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A REVIEW ON HIGH DENSITY PLANTING IN FRUIT CROPS#

*Prashant Joshi**

Abstract

In the Horticulture sector, fruits find a prominent position on account of their demand from all sections of society. India ranks 2nd in fruit with production of 61.8 million metric tonnes, accounting for about 10.3% of the total world fruit production. However the productivity of major fruit per hector (11.9 tones/ha) is far below compared to world average (25 tonnes/ha) . India is the largest producer of Mango, Banana, Grape and Litchi. However, the bulk of production is consumed domestically. Of the total global exports for fruits, India's share is only 0.3%. Fruits account for about 11% of the total horticultural export from country.Grape and mango together constitute 60% of India's exports of fresh fruits. Among fresh fruits citrus, banana, apple, grape, papaya and papaya are exported in maximum magnitude. Among the various biotic and a biotic factors responsible for low yield and quality is lack of knowledge about canopy management. Land is limiting factor in the production of fruits crop,so there is only solution is accommodation of maximum plant per unit area without compromising the quality of fruit crop is modern way of cultivation by maximum utilization of resources.

Key Words: HDP,Fruit crops,biotic,a biotic,Land

#Review Article

*College of Horticulture, Dr. PDKV, Akola (M.S)
E-mail:psjoshihort@gmail.com

Introduction

It is the improved production technology to achieve the objective of enhanced productivity of Indian fruit industry. It is one of the most efficient method of hastening productivity per unit area of land. In fruit crops which are perennial in nature,HDP is more useful as it helps in efficient utilization of land and other resources,better canopy management, farm mechanization,convient spray of pesticides,harvesting high yield of improved quality and consequently in getting higher net return.

Aim to Achieve Twin Requisites of Productivity

1. Maintain the balance between vegetative and reproductive load without impairing the plant health.
2. Is one of the most effective measures to increase productivity per unit area.
3. Efficient method of orchard system
3. Precocious, easily manageable, high yield potential with higher returns per unit area.
4. More efficient way of harvesting radiant energy.

History

HDP orchards first planted in Europe at the end of 1960s in undertaking apple plantation following the use of dwarfing rootstocks Besides Europe,HDP is in commercial practice to grow temperate fruit crops in Australia,America,Japan,New Zealand and in Israel.In India ,good success has been reported in HDP in fruit crops like apple,peach,pear,plum,sweet cherry,banana,papaya,guava,mango,citrus and pineapple and two-three times more yield has been realized.

However in plantation crops,like coconut and arecanut the concept of HDP is realized by opting to multi-crop species cropping system. Such type of cropping system favours accomodation of more number of plants, through of different crop species, per unit area of land.

Definition

High Density Planting is the planting of small trees densly, controlling growth by pruning, chemicals, dwarfing rootstocks, harvesting by machines.

Need of HDP

India ranks 2nd in fruit with an production of 61.8 million metric tonnes ,accounting for about 10.3% of the total world fruit production. However the productivity of major fruit per hector(11.9 tonnes/ha) is far belown compared to world average (25 tonnes/ha).Among the various biotic and abiotic factors responsible for low yield and quality is lack of knowledge about canopy management. Due to increase in population and limited land availability is has become necessary to increase our production target and it can be achieved through high density planting.

The underlying principle of HDP is to make the best use of Verticals and horizontal space per unit time and harness maximum possible return per unit of input and national

resources. HDP offers high productivity per unit area both in short duration as well as perennial fruit crops.

Techniques of Planting

The system of fruit growing classified on the basis of density or intensity of planting as -

Medium high density Planting (MHDP)
Optimum high density Planting (OHDP)
Ultra high density Planting (UHDP)

Classification of these systems again made based on the shape, size and form of such trees as
1. Bush
2. Tatura trellis
3. Pyramid
4. Cordon
5. Curtain
6. Hedge row
7. Meadow orchard

Planting Intensities

In HDP, planting intensity is maintained many times higher than normal planting. Accordingly, it is named differently, as:

Semi-intensive	: 500 - 1,000 trees/ha
Intensive	: 1,000 - 10,000 trees/ha
Super-intensive/meadow orcharding	: 20,000 - 1, 00,000 trees/h

1) Medium High Density Planting

1. Bush Orchard

This is semi-intensive or medium HDP system of fruit growing with planting Density 500-1500 trees/ha(as against 120-177trees/ha).In which trees resemble a bush.Either a dwarf cultivar or dwarfing rootstock used to control tree height. Modified central leader or any other training system used.

