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Apple High Density Orcharding – Performance Reckoning Studies in Respect of the Agro-ecological Challenges of Kinnaur

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Abstract: ***High density orcharding and the quest for high quality produce is gaining day by day and extending its spread into the dry temperate regions. Kinnaur region of Himachal Pradesh, India is known for its quality apple production but is a quite fragile ecotype with high degree of vulnerability to the climatic changes. Agro-ecologically the region is quite variable from wet temperate conditions to highly dry temperate dessert conditions. Intensive apple cultivation therefore in the region needs critical prior assessment for its sustained success. Reckoning studies presented in this article discuss the expected performance score of different clonal and seedling rootstocks, spur, non-spur and high colouring cultivars and high and ultrahigh densities of planting. The ready reckoner of rootstock, cultivar and planting densities combinations expected to perform better under the three distinct agro-ecological situations of Kinnaur have also been presented for future validation.***

Keywords: HDP, Dry Temperate, Climatic vulnerability, Clonal rootstocks, Spur types, High Colouring Apple, Intensive Orcharding

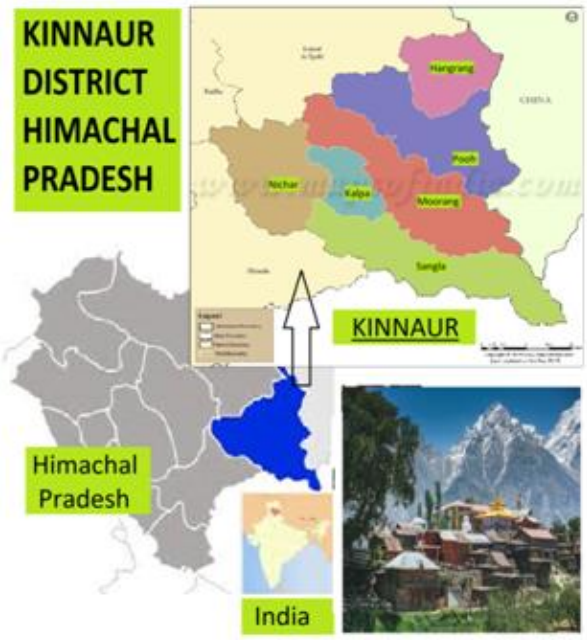
1. Introduction

Apples (*Malus x domestica*Borkh.) is the premier temperate fruit crop of the North-Western Himalayan region. It is predominantly grown in Himachal Pradesh, J&K, and Utrakhand in the NW region of India. Itwas first brought into India from Liverpool in 1838 and planted atMussoorie and thereafter the British planted some trees in the Nilgiri Hills during 1850. In Himachal Pradesh, it was Captain R. C. Lee who planted the first professionally managed orchard in 1857 inBandrol in Kullu District. In Shimla,the prime apple producing district of the State, the first orchard was planted in 1887 inMashobra by Alexander Coutts and this orchard was famous Coutts Garden and presently hosting Regional Horticultural Research Station, Mashobra of Dr. Y. S. Parmar University of Horticulture and Forestry, Solan[1]. The commercial production of apple in India started after introduction of Delicious group of cultivars by American settler Samuel Evan Stokes in Kotgarh, Himachal Pradesh in 1917-18 [2].Presently, India is fifth largest producer of apple in the world with a production level of 25.21 lakh metric tonnes, 7.77 metric tonnes of which are being produced in Himachal Pradesh [3]. But, besides being the premier producer, it is also one of the top importers of it. The current annual worth of import of apples in the country is around $238 million whereas the export is only $9million[4, 5]. This import is believed to stay despite the fact that these imported apples don't appeal to Indian taste buds as much as the standard delicious varieties. Therefore there is huge scope of expansion of apple production in the country and Himachal as well. Keepingthis scope in view people of the state are extending their apple plantations with the intent of getting more returns per unit area through High Density Plantings (HDP). And, therefore large scale introduction, multiplication and cultivation of new and old varieties on different type of rootstocks is exponentially proliferating haphazardly across different apple growing regions of the State.

