An Experience of High Density Planting of Apple in Nepal

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Abstract

High density planting is one of the recent novel concepts of increasing the productivity without altering the quality of fruits. 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. Basically dwarfing rootstocks (M.9T337), columnar and compact varieties are the first and foremost pre-requisite for establishing high density orchard. High density planting was first commercially pioneered in Europe at the end of 1960's, now majority of orchards in Europe, America, Australia and New Zealand are grown under this system. Tall Spindle planting system developed in late 1990's, is the fastest way of shortening juvenility through use of high tree densities, highly feathered trees, minimal pruning up to five years, no permanent scaffold branches, branch angle manipulation and bending of feathers below horizontal at planting. In Nepal, first commercial high density orchard (3333 trees/ha) was established in 2015 by Agro Manang Pvt. Ltd. at Bhartang, Manang. Production data revealed that Golden Delicious was the highest yielder (17.0 mt/ha) followed by Fuji (13.8 mt/ha) while Gala was the lowest one (12.1 mt/ha). Likewise, medium density varietal evaluation block was established in 2011 at HRS, Rajikot, Jumla revealed that Starkrimson Delicious was the top most yielder (11.4 mt/ha) followed by Red Spur (9.9 mt/ha). This result indicates that high returns could be obtained from high density planting system. However, majority of farmers cannot afford the cost of imported saplings (NRs. 1200-1500/sapling), trellis support system, trickle irrigation systems. Most of the apple growers and technicians are unfamiliar with nursery and management techniques for high density orchards. Thus, government should provide international training opportunities to the apple growers and technicians, provide enough subsidies for establishment of high density orchards, develop cost effective and user friendly technology, establish demo plots and centre for excellence of proven technologies for providing technical knowhow to stakeholders and establish tissue culture laboratories for mass multiplication of dwarfing rootstocks.

Keywords: *High density planting, dwarfing rootstock, spur, feathered trees, support system*

1. Background

Apple is an important fruit crop commercially cultivated mostly in the western high hills of Nepal. The productivity of apple is very low (7.8 mt/ha) as compared to global productivity (15.4 mt/ha) (FAO, 2016). Nepal produced 43502 mt of apple fruits annually; however, 46970 mt apples were imported from China, India, USA and New Zealand to meet the domestic demand (MoAD, 2015). Trade of apple is highly imbalance and negative (-46954 mt) (MoF, 2015). Low productivity is mainly attributed by deterioration of existing varieties, traditional planting at wider spacing, lack of regular bearing varieties, inadequate pollinizers and pollinators, poor nursery and orchard management, incidence of diseases and insect pests, inadequate irrigation facilities, poor soil fertility (Subedi *et al.*, 2018). Presently, continuing decline in the availability of cultivable land, rising energy and land costs together with increased demand of apple and apple products have given thrust to the concept of high density planting. High density planting is one of the modern novel concepts of planting of fruit trees closer rather than conventionally recommended spacing using special orchard management techniques with the objective of increasing the productivity without compromising fruit quality, without sacrificing tree health and imparting soil fertility (Costa et al., 1997). 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 (Table 1). Maximum number of plants per unit area can be accommodated through manipulation of tree size. Basically dwarfing rootstocks, columnar and compact varieties are the first and foremost pre-requisite for establishing high density orchard. High density planting may be the fastest way of shortening juvenility through the use of feathered nursery trees, minimal pruning at planting, maximizing tree growth with drip irrigation and fertigation, proper crop load management through bending of feathers below horizontal after planting.

History of High Density Orchard

The conceptual background of high density planting system was pioneered in Europe at the end of 1960 for an apple orchard. Since then there is steady increase the establishment of commercial high density orchards throughout the world. High density planting system is being practiced for commercial cultivation of apple, peach, plum, pear, almond, cherry, etc. Heinicke (1975) developed Central Leader system which can accommodate 300-700 trees/ha utilizing semi dwarfing rootstocks. During late 1970's and early 1980's a significant number of growers started planting of more compact trees grafted M.9 on rootstocks at higher tree densities (1000-1500 trees/ha) to achieve higher early yields. A significant trend in late 1980's was to increase planting density in Slender Spindle system to improve light interception and thereby improve both early and higher yields (Oberhofer, 1987). Another more successful approach to improving yield in the late 1980's was to grow taller trees by using Vertical Axis system (1000-1500 trees/ha) developed by Jean Lespinase (1980). During the early 1990's higher tree densities between 4000-6000 trees/ha were tested in a V shape. Another significant trend during late 1980's to 1990's was greater emphasis on the use of highly featured trees to obtain significant yield in second year. Super Spindle Planting System was developed which has narrower tree form and extremely high early yield and excellent fruit quality (Nuberlin, 1993). In late 1990's, Tall spindle planting system was developed from a combination of slender spindle, Vertical axis and Super spindle systems. Major components include optimum planting density (2500-3300 trees/ha), use of feathered trees, minimal pruning, bending feathers and no permanent scaffold branches (Robinson, 2006). Majority of apple orchards in

