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High Density Cultivation of Major Fruit Crops: Opportunities and Challenges in Nepal

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Abstract

Apple, citrus, mango, banana, guava and papaya are the major fruits cultivated in different agro ecological zone of Nepal. The productivity of fruit crops remains almost constant since last 20 years. Orchard establishment in un-irrigated marginal lands, neglected management practices together with traditional cultivation technology has resulted low productivity. Continuing decline in the availability of cultivable land, depleting natural resources, impact of climate change, rising energy and land costs together with increasing demand have given thrust to concept of high density planting (HDP). HDP is one of the recent novel methods of increasing productivity of both short duration and perennial fruit crops. High yield with better fruit quality can be achieved when the orchard has good light distribution throughout the tree canopy and there is a balance between vegetative growth and fruiting. The underlying principle is to make the best use of vertical and horizontal space per unit time and per unit area to exploit maximum possible return per unit of inputs and resources. Planting density is one of the most important factors which determine the yield of an orchard. Research results showed that productivity of fruits could be improved if HDP techniques are followed properly. The use of dwarf scion varieties, dwarfing rootstocks and inter-stocks, efficient training and pruning, use of plant growth regulators and suitable crop management practices are the basic components of HDP. this paper. Until and unless commercial production is linked with market it will not get success. A holistic approach with packhouse and cold-chain facility is the utmost need of nation.

Keywords: *Canopy management, Dwarfing rootstock, High density, Precocity, Spur type*

1. BACKGROUND

1.1 INTRODUCTION

Diversity of soil and climatic conditions permits growing of a variety of fruits in different agro-climatic regions, due to which Nepal is regarded as a horticultural paradise. Apple, mandarin, sweet orange, acid lime, mango, litchi, guava and banana are important commercial fruit crops. The average productivity of fruits in Nepal is very low (9.2mt/ha) as compared to neighboring countries (MoALD, 2018). The main reasons for low productivity are old and senile orchards, low yielding varieties, poor orchard

management, incidence of diseases and insect pests, inadequate irrigation facilities, poor soil fertility, inadequate technological up gradation and adoption by the fruit growers (Subedi et al., 2019). Shrinkage of arable land for agriculture due to urbanization and global competition has limited the possibilities for horizontal expansion.

Presently, continuing decline in the availability of cultivable land, rising energy and land costs together with increasing demand of horticultural produce have given thrust to the concept of HDP of horticultural crops. The underlying principle is to make the best use of vertical and horizontal space per unit time and per unit area to exploit maximum possible return per unit of inputs. It is the modern novel concepts of accommodation of maximum number of plants per unit area to reduce the gestation period, increase productivity, get maximum return per unit tree volume and improve fruit quality without imparting the plant and soil fertility (Robinson, 2014).

High density planting basically comprise the planting of small tree densely, restricting their vegetative growth by using dwarfing rootstocks, bio regulators or other horticultural technique such as pruning thereby, diverting much of the plant energy to the economical parts.

Basically dwarfing rootstocks and dwarf scion varieties are the first and foremost pre-requisite for establishing high density orchard. This system is more eco-friendly which provides efficient use of light, water, and nutrient along with easy working environment increases earlier net return per unit area and time by reducing cost of production in long run. It is one of the most innovative technologies to achieve high production per unit area both in perennial and short duration fruit crops. Being an intensive system, it required more capital to establish and is more productive and profitable, if followed scientifically. The adoption of HDP systems is revolutionizing fruit growing over much of the world and promises to have a significant effect on horticultural industry. It is a very intensive form of fruit production which has high relevance to the food and nutritional security of our ever increasing population.

HDP system was first pioneered in Europe for apple in the early sixties; now days, high density planting techniques have been developed on various fruits for different agro climatic regions. In India, HDP technology has been successfully demonstrated in apple, peach, pear, plum, sweet cherry, banana, pineapple, papaya, mango, guava and Kinnow mandarin. In Nepal, HDP technology has been commercially applied on apple in Manang, Mustang, Jumla and solu districts. Experiments on HDP of mandarin orange, sweet orange and acid lime grafted on trifoliate orange and citrange rootstocks are going on at National Citrus Research Program, Paripatle, Dhankuta and Subtropical Horticulture Centre, Kirtipur, Kathmandu. High density demonstration plots on regular bearing varieties of Mango (cv. Amrapali and Mallika) planted at 3m apart have been already established at Regional Agricultural Research Station, Khajura, Banke. Likewise, high density commercial orchards of acid lime, banana and papaya have been already established in the terai and inner terai regions of Nepal since last decade.

