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***Review***

# An overview of canopy management in cashew (*Anacardium occidentale* L.)

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## ABSTRACT

**Being a tree crop of commercial importance, the productive performance of cashew is greatly influenced by how best its canopy is architectured for harnessing maximum benefits in terms of yield. The initial training is crucial for the development of photosynthetically efficient canopy in cashew as in other perennial fruit trees. Pruning of dead wood and crisscross branches can alone increase the yield by 30-40 per cent. The dwarf rootstocks also play a role in manipulating the canopy in cashew, wherein, canopy containment and yield were influenced by such rootstocks. By resorting to soil application of growth retardants like paclobutrazol, cashew canopy could be successfully contained to suit high density planting system. The studies on planting geometry has indicated the advantage of high density planting in enhancing profitability of cashew orchards in the initial years of plantation. The advantages of rejuvenation as well as top working techniques are also discussed in this paper.**

**Key words**: Canopy management, PBZ, Planting geometry Pruning, Rootstocks and Training,

## INTRODUCTION

Cashew, being a commercial plantation crop of India with high export demand, is confronted with an issue of low productivity which has necessitated the processing industries to import raw nuts from other countries to meet the demands of domestic and overseas consumers of Indian cashew. The lower productivity is attributed to various reasons like larger area under senile plantations of seedling origin, poor management practices, etc. Under management practices, management of canopy plays a significant role in cashew production and productivity.

The canopy management comprises of its components like training and pruning, use of growth regulators, selection of rootstocks/variety, etc. Canopy in a fruit yielding tree refers to its physical composition comprising of stem, branches, shoots and leaves. Canopy density is determined by the number and size of the leaves. Canopy architecture is determined by the number, length and orientation of the stem, branches and shoots. Canopy management refers an interpretation of physiology of light penetration and interception which are critical components of overall tree productivity. The main controlling factors are amount of incoming radiation and percentage of radiation intercepted by tree canopies. The productivity of fruit crops depends on several factors, management of canopy architecture being the most important one (Goswami *et al.,* 2014).

## PRINCIPLES OF CANOPY MANAGEMENT

Fruit trees produce fruits regardless of human intervention. However, it is important to manage fruit tree canopies to optimize the balance between vegetative growth and fruit production, and also for easy inter-cultural operations such as spraying, ploughing interspaces and fruit picking at manageable heights.

The basic concept in canopy management of a perennial tree is to make the best use of land and the climatic factors for an increased productivity in three dimensional approaches. Canopy management includes a range of techniques to alter the position and the number of leaves, shoots and fruits in space which determines, to a large extent the plant geometry

structure including spatial distribution of leaf area and leaf orientation.

Orchard architecture largely depends upon orchard production system which is a combination of variety, rootstock, tree spacing, training and pruning. These factors strongly interact to develop a specific production system and determined yield, fruit quality and longevity of the trees. In perennial fruit crops, cultural practices like nutrition, irrigation, planting density, rootstocks training system, pruning and growth retardants can be used as potential means to alter the shoot vigor, size and shape of the canopy and the microclimate at the canopy and thereby increase yield and quality (Vandana *et al*., 2017).

The cashew is a vigorous evergreen perennial woody plant having long juvenility and high heterozygosity. Canopy development in cashew is a seasonal and continuous process. However, the varieties which are available nowadays are of semi vigorous to vigorous type. Canopy management has a direct influence on plant vigour which ultimately influences the cashew nuts yield. The manipulation of the canopy by training and pruning, plant growth inhibitors and dwarfing rootstocks plays an important role in management practice to regulate vegetative growth, flowering and yield in fruit trees (Srilatha *et al.*, 2015).

The response to pruning depends on age, growth habits, tree vigour, varieties, location and cultivation practices of cashew. Heavy pruning promotes excessive vegetative growth and often reduces the yield due to the dense canopy with reduced flowering (Balamohan *et al.*, 2016). The application of plant growth retardants such as paclobutrazol (PBZ) has been found useful in the manipulation of vegetative growth, vigour and yield of cashew (Meena *et al.,* 2018; Babli *et al.*, 2019). The optimized application of PBZ helps to obtain maximum benefit with minimum undesirable impact on food and environmental safety aspects (Kishore *et al.*, 2015).