Europe, America, Australia and New Zealand are grown under Tall spindle system. In Nepal, first commercial high density orchard (3333 trees/ha) was established in 2015 by Agro Manang Pvt. Ltd. at Bhartang, Manang. Likewise, medium density varietal evaluation block of spur type apple varieties (400 trees/ha) was established at Horticulture Research Station, Rajikot, Jumla in 2011 (Subedi *et al.*, 2018).

Principles of High Density Orchard

a. Higher early yield with best quality fruits through planting of more number of high quality featherd nursery trees per unit area
b. Balance between vegetative growth and fruiting (Tree height = 0.9 x row width)
c. Grow fruit, not the trees
d. Optimizing exploitation of natural resources as land, solar energy, water, nutrients, air (High light Interception 70-75%)

Characteristics of High Density Orchard

a. High Density orchard should have maximum number of fruiting branches and minimum number of structural branches
b. Trees are generally trained with the central leader surrounded by nearly horizontal fruiting feathers
c. Branches should be so arranged and pruned in such a way that each branch has minimum amount of shade on other branches

Categories of High Density Orchard

Six categories of High density or closed density planting or high density orchard include:

a. **Low density planting (LDP):** Planting at wider spacing accommodating about 100-250 plants/ha, no use of dwarfing rootstocks, non intensive, trees acquire into potential production after 15-20 years, projected orchard life is 40 years.
b. **Medium density planting (MDP):** Planted at minimized spacing accommodating about 250-500 plants/ha, use of semi dwarf rootstocks, requires proper training and pruning, 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.
c. **High density planting (HDP):** Very closer planting with 500-2000 plants/ha. Requires rigorous training and pruning, use of dwarfing rootstocks and chemicals, both yield and expenses are higher, maintenance of orchards requires technical backup, trees acquire into potential production after 6-9 years.
d. **Ultra high density planting (UHDP):** Accommodates 2000-5000 plants/ha. It requires severe pruning and training, proper canopy management, chemical assistance and nutrient management and also requires technical backup, trees acquire into potential production after 4 to 7 years.
e. **Super high density planting (SHDP):** Accommodates 5000-10000 plants/ha. Severe top pruning, use of growth regulators, canopy management, fruiting after 1-2 years.
f. **Meadow orchard (MO):** Ultra closer planting, accommodates about 70000 plants/ha, harvesting by moving around orchard.

Table 1: Comparative advantages of high density orchards vs traditional orchards		
Attributes	**Traditional planting system**	**High density planting system**
Tree density	Very low (150-200 trees/ha)	Very high (500-70000 trees/ha)
Precocity	Very late (After three years)	Very early (From first year)
Productivity	Less	Very high
Management	Difficult to manage due to large tree size	Easy to manage due to small tree size
Harvesting	Difficult	Easy
Quality	Large canopy, poor air and sunlight penetration and poor-quality fruits	Small canopy, better air and light penetration, minimum incidence of diseases, better quality fruits with good color development
Establishment cost	Less	Very high
Production cost	Higher	Lower
Labor requirement	More	Less
Machinery	Difficult to use	Required for reducing cost
Bio-regulators	Not required	Required

2. Components of High Density Orchard

If vigour is too low, excessive fruiting results, fruit size declines, biennial bearing increases and trees fail to fill their allocated space to make the orchard profitable. If vigour is too excessive, then flowering and fruiting are reduced. Successful balance of vegetative vigour and fruiting results in *calm trees* that produce heavy annual fruiting. High yield and superior fruit quality can be achieved when the orchard has good light distribution throughout the tree canopy (Verma, 2015). High tree density, highly feathered trees, minimal pruning at planting (no heading leader or tipping feathers), branch angle manipulation through bending feathers below horizontal at planting induces early cropping, proper crop load management and limits branch size, branch calliper management through removal of large branches. Development of pendant fruiting branches are the primary management tools along with moderate levels irrigation and application of nitrogenous fertilizers that are used to achieve a balance between vegetative growth and fruiting which are highly affected by planting density, tree quality and training strategies. High density orchard consists of the following components.

