Annals of R.S.C.B., ISSN: 1583-6258, Vol. 25, Issue 6, 2021, Pages. 948-962
Received 25 April 2021; Accepted 08 May 2021.

High Density Orcharding in Fruit Crops: A Review

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Abstract
Soil application of paclobutrazol resulted in a significant increase in flowering and slightly earlier flowering whereas a combination of soil application of paclobutrazol (1.0gm/canopy diameter/tree) and soil drench application 8 weeks after paclobutrazol treatment induced very early flowering. Twenty year-old mango trees (Manqifera indica L.) Cv. Dashehari planted in high density system (2.5m x 2.5m) was hard pruned. Three weeks later, as the new flushes expanded, paclobutrazol was applied to soil by spraying the basin. It was found that the third and fourth flushes of the treated trees were significantly shorter than that of the control, and their intermodal lengths were remarkably reduced. The canopy sizes of the treated trees were significantly reduced in height and speeded once year. This gave the optimal canopy size for high density planting while the canopy of the control trees became overlapping. High density orcharding is one of the recent novel concepts of increasing productivity without affecting quality of fruits. It gives earlier production and return per unit area, shortens juvenility provides efficient resources. Dwarfing root stocks play key role to accommodate more number of plants per unit area. Under HDP has been found most suitable technique for some tropical and subtropical fruits accommodating more number of plants per unit area viz., Dashehari mango (1333 plants/ha), guava (5000 plants/ha), papaya (6400 plants/ha), Highest yield (6.4 MT/ha) was recorded with a spacing of 5 m x 5 m without reduction in fruit size in 15 year old plants compared to the mean yield of 1.12 MT/ha in 10m x 10m normal spacing. High density plantation helped to get significantly higher yield per unit area compared to the normal spacing, without affecting size and quality of mango fruits. The present findings show promise for more yield and returns per unit area during the initial years of mango plantation by adopting 2.5m x 2.5m high density planting.

Keywords: Fruit Crops, High Density Planting, Dwarfing Root Stock, Inters Tock, Canopy

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical and subtropical fruits of the world and is popular both in fresh and the processed forms (Ahmed and Mohamed, 2016)[2]. It is called as ‚the king of fruits' (Acema et al. 2016) [1] preferred by all sections of people for its delicious taste, flavour, attractive colour, nutritive value and superior fragrance (Banerje 2011)[6]. India is first ranks in production in the world among mango growing countries (Sekhar et al. 2013)[32]. The important mango producing states of the country are Andhra Pradesh, Utter Pradesh, Karnataka, Bihar, Gujarat, Maharashtra, Tamil Nadu, West Bengal, Kerala and Orissa (Lokesh et al. 2016)[21]. The high density planting (HDP) in fruit crops is one of the recent novel concepts of increasing the productivity without affecting the quality of fruits. India is the largest producer of fruits in the world after China. The average productivity and per capita availability of fruits in India is, however, low as compared to many developed countries. The main reasons for low productivity are old and senile orchards, wider spacing, low yielding varieties, poor orchard management and inadequate technological up-gradation and adoption by the growers. Presently, the continuing decline in the availability of cultivable land, rising energy and land costs together with the increased demand of fruit and fruit products, have given thrust to High density planting gives earlier production and return per unit area, shortens juvenility, eco-friendly, provides efficient land use and better use of resources like light, water and fertilizers, efficient pesticides application, besides, in this system the harvesting becomes easy. Among the factors such as cultivar, rootstock, quality of planting material and cultivation practices contribute to high yield of fruit trees, however, the number of trees-1 is the most important factor which brings about radical increase in fruit production. Therefore, high density planting has great potential for increasing productivity in fruit crops. The success of this technology in most of the fruit crops is dependent on the use of methods to control shoot growth and maximize light interception as the trees begin to bear fruit (Menzel and Lagadec,2014)[22]. The main aim of HDP is to achieve the twin requisites of productivity by maintaining a balance between vegetative and reproductive growth without impairing the plant health and fruit quality. Mango is a member of the family *Anacardiaceae* from Asia and has been cultivated for at least 4000 years (Crane, 2008)[8]. It is one of the most important members of this family. It is ranked fifth in overall fruit production worldwide (Normandet al., 2015)[27]. Other popular large trees from the same family include cashew (*Anacardium occidentale*) from tropical America and pistachio (*Pistacia vera*) from Iran and Central Asia, both important nut crops. Related fruit trees include marula

(*Sclerocarya birrea*)from Africa and Madagascar, and yellow mombin or tropical plum(*Spondias mombin*) from tropical and subtropical South America. The main centre of origin for mango is within the region between north-east India and Myanmar (Crane, 2008; Bompard, 2009) [27,7].