Advantages:
1) Low cost of orchard establishment
2) Useful where land availability is not limiting factor
3) Useful for cultivar not suitable for intensive system

Disadvantages:
1) Take long time (4-5) year for Substantial return
2) Pruning, hand thining, and harvesting operation are more intensive

2) Optimum High Density Planting

i) Intensive System: In this system plant population will be 1,500-10,000 trees/ha According to different shape, size, form different systems under this are

a) Tatura Trellis: System was developed in Irrigation Research Institute, Tatura, Australia in 1973. Rows of 'V' shaped running north-south. The main framework consists of Y – shaped leaders which are tied with the wires. Each tree has only two limbs grow east-west at angle $<60^0$. Trials conducted with this system have shown early and high yield.

b) Pyramid System: Fruit trees planted at densities upto 3000 trees/ha.Trees trained to central leader pyramid having height and maximum spread measurement of 4m. Benifial on less fertile soil. Suitable for trees that require no support and summer pruning.

c) Cordon System: Firstly used in France for Peach by Du Brenil in 19^{th} century using seedling as rootstock. Most common planting distance is 4x1 m (2500 trees/ha). Trees are 4-5 m in height at an age of 5^{th} .First two years of orchard life are important to remove the basal lateral which have tendency to become too strong and to leave the main vertical shoot, thus realizing the cordon shape. Fruit production begins in 2^{nd} year and in 4^{th} to 5^{th} year achieved full bearing.

d) Curtain System: System based on mechanization of harvesting and pruning developed in Hangary for Apple. Maximum height of tree is 3.2. The mechanization of Apple harvesting needed a tree with flexible yield holding twigs and as few as possible rigid skeleton. The skeleton of curtain system is a central leader with 1 or 2 pairs of horizontal scaffolds,180-220cm long in a tree density of 3000 trees /ha.

The cropping twigs hang vertically to give hanging twig curtain which accommodate the horizontally vibrating fingers of the fruit harvester.

Tree flexibility very important because of both fingers and fruit collecting device penetrate into the tree canopy.

The Apple Curtain System with the use of Over-row harvester increases the efficiency in growing Apple without any loss in investment and yield.

e) Hedge-row system: The hedge row (fruit wall or tree wall) most common modern system used in Apple Pear, and Peach production.

Based on use of growth regulator combined with root competition to reduce the size of tree. It is designed primarily for mechanical harvesting by an Over–row harvester. Trees are planted at a spacing of 30 or 50 cm apart in row 3m between row Tree density range 2500 to 10000 trees/ha. Tree planted in single, double, or multirow system. Tree supported on wire and is trained as vertical cordon grown to a height of 2m.

3) Ultra High Density Planting

1) Meadow Orchard

It is super intensive system, in which fruit trees are grown at density of 20,000-1,00,000 /ha. This system designated to produce fruits on 2 year old plants which are chemically disciplined and regulated to produce a simpler and smaller structural framework rather than the traditional well branched. Ultimately harvesting is carried out by moving the orchard (hence termed meadow) with some form of combine harvester, which would separate fruits from shoot.

However, orchard of small trees that can be handled from the ground has reasonable established and very precocious in cropping, attractive for small growers, harvest manually.

1) Mechanical system: System developed for mechanical harvesting using a combine harvester that separate the fruit from cut canopy. Detach stem from tree at harvest, leaving short stump from which re-growth would begin.

2) Intensive System: Pruning is separated from harvesting by delaying it until after the harvest. Tree trained to two main shoots rather than one as in mechanized system.