1.2 Principles of High Density Orchard

- Higher early yield with best quality fruits through planting of more number of nursery trees per unit area.
- Maximum possible returns per unit of inputs through efficient exploitation of natural resources. Best use of vertical and horizontal space per unit area and per unit time.
- Balance between vegetative growth and fruiting i.e. grow fruit, not the trees.
- Maximum number of fruiting branches and

minimum number of structural branches.

- ❖ Training and pruning in such a way that each branch has minimum shade to others.

1.3 Categories of High Density Orchard

Categories of planting system include:

i. Low density planting: Trees planted at wider spacing accommodating about 70-250 plants/ha, no use of dwarfing rootstocks, less inputs, non intensive, minimum training and pruning, trees acquire into potential production after 15-20 years, projected orchard life is 40 years and holds popularity among the fruit growers.

ii. Medium density planting: Trees planted at minimized spacing accommodating about 250-500 plants/ha, semi dwarf rootstocks, requires proper training and pruning to manage desirable tree shape, more care intensive, labor requirement, gives higher yield and quality fruits and have long productive life, trees acquire into potential production after 9-15 years.

iii. High density planting: Very closer planting with 500-2000 plants/ha. Requires rigorous training and pruning, dwarfing rootstocks and chemicals to maintain optimum growth, both yield and expenses are higher, establishment and maintenance of orchards requires technical backup, trees acquire into potential production after 6-9 years.

iv. Ultra high density planting: Accommodates 2000-5000 plants/ha. It requires severe pruning and training, proper canopy management, chemical assistance and nutrient management and also requires technical backup, potential production after 4 to 7 years.

v. Super high density planting: Accommodates 5000-10000 plants/ha. Severe top pruning is practiced similar to mowing of grass land, heavy use of growth regulators as well as judicial canopy management and tree yields after 1 or 2 years after planting.

vi. Meadow orchard: Accommodates 10000-100000 plants/ha, severe top pruning similar to mowing of grassland is practiced to maintain tree form, judicial training and proper canopy management, heavy use of growth regulators and nutrient management.

Table 1: Comparison between traditional planting system and high density planting system of growing of different fruits

Attributes	Traditional planting system	HDP/Meadow orchard system
Plant density	Few large trees (70-250 trees/ha)	Many small trees (250-100000 trees/ha)
Precocity	Very late (After three years)	Very early (From first year)
Productivity	Low yield	Very high yield
Management	Difficult to manage due to large tree	Easy to manage due to small tree
Labor requirement	More	Less
Production cost	Higher	Lower
Harvesting	Difficult	Easy
Quality	Large canopy, poor air and sunlight penetration, poor fruit quality	Small canopy, better air and light penetration, minimum incidence of diseases, high quality fruits with good color development
Establishment cost	Less	Very high
Machinery	Difficult to use	Required for reducing the cost

2. Components of High Density Orchard

If the vigor of tree is too low, excessive fruiting results, fruit size declines, biennial bearing increases and trees fail to fill their allocated space soon enough to make the orchard profitable. If the vigor of tree is too excessive, then flowering and fruiting are reduced and containment of tree to allocate space becomes problematic. High yield with better fruit quality can be achieved when the orchard has good light distribution throughout the tree canopy and balance between vegetative growth and fruiting (Robinson et al., 2014). Balance of vegetative vigor and fruiting results in calm trees that produce annual fruiting. Tree size can be controlled by applying various techniques such as use of genetically dwarf scion cultivars, dwarfing rootstocks and inter stock, efficient training and pruning, growth retardants, incompatible rootstock, induction of viral infection, application of moderate level irrigation, nitrogenous fertilizers and appropriate crop management practices (Subedi et. al., 2019).