I. Use of Genetically Dwarf Scion Varieties

Genetically dwarf varieties offer a great scope for close planting. Columnar varieties are naturally dwarf, grow only 8-12' tall, fruiting occurs in clusters one year after planting, tree growth is vertical with almost no branching. Spur type apple varieties are more compact and profitable than non spur one that have characteristics of regular bearing, early fruiting, dwarf trees, attractive fruit

color, good quality fruits, less pruning requirements and greater hardiness. They tend to grow in an upright manner with narrow crotches, sparse branching, smaller than standard trees even when grown on seedling rootstock. Trees develop several leaders with no predominant central leader, fruiting occurs on numerous short spurs after two years and fruiting zone tends to remain close to trunk. Nursery trees of spur type apple varieties grafted on crab apple rootstock were introduced from HRS, Kandhaghat, Solon and RARS, Mashobra, Shimla, H.P., India in 2011. The saplings were planted at Horticulture Research Station, Rajikot, Jumla for varietal evaluation in a Randomized Complete Block Design with 7 replications (Table 2). Six years result revealed that Starkrimson Delicious was the top most yielder (11.4 mt/ha) followed by Red Spur (9.9 mt/ha). On the other hand, spur type apple varieties acquire potential commercial production only after ten years. Thus, there is tremendous potentiality of enhancing productivity and quality by establishing medium density orchards using spur type apple varieties.

Table 2: Fruit yield of six years old spur type apple varieties tested at Horticulture Research Station, Rajikot, Jumla during September 2018

Varieties	Plant density (trees/ha)	Fruit size (g)	Fruits/plant (no)	Fruit yield (kg/plant)	Fruit yield (mt/ha)
Vance Delicious	400	165	13±70	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

II. Use of Dwarfing Rootstocks

Rootstocks have a profound effect on tree vigor, precocity, fruiting, fruit quality and longevity of orchard (Table 3). M.9T337 is the commonly used precocious dwarfing rootstock (Robinson *et. al.*, 1992). Combinations of dwarfing rootstocks with spur type varieties will result in much smaller trees than the same rootstock with non spur varieties. Performance study of Delicious cv. grafted on M9 dwarfing rootstock was initiated at NTHRS, Marpha, Mustang from 1977. However, no results were obtained from this investigation due to frequent change in the organizational set up.

The first commercial high density orchard (3333 trees/ha) was established in 2015 by Agro Manang Pvt. Ltd. at Bhratang, Manang, Nepal (Table 4). Feathered nursery trees of Gala, Golden Delicious and Fuji varieties grafted on dwarfing rootstock (M.9T337) at Nischler Nursery, Italy were introduced from 2015 and high density orchard was established at Bhartang, Manang by Agro Manang Pvt. Ltd at spacing of 3m x 1m (3333 trees/ha). A total of 65000 saplings were planted during 2015-2018. 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 (12.1mt/ha) (Table 5). Awasthi and Chauhan (1997) reported that fruit yield of 30-35 mt/ha has been achieved from 12 year old orchards of color mutants of apple on MM.106 rootstock under a planting density of 2222 plants/ha (3m ×1.5m) in cooler hills of H.P., India.

Table 3: Characteristics of major apple rootstocks (Subedi et. al., 2018)

Rootstock	Category	Fruiting	Anchorage	Crown rot	Fire blight	Woolly aphid
Seedling	Vigorous	Slow bearing, variable yield	Well anchored	Variable	Tolerant	Susceptible
MM.106	Semi vigorous	Precocious, productive	Good	Very susceptible	Moderately susceptible	Resistant
MM.111	Semi dwarf	Moderately precocious, medium yield	Well anchored	Tolerant	Tolerant	Resistant
M.7, EMLA.7	Semi dwarf	Precocious, moderate productive	Free standing	Susceptible	Tolerant	Susceptible
M.26, EMLA.26	Semi dwarf	Very precocious, productive	Early support Needed	Moderately susceptible	Very susceptible	Susceptible
G.11	Semi dwarf	Very precocious, very productive	Early support Needed	Moderately resistant	Moderately resistant	Susceptible
EMLA.9, M.9	Dwarf	Very precocious, very productive	Support needed	Resistant	Very susceptible	Susceptible
Bud.9	Dwarf	Very precocious, very productive	Support needed	Very resistant	Susceptible	Susceptible
G.65	Dwarf	Very precocious, very productive	Support needed	Resistant	Very resistant	Susceptible
Supporter. 4	Dwarf	Precocious, productive	Support needed	Resistant	Resistant	Susceptible
M.27, EMLA.27	Ultra dwarf	Very precocious, very productive	Support needed	Resistant	Susceptible	Susceptible