One of the two shoot is headed back to stump, allow regeneration of new growth and fruit bud formation in growing season. Other shoot not pruned, it fruits and headed lightly after harvest to reduce the shading on adjacent growing shoot. Hence every shoot fruits every 2nd year. The main problems are:

1) How to obtain new vigorous annual growth from shaded lower part of tree.
2) How to prevent shading of lower part of developing shoot by remaining uncut shoot

High Density Planting in Banana

Most banana growing regions, solar radiation is abunduntand thus productivity largely depends on efficient utilization of solar radiation. For this plant density needs to be designed to intercept solar radiation effectively. An ideal planting density is determined by a complex integration of factors,viz cultivar, soil fertility, management level sand economic considerations(B.M.C.Reddy and H.P.Singh)

Table 1. Effect of various planting densities on yield of Basrai banana(Kg/ha)

Spacing (m)	Total no. of plants / ha	1977-78	1978-79	Mean yield
1.2 x 1.2	6944	58784^{c}	71497^{d}	65140^{d}
1.3 x 1.3	5917	50890^{b}	54994^{c}	50942^{c}
1.5 x 1.5	4444	38330^{a}	48311^{b}	43321^{b}
1.7 x 1.7	3460	37598^{a}	44036^{b}	40817^{b}
1.8 x 1.8	3086	36730^{a}	30295^{a}	33512^{a}
Mean		444466^{a}	49827^{b}	

Above table revealed that the highest yield was recorded in 1.2 x 1.2 m spacing which kept on decreasing with increase in space with minimum in 1.8 x 1.8 spacing. Yield was significantly higher in 1978-79 than 1977-78.

High Density Planting In Mango

Mango is the most important fruit crop of India and comes next to banana, apple and oranges on the basis of global acreage and production. India contributes about 60% (9.5 million t) in the world mango production (15.7 million t). Mango contributes 40% to national fruit production (22.168 million t) and occupies 42% of the total fruit area (24.87 million ha) of the country. Indian mangoes are world famous and have great potential for export as compared to other fruits of the country.

In general, recomanded planting distance is 10-12 recomanded as per tree vigour and variety. This makes the mango orcharding unattractive particulary on small holdings because of long gestation period.High density orcharding makes maximum use of land to achieve high yields in early period of orchard life .

In general, 3m tree height and 10m circumference was maintained in high density by dehorning and pruning of branches and shoots, whereas unpruned shoots and branches of normal density trees grew upto 6m height and 20m circumference in 19 years.

Table 2. Effect of high density planting system on fruit quality of 'Amrapali' mango

	1997-98				**1998-99**			
Treatment	TSS (%)	Acidity (%)	Total sugar	Reducing sugar	TSS (%)	Acidity (%)	Total sugar	Reducing sugar
Square system	22.70	0.21	13.11	4.13	21.90	0.22	13.00	4.13
Hedge Row system	22.53	0.22	14.50	4.62	22.40	0.23	14.60	4.68
Double hedge row system	22.58	0.23	14.70	4.93	22.43	0.25	14.80	4.97
Paired planting	22.49	0.23	14.20	4.58	22.00	0.24	14.39	4.62
Cluster planting	22.10	0.20	14.17	4.43	21.95	0.21	14.20	4.49
LSD *P*=0.05	NS	NS	O.23	0.26	NS	NS	0.22	0.29

Above table revealed that the quality of Mango fruits in terms of TSS ,acidity,total sugar content and reducing sugar were estimated during 1997-99.Fruits from narrow spacing showed higher values of sugar .However there was no significant effect of different planting systems on acidity and TSS of fruit.

Ultra High Density Planting in Guava

Guava largely cultivated in traditional system. Under this system difficult to achieve desired level of production /unit area. Also need high labour input. (Mohmmed *et al.*,1984;Araujo et al.,1999;Singh et al., 2003) Large tree take several years before they come into bearing and increased overall cost of production. Certain important strategies have been identified for enhancing guava production in India in order to be competitive in the world market. It involves adoption of modern, innovative and high-tech methods which includes high density planting.

