

**STANDARDIZATION OF CANOPY ARCHITECTURE  
TECHNIQUES OF NURSERY PLANT FOR HIGH  
DENSITY PLANTATION OF MANGO  
(*Mangifera indica* L.)**

*Thesis*

by

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(NH-2018-20-M)**

submitted to



**Dr. YASHWANT SINGH PARMAR UNIVERSITY  
OF HORTICULTURE & FORESTRY  
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in

partial fulfilment of the requirements for the degree  
of

**MASTER OF SCIENCE  
(HORTICULTURE)  
FRUIT SCIENCE  
DEPARTMENT OF FRUIT SCIENCE  
COLLEGE OF HORTICULTURE AND FORESTRY, NERI  
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## CERTIFICATE - I

This is to certify that the thesis entitled “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**” submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) FRUIT SCIENCE** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Miss Sunita Pathania (NH-2018-20-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

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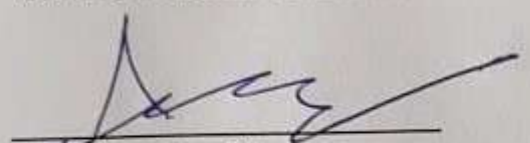
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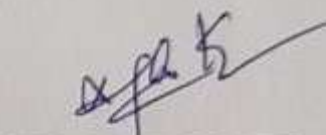
  
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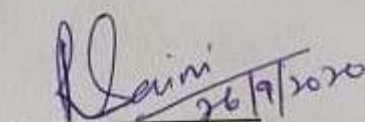
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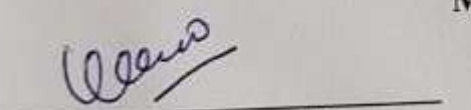
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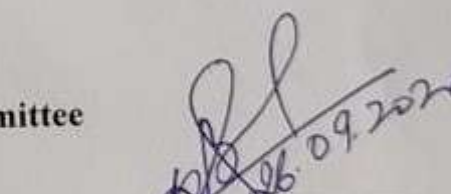
  
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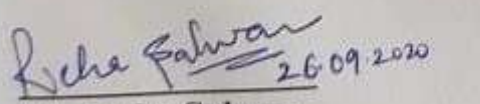
  
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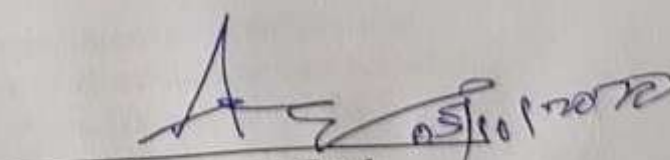
  
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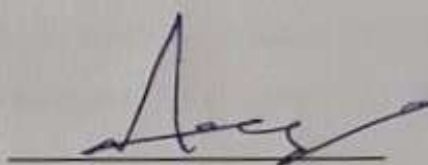
  
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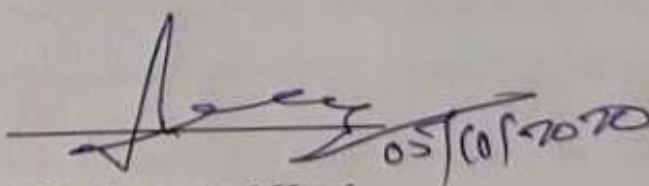
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This is to certify that all the mistakes and errors as pointed out by the external examiner have been incorporated in the thesis titled, “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**”, submitted by **Miss Sunita Pathania (NH-2018-20-M)** Daughter of Sh. Joginder Singh to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (H.P.)- 173230 in the partial fulfilment for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) FRUIT SCIENCE**.



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Needless to say, errors and omissions are solely mine.

Place: Neri, Hamirpur  
Dated:

(Sunita Pathania)

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## **ABBREVIATIONS**

%	: Per cent
$\pi$	: Pi
@	: At the rate of
°C	: Degree centigrade
ANOVA	: Analysis of variance
CD	: Critical difference
Chl	: Chlorophyll
cm	: Centimeter
CRD	: Completely Randomized Design
cv.	: Cultivar
df	: Degree of freedom
<i>et al.</i>	: Co-workers
E-W	: East-West
g	: Gram
H P	: Himachal Pradesh
i.e.	: That is
K lux	: Kilo lux
LAI	: Leaf area index
m	: Meter
m <sup>3</sup>	: Meter cube
ml	: Milliliters
NS	: Non-significant
N-S	: North-South
RH	: Relative humidity
RWC	: Relative water content
SE	: Standard Error
TGA	: Total ground area
TLA	: Total leaf area
<i>viz.</i>	: Videliscet

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## *Chapter – 1*

### **INTRODUCTION**

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Mango (*Mangifera indica* L.) is one of the pre-eminent fruit crop of India which give delightful flavour and taste to life in the tropical world. It is extensively grown in tropical and subtropical regions of the world. It is native to the South Asian region mainly Eastern India, Burma, and the Andaman Islands. Mango belongs to the family Anacardiaceae and acknowledged as King of fruits, Peach of Tropics, and the National Fruit of India.

Mango occupies the most important place in the horticultural wealth of our nation. It continues to dominate the Indian fruit basket, contributing an area of 22,58,000 hectares with production of 2,18,22,000 metric tonnes (Anonymous, 2018a) and an average productivity of 8.5 tonnes per hectare in India. India is the leading producer and produces 40.48 per cent of the total world mango production. Fresh mango export of India is 46,510.27 metric tonnes which value at rupees 40649.55 lakhs and the highest annual exports are to the United Arab Emirates levelling around 16,398.18 metric tonnes with the value of rupees 15,336.16 lakhs (Anonymous, 2018c). Uttar Pradesh, Andhra Pradesh, Karnataka, Bihar, Gujarat and Tamil Nadu are the leading mango producing states in India. Uttar Pradesh leads in productivity with 12.8 tonnes per hectare. In Himachal Pradesh, mango covers an area of 41,989 hectares with a production of 31,353 metric tonnes with a productivity of 0.75 tonnes per hectare (Anonymous, 2018b).

Mango is one of the finest fruit in the world market with distinctive nutritional and medicinal utility. It is a good source of Vitamin A, C, carbohydrates and also an integral part of Indian culture being grown since antiquity. It is widely used in Ayurveda and helps to cure constipation, diarrhoea, eye disorder, hair loss, piles, scurvy, sinusitis and spleen enlargement. Mango trees have rhythmic growth, sympodial branching, bearing perfect-hermaphroditic flowers and purely male-staminate flowers. Inflorescence of mango is terminal with 1000 to 6000 flowers in a panicle varying with different varieties.

India being the largest producer, it is necessary to improve the productivity and quality of mangoes to compete with other nations. The reasons for low productivity include poor quality plant material available to farmers, low planting density, long gestation period,

poor canopy management, lack of technical know-how, lack of proper nutrition and irrigation etc.

Juvenile mango trees do not flower as shoots get only short intervals of 2 to 3 months between vegetative flushes. It normally takes 3 to 4 years to achieve sufficient numbers of branches and height to reduce this frequency of growth flushes. It is only then that sufficient stem maturity can be achieved to allow flowering and produce a commercially viable crop. Poor canopy management is one of the major limiting factor in mango productivity. Being evergreen tree, mango is hardly pruned as compared to temperate fruits, which leads to overcrowding of branches that results in poor light penetrance causing low productivity and inferior quality fruit with higher disease and insect pest incidence. Canopy architectural management at nursery stage is one of the most important and emerging factor to sustain the yield and quality of mango.

The use of heavily branched (feathered nursery plants) combined with high-density plantation and minimal pruning appear as the most appropriate solution to overcoming low productivity and shortening the long gestation period for early returns. The terminal buds with the presence of auxin promote apical dominance, which affects the development of lateral buds in plants (Cline, 1997). Lateral buds can be induced by pinching, heading back of shoot and with the application of growth regulators. For a high-quality tree, the presence of a sufficient number of feathers is desirable because they enable the tree to bear fruit in the first year itself following field planting (Robinson *et al.*, 2006). Feathered nursery plants with wide crotch angled shoots around 45° are critical components of most high-density planting systems. This fulfils one of the main purposes of fruit nurserymen by improving fruiting sites during early years of planting. Wide crotch angle is preferable in feathered plants as these bloom early and more easily trained after planting on various training systems (Warner, 1991).

Feather length and fruit plant productivity are linked to each other and thus, an important factor in determining plant quality (Sadowski *et al.*, 2007). Crown of nursery plants having feathers is formed from axillary buds of the main shoot, the emergence of which is governed by the auxin/cytokinin ratio (Wit *et al.*, 2002). The presence of sufficient number of feathers at planting, the greater and earlier is the yield (Elfving, 2010). Early fruiting in pear with higher production was achieved with large and efficient bearing area using the canopy management techniques (Ende, 1994). Good ordering quality of mango nursery plant will

reduce the time, effort and technical know-how needed for tree training by farmers. Important factors which govern lateral branching are nutrient availability status, ecological conditions and apical dominance (Tromp, 1996). Moreover, as feathered trees facilitate earlier canopy structure formation, pruning is consequently simplified and management cost is reduced as compared to plant with less number of lateral shoots (Robinson, 2007).

Considering the need, time and future thrust, it is very necessary to standardize canopy architecture techniques of nursery plants for high density plantation of mango under prevailing climatic condition of subtropics of Himachal Pradesh. The study was conducted with the following objectives:

- A. To develop canopy architecture of nursery plant for high-density plantation
- B. To study the effect of pruning on different orders for canopy development

## *Chapter – 2*

### **REVIEW OF LITERATURE**

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Major constraints in mango production are poor quality planting material, low-density planting, long gestation period, poor canopy management due to lack of technical know-how. To overcome these constraints there is a need for the standardization of canopy architecture techniques of nursery plants for high density plantation of mango. By standardizing the canopy architecture of nursery plant for high density plantation, farmer will get good planting material which will start to give fruits within 1-2 years after planting in the field with earlier and higher return. After planting in the field only maintenance of the canopy will be required. The available literature of the present investigation entitled, “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**” and in other fruit crops relevant to the present study have been reviewed and presented under the following heads in this chapter.

#### **2.1 Effect of pruning levels on growth characteristics**

2.1.1 Plant height

2.1.2 Stem diameter

2.1.3 Time taken for bud sprouting after heading back

2.1.4 Number of shoots per branch

2.1.5 Shoot length after pruning

#### **2.2 Effect of pruning levels on canopy microclimatic characteristics**

2.2.1 Leaf Area

2.2.2 Leaf Area Index

2.2.3 Canopy volume

2.2.4 Relative water content

2.2.5 Light penetrance

2.2.6 Canopy temperature

### 2.2.7 Canopy relative humidity

## 2.3 Effect of pruning levels on biochemical characteristics

### 2.3.1 Chlorophyll content

## 2.1 Effect of pruning levels on growth characteristics

Effect of different pruning intensities on growth parameters *viz.*, plant height, stem diameter, time taken for bud sprouting after heading back, number of shoots per branch and shoot length in mango and some other fruit crops has been reviewed in following heads.

### 2.1.1 Plant height

Ingle *et al.*, (2005) observed increased plant height with light pruning (15-20 cm) in June as compared to medium and heavy pruning in acid lime. Davenport (2006) stated that the purpose of shape pruning was to reduce the dimensions of the canopy in trees which become overcrowded or to make it more convenient for tip pruning. The depth of pruning into the canopy must be at least 1 m inside the final desired dimensions in order to allow regrowth of the mango canopy. Lal and Mishra (2007) studied the impact of pruning on mango cv. 'Chausa' under North Indian conditions. Three pruning intensities, *viz.*, heading back up to tertiary branches, heading back up to secondary branches and center opening were given to the mango tree. After eight years, they recorded minimum tree height (4.60 m) on trees headed back up to tertiary branches followed by heading back up to secondary branches (4.90 m).

Lal and Mishra (2008) performed different pruning practices in mango cv. 'Dashehari' for rejuvenation by removing the first order to the fifth order growth of the main trunk. They concluded that after 12 years of pruning, maximum increase in the height was achieved in first order pruned trees followed by second order pruned tree while, the lowest was recorded in control (unpruned). Kumar and Rattanpal (2010) found decrease of tree height with increase in severity of pruning on 13 years old trees of 'Sardar' guava. Das and Jana (2012) studied the effect of canopy management on growth of 24 year old mango cv. 'Amarpali' under high density plantation and headed back at different heights: 1 m, 1.5 m and 2 m above the ground during December. Heading back of primary shoot (60 cm, 120 cm and unpruned) and secondary shoot (60 cm and unpruned) were imposed after one year of pruning. Heading back at 1 m resulted in lower tree height than 1.5 m and 2 m.

Gracia *et al.*, (2014) evaluated the impact of pruning on plant canopy in mango cv. 'Ataulfo'. They used three pruning dates (20 April, 20 May and 20 June) to assess the impact of pruning treatment on the vegetative growth of mango. They observed only one vegetative growth cycle during the productive cycle of unpruned (control) mango trees, whereas trees that were pruned had up to three vegetative growth cycles before flowering, regardless of whether pruning was done in April, May or June.

Kishore *et al.*, (2017) conducted an experiment in mango var. 'Arka Neelachalkesari' (an extra early irregular variety), on 7-8 year old and 10-12 year old trees planted at a spacing of 3 × 4 m and 5 × 5 m respectively. Study was conducted to optimize plant canopy architecture by regulating the number and orientation of primary and secondary branches. Along with the combination of branches, trunk height (80-90 cm) was also optimized for developing an ideal canopy framework for harnessing solar energy efficiently and ensuring high yield efficiency. At spacing 3 × 4 m, the height and spread of plants were restricted to 2 m, while tree height and spread of 3.5 m were regulated under 5 × 5 m spacing. They regulated canopy height and spread by annual pruning that was carried out during June and July (after fruit harvest). The canopy of trees was reduced every year by 60-80 cm in order to regulate the canopy under different tree densities.

Singh *et al.*, (2017) studied impact of pruning on vegetative growth of mango cv. 'Dashehari'. They observed vigorous height (4.56 m) under control (unpruned) trees. Whereas, trees which were pruned annually by heading back 20 cm at terminal shoots during rest period before emergence of new growth along with paclobutrazol application showed minimum tree height (3.30 m) and spread (2.21 m). The annual pruning by heading back 10 cm at terminal shoots immediately after fruit harvest proved effective for dwarfing effect on the tree. Sagar *et al.*, (2019) carried out study to know the effects of high density plantation and pruning seasons on the growth of mango cv. 'Alphonso'. They recorded maximum increment in tree height (17.66 cm) at 5.0 × 5.0 m spacing with pruning of previous season growth.