India is considered to be the centre of domestication of mono-embryonic cultivars, while South-east Asia including Indonesia, the Philippines, Thailand, Viet-nam and Myanmar is the main centre for poly-embryonic cultivars. The poly-embryonic cultivars produce a seed with several genetically identical embryos. Cultivars from India tend to have highly coloured skin at maturity and are susceptible to anthracnose (*Colletotrichum gloeosporoides*). In contrast, cultivars from South East Asia tend to have green to yellow skin and are less susceptible to anthracnose. India is the most important producing country, and accounts for nearly 40% of total world production. Other important mango growing countries include China (11%), Kenya (7%), Thailand (6%), Indonesia (6%), Pakistan (6%), Mexico (5%), Brazil(3%), and Bangladesh (2%). Although India is the main producer, it accounts for only about 16% of world mango trade. Exports are more important for Mexico, with 20% of total world trade. Other important exporting countries include Thailand (11%), Brazil (9%), Peru (9%), and Pakistan (7%). The United States and Europe are the main markets for imported mangoes. Mexico is by far the main supplier to North America, while Brazil and Peru are the main suppliers to Europe (Galán Saúco, 2000; Gallo, 2015) [11, 12]. India exports mainly to the United Arab Emirates and other countries in the Middle East (Balyan et al., 2015)[5] .Mango orchards are normally planted at fairly wide spacing's because the trees can grow into large specimens. Non-domesticated wild seedling trees often grow up to 10 m in suitable environments (Khan et al., 2015)[16]. Traditional orchards are commonly planted out at 100–200 trees per ha. Yields per unit are are low for the first few years after planting and keep increasing until the trees start to shade each other. This period can last from ten to twenty years. There is usually a long period to recover the costs of planting and establishment under this scenario. Trees are planted on a range of different rootstocks and pruned in various ways, which affects the performance of the trees and the commercial life of the orchard. There is strong interest in the use of plantings up to 4000 trees per ha to increase the long-term productivity and economics of growing mango, with several studies in India, South Africa and elsewhere (Fivaz, 2009; Gunjate et al., 2004; Gunjate,2009; Bally and Ibell, 2015; Kumar, 2015)[10,13,14,4]. Mango trees are often irregular in their cropping habit, with noclear pattern across different years. Plantings can also suffer fromalternate or biennial bearing, where a tree or an orchard producesa large crop in an on-year followed by a small crop in the following off-year (Souza et al., 2004)[35]. There can be periods of irregular bear-ing and periods of alternate bearing in the same orchard (Fitchettet al., 2016)[9].

In Thailand, yields of 'Chok Anan' varied considerable between years (Spreer et al., 2009)[39]. Between 38 and 75% of the trees in a single orchard bore alternately, with heavy crops in one year followed by poor flowering and fruit set the following year. Souzaet al. (2004)[37,38] studied the pattern of fruiting in 19 cultivars over 18years in Brazil. Alternate bearing occurred in some cultivars and worsened as the trees aged. Other cultivars displayed a pattern of alternate bearing for a few years of production and were classifieds having a low alternate bearing behavior. Other cultivars showed an erratic behavior with no clear pattern of alternate bearing, and certainly no regular bearing. For example, 'Alphonso' yielded 20 tper ha for four cycles and then had progressively lower yields for the next three cycles. The analysis of alternate bearing can be complicated because poor weather can reduce cropping in an on-year. Singh et al. (2014a)[35] studied the performance of 100 'Langra' trees over five years in Lucknow in India. Their analysis took into account the effect of individual seasons and individual trees on yield and showed that the orchard had a distinct pattern of alternate bearing. Average yields in the orchard over the period ranged from 26 to 107 kg per tree.

1.1. Status of High Density Orcharding in Fruit Crops

There has been much talk about the potential of high density orcharding in fruit crops, but few studies demonstrated the long-term economic benefits (Ram, S, et al. 2001,1988, 1991)[29,30,31]. In some of the cases, yield was declined after few years as trees began to crowd each other. The high-density orchard provides several times (8-9) higher yields than the traditional densities as demonstrated by Ram et al. in alternate bearing Dashehari mango in north India. Dashehari mango at 2.5 m x3 m (1,333 plants/ ha) was raised under HDP with pruning and dehorning after the harvesting followed by paclobutrazol application and yield was secured every year. In an experiment at CISH, Lucknow, ultra high density system of planting in guava was standardized. The ultra high density orchard system of guava accommodates 5000 plants /ha, at a spacing of 2.0 x1.0m and managed with regular topping and hedging during initial stages which helped in controlling tree size and getting higher yield. Pusa Nanha papaya may be planted at a distance of 1.25 x1.25 m (6,400 plants/ ha). Similar observations have been made by various workers in citrus, litchi, banana and pineapple.

1.2. Mango Varieties Suitable for Ultra-High Density Planting

Ultra High Density Planting System Recently, experiment conducted by TNAU in collaboration with Jain Irrigation Systems Ltd (JISL), Udumalpet revealed that we can go for still closer spacing of 3 x 2 m called Ultra High Density Planting System (UHDP). The varieties that can be grown successfully under UHDP in different states are shown in Table 2. As the Cultivation Practices are very intensive, high value varieties are recommended. Under UHDP, Mango is planted at 3 m x 2 m which accommodates 674 plants Acre. Pits should be marked at 3 m x 2 m before pit digging and pits of l x l x l m are to be dug at marked places. Alternatively one meter deep and one meter wide trench can be prepared at every three meter, but it is bit costly, however, it is more convenient, good for establishment and growth. The pits should be allowed to wither for some weeks before filling with mixture of planting media. The media consists of 40-50 kg native soil, 0.5- 1.0 kg Single Super Phosphate (SSP), 0.25 kg Neem cake, 20 kg compost or 10 kg vermi-compost and 10-15 g of Thimet or 20 g Furadon. Plantations are to be raised by using grafted saplings. Plants must be procured well before planting. While planting, soil around each graft should be pressed well. The ball of earth around the base of the graft should be retained intact and the graft joint should remain just above the ground level. The success of high density planting depends upon certain factors which are dealt here. Canopy Management Canopy management is essential in high density planting system to control size of the tree and also to strike a balance between vigour and productivity. It starts from early months from planting Training, when the plant height reaches 45-60 cm, the terminal bud should be pinched at 5-6 cm below the apex to encourage growth of auxiliary buds.

1.3. Mango varieties suitable for Ultra-High Density Planting: State Varieties

1). Andhra Pradesh: Alphonso, Alampur Baneshan, Banganapalli, Totapuri (Bangalora), Mallika **2). Bihar:** Bombai, Himsagar, Langra, Chausa 3. Goa Fernandin, Mankurad Gujarat Alphonso, Kesar **4). Karnataka**: Alphonso, Bangalora, Neelum, Mallika 5.) Madhya Pradesh: Alphonso, Kesar, Ratna 6.)Tamil Nadu: Alphonso, Banganapalli, Imampasand, Totapuri (Bangalora) 7). Uttar Pradesh: Bombay Green, Dashehari, Langra, Lucknow Safeda, Mallika, Chausa.