2.1 Use of Genetically Dwarf Scion Varieties

Columnar varieties of apple (Top Red, Vance Delicious) are naturally dwarf and grow only 8-12' tall. Fruiting occurs one year after planting in clusters along the trunk on short spurs, tree growth is vertical with almost no branching. Spur type cultivars are more compact and profitable than non spur varieties that have characteristics of regular bearing, early fruiting, dwarf trees, attractive fruit color, less pruning requirements and greater hardiness. Spur type apple varieties grafted on crab apple rootstock evaluated at Horticulture Research Station, Rajikot, Jumla after six years revealed that Starkrimson Delicious was the top most yielder (11.4mt/ha) followed by Red Spur (9.9mt/ha) (Table 3). There is tremendous potentiality of enhancing productivity and quality of various fruit crops by establishing high density orchards of genetically dwarf scion varieties (Table 2).

Table 2: Genetically dwarf scion varieties of various fruit crops (Saroj and Singh, 2018)

Fruits	Varieties	Desirable characteristics
Apple	Red chief, Oregon spur, Red spur, Stark spur gold, Well spur, Starkrimson delicious	Bear more spurs, dwarf, high yield
Banana	Dwarf Cavendish (AAA), Pusa Dwarf	Dwarf stature, high yield
Cherry	Compact Lambert, Meteor, North Star	High yielding, self fruitful, dwarf
Guava	Pant Prabhat	Less spreading, high yielder
Mango	Amarpali, Arunika, Mallika	Precocious, regular bearer
Litchi	Calcuttia, China	Upright growth habit
Papaya	Pusa Nanha, Pusa Dwarf, Red Lady 786	Dwarf, tend to bear at lower height
Peach	Red heaven,Candor	Dwarfing, high yielding
Sapota	PKM-1, PKM-3	Columnar shape, dwarf stature

Table 3: Fruit yield of six years old spur type apple varieties grafted on Crab apple rootstock tested at Horticulture Research Station (HRS), Rajikot, Jumla in 2018 (Subedi et. al., 2019)

Varieties	Plant density (trees/ha)	Fruit size (g)	Fruits/ plant (no)	Fruit yield (kg/lant)	Fruit yield (mt/ha)
Vance Delicious	**400**	**165**	**13±7**	**2.2±1.2**	**0.87**
Red Chief	400	128	77±75	9.9±10.6	3.96
Red Gold	400	117	121±68	14.2±8.0	5.66
Bright N Early	400	164	114±84	18.7±13.7	7.49
Oregon spur II	400	142	66±26	9.3±3.7	3.72
Top red	400	164	84±40	13.7±6.5	5.48
Well Spur	400	129	82±46	10.6±5.9	4.25
Starkrimson Delicious	400	166	172±72	28.5±12.0	11.41
Red Spur	400	160	154±99	24.7±15.9	9.87
Stark Spur Gold	400	148	88±52	13.0±7.7	5.21

2.2 Use of Dwarfing Rootstocks

Rootstocks have a profound effect on tree vigor, precocity, fruiting, fruit quality and longevity of orchard on different fruit crops (Table 4).

Table 4: Genetically dwarf rootstock varieties of various fruit crops (Saroj and Singh, 2018; Goswami et al., 2014)

Fruits	Dwarfing Rootstocks
Apple	M27, M9T337, M26, Bud9, P22, Ottawa3, MM111, MM1006
Ber	Zizyphus rotundifolia, Z. nummularia
Citrus	Trifoliate orange (Poncirus trifoliate var. Flying dragon), Troyer citrange, Citrangequat, Feronia, Severinia buxifolia, Karna Khatta, Sour orange
Guava	Psidium friedrichsthalianum, P. pumilum, P. chinensis, Pusa Srijan, Aneuploid-82
Mango	Vellaikolumban (Alphonso), Olour (Himsagar, Langra)
Pear	Quince C
Peach	Siberian C, St Julien X, Prunus besseyi, Rubira
Plum	Pixy
Cherry	Colt, Charger

2.2.1. Apple

The first commercial high density orchard (3333 trees/ha) was established in 2015 by Agro-Manang Private Limited, Bhartang, Manang. Feathered nursery trees of Gala, Golden Delicious and Fuji varieties grafted on dwarfing rootstock (M9T337) at Nischler Company, Italy were introduced from 2015 and high density orchard was established at Bhartang, Manang at spacing of 3m x 1m (3333 trees/ha). A total of 65000 saplings were planted during 2015-2018 (Table 5). Fourth year production data revealed that Golden Delicious was the top most yielder (17.0 mt/ha) followed by Fuji (13.8 mt/ha) while Gala was the lowest one (Table 5).