High Density Planting (HDP) was specially pioneered for apple in Europe during early 1960s by way of planting of more number of plants than optimum through manipulation of tree size for achieving enhanced productivity and fruit quality by maintaining a balance between vegetative and reproductive load without impairing the plant health. Through this technique the growers across the globe are getting 5-6 times more production per unit area than the conventional apple growing. The worldwide experimentation on apple high density has led the researchersto two main conclusions: First, there exists a direct relation between the initial investments and planting density; the higher the plant density, the higher initial investment is required. But, total growing costs are less than the central or modified leader system when compared over the 20-year life of orchard [6, 7, 8]. The net result is that there is no significant difference in the total establishment and growing costs of these two procedures. Second, the plant training systems are crucial depending upon planting density and maintenance of canopy architect. All most all high density training systems are profitable over the standard central or modified leader system if properly maintained [9]. Further, the high density planting systems extend the possibilities to the growers for realizing greater returns by way of planting of new cultivars and getting significant production. Added to it, the growers have an option to remove high density orchard after15 years or so to replant to newer, higher value cultivars which further enhance the probability of profit.

As far as harnessing the benefits of apple HDP in India is concerned there does not exists much data which could advocate the suitability of high density plantations under Indian perspective especially under the hilly terrain of Himachal Pradesh. Most of the data which exists worldwide is based on HDP studies are from the regions which are

technologically sound in nutrition and moisture management, rootstock and cultivar choices, plant canopy management and having strong marketing network. And, therefore there is greater opportunity for adoption apple HDP under the Indian conditions especially in Himachal Pradesh and more specifically in Kinnaur where the agro-ecological situations are quite variable and extreme. Adoption of alien recommendations without rational exegesismay prove perilous leading to escalation in proportion of debit laden growers in the region. On the other hand, drawing recommendations that too ad-hoc, after conducting systematic trails may take more 5 to 10 years also doesn't seem logical as the growers are not going to wait for this much time keeping in view the global apple industry growth. Therefore, the purpose of this article is to translate the world wide developments in apple HDP into a reckoning document on selection of apple varieties, rootstocks and planting systems for the varied agro-ecological situations of Kinnaur region of Himachal Pradesh.



2. Agro-Ecological Description of Kinnaur

Himachal Pradesh is the northern state of India and situated on the southern side of the mighty Himalayas. Though the entire region of the State falls geographically under the subtropical coordinates (75°45'55'' to 79°04'20''E longitude and 30°22'40'' to 33°12' 40''N latitude) but due to high altitudinal variation (1350 to 6975m asl) it has been divided into four agro-climatic zones viz. i) Sub-tropical low hill and valley zone, ii) Sub-temperate mid hill zone, iii) Humid temperate high hill zone, iv) Dry temperate zone. The Kinnaur region largely falls under the dry temperate zone in the three high mountain ranges viz. Zanskar, Greater Himalaya and Dhauladhar enclosing very narrow valleys of Satluj, Sapiti, Baspa Rivers and their tributaries.

The altitudinal variation of the region greatly adds to the variation in the temperature and rainfall in the region. The entire region experiences long winters from October to May. The lower parts of Sutlej and Baspa basin in the Dhauladhar ranges are comparatively warmer and receive monsoon rains to some extent but the upper Zanskar and Greater Himalayan region falls mainly in the rain shadow area therefore remains dry for most part the year. Therefore, as we move higher along the Sutlej and Sapiti basin the dryness of the region increases. Here more than 60% of the precipitation is received in the form of snow during winters. The soil conditions are sandy, sandy loam, stony and gravel, in general. These soils are generally known as virgin soils which are usually poor in fertility. The region suffers with severe erosion due to steep slopes, high wind speed and flood irrigation. Therefore, depending upon the above described features and other factors like topography, soil type, precipitation, temperature and land use the district has been classified into three agro-ecological situations (AES) which are described here under in Table 1.