In cashew canopy development, two types branching exists, in which one is intensive and the other is extensive (Saroj *et al*., 2014). In high yielding trees more than 60 per cent intensive branches are seen whereas low yielders possess less than 20 per cent intensive branches. The ‘intensive shoot’ grows to a length of about 25- 30 cm and ends in a panicle, while in the ‘extensive type’, the shoot grows to 20-30 cm length and rests. Concurrently, in the intensive type that tends to give bushy appearance to the tree, 3 to 8 lateral shoots come up below 10-15 cm of the apex and few of these laterals may also bear panicles. On the other hand, in the ‘extensive type’, a bud sprouting 5-8 cm below the apex gives rise to further growth which continues for two or three years without giving flowers and results in spreading tree habit.

The training and pruning in tree crops affect the quantity of sunlight intercepted as tree shape determines the presentation of leaf area to incoming radiation. An ideal training strategy focuses around the arrangement of plant parts, especially, to develop a better plant architecture that optimizes the utilization of sunlight and promotes productivity. Light is critical to growth and development of trees and their fruits and productivity. The green leaves harvest the sunlight to produce carbohydrates and sugars which are transported to the sites where they are required – inflorescence, buds, flowers and fruits. Better light penetration into the tree canopy improves tree growth, productivity and fruit quality. The density and orientation of planting also impact light penetration in an orchard. Generally, in close planting, quicker shading becomes a problem. An east-west row orientation results in more shading as compared to the western and southern orientation of trees. The strong bearing branches tend to produce larger fruits. The problem of a fruit grower is initially to build up a strong and balanced framework of the trees, then equip them with appropriate fruiting. Obviously, pruning in the early years has to be of a training type to provide strong and stocky framework with well-spaced limbs or any other desired shape. Some of the basic principles in canopy management are maximum utilization of light, avoidance of built-up microclimate which is congenial for pest and disease infestation, convenience in carrying out the inter-cultural operations, maximizing productivity with quality fruit production and economy(Singh, 2010).

## TRAINING OF YOUNG CASHEW PLANTATION

In case of the new plantations with the grafts, the plants should be trained in the early years i.e., 2-3 years so as to provide better plant architecture which

facilitates the easy inter-cultural operations. Training indirectly assists in ease of other operations such as weeding, manuring and pest and disease management (Satpathy, 1988). The lateral shoots arising from rootstocks need to be removed periodically till 2-3 years. This will assure the proper growth of the scion portion of the grafts. The grafted plants should be shaped by removing the branches and water-shoots growing from the main stem up to a height of 0.75m to 1.0m from the collar region during first 3-4 years. Besides, weak and interlocking branches should also need to be removed. After the age of 4-5 years, in tall type of cashew plants the main trunk may be de-topped at a height of 4-5 m from the ground region. This will ensure a round globular canopy which helps to harvest maximum sun light for photosynthesis. Severe pruning of the young grafts may be avoided as it may extend the juvenility and the pre-bearing period of the plants (Nayak *et al*., 1996). In general, two types of training systems are being practiced in cashew, a) Modified leader system and, b) Open center system.

**a) Modified leader system**

In this system, cashew grafts are allowed to grow as single stem up to a height of 75 to 100 cm by removing side sprouts. Then lateral branches are allowed to grow at desirable direction by de-topping. De-topping height varies from 2.5 to 4 m depending on spacing. Under normal spacing (8m x 8m), de-topping at 4 m from ground level is recommended. Whereas, for high density planting (5m x 5m), de-topping at 2.5 m from ground level is recommended. Removal of crisscross branches and trimming of branches has to be resorted to get dome shape canopy and the same should be maintained in later years by imposing mild pruning. This kind of canopy helps in reducing weak shoots and water shoots development. Modified training system is suitable for both normal and high-density planting system.