Table 4: Fresh fruit yield of apple varieties from a high density orchard of Agro Manang Private Limited, Bhartang, Manang for four consecutive years

Year	Gala Mema		Golden Delicious Mema		Fuji Kiku Fubrax		Total	
	Bearing trees	Yield (kg)	Bearing trees	Yield (kg)	Bearing trees	Yield (kg)	Bearing trees	Yield (kg)
2015	8707	1764	10237	3720	28104	9455	47048	14939
2016	8057	24337	9537	35395	34793	87634	52387	147366
2017	12121	33672	9927	38309	39986	90673	62034	162655
2018	11941	43172	9737	49561	37146	153770	58824	246503

Table 5: Fresh fruit yield of apple varieties from a high density orchard of Agro Manang Private Limited, Bhartang, Manang for four consecutive years

Year	Plant density (trees/ha)	Gala		Golden Delicious		Fuji		Mean	
		Fruit Yield							
		kg/tree	mt/ha	kg/tree	mt/ha	kg/tree	mt/ha	kg/tree	mt/ha
2015	3333	0.20	0.68	0.36	1.21	0.34	1.12	0.32	1.06
2016	3333	3.02	10.07	3.71	12.37	2.52	8.40	2.81	9.38
2017	3333	2.78	9.26	3.86	12.86	2.27	7.56	2.62	8.74
2018	3333	3.62	12.05	5.09	16.97	4.14	13.80	4.19	13.97

III. High Plant Density

Plant density has a strong influence on tree size, yield and light interception which is the most important factor that determines the yield of an orchard for the first 5 years (Robinson, 2011). Tree density depends on vigor of scion and rootstock varieties and soil fertility (Table 6). Optimum spacing between trees should 3-4' and 11-12' between rows for high density orchards (2400-3700 trees/ha).

Table 6: Optimum spacing for spur types and color mutants of standard apples (Awasthi and Chauhan, 1997)

Type	Rootstocks	Spacing (m^2)	Plant density (ha)
Standard Type	Seedling (Crab apple)	7x7	204
Spur Type	Seedling (Crab apple)	5×5	400
Spur Type	MM.111, MM.109	4×4	625
Standard Type	MM.106, MM.109	5×5	400
Spur Type	MM.106, M.7	3×3	1111
Standard Type	M.9	3×1	3333
Spur Type	M.9	3x0.75	4444

IV. Use of High Quality Feathered Nursery Free

Studies have shown that the greater the number of feathers, the greater the yield in 2nd and 3rd year (Robinson, 2011). High density orchards can have significant yield if highly feathered nursery trees are planted and if trees grow well on first year (Table 7). If growers use whips or small caliper nursery trees these do not produce significant quantities of fruit until year 4 or 5. Highly feathered nursery trees must be 6-8' tall, ideally have 10-15 well positioned wide angled feathers of 1feet long developed from all sides of the leader at regular interval and first feather at 60 cm height from the soil surface.

Table 7: Effect of tree quality on early fruiting of apples on M.9 rootstock (Palmer, 2004)

Cultivar	Age of orchard	No. of fruits/tree	
		Feathered nursery trees	Whip nursery trees
Royal Gala	2	42	15
Fuji	2	22	7
Royal Gala	3	139	64
Fuji	3	152	61

V. Minimal Pruning at Planting

It's recommended that the nursery trees must have 10-15 well positioned feathers with a maximum length of 1 foot. Highly feathered nursery trees require almost minimal or no pruning at planting time (Robinson, 2014).