1.4. Canopy Management in Young Trees

After 4-6 months growth of primary branches, they should be headed back at 45-60 cm length to allow further growth of 4-5 secondary shoots on each branch, which in turn will form tertiary shoots in due course. Ultimately the tree row will form a dome shaped hedge. In many orchards, improper training especially the formative pruning resulted in overcrowding of branches resulting in more incidences of hopper, powdery mildew and anthracnose disease etc. Pruning is very essential and critical operation of HDP or UHDP to maintain fruiting shoots and contain the canopy. Pruning must be completed as soon as possible after harvest preferably before 15th June in Central and Southern India. Tertiary branches have to be headed back in such a way that the plant height can be maintained at 1.5 m and having 10-15 tertiary shoots. Excess tertiary shoots have to be thinned out to avoid overcrowding. Cut ends to be pasted with Bordeaux paste or 2% Copper Oxychloride (COC) suspension. About one month after pruning, thinning of newly emerged shoots is essential to avoid excess shoots and overcrowding. On each tertiary shoots 3-4 new shoots are to be maintained. Dried panicle along with 2-3 leaves and dried shoots / branches must be removed at the time of pruning.

The following points are to be borne in mind for new orchard while carrying out canopy management. • Heading back of plants when they attain the age of one year. • Heading back should be done with sharp secateurs to give a sharp and smooth cut during October -December. • Height of heading back should be 60-70 cm from the ground. • Heading back results in emergence of new shoots during March-April (spring season). • For development of ideal open canopy, thinning of excessive shoots is needed during May. Thinning should be done in such a manner as to retain four well distributed shoots in all directions. These shoots develop as primary branches. • If crotch angle of retained shoots is smaller, then bending should be done at this stage to increase the crotch angle of newly developed shoots. It should be done with a jute rope (use of nylon or poly threads should be avoided). • Second cutting is required when these shoots attain maturity. Shoot maturity in mango is determined by colour change of shoots from green to brown. Generally, this stage comes after 7-8 months of growth in north India. • Thus, second cutting of primary branches is done in October-November. This cutting also induces new growth during ensuing spring season. • Again, thinning of excessive shoots should be done to ensure 2-3 shoots per primary branch. These shoots develop as secondary branches. This initial training results in open and spreading canopy of trees.

1.5. Canopy Management in Bearing Mango Orchards

In TNAU experiments proved that canopy management through pruning immediately after harvesting and checking its vegetative growth by September through soil application of paclobutrazol @ 1.0 g a.i. per canopy diameter is beneficial. Further, off-season cropping can be induced in mango through appropriate canopy management practices. The limitation to these techniques is that it can be practiced only under irrigated and well maintained plantations. As manual method of heading back of the shoots is a laborious one under large scale,

mechanical means to prune the mango tree is to be developed (Kumar et al. 2014,15)[18,19,20]. Similarly, the problem of large tree size in mango can be tackled by using topping and hedging because large and crowded trees pose many disadvantages. Appropriate height, topping and hedging, cutting angles, as well as time and frequency of hedging determined for mango, which are common practices in Israel, USA, Australia and South Africa, can be used for increased efficiency and production in India. Shaping the mango tree immediately after planting has its own importance for keeping desirable plant height at first branching, so that proper clearance for equipment is possible.

The following points are to be borne in mind while carrying out canopy management in bearing orchard. • In bearing mango trees, for management of canopy and enhancing their productivity, identify uprightly growing branches in each tree and thin them out for increasing the productivity. • Remove only one or two uprightly growing branches from centre of tree to reduce tree height significantly and increase availability of light inside the canopy for better photosynthesis. • Cutting of uprightly growing branches should be done during October-December from the base of their origin. • During removal of branches, first cut should be given on lower side of branch to give a smooth cut and avoid bark splitting. • Protect branches with wide crotch angle as they are more productive. • In bearing mango trees, not more than 25 % biomass should be removed at a time for better canopy management; otherwise it results in excessive vegetative growth. • Under high density planting system, remove 10-15 % biomass annually during October-December to increase light penetration inside the canopy. Removal of 10-15 % biomass should include criss-cross branches, dead wood and diseased shoots. Management of pests and diseases under HDP or UHDP As proper pruning is taken up in these orchards, generally the pests especially hopper or diseases like anthracnose and powdery mildew would be minimum as spraying operations are easy and efficient. Studies conducted at TNAU revealed that anthracnose disease incidence was found to be high in mango trees planted in the 'Double hedge row system of planting', however, they were better managed by periodical pruning of trees and spraying recommended dose of fungicides or bio control agents at regular intervals.

However, they observed no significant variation in hopper numbers among the various planting systems over the years. A problem faced in certain HDP mango orchards Once HDP is adopted, all the recommended practices are to be followed scrupulously, and otherwise, it would result in failure only. The experience of HDP/UHDP in three different mango orchards is described below. Orchard Number One The orchards is 12-13 years old with spacing 7 m x 6 m. Soil depth is good with poor water retention capacity. Annual rainfall is 1250-1500 mm. The orchard is under rainfed condition with no drip system. No addition of NPK fertilizers etc. Problems confronted included vigorous, more crowdy, upright growth, no sunlight penetration, very poor yield, (1.5-2.0 MT ha-1) harvesting problem because of higher growth, severe incidence of powdery mildew, white scale and anthracnose. The leaf nutrient content low level of K found in the leaves would have encouraged the heavy incidence of powdery mildew and anthracnose disease prevailing in the mango orchard. The low amount of micronutrients like Boron and Zinc are also causing a concern as their critical level helps to provide resistance against diseases and insect pests. In order to improve the yield potential of the orchard, following recommendations were made: • Soil moisture conservation practices which include mulching, use of coir brickets • Use of VAM application • Decomposing the fallen leaves and the cut savannah grasses • Developing the infrastructure for irrigating the mango orchard • Further, canopy management in mango orchards such as rejuvenation pruning • Centre opening and Formative pruning in young.

