PRODUCTIVITY IN RELATION TO BRANCHING PATTERN AND PRUNING IN CASHEW

(*Anacardium occidentale.* L.)

By

P. V. NALINI

THESIS

Submitted in partial fulfilment of the requirement for the degree

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Faculty of Agriculture
Kerala Agricultural University

Department of Plantation Crops and Spices
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680654

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DECLARATION

I hereby declare that the thesis entitled "**Productivity in relation to branching pattern and pruning in cashew (*Anacardium occidentale* Linn.)**" 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, associateship or other similar title, of any other university or society.

Vellanikkara

P.V. NALINI

CERTIFICATE

Certified that the thesis entitled "**Productivity in relation to branching pattern and pruning in cashew (*Anacardium occidentale* Linn.)**" is a record of research work done independently by **Mrs.P.V. Nalini**, 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.

G. Sreekantan Nair 10.1.1997

Dr.G.SREEKANTAN NAIR
Chairman
Advisory Committee
Professor and Head
Dept. of Plantation Crops & Spices
College of Agriculture, Vellayani

Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mrs.P.V.Nalini**, a candidate for the degree of **Doctor of Philosophy in Horticulture**, agree that the thesis entitled "**Productivity in relation to branching pattern and pruning in cashew (*Anacardium occidentale* Linn.)**" may be submitted by Mrs.P.V.Nalini, in partial fulfilment of the requirement, for the degree.

G. Sreekantan Nair 25.7.97

Dr.G.Sreekantan Nair
Professor and Head
Department of Plantation Crops and Spices
College of Agriculture, Vellayani
(Chairman)

Dr.Luckins C. Babu
Associate Professor
College of Forestry
(Member)

Sri.K.C.Chandy
Associate Professor
Cashew Research Station
Anakkayam
(Member)

Dr.K.Gopikumar
Associate Professor
College of Forestry
Vellanikkara
(Member)

Dr.A.V.R. Kesava Rao
Associate Professor
College of Horticulture
Vellanikkara
(Member)

EXTERNAL EXAMINER

25-8-97

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Introduction

INTRODUCTION

Cashew is one of the major commercial crops, which earns considerable foreign exchange for India. The crop is mostly grown in coastal belts of India especially in marginal lands and lands unsuitable for other crops. Out of the total area under cashew, about 30 per cent lies in Kerala and about 50 per cent of the production of raw cashewnuts comes from Kerala. The average national productivity is 554 kg per hectare as against 940 kg per hectare in Kerala. Though the average productivity is high in Kerala there is still scope for increasing the productivity.

According to the information available, the world exports of cashew kernals had crossed 1,00,000 MT in 1994 of which India's share was 77,000 MT. With the emergence of more than 20 countries producing and processing cashew kernals, the world cashew scenario has changed. India still holds her position as the largest exporter of cashew kernals in the world, by importing large quantities of raw cashew nuts from all available sources and processing and exporting, cashew kernels.

During the year 1993-94 cashew was the second largest foreign exchange earner among the agricultural commodities, exported from India. The income from cashew exports constituted 1.4 per cent of the total export earnings of the country. Cashew industry provides employment to more than 5 lakhs people in farms and factory.

Current total world production of raw cashewnuts is estimated at 7,50,000 MT. India has produced on an average 3,50,000 MT of raw cashewnuts per annum in the recent past (Nayar, 1994).

Eventhough the crop was restricted to marginal lands of Kannur, Kasaragod and Malappuram districts, the high profitability and internal demand has made the crop very attractive for large scale planting. The advent of large scale planting has necessitated the need for evolution of ideal plant type suitable for intensive management and high density planting.

Canopy development in perennial crops like cashew, has a seasonal and life time developmental pattern. The sum of development over individual seasons results in the final canopy dimensions and form. Wide variations are observed in growing habits and tree forms in cashew (Ohler, 1979).

Normally, a seedling of cashew develops a canopy of umbrella shaped crown that extends to a diameter of about 5-7 meters. Wide variations are observed in growing habits and tree forms in cashew. Halle *et al.* (1978) formulated a central concept of tree architecture and they have reduced the total diversity of tree forms to 23 developmental models or architectural models and they have grouped cashew under Scarrone's model.

The large umbrella shaped canopy architecture has many disadvantages in the management of the crop. It is difficult to spray, prune and harvest. It has poor distribution of light throughout the canopy and has low early life light interception. There has been wide spread efforts to reduce tree size and increase tree density, accelerate canopy and yield development and improve canopy form to overcome the limitations of a large tree.

The total yield of a crop is shown to be related to total light interception (Jackson, 1980). It is a function of light interception along with a few other variables such as site quality, genetic make up of the plant etc.

It has been observed in cashew that real productive branches are of the sixth order branches. Often the sixth order branches that develop in the lower strata of the canopy become unproductive due to poor light penetration.

Two approaches are possible to improve the light interception and distribution in cashew. One is breeding relatively natural tree forms that allow light penetration through the canopy by providing very small openings in the foliage. The latter approach is modifying the canopy by artificial means or by manipulating the canopy artificially.

For the exploitation of the former possibility the canopies of different varieties and those of seedlings, grafts and layers are critically evaluated in the present investigation and attempts are made to identify natural tree forms, that allow enough light penetration for the inner branches of the canopy.

For the latter course of action in improving light penetration, experiments are designed to show the different light interception regimes and to relate this to the final yield. The present work also aims to monitor and establish significance, if any, in the chlorophyll content, carbohydrate nitrogen ratio, total soluble sugars etc. in the different treatments.

The major objectives of the present investigation are the following:

1. To study the different phenological phases of cashew

2. To critically evaluate the canopies of seedlings grafts ans layers of different varieties of cashew

3. To ascertain the optimum degree and frequency of manipulation of the canopy, which results in better distribution of light and subsequent yield

4. To assess as to how canopy manipulation and resultant re-distribution of light, affect the chlorophyll content, the total soluble sugars, total nitrogen and the carbohydrate nitrogen ratio of the branches.

Review of Literature

REVIEW OF LITERATURE

Cashew cultivation in India is being encouraged primarily as an export oriented commodity. Agroclimatic conditions of the Konkan region is favourable to cashew plantation. It is also learnt that four southern states of Andra Pradesh, Karnataka, Tamil Nadu and Kerala together have nearly 61,000 Kms of waste lands of various types. At least ten per cent of these area may be suitable for cashew cultivation. Because of high profitability and the drought hardy nature of the crop there is great prospect for increasing the area under the cashew crop in the above mentioned region. The Department of Wastelands Development also has schemes for providing financial assistance to progressive cashew farmers. Many private entrepreneurs and progressive farmers are keen to develop cashew plantation. With the adoption of intensive management practices coupled with high density planting, the need for evolving a crop idiotype in cashew is a long felt need. Ohler (1979) opined that higher yield must be expected from the high growing conically shaped trees and it is possible to plant more of such trees per hectare.

Remarkable work has been done in India and abroad to increase the productivity and to improve the quality and recovery of cashew kernels. Pioneer work has been done by scientists of the various research organisations in India such as Cashew Research Station, Anakkayam; Cashew Research Station, Madakkathara; National Research Centre for Cashew, Puthur and Cashew Research Stations at Ullal and Bapatla.

From the Cashew Research Station, Anakkayam, varieties such as Anakkayam-1, Madakkathara-I, Madakkathara-II, Sulabha and Dharashree were released for commercial planting. These varieties are superior to the existing varieties with regard to yield, nut size, shelling percentage and kernel quality. The yield potential of these varieties is to the tune of about 2250 to 3400 kg per hectare, about four to five times of the national average (KAU, 1993). Efforts were made to evolve hybrids with larger nut size.

From Cashew Research Station, Madakkathara varieties such as Kanaka, Dhana and Priyanka were released which also have yield potential similar to the varieties mentioned earlier.

Cashew Research Station, Ullal have programmes for breeding high yielding varieties suitable for local requirements and for high yield potential. They have evolved varieties such as Ullal-1, Ullal-2 for commercial planting in Karnataka (Rao, 1993).

National Research Centre for Cashew at Puthur have evolved high yielding strains of cashew suitable for cultivation in various parts of India. These varieties include NRC-Selection-I and NRC-Selection-II (NRCC, 1992).

In addition to India countries such as Brazil, Tanzania, Mozambique, Kenya, Vietnam, Thailand, etc. have also large scale cashew cultivation. Research efforts from these countries also have contributed many high yielding types of cashew (Nayar, 1994). It has been observed by various research workers that when the seeds are used as planting material, the progeny may not be true to type and it gave poor yield (Nalini and Santhakumari, 1990).

Besides the efforts for breeding high yielding varieties of cashew, attempts have also been made by researchers in the field, to maximise the productivity by various cultural practices and to manipulate the canopy of the crop so as to make it more efficient in terms of energy conversion.

Pruning, the removal of unwanted plant parts is little known in cashew.

In cashew, Mohan (1991) has reported that pruning in August ie. heading back 2/3 length of the leader shoots to an extent of 50 per cent of the total shoots doubled the yield. Observational trials on pruning of cashew after the monsoon in August-September have shown to increase the yield to about two times (KAU, 1991). Eventhough there was marked improvement in yield as a result of canopy manipulation by pruning, the literature available on pruning, time of pruning, the amount and quantumn of branches to be pruned seems to be scanty.

Khan *et al.* (1984) reported that the pruning of the dead wood alone in older trees helps in increasing the nut yield by 30 to 40 per cent. Results from earlier studies have revealed that the leader shoot pruning helps in stabilizing the yield in older plantations with declined yield.

Works similar to this has been carried out in various horticultural crops by investigators.

Canopy architecture and branch formation

Canopy architecture is the sum of the features of the crown, major branches and stem that characterizes a whole tree. Ecologists and others classify form on the basis of how it affects leaf display and energy exchange for photosynthesis and transpiration (Bruning, 1976). Halle *et al.* (1978) classified tree form on the basis of architectural developmental models. The problem faced in studying the development form is to explain how a mature tree, an organized recognizable structure with thousands or hundred thousand leaves and twigs grew from one single shoot of a germinating seed, graft or layer. There are two aspects of the answer to this problem that should be handled in sequence. (a) To describe what actually happens during the process of form development and (b) To describe how that process is controlled.

The most critical step in understanding of form development in trees was stated by Ward (1909). "What a complex matter in it's sumation, but what a simple one in it's graduated steps, the shaping of a tree is". In modern model oriented terms, form development is an iterative process. Film makers use the regularity of this iterative process to develop computer graphics that "grow" realistics trees of various species (Smith, 1984). If the terms "axis" is defined to include any branch, branchlet, or stem produced by a single apical meristem, then trees grown by each axis elongating and by each axis branching to add new lateral axes. Halle *et al.* (1978) stated that the single most important functional characters in the classification of their developmental models is whether or not the terminal meristem of an axis persists, because in many species it does not. An axis may not branch, particularly if it is growing relatively slowly, and the branches may grow out while the leaves are still present or they may be delayed until later, often until after a winter dormant period in many temperate species. Thus the process of elongation and branching is repeated again and produces new axis to build up the huge population of axis that constitute the tree.

Axes are added in patterns, with relative lengths in positions, consistant for each species. For example, the iterative process is annual in temperate trees (Wilson, 1984). Lateral branches grow out after a season of cold treatment. The number of laterals is a function of axis length and the shortest axis produce no laterals. If the terminal meristem does not persist, as in *Populus,* Betula, etc. the most distal lateral grows in the same direction as the parent axis, effectively replacing it. Among branches produced on an axis in a year, the distal laterals are usually the longest, although generally shorter than the parent or the replacement so that elongation decreases as the generations, or order number, of axis increases. Ultimately as order number increases, elongation is so slow that axis do not branch and a maximum order number is reached.

In addition to the iterative process of elongation and branching in specific patterns, axes, grow in characteristic orientations. The tremendous range of orientations among species and within a tree can be best appreciated in tropical trees (Halle *et al.*, 1978). Laterals usually grow at angles to their parent axis, but they may bend or twist to grow vertically or in two ranked, bilaterally symmetrical, branching structures.

Once the characteristic frame work of axes is established by elongation, branching and axis orientation, then secondary processes affect form (i) Axis thicken differentially with the thicker forming major branches and the thickest the stem (Champagnat, 1978). (ii) Axes die, particularly the smallest and those shaded by other branches, resulting characteristically in a tree with a stem bare of lower branches and the major branches bare of laterals toward the base. (iii) Axis may change orientation either through rotation of a parent axis, sagging from weight or being bent by internal reaction wood (Wilson and Archer, 1979). Thus the process in form development are: Elongation and branching in specific patterns and orientations, differential thickening and mortality, and secondary changes in orientation. These process proceed iteratively, in the many connected axis of the system, we call a tree.

Like many systems, trees are somewhat stable and tend to return to their original conditions after perturbation. Perturbation for trees means injury to leaves or more importantly for the development of form, the destruction of the terminal meristem of axes. Destruction of terminal meristems by insects disease abrasion, weather flower formation, or cultural practices is common in trees. There are two major possible responses following injury to a terminal meristem. Previously inhibited buds may grow out rapidly and often vertically, when they form in older trees. Halle *et al.* (1978) call the growth of these new shoots re-iteration, because it follows the pattern of a young, vigorous trees. Another possible response is that existing laterals near the injury may bend upward, through formation and action of reaction wood and replace the injured axis. If more than one lateral replaces the injured axis then there is fork. This forking following injury or flowering is common in the stems of trees, particularly when they pass from the juvenile to the mature phase. Injuries have a constant modifying effect on development of some axis, but in general the response is to restore the characteristic form of the tree rather than to change it.

There are three major mechanisms that control the development of tree form (i) corrective processes, called apical dominance and control, among axes that determine both the patterns and the orientation of axis development, (ii) shading that reduced light intensity and branch productivity, ultimately leading to death of axes and (iii) allocation mechanisms that maintain feedbacks between leaf and wood production for both transport capacity and mechanical support.

Apical dominance

Apical dominance refers to whether lateral buds grow out and apical control refers to the relative length and orientation of the lateral axes that do grow out. Researchers who study herbaceous plants use only the term apical dominance. Many of those who study trees find that the term apical control is useful, particularly in describing regulation of growth in large branches (Brown *et al.*, 1967).

To test whether a process is under either apical dominance or apical control, remove the terminal (i.e., simulate injury) and see whether the process changes. Major possible results of removing the terminal axis are (i) old, inconspicuous lateral buds grow out to form epicormic shoots, therefore bud growth was inhibited by the terminal, (ii) the most distal lateral or several laterals, bend to replace the injured terminal (this may occur either in elongating laterals or in thick large branches), therefore the terminal regulates the orientation of the laterals or (iii) the most distal laterals elongate more than they would have if the terminal had remained intact, therefore the terminal inhibits lateral elongation.

The physiological bases for apical dominance and control are complex and not well understood (Woodman, 1971, Zimmerman and Brown, 1971, Wilson, 1984). They have investigated primarily in herbaceous plants with respect to lateral bud inhibition. Auxin seems to be intimately involved in dominance and control in trees. If it is put on the cut surface of an injured terminal in a replacement experiment, the buds stay inhibited, lateral elongation does not increase, and the laterals do not bend either through differential elongation or reaction wood formation. What auxin is doing to this range of process in replacement experiments is not known. The process is complex and the other major classes of hormone undoubledly are involved with auxin (i) It is difficult to reconcile basipelal polar transport of auxin, which fits with control of pattern formation with inhibition of elongation of branches because the auxin would apparently have an interesting of apical control is reaction wood formation in branches. If branches on an intact tree are experimentaly restrained out of their normal position, by bending them up, down or sideways, they form reaction wood that is located so as to bend the branch back to its original position (Sinnof, 1964). There is a lengthy debate in the literature as to whether the stimulus to form reaction wood in these experiments is mechanical from bending or a result of changing angle relative to gravitational force (Wilson and Archer, 1979). Whatever the stimulus, branches, do seem to have a "preferred position" that is maintained by appropriate location of reaction wood. When the stem is cut to remove apical control, the branches start forming reaction wood to bend them upwards, out of their preferred position, with neither mechanical nor gravitational stimulus. A possible explanation is that apical control determines the normal position of branches. When apical control is removed, the preferred position changes and the branch forms reaction wood to bend in to the new position.

Shading to leaves on an axis, either from competing trees or from upper branches on the same tree, reduces photosynthesis and eventually reduces leaf production and growth. As growth of the branch slows, photosynthesis and hormone production continue to slow. Many trees have small shoots that can continue to grow less than a centimeter each year, but if they are too shaded, they ultimately die. As a result the lower and internal portions of tree crowns are free of leaf bearing axes unless the foliage on the outer portion is sparse enough to let light through. In the forest, branches whose tips do not reach the top of the canopy soon die and the trunk is left free of branches, but specimen trees in the open may retain lower branches.

In excurrent trees, like many conifers, with a dominant central stem and major branches at wide angles to the stem, upper branches shade lower branches. As a result, there is a regular sequence of branches from the top to the bottom of the crown, each progressively more shaded. If the branch tip can grow out horizontally enough to expose leaves to light, the branch can survive, but in older branches, the costs of growing horizontally are large and branch productivity small. The branches do not thicken much as they grow out and as a result tend to sag down under their own weight. Eventually, the lower most branches die. In decurrent trees, there is no single dominant stem and branches tend to curve upward so their tips are at the canopy surface. Good examples are mature *Quereus* spp. with wide spreading crowns. Lower branches that do not bend up still are shaded out, particularly in the forest, but the other major branches thicken so that there is no semblance of a central stem in the upper crown (Long *et al.*, 1981).

Tree shape and dimension are determined by the rate of growth in height, the number and relative length of branches and branch crotch angles (Jankiewicz and Stecki, 1976).

Understanding canopy development in any crop is paramount to achieving optimum efficiency through improved management.

Canopy architecture and tree form development have been extensively studied by Halle and Oldman (1979). Based on this, they classified the canopy development and crown pattern of most of the tropical trees and come out with 23 developmental models. According to them cashew has a development pattern of an orthotropic rhythmically active, terminal meristem which produces an indeterminate trunk bearing tiers of branches, each branch complex orthotropic and sympodially branched as a result of terminal flowering. Which has been termed as Scarron's model. The model is named after Francis Scarrone, since the mango (*Manfigera indica*) which he has investigated in great detail provides an example of its architecture (Scarrone, 1964, 1965, 1966). Species of *Mangifera*, Spondias, *Triplaris surinamensis* (Poligonaceae), *Pandamus vandamii* (Pandanaceae), *Gardmia imperialis* (Rubiaceae) comes under the model (Halle *et al.*, 1978).

Kanwar (1988) has defined three types of tree forms on the basis of height in apple. Bush trees have a height of 15 to 17 cm. The half standard and standard trees have the lowest branch between 1 to 1.5 and 1.8 m height respectively from the ground level.

In the late fifties, when clonal root stocks of apples were introduced to India, some experimental dwarf plants were raised as spindle bushes, dwarf pyramids and cordons. These were later identified as training system for dwarf trees in Himachal Pradesh. Singh (1970) and Awasthi and Verma (1986) found spindle bush system of training is most suitable in the agroclimatic conditions of Himachal Pradesh. Kanwar (1988) reported encouraging success in spindle bush raised on M 9, M 7 and M 4 root stocks and suggested palmette's on sloppyland with narrow terraces. He has also suggested head and spread and spindle bush system of training.

In other regions Sharma (1989) found spindle bush training to be better on M 7 rootstock and modified central leader on MM 106. Trees trained to spindle bush had higher tree volume, photosynthetic efficiency, fruit set and yield efficiency, but the fruits were found to be smaller in size and firm with higher soluble solids and anthocyaminin pigments. Upadhya *et al.* (1984) reported more dwarfing in Red Delicious M 9 on espalier than on spindle bush, dwarf pyramid or untrained trees. The fruit yield and quality were better on Espalier than on the other systems. Tripathi *et al.* (1984) found increased yield and better fruit quality of Red Delecious on M 7 roostocks trained to modified central leader comparison to open central leader or central leader. Sharma (1987) reported increased spur density and yield efficiency in Royal Delecious apple on M 7 at 45° orientation from the soil surface. The tree volume and yield were with 60° orientation.

Dynamics of branching is an important element of canopy architecture. Halle and Oldman (1979) have recognized different orders of branches which fall under two major categories namely sylleptic and proleptic branches. In many tropical forest species, they have described sylleptic branches are those where continuous development of a lateral from a terminal meristem to establish a branch without an evident intervening period of rest of the lateral meristem. They have identified proleptic branches as those where the discontinuous development of a lateral from a terminal meristem to establish a branch, with some intervening period of rest of the lateral meristem.

Branch polymorphism were also studied in detail by the above authors. They have recognized different classes of branches like orthotropic branches and plagiotropic branches in tree species.

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From the time of Sach's (1879) and even earlier (Frank, 1868) the difference between erect and horizontal aerial shoots in plants has been circumscribed using several criteria as follows:

(1) Orthotropic shoots ie., shoots which are errect with essentially radial symmetry, phyllotaxy spiral or decussate, branching 3 dimensional, axis negatively geotropic, often non flowering.

(2) Plagiotropic shoots ie., shoots which are more or less horizontal with dorsiventral symmetry, leaves either distichous or secondarly arranged in one plane, branching two dimensional, axis dia geotropic, often flowering.

In tree with differential shoot systems, the chronological sequence of branch initiation is an evident factor in determining meristem differentiation. It seems clear in such examples that the processes of syllepsis and prolepsis control shoot organization in a remarkable way in cocoa (Greathouse and Laetsch, 1969). It must be recalled that with syllepsis a lateral meristem develops as a branch without rest. With prolepsis, the lateral meristem undergoes a period of rest after initiation but prior to further development, morphologically the resulting shoot types are readily contrasted. By pruning orthotropic shoots it was shown that resting buds could be induced to develop as either plagiotropic shoots or orthotropic shoots. Another way of stating this is to say that syllepsis results in plagiotropic meristems while prolepsis mainly results in a meristem producing an axis similar to the parent meristem.

Mathai (1989) has reported that in guava tree, there are five orders of interdependant branches. He has also observed n_4 and n_5 branches are the bearing branches in guava. Kurien (1985) has recognised two types of branches namely sylleptic and proleptic in ber, and in two species of zyzyphus.

High density planting

Cashew traditionally has been grown in marginal and unproductive waste lands. As the crop emerged as a highly profitable commercial crop with the introduction of high yielding varieties, more and more farmers have taken up the planting of cashew in large plantations and also fertile agricultural lands. The crop also is given intensive management practices which has resulted in high density planting with lesser spacing and more number of trees/unit area. The major requirement of high density planting is tree size control. This can be brought about by evolving dwarf varieties which are also less spreading (spindle types) or by use of dwarfing rootstock and use of interstock. Management practice for manipulation of the canopy by various degrees of targeted and timed pruning can successfully employed in HDP. HDP has become successful in many fruit plants like apple, pear, citrus etc. Santram (1993) has found that HDP was very successful in mango variety Dashehari. The growth of Dashehari trees in high density planting system in terms of scion length, main stem diameter, and circumference increased progressively up to 10th year. (Ram and Sirohi, 1988 and 1989). When branches started touching each other dehorning of 50 per cent branches after fruit harvest was done in the eleventh year and another 25 per cent was done in the 12th year. Dehorning of branches at this stage brought a reduction of 37 per cent in scion length and 59 per cent its circumference. The tree grew rapidly and made up the growth loss during the following season. However, there was no increase in the number of primary branches. The yield increased progressively both in low as well as in high density plantings of Dashehari trees. The average yield per tree was also similar under both the densities up to 10 years. Thus the yield increase in high density plantation was because of the increase in number of trees/unit area resulting an yield of giving 2.4 tonnes/ha in fifth year which further increased to 18.6 tonnes/ha at the end of 10th year as compared to only 0.2 tonnes/ha in fifth year. For high density planting in these varieties, light to heavy pruning after fruit harvest is essential. Shanmugavelu and Saidha (1993) has reported that HDP resorted to the Malgoa variety of mango gave a significant increase in fruit yield.

The concept of high density orcharding in citrus has drawn considerable attention of citrus growers in USA, Japan, Australia, Israel, South Africa, Brazil, Mexico, Spain and Italy during the last three decades. Such orchards not only provide initial high production and net returns, especially during the first 10 to 15 years, but also facilitated more efficient use of fertilizer and water due to greater root densities per unit area, efficient fungicidal and pesticidal application due to greater degree of spray interception and effective control of weed growth. Moreover, this system is better adapted in areas where normal productive life of the grove is expected to be short. However, the establishment of such orchards involves relatively higher capital investment (Goswamy *et al.*, 1993).

The present day spacing that is recommended for cashew is 7.5 m x 7.5 m accomodating 170 trees/ha. Extending HDP concept to cashew, there is the need of evolving an ideal plant type with lesser canopy spread and high productivity. This might enable us to accomodate about 625 plants/ha and to increase the yield by about three times.

Light interception is the amount of available light intercepted by tree canopy. Hence the interception is a function of plant density, canopy shape, size and LAI. Jackson (1980) has reported that total yield of apples is related to total light interception. However, the yield of high quality fruit is not a single function of light interception. The goal of tree design is to intercept a high proportion of available light and to adequately expose the maximum number of fruits sites by distributing the light uniformly within the canopy (Lakso *et al.*, 1989b).

A high level of light interception can be achieved with a closed canopy. However, the extinction of light which is proportional to the depth of foliage leads to unfavourable light exposure of the lower part of closed canopies. Orchard canopy architecture must therefore be a matter of compromise, a portion of the incident light must be sacrifised to the orchard floor to provide adequate levels of light exposure for the lower limbs of the canopy. In the study of canopy modification, the effect of tree form is best studied by measuring light distribution within the canopy, while the effect of tree spacing and arrangement is best quantified by measuring total light interception.

Two approaches have been used to improve the light distribution in apple canopies. One is to use relatively natural trees forms that allow light penetration through the canopy by providing many small openings in the foliage such as in the multiple leader, central leader, vertical axis or slender spindle forms (Wertheim, 1968; Mc Kenzie, 1972; Heinicke, 1975 and Lespinasse and Delort, 1986). This approach can be successful, but generally requires a high degree of horticultural skill to manage the growth of the canopy. A second approach is to provide fewer large, permanent openings for light penetration in to canopies restricted into geometric forms. Examples are then restricted planes of foliage such as narrow hedge rows, tree walls and A, V or T forms (Chalmers and Van de Ende, 1975; Luckwill, 1978; Mc Kenzinc *et al.*, 1978; Dunn and Stolp, 1987; Hutton *et al.*, 1987; Van den Ende *e al.*, 1987 and Palmer, 1988; Lakso *et al.*, 1989a). This approach generally requires severe geometric restriction of the canopy, expensive support structures and significant labour to place and maintain the branches in specific locations. The value of these different tree forms lies in their light distribution properties and the resultant improvement in fruit yields and/or quality. Heinicke (1963) and Looney (1968) showed that in large round crowned trees light intensity decreased rapidly with increasing depth of foliage and that lower and center positions of the tree received very low light intensities (6% to 30% of full sun light). The exterior quarter of the tree had a small percentage of the total leaf area yet had a large shading effect on the rest of the tree where the major portion of the leaf surface was located. Heinicke (1963) proposed that 30 per cent of full sun serve as a lower limit of desired light level in apple canopies. Jackson (1970) found a more rapid decline in light level with depth of canopy, with light levels reduced to 34 per cent of full sun within 1 m of the canopy exterior. He found that the main cropping zone of the tree received a minimum of 35 per cent full sun, while the more shaded areas produced relatively few fruits. This result has led to the rule of thump that effective penetration depth of light in the unrestricted apple canopies is $\approx$ 1 m.

Narrow hedgerow trees were studied by Verheij and Verwer (1973) who found average light levels of more than 50 per cent of full sun light occured only at the top perephery of the canopy. Moving down and inward in the canopy of dense hedgerows, average light levels dropped sharply to 15 per cent of full sun light or less. Cain (1970) showed a negative linear relationship between production per unit of tree area and the size of the tree. The relationship showed a decrease of 0.6 kg m^2 for each meter increase in tree spread. The decreased efficiency of large trees is likely the result of greater internal shading.

The benefits of smaller trees led to the development of the "central leader" tree form as reported by Heinicke (1975) and Mc Kenzie (1972). Barritt *et al.* (1991) have reported on the seasonal changes in the interior canopy light climate of 'Delicious' central leader trees. The rapid seasonal decline in light exposure of the interior central leader trees has led to summer pruning to improve fruit colour with most of the cultivars grown in the eastern United States. Lasko *et al.* (1989a) described a modification of the central leader tree form named the palmette leader designed to improve the light distribution of the tree canopy.

Canopy design and shape influence light interception. Jackson and Palmer (1980) modelled the influence of canopy shape on interception and validated the models using solid scale models. Interception was proportional to the area of ground covered by the tree and the hedge height in relation to clear alley way. Interception was more dependent on the horizontal than vertical components of tree size. Wertheim *et al.* (1986) compared single and multiple row beds of trees trained to two systems. Light interception of the systems differed only 3 per cent, with the taller and wider trees intercepting more light. Multiple row beds, two to four rows, however, intercepted 10 per cent more light than single rows.