Tree spacing is a method used for efficient and profitable land use for efficient and profitable land use. Its basic function is to confine the exploration zone of the plant with regard to light, water, and nutrients so that highest total yield potential can be reached in the smallest possible area (Boswell et al.,1982;Singh.2005).Studies on high density planting in guava have increased and considerable data has been published(Chapman et al.,1979;Singh et al.,1980;Lal et al.,1996;Singh.2004)

Table 3. Influence of planting density on yield of Guava cv. Allahabad Safeda

Planting distance(m)	**Rainy season**		**Winter season**		**Total yield (Rainy and Winter season)**	
	Yield kg/tree	Yield/unit Area(kg)	Yield kg/tree	Yield/unit Area(kg)	Yield kg/tree	Yield/unit Area(kg)
3 x1.5 (2222 tree/ ha)	20.6	4.57	12.00	2.66	32.6	7.24
3 x 3 (1111 tree /ha)	24.1	2.67	16.9	1.87	41.0	4.55
3 x 6 (555tree /ha)	56.00	3.10	23.5	1.30	79.5	4.41
6 x 6(277 tree/ha)	48.6	1.34	21.2	0.58	69.5	1.92
F test sig (*) CD (0.05)	* 6.89	* .0.56 .	* 4.17	* 0.38	* 9.84	* 0.79

Above table revealed that the highest fruit yield was recorded from the tree planted at distance 3.0 x 6.0 m .It has been observed that the fruit yield decreased with the increases in planting distance and was minimum at spacing 3.0 x 1.5 m

Table 4. Influence of tree density on tree height, trunk circumference and canopy size of Guava cv. Allahabad Safeda

Spacing (m)	Tree height (m)	Trunk Circumference (cm)	Canopy area (m)	
			N-S	N-S
3 x 1.5 (2222 tree /ha)	5.76	35.00	4.46	4.31
3 x3 (1111 tree/ha)	4.81	42.00	5.10	4.64
3 x 6 (555 tree/ha)	4.52	41.00	4.88	4.36
6 x 6 (277 tree/ha0	4.9	49.00	5.26	5.2
F test sig(*) CD(0.05)	*0.66	*0.15	*1.33	*0.93

Above table revealed that the among different tree densities,the highest one(2222 tree /ha) had the maximum tree height whereas it was lowest in the tree planted at spacing 6.0 x 6.0 m. Wider spaced tree had maximum trunk circumference than those planted at other densities.Tree density was maximum at planting distance 6.0 x 6.0 m in NS/EW direction whereas minimum canopy area was at 1.5 x3.0m followed by 3.0 x 6.0 m.

Table 5. Effet of high density planting system on vegetative growth of the aonla

Treatment	Annual extension of vegetative growth									
	Plant height (cm)		Root stock girth(cm)		Scion girth (cm)	Plant spread (m)				
						2003		2004		
	2003	2004	2003	2004	2003 2004	E-W	N-S	E-W	N-S	
Square system	52.12	53.14	4.89	6.98	3.44	4.71	0.40	0.55	0.53	0.45
Hedge row system	50.15	52.19	4.72	6.14	3.25	4.45	0.34	0.34	0.47	0.40

Double hedge row system	51.19	56.14	4.63	6.16	3.20	4.40	0.35	0.43	0.40	0.35
Cluster system	48.17	54.15	4.54	6.18	3.30	4.40	0.38	0.47	0.45	0.40
Paired system	46.12	51.18	4.75	6.15	3.28	4.64	0.37	0.51	0.42	0.40
C.D. at5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Above table showed that the maximum growth extention i.e.rootstock girth,scion girth and plant spread were recorded in square system of planting during both the year of experimentation but the annual extention growth i.e. plant height was recorded in square system of planting and double hedgerow system in year 2003-2004,respectively.