2. Establishing High Density Orchards

HDP can be achieved with the suitable use of following components, they are (a) Dwarf scion varieties, (b) Dwarfing rootstocks and inter-stocks, (c) Training and pruning, (d) Use of growth regulators and (e) Suitable crop management practices. These components are harnessed in HDP which helps in attaining the goal of high yield and quality. Use of pruning to control tree growth: Mango trees typically grow into large specimens, up to 10 m or more. When the trees are planted closely together, they usually grow into each other and shade large sections of the lower canopy. Productivity often declines at this stage, normally about ten years after establishments. The development of high-density plantings in mango will require effective strategies to control the growth of the trees (Oosthuyse, 1995; Yeshitela et al., 2005, 2004a, 2004b)[28,42,43,44],.There have been numerous studies which have reported on the effect of pruning on tree physiology, growth, and yield. However, only a few of these studies relate directly to the sustain ability of high-density plantings. Most of the research on canopy management has been conducted in South Africa and India, with some studies in Australia and Central and South America. Some researchers have initiated relatively simple experiments and com-pared the yields of pruned and un pruned trees. Other workers have undertaken more complex experiments, and have compared the yields of trees pruned using different techniques or at different times of the year. The research has been conducted on both new and old plantings that have become crowded and unproductive. Pruning usually leads to better distribution of light within the tree's canopy. Following pruning, the trees are initially smaller but even-

tually the canopy recovers. The effect of pruning on productivity depends on the interaction of between improved light distribution and the loss of fruiting wood and leaf area. We examined the effect of canopy management on the performance of mango trees growing in different environments. Several key issues were analyzed, including the relationship between productivity and the architecture of the trees, the different responses of young and old trees to canopy management, the importance of time of pruning, and the relationships between yield, flowering, light interception and pruning. They were interested in determining whether trees pruned to different shapes were more productive than trees left to grow without canopy management.

2.1. Genetically Dwarf Scion Varieties

As part of the National Horticulture Mission, the department of horticulture in Madurai has introduced ultra high density planting of mango this year."While high density planting of mango is being practiced by farmers in T. Kallupatti and Sedapatti for the last two years, the ultra high density planting, which will considerably increase the harvest for the farmers, has been introduced this year," said T. Padmini, Deputy Director of Horticulture, Madurai. Under the ultra high density method, the mango trees will be planted closer together with lesser space left than in the high density and normal method of cultivation. "At least 800 trees can be planted in one hectare of land under this method. The target area to be covered under this method of cultivation in the district has been fixed at five hectares for this year as it is just being introduced," Ms. Padmini said. It is easier to establish high density orchards if the trees are naturally small. Use of genetically dwarf cultivar offers great scope for close plantings, which have the potential for higher yields and returns than traditional plantings. However, availability of dwarfing scion cultivars are meager as indicated below additionally, the target area to be covered this year under high density planting of mango and guava has been fixed at 130 hectares and 40 hectares respectively. The area under cultivation of mangoes in the district experienced a sharp fall after 2013-14 owing to lack of rainfall and drought-like situation when many mango trees dried up.

2.2. Crop Dwarf Cultivar Desirable Characters

2.2.1. Banana

Dwarf Cavendish, Dwarf stature with **high yield Guava:** Pant Prabhat Less spreading and **high yielder Litchi:** Calcuttia, China, **Upright tree growth habit Mango:** Amrapali, Arunika Precocious and **regular bearer Papaya:** Pusa Dwarf, Pusa Nanha **Bears at lower height Sapota**: PKM-1, PKM-3.

2.3. Use of Dwarfing Root Stocks

Root stocks are known to have a profound effect on the tree vigour, precocity, productivity, quality of fruits and longevity of varieties grafted on them. Dwarfing can be due to the rootstock or the scion, or both. Attempts have made to standardize dwarfing rootstocks especially in the fruit crops like ber, citrus and grape. However, much choice is not available for most of the tropical and subtropical fruit crops in comparison to the temperate fruits. Use of graft incompatible scion and rootstock induces dwarfness in the composite plant. As in case ber, if scion cultivars grafted on to the *Zizyphus rotundifolia, Z. nummularia* dwarfness may be induced due to graft incompatibility.

2.3.1. Crop Dwarfing Rootstocks

1. **Ber**: *Zizyphus rotundifolia, Z. nummularia*
2. **Citrus:** Troyer citrange, Flying Dragon (*Poncirus trifoliata*), Karna Khatta
3. **Guava:** *Psidium friedrchsthalianum, P.chinensis*, Pusa Srijan
4. **Mango:** Vellaikullamban

3. Use of Pruning to Control Tree Growth

Overcrowding poses a serious problem for orchard access and for adequate light interception needed for optimum photosynthesis, flowering and fruit set and quality. Attempts have been made by various workers on the use of pruning for canopy management in high density orchards (Sharma and Singh, 2005: Mishra and Lal,2013 ; Nath *et al.,2005*)[33 &34,23,26],. Pruning and production of new shoot was found essential to maintain continuity of vigour and to provide terminal bud for panicle emergence in Dahehari mango at Pantnagar. Pruning can be used to increase the distribution of light through the canopy, although productivity is not always restored in the same season. For instance, heavy pruning of 34 year old avocado trees inhibited production for the following two to three years (Crane *et al.*)[8].