Pruning generally reduces total light interception because of reduced growth and canopy size. Summer pruning has been shown to improve light penetration within tree canopies (Marini and Barden, 1987). Summer pruning in combination with dormant pruning reduced light interception by 15 per cent

(Wertheim *et al.*, 1986). Light interception varies during a season due to leaf surface area development and solar angle and during orchard extablishment due to increase in tree size. Light interception during the season closely follows leaf area development (Palmer, 1974; Palmer and Jackson, 1977).

Light interception is typically expressed as percentage of available light. Reporting interception or irradience as per cent full sun is useful for comparisons with in a single experiment but does not allow comparisons in time or space and the evaluation of energy input requirements for cropping. Some preliminary relationships between light quantum or energy interception and crop production were discussed by Robinson *et al.* (1991).

Pruning fruit trees and bushes is an age old cultural practice that over the centuries has been developed in to a skilled, accurate technology which are derived from the visual effects of pruning operations. Practical knowledge of pruning and training of grape vines was the first to develop in antiquity. Most of the experiments on fruit tree pruning have been conducted from a practical point of view. The effects of pruning on growth, fruit bud formation, fruit set, yield, size and fruit quality have been studied. Koopmann (1896) was one of the first to summarize pruning effects in to two general rules (cited by Jonkers, 1932). (1) The new terminal shoot obtained was found to be longest if 70 per cent of the old terminals were pruned away. (2) The total length of old branch and new terminal shoots was greatest if no pruning was done. These were also confirmed in a special experiment performed 86 years later by Jonkers (1982). In 1938, Grubb outlined results of winter pruning experiments with apple at the East Malling Research Station. He pointed out that pruning influenced the following characteristics of a tree.

1. Size as measured by stem size, height and spread.
2. Characters other than size particularly shape and spur development.
3. Precocity, number of blossoms, number of fruits and percentage of blossoms setting fruit.
4. Fruit quality, particularly size and colour.
5. Susceptability to diseases.

Tubbs (1955) in a review on the control of vegetative growth and reproduction of fruit trees pointed out that response to pruning in mature trees is related both to tree vigour and the balance between vegetative and reproductive processes. He referred to data of Murneek (1941) indicating that although important reserves are present in the twigs and branches of apple trees, their main mass is located in the trunk and roots.

Pruning, removal of unwanted plant parts is little known in cashew. Khan *et al.* (1984) reported that the pruning of the dead wood alone in older trees helps in increasing the nut yield by 30 to 40 per cent. Results from earlier studies have revealed that pruning of leader shoots helps in stabilizing the yield in older plantations with declined yield. Studies on the effect of pruning on cashew plants are scanty except the yield performance (NRCC, 1992).

In apple summer pruning helps in reducing dwarfing and there by better shape and size of the canopy (Pickering *et al.*, 1908; Swasbrick and Berry, 1938) and the same has been recommended in high density planting to restrict the tree size and to improve the quality of produce (Toylor and Ferree, 1981; Carlson, 1982; Mika, 1981). Pruning also helps in changing the pattern of branching and flushing in grapes and apples.

Rudolph *et al.* (1991) have shown that severe pruning resulted in the formation of many vigorous shoots to a poor crown structure and yield in sweet cherry. They have further observed that annual pruning was desirable in this crop. Elfving (1990) has reported that heading back pruning treatment in apple tree decreased the yield considerably. Marini *et al.* (1991) have found that "Campbell Red Chief Delicious" varieties of apple trees, when subjected to annual pruning treatments, there was considerable reduction in yield. Nautiyal *et al.* (1991) have found that training of peach tree by open center system has resulted in better regulation of cropping in peach. Bassi and Dima (1994) studied the pruning response of six peach growth forms. They have trained pillar and upright trees to spindle, two years after field planting. Semidwarf, spur type and standard trees were trained to the open or delayed vase form. Weeping trees were pruned in a manner similar to the Lepage hedge. Branch density before pruning was highest in semidwarf spur type and upright trees and lowest in pillar trees. Standard, semidwarf and spur type trees reacted similarly to pruning, but semidwarf trees produced as much wood in the following season as had been pruned off and produced large numbers of fruiting branches. The small size of semidwarf trees suggested their use for medium density planting (MDP). Pillar trees needed only light pruning. No major cuts were necessary and many fruiting branches were produced even on non pruned trees. The pillar canopy was 60 per cent thinner and required 50 per cent fewer pruning cuts than the standard canopy and may be particularly suited to high density planting (HDP). The upper canopy of weeping trees grew more than most other forms. They were intermediate in branch density and required an intermediate amount of pruning. Most striking was the unique canopy form of weeping trees, which may be used in developing new training systems. The results of this study suggest that new growth forms have the potential to reduce pruning and training requirements for peach, particularly in MDPs and HDPs. This potential suggests further investigation and exploitation of alternate peach tree growth forms. Worley (1991) has found that by remvoing two or three limbs per year at a height of less than 9 m has resulted in tree height reduction in peach tree. Pruning improved tree vigour, nut size, terminal shoot growth, leaf NP but reduced leaf potassium and percentage of fancy grade kernels. Cutting *et al.* (1994) investigated the effect of two pruning cuts in late summer and late autumn either through uppermost budring or below budring on resultant vegetative growth in avocado. The cuts were repeated at a second date to determine if time of pruning had an effect on shoot growth characteristics. The cut through the budring released an average of seven buds and greatly increased shoot complexity. The cut below the budring depressed vigour and released on average one bud. Time of pruning had an effect in that the later in to Autumn that the cut was done, longer was the resultant shoot. The results show that properly targetted and timed pruning could replace the need for growth retardant chemicals in the manipulation of the vegetative reproductive balance in an evergreen tree crop such as the avocado. In plum, Myers and Ferree (1983) have found that pruning decreased limb and trunk cross sectional area in "Delicious" apple trees. Horizontal limb cross sectional area increase was less than that of vertical limbs. Pruning also increased spur leaf numbers, area and size.

Saunders *et al.* (1991) examined the effect of pruning on fruit set and shoot growth of pechams triumph pear trees. They have manipulated the new shoot growth location by removing these shoots from various sections of two year old shoot unit. Shoot units were pruned at various intervals before and after anthesis. It was found that percentage fruit set increased with pruning. The poor correlation between percentage fruit set and number of new shoots indicated that competition between fruit and shoots alone could not explain the variable fruit set. Location of new shoots relative to fruits was important. Pruning delayed 3 weeks or longer after failed to improve fruit set. Stephen *et al.* (1989) have found that trees headed about 1/2 m above soil surface resulted in fewer primary branches produced by one year old tree than those headed at 3/4 m above soil surface.

The effects of pruning on shoot growth depend on the type and time of pruning. In the dormant phase of growth, twigs produced the previous season or older branches may be shortened and or removed entirely. The invigorating effect of dormant pruning on shoot growth is well known. Early experiments on pruning by Aldermann and Auchter (1916); Gardner *et al.* (1922); Knight (1927); Grubb (1938) and many others proved that pruning stimulates growth of new shoots. Pruning stimulates the growth of young, vigorous trees grown in favourable conditions more than that of older or dwarfing rootstock trees or trees grown in unfavourable conditons. Outstanding experimental work on the response of whole trees to pruning was carried out at the East Malling Research Station by Maggs (1959; 1965). Based on the studies of Gardner *et al.* (1952); Magness *et al.* (1977) and Lockard (1956). Maggs (1959) concluded that the general growth responses of the fruit tree to dormant winter pruning were fairly well established and could be summarized as follows.

a) The individual shoots arising from a pruned branch are larger than those on an unpruned branch.

b) Despite the faster growth of their individual shotos, pruned trees do not equal unpruned trees in size, at least until fruiting has checked the latter's growth.

c) For a given degree of pruning the size of the shoot growing from a pruned stem is positively correlated with the length of the stem before pruning.

Maggs (1965) pointed out that a pruned tree is different from an unpruned tree in 3 ways. (1) Absence of the apical meristem and upper buds so that a lower bud becomes the upper most. (2) Loss in cambial surface and consequent change in cambial proportions. (3) Loss of the pruned material including leaves in the case of summer pruning. Basak (1986) has shown that light winter pruning in apple meadow orchards, could be successfuly used to control shoot growth and cropping.

A small reduction in trunk growth each year may lead to significant dwarfing of the whole tree after several years. Jonkers (1962); Preston, (1969) and Norton (1980) mentioned that the growth response to pruning restores the disturbed balance between the above and underground parts of a tree by increasing shoot growth and reducing root growth. Shoot growth response to pruning is influenced not only by the amount of removed wood but also by the type of cuts. If the same amount of wood is removed, heading cuts will induce more new shoot growth than thinning cuts (Mika *et al.*, 1981, 1983).

Tree response to pruning is also influenced by the size of cuts. Numerous small cuts stimulate more new shoot growth than a few large cuts when comparable amounts of wood are pruned (Mika, 1982).

Summer pruning

Summer pruning is an old cultural practice, originally performed mainly in dwarf orchards to control the size and shape of traditionally trained trees. The French (Loretle, 1925) and English (Bagenal and Turner, 1936) systems of summer pruning were the best known and involved shortening of lateral shoots in July or August once or on successive days. Summer pruning is recommended mainly for high density orchards to restrict tree size and to improve fruit quality (Taylor and Ferree, 1981; Carlson, 1982; Mika, 1982). Several experiments have shown that summer pruning decreases shoot growth of young trees in comparison with that of either dormant pruned or unpruned trees (Aldermann and Auchter, 1916; Maggs, 1965; Aselage and Carlson, 1977; Ferree and Stang, 1980; Mika *et al*, 1983). In the case of older, bearing fruit trees, summer pruning retards trunk growth, decreased root growth and restricts canopy dimension (Utermark, 1977), but is ineffective in decreasing shoot growth (Gardner, 1916; Beakbane and Preston, 1962; Engel, 1974; Parnia *et al.*, 1979; Taylor and Ferree, 1981, 1984). Mika *et al.* (1981, 1983) found that all pruning systems restricted canopy dimensions. Engel (1974) reported less stem increment and smaller canopy diameter after summer pruning than after winter pruning of apple trees grafted on seedlings. Heinicke (1975) maintained that summer pruning slows down the growth of apple trees and promotes the development of stronger spurs. Parnia *et al.* (1979) reported that summer pruning of sourcherry by shoot pinching to 6 to 8 leaves reduced tree size and resulted in compact growth. Zbindew and Widmer (1980) showed that summer pruning of sweet cherry trees restricted canopy height and spread. Sako and Laurinew (1982) demonstrated that regular summer pruning for 5 consecutive years of bearing "Mantet" apple trees lead to a 20 to 25 per cent reduction in the growth of stem girth. Greene and Lord (1983) found that summer pruning of bearing "Cortland" apple trees for 3 consecutive years reduced trunk circumference increase but did not affect re-growth compared with dormant pruned trees. Myers and Ferree (1983) reported that summer pruning of dwarf "Red Prince Delicious" apple trees decreased limb and trunk cross-sectional area increase, and also tree height and spread compared with unpruned trees. Taylor and Ferree (1984) compared light dormant thinning with summer shoot heading of dwarf Jonathan apple trees and found that although shoot heading stimulated terminal growth, it effectively restricted an increase in canopy dimensions.

Growth correlations

Pruning performed on growing or dormant shoots removes apical dominance, releases buds from correlative inhibition and changes tree form and construction. Growth correlations and apical dominance were recently reviewed by Jankiewicz and Stecki (1976) and Philips (1969). Auxin produced in the shoot apex inhibits the growth of axillary buds; the concept that specific factors or inhibitors (Dostal, 1908) are responsible for correlative bud inhibition. Barlous and Hancock (1960, 1962) showed experimentally that decapitation of growing apple shoot tips stimulates axillary buds to sprout precociously in to laterals and that the pattern of branching indcued in this way depends on the phase of development during which shoot tips or growing leaves are removed. Champagnat (1961) maintained that buds in the apical region are predisposed towards fast growth, where as buds at the shoot base are predisposed towards dormancy. During dormancy the correlation between buds may change fundamentally and some buds may gain advantage over others. Mullins (1965) showed experimentally that maiden apple trees have two centers of branching in the second year. At the beginning of the growing season, strong outgrowths occur at the apical region, while later in the season, strong outgrowths occur at the basel region. Outgrowths in the middle part of the maiden apple tree are the shortest. Because correlative inhibition between the buds may change with chilling, the growth pattern after pruning may be altered with the time of pruning. Under tropical climates excessive apical dominance in "Rome beauty" apple may be overcome by defoliation and shoot bending or heading (Alexander and Maggs, 1974).

Day and De Jong (1989) have investigated the effect of post harvest and preharvest summer pruning techniques on photosynthentic photon flex densities (PPFD) and yield characteristics in mature "fire bright" nectarine (*Prunus persica* L.) Batsch, trees. The treatments 14 days after harvest included - unpruned control, hand topping, interior water sprout removal (W.S.R.) and combination of hand topping, W.S.R. All pruning treatments initially increased PPFD within the canopies, 45 days after pruning. The topped trees had PPFD similar to improved controls while PPFD in other treatments remained higher. PPFD were similar for all treatments 90 days after treatment. Preharvest summer pruning imposed on the same set of trees increased fruit size, weight and redness relative to improved trees.

It is evident from many studies that pruning changes total dry weight partitioning in such a way that more dry weight is added to new shoots than to the remaining wood of the frame, trunk and roots. The high production of new shoots should be expected to decrease the reserves of nutrients particularly CBH stored in the remaining parts of the tree which are indispensable for such improvement processes for fruit bud formation. Hooker (1924) reported that dormant pruning decreased starch and soluble sugars content in branches of apple trees but increased water and nitrogen content. Cameron (1923) showed that dormant pruned pear and peach trees started to accumulate starch and soluble sugars later in the season than unpruned trees. Aldrich and Grim (1938) found that dormant pruning pear trees did not change significantly CBH reserves of spurs in the spring. A long time study by Soezek *et al.* (1970) indicated that dormant pruning did not change CBH reserves nor the ratio of CBH to N in leaves, shoots and roots of apple trees. Groechowska *et al.* (1977) reported that dormant pruning and disbudding did not significantly change total CBH levels in the shoots and roots of maiden apple trees. However, the metabolism of CBH's in annual shoots of pruned trees differed from that of unpruned trees. In the beginning of the growth season, pruned trees had a higher level of soluble sugars during the stage of fast growth and 2-3 times higher ratio of soluble sugars to starch. They concluded that the difference in CBH metabolism, is related to general metabolic process, catabolic in nature that dominate in plant tissues abounding in growth promoting hormones. Not much information is available on the effect of dormant pruning on soluble solids in fruits. The effect of dormant pruning appears to depend on factors such as the type of pruning cuts, tree vigour, and fruit load. Large thinning cuts which facilitate light penetration to the interior part of the tree canopy and increase the rate of photosynthesis, may increase the content of soluble solids in fruits. Indirectly this effect can be observed in improved fruit colouration. In contrast small heading cuts which stimulate much new shoot growth and create shading may decrease soluble solids content in fruits. Such an effect was observed in a densily planted apple oarchard, that required severe pruning (Ibrahim-Ahamed *et al.*, 1983).

The proportion of fruit load to the available pool of assimilates also seems to have an important influence on the soluble solid contents of fruits. In vineyards if many buds are left after dormant pruning on fruiting cames but soluble solids content may be decreased (Naidenov *et al.*, 1980). Stropek (1983) demonstrated with plum trees that when fruit load was decreased due to pruning, the content of soluble solids in fruits was increased. There is evidence that summer pruning of apple trees may decrease the content of soluble solids in fruits when leaves adjacent to fruits are removed (Marini and Bardens, 1982; Greene and Lord, 1983). However, when some leaves are left in close proximity to the fruit, the content of soluble solids is not reduced (Greene and Lord, 1983). Tymoszuk *et al.* (1980, 1984) found that in apple trees only assimilates from the laterals situated on fruiting spurs are translocated to adjacent fruits. The strong laterals situated at some distance from fruits do not contribute to their nourishment.

Yang (1989) studied the Ist year shoot development and CBH distribution in fall and spring planted apple trees. Fall planting resulted in significantly greater shoot extension growth and lower tendency to become spur bound than spring planting during two years for 2 strains of spur "Delicious". Higher starch reserves were found following the growing season after fall planting than spring planting. Birrenkott *et al.* (1991) monitored the CBH levels and the development of fruits in crawberry. Except during dormancy, crawberry uprights in the field had the highest concentration of CBH (soluble and strach) at earlyblossom, when the lower flower were at anthesis. As early flowers developed in to fruit and upper flowers were at or just beyond anthesis, uprights had lower CBH concentrations. As fruit growth slowed soluble CBH levels increased and were highest at dormancy. Upright shoot tissue produced the previous year and trailing woody stem followed the same trend as the current seasons growth but had consistently lower soluble CBH levels at each growth stage. Starch levels were low in current growth and did not change appreciably with fruit development. Starch was primarily stored and subsequently depleted in the previous season's upright growth and trailing woody stems. Tissue from the green house was generally higher in CBH than was field grown tissue. Fruit developed from 53 per cent of the flowers under green house conditions, compared to 38 per cent in the field. Insufficient carbohydrate levels may be responsible for the low fruit set observed in the field. Sucrose, glucose, fructose, raffinose and stachyose were present in crawberry vegetative tissue.

Seasonal carbohydrate cycles have been well investigated in many woody species. Total carbohydrate contents of perennial parts of trees in the temperate zone reach a maximum in autumn, begin to decrease in late winter and decrease rapdily in early spring. The summer minimum is followed by a stage of re-constitution in autumn and early winter (Priestly, 1969; Kramer and Kozlowski, 1979; Bory and Clair-Maczulajtys, 1993). In many respects, the level and the fluctuations of reserve substances can also be indicators of the physiological state of trees, providing an understanding of organogenesis or the effects of stress (Bory and Clair-Maczulajtys, 1993). Bory *et al.* (1994) conducted experiments to study seasonal variations in starch and soluble sugars and to analyse the effects of time of pruning on the level and the spatial and temporal distribution of non-structural carbohydrates in the trunk of sweet cherry *Prunus avium*. They observed that during the annual carbohydrate cycle, starch and soluble sugar concentrations were quite similar in the lower and upper parts of the trunk of sweet cherry. The seasonal variations were characterized by a maximum carbohydrate content between summer and mid November and at the end of winter. Bloom and fruit development were distinguished by carbohydrate depletion. The effects of the removal of low branches on the level of the carbohydrates were related to the time of pruning. After summer pruning, the middle and upper parts of the trunk contained the highest concentrations of starch and soluble sugars. In the following year, starch had completely disappeared in the upper and lower parts of the trunk. The autumn pruning induced an increase in starch and soluble sugar levels in the upper part. The winter pruning mainly induced a rapid accumulation of soluble sugars in the upper part only.

The storage and mobilisation of carbohydrate (Oliveira and Priestley, 1988; Loescher *et al.*, 1990) and nitrogen (Titus and Kang, 1982) reserves in perennial parts play essential roles in deciduous fruit trees. Seasonal changes in carbohydrate content, well documented in cherry (Keller and Loescher, 1989) and apple (Yoshioka *et al.*, 1988) clearly illustrate this. Similarly the role of storage proteins has been clearly demonstrated in apple by Tromp and Ovaa (1973); O'Kennedy *et al.* (1975), poplar (Sauter and Van dere, 1990) and recently in a prunus species (Arora *et al.*, 1992). Brown *et al.* (1985); Renaud *et al.* (1991) suggested the role of rootstocks modifying vegetative growth in fruit trees. Similarly different training systems also were used to influence canopy development (Jonkers, 1967; Palmer and Jackson, 1977). The severity of dormant pruning is known to modify shoot growth and tree shape and vigour (Mika, 1986). Moreover bending shoots to horizontal positions is known to slow down shoot growth (Jonkers, 1967; Mika, 1969).

To determine if differences in the pruning and training system adopted could modify the concentration of C and N reserves in trees, a *Prunus domestica* L. scion genotype grafted on Ishtara rootstock clone was pruned and trained in two different ways. One system induced vigorous vertical shoots, while the other maintained less vigorous bent shoots. Two years after planting in the orchard, just after leaf fall, non structural carbohydrates, total free amino acid and soluble protein content were determined in the wood and bark of one year old shoots. The mean concentration and distribution of carbohydrate reserves in wood or bark appeared to be only slightly influenced by the training system. The mean concentration and distribution of soluble proteins was the same for both training systems. The major amino acids in wood and bark were arginine and asparagine. The mean concentration of total amino acids was higher in shoot bark for the bent training system than for the vertical training system. However, no similar difference appeared for total amino acids in shoot wood. Therefore, C and N reserves showed little modification with a change in the pruning and training system under experimental conditions mentioned (Moing *et al.*, 1994).

Materials and Methods

MATERIALS AND METHODS

The experiments were carried out at the Cashew Research Station, Anakkayam which falls 13°N 76°E at an altitude of 106.8 M above MSL under the Kerala Agricultural University.

Anakkayam has a highly leached laterite soil (Oxisol and Ultisol) and it receives a total rainfall of about 2690 mm per annum. The maximum termperature varies from 35 to 40°C and the minimum temperature varies 18 to 20°C. Whether data for the two year period ie., 1992 and 1993 when the experiments were carried out, are presented in Fig. 1 and Fig. 2 respectively.

The experimental materials used for the study, were 18 year old cashew layers and eight year old seedlings, grafts and layers maintained in the station. These plants were raised at a spacing of 7.5 m x 7.5 m and the trees were managed as per the package of practice recommendations of the Kerala Agricultural University. The varieties included for the experiments were the following:

1) Anakkayam-1
2) Madakkathara-1
3) K-10-2
4) K-16-1
5) NLR-2-1

The experiments under the investigations were broadly divided in to five parts.

Fig. 1. RAIN FALL AND NUMBER OF RAINY DAYS AT ANAKKAYAM DURING 1992 AND 1993

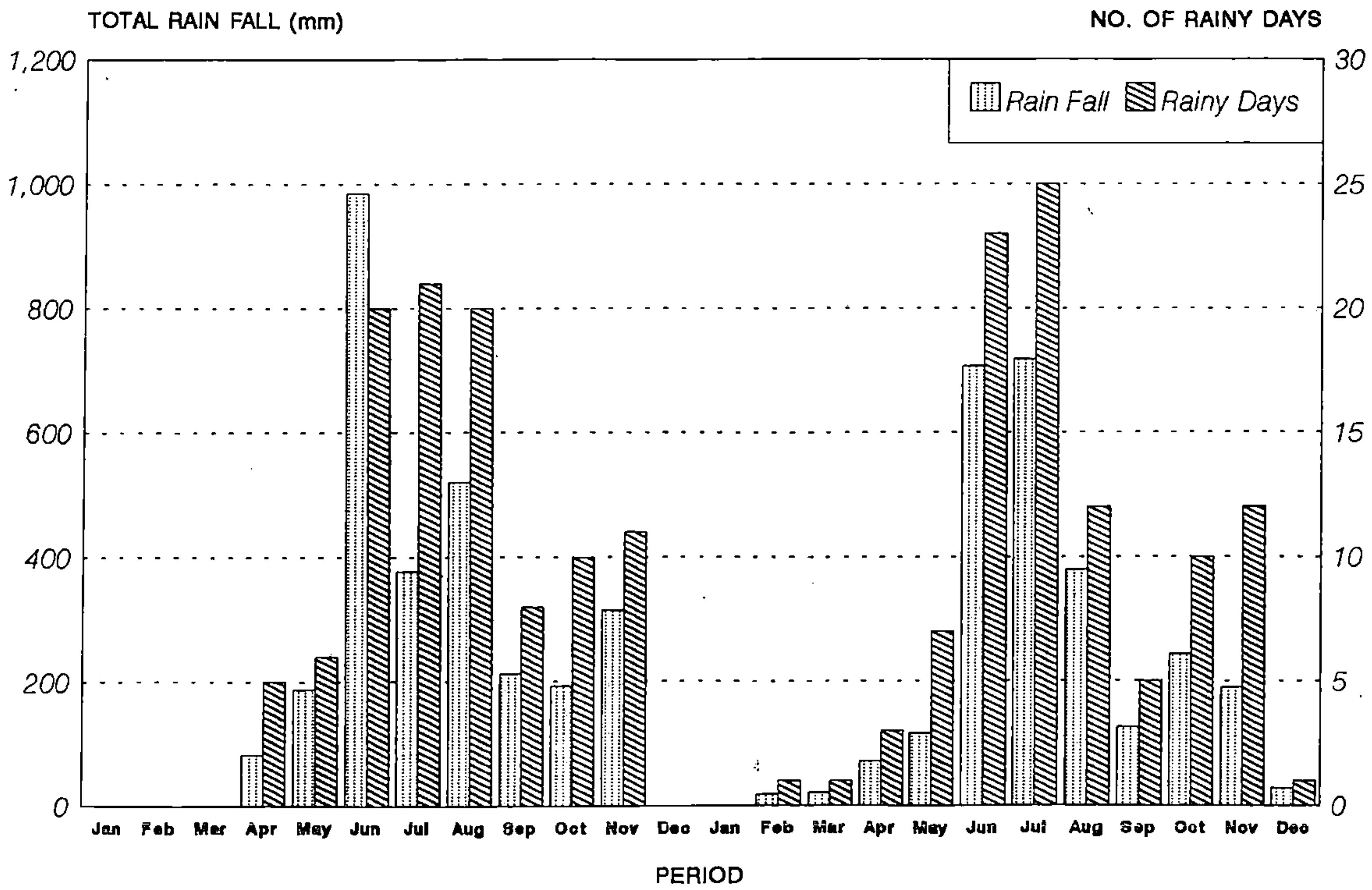
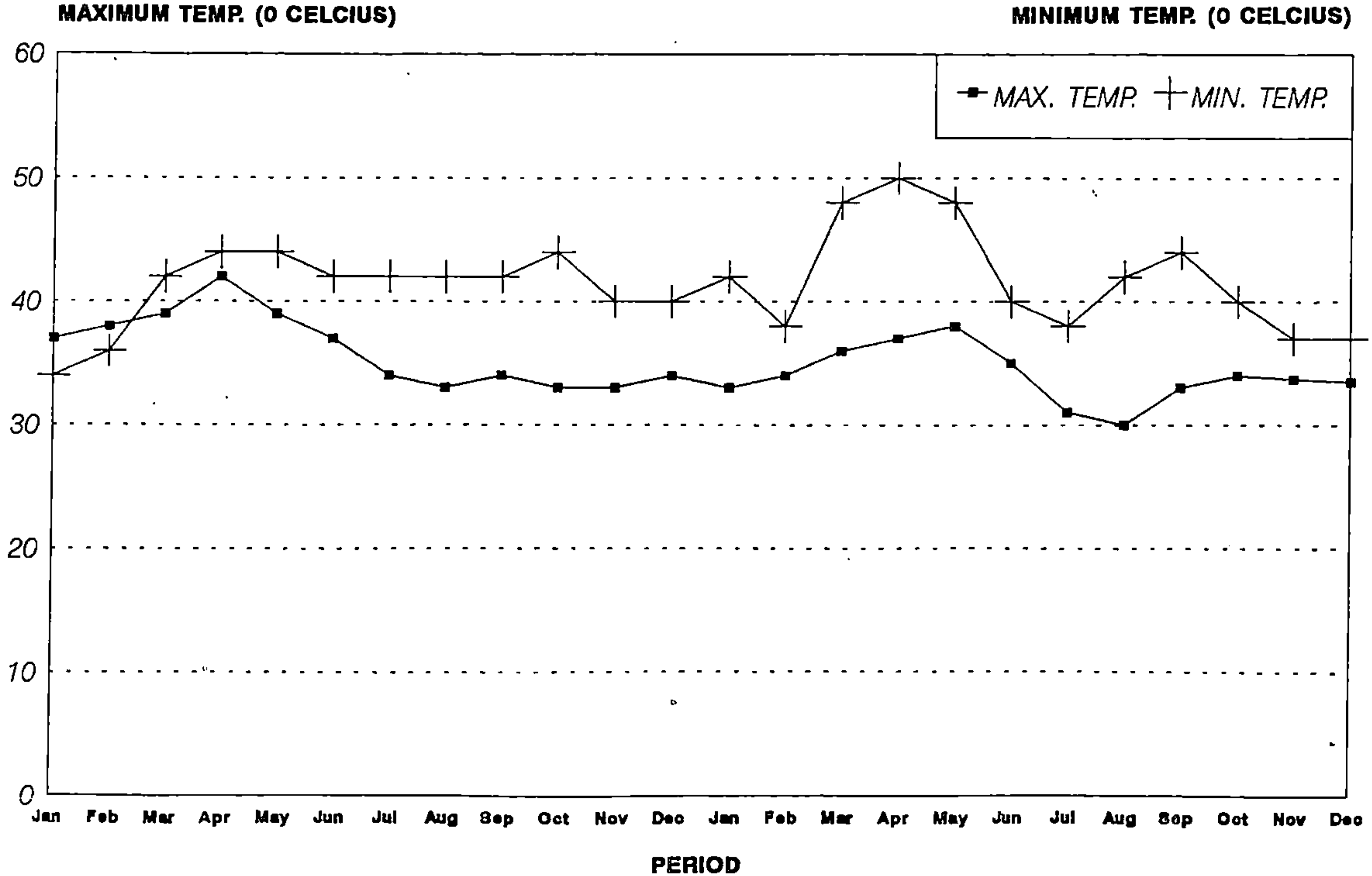


Fig. 2. MONTHLY MAXIMUM AND MINIMUM TEMPERATURE
AT ANAKKAYAM DURING 1992 AND 1993



3.1 Canopy architecture

3.1.1 Phenological and morphological observations

Visual observations were made with respect to the onset and extent of the different phenological changes such as flushing, period of active growth, flowering, harvesting, leaf fall and dormancy in the experimental trees over a period of one year starting from January 1992 and ending in December 1992. The studies were carried out on five varieties.