Table 6. Effect of High Density Planting System on Yield and Qualitative Parameters of Aonla Fruit

Treatment	Yield /ha (kg)	Fruit Wt (g)	Fruit Dia (cm)	TSS (%)	Acidity (%)	Vitamin C (mg/100gm)
Square System	315.00	4.10	4.10	8.54	2.20	490.75
Hedge Row System	559.64	3.98	3.98	8.43	2.35	498.47
Double Hedge Row System	687.31	4.06	4.06	8.72	2.12	492.28
Cluster System	580.22	4.02	4.02	8.56	2.34	482.28
Paired System	403.21	4.00	4.00	8.71	2.17	489.33
C.D. at 5%	15.21	NS	NS	NS	NS	NS

Above table showed that total yield per hectare was recorded highest in double hedgrew system followed by cluster system,hedgrew system and it was recorded lowest in square system.Fruit weight,fruit diameter were recorded maximum in square system of planting

Management of HDP Orchards

The successful management of HDP system depends upon maintaining a balance between vegetative growth and fruiting. The High Density of fruit orchard generally

achieved by close planting which possible through control of tree size or planting system which accommodates more number of plants.

Manipulating tree size/vigour achieved by canopy management.

Canopy Management

Canopy in fruit tree refers to its physical composition comprising the stem, branches, shoots and leaves.The canopy density is determined by the number, length and orientation of branches and shoots.

Canopy management of fruit trees deals with the development and maintenance of their structure in relation to the size and shape for maximum yield quality.

What Is Canopy Management and Why Is It Important?

Canopy management is the manipulation of tree canopies to optimize the production of top quality fruit. It involves more than just pruning and tree training. It also includes the regulation of flowering and fruit growth. In many fruit crops, improved production and fruit quality has come from producing more fruit from smaller trees. This is because small trees are better at capturing and converting sunlight into fruit than large trees.

Light Interception

Fruit production involves the capture and conversion of light energy into fruit biomass (dry matter). The main controlling factors here are the amount of incoming radiation, the percentage of that radiation which is intercepted by the tree, and how efficiently the tree converts that energy into fruit (Wünche and Lakso, 2000). Once trees have intercepted the incoming radiation, tree architecture will also influence the efficient conversion of this light energy into fruit. Put simply, the target is to have less wood and more fruit. Pruning trees to be shorter and with less structural wood can achieve this, as in the slender pyramid pruning systems.

A) Use of Genetically Dwarf Scion Cultivar

The genetically dwarf cultivars offer a great scope for close planting.Such varieties are limited in number and available only in few crops as given below-

Eg.	Mango	Amrapali
	Papaya	Pusa Nanha
	Banana	Dwarf Cavendish
	Apple	Mc Intosh , Nugget,Golden
	Cherry	Meteor,North Star
	Sapota	PKM1,PKM2

B) Use of Dwarfing Rootstock

Technology 1st adopted with use of rootstocks,spur bearing varieties and training and pruning,the choice of rootstock and dwarf varieties is limited in tropical and subtropical crops. Nevertheless it has been perfected for some of the fruits by planting

dwarf varieties (banana,papaya and mango) and dwarfing rootstocks(apple and citrus) and training and pruining(apple and peach).

The dwarfing rootstock of major fruit crops are given below.

Apple	M9, M26, M27, Bud.9, Bud.146, P-22 and Ottawa 3
Ber	*Zizyphus rotundifolia*
Cherry	Colt, Charger and Rubira
Citrus	Thomasville, Citrangequat
Guava	*P. pumilum*, Chinese guava ,Pusa Srijan
Pear	EM Quince A and C
Plum	Pixy
Mango	Vellaikolumban