### **2.1.2 Stem diameter**

Lal *et al.*, (2000) evaluated the impact of pruning severity on mango cv. 'Dashehari' which was more pronounced on shoot girth as compared to unpruned trees. They found that shoots emerged in first order (branches emerging from main trunk) and second order (branches emerging from first order) had more girth than the shoots from fourth and fifth

order pruning, which was probably due to the diversion of more nutrients to these shoots because these being closer to the main trunk of the trees. Banik and Sen (2002) experimented for rejuvenation of unproductive trees of mango cv. 'Fazli' between 30 to 50 years old by different levels of pruning and fertilization in West Bengal. They recorded highest increase in trunk girth (4.55 cm) by heading back the leader branch in 30 to 40 year old tree as compared to 40 to 50 years old tree.

Davenport (2006) performed shape pruning to reduce the dimensions of the canopy in overcrowded trees and to make tip pruning more convenient as part of the flowering management program. Shape pruning required cutting of branches ranging in size from 2-10 cm in diameter depending upon the original size of the mango tree. Lal and Mishra (2008) evaluated impact of different pruning levels in rejuvenation of 45 years old mango orchard of cv. 'Dashehari' by removing the first order to the fifth order growth of the main trunk. After twelve years study they found that, first order pruned mango trees resulted maximum increase in shoot girth.

Singh *et al.*, (2009) studied the effect of pruning on morphophysiological parameters under high density plantation of mango. They found that the pruning intensities significantly affected trunk girth but the maximum girth was noticed during flowering in light pruned trees. Iosif *et al.*, (2011) studied the impact of four different pruning intensities on apple cultivars 'Pionier', 'Prima', 'Generossi' and 'Florina'. They found that trunk growth was positively influenced by heading back the semi-scaffold and annual branches to half and heading of semi-scaffold to  $2/3^{\text{rd}}$  their length.

Das and Jana (2012) studied the effect of canopy management on growth of 24 year old mango cv. 'Amarpali' under high density plantation and headed back at different heights: 1 m, 1.5 m and 2 m above the ground during December. Heading back of primary shoot (60 cm, 120 cm and unpruned) and secondary shoot (60 cm and unpruned) were imposed after one year of pruning. They found that trees that were headed back at 1 m height resulted in lower shoot girth of primary shoots whereas higher shoot girth was reported in control. Rossi *et al.*, (2012) reported lower value of shoot girth from severe pruning due to low rate of cambial differentiation of shoots emerging out of older tissues having higher accumulation of growth inhibitors.

Dhaliwal *et al.*, (2013) found improved shoot length and girth on pruning in both types (vigorous and normal growth) of 'Kinnow' mandarin plants. They performed pruning

with different intensities at 5, 6 and 8 feet level and observed the maximum increase of shoot girth (2.60 cm) in plants pruned at 8 feet level from July to August. Sagar *et al.*, (2019) studied the impact of high density plantation and pruning seasons on growth of mango cv. 'Alphonso'. They recorded maximum plant girth (1.87 cm) in plants with spacing  $2.5 \times 2.5$  m and pruning the current season growth.

### **2.1.3 Time taken for bud sprouting after heading back**

Lal and Ram (1975) observed that generally during the off year in mango trees the initiation of vegetative growth takes place during March to April. When shoots were decapitated in April new vegetative growth initiated immediately after pruning while, upon decapitation in May and June, it started in June-July. However, shoots decapitated in July, August, September, October and November did not produce new shoots until January due to shorter length than the control mango trees. The April decapitated shoots produced maximum new shoots (132 %), while lowest (25 %) was observed in May decapitated shoots.

Jadhav *et al.*, (2002) observed earliest emergence of vegetative bud sprout on severely pruned (60 cm) trees of guava which was significantly more than mild pruned (30 cm) and control (unpruned) trees. Das and Jana (2012) studied the effect of canopy management on growth of 24 year old mango cv. 'Amarpali' under high density plantation and headed back at different heights: 1 m, 1.5 m and 2 m above the ground level during December. Heading back of primary shoot (60 cm, 120 cm and unpruned) and secondary shoot (60 cm and unpruned) were imposed after one year of pruning. They found that light pruning (2 m above the ground level) took less time for initiation of bud sprouting (25 days) whereas, maximum time (56 days) was took by severe pruning (1 m above the ground level).

Dhaliwal *et al.*, (2013) recorded that severe pruning took less time for bud sprouting (9.66 days) as compared to other pruning intensities in 'Kinnow'. Bhagwati *et al.*, (2015) studied the effect of different pruning intensities on guava. Different pruning intensities (light, moderate and severe and unpruned) were given to the plants and they found that severe pruning takes the minimum time for first vegetative bud emergence (3.98 days) followed by moderate (4.44 days) and light (5.01 days).

### **2.1.4 Number of shoots per branch**

Reece *et al.*, (1946) recorded the maximum number of panicles in July pruned 'Dashehari' mango trees. The axillary buds were emerged and started developing lateral

inflorescence. Singh and Godara (1985) obtained maximum leaf area was obtained by severe pruning in ber whereas, the per cent bud sprouting increased on medium and severe pruning as compared to light pruning.

Shu and Sheen (1987) demonstrated that the longer exposure to low temperatures resulted in reduced number of flowering branches and increased number of vegetative and dormant buds in deblossomed mango trees. Bisla *et al.*, (1991) recorded maximum emergence of primary shoots (5.63) in control (no pruning) and minimum (3.46) with severe pruning in ber cv. 'Umran' under Hissar conditions. They also observed higher number of secondary and tertiary shoots with severe pruning.

Issarakraisila *et al.*, (1991) and Singh *et al.*, (1974) reported that pruning performed shortly before or after the start of normal terminal bud development resulted in flowering in mango. Oosthuysen (1994) pruned mango cv. 'Sensation' with the objectives of encouraging the branching (feathering) of young plants particularly in cultivars which do not branch readily on their own and stimulating the development of new shoots to maintain the tree size. He found pruning effective for the early and higher accumulation of reserves by enhanced uniform post-harvest flushing and reduced flowering variation.

Gross (1996) evaluated tipping or heading back as a form of very light pruning and found early shoot development in about 30-40 days. Mango var. 'Kent' tended to generate 3 or more sprouts on head back surface and the secondary cut of 15° to 20° angle resulted in only one or two sprouts. Rojas and Leal (1996) reported that with the increase in magnitude of pruning, there was increased branching. Pruning on one side of the tree showed a reduction of 25.3 per cent of terminal branches, 54.4 per cent reduction upon pruning at three sides of the tree and pruning on five sides of the tree reduced 84.2 per cent terminal branches.

Swaroop *et al.*, (2001) studied the effect of pruning on growth of 21 year old mango cv. 'Dashehari'. Where, trees were categorized into 'off' and 'on' years, pruned from July to February for 2 years. Apical shoot apex (4.5 cm) was pruned on the 20<sup>th</sup> day of each month as a treatment. They found double number of panicles in 'on' year pruned trees. July-August pruning resulted in more number of shoots than control (unpruned) and December pruning produced auxiliary panicles only, whereas July-August pruning increased both terminal and auxiliary panicles on pruned shoots. The panicle length in July-August pruning was found higher than the control whereas, no such effect was shown by November and December pruned shoots. Data suggested that 'on' year mango trees should be pruned in July, August

and December for increasing panicles on a shoot and hermaphrodite flower in panicles. Whereas, 'off' year trees produced 226.3 per cent vegetative shoots in April next year without any shoot pruning after harvest. But when pruned in November-December, the number of shoot rose to 373 per cent in November next year and many of them flowered and fruited in the same year. Thus 'on' year pruning forced new vegetative shoot production (100-400 per cent) and many of them produced panicles (1-3 per shoot).

Banik and Sen (2002) carried out the investigation for rejuvenation of unproductive mango trees cv. 'Fazli' between 30 to 50 years old by different levels of pruning in West Bengal. They observed highest number of new shoots (23.50) when the leader remained intact and removal of first order branches and pruning of secondary in 30 to 40 years old trees. Awasthi *et al.*, (2003) observed decreased number of new sprouts after pruning at height of 25 cm (light), 50 cm (medium) or 75 cm (severe) from the base of secondary branches whereas, the height and girth of new shoots increased in comparison to the unpruned peach plant.

Kumar *et al.*, (2003) evaluated the effect of pruning the shoots 10 cm back from the tips in mid-July and subsequent production of new shoot growth (8 year old mango cv. 'Baneshan' trees). They found highest number of shoots produced 2 laterals (261) followed by 3 laterals (230), whereas up to 6 laterals were produced by some shoots and the lateral shoots resulted in to 1-4 vegetative growth flushes. They also found that number of lateral shoots directly influenced the diameter and the length of flushes increased as the number of laterals decreased. Occurrence of the lateral shoots after pruning was negatively correlated with flush production and percentage of flowering shoots.

Shinde *et al.*, (2003) evaluated the impact of pruning on 35 year old mango cv. 'Alphonso' trees. Three pruning methods (heading back of branches at 50 cm level on entire tree, heading back of branches at 50 cm level on alternate limbs. Thinning of overcrowded branches, centre opening), 2 pruning times were given after fruit harvest and during the rest period. They found that light pruning i.e., 50 cm heading back of branches during the rest period gave rise to uniform vegetative growth whereas, centre opening and branch thinning during the rest period resulted in more number of shoots (54) inside the tree canopy.

Davenport (2006) observed that juvenile mango trees did not flower due to short intervals between vegetative flushes. Normally mango tree took three to four years to reduce the flushing frequency and sufficient stem maturity there by allowing flowering and to

produce a commercially viable crop. Tip pruning forced a synchronized flush from pruned stems, which resulted in synchronized flowering in 'Keitt' mango. Yadav *et al.*, (2007) investigated the impact of one side pruning and time on growth parameters of mango cv. 'Alphonso'. Pruning was given in September, October, November and December. They observed that there was not any significant impact of pruning time on vegetative shoots per m<sup>2</sup> over control (unpruned) whereas, pruning in December resulted in higher (15.88 %) number of vegetative shoots over control (unpruned) plants.

Singh *et al.*, (2009) studied the effect of pruning on microclimate characteristics under high density plantation in mango (cvs. 'Amrapali', 'Mallika' and 'Dashehari'). Four different pruning intensities, i.e., control (unpruned), light (30 cm from the apex), moderate (60 cm from the apex) and severe (90 cm from the apex) were given and they found that the severe pruning resulted in sprouting of maximum number of shoots due to low shoot: root ratio compared to control (old-aged trees). Singh *et al.*, (2010) observed the influence of different pruning intensities in three mango cultivars ('Amrapali', 'Mallika' and 'Dashehari') planted under high density (2.5 × 2.5 m, 6 × 6 m and 3 × 2.5 m). They recorded highest number of panicles per branch (5.13, 5.66) with moderate level pruning intensity whereas, lowest number of panicles per branch found in unpruned (control) trees.

Kishore *et al.*, (2017) conducted an experiment in mango var. 'Arka Neelachalkesari' planted at a spacing of 3 × 4 m and 5 × 5 m respectively. To optimize plant canopy architecture by regulating the number and orientation of primary and secondary branches. They reported that combination of three primary branches (in different directions) and two secondary branches per primary branch were suitable for mango planted at 3 × 4 m spacing, whereas a combination of four primary branches (in different directions) and two secondary branches were optimal for 5 × 5 m spacing. Sagar *et al.*, (2019) carried out study to know the effects of high density plantation and pruning seasons on growth of mango cv. 'Alphonso'. They found highest number of primary branches (4.08) and tertiary branches (26.76) with 5.0 × 2.5 m spacing in combination with pruning of previous season growth. The highest number of secondary branches (8.81) was recorded with 5.0 × 2.5 m spacing and current season growth pruning.

### **2.1.5 Shoot length after pruning**

Iyer and Subramaniam (1973) evaluated effect on pruning for inducing dwarfness in 18 years old 'Banganapalli' and 'Suvarnarekha' mango trees. They found that pruning

produced more dormant buds than it was produced by shoots of sufficient length to bear flower panicles and normal fruit in the following season. However, these shoots produced after pruning was less than half the length of shoots produced on control (unpruned) trees.

Rao and Khader (1980) reported terminal regions of shoots and young leaves as main source of antiflowering, gibberellins and their removal by pruning might results in flowering mango. Hackett (1985) found increase in vegetative vigour of different fruit crops by increasing pruning severity. Mika (1986) reported increased accumulation of gibberellic acid in different crops by increasing severity of pruning. Charnvichit *et al.*, (1989) studied the effect of hard pruning on mango trees and recorded six growth flushes after hard pruning. Shoot lengths formed after first flush was almost similar but there were differences in shoot length of second, third, fourth flushes after pruning. They recorded 2.3 m height after 4 month of hard pruning and 2.52 m after 8 month and 2.86 m after 12 month.

Oosthuysen (1995) studied pruning of ‘Sensation’ mango trees to maintain their size and he found pruning after harvest as a measure to maintain the size of mature ‘Sensation’ mango trees. It was observed that prolific and synchronous regrowth was initiated within 13 days of pruning and higher number of new shoots emerged from pruned branches than unpruned branches. In unpruned trees, new shoot development was delayed after harvest and occurred early during March, April and May. Shoot length was similar both in pruned and control trees, whereas fewer leaves were produced by shoots on pruned branches. Pruning resulted in to slightly delayed and more uniform flowering. Higher starch content was found in the leaves and stem of new shoots on pruned trees at flowering. Gross (1996) studied the effect of different pruning levels in mango under Florida conditions and concluded that light pruning (6-8 inches from shoot tip) facilitated the development of vegetative flush that helped in maintaining the bearing.

Oosthuysen (1996) explained the principles of mango pruning and adopted some practices of pruning mango trees in South Africa. He suggested that young mango plants maintained as single stemmed whips should be allowed to attain a height of more than 1m before any branching was permitted. Unwanted lateral shoots should be removed (thinned) by pinching soon after they start to develop. Trees were headed at 0.8 to 1 m at first order. Heading to initiate branching should not be performed during April, May, June, July, August and September because of the initiation of axillary inflorescence rather than new shoots which often developed after heading back in these months. The unwanted development of

inflorescence creates a demand on the pool of available carbohydrates. He also highlighted the importance of terminal shoot pruning (mature terminal shoots) during the prebearing years of a tree's life. Inflorescence occurred in October should be removed by hand and new shoots arising from the apical bud on pencil-thickness or thicker at this time should also be removed in the same way. The pencil-thick or thicker shoots that do not show signs of growth or just started to show signs of bud development should be pruned.