3.1.2 Branching pattern

Visual observations of the branching pattern of cashew trees in the plantation were made. For this the main branch was designated as '0' order, the next as first order, second as second order, the third as third order, fourth and fifth as fourth and fifth order of branches respectively. The number of different orders of branches of 30 plants including 10 seedlings, 10 grafts and 10 layers was recorded and tabulated. Number of branches of different orders especially n_4, n_5 and n_6 per square metre was also recorded. For this a wooden frame of one metre square was fabricated and this was randomly placed at different sites of the canopy and counts were taken. The total number of branches per tree was worked out from the total canopy surface area and number of branches per square metre of surface area.

Surface area was worked out by using the method as narrated under 3.1.4.1.

The Rb_n (branch bifurcation ratio) was calculated using Steingraeber's formula (Steingraeber *et al.*, 1979).

$$Rb_n = \frac{Nn}{Nn + 1}$$

Where N is the total number of branches of the n^{th} order on a tree crown,

n is the order number

In order to assess the real productivity of a tree crown a method using the following formula was used. The branch bifurcation ratio was linked to productivity and is called productivity weighted branch bifurcation ratio (PWBBRn). In cashew it has been observed that the 6th order branches are the productive branches and hence the PWBBRn was calculated using the 6th order branches.

$$PWBBRn = \frac{Fn}{PPBn} \times Bpn$$

Where Fn is the total number of fruits produced by the potentially productive branches of the n^{th} order on a tree crown.

PPBn is the total number of potentially productive branches of n^{th} orders, on the same tree crown and

BPn is the actual number of productive branches among the n^{th} branch order, on the same tree crown.

The length and girth of different orders of branches were also measured.

3.1.3 Leaf characteristics

Observations regarding leaf area, leaf colour, leaf texture and shape of leaf of the varieties were recorded. The leaf area index (LAI) of the five varieties of cashew namely Anakkayam-1, Madakkathara-1, K-10-2, K-16-1 and NLR-2-1 was determined using LI-COR canopy analyzer.

3.1.4 Canopy characteristics

3.1.4.1 Height, spread, shape and surface area of the canopy

The height and spread of the canopies of seedlings, grafts and layers were measured.

The three canopies namely that of seedlings, grafts and layers fell in to three geometrical configurations. The canopy of the seedling could be assumed to be a cylinder and a hemisphere placed above it in both the varieties. The canopy of the graft fell in to the geometrical configuration of a cylinder and a cone placed above it and the canopy of layers of both the varieties was like a hemisphere. Using the formula of finding out the surface area of the above mentioned shapes, the canopy surface area of seedlings, grafts and layers were calculated.

For working out the surface area of the canopy the following formulae were used.

Cylinder

Area excluding upper and lower surface $= 2\pi rh$

Area of hemisphere excluding lower surface $= 2\pi r^2$

Area of cone $= \pi rl$

where l = slant height

$l = \sqrt{r^2+h^2}$

Measures of radius, height and slant height of the cylindrical, hemispherical and conical areas of the canopies of seedlings, grafts and layers were taken separately and the surface area of the canopies were arrived at by using the above formulae.

3.1.4.2 Yield efficiency

The yields of the above mentioned seedlings, grafts and layers were separately recorded and from the calculated surface area, the yield efficiency ie. per metre surface area yield was worked out.

3.1.4.3 Height of main trunk from ground level

In addition to the above, height of the main trunk from ground level and the angle from the main stem of the different orders of branches were also measured.

3.2 Yield and yield attributes

3.2.1 Path Analysis

In another experiment, 30 trees consisting of ten plants each of seedlings, grafts and layers were choosen and the data pertaining to their height, spread, numbers of n_0, n_1 and n_2 branches per tree were recorded. The number of n_5 and n_6 branches, the number of flowering and nonflowering n_6 branches per m^2, percentage of bisexual flowers, number of leaves on the n_6 laterals, number of nuts per panicle and nut size were taken. The total canopy surface area of the above trees was also determined and their yields also were recorded. The above mentioned variables which are identified as the major components of yield were statistically analysed by path coefficient analysis to find out the effect of these components both direct and indirect on yield.

3.2.2 Correlation studies

The correlation among the number of different orders of branches also was analysed using the package as suggested by Panse and Sukhatme (1985).

3.3 Canopy manipulation

3.3.1 Experimental description

The canopies of the experimental plants were opened by removing branches of different orders, thus brining in different regimes of light penetration. The experimental design used was a Simple Randomised Design. Seven treatments were given with five replications each using two varieties. The treatment details are furnished here under:

Treatment I - Removal of 25 per cent of 6th order branches

Treatment II - Removal of 50 per cent of the 6th order branches

Treatment III - Removal of 100 per cent of the 6th order branches

Treatment IV - Removal of 25 per cent of the 5th order branches

Treatment V - Removal of 50 per cent of the 5th order branches

Treatment VI - Removal of 100 per cent of 5th order branches

Treatment VII - Removal of 100 per cent of 4th order branches

Treatment VIII - Control - without any manipulation

The removal of the various orders of branches was carried out during August, 1992. To pervent fungal infection, Bordeaux paste was applied to the cut ends of the branches.

The subsequent development of the canopy for the following three years was monitored. Obsevations with respect to the time taken for emergence of new branches were made. The yield of the experimental plants for the three years was also recorded.

3.3.2 Observations on days to flushing, growth increment and span of flowering

3.3.2.1 Days taken to flushing

The number of days taken for flushing after the pruning treatments were imposed, was recorded.

3.3.2.2 Growth Increment

The growth in length of the branches produced after pruning over the three year period was monitored.

3.3.2.3 Total number of laterals and flowering laterals

The total number of branches both flowering and non flowering produced per square metre area of the canopy after the imposition of the treatments, to the following three years was observed.

3.3.2.4 Span of flowering

The date of start, extent and end of flowering for the subsequent three years were recorded.

3.3.2.5 Sex ratio

Twenty five panicles of all the treatments were tagged and counts of the total number of flowers both male and bisexual flowers were taken and from this the percentage of bisexual flowers was worked out.

3.3.2.6 Yield

The yield of the experimental plants for the three years was also recorded.

3.3.3 Leaf Area Index (LAI)

One year after the pruning, Leaf Area Index (LAI) were measured by using the instrument LI-COR canopy analyzer. The values of leaf area index were recorded directly from the instrument. This observation was conducted in all the treatments of canopy manipulation. Apart from the trees in the treatment, the observation was done in the canopies of trees grown from seedlings, grafts and layers. Readings were taken from all the four sides of the canopies and the mean of the four indice is worked out to arrive at the LAI of each tree.

3.4 Studies on Growth Light Regime (G.L.R.)

Light measurements were made for the control and the treatments of canopy manipulation using a line quatumn sensor. Measurements were taken during early morning hours, noon and evening both in the open and under the canopy. The light available under the canopy is expressed as a percentage to the total in the open.

3.5 Biochemical studies

The chlorophyll content, the amount of carbohydrate at various stages of development and the nitrogen content are some of the biochemical factors that have a direct bearing on flowering, fruit set and subsequently on yield. In the present investigation, the content of the above factors was monitored for the five varieties and the experimental trees, where different degrees of pruning was carried out.

3.5.1 Chlorophyll content

The chlorophyll content of leaves of mature shoot of the five varieties of cashew namely, Anakkayam-1, Madakkathara-1, K-10-2, K-16-1 and NLR-2-1 was estimated spectrophotometrically in a known aliquot of acetone 80 per cent extract using standard procedure as suggested by Sadasivam and Manickam, 1992. The absorbance of the extract was measured respectively at 645, 663 and 652 n.m. for the estimation of chlorophyll-a, Chlorophyll-b and total chlorophyll.

The following standard formulae were used for the estimation of different fractions of chlorophyll.

Chlorophyll a - 1.27 (Abs. at 663 nm)-2.69 (Abs. at 663 nm) x V/1000 x W

Chlorophyll b - 22.9 (Abs. at 645 nm)-4.68 (Abs. at 663 nm) x V/1000 x W

Total chlorophyll - 20.2 (Abs. at 645 nm)+8.02 (Abs. at 663 nm) x V/1000 x W

Where

ABs - Absorbance

V - Final volume of chlorophyll extract

W - Fresh weight of the leaf extracts in grams

The data pertaining to chlorophyll-a, chlorophyll-b, total chlorophyll and yield were statistically analyzed and the correlation of chlorophyll-a, chlorophyll-b and total chlorophyll to yield was worked out.

Using the same procedure chlorophyll-a, chlorophyll-b and total chlorophyll content of the experimental trees, where pruning was carried out, was also estimated during flushing and at maturity.

3.5.2 Carbohydrate and total soluble sugars

The total carbohydrate content was estimated at flushing and flowering of the above mentioned trees. For the estimation of carbohydrate, phenol sulphuric acid method was followed (Sadasivam and Manickam, 1992). One gram of material was taken.

3.5.3 Nitrogen content

Nitrogen content of the experimental trees in which canopy was manipulated to different regimes of light penetration was determined using the methods as suggested by Jackson, 1958. The sample taken was 0.5 g.

3.6 Statistical analysis

The recorded data were statistically analysed following the method suggested by Panse and Sukhatme (1985).

Results

RESULTS

4.1 Canopy architecture

4.1.1 Phenological and morphological observations

The observations made on five varieties of cashew on various phenological and morphological characteristics are presented in Table 1 and in Fig. 3.

It is clear from the data that, the onset and extent of flushing varied in different varieties. Generally, flushing took place between October to January. Varieties Anakkayam-1, Madakkathara-1 and NLR-2-1 were found to be early flushing type while K-10-2 and K-16-1 were late flushing types. The period of flushing also was shorter in the early flushing types ie. about 20 days while it was higher in the latter mentioned varieties to about 30 days.

The active growth period also varied in the five varieties of cashew, observed. K-10-2 has a lower range of active growth of 50 days, while in the rest, the active period was about 65 days.

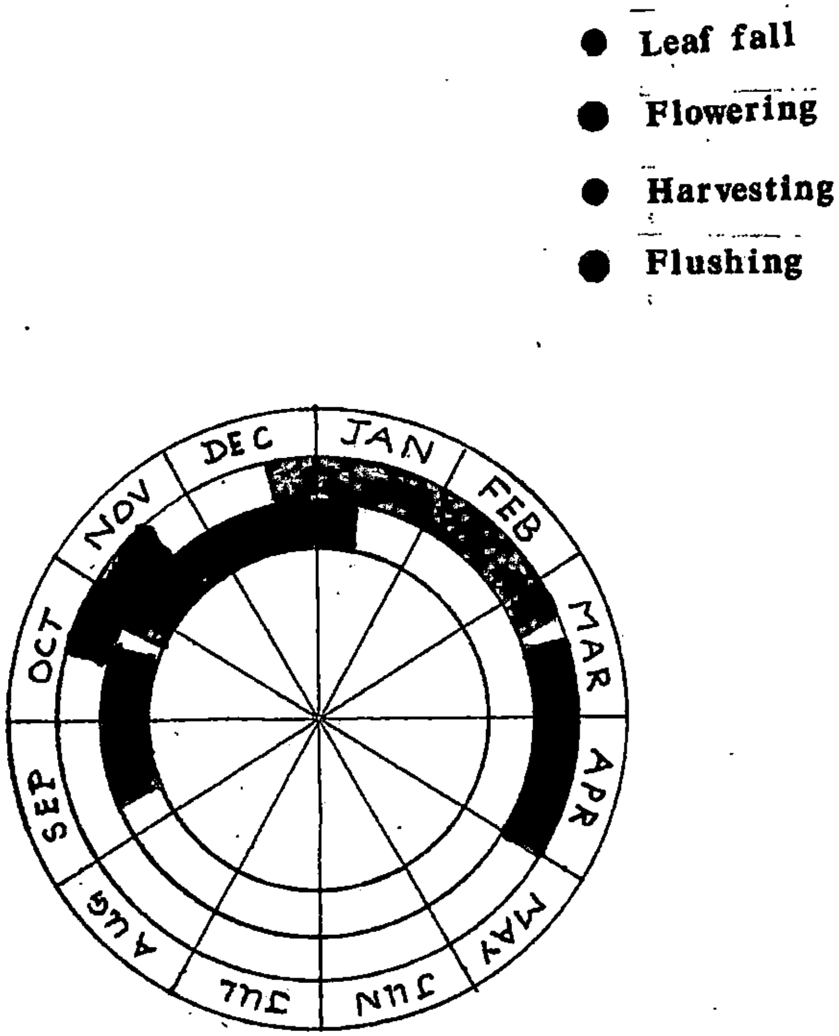
In cashew flowering usually starts during October along with flushing. The onset of flowering also varied in these varieties as flushing. However, the extent of flowering period was higher in Madakkathara-1 and K-16-1 to the tune of about more than 80 days while in the rest of the varieties it was about 70 days.

Harvesting of cashew varieties usually is carried out during the period from December to March. Varieties Anakkayam-1, Madakkathara-1 and NLR-2-1

Table 1. The extent of major phenological phases in five varieties of cashew

Sl. No.	Variety	Flushing (days)		Period of growth (days)		Flowering (days)		Harvesting (days)		Leaf fall (days)	
		From	To	From	To	From	To	From	To	From	To
1	Anakkayam-1	Oct. 15	Nov. 15	Oct. 15	Dec. 15	Oct. 25	Jan. 5	Dec. 20	Mar. 10	Sep. 10	Oct. 20
		(30)		(65)		(70)		(80)		(40)	
2	Madakkathara	Nov. 10	Nov. 30	Nov. 10	Jan. 20	Nov. 20	Feb. 10	Jan. 15	Apr. 10	Nov. 1	Nov. 30
		(20)		(70)		(80)		(85)		(30)	
3	K-10-2	Dec. 25	Jan. 20	Dec. 25	Feb. 15	Jan. 25	Apr. 5	Mar. 26	May. 15	Dec. 10	Dec. 25
		(25)		(50)		(70)		(50)		(15)	
4	K-16-1	Nov. 25	Dec. 30	Nov. 25	Feb. 5	Jan. 20	Apr. 15	Mar. 20	May 20	Nov. 1	Dec. 15
		(35)		(70)		(85)		(60)		(45)	
5	NLR-2-1	Nov. 10	Nov. 30	Nov. 10	Jan. 15	Nov. 25	Feb. 10	Jan. 15	Mar. 30	Nov. 1	Nov. 25
		(20)		(65)		(75)		(65)	(25)	(25)	

Fig.3. Important phenological phases of cashew



were harvested earlier while varieties K-10-2 and K-16-1 were found to be late maturing types.

The leaf fall phase that followed harvesting also varied with varieties. The varieties K-10-2, Madakkathara-1 and NLR-2-1 had comparatively short leaf fall period while Anakkayam-1 and K-16-1, the leaf fall period extended to about 40 days. Leaf fall period is considered as a dormant phase of the vegetative growth.

4.1.2 Branching pattern

The tabulated data on the total number of n_0, n_1, n_2, n_3, n_4, n_5 and n_6 of ten seedlings, ten grafts and ten layers along with their per tree yield are presented in Tables 2, 3 and 4.

The branch bifurcation ratio, calculated as per steingraeber's formula for seedlings, grafts and layers are also presented in Table 5.

The bifurcation ratio of seedlings with regard to various order of branches was higher with respect to n_1, n_2, n_3 branches, the values were 0.42, 0.43 and 0.52 respectively. Grafts also showed a similar pattern. But in the case of layers, higher ratio was seen for n_3 and n_4, the values were 0.49 and 0.51 respectively.

The Productivity Weighted Branch Bifurcation Ratio (PWBBRn) for seedlings, grafts and layers were worked out and it was found that, it was the highest in the case of grafts (11.07) and lowest in seedlings (7.07). The data are presented in Table 6.

Table 2. Number of different orders of branches and yield in seedlings of cashew

Sl. No.	n_0	n_1	n_2	n_3	n_4	n_5	n_6			Total yield kg ha^{-1}
							Flowering	Non flowering	Total	
1	1	2	4	6	8	247	1015	1064	2079	10.2
2	1	2	2	5	6	230	1178	1383	2561	16.5
3	1	2	2	3	8	128	558	809	1367	11.4
4	1	2	3	6	8	86	550	447	997	17.1
5	1	2	3	5	7	178	1065	781	1846	16.2
6	1	2	3	7	24	131	842	499	1341	15.4
7	1	3	8	14	27	142	897	759	1656	11.6
8	1	3	10	18	49	199	840	1146	1986	20.1
9	1	4	12	24	56	147	340	780	1120	16.5
10	1	2	9	19	62	128	570	798	1328	12.1
Mean	1	2.4	5.6	10.7	25.5	161.6	785.5	846.6	1632.1	14.7

Table 3. Number of different orders of branches and yield in grafts of cashew

Sl. No.	n_0	n_1	n_2	n_3	n_4	n_5	n_6			Total yield kg ha^{-1}
							Flowering	Non flowering	Total	
1	1	2	4	12	38	125	732	732	1464	21.0
2	1	2	3	10	36	86	731	817	1548	23.2
3	1	1	1	4	18	85	551	466	1017	19.2
4	1	1	2	8	24	128	998	873	1871	20.4
5	1	2	3	12	39	164	1197	1071	2268	22.1
6	1	3	4	15	46	131	947	845	1792	18.6
7	1	1	4	13	41	141	784	663	1447	19.4
8	1	3	5	14	36	278	1322	1322	2644	20.5
9	1	2	6	16	40	271	1604	1452	3056	23.4
10	1	1	2	7	18	251	1778	1454	3232	23.8
Mean	1	1.8	3.4	11.1	33.6	166.0	1064.4	969.5	2033.9	21.16

Table 4. Number of different orders of branches and yield in layers of cashew

Sl. No.	n_0	n_1	n_2	n_3	n_4	n_5	n_6			Total yield kg ha^{-1}
							Flowering	Non flowering	Total	
1	0	4	8	21	32	192	896	931	1835	16.8
2	0	2	4	15	35	192	802	1043	1845	15.2
3	1	2	5	12	24	141	640	800	1440	19.5
4	1	3	7	15	32	82	429	488	917	20.1
5	0	2	6	11	20	265	1179	1179	2358	18.7
6	0	3	7	10	22	260	985	1164	2149	19.1
7	0	4	9	12	33	224	1547	960	2507	23.5
8	0	3	10	21	36	267	1688	1969	3651	19.2
9	0	3	12	18	41	167	833	833	1666	22.1
10	0	4	11	26	42	333	1348	2458	3806	15.2
Mean	0.2	3.0	7.9	16.1	31.7	212.3	1034.7	1183.3	2218.0	18.94

Table 5. Bifurcation ratio (Rb)n of various orders of branches in seedlings, grafts and layers of cashew

Branch orders	Seedlings	Grafts	Layers
$Rbn_0 : n_0+1$	0.0417	0.0556	0.0667
$Rbn_1 : n_1+1$	0.4286	0.5294	0.3371
$Rbn_2 : n_2+1$	0.5234	0.3063	0.4907
$Rbn_3 : n_3+1$	0.4196	0.3304	0.5079
$Rbn_4 : n_4+1$	0.1578	0.2024	0.1493
$Rbn_5 : n_5+1$	0.0990	0.0816	0.0957

Table 6. Productivity weighted branch bifuraction ratio (PWBBRn) of seedlings, grafts and layers of cashew

Planting materials	Method of deviation	Ratio
Seedlings	$\frac{14.7}{1632.1} \times 785.5$	7.075
Grafts	$\frac{21.16}{2033.9} \times 1064.4$	11.07
Layers	$\frac{18.94}{2218.0} \times 1034.7$	8.84

4.1.3 Leaf characteristics

4.1.3.1 Leaf area

The leaf area of the varieties studied is expressed as Leaf Area Index (LAI). The data on LAI of seedlings, grafts and layers of the five varieties are presented in Table 7.

The trees raised from seedlings showed a comparatively higher LAI in all the varieties ranging from 2.3 to 3 with K-10-2 registering the highest LAI.

4.1.3.2 Leaf colour

The observations on the colour of leaves of five varieties of cashew at different phenological phases are presented in Table 8.

The colour of the leaves at different phenological stages did not show much variations among the varieties. However, the mature leaves of varieties K-10-2 and K-16-1 were darker as compared to the other varieties.

4.1.3.3 Leaf texture

Observations on texture of leaves of 5 varieties are presented in Table 9. The ventral surface was soft and glabrous while the dorsal surface was leathery in all the varieties.

4.1.3.4 Shape of leaf

The shape of leaves of five varieites of cashew are presented in Table 10. The varieties K-10-2 and K-16-1 had bigger leaves.

Table 7. Leaf area per crown of five varieties of eight year old cashew as expressed as Leaf Area Index (LAI)

Type of planting materials	Varieties	LAI
Seedlings	Anakkayam-1	2.3
	Madakkathara-1	2.5
	K-10-2	3.1
	K-16-1	3.0
	NLR-2-1	2.4
Grafts	Anakkayam-1	2.2
	Madakkathara-1	2.3
	K-10-2	3.0
	K-16-1	2.8
	NLR-2-	2.3
Layers	Anakkayam-1	2.1
	Madakkathara-1	2.3
	K-10-2	2.9
	K-16-1	2.9
	NLR-2-1	2.2

Table 8. Colour of leaves of five varieties of cashew at different stages

Sl.No.	Varieties	Colour		
		Young stage	Mature stage	Senescence
1	Anakkayam-1	Light brown/ choclate	Light green	Yellow
2	Madakkathara-1	Light brown	Light green	Yellow
3	K-10-2	Light green	Dark green	Yellow
4	K-16-1	Light green	Dark green	Yellow
5	NLR-2-1	Light green	Light green	Yellow

Table 9. Texture of leaves of five varieties of cashew

Type of planting materials	Varieties	Colour of leaves	
		Ventral surface	Dorsal surface
Seedlings	Anakkayam-1	Soft/glabrous	Leathery
	Madakkathara-1	Soft/glabrous	Leathery
	K-10-2	Soft/glabrous	Leathery
	K-16-1	Soft/glabrous	Leathery
	NLR-2-1	Soft/glabrous	Leathery
Grafts	Anakkayam-1	Soft/glabrous	Leathery
	Madakkathara-1	Soft/glabrous	Leathery
	K-10-2	Soft/glabrous	Leathery
	K-16-1	Soft/glabrous	Leathery
	NLR-2-1	Soft/glabrous	Leathery
Layers	Anakkayam-1	Soft/glabrous	Leathery
	Madakkathara-1	Soft/glabrous	Leathery
	K-10-2	Soft/glabrous	Leathery
	K-16-1	Soft/glabrous	Leathery
	NLR-2-1	Soft/glabrous	Leathery

Table 10. Shape of leaves of five varieties of cashew

Name of variety	Shape of leaf
Anakkayam-1	Leaves are obovate with wavy margins and emarginate tip. Leaves usually 7-11 cm long and 1-8 cm broad.
Madakkathara-1	Leaves are obovate with wavy margins and emarginate tip. Leaves usually 7-11 cm long and 7-8 cm broad.
K-10-2	Leaves little more obtuse with emarginate tip. Margins are less wavy. Leaves usually 15-19 cm long and 8-10 cm broad.
K-16-1	Leaves obtuse. Size varies from 15-18 cm long and 9-10 cm broad.
NLR-2-1	Leaves obovate with slightly mucronate tip, 12-15 cm long and 6-8 cm broad.

4.1.4 Canopy characteristics

4.1.4.1 Height, spread, shape and surface area of the canopy

It has been observed that the canopies of seedlings, grafts and layers were of different shapes. In seedlings six classes of branches could be identified. These six classes are the main trunk, that has got an orthotropic rhythmically active terminal meristem which produces an indeterminate trunk bearing tiers of branches. These main trunk in the present study is designated as n_0 and from the n_0 main trunk, n_1 order of branches are produced in an acropetal succession. These n_1 order of branches eventhough are orthotrops in nature, in the course of development of the canopy, grow almost parallel to the surface of the soil. From the n_1, which again shows rhythmic growth n_2, n_3, n_4 and n_5 branches develop in the same sequence. From the n_1, n_2 branches are produced. Initially three or four or up to five branches are produced in one season, but in the final development only one or two will be remaining, the rest of the branches are aborted by self thinning (pruning). The resultant canopy incase of a seedling after a few years of growth will be like a hemisphere placed above a solid cylinder (Fig. 4).

Branching pattern of grafts was also examined critically. It was found that n_0 main trunk followed a rhythmic growth like that of the seedling. The n_1 order of branches unlike the ones in seedlings were acute in orientation. In the case of subsequent order of branches, the pattern was intensive ie. out of the total branches produced during each season, more number persisted and formed part of the canopy. The canopy which resulted due to this intensive branching was like a cone, placed above a small cylinder (Fig. 5).

Fig.4. Canopy architecture of a cashew seedling

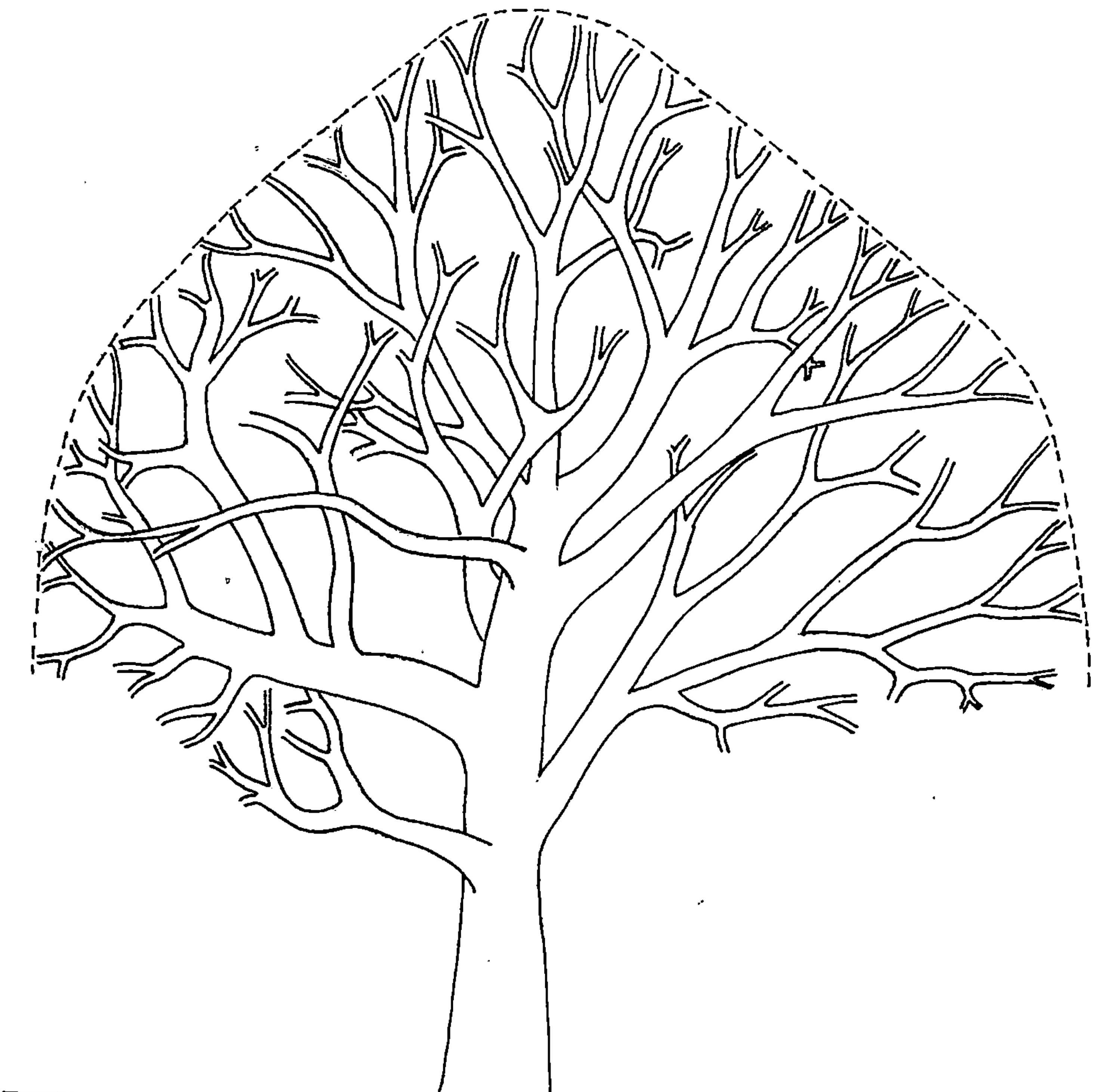
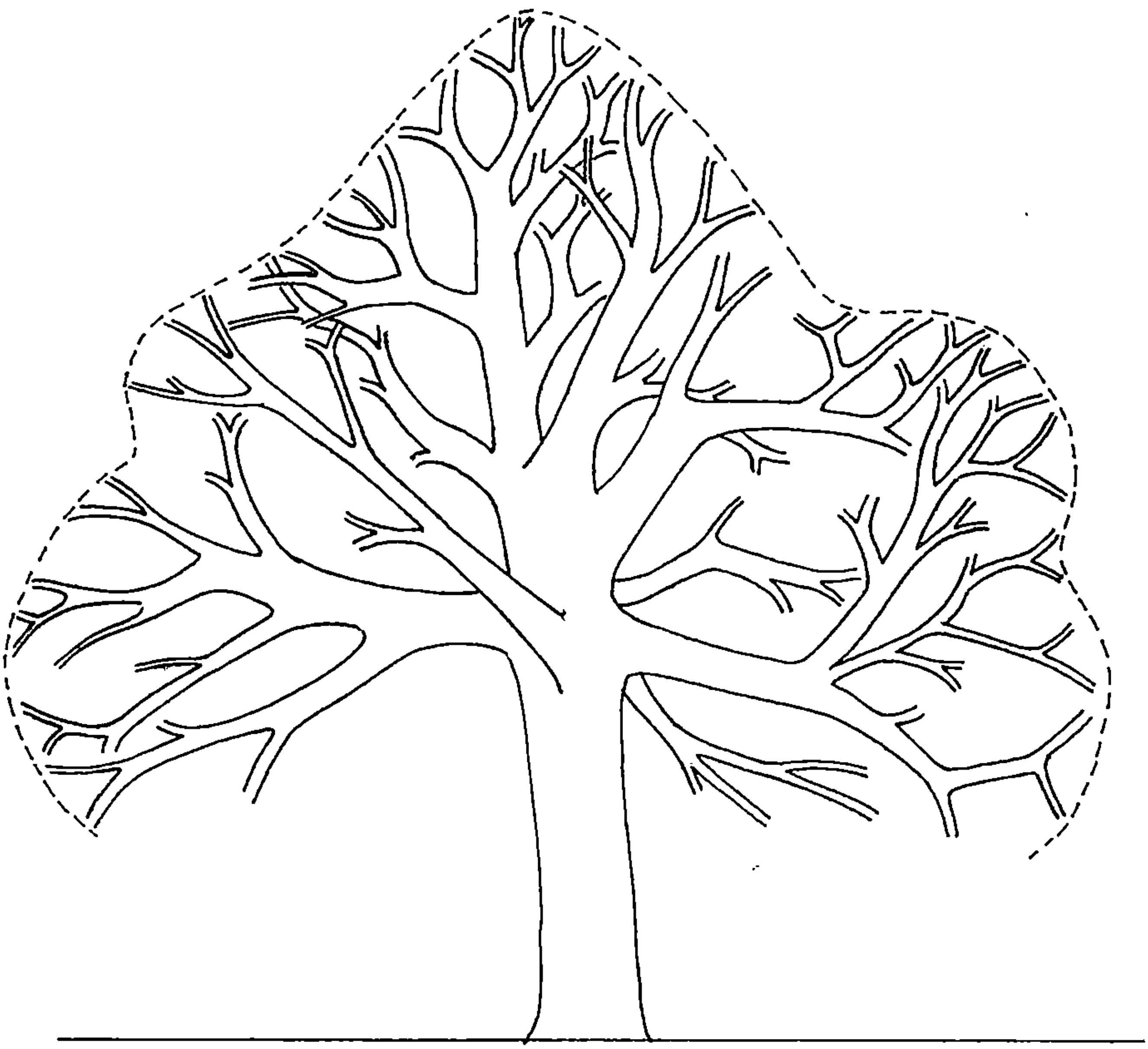


Fig.5. Canopy architecture of a cashew graft



In most of the layers, it was observed that n_0 main trunk was very short and the n_1 order of branches three to four in number became predominant. They got oriented more or less parallel to the ground surface and the subsequent development of the remaining orders of branches was intensive which resulted in a canopy that was compact and hemispherical (Fig. 6).

