262	,,	,,	0.82	1.20
263	,,	,,	0.62	0.58
264	,,	,,	0.38	0.70
265	81	H - 9 – 3	2.12	1.80
266	,,	,,	1.38	1.60
267	,,	,,	0.62	1.40
268	,,	,,	0.58	1.20

Year of planting : Acc .No. 15 to 50 in 1988, 51 to 81 in 1989.

Appendix - IV General analysis of variance on morphological characters of 27 cashew varieties

Vegetative characters								
		Mean squares						
Source of variation	df	Height (m)	Trunk girth (cm)	Spread (m)	Number of flushes (m^{-2})	Flush length (cm)	Shoot girth (cm)	Number of leaves ($flush^{-1}$)
Genotypes	26	8.77**	175.81**	1.78**	17.37**	21.59**	9.28**	6.65**
Error	78	0.89	32.6	0.12	1.41	1.61	1.82	0.69
Flowering characters								
		Mean squares						
Source of variation	df	Number of panicles (m^{-2})	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	Number of nuts ($panicle^{-1}$)		
Genotypes	26	30.98**	866.25**	48.04**	33.26**	47.38**		
Error	78	1.29	12.35	1.71	3.05	1.08		
Nut and yield characters								
		Mean squares						
Source of variation	df	100 nut weight (g)	Nut length (cm)	Nut breadth (cm)	Shelling percentage	Kernel weight (g)	Yield (kg)	
Genotypes	26	266647.69**	0.90**	0.39**	83.86**	1.15**	1.33**	
Error	78	3602.15	0.05	0.05	0.61**	0.03**	0.33**	

* Significant at 5 % level, ** Significant at 1 % level

Appendix - V General analysis of variance on different characters of the variety Madakkathra 2 (second screening trial)

Vegetative characters							
		Mean square					
Source of variation	df	Days to flusing	Number of flushes (m-2)	Length of flush (cm)	Number of leaves (flush-1)	flushing span (days)	
Treatments	4	922.20**	93.59**	4.29**	2.43**	60.13**	
Error	15	1.80	7.60	0.68	0.23	3.50	
Flowering characters							
		Mean squares					
Source of variation	df	Days to flowering	Number of panicles (m-2)	No of hermaphrodite flowers(panicle-1)	Duration of flowering (days)	Number of nuts (panicle-1)	
Treatments	4	1513.18**	110.34**	80.05	414.88*	25.00**	
Error	15	2.03	19.56	44.18	103.57	2.08	
Nut and yield characters							
		Mean squares					
Source of variation	df	Nut length (cm)	Nut breadth (cm)	100 nut weight (g)	Kernel weight (g)	Yield (kg)	Fruit weight (g)
Treatments	4	0.03*	0.02	1025.43*	0.01	7.31**	2.62
Error	15	0.006	0.01	247.03	0.01	0.45	1.16

* Significant at 5 % level, ** Significant at 1 % level

Appendix - VI General analysis of variance on varietal response to spray application of selected chemical combination

Vegetative characters							
		Mean squares					
Source of variation	df	Days to flushing	Number of flushes (m-2)	Length of flush (cm)	Number of leaves (flush-1)	flushing span (days)	
Treatments	6	232.48**	49.29**	3.47**	1.62*	162.45**	
Error	21	1.24	7.05	0.28	0.44	5.06	
Flowering characters							
		Mean squares					
Source of variation	df	Days to flowering	Number of panicles (m-2)	No. of hermaphrodite flowers(panicle-1)	Duration of flowering (days)	Number of nuts (panicle-1)	
Treatments	6	244.37**	71.09**	62.87*	65.58**	14.89**	
Error	21	3.75	5.12	17.42	9.21	3.59	
Nut and yield characters							
		Mean squares					
Source of variation	df	Nut length (cm)	Nut breadth (cm)	100 nut weight (g)	Kernel weight (g)	Yield (kg)	Fruit weight (g)
Treatments	6	0.02*	0.16**	283.31**	0.06**	5.13**	6.55*
Error	21	0.07*	0.02	607.85	0.01	0.65	1.81

* Significant at 5 % level, ** Significant at 1 % level

Appendix -VII General analysis of variance on varietal response to soil application of cultar