Table 5: Fruit yield of apple varieties grafted on M9T337 rootstock from a high density orchard at Agro-Manang Private Limited, Manang for 4 consecutive years (Subedi et. al., 2019)

Fruit Yield								
Year	Gala Mema		Golden Delicious Mema		Fuji Kiku Fubrax		Mean	
	kg/tree	mt/ha	kg/tree	mt/ha	k g / tree	mt/ha	kg/tree	mt/ha
2015	0.20	0.68	0.36	1.21	0.34	1.12	0.32	1.06
2016	3.02	10.07	3.71	12.37	2.52	8.40	2.81	9.38
2017	2.78	9.26	3.86	12.86	2.27	7.56	2.62	8.74
2018	3.62	12.05	5.09	16.97	4.14	13.80	4.19	13.97

2.2.2 Mandarin Orange

High density planting experiment on Mandarin orange cv Khoku local grafted on trifoliate orange rootstock has been initiated by National Citrus Research Program, Paripatle, Dhankuta since 2010 (Table 6).

Table 6: Effect of plant density on fruit yield and quality of mandarin orange grafted on trifoliate orange rootstock from a high density orchard during 2017/2018 (NCRP, 2019).

Crop geometry (m)	Plant density (trees/ha)	Fruit weight (g)	Juice (%)	TSS (0brix)	TA (%)	Productivity (mt/ha)
1.50 x 3.0	2222	92.8	35.1	9.76	0.83	1.59
1.75 x 3.0	1905	88.7	36.7	9.49	1.16	7.49
2.25 x 3.0	1481	93.4	36.5	10.13	0.96	7.17
2.50 x 3.0	1333	79.3	33.9	9.98	0.85	2.64

2.3 High Plant Density and Planting System

Plant density has a strong influence on tree size, yield and light interception which is the single most important factor that determines the yield of an orchard. Tree density depends on vigor of scion and rootstock and soil fertility. An optimum tree density is the level of density which is required to facilitate optimum light distribution and interception leading to high photosynthesis. Combinations of dwarfing rootstocks with spur type varieties will result in much smaller trees than the same rootstock with non spur varieties (Robinson, 2014). Optimum spacing between trees should 1m x 3m between rows is recommended for high density apple orchards.

Maniplating plant spacing using different planting systems like single hedge row, double hedge row, paired and cluster planting. Kew and Queen cultivars of pineapple are found highly suitable for HDP using double row method of the planting suckers or slips spaced at 25 to 30 cm in the rows at a distance of 45 to 60 cm with a spacing of 90 to 105 cm between the beds (63000 plants/ha).

Higher best quality guava fruits could be is achieved from Allahabad Safeda, Lalit, and Sardar (L 49) varieties through judicious canopy management and adoption of suitable tree training systems (Singh, 2008). Trees planted at 2.0m x 1.0m under Meadow orcharding accommodates 5000 plants/ha and managed with regular topping and hedging during initial stages which help in controlling tree size and extending fruit availability (Goswami et. al., 2014).

The concept of HDP in mango started after development of dwarf and regular bearing varieties of mango at IARI, New Delhi (Kumar, 2019). Trees planted at 3.0m x 2.0m for Alphanso, 3.0m x 2.5m for Dashehari and 2.5m x 2.5m for Amrapali, Mallika, Ratna with pruning and dehorning after the harvesting. Amrapali, being distinctly dwarf variety of mango has been recommended to be grown at 2.5m x 2.5m (triangular method) accommodating 1600 plants/ha.

Dwarf Cavendish and Robusta varieties of banana can be planted at a planting distance of 1.2m x 1.2m (6944 plants/ha) in a rectangular system of the planting.