**b) Open center system**

Cashew grafts are allowed to grow straight up to 50-60 cm from ground level. The terminal growing point is pinched off to form lateral branches. The branches are regulated to grow in four directions at equal distance. Because of fast vegetative growth, the canopy spreads rapidly. To avoid this, canopy center needs to be opened up once in a while to support more light interception to the interior plant parts. This encourages flowering at inner and outer surface of canopy and thus increases the yield (Nayak *et al*., 2019).

## PRUNING IN THE ESTABLISHED PLANTATIONS

The trees which have not received any training and pruning in the initial years grow haphazardly and resulting in canopies without desirable shape and size. Besides, the development of deadwood, inter-mingling of branches with neighboring trees, crisscross branches, development of water shoots etc. will bring down the productivity of the tree (Nayak *et al*., 1996).

**Deadwood/dry branches**

The dead wood/dry branches develop mainly because of the effect of shade on lower branches caused by overlapping of the upper branches. Deadwood will be an additional burden to the plants. Furthermore, the dead and decaying woods may invite the entry of pathogenic organisms or saprophytic growth which may spread further in due course of time.

**Crisscross branches**

The lower branches remain crawling on the ground for want of space and sunlight, where the plants are not trained or pruned in the initial years. Similarly, the branches at higher level also grow haphazardly in search of sunlight resulting in irregular canopy architecture.

**Intermingling of branches**

The problem of entangling of branches starts after 10-12 years in regularly spaced (8x8 m) plantations. The exterior branches get entangled with neighboring trees as a result, only a portion of canopy (crown portion) remains exposed to sunlight. Such a development inside the plantation is a hindrance to the regular intercultural operations and general maintenance of the orchard.

**Water shoots/sprouts**

Water-shoots are vegetative shoots which are extraordinarily vigorous growing from dormant buds at higher points on main stem in upright direction. They grow at the expense of parent branches from which they arise. They are erect in growth and much thicker in size than the normal branches and bear much longer and coarser leaves. These branches

outgrow the rest of the neighboring drooping branches. If water shoots are not removed in time, they soon cover the center of the canopy and obstruct sunlight.

**Frequency of pruning**

The old trees with deadwood, crisscross branches, water- shoots and inter mingling branches should be pruned at least once in 2-3 years (Khan *et.al*., 1987). Pruning can be taken up in dormant season i.e., at least 2-3 months earlier to productive flushing. All the types of unwanted growth mentioned before are to be pruned off. However, the plant should have a better look and structure after pruning. This can be achieved using one's discretion and experience in pruning and orchard management.

**Leader shoot pruning**

Cashew trees enter a brief resting period after the harvest of the crop (May - June) and it continues up to next productive flushing season (September - November). The flushes or flower bearing twigs are known as lateral shoots. These shoots usually form the terminal portion of a leader shoot which will give a single shoot (lateral) from its terminal bud. If the terminal bud is disturbed by means of pruning the dormant lateral buds will sprout resulting in a greater number of lateral shoots per unit area. This will result in increased number of productive inflorescences.

Pruning the leader shoots can be taken up at least 2-3 months (July to August) before flushing. In a tree about 50-60% of the leader shoots may be headed back to one-third of their original length. A pair of leaves may be retained while pruning wherever possible. While pruning, the leader shoot should be of a pencil thickness and should not have turned to ash color before taking up pruning.

In Bhaskara variety of cashew, leader shoot pruning was not useful and the number of flowering laterals was drastically reduced. However, pruning of lateral shoots to 25per cent in the month of September was very effective in enhancing flower production and nut yield (Anon. , 2019).

**Yield increase in pruned trees**

The past season leader shoots can produce only one lateral from its terminal. Pruning enhances the production of lateral shoots; thus, the yield can be increased. Pruning intensity and time varies for different specific agro-climatic regions. Pruning of dead wood and crisscross branches can increase yield by 30-40% (Khan *et al*., 1987). Leader-shoot pruning doubled the yield in cashew (Mohan and Room Singh, 1988). Results of pruning on 28-year-old trees revealed that trees with three branches pruned recorded the highest number of panicles/ $m^2$ (39), highest number of flowers/panicle (588.70) and fruit-set to an extent of 14.42%, while unpruned trees recorded only 7.75% increase in yield (Panda, 1990). Under Jhargram conditions, pruning of leader-shoots during July enhanced the number of productive laterals, increased the number of bisexual flowers per panicle, fruits per panicle and yield per tree (Chattopadhyay and Ghose, 1994). Pruning treatment increased the number of laterals/leader but did not affect duration of flowering and harvest (Mohan and Rao, 1995).