Table 1: Different Agro-ecological situations of district Kinnaur and their physiographical attributes

Name of AES	Altitude (m asl)	Rainfall (mm)	Soil type	Topography	Temp.	Cultivated Area (ha)	% of Total Area	Representative Villages
AES-I High Hill Wet Temperate	1400-2100	>500	Inseptisol&Entisol (Sandy Loam)	Hilly Terrain	4 to 30	2358	31.02	Chaura, Nichar, Bari etc.
AES-II High Hill Temperate	1800-2800	200-500	Inseptisol (Sandy)	Steep Slope	-10 to 25	2798	36.81	Kalpa, Pangi,Kothi,Peo etc.
AES-III High Hill Dry Temperate	>2800	<200	Inseptisol (Sandy)	Steep Slope	-18 to 25	2446	32.17	Pooh, Nesang, Leo etc.

Source: Strategic Research and Extension Plan of District Kinnaur, Kinnaur 2009

The AES-I falls in the Dhauladhar ranges and experience highest rainfall amongst all the three. Here apple is main avocation of the people along with the agricultural crops like wheat, barley and vegetables to some extent. AES-II and III are dryer and apple is the main avocation of the inhabitants of this region. Here people grow minor millets like ogla, phaphra, koda and also rajmash and peas as second priority crops.

3. Climatic Vulnerability and Agro-climatic Challenges

A number of researchers have studied Himalayas in respect of the climate change. Shrestha et al. [10], Brohan et al. [11] and Diodato et al. [12] have reported that during the past few decades the Himalayan and Tibetan Plateau regions have been warming at a rate higher than the rates observed during the past century. They showed a 0.5°C increase in the

average maximum temperature during 1971and 2005 when compared to 1901-1960. Similar trends of increasing temperature in the Himalayas have also been reported by Dash et al. [13], Bhutiyani et al. [14] and Dimri and Dash [15]. Smadja *et al*. [16]reported that in the Himalayas, where the increase in temperatures is higher than the world average, climate change is expected to impact water resources in a significant manner. There are a number of studies whichhave reported depletion of natural resources with the progression of climate change and reported that crop production system is going to be more complex as this change is expected to stay. Therefore, the Kinnaur region which is a constituent of Dhauladhar, Zanskar and The Great Himalayan mountain ranges is not an exception and is expected to face these challenges in the years to come. Therefore, the choice of apple production system, which is the backbone of the economy, should be smart enough to sustain the impacts of climate change in the region. Though the specific data on impact of changing weather variables on apple production in the region is not available but we can learn a lesson from the Kullu region where, it has been observed that the 0.58^0C rise in temperature from the year of 1963 to 2007 with the average increase in minimum temperature rose 2.75^0C has led to a great shift in apple cultivation from lower valley region to the upper hilly region. About 80% of reduction in yield was estimated due to irrigation water shortage and 20% due to high evaporation rate in apples [17]. Apart from these direct effects, the physiological functioning of the plants also gets affected due to changing climatic parameters. Wagenmakers[18] conducted a simulation study on impact of weather variables on dry matter partitioning and potential apple yield. He reported that in seasons with 'good' weather, fruit production could easily be 25% higher than thatunder 'bad' conditions. Therefore, keeping in view the present state of climatic vulnerability, the agro climatic challenges in respect of apple HDP of different agro-ecological situations of Kinnaur region have been summed up as under:

Table 2: Agro-climatic and other challenges in respect of intensive farming under different agro-ecological situations of Kinnaur district

Challenges	AES-I	AES-II	AES-III
Rising Temperature Stress	Medium	Low	Very Low
Low – desiccating Temperature stress	Medium	High	Very High
Rainfall Stress	Low	High	Very High
UV irradiance level	Medium	High	Very High
Length of growing season	Medium	Low	Very low
Availability of water for irrigation	Medium	Low	Low
Irrigation Management capacity of the growers	Low	Low	Low
Farm formation	Small terraced	Small, Terraced, pockets of cultivated land masses	Very Small, Stripped fields, Patchy- very small cultivated land masses
Majority Soil type	Sandy Loam	Sandy	Sandy
Soil fertility status	Low	Very low	Very Low
Availability of quality germplasm	Low	Very Low	Very Low
Pest & Disease vulnerability	Very High	High	Medium
Awareness of growers to climate change resilient practices	Low	Very Low	Very Low
Capital Investment capacity of the Growers	Low	Very Low	Very Low
Orchard Management, transportation and marketing Risks	Medium	High	High
Fruit Quality Appreciation	Medium	High	Very High