VI. Crop Load Management

Management of crop load during the first four years to avoid biennial bearing is critical for maintaining a proper balance between vegetative growth and fruiting. With precocious dwarfing rootstocks, young apple trees can often overset in 2nd or 3rd year resulting in biennial bearing as early as 4th year (Robinson *et. al.,* 2011). Varieties differ in their biennial bearing tendency and this must be incorporated into crop loads allowed on young trees (Table 8). Within each year, low end of range should be used for low vigor trees and the high end of the range for high vigor trees. Management of crop load is balancing between reducing crop load sufficiently to achieve optimum fruit size and adequate return bloom without reducing yield excessively. Pruning, hand thinning and chemical thinning are the management practices that have a large effect on crop load (Table 8). Tall Spindle planting system produce heavy bearing on small trees, thus a strong wire support system is required immediately after planting to withstand crop and snow load.

Table 8: Optimum crop load for annual and biennial bearing varieties during the first four years in high density orchards (Robinson, 2011)

Varieties	Fruiting habit	Crop load/ cm^2 TCA	No. of fruits/tree		
			2nd year	3rd year	4th year
Gala, Red Delicious	Regular bearing	6	25-40	40-60	100-120
Fuji, Golden Delicious	Binnial bearing	4	15-20	25-40	50-70

VII. Leader Management

If well feathered trees having 10-15 lateral branches with wide crotch angles are planted and wire support system is needed to carry the crop load and support rootstocks. The best leader management techniques are those that do not rely upon pruning to maintain the tree shape. Research has shown that any pruning of young trees will reduce or delay fruit production early in the life of the orchard (Michael Parker, 1998).

a. Bagging

It is done by placing a polyethylene bag over the previous year's unbranched growth. It is only effective on 30-32" of leader. Bags should be applied 4-6 weeks before anticipated bud break. Ends of the poly bag must be closed tightly with rubber band until new lateral growth is 1-2" long. Immediately upon bag removal apply a foliar application of 250 ppm Promalin and an anti desiccant to previously bagged portion (Michael Parker, 1998).

b. Snaking

Snaking is a technique used to train a leader without pruning. It is the process of bending the leader during growing season when it is 18" long to a 60o angle and tying it to the tree stake. After the leader grows another 18", it is bent back towards the tree at a 600 angle and taped to the tree stake. It is a technique that can be used to devigorate the leader and increase lateral branching continuously along the leader. Each successive bend is done in the opposite direction to form a zig zag leader shape. In research plots in North Carolina, snaking resulted in greater early fruit production than weak leader renewal technique (Michael Parker, 1998).

c. Weak leader renewal

This technique removes the vigorous upright leader and replaces it with a weaker branch to devigorate leader, maximize branching and encourage early fruit production. Weak leader renewal involves pruning central leader during dormant season, just above the highest usable lateral. The lateral is then pulled up and headed at 12" and tied to the tree stake as the new leader. This technique can also be used with feathered trees that have lower branches and no higher branches. The leader is removed above the highest usable lateral and then that lateral branch is pulled up to replace the leader (Michael Parker, 1998).

d. Notching

A remedial technique used for feathered trees with blind wood. This is done by placing a notch above each node in the unbranched region of the leader 2-3 weeks before bloom with a hacksaw blade extending approximately one third of the way around the tree. Enough of the buds will break in the unbranched areas (Michael Parker, 1998).

VIII. Branch Angle Manipulation

A shoot grows more vigorously in vertical position than pendant position and tends to remain non fruitful. A pendant limb grows less vigorously and then fruiting occurs heavily in next year and bend under the weight of the fruit. At planting time, all the feathers must be tied down to induce fruiting and prevent them from developing into scaffold branches. 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'' long, spread them out horizontally or nearly horizontal with a clothespin. If a vertical limb is bent horizontal, lateral buds are released from dormancy. An

important method of shifting the balance between vegetative growth and fruiting in young trees is tying down of the feathers below horizontal to keep trees within a specific area and to promote production of fruiting buds each year. If not pruned, they will bend with fruiting. Larger feathers are tied down after planting to keep trees within a specific area and to promote the production of fruit buds each year (Robinson, 2011). Four tools are used for spreading branches are clothespins, toothpicks, concrete weights with clothespins and tying down with string. Branches are spread outward as they are 3-6" long and maintained to approximately an 80-85o angle (Verma, 2015).