Effect of the pruning in different shoots in two varieties namely, BPP-4 and BPP-6 was conducted at the Cashew Research Station, Bapatla, Guntur district (AP). The shoots were decapitated back to 5 cm in mid-July, mid-August and mid-September months of the leader shoots, lateral shoots and leader as well as lateral shoots pruned separately and different growth parameters on individual trees were studied. In response to the pruning, the variety BPP-4 performed better as compared to BPP-6. The production of flowering shoots and nut yield as influenced by the cultivar, level of pruning and time of pruning that a moderate incremental growth with large number of flowering shoots could be obtained by pruning the leader shoot in mid-August under local agro-climatic condition. The study further indicated that the vigorous cultivar BPP-4 and off-season production cultivar BPP-6 performed well during a rainy year compared to the dry year which was associated with prolonged dry spell and delayed rains in August-September months. Another important observation from the study indicated that the off-season cultivar of cashew needs essentially the pruning of the leader shoot in mid-August so as to avoid the off-season flowering and to increase productivity in the normal season. Pruning of leader shoots in mid-July was found to be beneficial during both the years of study to produce higher tree yield of nuts (Prasannakumar *et al*., 2015).

## ROLE OF ROOTSTOCKS

Rootstocks play a very important role in propagation of plants. It may modify form or stature and adopt a variety to a soil in an incompatible climatic condition and also build up the resistance to biotic and abiotic stresses meanwhile increase the production and productivity. Rootstocks play a very important role in improving production, canopy architecture, flowering and fruiting quality and tolerance to stress. Although, lot of advancements was made in rootstock research of other fruit crops, such works on cashew is very limited.

The root system of the young dwarf cashew is one very well-developed main root that branches many times and can grow-up to 10 m or more in deep sandy soils. Lateral roots develop in the upper soil layers between 15 and 32 cm deep. The length of the superficial roots may reach twice the diameter of the crown in dry-land conditions (Barros, 1995). When irrigated the lateral roots are concentrated around the wet area of soil. The characteristics of the tap and lateral roots are of importance in relation to the fertilization of cashew (Crisóstomo *et al*., 2007).Great variation exists in the depth of the main root and distribution in depth and length of the lateral roots due to the effects of topography, soil texture, stoniness and the presence of a hardened soil layer on the development of the cashew root system (Falade, 1984).

Using dwarfing rootstocks offers the possibility to manipulate tree vigour, better anchorage, nutrient uptake, tolerance to biotic and abiotic stress, as well as yield and productivity without increasing input costs (Webster, 2004). Rootstock selection is a critical tool for the management of vegetative and reproductive growth of scion in perennial fruit crops, which are propagated by grafting or budding. Numerous studies have shown that they offer the advantage of rootstocks in the cultivation of tropical and temperate fruit crops on aboveground tree growth and yield (Balamohan *et al.*, 2016; Webster, 2004; Nibolkar *et al.*, 2016). Very limited studies have been investigated on cashew to select suitable rootstocks to modify scion vigour and increase productivity. The preliminary results reported by Adiga *et al*. (2014), provided the background information for the performance of vigorous cashew cultivars as influenced by dwarf rootstocks. The dwarf accession, NRC-492 could be used as a rootstock to induce semi dwarfism with a higher nut yield. Although cashew is a scion dominant species, the effect of rootstock is reflected in terms of stionic combination in particular, to control the plant vigour of the plant.