In mature cashew trees derived from seedlings, grafts and layers, it has been observed that the sixth order branches are the productive ones. The yearly growth of cashew shows a regular polymorphic branching cycle. Branches consists of both proleptic and sylleptic branches. Proleptic branches are lateral in position, produced after a period of latency, utilizing the reserves of the axis which bears it. These branches are usually short with basel internodes and bear scale leaves and are sturdier than the sylleptic branches (Fig. 7). Sylleptic branches are laterals with practically no reserves and depends mainly on the photosynthates of the leaves on them. They have long basal internodes and are delicate and slender as compared to proleptic branches (Fig. 7a and b). Proleptic branches during the flushing and flowering season become productive.

Sylleptic branches mostly perish in the next season. A few may remain in the coming season and from them proleptic branches may be produced rhythmically. This cycle is repeated.

It was found that pruning of sixth order and fifth order branches encouraged the production of proleptic branches which are sturdy and productive (Fig. 8 and 9 and Plates I and II).

Fig.6. Canopy architecture of a cashew layer

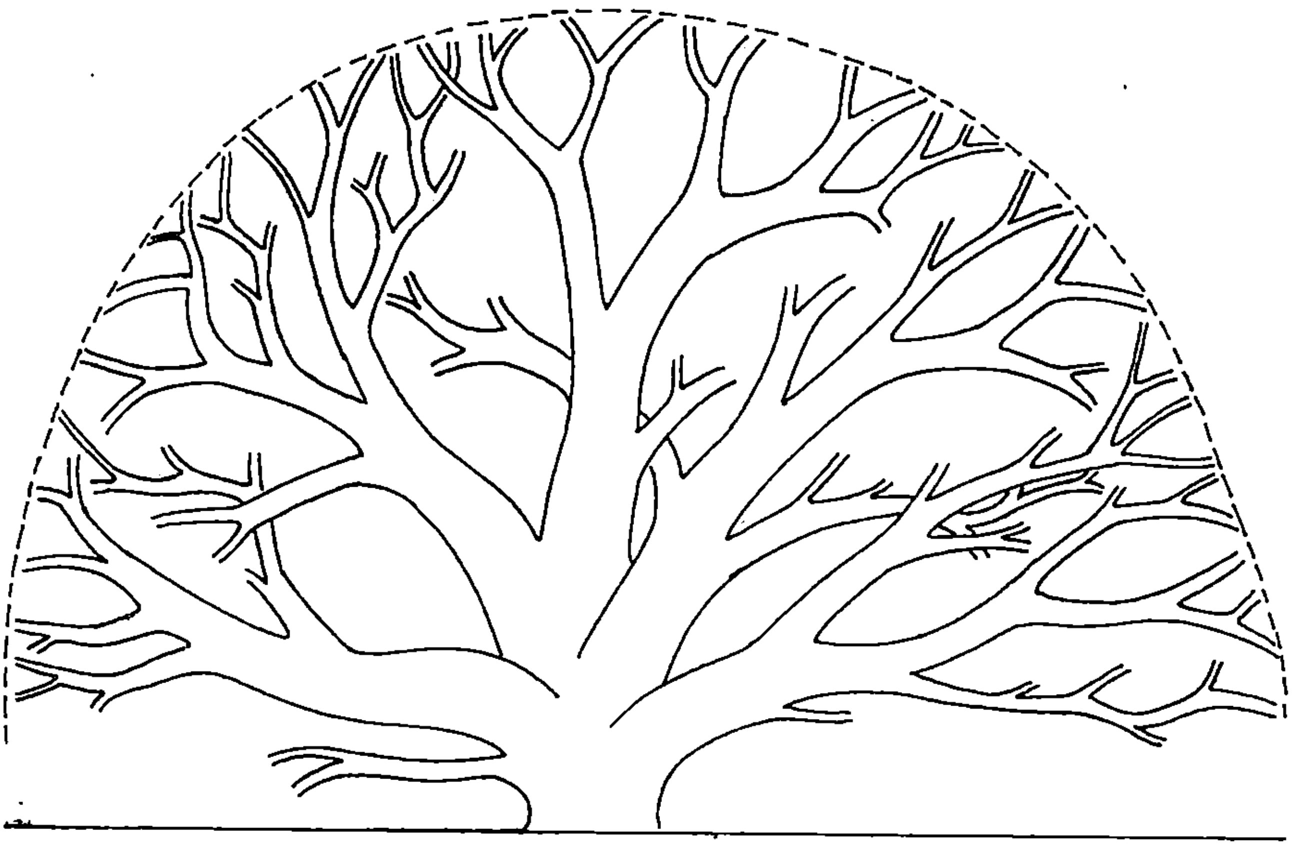


Fig.7(a). Branching pattern in cashew

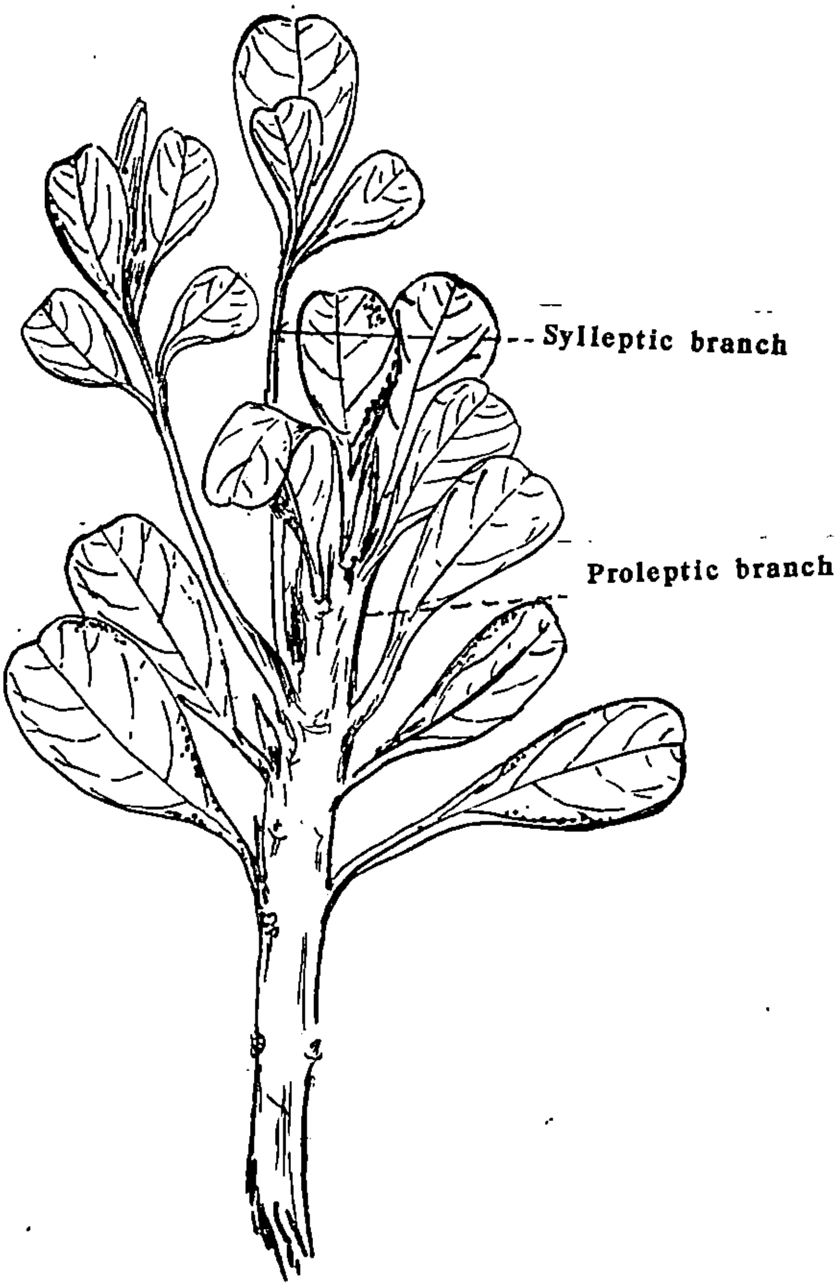


Fig.7(b). Branching pattern in cashew

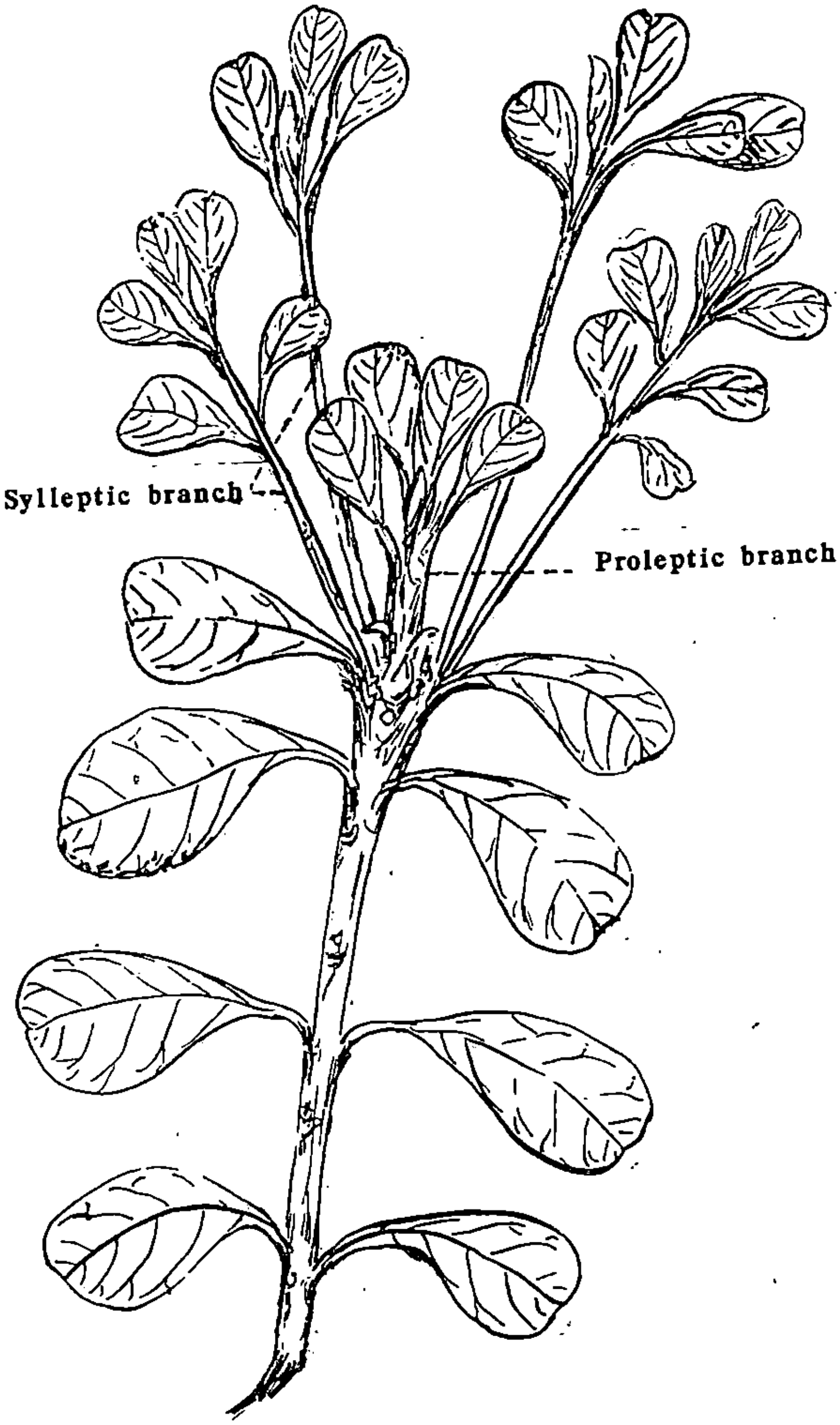


Fig.8. Proleptic branches produced after pruning of 5th order branches

Fig.9. Proleptic branches produced after pruning of 6th order branches

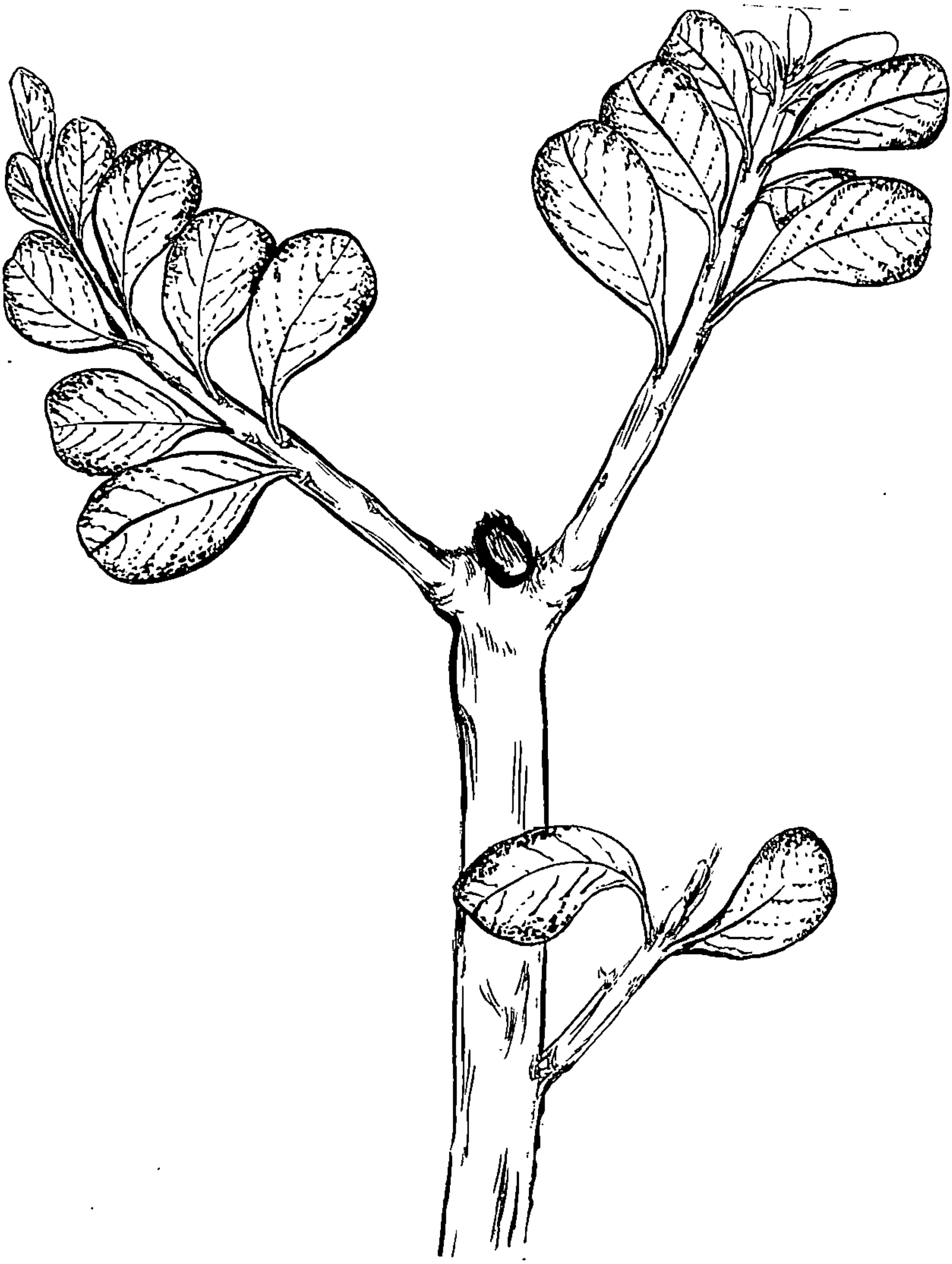


Plate I. Proleptic branches produced after pruning of 6th order branches

Plate II. Proleptic branches produced after pruning of 5th order branches


N6 Branches Pruned


N5 Branches Pruned

4.1.4.2 Yield efficiency of the canopies of seedlings grafts and layers

The canopy characteristics of seedlings, grafts and layers of the two varieties namely Anakkayam-1 and Madakkathara-1 were assessed and the yield of the trees also was recorded. For every treatment five trees each of both the varieties were used. From the spread and height of the canopy, the surface area of the canopy was calculated. From this the squaremetre yield efficiency was worked out. The data obtained were statistically analysed and are presented in Table 11. It is seen that varieties did not differ significantly with respect to canopy height, canopy spread, canopy surface area and yield. However, seedlings, grafts and layers differed significantly with respect to canopy height, canopy spread, canopy surface area and yield (Table 12). With respect to height, seedlings differed significantly from grafts and layers. However, grafts and layers did not show significant difference. With regard to canopy spread, seedlings and layers were on par and both differed significantly from grafts. The same trend was shown with respect to canopy surface area. As far as the final yield was concerned, grafts yielded significantly higher quantity of nuts as compared to seedlings and layers which were more or less on par. The worked out per squaremeter yield efficiency was the highest in grafts amounting to 0.277 kg. The yield efficiency of seedlings and layers was on par. With respect to yield efficiency, the varieties did not differ significantly.

4.1.4.3 Height of main stem

The height of the main trunk from ground level at which canopy begins, of seedlings grafts and layers were measured. The Table 13 shows the mean length of 10 replications of seedlings, grafts and layers of the two varieties.

Table 11. Canopy characteristics of seedlings, grafts and layers of Anakkayam-1 and Madakkathara-1

Treatments	Canopy height		Canopy spread(cm)		Canopy surface area (m^{-2})		Yield kg $tree^{-1}$		Yield efficiency kg m^{-2}	
	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1
Seelings	4.2	4.66	6.16	5.84	86.16	86.53	5.94	5.36	0.070	0.063
Grafts	3.5	3.60	3.92	3.70	41.98	38.76	11.30	10.56	0.279	0.276
Layers	3.9	3.60	6.02	5.68	95.87	81.97	6.88	6.32	0.066	0.080
Grand mean	3.91		5.22		71.88		7.73			
Varietal mean	3.88	3.95	5.37	5.07	74.67	69.09	8.04	7.41		
CD	0.47		0.87		21.04		1.95		0.059	

Table 12. Canopy characteristics of seedlings, grafts and layers irrespective of varieties

Treatments	Canopy height (m)	Canopy spread (m)	Canopy surface area (m^{-2})	Yield kg ha-1	Yield efficiency kg m^{-2}
Seedlings	4.43	6.00	86.343	5.65	0.066
Grafts	3.55	3.81	40.373	10.93	0.277
Layers	3.75	5.85	88.919	6.60	0.073
CD	0.47	0.87	21.04	1.95	0.059
Grand mean	3.91	5.22	71.88	7.73	0.139

It was found that trees raised from seedlings showed a higher trunk length as compared to grafts and layers. But because of the branching pattern and subsequent hemisphereical development of the canopy, the canopy got closed and the availability of reflected light was not significantly enhanced.

4.1.4.4 Length and girth of different orders of branches

The length and girth of different orders of branches of the varieties included for the study were measured and the data are presented in Table 14 and 15.

It was found that, as the branch number increased, the length and the thickness of the branches decreased progressively in both the varieties observed.

4.1.4.5 Angle of different orders of branches

The angles of the different orders of branches from the main stem of seedlings, grafts and layers are presented in Table 16.

It is seen that the first order branches of seedlings and layers were at an angle of about 85°. Subsequently in the case of layers, the angles become more acute as compared to seedlings. The resultant canopy in both cases was hemi-spherical in nature. In grafts, the initial branching was at an angle of about 65° from the main stem, little more acute than seedlings and layers. Subsequent branches followed a similar pattern as was seen in layers and seedlings which finally resulted in a canopy that is spear shaped.

Table 13. Height of main trunk from ground level at which crown of tree begins (meters). Mean of 10 replications

	Anakkayam-1	Madakkathara-1
Seedlings	1.8	2.5
Grafts	1.6	2.0
Layers	0.75	0.80

Table 14. Length of branches in different branch orders in seedlings, grafts and layers (cm)

Branch order	Types of planting materials			Mean
	Seedlings	Grafts	Layers	
0	143.70	58.50	64.50	88.90
1	66.60	45.30	180.20	97.37
2	43.40	37.60	134.90	71.97
3	38.80	32.80	98.70	56.77
4	33.70	29.70	77.30	46.90
5	24.90	23.90	57.80	35.53
6	14.10	14.20	18.70	15.67

CD (0.05) for planting materials 6.83
CD (0.05) for branch order 10.43

Table 15. Girth of branches in different branch orders in seedlings, grafts and layers (cm)

Branch order	Types of planting materials			Mean
	Seedlings	Grafts	Layers	
0	74.90	64.80	96.30	78.67
1	56.00	49.40	52.30	52.57
2	44.00	39.10	40.40	41.17
3	30.20	31.70	29.10	30.33
4	21.60	23.80	20.60	22.00
5	11.90	14.60	11.30	12.60
6	2.77	3.10	2.72	2.86

CD (0.05) for planting materials 2.53
CD (0.05) for branch order 3.86

Table 16. Angle of branch orders (mean of 10 in degrees)

Branch order	Seedlings	Grafts	Layers
n_1	85	65	85
n_2	65	50	75
n_3	45	45	65
n_4	35	35	45
n_5	30	25	35
n_6	25	20	30

4.2 Yield and yield attributes

4.2.1 Path analysis of major yield components

The data pertaining to 30 trees consisting of grafts, layers and seedlings, to determine the major yield components namely height, spread, number of various orders of branches, number of flowering and non flowering n_6 laterals, canopy surface area, percentage of bisexual flowers, number of leaves per n_6 lateral, number of nuts per panicle and nut size were statistically analyzed and presented in Table 17.

It is seen from the table that the yield components, namely height, number of n_2, n_4 and n_6 flowering branches and number of nuts per panicle and nut size have direct significant contribution to the yield. Among these, n_6 flowering laterals have the direct contribution of 0.71 followed by n_2 which has a value of 0.51 and height, which is 0.34.

The direct effect of characters such as spread, number of n_0, n_1, n_3 and n_5 and total canopy surface area and the number of n_6 laterals were found to contribute negatively to the final yield.

It is also seen that height indirectly contributes through number of n_3 and n_4 branches. Then number of n_2 branches have indirect effect through n_4 and n_6 flowering laterals. Number of n_4 branches have indirect effect through n_2.

4.2.2 Correlation studies

The data pertaining to the number of n_0, n_1 branches and their influence on yield are presented in Tables 18 and 19. Since the variable was dichotomous, the

Table 17. The effect of different yield components of cashew (Path analysis)

	Direct effect	Height (cm)	Spread	No. of branches per tree						Flowering laterals n_6	Non flowering laterals	Canopy surface area(m^2)	Percentage of bisexual flowers	No. of leaves/ n_6 panicle	No. of nuts/ panicle	Nut size	Correlation with yield
				n_0	n_1	n_2	n_3	n_4	n_5								
Height (cm)	0.34	-	-0.21	0.14	-0.01	-0.08	0.16	-0.28	0.01	-0.18	-0.001	-0.04	-0.002	0.01	-0.05	0.07	-0.08
Spread (Dia) (cm)	-0.41	0.18	-	0.29	-0.08	0.19	-0.03	-0.10	0.08	-0.40	-0.01	-0.06	-0.003	0.03	-0.08	0.14	-0.26
n_0	-0.49	-0.01	0.24	-	0.09	-0.26	0.24	-0.04	-0.05	0.31	0.01	0.09	0.002	-0.02	0.07	-0.17	-0.06
n_1	-0.19	0.01	-0.17	0.24	-	0.40	-0.40	0.17	0.04	-0.25	-0.004	-0.06	-0.002	0.01	-0.03	0.15	-0.08
n_2	0.51	-0.05	-0.15	0.25	-0.15	-	-0.49	0.28	0.04	-0.29	-0.004	-0.06	-0.001	0.01	-0.04	0.15	0.003
n_3	-0.58	-0.10	-0.02	0.20	-0.13	0.43	-	0.31	0.01	-0.15	0.003	-0.05	-0.001	0.004	-0.02	0.11	0.08
n_4	0.45	-0.18	0.09	0.04	-0.07	0.32	-0.47	-	-0.005	0.02	0.01	-0.004	0.001	-0.006	0.034	0.03	0.25
n_5	-0.23	-0.01	0.14	-0.09	0.03	-0.09	0.03	0.71	-	0.45	0.01	0.02	0.0004	-0.005	0.05	-0.08	0.23
n_6 flowering laterals	0.71	-0.09	0.23	-0.21	0.07	-0.21	0.12	-0.01	-0.15	-	0.01	0.05	0.002	-0.01	0.01	-0.11	0.53
n_6 nonflowering laterals	0.02	-0.02	0.24	-0.15	0.04	-0.09	-0.08	0.13	-0.14	0.43	-	0.01	0.001	-0.02	0.06	-0.08	0.36
Canopy surface area (m^2)	-0.13	0.10	-0.20	0.33	-0.08	0.25	-0.23	0.01	0.03	-0.26	-0.003	-	-0.004	0.009	-0.07	0.15	-0.10
Percentage of bixexual flowers	0.01	-0.15	0.26	-0.21	0.06	-0.14	0.09	0.09	-0.01	0.27	0.006	0.08	-	-0.02	0.10	-0.08	0.35
No. of leaves per n_6 lateral	-0.05	-0.09	0.26	-0.16	0.04	-0.15	0.05	0.06	-0.02	0.22	0.01	0.02	0.002	-	0.04	-0.05	0.19
No. of nuts per panicle	0.20	-0.09	0.16	-0.17	0.03	-0.10	0.07		-0.05	0.36	0.01	0.05	0.003	-0.01	-	-0.09	0.44
Nut size	0.24	0.10	-0.23	0.35	-0.12	0.32	-0.27		0.08	-0.32	-0.01	-0.008	-0.002	0.01	-0.08	-	0.04

correlation was not attempted with respect to this variable. It is found that the trees with no n_0 branches significantly out yielded the trees with one n_0 branch.