Oosthuysen and Jacobs (1996) also found a higher rate of re-flowering in mango cv. Sensation when the inflorescence of tree was pruned at the site of apical bud or inflorescence attachment as compared to the pruning including leaves clustered around the shoot apex. Urrutia and Elisea (1996) reported increased vegetative regrowth with increase in diameter of pruned wood and trees that were cut at a 15° or 30° angle produced new growth earlier than those pruned at 0° angle. They also studied the vegetative response of mango in hedged and pruned trees and found that hedging and cutting every year controlled tree size. Oosthuysen (1997) studied the effect of size maintenance pruning on vegetative growth of mango trees month after pruning. He pruned mango trees shortly after they were harvested, outer branches on each tree were headed back (the new shoots which developed after harvest the preceding season removed i.e., stimulation of hedgerow pruning) and found uniform and prolific flushes in the pruned trees whereas, growth flushes in the unpruned trees were prolific, but were less uniform and more protracted.

Burondhkar *et al.*, (1999) recommended hard pruning in the first fortnight of March with soil application of paclobutrazol @ 5-7g per tree in July or August of following year for rejuvenation of 40 years old mango orchard of cv. 'Alphonso'. Muhammad *et al.*, (1999) evaluated the vegetative growth pattern of 10 years old mango cv. 'Langra'. They concluded that April to August was active growth period whereas, flush ceased to grow from April to June and attained physiological maturity needed for blooming in next season and growth ceasing was observed more from July onward. Ram (1999) studied the physiology of flowering of 'Dashehari' mango and reported major vegetative flush in March- April followed by two minor flushes in June-July and September-October. The major vegetative flush yielded fruits whereas, the other two minor flushes did not. The fruited shoots rarely produced new vegetative flushes immediately after crop harvest and also did not flowered or gave fruits in the following season. Hence, to sustain tree vigour and productivity, fruited shoots were forced to produce vegetative growth soon after crop harvest by pruning (heading back).

Sasaki *et al.*, (1999) investigated the impact of pruning at panicle emergence on floral induction in axillary buds. Emerged terminal panicles were removed and pruning was done at 6-7 cm and 12-13 cm below the base of the panicle in March-April. Flower initiation was induced in the axillary buds in each portion, even in the proximal portion of pruned shoots. The March pruning showed more panicles than in April. The shoot with 3 growth flushes resulted in greater intensity of floral initiation. Irrespective of pruning time and intensity of pruning, axillary panicles emerged and flowered at about the same time. These results indicated that axillary panicles were produced by pruning well developed shoots during cool season in mango cv. 'Irwin'.

Lal *et al.*, (2000) observed the effect of pruning severity on mango cv. 'Dashehari'. They reported that pruning had more pronounced effect on shoot girth as compared to shoot length. They observed that the greater the height of pruning, lesser was the length of emerged shoots near the cut. However, less severe pruning in fourth orders (branches emerging from third order) and fifth order (branches representing a height of 4 m approximately) induced more canopy area. Swaroop *et al.*, (2001) found increased length of new flushes and panicle after moderate pruning in mango.

Banik and Sen (2002) performed different levels of pruning for rejuvenation of unproductive 30 to 50 years old trees of mango cv. 'Fazli' in West Bengal. They found maximum growth in 50 years old trees by keeping leader intact, removal of primary branches and pruning of secondary branches in September. Shinde *et al.*, (2002) evaluated the effects of hard pruning (heading back up to secondary branches, heading back up to tertiary branches, thinning out crowded branches and centre opening) on the rejuvenation of the mango cv. 'Alphonso' in Maharashtra. They found longest panicles (29.33 cm) on pruning of tertiary branches and centre opening.

Hasan *et al.*, (2006) carried out the investigation on rejuvenation of overcrowded 40 years old mango orchards of 'Himsagar' variety at 8 × 8 m spacing in December. They observed maximum increase in shoot length on pruning all branches at 4 m height during August (22.90 cm) and March (30.11 cm). Lal and Mishra (2007) evaluated the impact of pruning on mango cv. 'Chausa' under North Indian conditions. Three pruning treatments, *viz.*, heading back up to tertiary branches, heading back up to secondary branches and centre opening were given to the mango tree. After eight years of experimentation they found fast

growth with more length of newly emerged shoots on heading back up to tertiary branches and heading back up to secondary branches.

Mishra *et al.*, (2007) rejuvenated old and unproductive mango orchard by heading back trees at 3 m height from ground level during December-January from which 7-8 healthy shoots per branch per stump emerged in July-August. Yadav *et al.*, (2007) studied the impact of one side pruning and time of pruning (September, October, November and December) on growth attributes of mango cv. 'Alphonso'. They observed that there was no significant impact of pruning time on the length of shoots over control (unpruned). Lal and Mishra (2008) carried out pruning of mango cv. 'Dashehari' trees for rejuvenation by removing the first order to the fifth order growth of the main trunk. They observed highest values of shoot length in fourth order pruned trees, whereas the highest value of shoot girth was recorded in first order pruned trees.

Singh *et al.*, (2009) studied the impact of pruning on morphophysiological parameters and canopy microclimate under high density plantation of mango at different intensities *viz.*, control (unpruned), light (30 cm from the apex), moderate (60 cm from the apex) and severe (90 cm from the apex). They recorded longest shoot length because of lesser number of shoots produced in 'Mallika' whereas, shortest was found in 'Amrapali'. They also found longest shoot length with light pruning than severe or moderate pruning. Nafees *et al.*, (2010) evaluated the flushing pattern of mango cultivar in response to pruning of panicles and they found that pruning practices resulted in early vigorous vegetative growth with positive correlation between flush lengths and leaf number. Li *et al.*, (2011) found increased photosynthetic ability of leaves, shoot growth and number of longer and medium branches on pruning.

Das and Jana (2012) studied the effect of canopy management on growth of 24 year old mango cv. 'Amrapali' under high density plantation and headed back at different heights: 1 m, 1.5 m and 2 m above the ground level during December. Heading back of primary shoot (60 cm, 120 cm and unpruned) and secondary shoot (60 cm and unpruned) were imposed after one year of pruning. They recorded maximum shoot length after 6 month in plants headed back at 1 m height *i.e.*, 0.49 m whereas, 1.5 m and 2 m (shortest) head back attained 0.42 m and 0.41 m shoot length. Dhaliwal *et al.*, (2013) found that pruning improved shoot length in both types (with vigorous and normal growth) of 'Kinnow' mandarin plants. Different pruning intensities were given at 5, 6 and 8 feet level and 'Kinnow' exhibited

maximum shoot growth (1.26 m) on pruning at 6 feet level, which was more than 50 percent higher than unpruned. Sharma (2014) observed the maximum shoot growth in the heavily pruned 'Starking Delicious' apple trees.

Kishore *et al.*, (2017) conducted an experiment in mango var. 'Arka Neelachalkesari' (an extra early irregular variety) on 7-8 year old and 10-12 year old trees planted at a spacing of 3 × 4 m and 5 × 5 m respectively. They reported that combination of three primary branches (in different directions) and two secondary branches per primary branch were found to be suitable for mango planted at 3 × 4 m spacing, whereas a combination of four primary branches (in different directions) and two secondary branches were optimal for 5 × 5 m spacing. Along with primary and secondary branches, they also optimized trunk height (80-90 cm), length of primary (40-50 cm) and secondary branches (30-35 cm), and angular distance of primary branches (45° from horizontal axis) for developing an ideal canopy to utilize the solar energy more efficiently and ensuring high yield efficiency.

## **2.2 Effect of pruning levels on canopy microclimatic characteristics**

Effect of different pruning intensities on canopy microclimatic parameters *viz.*, leaf area, leaf area index, canopy volume, relative water content, light penetrance, canopy temperature and canopy relative humidity has been reviewed in relevant heads in mango and some other fruit crops.

### **2.2.1 Leaf area**

Awasthi *et al.*, (2003) evaluated the effect of different levels of pruning on peach plants and found that pruning at height of 25 cm (light), 50 cm (medium) or 75 cm (severe) from the base of secondary branches increased average leaf area significantly as compared to control (unpruned) plants. Pratap *et al.*, (2003) subjected fourteen year old mango cv. 'Amrapali' under high density plantation (2.5 × 2.5 m) to light (10 cm from the apex), moderate (20 cm from the apex) or severe (30 cm from the apex) pruning. They recorded maximum net photosynthetic rate in severely pruned trees which was due to large number of young leaves than the less young leaves growth in unpruned (control) trees.

Willaume *et al.*, (2004) reported that complete removal of one year old shoot resulted in increase of leaf area of remaining shoots in apple. Yadav *et al.*, (2007) studied the effect of one side pruning and time on growth characteristics of 'Alphonso' mango by pruning trees in September, October, November and December. They observed that there was no significant

effect of pruning time on leaf area over control (unpruned) whereas, September and October pruning reduced leaf area. Hussein (2012) studied the effect of different pruning intensities ( $\frac{1}{2}$ ,  $\frac{1}{3}$  and  $\frac{3}{4}$  length of shoot per trees) in pear cv. 'Le-conte' and observed maximum leaf area (27.37 and 26.32 cm<sup>2</sup>) by severe pruning than light and moderate pruning.

Thakur and Rana (2014) registered maximum leaf area (47.7 cm<sup>2</sup> and 44.4 cm<sup>2</sup>) in severe pruning intensity and minimum leaf area (33.3 and 29.2 cm<sup>2</sup>) in light pruning intensity given to nectarines cvs. 'Silver king' and 'Snow Queen', respectively. Raj *et al.*, (2017) studied the effect of high density plantation on physiological characteristics of rejuvenated mango plants of cv. 'Amrapali'. They reported significant effect of pruning on physiological parameters of trees and recorded the highest leaf area (156.68 cm<sup>2</sup>) under cluster planting system.

### **2.2.2 Leaf area index**

Rajan *et al.*, (2001) studied canopy traits of 26 Indian mango varieties on 10-year-old trees, planted at spacing 10 × 10 m, measuring an average LAI of 2.94 (1.18-4.48). They reported that the plants with a low leaf area index were better exposed to solar radiation which resulted in more reproductive stems and good colour fruits than varieties with denser foliage.

Breda (2003) stated that leaf area index reflects the photosynthetic capability of the crop, also act as transition zone between plant and atmosphere, most processes like photosynthesis, evapotranspiration, gas and water exchange take place on the of leaf surface. Das and Jana (2012) studied the effect of canopy management on growth of 24 year old mango cv. 'Amarpali' under high density plantation and headed back at different heights: 1 m, 1.5 m and 2 m above the ground level during December. Heading back of primary shoot (60 cm, 120 cm and unpruned) and secondary shoot (60 cm and unpruned) were imposed after one year of pruning. They found lower leaf area index in plants which were pruned at 60 cm on secondary shoots as compared to other pruning treatments due to reduction in foliage owing to removal of shoots emerging below 60 cm length of secondary shoot.

Barman and Mishra (2018) studied the effect of tip pruning in synchronized vegetative growth and controlling alternate bearing in mango. They found that leaf area index was significantly lower in tip pruning done in October followed by post-harvest tip pruning, as compared to control and the reduction in foliage due to removal of apical portion of all the

emerging shoots of tree (mostly 1.8 inch from top i.e., just below first node of the shoot) can be attributed to lower values of leaf area index.

### 2.2.3 Canopy volume

Charanvichit *et al.*, (1989) studied the effect of hard pruning on mango plant. Canopy spread after 4 month of hard pruning was 1.8 m and after 8 month was 2.01 m and after 12 month 2.15 m. Gross (1996) tried pruning (tipping, heading back) in mango and concluded that light pruning (6-8 inches from shoot tip) facilitated the development of vegetative flush, which helped in maintaining the bearing.

Burondkar *et al.*, (1997) reported pruning as unavoidable necessity to control the canopy size and to produce high quality marketable fruits by facilitating better ventilation, high penetration of sunlight, easy application of plant protection chemicals and ease in harvesting in perennial fruit crops like mango. Lal and Mishra (2007) studied the effect of pruning on mango cv. 'Chausa' which had become over crowded after 35-40 years of growth and three pruning intensities, *viz.*, heading back up to tertiary branches, heading back up to secondary branches and centre opening were given to the trees. Difference in canopy spread was found non-significant in all the pruning intensity followed.

Lal and Mishra (2008) experimented pruning mango cv. Dashehari trees for rejuvenation by removing the first order to the fifth order growth of the main trunk. In their study they observed that after 12 years of pruning, the canopy was vigorous in the control trees which were found to be at par with fifth order pruned trees. Least values of canopy spread were recorded in first and second order pruned trees. Singh *et al.*, (2009) studied the effect of pruning on microclimatic parameters of mango under high density planting and reported that the canopy microclimate drastically improved after pruning. The unpruned (control) trees had the higher canopy volume which decreased with the increase in pruning intensities.

Kumar and Rattanpal (2010) evaluated the decrease of tree spread and tree canopy volume with increase in severity of pruning in 13 years old plants of 'Sardar' guava. Sagar *et al.*, (2019) conducted a study to know the impacts of high density plantation and pruning seasons on vegetative growth of mango cv. 'Alphonso'. They reported maximum plant spread (in East-West was 22.62 cm and North-South was 26.04 cm) and canopy volume (0.92 m<sup>3</sup>) were recorded in plants with 5.0 × 2.5 m spacing in unpruned plants.

#### **2.2.4 Relative leaf water content**

Shivashankara and Mathai (2000) observed higher photosynthesis rate and stomatal conductance in non flowering branches as compared to the flowering ones. The reduction in photosynthetic rate was not attributed to variation in water status of the leaves since relative water content in both types of branches was not significantly different.

Singh *et al.*, (2009) studied the effect of pruning on microclimatic parameters under high density planting of mango and found that the canopy microclimate drastically improved after pruning. Unpruned trees showed highest value of relative water content and the lowest were in severely pruned trees due to more number of old leaves (reduction in differences of leaf turgid and dry weights) in unpruned trees than in younger leaves of pruned trees. Raj *et al.*, (2017) studied the effect of high density planting systems on physiological status of rejuvenated mango plants of cv. 'Amrapali'. The maximum leaf relative water content (87.63 %) was noted in plants under square planting system.