Different rootstocks differentially influence the morphology of grafted cultivars, including tree height, trunk cross-sectional area (TCSA), internodal length and yield. In one of the studies, Janani *et.al.* (2020) reported that VRI-3(scion)/ Taliparamba-1(rootstock) had low vigour based on lower means of tree height, plant volume, TCSA and canopy spread. The stionic combinations of VRI-3/ NRC-492 recorded the highest cumulative nut yield of 16.77 kg/tree (five seasons of cropping). This showed the possibility of manipulating cashew nut productivity through rootstock. Based on the observations on growth and yield of various stionic combinations, it was revealed that NRC-492 could be used as a rootstock to induce semi dwarfism with a higher nut yield. However, in Brazil, the different rootstocks tried for dwarf cashew clones could not influence the yield and nut weight in cashew (Paiva *et al.,*2004).

## USE OF GROWTH RETARDANTS

The canopy management by pruning in later stages of growth often affects orchard life and performance of trees. High density planting system (HDP) has been attempted in cashew to obtain early benefits in terms of yield during initial years of planting. Under HDP, maintenance of tree and canopy growth becomes important due to closer spacing and shading of canopy of trees. In cashew, due to non-availability of dwarf clones and dwarfing rootstocks, use of growth retardants like paclobutrazol (PBZ) assumes importance. Hence, a study was aimed to evaluate the morpho-physiological responses of cashew to PBZ treatments under field trials (Meena *et al*., 2018; Babli *et al.,* 2019). The PBZ treatments resulted in reduced vegetative growth and enhanced reproductive growth with most striking responses of PBZ @3 g a.i./tree treatment. PBZ treatments altered cashew tree physiology by modifying tree size, canopy growth, internodal length, branching pattern and overall ground coverage of the tree. Higher total leaf chlorophyll content, better photo assimilation and enhanced leaf photosynthesis contributed in inducing early flowering and development of more flowering panicles with perfect flowers. Enhanced fruit set and

increased number of nuts/$m^2$ canopy contributed in yield increment. Regression analysis showed leaf pigments, nut number and number of inflorescences as the most contributing traits for yield enhancement under PBZ. These findings highlight the exploitation of morpho-physiological traits for better canopy growth and yield maximization by PBZ in cashew under the HDP.

PBZ treatments are effective in arresting vegetative growth and promoting reproductive growth of cashew. The PBZ treatments altered cashew tree physiology through reduction in vegetative growth, enhancement of flowering, production of more fruits and more fruit set due to efficient distribution of photosynthates, enhanced total leaf chlorophyll contents and increased leaf photosynthesis. These ultimately resulted in enhanced nut yield. Therefore, the findings may provide useful insights on finding solutions to tackle low productivity of cashew by proper regulation of endogenous growth hormones that can relate to enhanced nut yield. In addition, these findings may also throw light on induction of the desired physiological effects in cashew trees that can help in modifications of canopy growth and tree vigour. These in turn can be exploited well under the HDP system to harness early benefits with enhanced yield in cashew.

## ROLE OF PLANTING GEOMETRY

In India, the established processing capacity of raw nuts is around 15-20 lakh tonnes, where the domestic contribution is around 7-8 lakh tonnes. In the recent years, there is an increase in the domestic demand for cashew. Thus, India has been importing nearly half of the raw cashew nuts processed in the country mainly from the African countries at the cost of Rs. 8839 crores annually (Anonymous, 2017). Of late, the import possibility from many of these African countries is dwindling, as these countries have setup their own processing facilities and also the competition for import of nuts from these countries by the major cashew processing and exporting countries like Vietnam is increasing. The major cause for deficit of raw nuts for processing by Indian cashew industries is the low productivity (720 kg/ha). It is mainly due to large area of old senile orchards, low plant population per unit area, poor canopy management and non-adoption of improved package of practices. In recent times, demand for cashew in both domestic and international market is growing every year. In India, cashew consumption has increased by about 5.5 times in the last decade and is expected to grow further in the future. It has been estimated that the domestic demand for raw cashew nut is about 50 million MT or more by 2050 (Saroj and Nayak, 2016).