IX. Judicious Training and Pruning

Adequate light interception is needed for optimum photosynthesis, flowering, fruit set and fruit quality. High yield and high 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. Growers will maintain a balance between vegetative growth and fruiting by regularly renewing of fruiting woods, moderate levels of nitrogen and proper crop load management. Growers should try to obtain 50cm of leader shoot growth in the 1st year, 75-100cm of leader shoot growth in the 2nd and 3rd years and 50cm of leader shoot growth in the 4th year. If this is combined with minimal pruning and a precocious rootstock, significant production should be obtained in the 2nd to 4th years which will limit vegetative growth in future years resulting in a calm tree (Robinson *et al.*, 2011). Early fruiting and rapid establishment of conical tree canopy can be achieved by high tree densities (2400-3700 trees/ha), use of dwarfing rootstocks (M.9, B.9, G.41, G.16), planting of highly feathered trees (10-15), minimal pruning at planting, bending feathers below horizontal after planting, no permanent scaffold branches and renewing of branches as they get too large and more emphasis on training rather than pruning. Maintaining a conical shape is necessary good light exposure, fruiting and fruit quality at the bottom of the tree. The best way to maintain good light distribution within the canopy as the tree ages is to remove whole limbs in the top of the tree as they grow too long. 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* (Robinson, 2014). It is a technique used to cut lateral branches to an angled stub, allowing latent buds at the bottom to grow with wide crotch angle. When this style of pruning is repeated annually, the top of the tree can be composed completely of young fruitful branches (Table 9). Tall spindle system was developed as an outcome of slender spindle system to take advantage of increased canopy volume by increasing tree height.

Table 9: Judicious training and pruning plan for high density orchards (Robinson, 2014)

Time		Operations
1st year	At Planting	Planting of highly feathered nursery trees (6-15) at a spacing of 3-4' x 11-12'. Adjust graft union 6" above soil level. Remove all feathers below 24" using a Dutch cut. Do not head leader or feathers.
	3-4" Growth	Rub off 2nd and 3rd buds below new leader bud to eliminate competitors to leader shoot
	May	Install a 4-5 wire tree support system or tree stakes. Attach trees to support system with a permanent tree tie.
	Early June	Tie down each feather that is longer than 10" to a pendant position below horizontal with biodegradable rubber bands

2nd year	Dormant	Do not head leader or prune trees. Pinch lateral shoots in top 1/4 of last year's leader growth removing about 5 cm of growth
	Early June	Hand thinning to 5 *fruits/cm*^{2} TCA leaving single fruit 4'' apart (Target 15-20 fruits/tree)
	Mid June	Re-pinch all lateral shoots in top 1/4 of last year's growth. Tie developing leader to support system with permanent tie
3rd year	Dormant	Remove vigorous limbs that are more than 2/3 the diameter of the leader
	Late May	Hand thinning to 5 fruits/cm^2 TCA (Target 50-60 fruits/tree)
	June	Tie developing leader to support system with a permanent tie
	August	Lightly summer prune to encourage good light penetration and fruit color
4th year	Dormant	Remove vigorous limbs that are more than 2/3 the diameter of the leader using a Dutch cut
	Late May	Hand thinning to 5 fruits/cm^2 TCA (Target 100 fruits/tree)
	June	Tie developing leader to support system with a permanent tie at top of pole
	August	Lightly summer prune to encourage light penetration and fruit color
5th-20th years	Dormant	Limit tree height to 10' by cutting leader back to a fruitful side branch. Annually, remove at least 2 limbs including lower tier scaffolds that are more than 2/3 the diameter of the leader. Shorten bottom tier scaffolds where needed back to side branch to preserve fruit quality on lower limbs. Remove any limbs larger than 1" diameter in upper 2' of tree.
	Late May	Hand thinning to 5 fruits/cm^2 TCA (Target 100-120 fruits/tree)
	August	Light summer pruning to encourage light penetration

X. Irrigation and Fertigation

Large and highly feathered trees often undergo water stress shortly after planting despite adequate soil moisture levels. This is due to the damaged root system of a transplanted tree which cannot adequately support the large top without frequent irrigation. Large, highly feathered trees produce much more leaf area shortly after planting than whip trees which creates a high water demand before the root system can re grow sufficiently to support the trees. Dry weather following planting results in water stress of newly planted trees which can limit tree growth. Installing trickle irrigation system immediately after planting is strongly recommended with high density orchards that use feathered trees to prevent water stress and maximize first year tree growth (Robinson, 2011).

Frequent low doses of nitrogen fertilizer should be delivered at least twice weekly through fertigation for the first 12 weeks of the season will greatly improve tree growth during the first two years to speed development of the canopy (Robinson, 2011). Immediate fertigation will improve tree growth and yield potential in the 2nd and 3rd year. However, excessive fertilization, especially nitrogen, can cause too much growth which results in delayed flowering, reduced yields, poor fruit quality and greater pruning. After the first few years, low nitrogen fertilization is desirable to keep the trees calm with a balance between growth and fruiting.