Very low < 15% of the Standard, Low <25% of the Standard Medium <50% of the Standard, High= Standard Average, Very High = Above Standard Average

From the information presented above in Table 2, it can be inferred that the agro-ecological and other crop production challenges are low to medium under the AES-I but under the AES-II these are in the high range whereas under these are quite daunting under the AES-III. But, as the level of challenges increases across the AESs the corresponding appreciation factor also increases in terms of quality of produce and the incidence of pests and diseaseswhich renders good market price to the growers. The apple HDP system is quite cost intensive [19, 20]hence the capital investment capacity of the growers has also been taken into consideration the while working on the challenges. From the information above it can be observed that the capital investment capacity of the growers of all the AESs is low to very low which render them highly vulnerable to orchard management debit in case of low returns from the HDP production system. Worldwide there is increasing concern for the socio-economic improvement and agro-ecological sustainability of the cold dessert regions as the inhabitants of these regions are quite are quite vulnerable to the consequences of global climatic change.

Multi-dimensional efforts are gaining importance for consolidating scientific knowledge on farming, food security and environmental conservation in the cold dessert areas. Integration of the knowledge on climatic factors, crop production factors and the socio-economic status of the local inhabitantshave been considered must by a number of researchers across the globe for planning sustainable crop production strategies for these regions[21, 22, 23]. The information presented above is therefore has been considered pivotal for evolving reckoning data on sustainable high density planting system for the varied agro-ecological situations of the Kinnaur region.

4. Performance Reckoning of different rootstock, cultivar and planting density combinations

The reckoning data on Expected Performance Score (EPS) for apple HDP with different rootstocks, cultivar and planting densities combinations (RCP) were generated in respect of the agro-ecological challenges were generated on the bases of abundance of information available in the literature, experts' weighted score and subjective data available from experimental and growers farms. The abundance of information available for a particular RCP, the subjective data from experimental and farmers' orchards and expert opinion served as sources of information on EPS of a given RCP. The data were simulated in respect of free central leader system of training considering all other

production variables constant. The RCP combinations, for which no information was available was treated as missing plot for which data were generated as per procedure described by [24] for several missing plot technique. The information available from all the above said sources was transformed on to a scale of 0 to 100, depicting zero for non-performer and 100 for excellent performer. Each information source was treated as a replication and the data were analysed statistically as per standard procedures described for the randomized block design by [25].The details of the RCP combinations for which the EPS was reckoned are as under:

Rootstocks (Seedling and clonal):

1) Crab Apple seedlings: Local Crab apple(Pallu)
2) Golden Delicious Apple seedlings
3) Highly Dwarfing: M-27 and others
4) Dwarfing: M-9 and others
5) Semi Dwarfing: M-7, MM-106, M-4, M-24 and others
6) Semi Vigorous: MM-111, MM104 and others
7) Vigorous:Merton-793 and others

Cultivars

1) Standard: Royal Delicious, Red Delicious, Rich-a-Red etc.
2) Standard Colour Mutant: Vance Delicious, Top Red, skyline Supreme etc.
3) Standard Early Colouring &High Yielding Types: Red Velox, Jeromine, King Roat, Early Red One
4) Spur Types: Red Spur, Well Spur, Oregon Spur, Red Chief, Scarlet Spur etc.
5) Spur Types Early& High Colouring Types: Super Chief, Scarlet Spur-II, Oregon Spur-II,Red Cap Valtodetc.