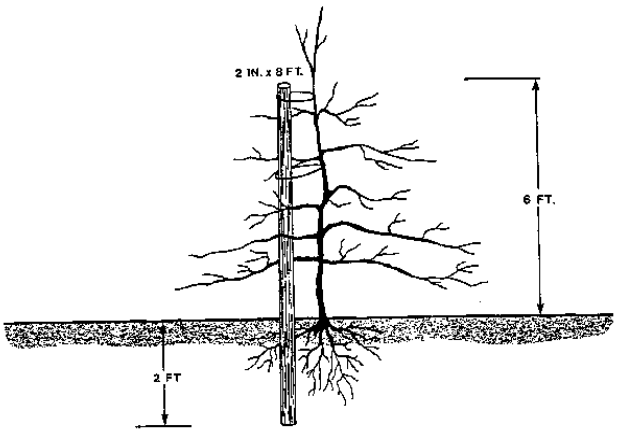
C) Pruning and Training

Pruning establishes the structure of the tree, its shape and form, provides a framework to support the crop and facilitate
mechanical operations. As trees age, pruning removes broken and diseased wood, stimulates new growth, and provides essential light distribution throughout the tree for the formation of strong fruit buds and acceptable fruit quality with appropriate fruit color, soluble solids, and ripeness.

It is well known that the pruning has dwarfing effect on tree. Slow growing tree respond more favorably and be maintained at a given size and shape without sacrificing yield. Removal of apical portion results in compact and bushy tree through stimulation of lateral bud growth and suppression of apical dominance. Mango guava, litchi and most of the other fruit crops in India are evergreen and are seldom pruned.

Particularly tree training and pruning, also affects the percentage of sunlight intercepted by the tree, as tree shape determines the presentation of the leaf area to incoming radiation. Generally a narrow tree that is wider at its base than its top will have the greatest area of leaves exposed to sunlight.

Fig-Slender Spindle tree with a single pole or single stake suppor



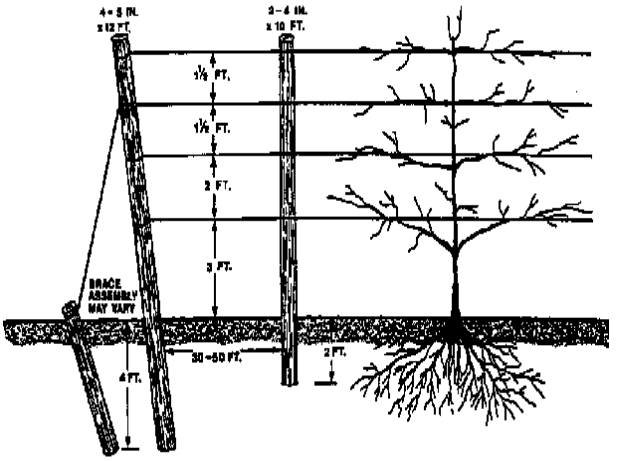


Fig-Three wire support or individual tree stake in apple

Pruning is also done to regulate crop in guava, ber and fig and rejuvetion of old orchards in mango. Tree size control through pruning limited in Grape, Apple, and some temperate crop. e.g. In Apple Spindle bush ,dwarf pyramid, espaliers, cordon, palmette training systems used.

d) Use of Growth Retardant

Various growth retardants have been used to restrict vegetative growth of plant. Among them commercially adopted GR are AMO 1618, CCC, Ancymidal, Paclobutrazol,B-9 and Chloramquat etc. Paclobutrazol has gained commercial application in crop regulation in Mango.

e) Induction of Viral Infection

Though not commercially adopted tree size reduced by viral infection. e.g. Citrus, Apple, In Apple virus free rootstock series EML more vigourous than their infected counterparts.

f) Use of Incompatible Rootstock

Use of graft incompatible scion and stock induces dwarfness in composite plant. It is not commercial exploited. e.g. In Ber *Zizyphus rotundifolia* and *Z.nummularia* induces dwarfness due to graft incompability which can be exploited for HDP.

g) Nutrition Management

High amount of plant nutrients required in early years when they are directly related to the no. of trees. It was found that careful N control may be useful for controlling the tree vigour and encouraging fruiting, especially before or soon after heavy pruning. After first few years, low N fertilization desirable. When trees are planted more densly, the