3.1. Use of Growth Regulators to Control Tree Growth

Pruning often leads to strong re-growth of shoots in mango and other fruit crops. Plant growth regulators such as *Paclobutrazol, Alar, Uniconazole, prohexadione- calcium* have been used to restrict vegetative growth. Of these Paclobutrazol treatments in mango at Pantnagar induced flowering and fruiting in new shoots produced in July after pruning without any loss in fruit quality. September to November treatment was highly effective in increasing flowering and fruiting besides reducing vegetative growth (30-35%). Thus, paclobutrazol treatments induced flowering and fruiting and helped in reducing the vegetative growth required for high density orcharding. However, uniconazole was more effective for restricting shoot growth than paclobutrazol in avocado in South Africa (Kohne and Kremer-kohne,1989)[17]. Prohexadione-calcium sprays on five year old 'Hass' avocado trees reduced the growth of spring shoots compared with the growth achieved in control, but did not affect yield (Menzel and Lagadec,2014)[22].

4. Drip Irrigation Must

"With sufficient rain last year and good rainfall in the last two months in the district, technologically advanced methods like the ultra high density planting is being implemented to benefit the farmers. Farmers should, however, practise drip irrigation when it comes to cultivating mangoes," an official said, adding that many mango trees could have been saved two years back if the farmers had implemented the effective irrigation system. Planting activities with regard to the new method of cultivation commenced at the beginning of June and would continue till December, he added.

5. Hand Pruning in High-Density Plantings

Daniel starts hand pruning trees when they are young so the trees have a good structure by maturity. Average annual pruning costs are $1.60 per tree on the standard high-density layout ($1000/ha) and about $1.30 for the twin row layout ($1250/ha). The twin row layout trees are smaller and therefore have a slightly lower per tree cost. Pruning costs will vary season to season. The program has been producing very good long-term average yields of navels of about 55t/ha for the standard layout high-density navels and 63t/ha for the twin row layout. Without the annual hand pruning program, yields would be 15 to 20t/ha less; that's a loss of up to $13,500/ha ($650/t fruit price). Investing $1250/ha in pruning and getting $13,500/ ha return is a very good investment. Daniel says he also gets less blemished fruit which increases his pack-out and per ton price. The take home advice Daniel wishes to provide growers is high-density planting will provide higher early yields and twin row planting will provide higher mature tree yields, but annual hand pruning is essential to maintain good yields.

6. Selection and Site of an Orchards

6.1. Establishment of Orchard

Establishment of an orchard is a long term investment and deserves a very critical planning. The selection of proper location and site, planting system and planting distance, choosing the varieties and the nursery plants have to be considered carefully to ensure maximum production.

6.1.1. Location and Site

Proper selection of site is important. Selection may be made based on the following criteria:

1. The location should be in a well established fruit growing region because one could get the benefit of experience of other growers and also get the benefit of selling the produce through co-operative organizations with other fruit growers.
2. There should be a market close to the area.
3. The climate should be suitable to grow the chosen fruit crops.
4. Adequate water supply should be available round the year.

6.1.2. Before a Grower Selects a Site for Establishing a New Orchard, He must have Assessed the Following Factors:

1. Suitability of soil, its fertility, the nature of subsoil and soil depth.
2. Site must have proper drainage and no water stagnation during rainy season
3. Irrigation water must be of good quality.
4. There must be proper transport facilities either by road or rail within the reach.
5. Whether the climatic conditions are suitable for the fruits to be grown and are whether site is free from the limiting factors such as cyclones, frost, hailstorms and strong hot winds.
6. Whether there are seasonal gluts or over production in any particular period of the year.
7. Whether there is assured demand in the market for the fruits to be grown.
8. Whether his orchard is a new venture or whether there are already other growers.
9. Availability of labours.

6.1.3. Preliminary Operations

After selecting the suitable location and site, some preliminary operations have to be done. Trees are felled without leaving stumps or roots. The shrubs and other weedy growth are also cleared. Deep ploughing is essential to remove big roots. The lands should be thoroughly ploughed, leveled and manured. Leveling is important for economy of irrigation and preventing soil wash. In the hills, the land should be divided into terraces depending upon the topography of the land and the leveling is done within the terraces. Terracing protects the land from erosion. If the soil is poor, it would be advisable to grow a green manure crop and plough it *insitu* so as to improve its physical and chemical conditions before planting operations are taken up.

6.1.4. Planning of an Orchard

A careful plan of the orchard is necessary for the most efficient and economic management. The following points should be borne in mind in preparing the plan.

1. Optimum spacing to accommodate maximum number of trees per unit area.
2. Stores and office building in the orchard should be constructed at the centre for proper supervision. .
3. Wells should be located at convenient places in different parts at the rate of one well for 2 to 4 hectares.
4. Each kind of fruit should be assigned in a separate block.
5. Fruits ripening at the same time should be grouped together.
6. Pollinators should be provided in deciduous fruits. In deciduous fruit trees, there are some varieties which require pollen from another variety to set fruits in them, otherwise, they will be barren. Such pollen donors are known as pollinators..Every third tree in every third row should be planted with a pollinator.
7. Irrigation channels should be laid along the gradients for most economical conduct of water. For every 30m length of channel, 7.5 cm slope should be given.
8. Roads should occupy minimum space for the economy of transport. The clearance between wind break and first row of trees is advantageous for the road.
9. Short growing trees should be allotted at the front and tall at the back for easy watching and to improve the appearance.
10. Evergreen trees should be in the front and deciduous ones behind.
11. Fruits attracting birds and animals should be close to the watchman's shed.
12. A good fence is essential. Live fencing is economic and cheap to other kind of fences. The plants suitable for live fencing should be drought resistant, easy to propagate from seed, quick growing, have dense foliage, should stand severe pruning and should be thorny. *Agave, Prosopis juliflora, Pithecolobium dulce* and *Thevetia* if closely planted in 3 rows would serve as a good live fencing.
13. Wind breaks, rows of tall trees planted close together around the orchard, are essential to resist velocity of wind which cause severe ill-effects particularly moisture evaporation from the soil. Since the wind breaks are very effective in reducing the wind velocity and minimizing the damage to the fruit trees and to other crops, their presence in regions where strong winds prevail is of paramount importance. A wind break ordinarily has its maximum effectiveness for a distance about four times as great as its height but has some effect over twice about that distance. The most effective windbreak is a double row of tall trees alternately placed. There should be at least as much as space between the windbreak and the first row of the fruit trees as between fruit trees. It is preferable to dig a trench of 90 cm deep at a distance of 3m from the windbreak trees and prune and cut all the roots exposed and again fill up the trenches. This may be repeated for every 3 or 4 years in order to avoid the compe1ition between the wind breaks and fruit trees for moisture and nutrition. Trees suitable for windbreak should be erect, tall and quick growing, hardy and drought resistant and mechanically strong and dense to offer maximum resistance to wind. The trees which are suitable for growing as wind breaks are *Casuarina equisetifolia, Pterospermum acerifolium, Polyalthia longifolia, Eucalyptus globulus, Grevillea robusta, Azadirachta indica* etc.