Planting Densities

1) Standard : 180 tree/ha
2) Medium : 400 trees/ha
3) High : 1111 trees/ha
4) Ultra High : 4444 trees/ha

The EPS data for different RCP combinations in respect of the different agro-ecological situations presented in Table 3 reveal that under AES-I the combination *4ez* scored highest ESP value though it statistically it has been found at par with the EPS values of *4cy*, *2ey*, *6ey*, *5by* and *1ey*. There were other combinations also which were above average performer but these were not statistically superior to the above said combinations. Therefore, it may be inferred from the above said information that for AES-I the raising of ultra-high density (4444 plants/ha) apple plantations with all spur types on dwarfing rootstocks like M9, may be highly beneficial; high colouring spur types may give additional edge over the normal spur types with this combination of rootstock and planting density. Equivalent performance of these spur types have been expected under high density (1111 plants/ha) if raised onGolden Delicious, semi-dwarfing & Semi-vigorous clonal

Table 3: Expected performance Score (EPS) for different rootstock, cultivar and planting Density Combinations of apple for different AES of Kinnaur District

R-C-P	AES-I	AES-II	AES-III
1aw	58	61	64
1ax	74	72	76
1ay	56	74	73
1az	42	75	85
1bw	54	66	64
1bx	56	71	77
1by	47	72	78
1bz	41	71	82
1cw	50	66	72
1cx	71	64	81
1cy	72	82	87
1cz	64	74	81
1dw	64	63	67
1dx	75	70	78
1dy	78	90	88
1dz	76	72	79
1ew	67	61	52
1ex	72	76	64
1ey	85	87	66
1ez	76	72	80
2aw	58	61	57
2ax	56	75	68
2ay	44	44	81
2az	41	43	71
2bw	42	61	62
2bx	51	68	84
2by	55	44	73
2bz	44	41	74
2cw	51	62	63
2cx	62	80	75
2cy	66	82	82
2cz	63	82	76
2dw	54	71	71
2dx	74	78	77
2dy	81	80	82
2dz	75	80	78
2ew	66	61	70
2ex	74	82	80
2ey	90	82	79
2ez	76	83	78
3aw	42	52	49
3ax	51	62	44
3ay	53	64	43
3az	61	55	47
3bw	51	51	44
3bx	63	64	47
3by	64	62	46
3bz	77	61	45
3cw	48	51	46
3cx	57	62	47
3cy	62	61	48
3cz	72	82	40
3dw	33	53	45
3dx	35	66	49
3dy	36	64	51
3dz	37	62	54
3ew	38	53	52
3ex	31	62	53
3ey	33	61	53
3ez	34	67	52
4aw	34	66	62
4ax	61	74	73
4ay	66	87	71

4az	65	71	74
4bw	36	63	65
4bx	78	72	70
4by	81	87	76
4bz	78	88	72
4cw	42	63	59
4cx	76	72	73
4cy	90	86	74
4cz	83	74	68
4dw	37	63	65
4dx	38	69	67
4dy	89	78	76
4dz	80	86	71
4ew	32	68	56
4ex	33	76	78
4ey	76	73	79
4ez	92	85	65
5aw	34	70	66
5ax	75	80	78
5ay	81	87	87
5az	68	82	85
5bw	32	71	60
5bx	61	80	74
5by	86	88	71
5bz	65	80	73
5cw	32	71	62
5cx	63	80	72
5cy	75	88	73
5cz	74	80	71
5dw	32	71	64
5dx	69	84	77
5dy	73	90	84
5dz	82	83	90
5ew	38	71	66
5ex	72	81	77
5ey	76	82	76
5ez	81	93	81
6aw	62	66	66
6ax	72	71	77
6ay	66	72	82
6az	66	73	74
6bw	52	64	66
6bx	67	76	78
6by	68	77	81
6bz	75	78	80
6cw	64	66	66
6cx	73	74	77
6cy	81	73	78
6cz	76	74	79
6dw	64	65	70
6dx	72	75	82
6dy	81	84	92
6dz	76	77	83
6ew	57	67	71
6ex	78	76	80
6ey	86	82	81
6ez	79	71	77
7aw	52	53	62
7ax	52	64	72
7ay	50	63	77
7az	51	64	76
7bw	41	56	65
7bx	56	62	73
7by	54	64	74
7bz	50	69	73
7cw	44	53	62
7cx	61	61	75
7cy	68	62	79
7cz	66	63	78
7dw	44	58	67
7dx	75	67	77
7dy	73	82	84
7dz	68	62	78
7ew	38	54	69
7ex	71	63	74
7ey	73	81	80
7ez	72	62	76
$CD_{(0.05)}$	6.44	6.12	5.11