Pusa Nanha and Pusa dwarf varieties of papaya may be planted at a distance of 1.25 x 1.25m (6400 plants/ha). Kinnow was developed by raising Kinnow mandarin on Troyer Citrange rootstock at a planting distance of 2x2 meter (2500 plants/ha) in square system of planting and allowing multiple shoots to come out above the bud union.

Cleopatra mandarin rootstock was ideal for Mosambi sweet orange and Khasi mandarin, a spacing of 5m x 5m (400 plants/ha) was found ideal for high density planting (Goswami et. al., 2014).

Table 7: Optimum plant spacing for spur types and standard color mutants of apple in Himachal Pradesh, India (Awasthi et al., 1997)

Variety	Rootstock	Crop geometry (m)	Plant density (trees/ha)
Standard Type	Crab apple seedling	7.0 x 7.0	204
Spur Type	Crab apple seedling	5.0 × 5.0	400
Standard Type	MM106, MM109	5.0 × 5.0	400
Spur Type	MM111, MM109	4.0 × 4.0	625
Spur Type	MM106, M7	3.0 × 3.0	1111
Standard Type	M9	3.0 × 1.0	3333
Spur Type	M9	3.0 × 0.75	4444

Table 7: Optimum plant spacing for spur types and standard color mutants of apple in Himachal Pradesh, India (Awasthi et al., 1997)

Crop	Crop geometry	Plant density (trees/ha)	Yield (mt/ha)	Yield increment
Apple	3.0m x 1.0m	3333	25	260
Banana	1.4m x 1.4m	4444	145	250
Guava	1.0m x 2.0m	5000	50	250
Kinnow	6.0m x 3.0m	555	177	200
Mango	2.5m x 2.5m	1600	19	250
Pineapple	25cm x 35cm x 90cm	64000	90	200

Table 9: Spacing on various fruits crops under different planting system (Saroj and Singh, 2018)			
Crop	**Crop geometry (m)**		
	Traditional system	**High density system**	**Meadow system**
Apple	10.0 x 10.0	3.0 x 0.75	3.0 x 0.37 – 0.60
Aonla, Sapota	10.0 x 10.0	5.0 x 5.0	-
Banana	2.0 x 2.0 – 2.0 x 3.0	1.5 x 1.5 – 1.8 x 1.8	1.2 x 1.2 – 3.0 x 0.5
Citrus	6.0 x 6.0 – 8.0 x 8.0	3.0 – 6.0 x 3.0 – 4.5	-
Guava	6.0 x 6.0 – 8.0 x 8.0	3.0 x 3.0 – 3.0 x 1.5	2.0 x 2.0 – 2.0 x 1.0
Mango	7.5 x 7.5 – 12.5 x 12.5	3.0 x 2.5 – 5.0 x 5.0	2.5 x 2.5 – 3.0 x 1.0
Papaya	2.0 x 2.0 – 3.0 x 3.0	1.8 x 1.8	1.2 x 1.2 – 1.0 x 1.0

Table 10: Density of Mango plants under different planting system at Indian Institute of Horticulture Research, Bangalore, India (Singh, et. al., 2017)		
Planting system	**Crop geometry (m)**	**Plant density (trees/ha)**
Low Density	12.0 x 12.0	70
Medium Density	7.0 x 7.0	204
High Density	5.0 x 5.0	400
Ultra High Density	5.0 x 2.5 2.5 x 2.5	800 1600

Table 11: Density of Guava plants under various planting system at Central Institute for Subtropical Horticulture, Lucknow, India (Singh, 2008)		
Planting system	**Crop geometry (m)**	**Plant density (trees/ha)**
Low Density	8.0 x 8.0	156
Medium Density	6.0 x 6.0	278
High Density	6.0 x 3.0	555
Ultra High Density	3.0x 1.5	2222
Meadow Orchard	2.0 x 1.0	5000

Table 12: Density of Acid lime plants under various planting system at Central Citrus Research Institute, Nagpur, Maharashtra, India (Ladaniya et. al., 2019).			
Planting system	**Crop geometry (m)**	**Plant density (trees/ha)**	**Yield (mt/ha)**
Low Density	5.0 x 5.0	400	7.4
High Density	5.0 x 2.5	800	25.1
Ultra High Density	2.5 x 2.5	1600	35.4

Table 13: Density of Banana varieties under different planting system at National Research Centre for Banana, Tiruchiapalli, Tamil Nadu, India (Kumar et. al., 2018).