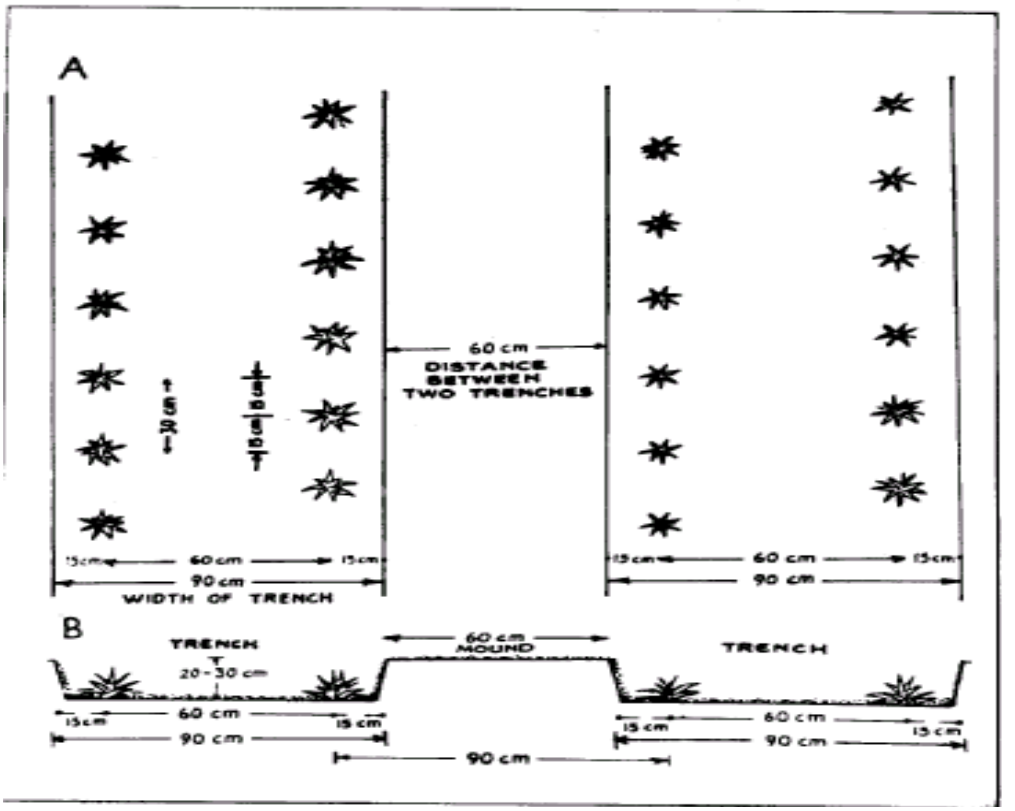
contribution of N fertilization to productivity shifts from promotion of tree size by shoot growth to support flower initiation and possible fruit set under condition of drought.

h) Irrigation and Fertigation

Frequent low doses of nitrogen fertilizers delivered at lst twice weekly through the trickle system (fertigation) for the first 12 weeks of the season will greatly improve tree growth during the first 2 years to speed the development of the canopy.