and local crab apple rootstocks. Standard early colouring and high yielding types have been expected to perform equally if raised on dwarfing or semi-dwarfing rootstocks. Similarly, for AES-II the best reckoned rootstock-cultivar-planting density combination was *5ey* though statistically it was at par with *5dy*, *4dz*, *4by*, *1dy*, *1ey* combinations. It implies that semi-dwarfing clonal rootstocks in combination with high colouring spur types have been reckoned as best performer at high density (1111 plants/ha) with all spur types for these agro-ecological situations, similar performance may also be expected from other spur types on these rootstocks and planting density. The HDP with the combinations of dwarfing root stock and standard colour mutants or with crab apple rootstock with spur types may give similar performance under these situations. Further, for the ultra-high density combination of dwarfing rootstocks and normal spur types may prove better for AES-II i.e. medium dry temperate conditions of Kinnaur. For the AES-III, the combination *6dy* was reckoned as best performer though it was statistically not superior to *5dz*, *1dy*, *5ay* and *1cy*. Therefore, under the extreme dry temperate conditions of Kinnaur, semi-vigorous clonal rootstocks have been reckoned best for high densityorcharding (1111 Plants/ha) in combination with spur types which have also been reckoned good for ultra-high density on semi dwarfing clonal rootstocks under these conditions. Performance of spur types also expected good with crab apple seedling rootstocks if raised at High density under these agro-ecological situations.

5. Discussions

The crop production conditions are quite challenging under the varied agro-ecological situations. Rational decision on the choice of rootstock, variety and planting density apple high density orcharding under these agro-ecological situations is therefore the major determinant of economic viability of this intensive production system. Sound scientific reports with precise recommendations on this aspect of crop production under these situations are scares therefore, reckoning data projecting low level of inequality between the prediction and realization values are of great significance today. The above presented data in Table 3are in close proximity with the findings of a number of scientists who have worked closely on the performance evaluation of high density orcharding under different agro-ecological situations. For example,Sansavini*et al.*[26] compared the yield efficiency of high-density plantings (HDP) of dwarf apple trees on M.26 (5000 per ha in 'bed systems' with cvs. 'Cooper 4 spur Red Delicious' and 'Yellow-spur Golden Delicious'), trained as free central-leader trees until the fifth year, with bearing capacity and fruit quality with those of medium-

density plantings (MDP) with 1666 trees/ha, with palmette hedgerow training, of the same cultivars and rootstock. The main differences they observed were: Accumulated crop per tree was always greater in the medium density plots. Per hectare, it was around 50% greater in the high-density 'Yellowspur' bed system whereas it was only slightly higher for bed systems of cv. 'Cooper 4', which showed alternate bearing. Yield efficiency of the tree was always greater in the MDP, as was fruit size even though there were fewer apples per tree in the HDP plots. Significant performance impact they also reported due to varietal component. Fruit qualitywas also reported to be reduced by the excessive density; there were fewer apples per tree in the HDP plots. Significant performance impact they also reported due to varietal component. Fruit quality was also reported to be reduced by the excessive density; ripening began earlier and was more uniform on MDP, as revealed by skin brightness, lower acidity and firmness (in 'Cooper 4') and greater sugar content (in 'Yellowspur'). Light intensity at noon-time in the lower and upper halves of the canopy of 'Cooper 4' trees ranged, on the average, from 18% to 52% of full daylight in HDP and from 33% to 75% in MDP *i.e.* 1666 plants/ha. In North-Eastern Italy, the yield and fruit quality of six cultivars and three planting densities were compared by Costa et al. [27] for determining if high density plantings (HDP) would be appropriate for apple cultivation. 'Golden Reinders', 'Jonagored', 'Staymared', 'Braeburn' and 'Fuji' all grafted on M.9 and planted in March 1992 at 2,778, 4,444 and 6,667 trees.ha^{-1}. In addition, 'Red Chief, a 'Red Delicious' spur-type clone, was grafted on M.26 and planted at 4,167, 6,667 and 9,524 trees.ha^{-1}. They reported that in general all cultivars performed well in a HDP orchard and began cropping early. 'Braeburn', 'Fuji', 'Staymared' and 'Red Chief' started to crop substantially in the second year. High and medium planting density performed better than low planting density. In another study, in order to determine appropriate Malling or malling-merton rootstock and densities planting for apple cultivar Red Delicious in Meshkinshahr region;Pirayesh*et al.* [28] carried experiment for five years period and compared two planting densities at (4*2 and 4*3 m) and three rootstocks, M9, M26, and MM106. They reported that Red Delicious apple trees on MM106 and M9 had biggest and lowest trunk diameter, canopy per tree, tree height and branch length, respectively. Planting densities have significant effects on vegetative characteristics too. Trunk diameter, canopy per tree on each three rootstocks (MM106, M9, M26) in low density was bigger than high density. Yield at high density was higher than low density planting. But, flower density per tree at low planting density was higher than other. Fruit size at low planting density was bigger than high planting density, and fruit size on M9 was bigger than other rootstocks. Results showed that apple cultivar Red Delicious on M9 had highest yield but yield on M26 and MM106 was similar. Apple cultivar Red Delicious on M9 and M26 rootstocks had highest and lowest flower density respectively. Dr. Y. S. Parmar University of Horticulture and Forestry, Solan after experimentation at its regional station Mashobra has recommended adoption of high density plantation on flat, fertile and moisture sufficient areas; high density planting of Vance Delicious and Top Red on MM106 rootstock (2222 plants/ha) have been reported to show the yield potential of 3-4 times higher than standard plantation.