Varieties	Planting system	Crop geometry (m)	Plant density (trees/ha)
Gandhi Selection	Paired row	1.2 x 1.5 x 2.4	2808
Grand Naine, Basrai	Paired row	1.0 x 1.2 x 2.0	6250
Malbhog, Dwarf Cavindish, Rasthali, Palayankodan, Robusta, Jahaji	Paired row	1.2 x 1.2 x 2.0	5208
Rajpuri, Grand Naine, Jahaji, Nendran, Robusta, Alpan, Kothia	3 suckers/hill (45 cm apart)	2.0 x 3.0	5001
Robusta, Grand Naine, Alpan, Kathia	3 suckers/hill	1.8 x 3.6	4629
Ney Poovan, Poovan, Rasthali, Nendran, Monthan	2 suckers/hill	2.1 x 2.4 2.1 x 2.7	3525 3960

Table 14: Density of Kinnow mandarin plants under various planting system at Haryana Agricultural University, Hisar, India (Dalal et. al., 2013).

Planting system	Crop geometry (m)	Plant density (trees/ha)	Fruit yield (mt/ha)
Conventional	6 x 6	277	106
Medium Density	6 x 5	333	120
High Density	6 x 3	555	177

2.4 Crop Management Practices

2.4.1 Use of Highly Feathered Nursery Trees in Apple

Highly feathered nursery trees must be 6-8' tall, ideally have 10-15 well positioned wide angled feathers of 1 feet long developed from all sides of the leader at regular interval and first feather at 60cm height from the soil surface. Studies have shown that the greater the number of feathers, the greater the yield of apple in 2nd and 3rd year (Robinson, 2014). Upright scaffold branches are devigorated by bending and tying down the lateral branches below horizontal through weights, rubber bands, or tying. When new laterals are 3-6 inches long, spread them out horizontally or nearly horizontal with a clothespin or toothpick. As the diameter of the lateral branches approaches 2/3 of the leader's diameter, the lateral is removed by a cut at a downward angle, referred as Dutch cut.

2.4.2 Training and Pruning

Training and pruning are most effective tools in high density and meadow orcharding by virtue of their impact on shape and size control of the tree. Tree size control through pruning is limited

to grape, apple and other temperate fruits. Mango, guava, litchi, citrus, etc are evergreen and are seldom pruned. The training begins when the tree is first planted and continues throughout its productive life. Proper tree forms, branch angle and limb spacing in it aids in growth control. First training is done after one growing season. Each plant is allowed to maintain single stem with upward growth up to 60-80cm and then four scaffold branches are allowed in four directions to make the tree frame. Thereafter, two shoot arising from each primary branch at a distance of 60-75cm from main stem is allowed to form secondary and likewise the tertiary branches. After start of bearing in plants, shoot arising from secondary and tertiary branches are given 15-20cm deep pruning soon after fruit harvest. Pruning often leads to strong re-growth of shoots in mango, guava and other fruit crops. Efficient training system for apple raised on dwarfing rootstock is Spindle bush system (Saroj and Singh, 2018).

2.4.3 Use of Growth Retardants

Use of plant growth regulators may prolong dormancy, reduce vegetative growth, delay flowering, reduce fruit drop, etc. Commercially adopted growth retardants to restrict vegetative growth are CCC, Ancymidal, Phosphon D, Paclobutrazol, Alar, Uniconazole and Chloramquat. Paclobutrazol is commercially used for crop regulation on alternate bearing cultivars of mango such as Dashehari, Chausa and Bombay Green (Saroj and Singh, 2018).

2.4.4 Use of Incompatible Root-stock

Graft incompatible scion and stock could be used to induce dwarfness in the grafted plant. If scion cultivars of ber grafted on Zizyphus rotundifolia, Zizyphus nummularia rootstocks, dwarfness may be induced due to graft incompatibility (Saroj and Singh, 2018).