#### **2.2.5 Light penetrance**

Schaffer and Gaye (1989a) found better light penetration on the North-West and South-West sides of tree canopy, perhaps due to different growing conditions in their study. The light penetration was lower in the centre of the mango tree canopy, probably due to criss-cross branches. Schaffer and Gaye (1989b) studied the effect of pruning on light penetration in mango. Light penetration within pruned canopies was found more than 25 per cent during each measurement period, whereas light penetration in unpruned canopies was found about 10-15 per cent in April and July and 5 per cent in November. Reduced light penetration within unpruned canopies in November was because of the increased shading by the new growth.

Davie and Stassen (1996) reported that pruning back half the branches opened the tree for better light penetration in mango cv. 'Sensation'. Shinde *et al.*, (2003) evaluated the effect of pruning on the fruit yield of 35 years old mango cv. 'Alphonso' trees. The treatments comprised 3 pruning methods i.e., heading back of branches at 50 cm level on entire tree, heading back of branches at 50 cm level on alternative limbs of the tree and thinning of overcrowded branches and centre opening along with 2 pruning times (at fruit harvest and during the rest period). Centre opening and branch thinning during the rest period resulted in higher light penetration (690 lux) inside the tree canopy.

Sharma *et al.*, (2006) evaluated influence of pruning intensity on light penetration and leaf physiology in high-density orchards of mango trees. The diffuse light availability (per cent available photosynthetic photon flux) was influenced by pruning intensity, being greater for pruned trees than for unpruned trees, though non-significant between tipped and unpruned trees, and slightly affected by canopy direction. Among different pruning intensities, the per cent photosynthetic photon flux was the maximum (55.4 %) in severely pruned and the minimum (11.6 %) in tipped tree canopies. Further, the per cent photosynthetic photon flux was greatest (33.9 %) in the South-East and the least (25.0 %) in the North-West side of the tree canopy. Similarly, the available photosynthetic photon flux was greater at the higher point above the crotch (0.5-1.0 m) than for the lower point (0-0.5 m).

Sharma and Singh (2006) evaluated that how pruning intensity modified canopy microclimate in 'Amrapali' mango. The results revealed that the light penetration and rate of photosynthesis increased with the extent of pruning. The better light penetration in the canopy of pruned trees was noticed due to more sieving of light for photons. Singh *et al.*, (2009) studied the effect of pruning on microclimatic parameters under high density planting of mango and found that the canopy microclimate drastically improved after pruning. Severe pruning resulted in the greatest light penetration. Light penetration was greater at 1-2 m from the crotch than 0-1 m from the crotch. The light penetrance as photosynthetic photon flux was high as one moved away from main trunk (due to exposure of maximum interior canopy to the sun). The light penetration was highest in severely pruned trees (low spreading and dwarf stature canopy).

Das and Jana (2012) studied the effect of canopy management on growth of 24 years old mango cv. 'Amarpali' in high density plantation where plants were topped back at different heights were imposed after one year of rejuvenation pruning. Light penetration of secondary shoot with 60 cm length was higher as compared to other treatments. Barman and Mishra (2018) studied the effect of tip pruning on vegetative growth in mango. They found that tip pruning improved light penetration and distribution within the tree canopy. Raj *et al.*, (2020) studied the effect of high density planting systems on growth of mango cv. 'Amrapali' after rejuvenation found the maximum light penetrance in square planting system (6.92 K lux) in North-South direction whereas; in East-West direction it was maximum (5.25 K lux) in square planting system due to wider spacing. The minimum light penetrance was observed in hedge row planting system (4.08 K lux) due to closed spacing.

### **2.2.6 Canopy temperature**

Robinson *et al.*, (1991) in his review on modification of plant canopy to achieve higher production efficiency in apple reported that tree shape strongly influence the density and spatial distribution of branches, leaves and fruit within a canopy. They suggested that the differences in these distributions cause variations in light intensity and temperature forming unique microclimates that differ from the external environment. Sharma and Singh (2006) studied the impact of pruning intensity on microclimate modification in ‘Amrapali’ mango trees Canopy microclimate and temperature in high density mango orchard was significantly influenced by pruning intensity, canopy height and their interaction. Canopy temperature was found lowest (31.3 and 25.3 °C) in unpruned plants in August and March, respectively and the highest (36.4 and 27.9 °C, respectively) in severely pruned plants. Further, canopy temperature was observed highest at canopy top (34.4 and 27.4 °C) and lowest (32.8 and 25.8 °C) at 0.5 m above the crotch.

Singh *et al.*, (2009) studied the effect of pruning on microclimatic parameters under high density planting of mango. The canopy microclimate drastically improved after pruning. Canopy temperature was highest under severe pruning, and lowest under light pruning and control. Severely pruned trees showed the highest canopy temperature owing to defoliation (removal of branches), exposure of interior branches to sunlight and the unpruned trees showed drastic reduction in canopy temperature.

Raj *et al.*, (2020) studied the effect of high density planting systems on growth of mango cv. ‘Amrapali’ after rejuvenation. The canopy temperature differed among the different treatments. The maximum canopy temperature (38.12 °C) was observed in paired planting system due to lower canopy volume and it was followed by square planting system (37.85 °C), hedge row planting system (37.20 °C) and double hedge row planting system (37.15 °C). The minimum canopy temperature was observed in cluster planting system (36.60 °C).

### **2.2.7 Canopy relative humidity**

Robinson *et al.*, (1991) have also attributed the density and spatial distribution of branches, leaves and fruit within a canopy to cause differences in relative humidity of apple tree canopy. Sharma *et al.*, (2001) evaluated that denser canopy with very poor light interception at lower tree heights may be responsible for higher canopy relative humidity at lower tree height. Pratap *et al.*, (2003) reported highest canopy relative humidity in unpruned

mango cv. 'Amarpali' trees (control) due to intermingling of branches in very old shoots and poor light interception, while lowest value was estimated in severely pruned tree due to open centre of canopy with better light penetration.

Sharma and Singh (2006) studied the effect of pruning intensity on microclimate modification in 'Amrapali' mango trees and found that canopy microclimate in high-density 'Amrapali' mango orchard was significantly influenced by pruning intensity, canopy height and their interaction. Highest relative humidity was recorded both in August (64.1 %) and March (53.4 %) in unpruned (control) plants and lowest in severely pruned plants (49.7 and 46.3 %, respectively). Similarly, relative humidity was observed to be lowest at canopy top (55.6 and 48.5 %) and highest (60.1 and 51.2 %) at 0.5 m above the crotch during August and March, respectively.

Raj *et al.*, (2020) studied the effect of high density planting systems on growth of mango cv. 'Amrapali' after rejuvenation and found that the relative humidity of canopy was observed maximum (67.11 %) under the hedge row planting system and double hedge row planting system which was found statistically at par with cluster planting system and paired planting system (66.97 and 66.70 %). The minimum value (66.59 %) was noted in treatment involving square planting system.

### **2.3 Effect of pruning levels on biochemical characteristics**

Effect of different pruning intensities on biochemical parameter *viz.*, chlorophyll content (chlorophyll a, chlorophyll b, total chlorophyll content) has been reviewed in mango and some other fruit crops under following head.

#### **2.3.1 Chlorophyll content**

Majumder and Chatterjee (1972) observed the chlorophyll content of leaves obtained from twigs of spring, rainy season and autumn growth, which were encouraged after pruning in general in mango varieties like 'Langra' and 'Fazli' and from spring and autumn flush of variety 'Baramasia'. It followed an increasing trend of chlorophyll content during the initial stage of maturity of leaves and declined with the advancement of maturity. Severe pruning resulted in a higher number of young leaves which contained higher levels of chlorophyll a and total chlorophyll content.

Suryanarayan (1981) found that chlorophyll content of leaves increased consistently reaching the higher level at the preflowering bud formation stage (September-October) and

decreased slowly up to January. Chlorophyll a contents decreased at the preflowering stage compared to the vegetative stage. Syvertsen (1984) also reported increased leaf chlorophyll in mango with increased shade, and similar observations were made for citrus also. Thus, it appeared that mango leaves that developed in shade were physiologically more efficient in synthesizing chlorophyll than those on the sunny side.

Schaffer and Gaye (1989a) found that the leaf chlorophyll contents were significantly influenced by pruning intensity, being highest in the control (unpruned), which decreased as the extent of pruning increased. It was higher in leaves nearer to crotch than above 0.5 m and on North-West side of tree canopy. Schaffer and Gaye (1989b) studied the impact of pruning on leaf chlorophyll content at several positions in pruned and non-pruned mango canopies during April, July and November. One-fourth of center of the canopy was removed during March. During April and July, there were no significant differences in chlorophyll content between leaves of pruned and unpruned canopies. However, during November, leaves of unpruned trees had higher chlorophyll content at every position except in the outer North-East portion of the canopy.

Sharma and Chauhan (2004) reported higher chlorophyll content in pruned peach trees leaves as compared to unpruned trees. Hussain *et al.*, (2006) found that summer pruning of peach trees enhance chlorophyll content in leaves as compared to control (unpruned) trees. Sharma *et al.*, (2006) studied influence of pruning intensity on light penetration and leaf physiology in high density mango orchard and found that total leaf chlorophyll contents were significantly influenced by pruning intensity, being higher in unpruned and tipped tree canopies than in severely, moderately and lightly pruned trees. Height from the crotch also influenced leaf chlorophyll content, which was higher at the lower height from the crotch (0-0.5 m) than at the higher height (0.5-1.0 m). Likewise, among different canopy sides, leaves that developed in the South Eastern canopy side had lower chlorophyll content than those developed in other canopy sides.

Sharma and Singh (2006) evaluated the impact of pruning severity on light penetration and leaf physiology in 'Amrapali' mango trees under high density planting. They reported the highest leaf chlorophyll content in control plants, which decreased as the extent of pruning increased. Photosynthetic rate and chlorophyll contents were found higher in leaves that were on the South-East side of the tree canopy than on the other sides. Kumar *et al.*, (2010) evaluated effects of pruning intensity on the biochemical status of shoot

buds in three mango cultivars planted at high density found that severely pruned mango trees had the highest contents of chlorophyll a, while chlorophyll b and total chlorophyll contents were found to be highest in moderately pruned trees.

Singh *et al.*, (2010) studied the influence of pruning intensity on three mango cultivars planted under high density and found that severe pruning resulted in highest leaf chlorophyll a content while moderate pruning enhanced chlorophyll b and total chlorophyll content in the 'on' year. The total leaf chlorophyll content was highest in leaves that developed in unpruned and tipped tree canopies. This was caused by increased shade due to overlapping or crowding of tree canopies in these trees, which indicated that mango leaves developed in shade appeared to be more physiologically efficient at synthesizing chlorophyll than leaves that grew in the sun or on the sunny side.

Dhaliwal *et al.*, (2013) studied the growth behaviour of 'Kinnow' mother plants pruned at different intensities. The chlorophyll a and chlorophyll b were recorded minimum in unpruned (control) plants. Interaction between plant growth types and different time on levels of pruning treatments were found non significant for both chlorophyll a and b content. Raj *et al.*, (2017) studied the impact of high density planting systems on biochemical status of rejuvenated mango plants of cv. 'Amrapali'. High density planting systems showed significant effect on biochemical parameters of plants. The maximum chlorophyll a ( $1.50 \text{ mg g}^{-1}$ ), chlorophyll b ( $0.65 \text{ mg g}^{-1}$ ) and total chlorophyll ( $2.02 \text{ mg g}^{-1}$ ) contents were found in plants under square planting system.

## Chapter – 3

### MATERIALS AND METHODS

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The present investigation entitled, “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**” was conducted in the Department of Fruit Science, College of Horticulture and Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Neri, Hamirpur (H.P.) in the years 2019-2020. The experimental details and techniques employed in these studies are described as follows under suitable captions.

#### 3.1 Location of the experimental site

The experimental block of fruit nursery is located at an elevation of 618 m above mean sea level and lies between 31°41'46" North latitude and 76°28'5" East longitude.

#### 3.2 Climate

The study area where the experiment was conducted lies in the sub-montane and low hill sub-tropical agro-climatic zone of Himachal Pradesh. During May-June summers are very hot, followed by wet monsoon from July to September and the winters which are severe during December-January. During summer months the mean air temperature rises above 40 °C and drops to below 5 °C in winter months, occasionally accompanied by spring frost. The average annual rainfall ranges from 100-120 cm and major part of rainfall is received during the rainy season. The soil texture of study area is sandy loam with pH near neutral.

#### 3.3 Experimental details

The details of the experiments followed in the present investigations are given here under:

The experiment was laid out in a Completely Randomized Design with three replications, where each replication is represented with two plants (total of 6 per treatment) and twenty-eight treatment combinations.

- |                                  |   |                                    |
|----------------------------------|---|------------------------------------|
| <b>1. Experimental design</b>    | : | Completely Randomized Design (CRD) |
| <b>2. Number of Replication</b>  | : | 3                                  |
| <b>3. Plants per replication</b> | : | 2                                  |

4. **Treatments** : 28
5. **Total number of plants** : 168
6. **Experimental material** : One-year-old grafted Mango plants
7. **Substrate used** : Cocopeat: Vermiculite + Perlite: FYM: Soil  
(2: 1: 1: 1)

## 8. Treatment details

### 8.1 Different intensities of cuts at different orders

1 <sup>st</sup> order (main stem)	2 <sup>nd</sup> order (branches from first order)	3 <sup>rd</sup> order (branches from second order)
30 cm	25 cm	25 cm
40 cm	35 cm	35 cm
50 cm	45 cm	45 cm

### 8.2 The details of the treatment combinations of the experiment are given below

Treatment	Head back 1 <sup>st</sup> order at	Head back 2 <sup>nd</sup> order at	Head back 3 <sup>rd</sup> order at	
T <sub>1</sub>	30 cm	25 cm	25 cm	
T <sub>2</sub>			35 cm	
T <sub>3</sub>			45 cm	
T <sub>4</sub>		35 cm	25 cm	25 cm
T <sub>5</sub>				35 cm
T <sub>6</sub>				45 cm
T <sub>7</sub>			45 cm	25 cm
T <sub>8</sub>				35 cm
T <sub>9</sub>				45 cm
T <sub>10</sub>	40 cm	25 cm	25 cm	
T <sub>11</sub>			35 cm	
T <sub>12</sub>			45 cm	
T <sub>13</sub>		35 cm	25 cm	25 cm
T <sub>14</sub>				35 cm
T <sub>15</sub>				45 cm
T <sub>16</sub>			45 cm	25 cm
T <sub>17</sub>				35 cm
T <sub>18</sub>				45 cm
T <sub>19</sub>	50 cm	25 cm	25 cm	
T <sub>20</sub>			35 cm	
T <sub>21</sub>			45 cm	
T <sub>22</sub>		35 cm	25 cm	25 cm
T <sub>23</sub>				35 cm
T <sub>24</sub>				45 cm
T <sub>25</sub>			45 cm	25 cm
T <sub>26</sub>				35 cm
T <sub>27</sub>				45 cm
T <sub>28</sub>	<b>Control (unpruned)</b>			



**Cocopeat (2 part)**



**Vermiculite (1/2 part)**



**Perlite (1/2 part)**



**FYM (1 part)**



**Soil ( 1 part)**

**Plate 1. Media preparation for the experiment (Cocopeat: Vermiculite + Perlite: FYM: Soil in 2:1:1:1 ratio)**

### 3.4 Methodology of the experiment

The experiment was carried out in 2019 and 2020 with one-year-old grafted mango plants. The experiment was set up during end of July 2019 using a completely randomized block trial with three replications, where each replication is represented with two plants (total of 6 per treatment).