7. Laying Out of an Orchards

Any method of layout should aim at providing maximum number of trees per hectare, adequate space for proper development of the trees and ensuring convenience in orchard cultural practices. The system of layout can be grouped under two broad categories viz. (a) vertical row planting pattern and (b) alternate row planting pattern. In the former planting pattern (e.g. square system, rectangular system), the trees set in a row is exactly perpendicular to those. Trees set in their adjacent rows. In the latter planting pattern (i.e. Hexagonal, Quincunx and Triangular), the trees in the adjacent rows are not exactly vertical instead the trees in the even rows are midway between those in the odd rows.

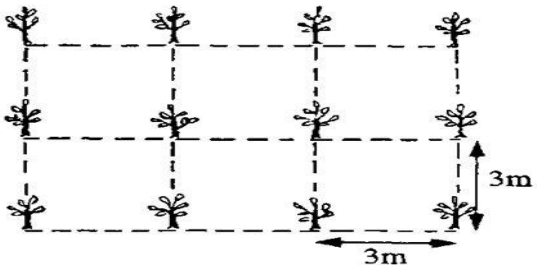
The various layout systems used are the following:

a) Vertical Row Planting Pattern

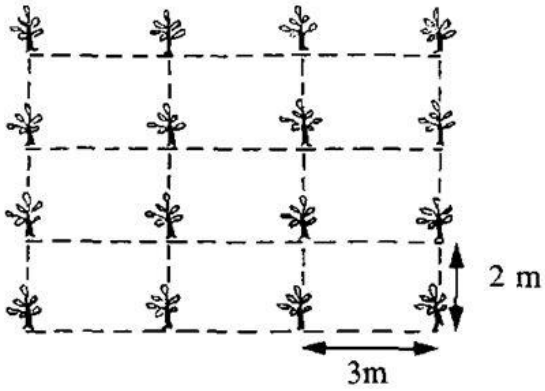
1. Square System: *In* this system, trees are planted on each comer of a square whatever may be the planting distance. This is the most commonly followed system and is very easy to layout. The central place between four

Annals of R.S.C.B., ISSN: 1583-6258, Vol. 25, Issue 6, 2021, Pages. 948-962
Received 25 April 2021; Accepted 08 May 2021.

trees may be advantageously used to raise short lived filler trees. This system permits inter cropping and cultivation in two directions.



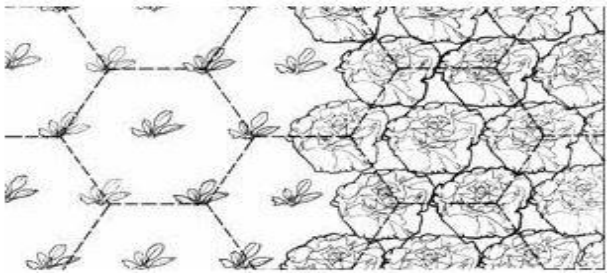
2. Rectangular System: In this system, trees are planted on each corner of a rectangle. As the distance between any two rows is more than the distance between any two trees in a row, there is no equal distribution of space per tree.



The wider alley spaces available between rows of trees permit easy intercultural operations and even the use of mechanical operations.

b) Alternate Row Planting Pattern

3. ***Hexagonal System:*** *In* this method, the trees are planted in each comer of an equilateral triangle. This way six trees form a hexagon with the seventh tree in the centre. Therefore this system is also called as 'septule' as a seventh tree is accommodated in the centre of hexagon. This system provides equal spacing but it is difficult to layout. The perpendicular distance between any two adjacent rows is equal to the product of 0.866 x the distance between any two trees. As the perpendicular distance between any two row is less than unity, this system accommodates 15% more trees than the square system. The limitations of this system are that it is difficult to layout and the cultivation is not so easily done as in the square system.



4. Diagonal or Quincunx System: This is the square method but with one more plant in the centre of the square. This will accommodate double the number of plants, but does not provide equal spacing. The central (filler) tree chosen may be a short lived one. This system can be followed when the distance between the permanent trees is more than 10m. As there will be competition between permanent and filler trees, the filler trees should be removed after a few years when main trees come to bearing.

5. Triangular System: The trees are planted as in square system but the difference being that those in the even numbered rows are midway between those in the odd rows instead of opposite to them.