Hence, to meet this huge demand for cashew there is an urgent need for increasing the productivity per unit area. This can be achieved easily by the adoption of ultra and high-density planting systems. In recent times, there is a shift in farmers' perception from production to productivity and profitability which can be achieved through accommodating a greater number of plants per unit area. Studies on high density planting systems in fruit crops such as guava, mango and cashew have been shown to be more economical compared to the traditional planting system (Yadukumar *et al.,* 2001, Bal and Dhaliwal 2003, Sousa *et al.,* 2012, Gaikwad *et al.* (2017). Efforts have been made to standardize the high-density planting in cashew (Rejani *et al*., 2013), and mango (Gunjate *et al*., 2009) and some pruning techniques for improving nut yield in cashew (Mohan and Singh 1988, Kumar *et al.,* 2015, Murali *et al.,* 2015). In a long-term experiment on standardizing the planting geometry for 9 popular cultivars of cashew under west coast conditions of Karnataka, Adiga *et al*. (2014) found that the spacing requirement varied with varieties for optimum performance with respect to yield. They found that planting density of 500 plants per hectare was associated with highest cumulative nut yield as against planting density of 200 plants per hectare. The variety Vengurla-4 which exhibited highest leaf area index (1.80) was also associated with highest nut yield of 3.60 tonnes per hectare in the sixth harvest. The results of these studies have revealed that closer planting will help in increasing the productivity. However, the responses of the varieties to the pruning varied. Therefore, it is very much essential to identify varieties suitable for ultra and high-density planting which respond to pruning. Study revealed that interaction effect of varieties by spacing was observed for most of the growth and yield related characters except plant height and nut traits. Though the unit cost of establishment and maintenance for the first decade was high under high density planting system, the net income expected from high density planting (625

plants/hectare) was 130 to 150 per cent higher than normal density (200 plants/hectare) planting system (Yadukumar *et al*., 2003).

## CANOPY REJUVENATION

About one third of plantations owned by cashew development corporations are old and senile and has contributed to lower productivity in the country. The rejuvenation of such plantations can address the issue of low productivity. The crux of canopy rejuvenation lies in the art of exploiting the existing root system of such senile trees to enhance canopy efficiency through severe pruning in case of named varieties or through top working if the plantation is of non-descript varieties or low yielding seedling origin trees.

The technology envisages beheading of trees, allowing juvenile shoots to sprout and taking up *in situ* grafting with scions of high yielding trees. This technology can offer 3-4-fold increase in cashew production in a short span of time. The increased yield of 5-10 kg/tree/year ensures sustained in come to the farmers (Khan *et al.,* 1986). The extent of growth in top worked trees at 5 years was on par with 17-year-old trees apart from 5-fold increase in nut yield (Kumar, 1990). The height of beheading of senile trees, the season of beheading and season of grafting decides the success of top working in cashew. Under Odisha conditions, beheading at 0.5m height in the month of May or June and grafting in the month of August resulted in the highest success rate of 81.80 per cent (Lenka *et al*.,1991). Under coastal Tamil Nadu conditions, the grafting success was highest between June to September (Pugalendhi *et al*., 1992). For Western ghat zone of Maharashtra, beheading in the first week of May followed by grafting in July resulted in highest success rate (85.70%) (Patil *et al*., 2004). One should exercise utmost precaution in beheaded trees as the cut trees are amenable for gummosis disease (Cardoso and Freire, 1998) or attack by cashew stem and root borer where mortality rate varies from 2.5 per cent to 100 per cent (Swamy,1995).

## CONCLUSION

Canopy management is an 'art' of fruit growing - it is much more than cutting off a few branches. In fact, removing wood/branch from a tree is one of the last things growers want to do. To optimize fruit production and productivity, thoughtful canopy management is one of the most important subjects to sustain the yield and quality of fruits. To establish an ideal plantation, the young grafts are to be trained from the first year of planting itself which helps in facilitating easy and effective intercultural operations like base cleaning, trench making, fertilizer application, irrigation, pesticide spray against TMB, swabbing against stem and root borer, harvesting and picking nuts. In old and unthrifty plantations, the development of deadwood, water shoots crisscross branches, intermingling branches with the neighbouring trees and the branches crawling on the ground should be pruned to enhance nut yield. The leader shoot pruning should also be attended at least once in 2-3 years along with the removal of the above-mentioned unwanted growth which will be of help in boosting the nut yield. Meanwhile dwarfing rootstocks, planting density, use of growth retardants and selection of varieties also play an important role in successful management of cashew canopy.

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