1. During June 2019 substrate preparation was done by washing cocopeat. Washing of cocopeat is necessary as it contains a higher concentration of unwanted salts that can hamper plant growth. Before washing the cocopeat, it should be dipped into water for a day so that unwanted salts get leached out into the water then washing of cocopeat is done with fresh water till clear solution came out of the shreds of cocopeat. Cocopeat (2 parts), vermiculite (0.5 part), perlite (0.5 part), well composed farm yard manure (1 part) and soil (1 part) mixed thoroughly.
2. Planting of 1 year old mango plant in polybags ( $42 \times 42$  cm) with media and were placed at a  $1 \times 1$  m distance in the field.
3. First order plant was pruned when plant attained approximately height of 1 m with different intensities i.e., 30 cm, 40 cm, 50 cm and unpruned (control) according to different treatments above the graft union. During the growth of the main shoot, all feathers below the cut of head back were removed.
4. By retaining 3-4 branches of second order, when these branches attained approximately 50-70 cm of growth, pruning was done with different intensities i.e., 25 cm, 35 cm, 45 cm and unpruned (control) from the base as per the respective treatment.
5. Two-three branches were retained of third order, when these branches attained approximately 50-70 cm of growth, pruning was done with different intensities i.e. 25 cm, 35 cm, 45 cm and unpruned (control) from the base according to the treatment.
6. For heading back of branches, a sharp slanting cut towards inner side of branch was especially undertaken as to enhance sprouting of lateral buds from periphery i.e., outer side of branch. The cut portions of branches were pasted with Bordeaux paste (1kg copper sulphate and 1 kg of lime in 10 litres of water) to prevent diseases infection. Immediately after heading back application of 19: 19: 19 (N: P: K) @ 1% was given with fertigation. Plant protection measures, irrigation and nutrient management was done at regular basis.

### **3.5 Observations recorded**

Various vegetative growth characteristics were studied and recorded during the course of investigation

#### **3.5.1 Growth Characteristics**

##### **3.5.1.1 Plant height before heading back (cm)**

One-year-old grafted mango plant height was taken with the help of measuring tape before first order pruning (heading back). Heading back of plant was done when plant attained a height of about 1 m. Plant height was also recorded one month after the pruning of third order branches in cm.

##### **3.5.1.2 Stem diameter (mm)**

Diameter of stem was taken 20 cm above the base of every plant at the time of first order pruning and one month after pruning of third order branches with the help of vernier caliper in mm.

##### **3.5.1.3 Time taken for bud sprouting after heading back (days)**

Time taken for bud sprouting after heading back first, second and third order of branches was calculated by counting the days after heading back up to bud sprouting.

##### **3.5.1.4 Number of shoots per branch**

After the pruning of first, second and third order of branches new shoots emerged. Number of shoots per branch was counted on branches of first, second and third order and their average were calculated for every order of branches.

##### **3.5.1.5 Shoot length after pruning (cm)**

Length of emerged shoots was recorded one month after pruning of first, second and third order of branches by using measuring tape. Average shoot length for each order was measured in cm.

#### **3.5.2 Canopy Microclimatic characteristics**

##### **3.5.2.1 Leaf Area (cm<sup>2</sup>)**

Leaf area of randomly selected leaves from each treatment was taken by using leaf area meter one month after pruning of third order branches.



**1. Potting media**



**2. Measurement of plant height for heading back**



**3. Head back at first order**



**4. Pasting cut ends with Bordeaux paste**



**5. Plant with second order branches**



**6. Head back at second order**



**7. Plant with third order branches**



**8. Head back at third order**

**Plate 2. Sequential procedure followed for developing canopy architecture in mango nursery plants**



**Plate 3. Experimental layout-Field overview**

### 3.5.2.2 Leaf Area Index

Leaf Area Index is defined as total area of leaves (of one surface only) per unit area of ground as suggested by Watson (1947). LAI was calculated one month after pruning of third order branches by calculating the ratio of TLA and TGA as below:

$$\text{LAI} = \text{TLA}/\text{TGA}$$

Where, TLA is total leaf area and TGA is total ground area which is under the canopy of sampled leaves.

### 3.5.2.3 Canopy volume (m<sup>3</sup>)

Canopy volume was calculated one month after pruning of third order branches of mango plant by using the following formula suggested by Samaddar and Chakarbarti (1989).

$$\text{Canopy volume (m}^3\text{)} = 4/3 \pi r^2 h$$

Where, r = diameter/2, h= height of the plant

The canopy diameter was calculated from every replicates by measuring tape fastened on bamboo stick from base of plant in East to West and North to South direction up to maximum spread of vegetative growth of plant and then working out the average of these two as below:

$$\text{Canopy diameter} = \{\text{Spread (N-S)} + \text{Spread (E-W)}\}/2$$

Plant height (m) was measured above the graft union to top of the plant by measuring tape fixed on a bamboo stick.

### 3.5.2.4 Relative water content (%)

The Relative water content in leaves was determined one month after pruning of third order branches in plant using the method suggested by Weatherley (1950). Mango leaves were collected and 8 mm diameter discs were made. Fresh weight of these discs were measured and then floated over distilled water in Petri dish for 4-6 hours. These discs were then surface dried by placing them in between two sheets of Whatman No. 1 filter paper and saturated (turgid) weight was recorded. After that the samples were dried in an oven at 70 °C for 24 h or till constant weight after two consecutive drying then the dry weight of the samples was recorded. The RWC (%) of mango leaves was calculated by using following formula.

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Turgid weight} - \text{Oven dry weight}} \times 100$$

### 3.5.2.5 Light penentrance (K lux)

Light penentrance was observed one month after pruning of third order branches in the middle of plant canopy by using portable digital lux meter by placing it vertical to the light.

### 3.5.2.6 Canopy temperature (°C)

Canopy temperature has been recorded one month after pruning of third order branches in the middle of plant canopy using wet and dry bulb thermometer and expressed in degree celsius.

### 3.5.2.7 Canopy relative humidity (%)

The canopy relative humidity was recorded one month after pruning of third order branches in the middle of plant canopy using dry and wet bulb hygrometer in percent.

## 3.5.3 Biochemical characteristics

### 3.5.3.1 Chlorophyll content (mg/ml)

Chlorophyll content in the extracted juice of mango leaves was estimated according to method suggested by Ranganna (2014). To 5 ml of leaves sample extract, 20 ml acetone (80 % acetone) was added and centrifuged at 5000 rpm for 5 minutes. The supernatant of centrifuged extract was transferred to a volumetric flask and made the volume to 100 ml with 80 % acetone. The absorbance of the resultant solution was measured at 645 nm, 663 nm and 653 nm against the solvent as blank by using spectrophotometer. Total chlorophyll content, chlorophyll a and chlorophyll b in the samples were estimated according to the following expression:

$$\text{Mg Chlorophyll a/ml extract} = 22.9(A_{663}) - 2.69(A_{645}) \times \frac{\text{Final volume of Chlorophyll extract in 80\% acetone}}{1000 \times \text{Volume of sample}}$$

$$\text{Mg Chlorophyll b/ml extract} = 22.9(A_{645}) - 4.68(A_{663}) \times \frac{\text{Final volume of Chlorophyll extract in 80\% acetone}}{1000 \times \text{Volume of sample}}$$

$$\text{Mg total Chlorophyll} = 20.2(A_{645}) + 8.02 (A_{663}) \times \frac{\text{Final volume of Chlorophyll extract in 80\% acetone}}{1000 \times \text{Volume of sample}}$$

### 3.6 Statistical Analysis

The data obtained from present investigation were subjected to appropriate statistical analysis by using standard procedures as suggested by Gomez and Gomez (1984). The statistical analysis was carried out for each observed parameter by using MS-Excel, OPSTAT.

#### 3.6.1 ANOVA for CRD used in present investigation:

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F <sub>cal</sub>
Treatments	(t-1)	S <sub>t</sub>	$M_t = \frac{S_t}{t-1}$	$\frac{M_t}{M_e}$
Error	(t)(r-1)	S <sub>e</sub>	$M_e = \frac{S_e}{(t)(r-1)}$	
Total	(rt-1)	S <sub>T</sub>		

Where,

- t = Number of treatments
- S<sub>t</sub> = Sum of squares due to treatments
- S<sub>e</sub> = Sum of squares due to error
- S<sub>T</sub> = Total sum of squares
- M<sub>t</sub> = Mean sum of squares due to treatments
- M<sub>e</sub> = Mean sum of squares due to error

The replication and treatment mean sum of square was tested against mean sum of squares due to error by 'F' test at (t-1), (t) (r-1) degree of freedom for CRD at 5 % level of significance. The calculated F-values were compared with tabulated F- value. When F- test found significant, critical difference was calculated to find out the superiority of one treatment over the others.

**Critical difference (CD) was calculated as follows:**

**For CRD:**

$$CD_{0.05} = S.E. (d) \times t_{(0.05)} (t) (r-1) \text{ df}$$

Where,

- SE (d) ± = Standard error of difference of mean
- CD<sub>0.05</sub> = Critical difference at 5 per cent level of significance

## *Chapter-4*

### **RESULTS AND DISCUSSION**

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The present investigations entitled, “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L)**” were carried out in the polyhouse of Department of Fruit Science, College of Horticulture and Forestry, Neri, Hamirpur, Himachal Pradesh, during the year 2019-2020. The studies were conducted on the effect of different pruning levels on growth, canopy microclimatic and biochemical characteristics of one-year-old mango plants. The results, thus obtained are presented, discussed and supported with suitable references under following headings:

4.1 Effect of different pruning levels on growth characteristics

4.2 Effect of pruning levels on canopy microclimatic characteristics

4.3 Effect of pruning levels on biochemical characteristics

#### **4.1.1 Plant height before heading back**

The data on the plant height before heading back are presented in Table 4.1a and it was found to be non-significant with mean value of 100.60 cm.

#### **4.1.2 Final plant height**

The results related to influence of different pruning levels on final plant height are presented in Table 4.1a. It is evident from the data that different pruning levels exerted a significant influence on plant height. The maximum plant height (182.00 cm) was recorded with T<sub>28</sub> (Control) treatment, which was found statistically similar to T<sub>27</sub> treatment. Whereas, minimum plant height (90.33 cm) was observed in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 cm + 3<sup>rd</sup> order at 25 cm) treatment, which was statistically at par with T<sub>2</sub> treatment. Mean value for final plant height was 137.86 cm.

The maximum plant height was recorded in unpruned (control) plants, which might be due to the effect of apical dominance. However, decrease in plant height resulted with increase in

severity of pruning (Ingle *et al.*, 2005). Pruned mango tree usually produced less total growth (compared to an unpruned tree) as its photosynthetic capacity was (at least temporarily) reduced by pruning. Similar results were obtained by Singh *et al.*, (2017), Das and Jana (2012), Lal and Mishra (2008), Lal and Mishra (2007) in mango and Kumar and Rattanpal (2010) in guava.

#### **4.1.3 Initial stem diameter**

The data presented in Table 4.1a on initial stem diameter was observed to be non-significant. Mean value for initial stem diameter was 11.26 mm.

#### **4.1.4 Increase in stem diameter**

The results related to influence of different pruning levels on increase in stem diameter are presented in Table 4.1a. It is evident from the data that different pruning levels exerted a significant influence on increase in stem diameter. Maximum increase in stem diameter (4.19 mm) was found in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 + 3<sup>rd</sup> order at 25 cm) and was statistically similar with T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub> and T<sub>10</sub> treatments. However, minimum value (3.47 mm) was found in T<sub>28</sub> control plants and was statistically similar with T<sub>16</sub>, T<sub>17</sub>, T<sub>18</sub>, T<sub>19</sub>, T<sub>20</sub>, T<sub>21</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>24</sub>, T<sub>25</sub>, T<sub>26</sub> and T<sub>27</sub> treatments.

The maximum stem diameter was recorded in severely pruned plants, which might be due to severe pruning removed excess vegetative growth that resulted in higher photosynthates supply to remaining portion leads to increase in stem diameter. Maximum value of shoot diameter was recorded with severe pruning, which was probably due to the diversion of more nutrients to these shoots because these being closer to the main trunk of the mango trees (Lal *et al.*, 2000). The results are in conformity with Dhaliwal *et al.*, (2013) in kinnow, Iosif *et al.*, (2011) in apple, Lal and Mishra (2008) in mango.

#### **4.1.5 Shoot length after pruning at first order**

It is inferred from the data presented in Table 4.1a that different pruning levels had a significant influence on shoot length. In present course of study, the values for shoot length at 1<sup>st</sup> order varies from 7.60 cm to 14.73 cm, whereas maximum shoot length (14.73 cm) was observed when mango plants were headed back at 40 cm in T<sub>12</sub> treatment and was statistically at par with

other plants that were headed back at 40 cm and the plants that were headed back at 50 cm (T<sub>4</sub>, T<sub>10</sub>, T<sub>11</sub>, T<sub>13</sub>, T<sub>14</sub>, T<sub>15</sub>, T<sub>16</sub>, T<sub>17</sub>, T<sub>18</sub>, T<sub>19</sub>, T<sub>20</sub>, T<sub>21</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>24</sub>, T<sub>25</sub>, T<sub>26</sub> and T<sub>27</sub>). But the plants which were headed back at 50 cm had less value of shoot length as compared to plants headed back at 40 cm. The minimum shoot length (7.60 cm) was recorded in control (T<sub>28</sub>) where no pruning was performed and was statistically at par with T<sub>2</sub> and T<sub>6</sub> (head back at 30 cm). Mean value of shoot length after pruning at first order was 12.58 cm.