Vegetative characters							
		Mean squares					
Source of variation	df	Days to flushing	Number of flushes (m^{-2})	Length of flush (cm)	Number of leaves ($flush^{-1}$)	Flushing span (days)	
Treatments	5	0.16**	0.01*	0.00*	0.00**	0.02**	
Error	18	0.00	0.00	0.00	0.00	0.00	
Flowering characters							
		Mean squares					
Source of variation	df	Days to flowering	Number of panicles (m^{-2})	No. of hermaphrodite flowers($pnicle^{-1}$)	Number of nuts ($panicle^{-1}$)	Duration of flowering(days)	
Treatments	5	333.40**	0.00**	0	0	184.04**	
Error	18	2.42	0.00	0.00	0.00	5.15	
Nut and yield characters							
		Mean squares					
Source of variation	df	Nut length (cm)	Nut breadth (cm)	100 Nut weight (g)	Kernel weight (g)	Yield (kg)	Fruit weight(g)
Treatments	5	0.00	0.00	0.04	0.00	0.00*	0.00
Error	18	0.00	0.00	0.02	0.00	0.00	0.00

* Significant at 5 % level, ** Significant at 1 % level

Appendix - VIII General analysis of variance on growth parameters of root stocks influenced by irradiation of seeds

		Mean squares											
Source of variation	df	Height (cm)				Girth (cm)				Number of leaves (plant-1)			
		15	30	45	60	15	30	45	60	15	30	45	60
Treatments	9	102.58**	212.51**	204.00**	242.34**	0.88**	0.83**	0.68**	0.53**	37.51**	40.78**	58.91**	77.89**
Error	90	3.72**	3.10**	5.21**	7.27**	0.01**	0.02**	0.03**	0.04**	0.43**	0.56**	0.74**	0.78**

* Significant at 5 % level, ** Significant at 1 % level

Appendix - IX. General analysis of variance on growth parameters of cashew grafts on root stocks raised from irradiated seeds

i. Height									
		Mean squares							
		Age of grafts(months)							
Source of variation	df	3	6	9	12	15	18	21	24
Treatments	7	59.90**	49.21**	84.61**	137.59**	220.45*	298.71**	494.76**	898.44**
Error	32	1.24	1.93	1.95**	3.98**	5.20**	7.91**	14.75	14.9
ii. Girth									
Source of variation	df								
Treatments	7	0.44	0.44*	0.44**	0.49**	0.74**	1.89**	2.81**	4.62**
Error	32	1.34	0.05**	0.05**	0.05	0.07**	1.11**	0.09**	0.09
iii Number of leaves (plant^{-1})									
Source of variation	df								
Treatments	7	9.93**	16.56**	39.40**	1.07**	137.45**	158.51**	87.01**	351.93**
Error	32	2.5	4.19	7.04	0.56	4.18**	12.44**	1.62	12.5

* Significant at 5 % level, ** Significant at 1 % level

Appendix - X General analysis of variance on growth parameters of cashew grafts treated with cultar

i.Height									
		Mean squares							
		Age of grafts(months)							
Source of variation	df	6	9	12	15	18	21	24	
Treatments	2	13.03	46.88	103.3	120.03*	344.12*	793.81	1161.32**	
Error	27	3.01	5.2	6.16	5.79*	7.35	6.42**	7.29	
ii. Girth									
Source of variation	df								
Treatments	2	0.06	0.49	1.42	3.47*	3.05*	4.37	7.10*	
Error	27	0.02	0.04	0.07*	0.07	0.08	0.09*	0.08	
iii. Number of leaves (plant^{-1})									
Source of variation	df								
Treatments	2	20.13	213.73	127.28	301.90*	109.90	21.70	7.60	
Error	27	5.10	2.80*	15.52	12.17	23.44	21.10	20.82	

* Significant at 5 % level, ** Significant at 1 % level

Appendix – XI Regulation of flowering in cashew by spray application of selected chemical combination (cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10 %) :

An economic analysis

Technology formulated for regulation of flowering in cashew :

Spraying the chemical combination, cultar 1000 mg l^{-1} + KNO_3 1% + carbaryl 0.10 % during late September before the onset of preblossom flushing (due to bud break of mature lateral shoots).