Number of n_1 branches varied from 1 to 4 only and since the variability was not sufficient to work out correlation, the analysis of varience was employed to find out the influence of n_1 branches on yield. It is found that out of the 30 trees observed, there were three trees with single n_1, 17 with 2 n_1 branches and 8 with 3 n_1 branches and 2 with 4 n_1 branches. The yield means of the four classes were signficantly different and shown in the Table 19.

For the remaining orders of branches, there was sufficient variability available and correlation coefficients with yield were worked out and are presented in Table 20. It is found that there exist a high significant correlation between the number of n_2 and n_3 branches and yield where as the correlation between n_4, n_5 and n_6 branches and yield were found to be not significant.

4.3 Canopy manipulation

4.3.1 Observations on days to flushing, growth increment and span of flowering

4.3.1.1 Days taken to flushing

The days taken for flushing after pruning did not differ significantly in the two varieties studied. The days taken for flushing where the removal of 25 per cent of n_6 and n_5 order branches were done was similar to that of control. When 25 per cent of n_6 and n_5 order branches were removed flushing could be observed after 33.90 and 33.60 days respectively. The treatments where 50 per cent and 100 per cent pruning was done, flushing was found to be very early (Table 21). Cashew

Table 18. Effect of n_0 branches on yield

Number of N_0 branches	Number of cases	Mean yield per tree (kg)
0	11	15.53
1	19	9.33

NS

Table 19. Effect of n_1 branches on yield

Number of N_1 branches	Number of cases	Mean yield per tree (kg)
1	3	11.67
2	17	9.13
3	8	15.95
4	2	15.15

NS

Table 20. Effects of different orders of branches on yield of cashew

Different orders of branches	Correlation coefficient with yield
N_2	0.426**
N_3	0.479**
N_4	0.244
N_5	0.031
N_6	0.205

** Significant at 1 per cent level

layers with 25, 50 and 100 per cent n_6 and n_5 order of branches removed are clearly depicted in Plates III to XVI.

4.3.1.2 Growth increment

The growth increment (interms of length) of shoots in different levels of pruning is presented in Table 22. In the treatment where removal of 100 per cent n_4 branches were done, the growth increment (increase in length) was found to be the highest in all the three years (170.0 cm, 260.0 cm and 40.2 cm in the first, second and third year, respectively), followed by the treatment where removal of 100 per cent n_6 branches was done. The growth increment was found to be the highest in the second year after pruning in all the treatments.

4.3.1.3 Days taken to flowering

The days taken from pruning to flowering did not differ significantly among the varieties. The treatment, where 100 per cent n_6 branches was removed recorded the shortest time for flowering (68.90). Flowering in the fifth order branches which were subjected to 50 per cent and 100 per cent pruning was later than that of control.

4.3.1.4 Total number of laterals and flowering laterals

The total number of laterals per squarmetre observed in different pruning treatments and during the first, second and third year after pruning are presented in Table 24.

Significant differences could be observed among the different pruning treatments and also between varieties. Anakkayam-1 recorded more number of laterals than Madakkathara-1.

Table 21. Days taken for flushing after pruning as influenced by various pruning treatments and varieties

Treatments	Anakkayam-1	Madakkathara-1	Mean
1. Removal of 25 per cent of n_6 order	96.80	98.20	97.50
2. Removal of 50 per cent of n_6 order	32.80	35.00	33.90
3. Removal of 100 per cent of n_6 order	34.00	35.40	34.70
4. Removal of 25 per cent of n_5 order	96.80	98.00	97.40
5. Removal of 50 per cent of n_5 order	33.40	33.80	33.60
6. Removal of 100 per cent of n_5 order	43.00	42.60	42.80
7. Removal of 100 per cent of n_4 order	73.00	74.00	73.60
8. Without any removal	96.40	100.40	98.40
CD(0.05)	4.39		

Table 22. Growth increment (in terms of length) of shoots in different levels of pruning

Treatments	First year (cm)	Second year (cm)	Third year (cm)
1. Removal of 25 per cent of n_6 order	24.20	28.20	31.30
2. Removal of 50 per cent of n_6 order	21.20	26.30	28.20
3. Removal of 100 per cent of n_6 order	30.10	29.10	28.50
4. Removal of 25 per cent of n_5 order	21.20	21.30	35.30
5. Removal of 50 per cent of n_5 order	20.60	28.20	36.20
6. Removal of 100 per cent of n_5 order	92.50	130.00	40.10
7. Removal of 100 per cent of n_4 order	170.00	260.00	40.20
8. Without any removal (control)	16.10	33.20	21.30

Table 23. The days taken from pruning to flowering as influenced by various pruning treatments and varieties

Treatments	Anakkayam-1	Madakkathara-1	Mean
1. Removal of 25 per cent of n_6 order	89.40	89.00	89.20
2. Removal of 50 per cent of n_6 order	94.40	93.80	94.10
3. Removal of 100 per cent of n_6 order	69.40	68.40	68.90
4. Removal of 25 per cent of n_5 order	94.60	94.00	94.30
5. Removal of 50 per cent of n_5 order	102.60	101.80	102.20
6. Removal of 100 per cent of n_5 order	109.20	107.40	108.30
7. Removal of 100 per cent of n_4 order	-	-	-
8. Without any removal (control)	100.00	98.20	99.10
CD (0.05)	11.33		

Plate III. A cashew layer with 25 per cent n_6 order of branches removed (flushing stage)

Plate IV. A cashew layer with 25 per cent n_6 order of branches removed (flowering stage)


NG25

Plate V. A cashew layer with 50 per cent of n_6 order of branches removed (flushing stage)

Plate VI. A cashew layer with 50 per cent n_6 order of branches removed (flowering stage)


No. 50

Plate VII. A cashew layer with 100 per cent n_6 order of branches removed

Plate VIII. A cashew layer with 100 per cent n_6 order of branches removed (flushing stage)

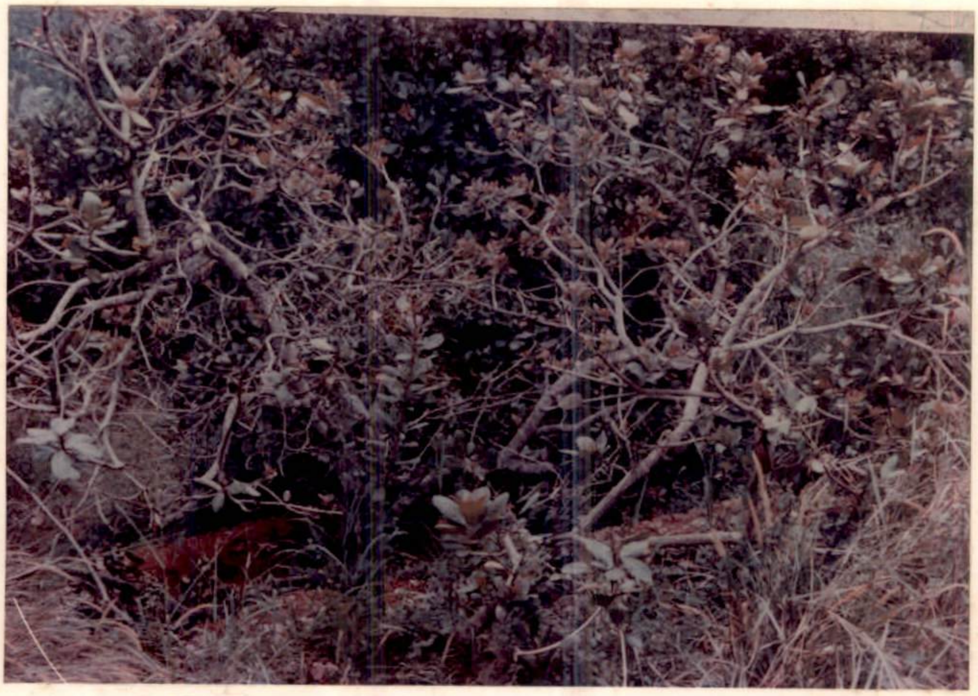


Plate IX. A cahsew layer with 100 per cent n_6 order of branches removed (flowering stage)

Plate X. A cashew layer with 25 per cent n_5 order of branches removed (flushing stage)

Plate XI. A cashew layer with 25 per cent n_5 order of branches removed (flowering stage)

Plate XII. A cashew layer with 50 per cent n_5 order of branches removed (flushing stage)


No 50

Plate XIII. A cashew layer with 50 per cent n_5 order of branches removed (flowering stage)

Plate XIV. A cashew layer with 100 per cent n_5 order of branches removed

Plate XV. A cashew layer with 100 per cent n_5 order of branches removed (flushing stage)

Plate XVI. Close up view of a cashew layer with new flushes (100 per cent n_5 order of branches removed)


Ns

During the first year after pruning, more number of laterals could be observed for the treatments where 100 per cent removal of branches was done as compared to 25 per cent and 50 per cent, irrespective of the branch order. The number of laterals was observed to be the highest in the treatment where 100 per cent removal of n_4 branches were done.

In the second year after pruning, the total number of laterals was the lowest in the treatment where 100 per cent of n_4 branches were removed (13.1). Pruning of 50 per cent of n_5 branches were found to be similar to that of control.

In the third year after pruning, the number of laterals increased and most of the pruning treatments were similar to control. Pruning of 100 per cent n_5 branches although showed increased number of laterals than in the second year, exhibited the lowest number of laterals, among all the treatments (35.10).

The number of flowering laterals per square metre during the first, second and third year after pruning in various pruning treatments are given in Table 26.

There was significant difference among the various pruning treatments in all the years. Significant differences could be detected among the varieties also. Anakkayam-1 recording more number of flowering laterals per squaremetre. In the first year after pruning, pruning of 100 per cent n_5 branches did not produce any flowering laterals, while the treatment where 50 per cent of n_5 branches were pruned, produced the highest number of flowering laterals (68.4%).

The treatments involving 100 per cent pruning in all the branch orders registered lower number of flowering laterals per squaremetre in the first, second and third year after pruning.

In the second year after pruning, the number of flowering laterals was increased, with the treatments 25 and 50 per cent pruning of n_5 branches recording highest number. Twenty five and 50 per cent pruning of n_6 branches also recorded higher number of flowering laterals. The treatment of 100 per cent pruning of n_4 branches recorded the lowest number of flowering laterals (7.9) but the percentage of flowering laterals was 61 per cent, which was more than that of control.

In the third year after pruning, the percentage of flowering laterals decreased as compared to the second year after pruning in all the treatments. As in the second year, pruning of n_5 branches at 25 and 50 per cent level recorded highest number of flowering laterals of 23.3 and 24.0 respectively.

4.3.1.5 Span of flowering

In the first year after pruning, the flowering span was the highest, where 100 per cent pruning of n_5 branches were done (86.70 days) followed by 100 per cent pruning of n_6 branches (84.70 days), registering an increase in the flowering span by 9-10 days compared to control and nearly 15 days more than the pruning treatments.

The flowering span during the second and third year after pruning registered a similar trend. The pruning treatments ranged from 70.80 days to 76.00 days. Significant variation could not be observed between the various treatments.

Table 24. Total number of laterals per squaremetre in various pruning treatments

Treatments	First year		Second year		Third year	
	Anakkayam-1	Madakkathara	Anakkayam-1	Madakkathara	Anakkayam-1	Madakkathara
1. Removal of 25 per cent of n_6 order	36.4	33.8	35.6	33.20	50.0	44.6
2. Removal of 50 per cent of n_6 order	32.6	30.4	33.0	31.20	47.4	41.6
3. Removal of 100 per cent of n_6 order	42.8	40.8	33.6	28.4	47.2	42.2
4. Removal of 25 per cent of n_5 order	36.2	33.4	36.4	34.2	47.8	41.8
5. Removal of 50 per cent of n_5 order	36.2	33.2	47.6	44.2	41.8	37.6
6. Removal of 100 per cent of n_5 order	47.6	44.0	42.4	40.4	42.2	38.2
7. Removal of 100 per cent of n_4 order	50.00	45.2	14.6	11.6	37.8	32.4
8. Without any removal (control)	46.0	44.2	49.2	44.0	49.6	43.6
Mean	41.4	38.3	35.8	32.9	45.48	40.25
CD (0.05) for treatment	1.96		1.40		1.85	
CD (0.05) for varieties	0.98		0.70		0.92	

Table 25. Total number of laterals per squaremetre in various pruning treatments irrespective of varieties

Treatments	First year	Second year	Third year
1. Removal of 25 per cent of n_6 order	35.1	34.4	47.3
2. Removal of 50 per cent of n_6 order	31.5	32.1	44.5
3. Removal of 100 per cent of n_6 order	41.5	31.0	44.7
4. Removal of 25 per cent of n_5 order	34.8	35.3	44.8
5. Removal of 50 per cent of n_5 order	34.7	45.9	39.7
6. Removal of 100 per cent of n_5 order	45.8	41.4	40.2
7. Removal of 100 per cent of n_4 order	47.6	13.1	35.1
8. Without any removal (control)	45.1	46.6	46.6
CD (0.05) for treatments	1.96	1.40	1.85

Table 26. Total number of flowering laterals per squaremetre in various pruning treatments

Treatments	First year		Second year		Third year	
	Anakkayam-1	Madakka-thara-1	Anakkayam-1	Madakka-thara-1	Anakkaryam-1	Madakka-thara-1
1. Removal of 25 per cent of n_6 order	23.6	19.6	23.8	19.4	23.6	19.6
2. Removal of 50 per cent of n_6 order	23.2	19.6	24.2	19.4	23.2	19.6
3. Removal of 100 per cent of n_6 order	18.6	17.0	18.2	15.6	18.6	17.0
4. Removal of 25 per cent of n_5 order	25.2	21.4	25.4	21.6	25.2	21.4
5. Removal of 50 per cent of n_5 order	25.4	22.6	25.0	21.8	25.4	22.6
6. Removal of 100 per cent of n_5 order	22.2	20.4	21.8	20.4	22.2	20.4
7. Removal of 100 per cent of n_4 order	-	-	8.6	7.2	15.6	14.0
8. Without any removal	20.2	18.8	21.8	19.0	20.2	18.8
Mean	15.43	13.36	21.85	18.58	21.75	19.18
CD(0.05) for treatment	1.02		1.097		1.13	
CD(0.05) for varieties	0.51		0.55		0.56	

Table 27. Number of flowering laterals per squaremetre in various pruning treatments irrespective of varieties

Treatments	First year	Second year	Third year
1. Removal of 25 per cent of n_6 order	17.4	21.6	21.6
2. Removal of 50 per cent of n_6 order	17.1	21.8	21.4
3. Removal of 100 per cent of n_6 order	8.9	16.9	17.8
4. Removal of 25 per cent of n_5 order	19.5	23.4	23.3
5. Removal of 50 per cent of n_5 order	22.8	23.4	24.0
6. Removal of 100 per cent of n_5 order	14.0	21.1	21.3
7. Removal of 100 per cent of n_4 order	-	7.9	14.8
8. Without any removal	15.2	20.4	19.5
CD(0.05) for treatment	1.02	1.097	1.13

Table 28. Flowering span (days) as influenced by pruning treatments

Treatment	First year		Second year		Third year	
	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1
1. Removal of 25 per cent of n_6 order	69.0	80.4	70.4	81.2	70.4	81.2
2. Removal of 50 per cent of n_6 order	66.0	74.2	70.6	81.4	70.6	81.4
3. Removal of 100 per cent of n_6 order	79.4	90.0	67.4	77.8	67.4	77.8
4. Removal of 25 per cent of n_5 order	70.8	82.0	69.4	79.6	69.4	79.6
5. Removal of 50 per cent of n_5 order	66.0	73.80	65.0	76.6	65.0	76.6
6. Removal of 100 per cent of n_5 order	81.6	91.8	70.4	81.4	70.4	81.4
7. Removal of 100 per cent of n_4 order	-	-	70.0	80.4	70.0	80.4
8. Without any removal	75.2	82.2	72.4	82.8	72.4	82.8
Mean	63.51	71.81	69.45	80.15	69.45	80.15
CD(0.05) for treatment	1.91		2.26		2.26	
CD(0.05) for varieties	0.95		1.13		1.13	

Table 29. Flowering span (days) as influenced by pruning treatments irrespective of varieties

Treatments	First year	Second year	Third year
1. Removal of 25 per cent of n_6 order	74.7	75.8	75.8
2. Removal of 50 per cent of n_6 order	70.1	76.0	76.0
3. Removal of 100 per cent of n_6 order	84.7	72.6	72.6
4. Removal of 25 per cent of n_5 order	76.4	74.5	74.5
5. Removal of 50 per cent of n_5 order	69.9	70.8	70.8
6. Removal of 100 per cent of n_5 order	86.7	75.9	75.9
7. Removal of 100 per cent of n_4 order	-	75.2	75.2
8. Without any removal	78.7	77.6	77.6
CD(0.05) for treatments	1.91	2.26	2.26

4.3.1.6 Percentage of bisexual flowers

The percentage of bisexual flowers as influenced by various pruning treatments are presented in Tables 30 and 31.

Pruning, in general enhanced the percentage of bisexual flowers. Significant differences could be observed between the treatments.

In the first year after pruning, removal of 25 and 50 per cent of n_5 branches registered highest number of bisexual flowers followed by removal of 25 and 50 per cent of n_6 branches. The control trees had the lowest percentage of bisexual flowers (11.19%).

In the second year, after pruning also pruning treatments registered increased percentage of bisexual flowers. Hence highest percentage of bisexual flowers was observed for removal of 25 per cent and 50 per cent n_6 branches while the lowest percentage was in the control trees (11.65%).

A similar trend was observed in the third year also, where the control trees showed 13.21 percentage of bisexual flowers. The pruning treatments leading to enhanced number of bisexual flowers (nearly 23%).

4.3.1.7 Yield

The yield of the experimental trees for the following three years after imposing the treatments were recorded. The per tree yield under various treatments during the three years after pruning is presented in Table 32 for the two varieties. As far as yield was concerned, varieties did not differ significantly. However, there was significant difference among the various teatments (Table 32 and 33).

Table 30. Percentage of bisexual flowers as influenced by pruning treatments and varieties

Treatments	First year		Second year		Third year	
	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1
1. Removal of 25 per cent of n_6 order	21.98	22.2	27.74	26.92	23.74	21.34
2. Removal of 50 per cent of n_6 order	26.10	23.16	27.20	22.64	26.40	21.08
3. Removal of 100 per cent of n_6 order	16.80	18.50	20.48	20.44	24.24	20.04
4. Removal of 25 per cent of n_5 order	24.70	25.50	23.78	25.22	27.12	24.04
5. Removal of 50 per cent of n_5 order	25.46	25.43	25.74	22.32	22.84	20.66
6. Removal of 100 per cent of n_5 order	21.90	18.24	22.42	22.90	22.74	19.80
7. Removal of 100 per cent of n_4 order	-	-	23.54	19.42	25.32	22.56
8. Without any removal (control)	13.03	9.40	12.52	10.78	14.70	11.72
CD(0.05) for treatment	2.99		2.53		2.43	
CD(0.05) for varieties	1.40		1.32		1.216	

Table 31. Percentage of bisexual flowers as influenced by pruning treatments irrespective of varieties

Treatments	First year	Second year	Third year
1. Removal of 25 per cent of n_6 order	22.09	27.33	22.54
2. Removal of 50 per cent of n_6 order	24.63	24.92	23.74
3. Removal of 100 per cent of n_6 order	17.64	20.46	22.14
4. Removal of 25 per cent of n_5 order	25.07	24.50	25.58
5. Removal of 50 per cent of n_5 order	25.44	24.03	21.75
6. Removal of 100 per cent of n_5 order	20.07	22.66	21.27
7. Removal of 100 per cent of n_4 order	-	21.48	23.94
8. Without any removal (control)	11.19	11.65	13.21
CD(0.05) for treatments	2.99	2.53	2.43

During the first year after canopy manipulation treatments 1, 2, 4 and 5 were on par with the control but these treatments were significantly differed from the rest of the treatments. Removal of 100 per cent n_4 order branches did not flower in the first year.

During the second year, treatment No.4 gave the highest yield (14.49 kg) which was significantly higher from the control (10.20 kg). But during that year treatment no.4 was not significantly higher with the yields of T_1, T_2, T_3 and T_5. Eventhough the treatments 1, 2, 3, 4 and 5 did not differ significantly among themselves, they were definitely superior to 6, 7 and the control. Removal of 100 per cent n_5 and n_4 registered the lowest yields of 8.16 and 6.57 kg respectively.

During the third year also treatments 2, 3, 4 and 5 gave higher yield as compared to the control and treatment number 6 and 7.

4.3.1.8 Leaf Area Index after pruning

Leaf Area Index of the trees which were subjected to pruning was measured at the time of flushing during the first year after pruning and the data are presented in Table 34.

When the LAI of the trees, where pruning treatments were imposed, was measured, it was found that treatment No.5 (pruning of 50% of n_5 branches) which gave the highest yield registered a leaf area index of around 2.5 in both the varieties. In the control leaf area index was around three.

Table 32. Mean yield (kilograms) per tree of Anakkayam-1 and Madakkathara-1 under various treatments during the three years after prunning

Sl. No.	Treatments	First year		Second year		Third year	
		Anakka-yam-1	Madakka-thara-1	Annakka-yam-1	Madakka-thara-1	Anakka-yam-1	Madakka-thara-1
1	Removal of 25 per cent of n_6 orders	10.56	11.04	12.22	12.26	12.28	13.10
2	Removal of 50 per cent of n_6 orders	11.72	10.62	12.78	12.74	15.18	15.26
3	Removal of 100 per cent of n_6 orders	4.36	4.66	11.98	11.76	13.36	12.78
4	Removal of 25 per cent of n_5 orders	13.52	13.30	14.76	14.22	16.78	16.40
5	Removal of 50 per cent of n_5 orders	10.56	10.60	11.90	11.78	13.66	13.78
6	Removal of 100 per cent of n_5 orders	2.10	1.88	7.96	8.36	7.78	10.66
7	Removal of 100 per cent of n_4 orders	0.00	0.00	6.82	6.32	9.30	8.72
8	Control	10.48	10.60	10.20	10.20	12.62	11.42
Mean		7.91	7.84	11.08	10.96	12.62	12.77

NS for varieties

Table 33. Mean yield (kilograms) per tree under the various treatments during the three years irrespective of varieties

Treatments	First year (kg)	Second year (kg)	Third year (kg)
1. Removal of 25 per cent of n_6 order	10.800	12.240	12.690
2. REmoval of 50 per cent of n_6 order	11.170	12.760	15.220
3. Removal of 100 per cent n_6 order	4.510	11.870	13.060
4. Removal of 25 per cent n_5 order	13.410	14.490	16.590
5. Removal of 50 per cent n_5 order	10.580	11.840	13.720
6. Removal of 100 per cent n_5 order	1.990	8.160	9.220
7. Removal of 100 per cent n_4 order	0.000	6.570	9.010
8. Without any removal (control)	10.540	10.200	12.020
CD	5.12	4.90	4.36
SEm±	6.396	6.133	5.453
Grand mean	7.875	11.016	12.693

Table 34. Leaf Area Index of the experimental trees (mean of 5 replications) at the time of flushing, during the first year after pruning

Sl. No.	Treatments	Leaf Area Index	
		Anakkayam-1	Madakkathara-1
1	Removal of 25 per cent of n_6 order	2.0	2.3
2	Removal of 50 per cent of n_6 order	1.9	2.2
3	Removal of 100 per cent of n_6 order	2.3	2.5
4	Removal of 25 per cent of n_5 order	2.2	2.4
5	Removal of 50 per cent of n_5 order	2.4	2.6
6	Removal of 100 per cent of n_5 order	2.7	2.8
7	Removal of 100 per cent of n_4 order	2.7	2.9
8	Control	2.9	3.1

4.4 Studies on Growth Light Regime

The results of the light measurements made during early morning hours, noon and evening using line quantumn sensor, outside the canopy, inside the canopy and the mean of which is expressed as infiltration percentage and presented in Table 35.

Percentage infiltration of light of the various treatments and control is presented graphically over the period from October, 1992 to July, 1994 in Fig. 10a and 10b.

It is seen that, the percentage infiltration in the control was low from October, 1992 to February, 1993. During March, there was an upswing in the percentage infiltration. From April to September there was maximum infiltration of about 40 per cent. There was a sudden fall in the percentage infiltration during October, which is followed by a sudden increase in November, 1993. It fell drastically to reach a value of 19 per cent during December. Then onwards the percentage light infiltration changed a little with peaks during January, April and June, 1994. During this period lowest value of 15 per cent was recorded in March.

As far as the treatments were concerned removal of 100 per cent of n_6 branches, removal of 100 per cent of n_5 branches and removal of 100 per cent of n_4 branches showed similar trend of percentage light infiltration over the two year period. These are shown in Fig. 10a. There was maximum infiltration in these treatments for the first three months (October to December, 1992) after pruning followed by a deep fall in January, 1993.

Fig.10b shows the patterns of light infiltration of the remaining treatments T_1 (Removal of 25% of n_6 orders), T_2 (Removal of 50% of n_6 orders), T_4 (Removal of 25% of n_5 orders) and T_5 (Removal of 50% of n_5 orders).

It can be seen from the figure that during the first six months after pruning, all these treatments have consistantly higher infiltration values compared to the control. When the difference between the treatments and the control is examined, it is observed that the differences of these treatments are less compared to the treatments T_3, T_6 and T_7.

It is interesting to note that starting from August, 1993 (one year after pruning) all the three treatments have shown patterns similar to that of the control. After January, there was sharp increase in light infiltration and higher values were recorded during February to July, 1993. Except for the peaks during September and November in 1993 and June and July, 1994 the light infiltration was in general varied around 25 per cent.

4.5 Biochemical status of cashew genotypes under normal and manipulated condition

4.5.1 Chlorophyll content

4.5.1.1 Chlorophyll content under normal condition

The chlorophyll content namely chlorophyll a, chlorophyll b and total chlorophyll of five varieties were estimated and the correlation of the chlorophyll content and yield was worked out. The data pertaining to chlorophyll content and yield are presented in Table 36. There was significant difference among varieties with respect to chlorophyll a, chlorophyll b, total chlorophyll and yield.