#### **4.1.6 Shoot length after pruning at second order**

The data presented in Table 4.1a on shoot length after pruning at second order was observed to be significant with maximum in T<sub>15</sub> (12.48 cm) when 1<sup>st</sup> order was headed back at 40 cm and 2<sup>nd</sup> order branches were headed back up to 35 cm which was statistically at par with T<sub>5</sub>, T<sub>6</sub>, T<sub>9</sub>, T<sub>10</sub>, T<sub>11</sub>, T<sub>12</sub>, T<sub>13</sub>, T<sub>14</sub>, T<sub>16</sub>, T<sub>17</sub>, T<sub>18</sub>, T<sub>19</sub>, T<sub>20</sub>, T<sub>21</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>24</sub>, T<sub>25</sub>, T<sub>26</sub> and T<sub>27</sub> treatments. However, minimum shoot length (7.60 cm) was recorded in control when no pruning was performed. Mean value of shoot length after pruning at second order was 11.39 cm.

#### **4.1.7 Shoot length after pruning at third order**

The maximum shoot length at 3<sup>rd</sup> order (9.79 cm) was observed with T<sub>14</sub> ( heading back 1<sup>st</sup> order at 40 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 35 cm), which was statistically at par with T<sub>2</sub>, T<sub>5</sub>, T<sub>8</sub>, T<sub>11</sub>, T<sub>15</sub>, T<sub>17</sub>, T<sub>20</sub>, T<sub>23</sub>, T<sub>26</sub> treatment plants. Whereas, minimum shoot length (4.40 cm) was recorded in control which was statistically at par with T<sub>1</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>19</sub> treatment plants. Shoot length after pruning at third order had mean value of 7.71 cm.

With the severity of pruning there was increase in shoot length which might be due to an increased photosynthetic optimization of light environment inside the canopy of plant results in higher photosynthesis rates. However, length of an individual shoot was increased by pruning as the plant's root system was able to direct more water and nutrients in to those shoots that remain after pruning. But it is also found that head back at very severe intensity i.e., 25 cm (had lower value than plants pruned at 35 cm and 45 cm but was more than unpruned plant) resulted in very less growth as plant might faced the stress condition as major portion of plant reserve food material was removed.

There might be an increase in accumulation of gibberellic acid with increase in pruning intensity which led to the maximum shoot length (Mika, 1986) in mango plant. The results are in conformity with Sharma (2014), Bai *et al.*, (2012), Shah *et al.*, (2006) in apple, Dhaliwal *et al.*, (2013) in kinnow, Shaban and Haseeb (2009) in guava.

#### **4.1.8 Number of shoots per branch at first order**

The data on the effect of different pruning intensities on number of shoots per branch at first order are depicted in Table 4.2b. It is evident from the data that number of shoots per branch at first order was influenced by different pruning intensities. At 1<sup>st</sup> order the maximum number of shoots per branch (15.65) was observed in T<sub>10</sub> (first order head back at 40 cm) which is statistically at par with T<sub>11</sub>, T<sub>12</sub>, T<sub>13</sub>, T<sub>14</sub>, T<sub>15</sub>, T<sub>16</sub>, T<sub>17</sub> and T<sub>18</sub>. However, minimum (2 shoots per branch) was recorded in control, which was statistically at par with T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> plants (head back at 30 cm) where no pruning performed. The average number of shoots per branch at first order was 9.53.

#### **4.1.9 Number of shoots per branch at second order**

The data on the effect of different pruning intensities on number of shoots per branch at second order are depicted in Table 4.2b. It is evident from the data that number of shoots per branch at second order was significantly influenced by different pruning intensities. At 2<sup>nd</sup> order the maximum number of shoots per branch (12.33) was observed in T<sub>13</sub> (head back at 40 cm at first order + 35 cm at second order) which was statistically at par with T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>14</sub>, T<sub>15</sub>, T<sub>22</sub>, T<sub>23</sub> and T<sub>24</sub> plants. However, minimum number of shoots per branch (1.67) was recorded in T<sub>28</sub> (control). The mean value number of shoots per branch at second order was 8.61.

#### **4.1.10 Number of shoots per branch at third order**

The data on the effect of different pruning intensities on number of shoots per branch at third order are depicted in Table 4.2b. It is evident from the data that number of shoots per branch at third order was influenced by different pruning intensities. At 3<sup>rd</sup> order the maximum number of shoots per branch (12.17) was observed in T<sub>11</sub> (head back at 40 cm at first order + 25 cm at second order + 35 cm at third order) which is statistically at par with T<sub>2</sub>, T<sub>5</sub>, T<sub>8</sub>, T<sub>14</sub>, T<sub>17</sub>,



**Bud sprouting**



**Shoots emergence**



**Shoot growth after one month**



**Plate 4. Bud sprouting, shoot emergence and shoot growth after heading back**

T<sub>20</sub>, T<sub>23</sub> and T<sub>26</sub> plants. However minimum number of shoots per branch (1.50) was recorded in T<sub>28</sub> control plants. The mean value of number of shoots per branch at second order was 8.47.

The severe pruning resulted in sprouting of maximum number of shoots due to low shoot: root ratio (Singh *et al.*, 2009) as compare to unpruned ones whereas, plant pruned at very high intensity had less number of shoots per branch than other pruning intensities. This may be attributed to the fact that plants with severe pruning intensity underwent a stress condition due to excess removal of plant part which resulted in very less carbohydrate reserves for plant to cope up with the pruning. Similar findings were also recorded by Dhaliwal *et al.*, (2013) in kinnow and Nichols *et al.*, (2008) in apple.

#### **4.1.11 Time taken for bud sprouting after heading back at first order**

The data on the effect of different pruning intensities on time taken for bud sprouting after heading back at first order are presented in Table 4.2b. It is evident from the data that time taken for bud sprouting was influenced by different pruning intensities. At 1<sup>st</sup> order the minimum time taken for sprouting (3.83 days) was observed in T<sub>10</sub> plant (1<sup>st</sup> order headed back at 40 cm) which was statistically at par with T<sub>1</sub>, T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>11</sub>, T<sub>12</sub>, T<sub>13</sub>, T<sub>14</sub>, T<sub>15</sub>, T<sub>16</sub>, T<sub>17</sub>, T<sub>18</sub>, T<sub>19</sub>, T<sub>20</sub>, T<sub>21</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>24</sub>, T<sub>25</sub>, T<sub>26</sub> and T<sub>27</sub> treatments, however maximum (28.33 days) was recorded in T<sub>28</sub> (control) where no pruning performed. Mean value for time taken for bud sprouting after heading back at first order was 5.58 days.

#### **4.1.12 Time taken for bud sprouting after heading back at second order**

As evident from data given in table 4.2b, the different pruning intensities significantly influenced the time taken for bud sprouting after heading back. At 2<sup>nd</sup> order the minimum days taken for sprouting (6.17 days) was observed in T<sub>13</sub> plant (1<sup>st</sup> order head back at 40 cm + 2<sup>nd</sup> order head back at 35 cm) which was statistically at par with T<sub>1</sub>, T<sub>10</sub>, T<sub>11</sub>, T<sub>12</sub>, T<sub>14</sub>, T<sub>15</sub>, T<sub>16</sub>, T<sub>17</sub>, T<sub>18</sub>, T<sub>19</sub>, T<sub>20</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>24</sub>, T<sub>25</sub>, T<sub>26</sub> and T<sub>27</sub> treatments, however maximum (29.50 days) was recorded in control (T<sub>28</sub>). Mean value for time taken for bud sprouting after heading back at second order was 7.94 days.

#### **4.1.13 Time taken for bud sprouting after heading back at third order**

The data presented in table 4.2b on the effect of different pruning intensities on time taken for bud sprouting after heading back at third order reveal that time taken for bud sprouting was also influenced by different pruning intensities. At 3<sup>rd</sup> order the minimum days were taken for sprouting (8.50 days) in T<sub>14</sub> plant (1<sup>st</sup> order head back at 40 cm + 2<sup>nd</sup> order head back at 35 cm + 3<sup>rd</sup> order head back at 35 cm) which was statistically at par with T<sub>2</sub>, T<sub>5</sub>, T<sub>8</sub>, T<sub>11</sub>, T<sub>15</sub>, T<sub>17</sub>, T<sub>20</sub>, T<sub>23</sub>, T<sub>24</sub> and T<sub>26</sub> treatments, however maximum (30.33 days) was recorded in control (T<sub>28</sub>) with no pruning performed. Mean value for time taken for bud sprouting after heading back at third order was 11.64 days.

With increasing pruning intensity there was an early emergence of more number of shoots in pruned plant due to low shoot: root ratio (Singh *et al.*, 2009) as compare to unpruned ones. Severe pruning resulted in delayed growth than other pruning intensities because plants were unable to make up the loss of growth caused by severe pruning in this short period as suggested by Kumar and Rattanpal (2010). Similar findings have been reported by Bhagwati *et al.*, (2015) and Jadhav *et al.*, (2002) in guava, Dhaliwal *et al.*, (2013) in kinnow and Das and Jana (2012) in mango.

**Table 4.1a Effect of different pruning levels on different stem and shoot growth characteristics of mango nursery plants**

<b>Treatment</b>	<b>Plant height before heading back (cm)</b>	<b>Final plant height (cm)</b>	<b>Initial stem diameter (mm)</b>	<b>Increase in stem diameter (mm)</b>	<b>Shoot length after pruning at 1st order (cm)</b>	<b>Shoot length after pruning at 2<sup>nd</sup> order (cm)</b>	<b>Shoot length after pruning at 3<sup>rd</sup> order (cm)</b>
<b>T<sub>1</sub></b>	89.00	90.33	11.48	4.19	10.83	10.51	6.03
<b>T<sub>2</sub></b>	97.67	97.20	10.46	4.14	10.71	10.78	9.20
<b>T<sub>3</sub></b>	92.00	103.33	11.60	4.16	11.51	11.04	7.36
<b>T<sub>4</sub></b>	95.00	107.33	9.64	4.13	11.91	10.94	6.29
<b>T<sub>5</sub></b>	97.00	108.33	12.35	4.10	11.35	11.26	9.45
<b>T<sub>6</sub></b>	106.00	110.33	12.08	4.06	10.02	11.48	7.62
<b>T<sub>7</sub></b>	112.33	114.00	12.30	4.02	10.77	10.68	6.20
<b>T<sub>8</sub></b>	104.67	116.00	9.83	4.01	10.83	10.95	9.36
<b>T<sub>9</sub></b>	98.33	120.67	10.67	3.93	10.80	11.14	7.53
<b>T<sub>10</sub></b>	101.33	125.00	11.38	3.93	14.26	11.51	6.36
<b>T<sub>11</sub></b>	110.00	127.00	12.63	3.88	14.31	11.78	9.53
<b>T<sub>12</sub></b>	106.67	130.67	10.04	3.86	14.73	12.04	7.70
<b>T<sub>13</sub></b>	106.00	137.33	10.60	3.84	14.64	11.94	6.62
<b>T<sub>14</sub></b>	102.00	138.67	9.89	3.82	14.49	12.26	9.79
<b>T<sub>15</sub></b>	102.33	140.67	11.02	3.77	13.41	12.48	7.95
<b>T<sub>16</sub></b>	104.67	143.00	12.36	3.75	14.31	11.68	6.53
<b>T<sub>17</sub></b>	96.00	144.67	12.11	3.73	14.25	11.95	9.70
<b>T<sub>18</sub></b>	99.00	145.33	11.36	3.72	14.49	12.14	7.86
<b>T<sub>19</sub></b>	91.67	153.67	11.98	3.69	12.81	11.18	6.20
<b>T<sub>20</sub></b>	103.00	155.67	10.27	3.67	13.37	11.45	9.36
<b>T<sub>21</sub></b>	100.00	159.00	11.60	3.66	13.84	11.70	7.53
<b>T<sub>22</sub></b>	99.00	162.67	10.57	3.71	13.83	11.60	6.45
<b>T<sub>23</sub></b>	99.00	164.33	11.49	3.69	13.56	11.93	9.62
<b>T<sub>24</sub></b>	94.67	165.33	12.01	3.65	12.63	12.15	7.79
<b>T<sub>25</sub></b>	107.67	170.67	10.28	3.62	12.73	11.34	6.36
<b>T<sub>26</sub></b>	107.00	171.67	11.76	3.61	12.17	11.61	9.53
<b>T<sub>27</sub></b>	94.67	175.33	12.14	3.60	12.20	11.81	7.70
<b>T<sub>28</sub></b>	100.33	182.00	11.53	3.47	7.60	7.60	4.40
<b>Mean</b>	<b>100.60</b>	<b>137.86</b>	<b>11.26</b>	<b>3.84</b>	<b>12.58</b>	<b>11.39</b>	<b>7.71</b>
<b>C.D. 0.05</b>	<b>NS</b>	<b>6.93</b>	<b>NS</b>	<b>0.29</b>	<b>3.14</b>	<b>1.39</b>	<b>1.91</b>

**Table 4.1b Effect of different pruning levels on different growth characteristics related to number of shoots and time taken for bud sprouting in mango nursery plants**