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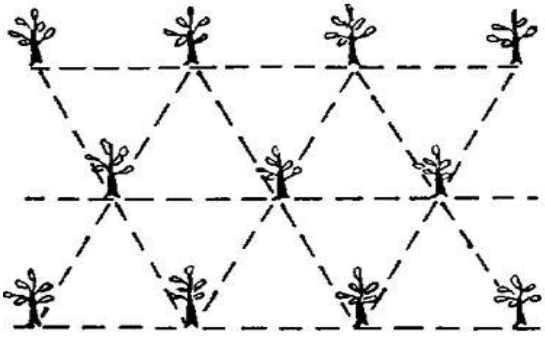
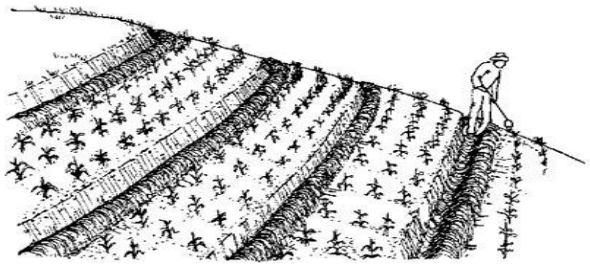


Triangular system is based on the principle of isolateral triangle. The distance between any two adjacent trees in a row is equal to the perpendicular distance between any two adjacent rows. However, the vertical distance, between immediate two trees in the adjacent rows, is equal to the product of (1.118 x distance between two trees in a row). When compared to square system, each tree occupies more area and hence it accommodates few trees per hectare than the square system.

6. **Contour System:** It is generally followed on the hills where the plants are planted along the contour across the slope. It particularly suits to land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult. The main purpose of this system is to minimize land erosion and to conserve soil moisture so as to make the slope fit for growing fruits and plantation crops. The contour line is so designed and graded in such a way that the flow of water in the irrigation channel becomes slow and thus finds time to penetrate into the, soil without causing erosion.



Terrace system on the other hand refers to planting in flat strip of land formed across a sloping side of a hill, lying level along the contours. Terraced fields rise in steps one above the other and help to bring more area into productive use and also to prevent soil erosion. The width of the contour terrace varies according to the nature of the slope. If the slope becomes stiff, the width of terrace is narrower and vice-versa. The planting distance under the contour system may not be uniform. In South India, tea is planted in contours either in single hedge system or in double hedge system. Double hedge contour planting system accommodates nearly 22 % higher population than single hedge system. Number of plant population that can be accommodated in this system is

$$\text{Plant population} = \frac{N \times \text{unit area}}{D\,(y + z)}$$

Where

- N- number of hedges
- D - distance between plants
- y - distance between hedges
- z - vertical distance between row

This system in tea helps to get early, high yield, conserve soil and suppress weed growth.

In South Indian hills, peas and beans are sown under paired row system which is almost similar to double hedge planting system. The seeds are sown at 10 cm interval in each double row of 30 cm apart with the distance of 1.5m between each pair of rows.

7.1. Planting Distance

The minimum vertical distance between any two trees or plants is referred as the planting distance and this varies depending upon many factors. The principles in deciding the planting distances are the following.

1. Trees when fully grown, the fringes of trees should touch each other but the branches should not interlock.

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2. Trees root will spread over a much larger area than top and there should be proper room for the roots to feed without competition.

7.1.1. Factors Which Decide the Planting Distance are the Following

1. Kind of fruit trees - mangoes are planted at a distance of 10m x 10m, guavas at a distance of 5m x 5m while papayas are planted at a distance of 2m x 2m.
2. Rainfall - wider spacing should be given in low rainfall areas than the high rainfall areas for a kind of tree.
3. Soil type and soil fertility - in heavy soils less spacing should be given because the top and root growth are limited.
4. Rootstocks - trees of the same variety grafted on different root stocks will grow to different sizes and as such require different planting distances. eg. Apple
5. Pruning and training - trees trained on head system requires closer spacing than the other type of training
6. Irrigation system: In general, if the spacing is too wide, it is obvious that the yield per unit area would be greatly reduced. Only in very, exceptional cases would this be justifiable. Ordinarily it is more profitable to plant the trees closer together and supply the needed water and food materials. If the trees are too close together, the trees grow tall rendering pruning, spraying and harvesting difficult. There is root competition and inadequate nutrition and the trees as such give less yield and produce smaller fruits of poor colour. Cultivation also becomes difficult in the closely planted orchards. Close planting results in a greater yield per unit area in the early life of the tree but less in the more important later years. Close planting .is therefore a false economy.
7. **High density planting system:** Planting of fruit trees rather at a closer spacing than the recommended one using certain special techniques with the sole objective of obtaining maximum productivity per unit area without sacrificing quality is often referred as 'High density planting' or HDP.

This technique was first established in apple in Europe during sixties and now majority of the apple orchards in Europe, America, Australia and New Zealand are grown under this system.

[High Density Planting System]

In this system, four planting densities are recognized for apples viz., low HDP (< 250 trees/ha), moderate HDP (250-500 tree/ha), high HDP (500 to 1250 trees/ha) and ultra high HDP (>1250 trees/ha). Recently, super high density planting system has been also established in apple orchards with a plant population of 20,000 trees per ha. In some orchards, still closer, planting of apple trees is followed (say 70,000 trees/ha) which is often referred as 'meadow orchards'.

Advantages of HDP are:

1. Early cropping and higher yields for a long time; the average yield in apple is about 5.0 t/ha under normal system of planting and it is about 140.0 t/ha under HDP
2. Reduced labour costs
3. Improved fruit quality

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Characteristics of HDP are

- The trees of HDP should have maximum number of fruiting branches and minimum number of structural branches.
- The trees are generally trained with a central leader surrounded by nearly horizontal fruiting branches. .
- These branches should be so arranged and pruned in such a way that each branch casts a minimum amount of shade on other branches.
- The height should be one and half its diameter at the base. A key to successful HDP depends upon the control of tree size.