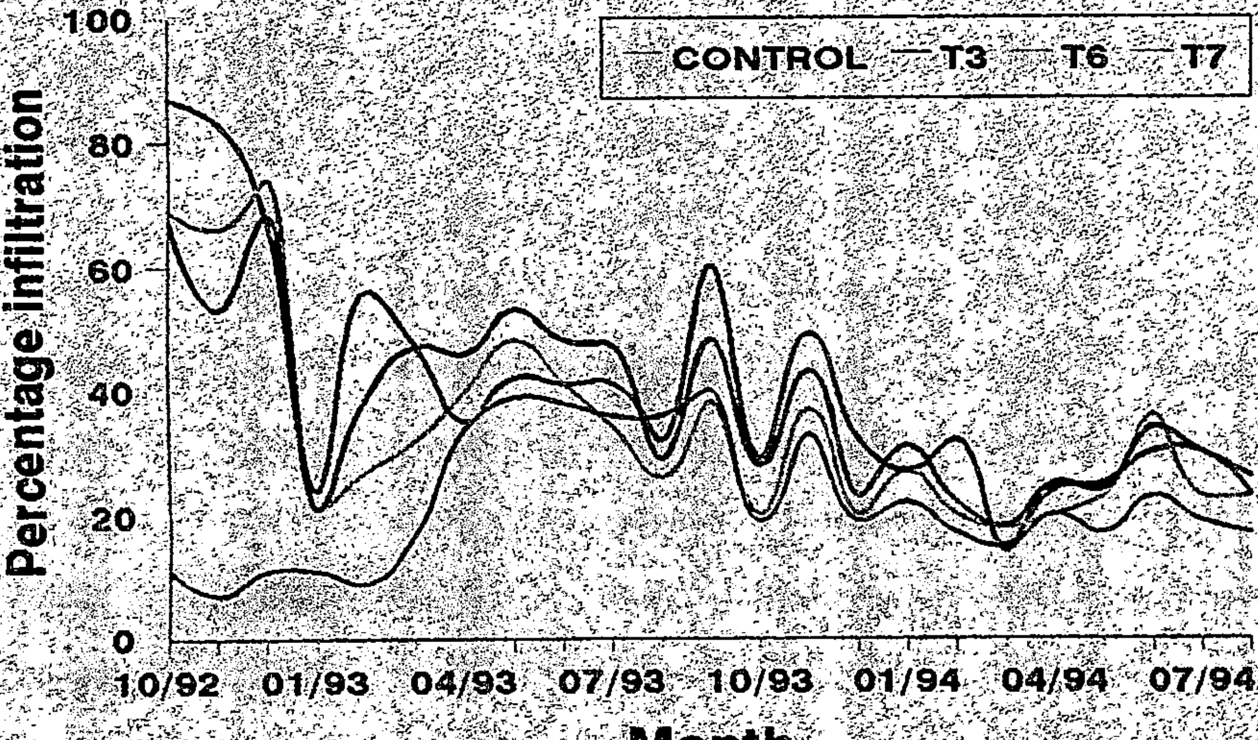
Table 35. Precentage of light infiltration through cashew canopy from October, 1992 to august 1994 for the various treatments imposed during August, 1992

Sl. No.	Treatments	1992			1993												1994							
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Removal of 25 per cent of n_6 order	16	16	33	29	23	33	40	36	46	34	44	33	21	39	20	26	16	16	19	15	17	23	19
2	Removal of 50 per cent of n_6 order	16	18	48	32	20	41	46	49	36	32	40	40	24	36	20	28	19	19	22	14	19	25	22
3	Removal of 100 per cent of n_6 order	67	53	68	21	39	47	48	53	48	47	29	48	28	43	23	31	22	18	25	24	34	30	26
4	Removal of 25 per cent of n_5 order	11	17	24	16	29	30	46	47	38	32	42	28	21	35	20	28	21	22	26	18	29	22	18
5	Removal of 50 per cent of n_5 order	11	26	15	26	30	27	43	43	46	39	34	36	28	34	23	27	22	21	22	14	31	27	16
6	Removal of 100 per cent of n_5 order	69	66	74	21	27	32	40	48	44	34	26	56	20	37	20	27	20	18	20	23	36	23	23
7	Removal of 100 per cent of n_4 order	87	83	67	24	56	47	35	42	46	41	32	60	29	49	32	27	32	14	24	25	30	30	23
8	Control	11	7	11	11	9	17	34	39	38	36	36	49	18	33	19	22	17	15	20	17	23	19	17

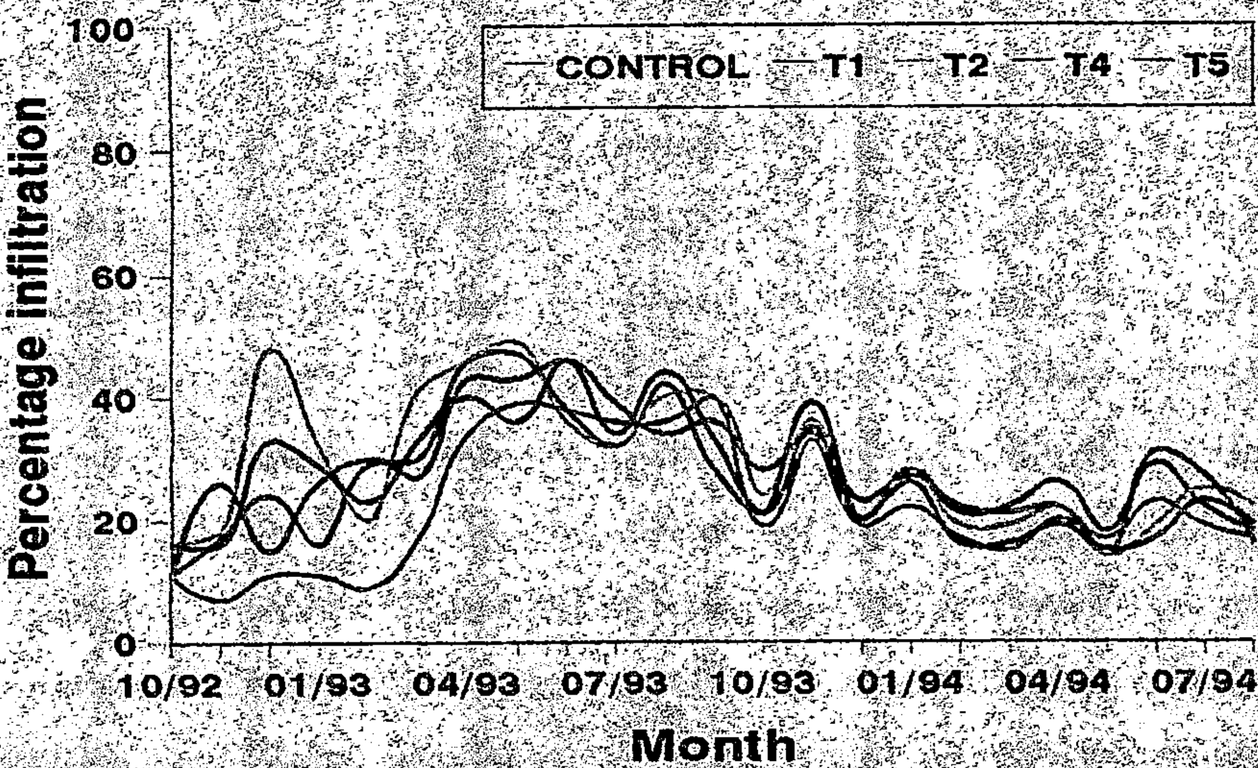
Expressed as percentage
Mean of 3 replications

Fig.10.Light infiltration through cashew canopy

a.



b.



Chlorophyll a content was almost similar in the first two varieties namely Anakkayam-1 and Madakkathara-1. The variety K-10-2 had the highest chlorophyll a content to the tune of 1.83 mg g^{-1} per grain of dry weight (Table 36).

Chlorophyll a content was least (1.284) in the variety K-16-1. With respect to chlorophyll b content also varieties differed significantly. Again the variety K-10-2 have the highest chlorophyll b content ie., 0.82 mg g^{-1} and the variety K-16-1 had the lowest chlorophyll b content (0.343). Varieties Anakkayam-1, Madakkathara-1 and NLR-2-1 were almost on par (Table 36).

The total chlorophyll was the highest in the variety K-10-2 showing a content of 2.65 mg g^{-1} which is followed by NLR-2-1, Anakkayam-1 and Madakkathara-1. The yield of these varieties studied also differed significantly. The highest yielder was the variety K-10-2 with an yield of 22.29 kg $tree^{-1}$. NLR-2-1 registered an yield of 18.2 kg $tree^{-1}$. Anakkayam-1 and Madakkathara-1 showed yield almost on par (Table 36).

The influence of chlorophyll a, chlorophyll b and total chlorophyll on yield was found to be positively significant and linear with a correlation coefficient of 0.922, 0.883 and 0.915 respectively. The scatter diagram along with graphs are given in Fig. 11, 12 and 13.

4.5.1.2 Chlorophyll content of manipulated trees

The chlorophyll content of the newly formed flushes and flushes at maturity of the experimental trees, where pruning treatments were imposed was

Table 36. Mean content of chlorophyll of leaves of different varieties and their yield

Sl. No.	Variety	Chlorophyll a mg g^{-1}	Chlorophyll b mg g^{-1}	Total chlorophyll mg g^{-1}	Yield kg per tree
1	Anakkayam-1	1.588	0.628	2.216	16.39
2	Madakkathara-1	1.549	0.576	2.125	15.25
3	K-10-2	1.831	0.821	2.652	22.29
4	K-16-1	1.284	0.343	1.627	11.76
5	NLR-2-1	1.597	0.641	2.238	18.22
Grand mean		1.570	0.602	2.172	16.782
CD		0.1008	0.1008	0.187	0.899

Fig.11. Effect of chlorophyll a on yield of cashew

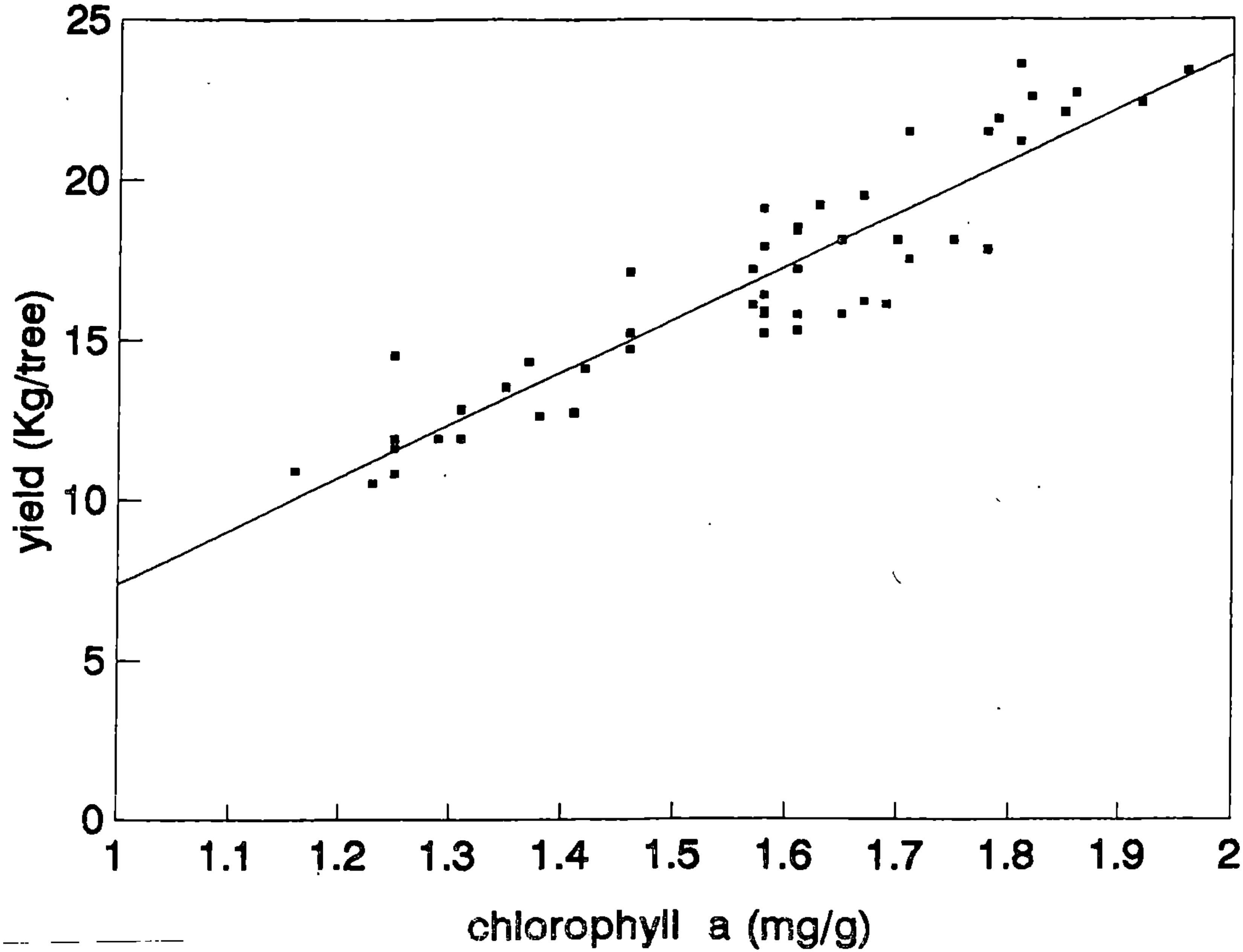


Fig.12. Effect of chlorophyll b on yield of cashew

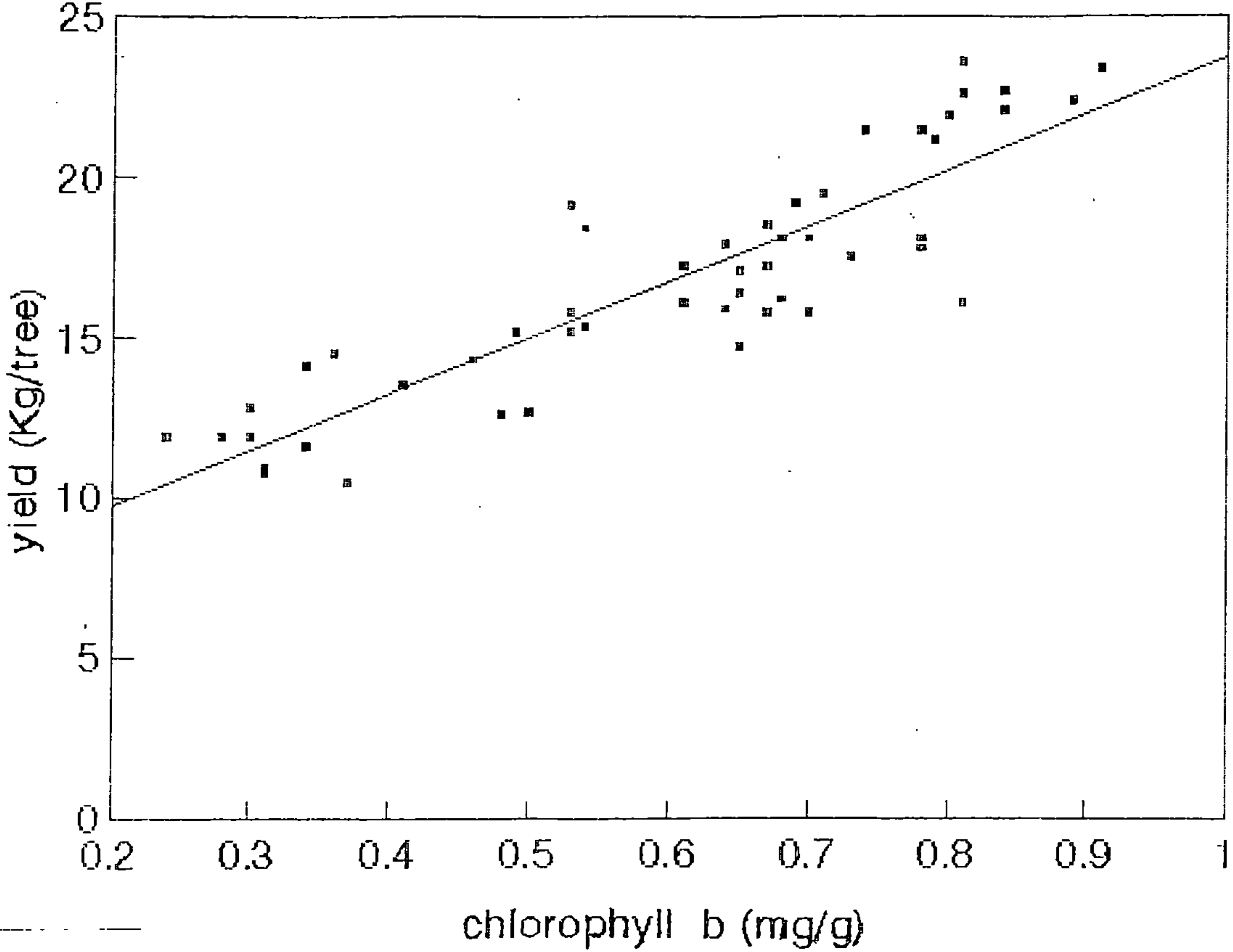
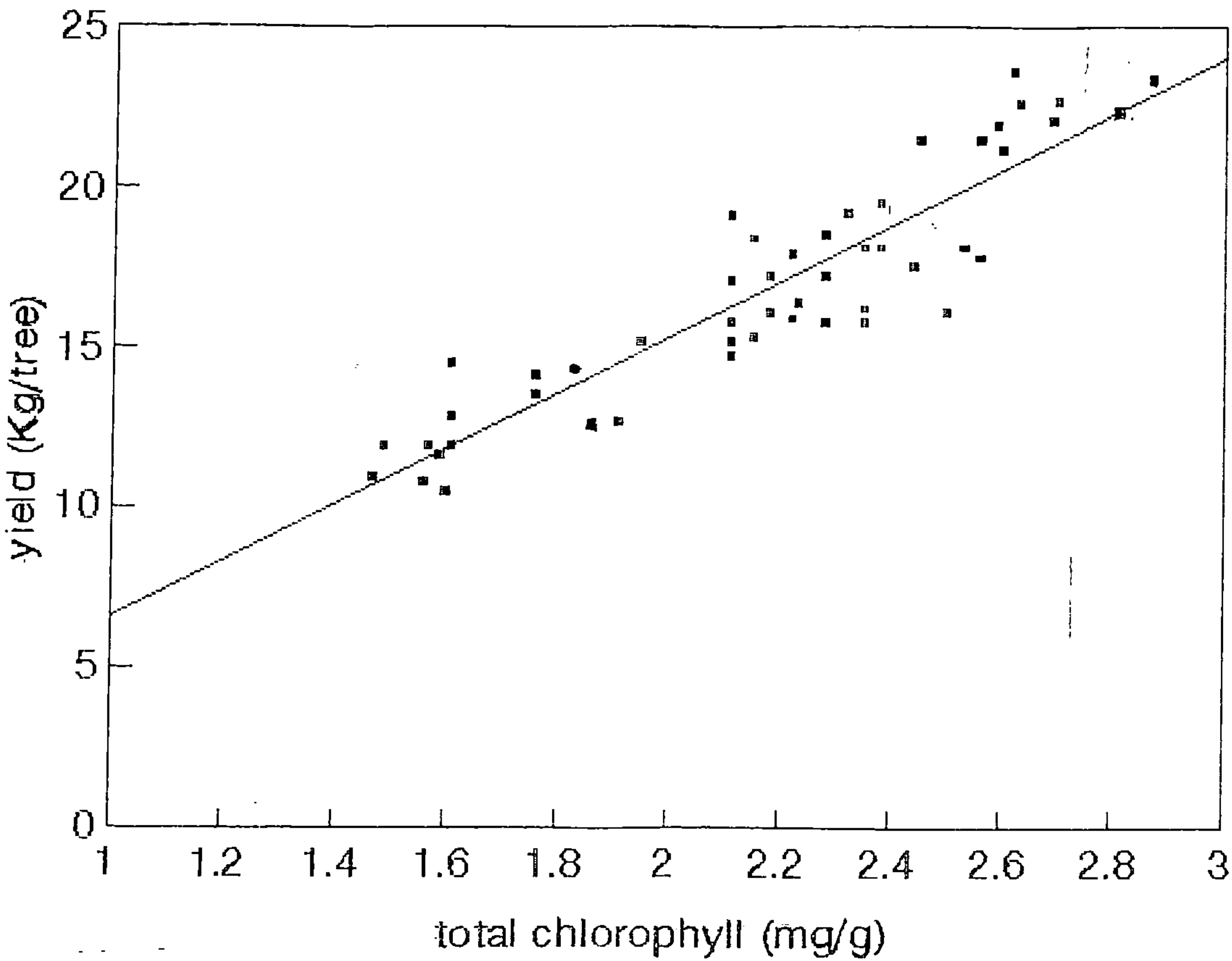


Fig.13. Effect of total chlorophyll on yield of cashew



estimated and the data are presented in Tables 37, 38, 39 and 40. It is seen from Table 37 that with respect to chlorophyll a and total chlorophyll, there was no significant difference between the two varieties, Anakkayam-1 and Madakkathara-1 in the newly formed flushes. However, there was significant difference between varieties as far as chlorophyll b was concerned. Treatments differed significantly with respect to chlorophyll a, chlorophyll b and total chlorophyll. Chlorophyll a content was above 0.6 in treatment 2, 4, 6 and 7. In treatment number one and the control, it was above 0.5 and below 0.6. Treatment 3 showed a chlorophyll content of 0.38 only.

With respect to chlorophyll b also, there was significant difference among treatments. All the first five treatments and the control registered a chlorophyll b content above 0.2 mgm g^{-1}. Treatment 6 and 7 showed chlorophyll b content of less than 0.2. The total chlorophyll content was the highest and above 0.9 in treatments 2, 4 and 5. It was above 0.8 in treatment 1, 6, 7 and the control. The least amount of total chlorophyll ie., 0.67 was noticed in treatment 3.

The data pertaining to chlorophyll content of mature shoots at the time of flowering of the two varieties and the different treatments are presented in Tables 39 and 40. From the Table 39, it is seen that at maturity also the varieties did not differ significantly as far as the content of chlorophyll a, chlorophyll b and total chlorophyll was concerned. Treatment means of chlorophyll content showed significant differences with respect to chlorophylla a, chlorophyll b and total chlorophyll. Chlorophyll a content at maturity was the highest in treatment 4 and the least in treatment 6. Treatment 1, 2 and the control were on par. The content of chlorophyll b also differed significantly, the treatment 4 registered the highest

Table 37. Content of chlorophyll of young shoots of Anakkayam-1 and Madakkathara-1 after pruning

Sl. No.	Treatments	Chlorophyll a mg g^{-1}		Chlorophyll b mg g^{-1}		Total chlorophyll mg g^{-1}	
		Anakka-yam-1	Madakka-thata-1	Anakka-yam-1	Madakka-thara-1	Anakka-yam-1	Madakka-thara-1
1	Removal of 25% of n_6 order	0.584	0.548	0.212	0.282	0.856	0.830
2	Removal of 50% of n_6 order	0.648	0.606	0.310	0.274	0.958	0.900
3	Removal of 100% of n_6 order	0.386	0.378	0.256	0.230	0.642	0.688
4	Removal of 25% of n_5 order	0.632	0.614	0.304	0.264	0.936	0.878
5	Removal of 50% of n_5 order	0.696	0.700	0.238	0.246	0.934	0.946
6	Removal of 100% of n_5 order	0.660	0.720	0.172	0.162	0.852	0.882
7	Removal of 100% of n_4 order	0.546	0.688	0.200	0.194	0.748	0.882
8	Control	0.554	0.638	0.266	0.260	0.820	0.898
Mean		0.588	0.611	0.252	0.239	0.843	0.863

Table 38. Content of chlorophyll of young shoots irrespective of varieties

Sl. No.	Treatments	Chlorophyll a mg g^{-1}	Chlorophyll b mg g^{-1}	Total chlorophyll mg g^{-1}
1	Removal of 25% of n_6	0.566	0.277	0.843
2	Removal of 50% of n_6	0.627	0.292	0.929
3	Removal of 100% of n_6	0.382	0.243	0.665
4	Removal of 25% of n_5	0.623	0.284	0.907
5	Removal of 50% of n_5	0.098	0.242	0.940
6	Removal of 100% of n_5	0.690	0.167	0.867
7.	Removal of 100% of n_4	0.617	0.197	0.815
8	Control	0.596	0.263	0.859
Grand mean		0.600	0.246	0.853
CD		0.098	0.040	0.120
SEm±		0.0245	0.009	0.009

amount of chlorophyll followed by treatment 2, 1 and the control. The same trend was shown by the treatments with regard to the total chlorophyll content.

4.5.2 Carbohydrate, nitrogen and C/N ratio of manipulated trees

4.5.2.1 Carbohydrate

Data pertaining to amount of carbohydrate, both soluble and total, nitrogen and carbohydrate nitrogen ratio of the varieties at flowering after pruning are presented in Tables 41 and 42. The two varieties did not differ significantly with respect to all the three parameters concerned. Treatments differed significantly with regard to soluble sugars, total carbohydrate, nitrogen content and C/N ratio. Total soluble sugars at the time of flowering was very high ie., above 4 in treatments 1, 2 and 4. Treatments 3 and 5 and the control showed a carbohydrate content of around 3.5.

Total carbohydrate content was the highest in treatment 2 and treatment 4 ie. 14.272 and 14.839 (Table 42).

4.5.2.2 Nitrogen

The amount of nitrogen at flowering was the highest in treatment 4 (1.422) and the least in treatment 5 (1.289) (Table 42).

4.5.2.3 Carbohydrate nitrogen ratio

Carbohydrate nitrogen ratio also showed significant variation among the treatments. Treatments 2, 4 and 5 showed a high carbohydrate nitrogen ratio (9.398, 9.812 and 9.463), while treatment 7 showed the least carbohydrate nitrogen ratio of 1.648 (Table 42).

Table 39. Content of chlorophyll of mature shoots at the time of flowering of Anakkayam-1 and Madakkathara-1

Sl. No.	Treatments	Chlorophyll a mg g^{-1}		Chlorophyll b mg g^{-1}		Total chlorophyll mg g^{-1}	
		Anakka-yam-1	Madakka-thara-1	Anakka-yam-1	Madakka-thara-1	Anaka-yam-1	Madakka-thara-1
1	Removal of 25% of n_6 order	1.546	1.506	0.594	0.546	2.140	2.072
2	Removal of 50% of n_6 order	1.582	1.458	0.620	0.668	2.202	2.130
3	Removal of 100% of n_6 order	1.300	1.378	0.400	0.356	1.700	1.734
4	Removal of 25% of n_5 order	1.638	1.660	0.686	0.728	2.324	2.388
5	Removal of 50% of n_5 order	1.358	1.280	0.432	0.386	1.816	1.676
6	Removal of 100% of n_5 order	1.162	1.230	0.366	0.358	1.558	1.588
7	Removal of 100% of n_4 order	1.294	1.342	0.390	0.324	1.684	1.666
8	Control	1.528	1.690	0.592	0.548	2.120	2.138
Mean		1.426	1.431	0.510	0.490	1.943	1.924

Table 40. Content of chlorophyll of mature shoots at the time of flowering after pruning irrespective of varieties

Sl. No.	Treatments	Chlorophyll a mg g^{-1}	Chlorophyll b mg g^{-1}	Total chlorophyll mg g^{-1}
1	Removal of 25% of n_6 order	1.526	0.570	2.106
2	Removal of 50% of n_6 order	1.520	0.644	2.166
3	Removal of 100% of n_6 order	1.339	0.378	1.717
4	Removal of 25% of n_5 order	1.649	0.707	2.356
5	Removal of 50% of n_5 order	1.319	0.414	1.746
6	Removal of 100% of n_5 order	1.196	0.362	1.573
7	Removal of 100% of n_4 order	1.318	0.357	1.675
8	Control	1.559	0.570	2.129
Grand mean		1.428	0.500	1.934
CD		0.183	0.110	0.270
SEm±		0.045	0.262	0.066

Table 41. Content of carbohydrate, nitrogen and C/N ratio in cashew at flowering after pruning

Sl. No.	Treatments	Soluble carbohydrate (%)		Total carbohydrate (%)		Nitrogen (%)		C/N ratio	
		Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1	Anakkayam-1	Madakkathara-1
1	Removal of 25% of n_6 order	4.062	4.578	11.728	11.696	1.748	1.748	6.764	6.760
2	Removal of 50% of n_6 order	4.458	4.728	14.272	13.488	1.468	1.524	9.930	8.856
3	Removal of 100% of n_6 order	3.348	3.516	8.790	8.990	2.362	2.358	3.736	3.886
4	Removal of 25% of n_5 order	4.484	4.186	14.839	13.056	1.414	1.430	10.494	9.130
5	Removal of 50% of n_5 order	4.042	3.708	12.093	12.302	1.280	1.298	9.448	9.478
6	Removal of 100% n_5 order	2.648	2.360	7.157	6.569	2.732	2.710	2.620	2.424
7	Removal of 100% n_4 order	1.926	1.932	4.875	5.337	3.082	3.114	1.582	1.714
8	Control	3.680	4.044	9.983	10.240	1.566	1.700	6.375	6.024
Mean		1.957	1.985	5.608	5.54	3.581	3.632	6.375	6.024
Grand mean		1.971		5.581		3.606		6.199	
CD		0.36		1.09		1.06		1.52	

Table 42. Content of carbohydrate, nitrogen and C/N ratio in cashew at flowering irrespective of varieties

Sl. No.	Treatments	Soluble carbohydrate (%)	Total carbohydrate (%)	Nitrogen (%)	C/N ratio
1	Removal of 25% of n_6 order	4.320	11.712	1.748	6.762
2	Removal of 50% of n_6 order	4.593	13.880	1.496	9.398
3	Removal of 100% of n_6 order	3.432	8.890	2.360	3.811
4	Removal of 25% of n_5 order	4.335	13.952	1.422	9.812
5	Removal of 50% of n_5 order	3.875	12.198	1.289	9.463
6	Removal of 100% of n_5 order	2.504	6.862	2.721	2.522
7	Removal of 100% of n_4 order	1.929	5.106	3.098	1.648
8	Control (without any removal)	3.862	10.100	1.633	6.185
Grand mean		3.606	3.581	1.971	6.199
CD		1.06	1.09	0.36	1.52

Discussion

DISCUSSION

Cashew generally produced new flushes during October-November followed by a growth period of one month. Flowering spreads in different varieties during October-January which is followed by harvesting during March-April. There is a leaf fall period observed during September-October and the cycle is repeated. During leaf fall period, the growth is arrested and the buds are in a state of dormancy.

Branch bifurcation ratio (Rb_n) was found to be higher with respect to n_1, n_2, n_3 branches in seedlings. A similar pattern was showed by grafts with a lesser bifurcation ratio with respect to the above mentioned branches. This could be possibly because of the extensive branching of seedlings and grafts as far as n_1, n_2, n_3 orders are concerned ie. out of the total number of potential branches, produced, less number persist. Initially the bifurcation ratio is lower in the case of layers but with respect to higher order of branches n_3, n_4 it increases. The above results show that, in case of seedlings and grafts, out of the total number of branches produced with respect n_3 n_4, more number of branches survive and hence the canopy does not get closed. In layers, less number of branches from lower orders survive and hence the lower ratio. Out of the total number of n_4, n_5 and n_6 branches, less number survive in seedlings and grafts because by that time during the over crowding of successive branches and subsequent closure of canopy. This applies to layers also.

The frequencies of this different order of branches, follows an ascending pattern as the branch order number increases. It is seen that n_6 branches are the potentially productive branches leaving the lower order of branches mainly for the basic structural growth of the crown. Hence it is imperative that efforts should be made to manipulate the crown in such a way so as to increase the production of n_6 branches which are potentially capable of bearing.