Chemicals required per tree

Cultar - 5 ml
KNO_3 – 50 g
Carbaryl – 10 g

Economic analysis

Additional cost		Additional returns**	
Cultar 5 ml (@ Rs. 4 per ml)*	Rs. 20	Overall yield increase per tree (pooled effect for 1996-'97, 1997-'98 and 1998-'99 seasons) due to the treatment	1.46 kg
KNO_3 50 g (@ Rs. 184 per kg).	Rs.9.20	Average cost of cashew nuts per kg (mean of 1996-'97, 1997-'98 and 1998-'99 seasons)	Rs. 40
Total	Rs. 29.20	Additional returns (1.46 x 40)	Rs. 58.40
Handling charge (10% of the total)	Rs. 2.92		
Total cost	Rs. 32.12		

* Retail price

** Calculated on the basis of pooled analysis (4.3.6.2)

Cost of carbaryl and spraying charges are not included :

To control tea mosquito attack in cashew and to counteract the tendency of pest to build up field resistance, three rational insecticide spray (endosulfan 0.05% or carbaryl 0.10 % or quinalphos 0.05%) is being recommended (KAU, 1996) as follows

- First, synchronising with the emergence of new vegetative flushes in October-November
- Second, synchronising with the commencement of panicle emergence in December-January
- Third, synchronising with the fruit set stage in January- February

Since flushing occurred immediately after application of the chemical combination in which carbaryl was included, the first insecticide spray recommended against tea mosquito attack was not given again. So the cost of carbaryl is not included as additional cost.

Economic highlights of the technology.

Increase in income through higher yield per tree

Price advantage due to early crop (usually early crop fetch more price than late crop)

Compact harvest phase reduce the labour charges through reducing the number of harvests

MORPHOPHYSIOLOGICAL ANALYSIS OF GROWTH AND YIELD IN CASHEW

(Anacardium occidentale L.)

By

P. B. Pushpalatha

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirements for the degree

Doctor of Philosophy in Horticulture

Faculty of Agriculture
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2000

ABSTRACT

The present investigation *"Morphophysiological analysis of growth and yield in cashew (Anacardium occidentale L.)"* was carried out with the objectives to study the variability in morphological characters among cashew genotypes, to elucidate the factors associated with yield, to analyse the variability in biochemical and anatomical characters among varieties at different physiological stages of reproductive growth, to explore the possibilities of chemical regulation of flowering and to control tree size through induction of dwarfism in cashew grafts at nursery stage.

Grouping of 67 genotypes based on flowering behaviour and yield performance was done. Studies on variability in 18 morphological characters among 27 genotypes showed high variability for flush length, number of leaves per flush, percentage of hermaphrodite flowers, number of nuts per panicle, nut weight and yield.

Correlation studies revealed that yield is positively correlated with number of panicles (m^{-2}), hermaphrodite flowers (%), panicle length and number of nuts per panicle and negatively correlated with flush length.

The presence of carbohydrate, nitrogen and chlorophyll in mature lateral shoots before flushing and in reproductive flushes after panicle development is found to determine the yield potential of cashew trees. High activity of the enzyme Nitrate Reductase was found necessary to impart better nitrogen use efficiency to cashew plants.

Studies on anatomical features of mature lateral shoots of different yield groups showed that thick bark and greater number of xylem vessels per unit area are the two characters associated with high yielders.

The distinct feature of reproductive flushes from vegetative flushes was the presence of a clear flowering primordia in them, before panicle emergence.

Foliar application of cultar at the rate of 1000 mg l^{-1} in combination with KNO_3 one per cent and carbaryl 0.10 per cent was effective in regulating flowering behaviour of cashew varieties and manipulating the yield contributing factors favourably. Late season varieties showed maximum response to chemical regulation of flowering.

Soil application of cultar to the grafts at the rate of 2 ml per plant, twice, first at one month and second at three months after sprouting was found effective in inducing dwarfism at nursery stage.

The anatomical features associated with dwarfism viz., bark thickness and number of xylem vessels per unit area in lateral shoots was found increased in response to soil application of cultar to the grafts.