XI. Weed Control

Weed competition can drastically reduce tree growth during the first few years and can cause a failure of the orchard to fill its allotted space which always results in diminished yield and return. Good weed control technique is strongly recommended during the first 3-4 months of a growing season (Robinson, 2014).

XII. Use of Bio-regulators

Shoot growth and fruiting can be controlled by bio regulators and light summer pruning. Chloromequat chloride, Paclobutrajol (Cultar), uniconazol, Diaminzidde (Alar) reduce vegetative growth. Alar 2000 ppm, Etherel 1000 ppm and a mixture of Alar 1000 ppm with Etherel 500 ppm not only allow significant reduction of shoot growth but also have positive influence over tree productivity and fruit quality (Parshant Bakshi, 2014).

3. Constraints

- High quality feathered nursery trees are produced by the Nischler Company, Italy. In Nepal, Agro Manang Pvt. Ltd. is sole importer as well as distributer of feathered nursery trees. The cost of imported feathered nursery trees is too high.
- Initial establishment cost is too high because of Trellis support system, drip irrigation and fertigation systems should be installed immediately after planting of nursery trees
- Dwarfing rootstocks (M.9) suitable for high density planting are not available
- Lack of *in vitro* techniques for mass multiplication of dwarfing rootstocks
- Lack of high quality feathered nursery trees production technology
- High density apple farming is a newly introduced novel method in Nepal since 2015
- Most of the apple growers and field technicians are still unfamiliar and have inadequate technical knowhow regarding nursery and orchard management techniques for high density orchading.
- Commercial utilization of dwarfing rootstock in the sloppy, shallow, rain fed and low fertile land is limited due to poor anchorage system. Mailing series rootstocks (M.9, M.27, M.26) are highly susceptible to wooly apple aphid and fire blight disease.
- Lack of consolidated land availability to establish high density orchards

4. Conclusion

- High density planting system make it possible to reduce the gestation period, increase productivity and improve fruit quality without affecting the tree health and soil fertility. Thus, it may be highly remunerative and beneficial method for increasing farm income.
- In new federal structure, the role of horticulture Farms/Centers should be revised and a mandatory role has to be provided to the concerned Farms/Centers to look after the research and development of high density planting technologies.
- Land availability for farm-based approach is most important for the success of high density planting system, so consolidation of land is necessary. The local government can play vital role in land consolidation process.

5. Way Forward

High quality fresh apple production can be increased by manifolds from the high density orchards if Government focuses on the following recommendations:

i. Subsidies to establish high density orchards

High quality feathered nursery trees are the pre-requisite for establishment of high density orchards, however feathered nursery trees are mostly produced in European countries. Agro Manang Pvt. Ltd. is the sole importer as well as the distributer of feathered nursery trees in Nepal. The cost of feathered nursery trees is too high (NRs. 1200-1500/tree), majority of farmers cannot afford the cost of feathered nursery trees. Thus, the government should provide subsidies for feathered nursery trees, establishment of trellis support system, drip irrigation and fertigation system.

ii. Strengthening Farms/Stations for production of highly feathered nursery trees

- Tissue culture laboratories should be established at various Farms/Stations for mass multiplication of dwarfing rootstocks
- Introduction of *in vitro* cultures of dwarfing and semi dwarfing rootstocks (M.9, MM.106, MM.111) from the European countries
- Standardization of *in vitro* mass multiplication technique for apple rootstocks
- Standardization of high quality feathered nursery tree induction technology
- Supply of mother plants of dwarfing rootstocks and modern nursery management technology to private nurseries
- Development of cost effective and user friendly technology for high density orchards
- Establishment of demonstration plots of high density orchards at government Farms/Stations
- Establishment of centre for excellence of proven technologies to provide technical knowhow to the technicians and apple growers

iii. Human resource development

- Most of the apple growers and technicians are still unfamiliar with high density nursery and orchard management techniques. Thus exposure visit, short and medium term training opportunities at national and international level must be provided immediately to technical staffs and farmers
- Long term advance study (M.Sc., Ph.D.) opportunities must be provided to horticulturists working in the farm/centres for expertise development and retention in the subjects as they are recruited.

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