<b>Treatment</b>	<b>Number of shoots per branch at 1<sup>st</sup> order</b>	<b>Number of shoots per branch at 2<sup>nd</sup> order</b>	<b>Number of shoots per branch at 3<sup>rd</sup> order</b>	<b>Time taken for bud sprouting at 1<sup>st</sup> order (Days)</b>	<b>Time taken for bud sprouting at 2<sup>nd</sup> order (Days)</b>	<b>Time taken for bud sprouting at 3<sup>rd</sup> order (Days)</b>
<b>T<sub>1</sub></b>	4.70	5.17	5.00	4.83	7.33	13.50
<b>T<sub>2</sub></b>	5.17	5.17	11.83	5.00	7.50	9.67
<b>T<sub>3</sub></b>	4.17	5.00	8.83	5.50	7.67	11.50
<b>T<sub>4</sub></b>	4.23	12.00	5.00	5.17	7.67	13.00
<b>T<sub>5</sub></b>	3.83	11.67	11.50	5.33	7.83	9.17
<b>T<sub>6</sub></b>	4.27	11.83	9.17	5.67	7.83	11.00
<b>T<sub>7</sub></b>	4.50	9.00	4.83	5.83	8.17	13.33
<b>T<sub>8</sub></b>	4.73	9.33	11.67	5.67	8.17	9.50
<b>T<sub>9</sub></b>	5.67	9.17	9.00	5.83	8.00	11.33
<b>T<sub>10</sub></b>	15.65	5.50	5.33	3.83	7.00	12.83
<b>T<sub>11</sub></b>	15.57	5.50	12.17	4.00	7.00	9.00
<b>T<sub>12</sub></b>	15.50	5.33	9.17	4.17	7.17	10.83
<b>T<sub>13</sub></b>	15.33	12.33	5.67	4.17	6.17	12.33
<b>T<sub>14</sub></b>	15.00	12.00	11.83	4.17	6.33	8.50
<b>T<sub>15</sub></b>	15.50	12.17	9.50	4.33	6.33	10.33
<b>T<sub>16</sub></b>	14.83	9.33	5.17	4.33	6.50	12.67
<b>T<sub>17</sub></b>	15.00	9.67	12.00	4.33	6.67	8.83
<b>T<sub>18</sub></b>	14.67	9.50	9.33	4.17	6.67	10.67
<b>T<sub>19</sub></b>	9.83	5.33	5.50	4.33	7.33	13.00
<b>T<sub>20</sub></b>	9.67	5.33	12.00	4.50	7.33	9.17
<b>T<sub>21</sub></b>	9.70	5.17	9.00	4.50	7.50	11.00
<b>T<sub>22</sub></b>	9.60	12.17	5.17	4.67	6.50	12.50
<b>T<sub>23</sub></b>	10.00	11.83	11.67	4.67	6.67	8.67
<b>T<sub>24</sub></b>	9.17	12.00	9.33	4.83	6.67	10.50
<b>T<sub>25</sub></b>	9.50	9.17	5.00	4.67	6.83	12.83
<b>T<sub>26</sub></b>	9.00	9.50	11.83	4.83	7.00	9.00
<b>T<sub>27</sub></b>	10.17	9.33	9.17	4.67	7.00	10.83
<b>T<sub>28</sub></b>	2.00	1.67	1.50	28.33	29.50	30.33
<b>Mean</b>	9.53	8.61	8.47	5.58	7.94	11.64
<b>C.D. 0.05</b>	2.29	1.69	1.84	1.52	1.28	2.04



**First order**

**First order plant before head back**



**Second order branches**

**Plant canopy with 2<sup>nd</sup> order of branches**

**Plate 5. Mango plant canopy at first and second order**



Third order branches

Second order branches

First order

Plant canopy with 3<sup>rd</sup> order of branches



Fourth order branches

Third order branches

Second order branches

First order

Plant canopy with 4<sup>th</sup> order of branches



Fully mature feather plant

Plate 6. Mango plant canopy at third, fourth order and fully mature feather plant

## **4.2 Effect of different levels of pruning on canopy microclimatic characteristics**

### **4.2.1 Leaf Area**

The results obtained on the effect of different levels of pruning on leaf area are presented in Table 4.2. Various pruning levels had significant effect on leaf area. The maximum leaf area (37.87 cm<sup>2</sup>) was observed in T<sub>1</sub> (1<sup>st</sup> order head back at 30 cm + 2<sup>nd</sup> order head back at 25 cm + 3<sup>rd</sup> order head back at 25 cm), which was statistically similar to T<sub>2</sub> and T<sub>3</sub> treatments. However, minimum leaf area (33.06 cm<sup>2</sup>) was found in T<sub>28</sub> (Control) treatment. Mean value for leaf area was 35.84 cm<sup>2</sup>.

The increase in leaf area increased with increasing severity of pruning might be due to reduced competition for carbohydrates and other metabolites by leaves as number of leaves per plant decreased after heading back. Schneider *et al.*, (1978) reported increase in rate of photosynthesis of intact leaves significantly after heavy pruning. Similar findings were also recorded by Thakur and Rana (2014) in nectarine, Hussein (2012) in pear.

### **4.2.2 Leaf area index**

The data given in Table 4.2 indicate that different levels of pruning treatments exerted significant influence on leaf area index. The values of leaf area index varied from 1.25 to 2.49. The highest leaf area index (2.49) was recorded in T<sub>28</sub> (Control) treatment, Whereas, lowest leaf area index (1.25) was reported in T<sub>1</sub> (1<sup>st</sup> order head back at 30 cm + 2<sup>nd</sup> order head back at 25 cm + 3<sup>rd</sup> order head back at 25 cm) treatment which was found to be at par with T<sub>2</sub> and T<sub>3</sub> treatments. Mean value for leaf area index was 1.71.

Highest leaf area index was recorded in control because of the dense foliage resulting from unrestricted growth and intermingling of branches. Leaf area index decreased with increasing severity of pruning as defoliation (removal of branches during heading back) leads to opening up of canopy of mango plant. Similar results were obtained by Das and Jana (2012) in mango.

### 4.2.3 Canopy volume

The data pertaining to the effect of different levels of pruning on canopy volume are presented in Table 4.2. A perusal of data inferred that canopy volume was significantly influenced by different levels of pruning. Among the treatments, maximum canopy volume (3.03 m<sup>3</sup>) was observed in T<sub>28</sub> (Control) treatment and minimum (0.42 m<sup>3</sup>) in T<sub>1</sub> (1<sup>st</sup> order head back at 30 cm + 2<sup>nd</sup> order head back at 25 cm + 3<sup>rd</sup> order head back at 25 cm) treatment. Mean value for canopy volume was 1.18 m<sup>3</sup>.

With the severity of pruning the canopy spread and plant height decreased resulting in decreased value of canopy volume whereas, in case of unpruned plant unrestricted growth led to higher value of canopy spread and plant height due to apical dominance of plant which resulted in maximum canopy volume. Usually potential energy captured by photosynthesis reduces after pruning, as the total leaf area (where carbohydrates generate) diminished. Additional energy reduction occurred because the starch reserves that had been stored in the branch were lost after pruning which might have led to decreased growth of plant and in turn, resulted in decreased canopy volume. These results are in conformity with Kumar and Rattanpal (2010) in guava, Singh *et al.*, (2009) in mango.

### 4.2.4 Relative water content

It is evident from the data presented in Table 4.2 that different levels of pruning had significant influence on the relative water content. The highest relative water content (93.63 %) was found in T<sub>28</sub> (Control) which was statistically at par with T<sub>3</sub>, T<sub>6</sub>, T<sub>9</sub>, T<sub>12</sub>, T<sub>15</sub>, T<sub>18</sub>, T<sub>21</sub>, T<sub>24</sub> and T<sub>27</sub> treatments. Whereas, lowest (90.13 %) was reported in T<sub>13</sub> (1<sup>st</sup> order head back at 40 cm + 2<sup>nd</sup> order head back at 35 cm + 3<sup>rd</sup> order head back at 25 cm) treatment which was found to be statistically similar with T<sub>1</sub>, T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>10</sub>, T<sub>11</sub>, T<sub>13</sub>, T<sub>14</sub>, T<sub>16</sub>, T<sub>17</sub>, T<sub>19</sub>, T<sub>20</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>25</sub> and T<sub>26</sub> treatments. Mean value for relative water content was 91.68 %.

The maximum relative water content observed in the leaves of unpruned plants and minimum in severely pruned plants might be due to more number of old leaves (reduction in differences of leaf turgid and dry weights) in unpruned plants in comparison to younger leaves found in pruned plants (Singh *et al.*, 2009).

#### **4.2.5 Light penetrance**

It was observed from the data presented in Table 4.2 that different levels of pruning treatments a significant influence on light penetrance. The maximum light penetrance (6.91 K lux) was recorded in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + Head back 2<sup>nd</sup> order at 25 cm + Head back 3<sup>rd</sup> order at 25 cm) treatment, which was statistically similar with T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments. However minimum light penetrance (4.16 K lux) was recorded in T<sub>28</sub> (Control), which was statistically at par with T<sub>21</sub>, T<sub>22</sub>, T<sub>23</sub>, T<sub>24</sub>, T<sub>25</sub>, T<sub>26</sub> and T<sub>27</sub> treatments. Mean value for light penetrance was 5.38 K lux.

With the severity of pruning increase in light penetration was observed within the canopy due to more sieving of light photons. Such results can be ascribed to increase in the openness and exposure of canopy which was proportionate to the severity or extent of pruning (Sharma and Singh, 2006). These results are in conformity with Sharma *et al.*, (2006), Singh *et al.*, (2009), Shinde *et al.*, (2003) and Das and Jana (2012) in mango and Singh and Singh (2005) in guava.

#### **4.2.6 Canopy temperature**

The data on the effect of different levels of pruning treatments on the canopy temperature were found significant and are presented in Table 4.2. Among different treatments, maximum canopy temperature (34.33 °C) was observed in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + Head back 2<sup>nd</sup> order at 25 cm + Head back 3<sup>rd</sup> order at 25 cm), which was statistically similar with T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub> treatments. While, minimum canopy temperature (27.67 °C) was recorded in T<sub>28</sub> (Control) treatment. Mean value of canopy temperature was 32.61 °C.

The highest canopy temperature observed in the severely pruned plants was due to openness of the canopy (had very scarce branches and thinly spread foliage) with higher light penetration (Singh *et al.*, 2009) leading to elevated levels of temperature. Similar results were obtained by Sharma and Singh (2006) in mango.

#### **4.2.7 Canopy relative humidity**

It is evident from the perusal of the data presented in Table 4.2 that different levels of pruning treatments had a significant effect on levels relative humidity. Among different

treatments, highest relative humidity (74.33 %) was recorded in T<sub>28</sub> (Control). Whereas, minimum relative humidity (60.33 %) was observed in T<sub>1</sub> (1<sup>st</sup> order head back at 30 cm + 2<sup>nd</sup> order head back at 25 cm + 3<sup>rd</sup> order head back at 25 cm) treatment, which was statistically similar with T<sub>2</sub> and T<sub>3</sub> treatments. Mean value of canopy relative humidity was 64.79 percent.

The highest canopy relative humidity was observed in un-pruned trees (control) due to close distribution and intermingling of branches. However, relative humidity decreased with the increase in pruning intensity due to opening up of plant canopy with better light interception (Singh *et al.*, 2009). Sharma *et al.*, (2001) suggested that denser canopy and very poor light interception at lower tree heights may be responsible for higher humidity at lower tree height. Sharma and Singh (2006) also reported higher relative humidity in the un-pruned mango trees than the pruned trees which was attributed to higher transpiration rate and poor light interception owing to dense canopy in the un-pruned mango trees (control). Similar findings were also reported by Pratap *et al.*, (2003) in mango.

### **4.3 Effect different pruning intensities on biochemical characteristics**

#### **4.3.1 Chlorophyll content**

The data presented in the Table 4.3 revealed that different levels of pruning had no significant effect on chlorophyll a, chlorophyll b and total chlorophyll content.

**Table 4.2 Effect of different levels of pruning on canopy microclimatic characteristics in nursery mango plants**

Treatment	Leaf area (cm <sup>2</sup> )	Leaf area index	Canopy volume (m <sup>3</sup> )	Relative water content* (%)	Light penetrance (K lux)	Canopy temperature (°C)	Canopy relative humidity** (%)
<b>T<sub>1</sub></b>	37.87	1.25	0.42	90.85 (9.58)	6.91	34.33	60.33 (50.94)
<b>T<sub>2</sub></b>	37.83	1.27	0.61	91.53 (9.62)	6.73	34.27	61.00 (51.34)
<b>T<sub>3</sub></b>	37.57	1.29	0.73	92.83 (9.69)	6.35	34.17	61.17 (51.43)
<b>T<sub>4</sub></b>	37.47	1.31	0.63	90.89 (9.59)	6.67	33.93	62.17 (52.02)
<b>T<sub>5</sub></b>	37.43	1.32	0.78	91.50 (9.62)	6.47	33.83	62.67 (52.32)
<b>T<sub>6</sub></b>	37.17	1.35	0.92	92.87 (9.69)	6.33	33.77	62.83 (52.42)
<b>T<sub>7</sub></b>	37.07	1.38	0.84	90.37 (9.56)	6.26	33.67	63.17 (52.61)
<b>T<sub>8</sub></b>	36.96	1.42	0.97	91.73 (9.63)	6.23	33.53	63.00 (52.51)
<b>T<sub>9</sub></b>	36.89	1.45	1.76	92.83 (9.69)	5.97	33.33	63.50 (52.81)
<b>T<sub>10</sub></b>	35.99	1.52	0.63	90.97 (9.59)	5.87	33.2	63.67 (52.91)
<b>T<sub>11</sub></b>	35.88	1.56	0.78	91.17 (9.60)	5.71	33.07	63.83 (53.01)
<b>T<sub>12</sub></b>	35.82	1.59	0.97	92.77 (9.68)	5.41	32.93	64.17 (53.21)
<b>T<sub>13</sub></b>	35.76	1.61	0.86	90.13 (9.55)	5.38	32.9	64.17 (53.21)
<b>T<sub>14</sub></b>	35.68	1.64	1.04	91.03 (9.59)	5.36	32.73	64.50 (53.41)
<b>T<sub>15</sub></b>	35.65	1.68	1.25	92.80 (9.69)	5.14	32.67	64.67 (53.51)
<b>T<sub>16</sub></b>	35.60	1.69	1.08	90.70 (9.58)	5.09	32.67	64.83 (53.61)
<b>T<sub>17</sub></b>	35.57	1.74	1.39	91.63 (9.63)	5.01	32.53	64.50 (53.41)
<b>T<sub>18</sub></b>	35.51	1.79	2.20	92.80 (9.69)	4.90	32.47	64.83 (53.61)
<b>T<sub>19</sub></b>	34.98	1.90	0.80	90.85 (9.58)	4.82	32.27	65.17 (53.81)
<b>T<sub>20</sub></b>	34.92	1.95	0.99	91.10 (9.60)	4.80	32.17	65.17 (53.81)
<b>T<sub>21</sub></b>	34.85	2.02	0.92	92.47 (9.67)	4.75	32.03	65.67 (54.11)
<b>T<sub>22</sub></b>	34.81	2.06	1.04	90.53 (9.57)	4.55	31.9	67.00 (54.92)
<b>T<sub>23</sub></b>	34.75	2.08	1.27	91.20 (9.60)	4.49	31.8	67.17 (55.02)
<b>T<sub>24</sub></b>	34.68	2.12	1.50	92.50 (9.67)	4.43	31.67	67.00 (54.92)
<b>T<sub>25</sub></b>	34.61	2.14	1.32	90.87 (9.59)	4.31	31.47	67.83 (55.43)
<b>T<sub>26</sub></b>	34.59	2.18	1.57	91.60 (9.62)	4.25	31.4	67.50 (55.22)
<b>T<sub>27</sub></b>	34.56	2.20	2.72	92.77 (9.68)	4.21	30.83	68.17 (55.63)
<b>T<sub>28</sub></b>	33.06	2.49	3.03	93.63 (9.73)	4.16	27.67	74.33 (59.54)
<b>Mean</b>	<b>35.84</b>	<b>1.71</b>	<b>1.18</b>	<b>91.68</b>	<b>5.38</b>	<b>32.61</b>	<b>64.79</b>
<b>C.D. 0.05</b>	<b>0.35</b>	<b>0.05</b>	<b>0.05</b>	<b>1.63</b>	<b>0.60</b>	<b>0.53</b>	<b>1.78</b>