The PWBBRn which gives an idea as to how many branches actually become productive out of the total potentially productive branches and this also gives a method of assessing the real productivity of a tree crown. The higher PWBBRn in grafts points to the fact that, because of the spear shaped canopy of the grafts, more number of potentially productive branches become productive. This could be due to better and efficient utilization of solar radiation. In layers and seedlings, many of the potentially bearing branches become unproductive because of shading effect of branches and they become parasitic on photosynthetically efficient branches which ultimately may result in their comparatively poor performance.

The canopy architecture that resulted in seedling of cashew because of the extensive branching abortion of produced branches by self pruning etc. was a massive hemisphere placed above a solid cylinder. Because of the acute orientation of the n_1, n_2 and n_3 order of branches and the intensive branching pattern, the canopy that resulted was like a cone placed above a short cylinder.

Because of the short nature of the n_0 main trunk and reduced number of n_1 order of branches and their parellel orientation to the ground, the canopy resulted in most of the layers was like a hemisphere.

When the yield efficiency of the three types of canopies were compared, it is found that the grafts performed better than seedlings and layers.

Obviously a massive canopy of the seedling with a cylindrical base and a hemispherical top will be less efficient in terms of utilization of solar radiation because of the shading of the lower branches. Studies on light distribution in bush trees with a spherical or hemispherical tree head form generally showed that only a limited outer zone of such trees received enough light to produce fruits of good quality in apple (Heinicke, 1963, 1964, 1966).

The canopy of the grafts which appears like a "Palmette leader" in apple, since it has got a very short cylindrical portion and corn like apical part of the crown receives solar radiation, the entire surface of canopy receives solar radiation uniformly without much overlapping.

The palmette leader like canopy of the grafts, with large permanent gaps in the upper canopy ensured good light distribution with in the canopy and that might have resulted better photosynthetic efficiency of grafts. Similar observations were made in Apple by Alan *et al.* (1989).

The canopy of the layers, eventhough hemispherical in nature is not massive as that of the seedling and hence might have had better light distribution. The higher yield efficiency of grafts could be attributed to the better utilization of solar radiation which in turn might have resulted more number of proleptic branches, which became productive. On other hand in the canopy of seedlings, the lower branches did not receive enough solar radiation because of shading and this in turn might have resulted in less number of productive branches and more number of sylleptic branches which become parasitic on photosynthetically active outer branches. Number of n_6 order of productive branches compared in tables of seedlings, grafts and layers also confirms this observation. Eventhough the total number of productive branches was slightly higher in layers, where all the flowering laterals did not become productive because of the poor photosynthetic utilization of solar radiation as was reflected in the lower yield efficiency of layers, when compared to grafts. The view that it is mostly the canopy shape that ultimately determines yield efficiency is further confirmed by the fact that in both the varieties compared in Anakkayam-1 and Madakkathara-1, the grafts with a spear shaped canopy outyield seedlings and layers.

Path analysis of the data pertaining to 30 trees consisting of seedlings, grafts and layers to determine the major yield components and to findout the contribution of each of the major components revealed that height, number of n_2, n_4 branches and number of n_6 flowering branches, number of nuts per panicle, nut size and number of bisexual flowers had positive direct effect on yield. The canopy spread, number of n_0, n_1 and n_3 branches and total canopy surface area had negative direct effect on yield. n_0, n_1 and n_3 mostly contribute to the structural development of the canopy. The spread and the total canopy surface area negatively affected yield, mostly because of the hemispherical massive canopy of seedlings and hemispherical canopy of layers. As was already pointed out earlier in such canopies, light distribution to the lower branches and branches inside the canopy, becomes restricted, which could have been the reason for their negative contribution. This point of view is further corroborated by the better yield efficiency of grafts (Table 12).

Positive direct contributions of height on yield has been amply documented in crops Apple by Barlow and Hancock (1960) and in cashew (Ohler, 1979). The direct contribution of n_2, n_4 and n_6 could be due to their role in the production of flowering laterls. n_6 being the potentially productive branch, encouraging the production of vigorous n_6 branches naturally will result in higher yield. The apparently quiescent fruit bearing buds might have been activated by the treatment of pruning as was shown in mango owing to the re0distribution of the endogenous hormonal substances to favour flowering and fruiting (Rao and Shanmugavelu, 1975).

The recently introduced high density management practices in orcharding of apple, pear, mango and citrus have made the above plantations much more profitable and remunerative (Santram, 1993 and Goswami *et al.*, 1993). This could be possible because of the optimum utilization of the space and planting of trees which are less spreading with a medium spear like canopy with lesser spacing.

To achieve this the use of dwarfing rootstocks, growth retardants and training and pruning systems have been made use of. The same concept can be extended to cashew also to make future plantations more productive and remunerative. For high density management in cashew, an ideal plant type with moderate height with a canopy architecture like that of "palmette leader" in apple with moderate surface area and having high yield efficiency is to be evolved.

From the observations, it is found that a tree with a height of 3 to 4 meters with a spread of about 3 to 4 meters with a canopy area of about 40 m^2 and with a canopy shape like that of a spear with high yield efficiency of about 0.28 kg per squaremetre (Tables 11, 12) is an ideal plant type in cashew for intensive management.

Grafts of Anakkayam-1 and Madakkathara-1 have been found to conform to the above standards and hence from the experimental evidences the grafts of the above mentioned varieties can be used for high density management orchards in cashew.

Canopy manipulation

The salient results of canopy manipulation treatments were:

1) The varieties did not differ significantly during the three year period with respect to yield after imposing the pruning treatments.
2) Treatments especially, removal of 25 per cent of n_6, 50 per cent of n_6, 25 per cent of n_5 were significantly different from the control and the rest of the treatments.
3) Observation regarding yield during the three successive years after manipulating the canopy revealed that during the first year after pruning, removal of 25 per cent n_6, 50 per cent of n_6, 25 per cent of n_5 and 50 per cent of n_5 gave an yield of 10.8 kg, 11.17 kg, 13.4 kg and 10.58 kg respectively. Which were significantly higher as compared to the control and rest of the treatments. Removal of 100 per cent of n_6 gave a very poor yield of 4.5 kg. When 100 per cent of n_5 and n_4 were removed, the yield was very negligible during the Ist year.

During the second year, removal of 25 per cent n_6, removal of 50 per cent n_6, removal of 100 per cent of n_6, removal of 25 per cent of n_5, 50 per cent of n_5 were yielding higher than the control and the rest of the treatments. However, removal of 25 per cent of n_5 branches, yielded 14.5 kg ie., about 4 kg more than the control. Eventhough removal of 25 per cent of n_5 gave the highest yield, it did not differ significantly from treatments 1 and 2 which yielded more than 12 kgs.

During the 3rd year, treatments of removal of 25 per cent n_6, removal of 50 per cent of n_6, 100 per cent of n_6, removal of 25 per cent of n_5 and removal of 50 per cent of n_5 gave higher yield as compared to the control. Removal of 100 per cent of n_5, 100 per cent of n_4 gave an yield of about 9 kg. Among the superior treatments, removal of 25 per cent of n_5 was found to be the best which yielded 16.59 kg.

It is seen that, removal of 25 per cent of n_5 consistantly gave higher yield during the three consecutive years after pruning. Eventhough removal of 100 per cent of n_6 during the first year gave very low yield, during the second year and third year the yield improve.

These results show that the n_6 branches are the major yield bearing branches. The pruning of 25 per cent of n_5 branches encourage the production of vigorous n_6 branches, in the very same flushing season and this might have resulted in higher yield. The apparently quiescent fruit bearing buds ought have been activated by the treatment of pruning as was shown in mango, owing to the re-distribution of the endogenous hormonal substances to favour flowering and fruiting (Rao and Shanmugavelu, 1975). This improvement in yield during the second year and third year shows that, during the first year, practically there were no fruit bearing 6th order branches but during the next year, the sixth order branches have regenerated. Removal of 100 per cent of n_4 resulted in poor yield during the Ist and second year shows that, the pruning was very drastic and most of the structural framework of the tree was removed. It took about 3 years of vegetative growth for the re-iteration of the canopy.

From the above facts, it became imperative that pruning can be efficiently employed as a cultural practice to imprive yield in cashew.

As to the degree of pruning and which order of branches are to be subjected to pruning, the results indicate that removal of 25 per cent of the branches which was confined to the n_5 order gave the best result consistantly during the three years.

The higher yield obtaining as a result of pruning might have been due to the following reasons.

1) Leaf area removed as a result of pruning might have been compensated for by leaves on subsequent regrowth as was shown by Taylor and Ferree, 1981 in apple.
2) Pruning might have stimulated photosynthetic activity of the leaves as a result of an increase in chlorophyll content as was shown in apple by Christopher (1970)
3) The pruning might have influenced photosynthesis indirectly by improving the interception of light and its distribution within the tree canopy as was evident from the percentage interception of light for the two year period after pruning (Table 35, Fig. 10a and b). Similar results were obtained by various workers in mango and apple (Feruguson, 1960)

Pruning which has resulted in the production of vigorous shoots, might have increased the percentage of blossoms that set fruits. Similar results were obtained by various workers in different tree fruit crops (Heinicke, 1975; Goswamy *et al.*, 1993; Madhava Rao and Shanmugavelu, 1985 and Nautigal *et al.*, 1993).

It is well known that the canopy with a spherical or hemispherical tree head form receives a limitted amount of photosynthetically active radiation restricted to the surface area only as was observed in apple (Heinicke, 1966)

The canopy of cashew also gets closed when the trees attain maturity. Naturally when canopy is opened at various degrees, the distribution of light availability with in the canopy and the surface area improved considerably.

From the experimental data, it appears that the drastic pruning of removal of 100 per cent of n_4 branches and 100 per cent of n_5 branches, it partially destroy the structural frame work on which the productive n_6 branches are to be born. Removal of 25 per cent of the n_5 on the other hand seems to be the optimum opening of the canopy. The result of the next experiment involving light infiltration also confirm this observation. During the first and second year, there is increased infiltration percentage which tends to become like that of the control during the third year. This gives us a clue as to how much time the effect of pruning of 25 per cent n_5 branches lasts. The subsequent increase in yield also sustained up to the third year. Once the percentage infiltration of light comes on par with that of the control it can be understood that the canopy gets closed and the original canopy surface is reformed. Hence it appears that there is a need for opening of the canopy again to improve yield.

The improvement in yield when the canopy was opened could be because of the better photosynthetic efficiency of the branches inside the canopy which were photosynthetically less active because of the non availability of light. It could also be due to the fact that light infiltration to the inside of canopy encouraged possibly an increase in the chlorophyll content and subsequent higher photosynthetic efficiency. Which might have triggered the production of optimum number of proleptic branches and also presumably higher percentage of bisexual flowers and higher number of nuts per lateral. Similar results have been reported in guava, apple and mango (Santram, 1993; Goswamy *et al.*, 1993 and Heinicke, 1975).

The above discussion of the results points to the fact that by pruning 25 per cent of n_5 branches at an interval of 3 year period coupled with high density management practices, the yield of cashew can be almost doubled.

If conventional planting materials mostly seedlings are planted at a recommended spacing of 7.5 metre x 7.5 metres, about 180 trees are accomodated per hectare of land area. The average yield of high yielding varieties of such trees with a spreading type of canopy is to the tune of about 20 kg per tree. So the average yield works out to be 3600 kg/ha. On the other hand, if grafts of the above mentioned varieties are planted, which more or less conform to the standard of the proposed ideal plant type suggested earlier, 650 trees can be accomodated per hectare. With a modest yield of 11.2 kg per tree of about 40 sq. m. canopy surface area, which is spear shaped, an yield of 7280 kg ha^{-1} can be obtained. So this comes to about a two fold increase in yield in cashew.

Biochemical studies

Chlorophyll content of varieties

The result of content of chlorophyll a, chlorophyll b and total chlorophyll, when compared revealed that, the highest amount was present in K-10-2 followed by Anakkayam-1, Madakkathara-1 and NLR-2-1. Yield is a direct function of chlorophyll content. When the yield of the five varieties were compared, K-10-2 registered the highest yield and this variety had the highest chlorophyll content. Anakkayam-1 and Madakkathara-1 are two varieties which are more or less similar in performance of yield and so is chlorophyll content.

Correlation worked out in Fig.11, 12, 13 among chlorophyll a, chlorophyll b, total chlorophyll and yield revealed that there was a positively significant linear relation with a correlation coefficient of 0.992, 0.883 and 0.915 respectively. Similar relation with chlorophyll and yield have been shown in other crops by various workers.

The present results indicate that K-10-2 has significantly different chlorophyll content with the rest of the varieties compared and the yield also was the highest. So the variety K-10-2 is a potential high yielding variety. The present experimental result also indicate that estimation of chlorophyll content is a very good index for screening high yielding varieties in cashew.

Pruning and chlorophyll content

Data pertaining to chlorophyll content of young shoots and mature shoots after pruning showed that canopy opening significantly increased the chlorophyll content of the treatments. In young shoots, the chlorophyll content was higher and in mature shoots with the degradation of chloroplast, the content was comparatively less and the treatments showed similar trend. The two varieties did not differ significantly with respect to chlorophyll content and these two varieties are more or less similar in performance as has been pointed out earlier.

Chlorophyll content seems to be genetically controlled in varieties. However, when two varieties are pruned the increase in chlorophyll content may be attributed to better light penetration and distribution of light in the opened canopies. Similar results have been obtained in citrus (Syverstsen, 1984), apple (Barden, 1974) and peach (Kappel and Flore, 1983; Marini and Marini, 1983).

Carbohydrate, Nitrogen and C/N ratio

Content of carbohydrate

The data pertaining to the amount of soluble sugars, total carbohydrate after pruning at the time of flowering was high in the treatments of 25 per cent of n_6 removal, 50 per cent of n_6 removal and 25 per cent of n_6 removal (Table 42).

Total carbohydrate content was found to be very high in 50 per cent n_6 removal and 25 per cent n_5 removal. The high soluble and total carbohydrate level in pruning treatments might have been due to the stimulus to photosynthesis as shown and the regeneration of leaf area and higher chlorophyll content in the pruned treatments (Table 41, 42).

The higher leaf area and higher photosynthetic efficiency might have resulted in the accumulation of carbohydrate in the pruned canopies.

Nitrogen content

The results of nitrogen content of pruned tree revealed that the highest nitrogen content was noticed in treatment with removal of 100 per cent of n_4 branches and the least was noticed in removal of 50 per cent of n_5 branches.

There was a depletion of nitrogen content at the time of flowering in the treatments of removal of 50 per cent of n_5, removal of 25 per cent of n_5, removal of 50 per cent of n_6 and removal of 25 per cent of n_6 which gave higher yield. The high rate of fruit set in the above treatments might have resulted in the mobilization of nitrogen in the developing sinks, namely the fruits. Obviously cashew kernel is rich in nitrogen. When the 100 per cent of removal of n_4 branches have resulted in poor fruit set as was reflected in the low yield and hence the nitrogen content remained high in the shoots.

Carbohydrate Nitrogen ratio (C/N ratio)

It is known high carbohydrate nitrogen ratio induces flowering and fruit set in tree crops (Kraus and Kraybill, Gardner *et al.*, 1952; Engel and Lenz, 1981; Saur, 1987; Loesher *et al.*, 1990; Borey and Clair Maczulagtys, 1993; Borey *et al.*, 1994). The treatments which gave higher yields namely removal of 50 per cent of n_6, 25 per cent of n_5 and 50 per cent of n_5 showed higher C/N ratio while the C/N ratio was low in the treatment of removal of 100 per cent of n_4 branches. The low C/N ratio in the treatment of 100 per cent n_4 removal could be attributed to the slow re-iteration and the poor development of photosynthetic surface area and the lower production of photosynthates.

It has also been showed that drastic pruning increase the nitrogen content of the shoots. The decrease of total carbohydrate and the increase of N content might have resulted in the low C/N ratio in the treatment of removal of 100 per cent of n_4 branches.

Summary

SUMMARY

The present investigation consisted of observations on different phenological phases of cashew and the critical evaluation of the canopies of seedlings, grafts and layers of different varieties of cashew. Another objective of the study was to ascertain the optimum degree of manipulation of the canopy resulting in better distribution of light and subsequent yield. The experiment also envisages how canopy manipulation and resultant re-distribution of light affected chlorophyll content, the total soluble sugars, the nitrogen and the carbohydrate-nitrogen ratio of the branches.

Experiments were carried out at the Cashew Research Station, Anakkayam, making use of the seedlings, grafts and layers of different varieties of cashew. For the evaluation of the canopy and further identification of yield components, the above mentioned trees were made use of and the data were analyzed statistically.

Canopy manipulation experiment consisted of eight treatments namely removal of 25 per cent n_6 branches removal of 50 per cent of n_6 branches, removal of 100 per cent of n_6 branches, removal of 25 per cent of n_5 branches,removal of 50 per cent of n_5 branches, removal of 100 per cent of n_5 branches, removal of 100 per cent of n_4 branches and control. The experimental design used was RBD. The salient findings of the experiment are given below.

Cashew generally produced new flushes during October-November followed by a growth period of one month. Flowering spreads in different varieties during October-January which is followed by harvesting during March-April. There

is a leaf fall period observed during September-October. In rare cases there is an additional flushing period of about 20 days during May-June.

The branch bifurcation ratio was found to be higher with respect to n_1, n_2, n_3 branches in seedlings. A similar pattern was showed by grafts with a lesser bifurcation ratio with respect to the above mentioned branches. The frequencies of this different order of branches followed an ascending pattern as the branch order number increases. It is seen that n_6 branches are the potentially bearing branches, leaving the lower order of branches mainly for the basic structural growth of the crown. Hence it is imperative that efforts should be made to manipulate the crown in such a way so as to increase the production of n_6 branches, which are potentially capable of bearing.

The PWBBRn for seedlings, grafts and layers were worked out and it was found that, it was the highest in the case of grafts. This gives a method of assessing the real productivity of a tree crown. The higher PWBBRn in grafts points to the fact that because of the spear shaped canopy of the grafts, more number of potentially productive branches became productive.

The canopy architecture that resulted in seedling of cashew, because of the extensive branching, abortion of produced branches by self pruning etc. was a massive hemisphere placed above a solid cylinder. Because of the acute orientiation of the n_1, n_2 and n_3 order of branches and the intensive branching pattern, the canopy that resulted in grafts was like a cone placed above a short cylinder. Because of the short nature of the no main trunk and reduced number of n_1 order of branches and their parallel orientation to the ground, the canopy resulted in most of the layers was like a hemisphere.

In mature cashew trees, derived from seedlings, grafts and layers, it has been observed that the sixth order branches are the productive ones. The yearly growth of cashew shows a regular polymorphic branching cycle. Branches consists of both proleptic and sylleptic branches. Proleptic branches during the flushing and flowering season turned to be productive. Sylleptic branches mostly perished in the next season. A few remained in the coming season and from them proleptic branches were produced rhythmically. This cycle is repeated. Pruning of the fifth and sixth order branches encouraged the production of proleptic branches.

The studies on canopy characteristics showed that seedlings, grafts and layers differed significantly with respect to canopy height, canopy spread, canopy surface area and yield and the varieties studied did not differ significantly with respect to the above mentioned canopy characteristics.

The yield efficiency was the highest in grafts amounting to 0.277 kg/sq.m. The yield efficiency of seedlings and layers was on par. With respect to yield efficiency, the varieties did not differ significantly.

Path analysis of data pertaining to 30 trees revealed that height, number of n_2, n_4 branches, number of n_6 flowering branches, number of nuts per panicle, nut size and number of bisexual flowers were the main yield components in cashew. The spread and the total canopy surface area negatively affected yield.

The salient results of canopy manipulation treatments were

1) The varieties did not differ significantly during the three year period with respect to yield after imposing the pruning treatments.

2) Treatments especially removal of 25 per cent of n_6, 50 per cent of n_6, 25 per cent of n_5 were significantly superior to the control and the rest of the treatments.

3) During the first year after pruning removal of 25 per cent n_6, 50 per cent of n_6, 25 per cent of n_5 and 50 per cent of n_5 gave an yield of 10.8 kg, 11.77 kg, 13.4 kg and 10.58 kg respectively which were significantly higher as compared to the control and rest of the treatments. Removal of 100 per cent of n_6 gave a very poor yield of 4.5 kg. When 100 per cent of n_5 and n_4 were removed the yield was negligible during the 1st year.

During the second year, removal of 25 per cent n_6, removal of 50 per cent n_6, removal of 100 per cent of n_6 removal of 25 per cent of n_5 and 50 per cent of n_5 were yielding higher than the control and the rest of the treatments.

During the third year, treatments of removal of 25 per cent n_6, removal of 50 per cent of n_6, 100 per cent of n_6, removal of 25 per cent of n_5 and removal of 50 per cent of n_5 gave higher yield as compared to the control. Removal of 100 per cent of n_5, 100 per cent of n_4 gave an yield of about 9 kg. Among the superior treatments, removal of 25 per cent of n_5 was found to be the best which yielded 16.59 kg.

The result of chlorophyll a, chlorophyll b and total chlorophyll when compared revealed that the highest amount was present in K-10-2 followed by Anakkayam-1, Madakkathara-1 and NLR-2-1. Yield is a direct function of chlorophyll content. When the yield of the five varieties were compared K-10-2 registered the highest yield and this variety had the highest chlorophyll content. Correlation worked out among chlorophyll a, chlorophyll b, total chlorophyll and yield revealed that there was a positively significant linear relation with a correlation coefficient of 0.992, 0.883 and 0.915 respectively. Chlorophyll content of young shoots and mature shoots after pruning showed that canopy opening significantly increased the chlorophyll content of the treatments. In young shoots the chlorophyll content was higher and in mature shoots, the content was comparatively less and the treatments showed similar trend.

The amount of soluble sugars and total carbohydrate after pruning at the time of flowering was high in treatments of 25 per cent of n_6 removal, 50 per cent of n_6 removal and 25 per cent of n_5 removal. Total carbohydrate content was found to be very high in 50 per cent n_6 removal and 25 per cent n_5 removal.

There was a depletion of nitrogen content at the time of flowering in the treatments of removal of 50 per cent of n_5 order, removal of 25 per cent of n_5 order and removal of 50 per cent of n_6 order.

C/N ratio was high in treatments, which gave higher yields namely removal of 50 per cent of n_6,25 per cent of n_5 and 50 per cent of n_5 while the C/N ratio was low in the treatment of removal of 100 per cent of n_4 branches.

From the study the following conclusions were drawn.

1. Because of the high PWBBRn and spear shaped canopy and high yield efficiency grafts are found to be much superior to seedlings and layers. For high density, intensive management, an ideal plant type is a tree with a height of 3 to 4 meters with a spread of about 3 to 4 meters with a spear shaped

canopy with a canopy surface area of 40 m^2 and with high yield efficiency of about 0.28 g per squaremetre. If such tree types are planted and intensive management practices are given, a two fold increase in yield could be easily achieved.

2. Pruning can be used as a management practice to improve yield in cashew as is done in Apple, mango and other crops.

3. Removal of 25 per cent of n_5 order of branches at an interval of 3 years seems to be ideal.

4. Chlorophyll content is found to have a direct bearing on yield and for future screening programmes for yield, chlorophyll content can be used as one of the major criteria for selection.

References

REFERENCES

Alan, N., Lakso, Terence, L., Robinson, K. and Steven, G. Carpenter. 1989. The palmette leader: A tree design for improved light distribution, *Hort. Science* 24(2):271-275

Alderman, W.H. and Auchter, E.C. 1916. The apple as affected by varying degrees of dormant and seasonal pruning. *W. Va. Agric. Exp. Stn. Bull.* 158

Aldrich, W.W. and Grim, J.H. 1938. Further investigations on the relation of pruning to set of fruit in pears. *Proc. Amer. Soc. Hort. Sci.* 36:328-334

Alexander, M.E. and Maggs, D.H. 1974. Adaptability of fruit crops to tropics and temperate zones. *Proc. 19th Int. Hort. Congr. Vol.3.* 105-113

Arora, R., Wisniewski, M.E. and Scorza, R. 1992. Cold acclimation in genetically related (sibling) deciduous and evergreen peach. 1. Seasonal changes in cold hardiness and poly peptides of bark and xylem tissues. *Plant physiol.* 99:1562-1568

* Aselage, J. and Carlson, R.F. 1977. Summer pruning as related to growth control of four apple cultivers. *Compact Fruit Tree*, 10:77-85

* Awasthi, R.P. and Verma, A.S. 1986. Apple cultivation in Himachal Pradesh. *Bull.* pp.39

Bagenal, N.B. and Turner, A.D. 1936. Dwarf pyramid apple culture at Cannington. *Sci. Hort.* 4:67-74

Barden, J.A. 1974. Net photosynthesis, dark respiration, specific leaf weight and growth of young apple trees as influenced by light regime. *J. Amer. Soc. Hort. Sci.* 99:547-551

* Barlow, H.W.B. and Hancock, C.R. 1960. The experimental modification of branch form in an apple root stock. *Bot. Gaz.* 121(4):208-215

* Barlow, H.W.B. and Hancock, C.R. 1962. The influence of leaf upon the development of it's axillary meristem. Ann. Rep. E. Malling. Res. Stn. 1961. pp.71-76

Barritt, B.H., Rom, C.R., Konishi, B. and Dilley, M.A. 1991. Light level influences supr quality and canopy development and light interception influence fruit production in apple. *Hort. Sci.* 26(8):993-999

Basak, J. 1986. Inheritance and genetic variation of spurred growth habit in apples. *Acta Hort.* 140:55-61

Bassi, D. and Dima, A. 1994. Tree structure and pruning response of six peach growth forms. *J. Amer. Soc. Hort. Sci.* 119(3):378-382

* Beakbane, A.B. and Preston, A.P. 1962. Three tree forms for plums. Ann. Rep. E. Malling. Res. Stn. 1961. pp.57-60

Birrenkott, A.B., Henson, A.C. and Stang, E.J. 1991. Carbohydrate levels and the development of fruit in cranberry. *J. Amer. Soc. Hort. Sci.* 116(2):174-178

Bory, G. and Clair-Maczulajtys, D. 1993. Lesmetabolites de reserves : on outil de perception de la physiologic de l'arbre entier. In. 4. Riedacker, E. Dreyer, H. Joly and G. Bory (Eds.). Physiologic des Arbres et Arbustes en zones Arides. John Libbey Eurotext, London. pp.97-115

* Bory, G., Sarthou, C. and Clair-Maezulajtys, D. 1994. Effects of pruning on carbohydrate distribution in the trunk of sweet cherry. *Scientia Hortic.* 59:61-67

Brown, C.L., Mc Alpine, R.G. and Kormanik, P.P. 1967. Apical dominance and form in woody plants : a reappraisal. *Amer. J. Bot.* 54:153-162

Brown, C.S., Young, E. and Pharr, D.M. 1985. Root stock and scion effects on carbon partitioning in apple leaves. *J. Amer. Soc. Hort. Sci.*, 110:701-705

Bruning, E.F. 1976. Tree forms in relation to environmental conditions : an ecological view point. *Amer. J. Bot.* 54:153-162

Cain, J.C. 1970. Optimum tree density for apple orchards. *Hort. Science*, 5:232-234

Cameron, S.H. 1923. Storage of starch in the pear and apricot. *Proc. Amer. Soc. Hort. Sci.* 20:98

* Carlson, R.F. 1982. Fruit tree training and pruning. *Compact Fruit tree.* 15:96-98

* Chalmers, D.J. and Vanden Ende, B. 1975. The "fatura trellis" : A new design for high yielding orchards. *J. Agr. Victoria* 73:473-476

* Champagnat, P. 1961. Dominance apicale, tropismses, epinastic. In: W. Ruhland (ed.) Handbuch pflanzen. Physiologic, vol.14, pp.872-877

Champagnat, P. 1978. Formation of the trunk in woody plants. p.401-422. In: P.B. Tomlinson and M.H. Zimmermann (eds.). Tropical trees as living systems. Cambridge Univ. Press, Cambridge.

Cutting, J.G.M., Bridgette Cocker and Wolsten holme, B.N. 1994. Time and type of pruning cut affect shoot growth in Arocado (*Perseaa americana*) Mill. *J. of Hort. Sci.* 69(1):81-88

Day, K.R. and De Jong, T.M. 1989. Post harvest and Pre harvest summer pruning of 'Firebrite' Nectarine trees. *Hort. Sci.* 24(2):238-240

* Dostal, R. 1908. Korrelationsbeziehungen bei den papicionaceen-keimlingen. *Rospr. Ces. Akad.* 17:1-44

Dunn, J.S. and Stolp. M. 1987. Apples on the Lincoln canopy. mechanized management *Hort. Sci.* 22(4):568-572

Elfving, D.C. 1990. Growth and productivity of 'Empire' apple trees following a single Heading-back pruning treatment. *Hort. Sci.* 25(8):908-910

* Engel, G. 1974. Einfluss des Sommerschnittes aufden Wuchs and Ertragvan Apfeln auf Samling. *Erwerbsobstbau*, 16:47-48

* Engel, G. and Lenz, F. 1981. Hinweis fur de Behandlung von Apfelw anf M9 nach totalem Blu ten frosts chedon. *Obstbau* **6**:296-297

Ferguson, J.H.A. 1960. A comparison of two planting systems in orchards as regards the amount of radiation intercepted by the trees. *Hort Science* 22:552-560

Ferree, D.C. and Stang, M. 1980. Yield and light efficiency of four apple management systems. In abstracts XXIst international. Hort. Congress. Hamburg vol.1. Abstract. No.1064

* Frank, A.B. 1868. Uber die Einwirkung der Gravitation auf das Wachsthum einiger Pflanzentheile. *Botan. Ztg.* **26**:873-882

Gardner, V.R. 1916. The early summer pruning of young apple trees. *Ore. Agr. Expl. Sta. Bul.* **139**:p.1-46

Gardner, V.R., Bradford, C.F. and Hooker, H.D. 1922. The fundamentals of fruit production, pp. 408-418. Mc Graw-Hill, New York.