2.4.5 Mechanization

Drip irrigation and fertigation have been identified as one of the key factors for the success of high density orchards. Assured drip irrigation coupled with fertigation is essential after transplanting, pruning and during fruit development in high density orchards (Saroj and Singh, 2018).

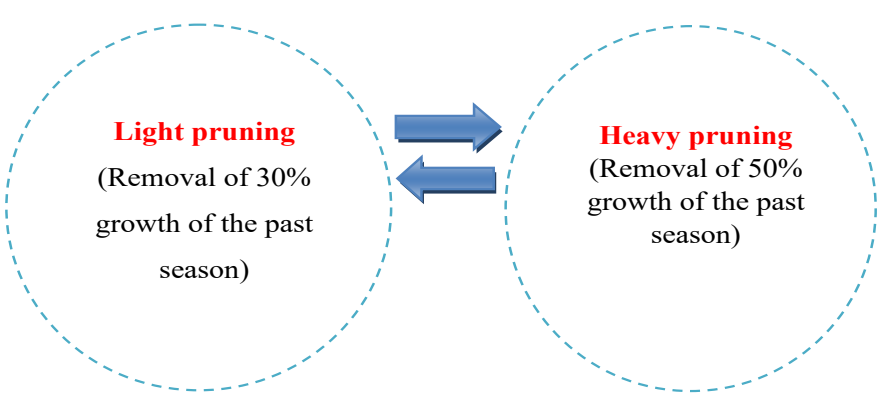
2.4.6 Induction of Viral Infection

Tree size can be reduced by inducing viral infection in citrus and apple, but not adopted commercially. In apple, virus free rootstock series developed by East Malling Long Ashton (EMLA) are more vigorous than their infected counterparts (Saroj and Singh, 2018).

2.4.7 Weed Control

Weed control is crucial during the first 2-3 years of orchard establishment, after which trees give enough shade to minimize weeds growth. Mulching at the base of trees can be done using 100 micron (400 gauges) black polyethylene sheet and organic residues such as straw, dried grass and banana leaves. Mulching with organic materials should be 12 - 15 cm thick to minimize weed growth and simultaneously permit rain water penetration to the root zone. Black polyethylene sheets prevent soil surface evaporation and conserve water, enhance growth, besides controlling weeds (Singh, 2008).

Table 15: Crop management practices on Guava under high density and meadow planting system at Central Institute for Subtropical Horticulture, Lucknow, India (Singh, 2008)	
Year	Crop Management Practices
1st year	❖ Field planting of guava sapling at 3.0m x 1.5m, 3.0m x 3.0m, 6.0m x 6.0m apart for High density orchards & 2.0m x 1.0m apart for Meadow orchards. ❖ Top the trees at a height of 60-70 cm from ground level for High density orchards and 30-40 cm from ground level for Meadow orchards after 1-2 months of planting. ❖ News shoots emerge below the cut points, retain 3-4 equally spaced shoots ❖ Prune the shoots after 3-4 months of emergence (Cutting back to 50% of their total length). ❖ News shoots emerge below the cut points. ❖ Further prune the shoots after 3-4 months of emergence (Cutting back to 50% of their total length).
2nd year	❖ Continuous shoot pruning for desired tree shape.
3rd year	❖ Pruning in January - February for rainy season fruiting (July - September). ❖ Pruning in May - June for winter season fruiting (December - February). ❖ Pruning in September - October for autumn season fruiting (March - April).

Table 16: Crop management practices on Mango under high density planting system at Indian Institute of Horticulture Research, Bangalore, India (Kumar, 2019)	
Month	Crop Management Practices
June	
July - August	Vegetative growth.
September	Stop vegetative growth through application of Paclobutrazol by drenching around the trunk @ 1 gm a. i. per meter canopy.
October - November	Floral bud initiation and differentiation.
December - January	Flowering.
February - March	Growth and development of fruit.