*\*Relative water content values in parentheses are square root transformed*

*\*\*Canopy relative humidity values in parentheses are angular transformed*

**Table 4.3 Effect different pruning intensities on biochemical characteristics in nursery mango plants**

<b>Treatment</b>	<b>Chlorophyll a</b>	<b>Chlorophyll b</b>	<b>Total Chlorophyll</b>
<b>T<sub>1</sub></b>	0.76	0.52	1.24
<b>T<sub>2</sub></b>	0.75	0.52	1.23
<b>T<sub>3</sub></b>	0.73	0.50	1.22
<b>T<sub>4</sub></b>	0.72	0.50	1.22
<b>T<sub>5</sub></b>	0.72	0.50	1.22
<b>T<sub>6</sub></b>	0.72	0.50	1.22
<b>T<sub>7</sub></b>	0.72	0.49	1.21
<b>T<sub>8</sub></b>	0.71	0.49	1.21
<b>T<sub>9</sub></b>	0.70	0.48	1.21
<b>T<sub>10</sub></b>	0.67	0.49	1.26
<b>T<sub>11</sub></b>	0.66	0.47	1.25
<b>T<sub>12</sub></b>	0.65	0.46	1.25
<b>T<sub>13</sub></b>	0.65	0.45	1.25
<b>T<sub>14</sub></b>	0.63	0.45	1.24
<b>T<sub>15</sub></b>	0.63	0.44	1.24
<b>T<sub>16</sub></b>	0.63	0.44	1.24
<b>T<sub>17</sub></b>	0.62	0.44	1.23
<b>T<sub>18</sub></b>	0.62	0.43	1.23
<b>T<sub>19</sub></b>	0.62	0.39	1.19
<b>T<sub>20</sub></b>	0.60	0.39	1.19
<b>T<sub>21</sub></b>	0.60	0.39	1.17
<b>T<sub>22</sub></b>	0.59	0.39	1.16
<b>T<sub>23</sub></b>	0.59	0.38	1.16
<b>T<sub>24</sub></b>	0.58	0.38	1.16
<b>T<sub>25</sub></b>	0.57	0.37	1.15
<b>T<sub>26</sub></b>	0.57	0.37	1.16
<b>T<sub>27</sub></b>	0.56	0.36	1.15
<b>T<sub>28</sub></b>	0.53	0.49	1.06
<b>Mean</b>	<b>0.65</b>	<b>0.45</b>	<b>1.20</b>
<b>C.D. 0.05</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>

## Chapter-5

### SUMMARY AND CONCLUSION

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Mango is an important fruit crop of subtropical regions of Himachal Pradesh. Various factors like climate, availability of cultivars, compatible rootstocks, quality of planting material, short gestation period, wider crotch angle with good bearing area, advanced cultural practices etc contribute to the yielding potential and quality of fruits in mango plants, but planting density is the most important single factor which brings about radical increase in production per unit area for higher and earlier returns. Training system followed in plants affect the plant growth and development, also contribute in increasing production efficiency and qualitative attributes of the plant and fruits by modification of plant geometry as dimensional approach.

The results obtained in the present investigation entitled, “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**” are summarized as under:

- 5.1 The maximum plant height (182.00 cm) was recorded with T<sub>28</sub> (Control) treatment, whereas minimum plant height (90.33 cm) was observed in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 cm + 3<sup>rd</sup> order at 25 cm) treatment. Maximum increase in stem diameter (4.19 mm) was found in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 cm + 3<sup>rd</sup> order at 25 cm) plants and minimum value (3.47 mm) was found in control plants.
- 5.2 The maximum shoot length after pruning at first order was observed when mango plants were headed back at 40 cm in T<sub>12</sub> which was statistically at par with other plants headed back at 40 cm and 50 cm. The minimum shoot length (7.60 cm) was recorded in control, which was statistically at par with T<sub>2</sub> and T<sub>6</sub> (head back at 30 cm). Maximum shoot length after pruning at second order was observed in T<sub>15</sub> (12.48 cm) when 1<sup>st</sup> order headed back at 40 cm and 2<sup>nd</sup> order branches were headed back up to 35 cm. However, minimum shoot length (7.60 cm) was recorded in control plants. The maximum shoot length at 3<sup>rd</sup> order (9.79 cm) was observed in T<sub>14</sub> (head back 1<sup>st</sup> order at 40 cm + 2<sup>nd</sup> order

at 35 cm + 3<sup>rd</sup> order at 35 cm) plants. Whereas, minimum shoot length (4.40 cm) was recorded in control plants.

**5.3** The maximum number of shoots per branch at 1<sup>st</sup> order (15.65) were observed in T<sub>10</sub> (head back at 40 cm at first order), however minimum (2 shoots per branch) was recorded in control plants. At 2<sup>nd</sup> order the maximum number of shoots per branch (12.33) were observed in T<sub>13</sub> (head back at 40 cm at first order + 35 cm at second order) plants, however minimum number of shoots per branch (1.67) were recorded in T<sub>28</sub> (control). At 3<sup>rd</sup> order the maximum number of shoots per branch (12.17) were observed in T<sub>11</sub> (head back at 40 cm at first order + 25 cm at second order + 35 cm at third order), however minimum number of shoots per branch (1.50) were recorded in T<sub>28</sub> (control).

**5.4** At 1<sup>st</sup> order the minimum time taken for sprouting (3.83 days) was observed in T<sub>10</sub> plant (head back at 40 cm), however maximum (28.33 days) was recorded in control. At 2<sup>nd</sup> order the minimum days taken for sprouting (6.17 days) were observed in T<sub>13</sub> plant (1<sup>st</sup> order head back at 40 cm + 2<sup>nd</sup> order head back at 35 cm), however maximum (29.50 days) was recorded in control (T<sub>28</sub>). At 3<sup>rd</sup> order the minimum days taken for sprouting (8.50 days) was observed in T<sub>14</sub> plant (1<sup>st</sup> order head back at 40 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 35 cm), however maximum (30.33 days) was recorded in control (T<sub>28</sub>) where no pruning performed.

**5.5** Maximum shoot length, maximum number of shoots per branch and minimum days taken for sprouting in case of order of branches was found in first order branches followed by second and third order branches (after head back). In case of different pruning level used in first order, maximum shoot length, maximum number of shoots per branch and minimum days taken for sprouting was found upon head back at 40 cm followed by 50 cm, 30 cm and unpruned. In case of different pruning levels used in second order and third order, maximum shoot length, maximum number of shoots per branch and minimum days taken for sprouting was found on head back at 35 cm followed by 45 cm, 25 cm and unpruned.

- 5.6** The maximum leaf area (37.87 cm<sup>2</sup>) was observed in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 cm + 3<sup>rd</sup> order at 25 cm) treatment, which was statistically similar with T<sub>2</sub> (37.83 cm<sup>2</sup>) treatment. However, minimum leaf area (33.06 cm<sup>2</sup>) was found in T<sub>28</sub> (control). Maximum value of leaf area index and canopy volume (2.49 and 3.03 m<sup>3</sup>) was recorded in T<sub>28</sub> (control), whereas, lowest leaf area index and canopy volume (1.25 and 0.42 m<sup>3</sup>) was reported in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 cm + 3<sup>rd</sup> order at 25 cm) plants.
- 5.7** The highest relative water content (93.63 %) was found in T<sub>28</sub> (Control) plants. Whereas, lowest (90.13 %) was reported in T<sub>13</sub> (Head back 1<sup>st</sup> order at 40 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 25 cm) treatment.
- 5.8** The maximum light penetrance, canopy temperature and minimum relative humidity (6.91 K lux, 34.33 °C and 60.33%) was recorded in T<sub>1</sub> (Head back 1<sup>st</sup> order at 30 cm + 2<sup>nd</sup> order at 25 cm + 3<sup>rd</sup> order at 25 cm) plants. However, minimum light penetrance, canopy temperature and highest relative humidity (4.16 K lux, 27.67 °C and 74.33 %) was recorded in T<sub>28</sub> (Control) plants.
- 5.9** Different levels of pruning had no significant effect on chlorophyll a, chlorophyll b and total chlorophyll content, initial and final stem diameter but showed a significant effect on increase in stem diameter.

## **Conclusion**

From the present investigation, it is concluded that different intensities of pruning significantly affected the growth and microclimatic characteristics but was found non significant for biochemical characteristics (Chlorophyll contents). One year old mango plants were subjected to different levels of pruning at first order (30 cm, 40 cm, 50 cm and unpruned) where, head back at 40 cm was found best in respect of shoot length, minimum days taken for bud emergence and number of shoots per branch which was followed by 50 cm and 30 cm cuts. In case of second and third order branches among the different pruning levels were given (25 cm, 35 cm, 45 cm and unpruned), 35 cm heading back was found the best which was followed by 45 cm and 35 cm cut.

Among, the different pruning treatments, the best results in terms of plant height, stem diameter, time taken for bud sprouting after heading back, number of shoots per branch, shoot length after pruning were recorded under moderate pruning. So, T<sub>14</sub> (Head back 1<sup>st</sup> order at 40 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 35 cm) was found to be better among all the 28 treatments with better canopy structure. However, T<sub>5</sub> (Head back 1<sup>st</sup> order at 30 cm + Head back 2<sup>nd</sup> order at 35 cm + Head back 3<sup>rd</sup> order at 35 cm) found better among the plant headed back at 30 cm cut at first order and T<sub>23</sub> (Head back 1<sup>st</sup> order at 50 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 35 cm) found best among the plant headed back at 50 cm cut at first order.

Overall, among the treatments, treatment T<sub>14</sub> (Head back 1<sup>st</sup> order at 40 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 35 cm) has been observed optimum for developing low headed canopy in nursery plants of mango in terms of better canopy architecture, stem/shoot maturity for early cropping, greater bearing area with better canopy microclimatic characteristics *viz.*, canopy temperature, canopy relative humidity and light penetrance. These features of nursery plant create non-congenial conditions in plant canopy for the growth and multiplication of various pathogens and pests. All these factors shall play a key role in enhancing the availability of quality planting material, thereby improving the quality of produce and productivity for ensuring better returns to farmers.

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**APPENDIX-I**

**ANOVA for growth characteristics**

Source of Variation	Degree of Freedom	Mean Squares						
		Plant height before heading back	Final plant height	Initial stem diameter	Increase in stem diameter	Shoot length after pruning at first order	Shoot length after pruning at second order	Shoot length after pruning at third order
Treatment	27	100.273	2,015.265	2.361	0.121	9.346	2.414	6.414
Error	56	87.369	17.842	2.484	0.030	3.672	0.714	1.360
Total	83							

**ANOVA for growth characteristics related to number of shoots and time taken for bud sprouting in mango nursery plants**

Source of Variation	Degree of Freedom	Mean Squares					
		Number of shoots per branch at first order	Number of shoots per branch at second order	Number of shoots per branch at third order	Time taken for bud sprouting after heading back at first order	Time taken for bud sprouting after heading back at second order	Time taken for bud sprouting after heading back at third order
Treatment	27	63.741	28.574	28.124	60.614	54.545	48.000
Error	56	1.948	1.065	1.256	0.854	0.607	1.548
Total	83						

**ANOVA for canopy microclimatic characteristics**

Source of Variation	Degree of Freedom	Mean Squares						
		Leaf Area	Leaf Area Index	Canopy volume	Relative water content	Light penetrance	Canopy temperature	Canopy relative humidity
Treatment	27	4.537	0.363	1.134	2.766	2.252	5.453	23.197
Error	56	0.046	0.001	0.001	0.982	0.135	0.103	1.176
Total	83							

**ANOVA for biochemical characteristics**

Source of Variation	Degree of Freedom	Mean Squares		
		Chlorophyll a	Chlorophyll b	Total chlorophyll content
Treatment	27	0.012	0.008	0.006
Error	56	0.067	0.028	0.051
Total	83			

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**Title of the Thesis** : **Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**  
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**ABSTRACT**

The present investigation entitled “**Standardization of canopy architecture techniques of nursery plant for high density plantation of mango (*Mangifera indica* L.)**” was carried out in the polyhouse of the Department of Fruit Science, College of Horticulture and Forestry, Neri, Hamirpur (H.P.) during the year 2019-20 on one year old grafted mango plants, spaced at 1×1 m in completely randomized block design. Plants were subjected to different intensities of pruning at 1<sup>st</sup> order (30 cm, 40 cm, 50 cm and unpruned), 2<sup>nd</sup> and 3<sup>rd</sup> order of branches (25 cm, 35 cm, 45 cm and unpruned). The statistical analysis revealed significant effect of different pruning intensities on growth and microclimatic characteristics but effect were non significant for biochemical characteristics. In 1<sup>st</sup> order head back at 40 cm was found best in respect of shoot length, minimum days taken for bud emergence and number of shoots per branch, followed by 50 cm and 30 cm head back. Similarly, in case of 2<sup>nd</sup> and 3<sup>rd</sup> order branches head back at 35 cm was found best, followed by 45 cm and 25 cm. Among, different pruning treatments, in the experiment best results in terms of time taken for bud sprouting after head back (3.83 days, 6.17 days, 8.50 days), number of shoots per branch (15.65, 12.33, 12.17), shoot length after pruning (14.73 cm, 12.48 cm, 9.79 cm) in first, second and third order were recorded from moderate pruning. And thus as result of heading back 1<sup>st</sup> order at 40 cm + 2<sup>nd</sup> order at 35 cm + 3<sup>rd</sup> order at 35 cm) i.e., T<sub>14</sub> produced nursery plants with best combination of the desired characters for high density planting in mango.

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