Gardner, V.R., Bradford, F.C. and Hooker, H.D. 1952. The fundamentals of fruit production, pruning - The season. 3rd Edn. Mc Graw Hill, New York.

Goswamy, A.M., Saxena, S.K. and Kurien, S. 1993. High density planting in citrus. In: Advances in Horticulture Vol. 2. Fruit crops. Eds. K.L. Chadha and O.P. Pareek, Malbotra publishing house, New Delhi.

Greathouse, D.C., Laetsch, W.M. 1969. Structure and development of the dimorphic branch system of Theobroma cacao. *Amer. J. Botany* **56**:1143-1151

Greene, D.W. and Lord, W.J. 1983. Effects of dormant pruning, summer pruning, scoring and growth regulators on growth, yield and fruit quality of "Delicious" and "Cortland" apple trees. *J. Amer. Soc. Hort. Sci.* **108**:590-595

* Groehowska, M.J., Karaszewska, A. and Mika, A. 1977. Studies on physiological aspects of pruning apple trees. II. The effect of pruning and disbudding on the level of carbohydrates in maiden trees. *Fruit Sci. Rep.* 4(3):7-13

* Grubb, N.H. 1938. Winter pruning of apple trees. Some advice based on the East Malling experiments. *Annu. Rep. E. Malling. Res. Stn.* 1937, pp.237-241

Halle, F., Oldeman, R.A.A. 1979. Tropical trees and Forests - An architectural analysis, Berlin, Heidelberg. New York. Springer - Verlag. pp.210-215

Halle, F., Oldeman, R.A.A. and Tomlinson, P.B. 1978. Tropical trees and forests. Spinger-Verlag, New York.

Hienicke, D.R. 1963. The micro climate of fruit trees. II. Foliage and light distribution patterns in apple trees. *Proc. Amer. Soc. Hort. Sci.* 83:1-11

Hienicke, D.R. 1964. The micro climate of fruit trees. 111. The effect of tree size on light penetration and leaf area in 'Red Delicious' apple trees. *Proc. Amer. Soc. Hort. Sci.* 85:33-41

Hienicke, D.R. 1966. Characteristics of McIntosh and Red Delicious apples as influenced by exposure to sunlight during the growing season. *Proc. Amer. Soc. Hort. Sci.* 89:10-13

Heinicke, D.R. 1975. High density apple orchards. Planting, Training and pruning. USDA. Agrl. Handbook No.458

* Hooker, H.D. 1924. Changes produced in apple trees by various types of pruning. *Missouri Stn. Res. Bull.* 72(3)

Hutton, R.J., Mc Fadyen, L.M. and Lill, W.J. 1987. Relative productivity and yield efficiency of canning peach trees in three intensive growing systems. *Hort. Sci.* 22:552-560

* Ibrahem-Ahmed, K.A., Mika, A. and Piatkowski, M. 1983. Fruit quality and storage ability of two apple cultivars as affected by rootstocks, planting systems, irrigation and growth retardants. I. Effect of orchard treatments on fruit quality and mineral content of apples. *Fruit Sci. Rep.* 10(4):161-172

* Jackson, M.L. 1958. Soil chemical analysis, Prentice Hall Inc. U.S.A.

* Jackson, J.E. 1970. Aspects of light climate within apple orchards. *J. Applied. Ecol.* 7:207-216

Jackson, J.E. 1980. Light interception and utilization by orchard systems. *Hort. Rev.* 2:208-267

Jackson, J.E. and Parmer, K. 1980. A computer model study of light interception by orchards in relation to mechanized harvesting and management. *Sci. Hort.* 13:1-7

Jankiewicz, L.S. and Stecki, Z.J. 1976. Some mechanism responsible for difference in tree form. In. M.G.R. Cannell and F.T.Last (edn.) Tree physiology and yield improvement. pp.157-172. Academic Press, London.

Jonkers, H. 1932. Pruning young apple trees and bending of branches. Proc. 16th Int. Hort. Congr. pp.441-443

* Jonkers, H. 1967. Tree size control by pruning and bending. In: H.B. Turkey (Editor) Proc. 16th Int. Hortic. Congress, Michigam State University, East Lansing, M1, pp.57-70

Kanwar, S.M. 1988. Effect of pruning intensities on the fruit drop, retension, yield and quality of apple cv. Royal Delicious. *Prog. Hort.* 15:17

Kappel, F. and Flore, J.A. 1983. Effect of shade on photosynthesis, specific leaf weight, leaf chlorophyll content in peach. *J. Amer. Soc. Hort. Sci.*, 96:664-667

Keller, J.D. and Loescher, W.H. 1989. Nonstructural carbohydrate partitioning in perennial parts of sweet cherry. *J. Amer. Soc. Hort. Sci.* 114:969-975

Kerala Agricultural University, 1991. Research Report, Directorate of Research, Vellanikkara, Thrissur, Kerala.

Kerala Agricultural University, 1992. Research Report, Directorate of Research, Vellanikkara, Thrissur, Kerala.

Kerala Agricultural University, 1993. Research Report, Directorate of Research, Vellanikkara, Thrissur, Kerala.

Khan, M.M., Kumar, D.P. and Hiremath, I.G. 1984. Pruning studies in cashew. The Cashew. 1(1):11-12

* Knight, R.C. 1927. The relation in the apple between the development of young shoots and the thickening of older stems. *J. Pomol.* 6:72-77

* Koopmann, K. 1896. Grundlehren des Obstbaumsehnittes. Padl Parey, Berlin.

Kramer, P.J. and Kozlowski, T.T. 1979. Physiology of woody plants. Academic, New York.

* Kraus, E.J. and Kraybill, H.R. 1918. Vegetation and reproduction with special reference to the tomato. *Creg. Agric. Exp. Stn. Bull.* 149:1-90

Kurien, R.M. 1985. Studies on sylleptic branches in *Zizyphus* species with special reference to productivity in Ber (*Zizyphus mauritiana* L.) var. Umran. M.Sc.(Hort.) Thesis, University of Agricultural Sciences, Bangalore.

Lakso, A.N. 1989. Aspects of canopy photosynthesis and productivity in apple trees. *Acta. Hort.* 144:100-109

Lakso, A.N., Robinson, T.L. and Carpenter, G.S. 1989. The palmette Leader. A tree design for improved light distribution. *Hort. Sci.* 24(2):271-275

Lespinasse, E.W. and Detort, K. 1986. Computed effects of spacing on light interception and distribution within hedge row in relation to productivity. *Acta Hort.* 114:80-88

* Lockard, R.G. 1956. Factors affecting shoot growth. Ph.D. Thesis, Univ. ov London.

Loeschur, W.H., Mc Camant, T. and Keller, J.D. 1990. Carbohydrate reserves, translocation and storage in woody plant roots. *Hort. Sci.* 25:274-281

Long, J.N., Smith, F.W. and Scott. D.R.M. 1981. The role of Douglas-fir stem sapwood and heartwood in the mechanical and physiological support of crowns and the development of stem form. *Can. J. For. Res.* 11:459-464

Looney, N.E. 1968. Light regimes within standard size apple trees as determined spectrophotometrically. *Proc. Amer. Soc. Hort. Sci*. **93**:1-6

Lorette, L. 1925. The Lorette system of pruning. Martin Hopkinson Ltd., London.

Luckwill, L.C. 1978. Meadow orchards and fruit walls. *Acta Hort.* **65**:237-243

Madhava Rao, V.N. and Shanmugavelu, K.G. 1985. Studies on the effect of pruning on mango. *Progressive Horticulture*. 21-24

Maggs, D.H. 1959. The pruning response of one year apple trees. *Ann. Bot.* **23**:319-330

Maggs, D.H. 1965. Dormant and summer pruning compared by pruning young apple trees once on a succession of dates. *J. Hort. Sci.* **40**:249-265

Magness, J.R., Edminster, A.F. and Gardiner, V.R. 1977. In: Pruning investigations: Second report. pp.57-73. *Ore Agric. Exp. Stan. Bull.* 146

Marini, R.P. and Barden, J.A. 1982. Growth and flowering of vigorous apple trees as affected by summer or dormant pruning. *J. Amer. Soc. Hort. Sci.* **107**:474-479

Marini, R.P. and Marini, M.C. 1983. Seasonal changes in specific leaf weight, net photosynthesis and chlorophyll content of peach leaves as affected by light penetration and canopy position. *J. Amer. Soc. Hort. Sci.* **108**:609-613

Marini, R.P. and Barden, J.A. 1987. Summer pruning of apple and peach trees. *Hort. Rev.* 9:351-376

Marini, R.P., Barden, J.A., Sowers, D. 1991. Growth and fruiting response of Red chief delicious apple trees to heading cutts and seaffold limb removal. *J. Amer. Soc. Hort. Sci*. **118**(4):446-449

Mathai, C.K. 1989. Branching pattern of a guava tree and it's relation to productivity. *Strat. Physiol. Regul. Plant Productivity Proc*. 216-220

* Mc Kenzie, D.W. 1972. Intensive orchards in New Zealand. The orchardist of N.Z. 44:175-181

Mc Kenzie, D.W., Dunn, J.S., Stolp, M. and Hutton, R.J. 1978. Horizontal canopy orchards for mechanical harvesting. *Acta Hort.* 65:267-276

* Mika, A. 1969. Effects of shoot bending apple trees on accumulation and translocation of ^{14}C labelled assimilates. *Biol. Plant.* 11:175-182

Mika, A. 1981. Effects of dormant and summer pruning, disbudding and growth retardants on growth, flower bud formation and fruiting of young apple trees. *J. Am. Soc. Hort. Sci.* 108:655-660

* Mika, A. 1982. The relation between the amount and type of pruning and the yield of apple trees. *Proc. 21st Int. Hort. Cong.I.* pp.209-221

Mika, A. 1986. Physiological responses of fruit trees to pruning. *Hort. Rev.* 8:337-358

Mika, A., Grochowska, M.J., Karaszewska, A., Jankowska, B., Maksymiuk, J., Tymoszeek, S., Olszewski, T. and Slowik, K. 1981. Physiological aspects of pruning and other treatments promoting flower formation and fruit retention in the apple tree. Report for 1975-1981. Research Institute of Pomology and Fruitology, Poland.

Mika, A., Grochowska, M.J. and Karaszeneska, A. 1983. Effect of dormant and summer pruning, disbudding and growth retardants on growth, flower formation and fruiting of young apple trees. *J. Amer. Soc. Hort. Sci.* 108:655-660

* Mohan, E. 1991. Studies on the effect of pruning and growth regulators on vegetative growth and flowering in cashew. M.Sc.(Agri.) Thesis, University of Agrl. Sciences, Bangalore.

Moing, A., Lafargue, B., Lespinasse, J.M., Grandillere, J.P. 1994. Carbon and nitrogen reserves in prune tree shoots, effect of training system. *Scientia Hortic.* 57:99-110

Mullins, M.G. 1965. The Gravitational responses of young apple trees. *J. Hort. Sci.* **40**:237-247

Murneek, A.E. 1941. Relative carbohydrate and nitrogen concentration in the new tissue produced on ringed branches. *Proc. Amer. Soc. Hort. Sci.* **38**:133-136

Myers, S.C. and Ferree, D.C. 1983. Influence of time of summer pruning and Limb orientation on growth and flowering of vigorous "Delicious" apple trees. *J. Amer. Soc. Hort. Sci.* **108**(4):634-638

* Naidenov, L.N., Gorechakov, S.A. and Nesterenko, A.A. 1980. Effect of pruning on grape yield and quality. *Sadovod. Vinograd. Vinodl. Mold.* **9**:32-34

Nalini, P.V. and Santhakumari, S. 1990. Performance of selected types of cashew at Anakkayam. *The Cashew.* Oct. - Dec. (4):1991

National Research Centre for Cashew. 1992. Annual Report, Puthur, Karnataka.

Nautiyal, M.C., Singh, P.K. and Shukla, R.N. 1993. Pruning regulates cropping in peach. *Indian Horticulture.* **41**(2):42-45

Nayar, K.G. 1994. Cashew export in India : An analysis of issues and performance. *The Cashew.* April - June (2):15-16

Norton, R.L. 1980. Managing pruning problems in high density plantings. *Annu. Rep. N. Y. State Hort. Soc.* **110**:35-47

O'Kennedy, B.T., Hannerty, M.J. and Titus, J.S. 1975. Changes in the nitrogen reserves of apple shoots during the dormant season. *J. Hort. Sci.* **50**:321-329

Ohler, J.G. 1979. Cashew communication. 71. Department of Agricultural Research Amsterdam.

Oliveira, C.M. and Priestley, C.A. 1988. Carbohydrate reserves in deciduous fruit trees. *Hort. Rev.*, **10**:403-430

Palmer, J.W. 1974. Computed effects of spacing on light interception and distribution within hedgerow trees in relation to productivity. *Acta Hort.* 114:80-88

Palmer, J.W. 1988. The measurement of leaf area in apple trees. *J. Hort. Sci.* 62(1):5-10

Palmer, J.W. and Jackson, J.E. 1977. Seasonal light interception and canopy development in hedgerow and bed system apple orchards. *J. Applied. Ecol.* 14:539-549

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for Agricultural workers. I.C.A.R., New Delhi, p.97-164

* Parnia, C.N., Minoia, N. and Modoran, I. 1979. Reducerea talici si marirea Sareinii de rod a visinului si ciresului prin taieri in verde. *Lucr. Stiint. Inst. Cercet. Prod. Pomicultura Pitesti.* 8:207-221

Phillips, I.D.J. 1969. Apical dominance. In: M.B.Wilins (eds.). Physiology of plant growth and development. pp.165-202. Mc Graw Hill, London.

Pickering, S.U. 1908. The summer pruning of fruit trees (lecture and discussion). *J. Roy. Hort. Soc.* 33:487-499

Preston, A.P. 1969. Pruning and root stock as factors in the production of primary branches on apple trees. *J. Hort. Sci.* 43:17-22

Priestly, C.A. 1969. Some aspects of the physiology of apple root stock varieties under reduced illumination. *Ann. Bot.* 33:967-980

Ram, S. and Sirohi, S.C. 1988. Studies on high density orcharding in mango cv. Dashehari. *Acta. Hort.* 231:339-44

Ram, S. and Sirohi, S.C. 1989. Feasibility of high density orcharding in Dashehari mango. *Acta. Hort.* 291:207-11

Rao, E.V.B. 1993. Cashew Research in India - achievements. *The Cashew.* Jan. - Mar. (1):5-7

Rao, V.N.M. and Shanmugavelu, K.G. 1975. Pruning a new technique for mango growers. Agriculture Agro Industries Journal. September 5-7

Renaud, R., Salesser, G., Roy, M. and Bonnet, A. 1991. Development and selection of new rootstocks of *Prunus domestica. Acta. Hort.* **283**:253-259

Robinson, T.L., Lakso, A.N., Carpenter, S.G. 1991. Canopy development, yield and fruit quality of emperor and delicious apple trees grown in four orchard production systems for 10 years. *J. Amer. Hort. Sci.* **116**(2):179-187

Robinson, L.T., Lakso, A.N. and Ren, Z. 1991. Modifying apple tree canopies for improved production efficiency. *Hort. Science*, 26(8):1005-1011

Rudolph, D.S., Hirst, P.M. and Warrington. 1991. Influence of orientation and position of fruiting laterals on canopy light penetration, yield and fruit quality of Granny Smith apple. *J. Amer. Soc. Hort. Sci.* 113:696-699

* Sachs, J. 1879. Über orthotrope und plagiotrope Pflanzentheile. Arb. Botan. Inst. Würzburg 2. 227-248

Sadasivan, S. and Manikam, A. 1992. Biochemical methods of agricultural sciences. pp.10-11. Wiley Eastern Ltd. and Tamilnadu Agricultural University.

Sako, J. and Laurinen, E. 1982. Effect of summer pruning on the growth and yield of apple trees. *Ann. Agric. Fenniae.* **21**:8-12

Sant Ram. 1993. High density planting in Mango. Advances in Horticulture Vol.2 - Fruit Crops: Part 2 (1993). Eds. K.L.Chadha and O.P.Pareek. Malhotra Publishing House, New Delhi.

Saunders, R.C., Jacobs, G. Strydom, D.K. 1991. Effect of pruning on fruitset and shoot growth of Packham's Triumph pear tree. *Scientia Hort.* 47(3-4):239-245

Saure, M. 1987. Dormancy release in decidual fruit trees. *Hortic. Rev.* 7:239-300

Sauter, J.J. and Van Cleve, B. 1990. Biochemical, immuno chemical and structural studies of protein storage in poplar wood. *Planta* 183:92-100

* Scarrone, F. 1964. Pouvoir inhibiteur des feuilles de grende taille cheze le Manguier (*Mangifera indica*. L.) C.R.Academic Science (Paris). 259:4342-4345

* Scarrone, F. 1965. Role respectif des rythmes endogenes et des facteurs climatiques doms la croissance du Manguier (*Mangifera indica*. L.) C.R.Academic Science (Paris) 260:3469-3472

* Scarrone, F. 1966. Pouvoir de croissance des bourgeone et influences foliains sur ler pousses de Manguier (*Mangifera indica*. L.) en repos vegetatif. C.R.Academic Science (Paris) 262:2344-2346

Shanmugavelu, K.G. and Saidha, T. 1993. Pruning in mango. Advances in Horticulture Vol.2 - Fruit Crops. Part 2. Eds. K.L.Chadha and O.P.Pareek. Malhotra Publishing House, New Delhi-110 064

Sharma, D.K. 1987. A study on high density orcharding in mango (*Mangifera indica* L.) var. Amrapali. *Punjab Hort. J.* 22:123-27

Sharma, D.K. 1989. A study on high density orcharding in mango (*Mangifera indica* L.) var. Amrapali. *Punjab Hort. J.* 25:224-227

Singh, L.B. 1970. Further studies on biennial bearing in mango as related to the chemical composition of shoots. *Hort. Advance*. 4:38

* Sinnof, D.L. 1964. The influence of light intensity temperature and atmospheric carbon dioxide concentration on the rate of apparent photosynthesis of a mature apple tree. *Maine Agr. Expt. Sta. Bul.* 626

Smith, A.R. 1984. Plants, fractals and formal language, Computer graphics. 18(3):1-10

* Soczek, Z.W., Klossowski, K., Slowik, K., Mika, A. and Reszezyk, W. 1970. Studies on nitrogen and carbon content in young apple trees as influenced by their bearing age. *Pr. Inst. Sadow. Skierniewicach*. 14:43-70

Steingraeber, D.E., Ascht, L.T. and Franck, D.H. 1979. Variation of shoot morphology and bifurcation ratio in sugar maph (*Acer saccharum*) Sapling. *Amer. J. Bot.* 66:441-45

Stephen, M.S., Yeager, J.T.a nd Grant, J. 1989. Initial heading height influences branch development in Bing Sweet Cherry. *Hort. Sci.* 24(2):245-247

* Stropek, M. 1983. Regulowanie owocowania sliw przy pomocy ciecia drzeus i chemicznego przerzedzania azwiazkow owocowych, orazwplyz tych zabiegow na jakose owocow i aplacalnose produkeji. Ph.D. Thesis, Skierniewice, Pland.

Syvertsen, J.P. 1984. Light acclimation in citrus leaves. *J. Amer. Soc. Hort. Sci.* 109:807-812

Swarbrick, T. and Berry, W.E. 1938. A comparison of pruning treatments in relation to apple tree shape. *Annu. Rep. Long Ashton Res. Stn.* 1937. pp.31-56

Taylor, B.H. and Ferree, D.C. 1981. The influence of summer pruning on photosynthesis, transpiration, leaf abscission and dry weight accumulation of young apple trees. *J. Amer. Soc. Hort. Sci.* 106:389-393

Taylor, B.H. and Feree, D.C. 1984. The influence of summer pruning and cropping on growth and fruiting of apple. *J. Amer. Soc. Hort. Sci.* 109:19-24

Titus, J.S. and Kang, S.M. 1982. Nitrogen metabolism, translocation and recycling in apple trees. *Hort. Rev.*, 4:204-246

Tripathi, S.P., Srivastava, R.P., Misra, R.s. and Upadhyay, S.N. 1984. Effect of various training systems in plant height, yield and quality of apple. cv. Red Delicious on M_7 rootstock. *Prog. Hort.* 15:256-59

Tromp, J. and Ovaa, J.C. 1973. Spring mobilization of storage nitrogen in isolated shoot sections of apple. *Physiol. Plant* 25:16-22

Tubbs, F.R. 1955. The control of vegetative growth and reproduction of perennial plants. Proc. 4th. Int. Hort. Congr. pp.39-50

Tymoszuk, S., Mika, A. and Antoszewski, R. 1980. The role of watershoots in modifying light climate within the apple tree canopy and in nutrition of fruits. *Acta. Hort.* 114:90

*Tymoszuk, S., Mika, A. and Antoszewski, R. 1984. Studies on the role of water sprouts on apple trees. II. Control methods of regrowth in apple trees after winter pruning, it's influence on light regime and fruit quality. *Fruit. Sci. Rep.* 11(4):131-141

Utermark, H. 1977. Summer pruning to control growth and maintain fruiting in mature apple trees. *Compact Fruit Tree* 10:86-90

Vanden Ende, B., Chalmers, D.J. and Jenie, P.H. 1987. Latest developments in training and management of fruit crops on tatura trellis. *Hort. Sci.* 22:561-568

Verheij, E.W.M. and Verwer, F.L.J.A.W. 1973. Light studies in a spacing trial with apple on a dwarfing and a semidwarfing rootstock. *Scientia Hort.* 1:25-42

Ward, H.M. 1909. Trees. Vol.V. Form and habit. Cambridge Univ. Press, Cambridge.

*Wertheim, S.J. 1968. The training of the slender spindle. Pub. Profestation. Fruiteelt, Wilhelminda dorp, Netherlands. No.7

Wertheim, S.J., Jager, A.D. and Dugzen, M.J.J.P. 1986. Comparison of single row and multirow planting systems with apple, with regard to productivity, fruit size and colour and light conditions. *Acta Hort.* 160:243-258

Wilson, B.F. 1984. The growing tree, Rev. ed. Univ. of Massachusetts Press, Amherst.

Wilson, B.F. and Archer, R.R. 1979. Tree design: Some biological solutions to mechanical problems. *BioScience* 9:293-298

Woodman, J.N. 1971. Variation of net photosynthesis within the crown of a large, forest grown conifer. *Photosynthetica* 4:50-54

Worley, R.E. 1991. Selective limb pruning intensity influences mature pecan tree and nut characteristics. *Hort.Sci.* 26(2):126-129

Yang, W.Y. 1989. Studies on the photosynthetic rate of densely planted apple trees. *Acta Hort.* 15(1):7-12

Yoshioka, H., Nagai, K. and Fukumoto, M. 1988. Seasonal changes of carbohydrates metabolism in apple trees. *Scientia Hortic.* 36:219-227

* Zbinden, W. and Widmer, W. 1980. Erfahrungen mit dem Sommerschitt bei steinbst. Schweiz. 2. Obst. Wein bau, 116:492-508

Zimmerman, M.H. and Brown, C.L. 1971. Trees: Structure and function. Springer-Verlag, New York.

* Originals not seen

Appendices

APPENDIX-I

Analysis of variance table for canopy characteristics

Source	df	Mean of squares				
		Canopy height	Canopy spread	Canopy surface area	Yield	Yield efficiency
Replication	1	0.06	0.65	233.9	2.9	0.01
Variety (A)	2	2.12**	15.00**	7461.0**	79.2**	0.144**
Planting material (B)	2	0.36	0.01	137.7	0.02	0.011
Interaction (AB)	24	0.14	0.48	276.7	2.4	0.002

APPENDIX-II

Analysis of variance table for branch characters

Source	df	Man squares	
		Length of branches	Girth of branches
Replication	9	1092	219
Planting materials (A)	2	56808	247
Branch orders (B)	6	25570	19877
Interaction (A x B)	12	12038	432
Error	180	425	58

APPENDIX-III

Analysis of variance table on influence of n_0 branches on yield

Source	df	Sum of square	M.S.	F
Between	1	1.56	1.56	0.116
Within	28	378.27	13.50	

Co-efficient of variation = 20.03%

APPENDIX-IV

Analysis of variance table on effect of n_1 branches on yield

Source	df	Some of squares	M.S.	F
Between	3	36.45	12.15	0.92
Within	26	343.38	13.21	

Coefficient of variation = 19.81%

APPENDIX-V

Analysis of variance table for flowering characters and yield after pruning

Source	df	Days to flushing	Mean of squares								
			Days to flower-ing	Total number of laterals			No. of flowering laterals			Span of flowering	
				Ist year	2nd year	3rd year	Ist year	2nd year	3rd year	Ist year	2nd year
Replication	4	825.3	5105.8	31.1	2.7	8.3	1.8	1.5	1.5	7.9	17.5
Pruning (A)	7	9502.0**	12315.6**	432.2**	1499.9**	172.6**	490.4**	124.5**	90.7**	7822.9**	46.5**
Variety (B)	1	40.6	15.3	198.5**	174.1**	546.0**	85.7**	214.5**	132.6**	1377.8**	2289.8**
Interaction (AxB)	7	4.2	1.0	3.6	5.70	1.5	1.7	3.0	3.0	34.9	0.5
Error	64	24.1	160.5	4.8	2.5	4.3	1.3	1.5	1.6	4.6	6.4

APPENDIX-V. Continued

Source	df	Mean squares					
		Percentage of bisexual flowers			Yield Ist year	Yield 2nd year	Yield 3rd year
		Ist year	2nd year	3rd year			
Replication	4	32.4	10.9	25.8	-	-	-
Pruning (A)	7	766.5**	126.4**	139.0**	246.3**	66.6**	69.8**
Varieties (B)	1	18.2	25.3	20.9	0.11	0.30	0.42
Interaction (AxB)	7	11.3	6.0	2.7	0.57	0.23	3.96
Error	64	21.8	8.0	14.8	6.4	6.13	5.45

APPENDIX-VI

Analysis of variance table for Biochemical studies

(a) Chlorophyll of varieties

Source	df	Mean squares			
		Chl. a	Chl. b	Chl. ab	Yield
Between	4	0.379**	0.295**	1.34**	150.328**
Within	45	0.011	0.011	0.04	0.995

(b) Pruning treatments

Source	df	Mean squares									
		Immature shoots			Mature shoots			Total CBH	Soluble CBH	Nitrogen	C/N
		Chl. a	Chl. b	Total Chlorophyll	Chl. a	Chl. b	Total Chlorophyll				
Replication	4	-	-	-	-	-	-	-	-	-	-
Pruning (A)	7	0.97**	0.019**	0.076**	0.24**	0.193	0.828	261.52**	8.872**	4.486**	105.94**
Varieties (B)	1	0.111	0.004	0.008	0.001	0.008	0.007	0.060	0.051	0.017	2.478
Interaction (AxB)	7	0.011	0.001	0.001	0.014	0.005	0.012	0.233	0.272	0.006	0.386
Error	64	0.006	0.001	0.009	0.021	0.007	0.044	0.743	0.697	0.082	1.439

PRODUCTIVITY IN RELATION TO BRANCHING PATTERN AND PRUNING IN CASHEW

(*Anacardium occidentale.* L.)

By

P. V. NALINI

ABSTRACT OF A THESIS

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Faculty of Agriculture
Kerala Agricultural University

Department of Plantation Crops and Spices
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680654

1997

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ABSTRACT

A study was carried out at Cashew Research Station, Anakkayam in the Kerala Agricultural University to investigate the canopy architecture of cashew and to ascertain the optimum degree and frequency of manipulation of canopy for increasing yield. The experiments were carried out during the period from March, 1992 to September, 1995.

The study revealed that the resultant canopy of a seedling was massive and like a hemisphere placed above a solid cylinder. The canopy of the grafts of the two varieties used for the study appeared like a cone placed abover a short cylinder. The layers had a small size canopy which was like a hemisphere.

Because of the high PWBBRn and spear shaped canopy and high yield efficiency, grafts are found to be much superior to seedldings and layers. For high density intensive management, it is shown that, the use of grafts of high yielding varieties could result in a two fold increase in yield. From the experimental evidences and identification of yield components by path analysis, an ideal plant type of cashew is proposed.

Experiments on canopy manipulation of cashew revealed that the crop responded very well for pruning. A pruning schedule of removal of 25 per cent of the n_5 order of branches at an interval of 3 years was found to increase the yield of the crop considerably.

Chlorophyll content is found to have a linear positive correlation with yield and the estimation of the chlorophyll content could be used as one of the tools for screening for high yield in cashew.