This is achieved by-**(a)** Use of size controlling root stocks. In apple, dwarfing root stocks and intermediate stocks like MM 106, MM 109, and MM 111 are used to control the size of the plant. In pears, Quince A, Adam and Quince-C are commonly used as dwarfing root stocks.**(b)** Use of spur type scions - In temperate fruit crops like apple, the cultivars can be classified into a spur type or non-spur type. The spur types which have restricted annual growth are alone suitable for HDP.**(c)** Training and pruning methods to induce dwarfness - under Indian conditions, apple trees trained under spindle bush, dwarf pyramid, cordon systems are found to contain the growth of the trees appreciably for HDP systems.**(d)** Mechanical device and use of chemicals to control size – Growth regulators such as daminozide, ethephon, chlormaquat and paclobutrazal are extensively used to reduce shoot growth by 30 to 0 %. This results in increased flowering in the subsequent years and may be useful in encouraging earlier commercial fruit production in strongly vegetative fruitful young trees. Besides chemical manipulation, mechanical devices employing the use of spreaders and tying down the branches to make them grow from near horizontal to an angle of 45° from the main stem are also some of the standard practices to control tree size.

8.1. Planting System for HDP: The success of HDP depends upon the right choice of planting system. Generally, rectangular planting with single, double and three row plantings are followed. In single row planting, the distance within the row is close, whereas the distance between the row is wide (4x2m). In double row planting, a wider spacing is given after every two rows (4+2x2m) whereas in three row planting, a wider spacing is given after every three rows (4+2x2x2m). In meadow orchard system, a bed of 10 to 15 rows is closely planted *(nay* 30x45cm) and separated by alleys of 2.5m width between beds. This system is also called bed system.

8.2. Planting Season: the season of planting varies with different fruits and local conditions. There are two seasons of planting in vogue in India. **i)** Monsoon (June - August) and **ii)** Spring (February - March) Monsoon season is considered to be the best for planting evergreen fruit trees like citrus, mango, sapota and guava. If the trees are planted early in the rainy season they soon establish themselves and grow vigorously. Deciduous trees may be planted during the dormant period without shock. Care should be taken that planting is done before the growth starts, otherwise trees suffer severely and will be in poor condition to withstand the next hot weather.

8.3. Planting methods: After locating the positions of the orchard trees, it is important that the trees are planted exactly where the stakes stood. It can be easily done with the help of a planting board. The planting board is usually of 15m long, 10 cm wide and 2.5cm thick with a central notch and one hole on either end, the central notch and the two holes (one on either end) are in a straight line. The planting board is placed in such a way that the stake (tree marker) fits into the central notch. Two small stakes are inserted one in each end hole. The planting board along with the tree marker is then lifted straight up without disturbing the end stakes. A pit of about 1m cube or of the desired dimensions at the position of the tree marker is then dug. The pits are allowed to wither for few weeks before planting in some cases. The pits are then filled with top soil already mixed with red earth and well rotten farm yard manure. Irrigation is then applied to enable the contents of the pits to sett1e down properly. In the event of depressions taking place as a result of irrigation, more soil should be added to the pits to fill them to the level of the land. The pits are then ready for planting.

8.4. Transplanting: The trees should be planted approximately where the original pegs were placed. This is achieved by replacing the planting board in position with the help of the guide pegs and the stem of the trees is brought to the central notch with the help of a hand hoe. One of the most common mistakes is that of planting the trees too deep. The plants should be sent in such a way that the bud union remains slightly above the ground level. The trees in the field should be planted as deep as they stood in the nursery. The trees are irrigated soon after p1anting.This consolidates the soil and .helps the roots to establish contact with it and to secure a supply of water quickly. A small basin may be made around the tree for this purpose. Planting if taken up during the rains, this basin should be demolished within a day or two so that water will not collect around the tree. This is more dangerous on heavy than light soils. Spring winds cause damage to the growing p1ants by giving a constant shaking. To prevent this, plants should be staked when p1anted. Some young plants are subject to considerable injury from sunburn particularly if they have been trained to single stem with no branches for 45cm or more

from the ground. Such trunk can be protected by wrapping them with paper or other material or by painting them with white wash. The latter is probably best, as most materials wrapped around the trunk would be subject to termite attack.

8.4.1. Use of New Planting Systems: No systematic research has been conducted to develop tree forms and planting designs for improved yield, fruit quality and profitability in tropical and subtropical fruit crops. Early production of high quality fruit and its sustainability in long run is an important factor determining the profitability of an orchard. Hence under these situations, standardization of planting system following high density principle for accommodating more number of plants per unit area is essential to enhance productivity without any compromise with fruit quality. High density planting systems has been successfully demonstrated for earliness, improved yield, smooth handling and cultural practices using double hedge row system of planting in litchi, mango, aonla and guava, Moreover, by manipulating plant spacing using different planting systems like hedge row, double hedge row, paired planting and cluster planting proved to be an important tool to achieve high quality produce and productivity.

9. CONCLUSIONS

Thus, it is imperative that once HDP or UHDP is adopted, the related technologies like formative pruning to develop proper plant architecture and annual canopy management are to be followed regularly. Besides, providing optimum irrigation through drip to replenish moisture loss through evapotranspiration (ET) and proper fertigation practices to provide balanced vegetative growth and fruiting, are highly essential so as to get higher yield. If these practices are followed, the management of pests and diseases would be very effective. There have been various attempts to standardize HDP in fruit crops with variable success, however, commercial adoption at farmers field is still lacking. As most of tropical and subtropical fruits crops like mango, litchi and guava are naturally vigorous. Canopy management through pruning is not well understood and in addition to this use of machinery for pruning is negligible or absolutely not available in India. Therefore, the lasting solution for this would be development of dwarfing rootstock and scion cultivars. Modern tree training systems, which have been successfully used in temperate fruit crops may tried and adopted after long term evaluation.

10. ACKNOWLEDGMENT

I take this opportunity to express my sincere thanks, profound sense of severance and gratitude to Dr. Sant Ram, Prof. and Dean PGS for his valuable suggestions, guidance, kneen interest constructive criticism and unending encouragement during the course of these investigation and preparations of manuscript.

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