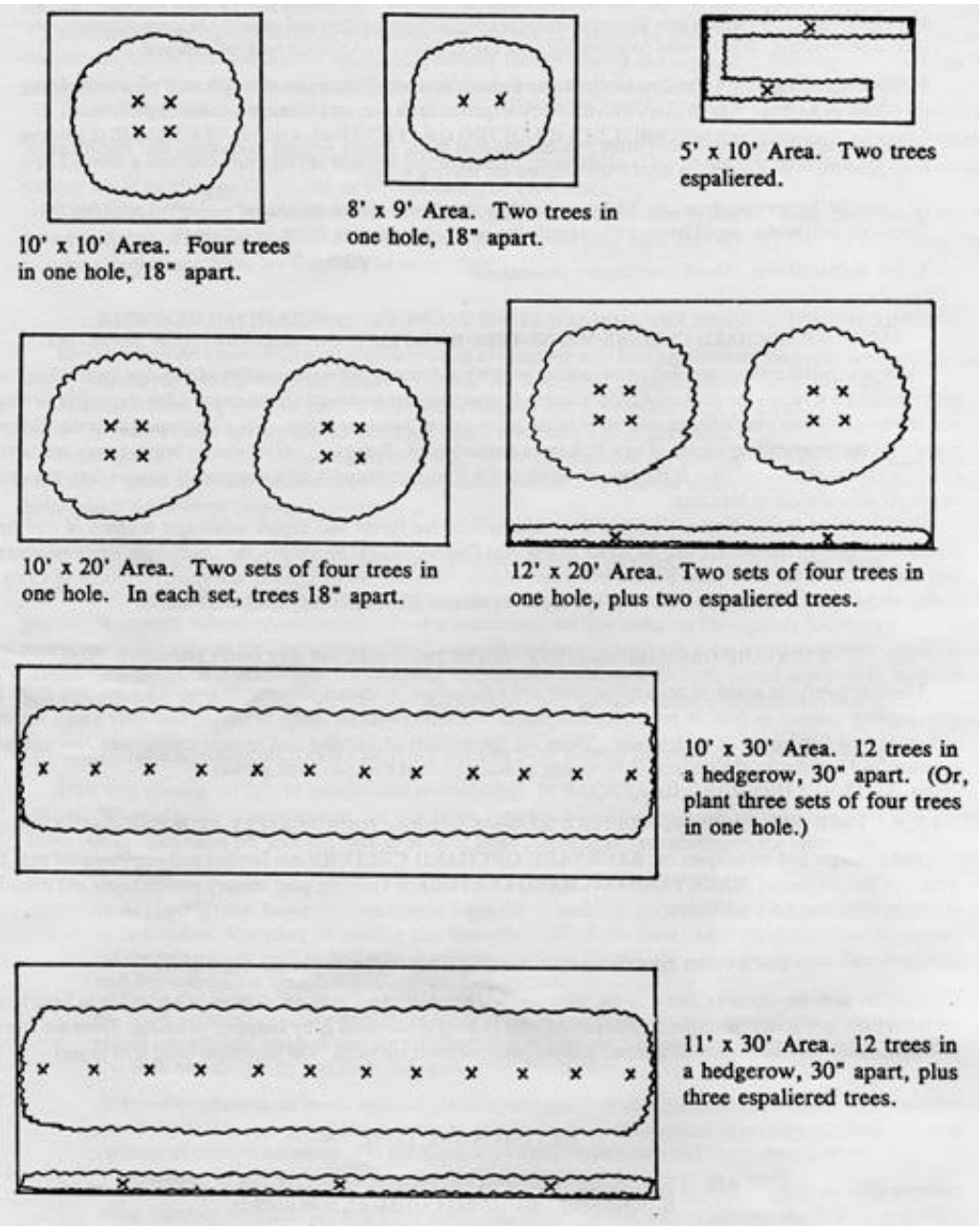
Planting Systems

Planting Systems and optimization of plant density is aim to achieve high assimilated production for its convertion into economic yield. Various planting systems square, trangular, quincunx, rectangular hexagonal, hedgerow, paired planting, cluster planting. Of these square and trangular systems – are followed for HDP in Mango, Banana, Papaya kinnow and hedgerow system in Apple and Pineapple in India. e.g. In Pineapple ,planting in two row bed system most productive.



Layout of pineapple plot for population density of 43, 500 plants/hectar

Example of High Density Planting



Constraints of HDP

- Lack of standardization of production technology in HDP of various fruit crops and extension of technical knowhow to the farmers.
- High initial establishment cost of high density orchards.
- Lack of promising dwarfing rootstock in mango, guava, sapota, peach and sweet cherry etc.
- In apple, though dwarfing rootstocks were introduced in late fifties is restricted due to their poor anchorage, occurrence of slopy, shallow and rainfed lands and low fertility.
- High incidence of some pest and diseases in HDP eg. Sigatoka leaf spot and finger tip in banana.

Conclusion

- HDP is the most efficient method of hastening productivity per unit area of land.
- It offers high productivity per unit area both in short as well as perennial fruit crops.
- HDP is to make the best use of verticle and horizontal space per unit time.

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