3. Opportunities of High Density Planting in Nepal

Traditional planting system has often created difficulties in orchard management, plant protection and harvesting operations. High density planting system may be one of the most innovative technologies to achieve higher production per unit area both in woody perennial and short duration fruit crops. HDP system makes it possible to reduce the gestation period for early returns, overcome low productivity and improve fruit quality without affecting the tree health and soil fertility. HDP system will bring bright prospective in near future through evolving and adoption of cost effective and user friendly techniques which can fit in the Nepalese scenario and more importantly their adoption at farm level. In Nepal, HDP has already started in different fruit crops; however, commercially applied only in apple. Opportunities of high density orcharding under Nepalese context are summarized as follows:

- Fruit trees planted at high densities improve early yields and profitability during the first 5 or 10 years.
- High density farming techniques use land more efficiently, boosts fruit yields without increasing the space required for planting.
- HDP system may be the highly remunerative and beneficial method for increasing farm income per unit area due to earlier production of best quality fruits.
- Potential technique for efficient utilization of applied and natural resources as land, solar radiation, labor, water, skilled manpower, fertilizers, fungicides, herbicides, insecticides and other inputs.
- Facilitates more efficient utilization of solar radiation, increase photosynthetic efficiency and bearing surface per unit area of the tree.
- HDP reduce gestation period, induce precocity, higher yield efficiency per unit area, and improve better fruit quality.
- Fetch higher early economic return on investment per unit area.
- HDP system is more amenable to horticultural operations such as pruning, plant protection measures and harvesting which reduces labor cost resulting low cost of production per unit area.
- Easier to manage intercultural, plant protection, harvesting operations and enables mechanization in various fruit crops.
- High density orchards have better amenability to modern input saving horticultural techniques such as drip irrigation, fertigation, mechanical harvest, etc.
- High density planting may be highly remunerative and beneficial for generation of farm income and creation of rural employment creation.

4. Challenges of High Density Planting in Nepal

- Higher initial establishment costs are needed as compared to traditional system.
- Economic life span of the orchard becomes shorter.
- Growth retardants may affect the size and quality of fruit in long run.
- Intercultural operation becomes difficult.
- Obstacle in use of intercropping and mixed cropping system.
- Need for a more professional and scientific skill for effective canopy and plant architecture management compared to the conventional planting at wider spacing.
- Poor availability of planting material in dwarf varieties as well as vegetatively propagated rootstocks in different horticultural crops such as mango, guava, peach, cherry, etc.
- Non availability of production technology for HDP of various fruit crops.
- Lack of extension of technical knowhow to the technicians and farmers.

- ❖ High incidence of some pest and diseases (Sigatoka leaf spot & finger tip in banana; woolly aphid & fire blight disease in apple).
- ❖ Commercial utilization of dwarfing rootstocks in apple is restricted due to their poor anchorage system in the sloppy, shallow, rain fed lands with low soil fertility.
- ❖ Crowding and intermingling of branches may occur in coming years which can result in poor performance of trees.
- ❖ Over crowded growth of canopy in high density orchards results heavy competition for space, nutrients and water; build up of high humidity, reduced cross ventilation which is conducive for incidences of more pests and diseases.
- ❖ Lack of consolidated land availability to establish high density orchards.

5. WAY FORWARD

Strong research is needed on time and intensity of pruning, screening of cultivars that have less canopy area with erect growth and application of plant growth regulators. Following recommendations are made for promotion of high density planting system on different fruit crops under Nepalese context:

- Infrastructural Development

  Subsidies should be provided for purchase of quality saplings, establishment of trellis support system, drip irrigation, fertigation and fencing.
- Strengthening of Government Farms/ Stations for Sustainable Production of Quality Nursery Trees
  - ❖ Introduction of genetic resources of major fruit crops suitable for high density planting.
  - ❖ Establishment of tissue culture laboratories at various Farms/ Stations for standardization of mass multiplication techniques for dwarfing rootstocks.
  - ❖ Development cost effective and user friendly high density planting technology.
  - ❖ Supply of quality mother plants to private sector.
  - ❖ Establishment of demo-plots and centre for excellence of proven technologies for providing the technical knowhow to the concerned stakeholders.
- Human Resource Development

Most of farmers and technicians are still unfamiliar with high density orchard management techniques; thus exposure visits, short and medium term trainings opportunities should be provided to technical staffs and farmers. Likewise, long term advance study (M.Sc., PhD) opportunities must be provided to the concerned personnel.

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