Table 4: Ready Reckoner for Rootstock-Cultivar and Planting Density Combinations for different AES of Kinnaur District

AES-I	AES-II	AES-III
HDP: -Dwarfing Clonal Rootstocks-Early colouring & high yielding Standard cvs, -Semi vigorous clonal rootstocks-Early & High colouring spur types -Semi dwarfing clonal rootstock-Standard colour mutants -Seedling rootstock-Early & High colouring spur types, UHDP: -Dwarfing Clonal Rootstocks- Early colouring Spur cvs.	HDP: -Semi dwarfing clonal rootstock-Standard, colour mutants, early colouring & High yielding cvs. -Crab apple seedling rootstock-Early & High colouring spur types -Dwarfing clonal rootstock-Standard or early colouring & High yielding cvs. UHDP: -Dwarfing clonal rootstock- Spur type cvs.	HDP: -Semi vigorous clonal rootstock-Spur type cvs. -Semi Dwarfing clonal rootstock-Standard cvs. -Crab apple seedling rootstock-Early Colouring & high yielding standard cvs. UHDP: -Semi dwarfing clonal rootstocks-Spur type cvs

From the foregoing discussions it has been concluded that the challenges are quite variable across the agro-ecological situations of the Kinnaur region hence to facilitate the critical assessment of the rootstock, cultivar and planting density combinations at layman level ready reckoner presented in Table 4 may be followed for avoiding economic losses under the high density production system.From the information enlisted in this table it may be concluded that for the partial wet temperate conditions of Kinnaur *i.e.*AES-I, it is better to raise apple HDP withearly colouring& high yielding standard cultivars grafted ontodwarfing clonal rootstocksor with early &high colouring spur types on semi-vigorous rootstocks. Almost similar performance may also be expected from the combination of semi-dwarfing rootstocks and standard colour mutants of apple. For raising ultra-high densities in one may go for combination of dwarfing rootstocks and early colouring spur types under these agro-ecological situations. For the medium dry temperate conditions *i.e.* AES-II, it has been speculated that semi-dwarfing rootstocks may be combined with standard colour mutants or early colouring& high yielding cultivars for raising best performing apple high density plantation. For raising ultra-high densities, combination of dwarfing clonal rootstocks and the spur types has been reckoned better for these situations. Under the dry temperate conditions *i.e.*AES-III thecombination of spur type varieties with semi-vigorous clonal may yield better results followed by the standard cultivars raised on semi-dwarfing clonal rootstocks.The early colouring& high yielding standard cultivars on crab apple rootstocks may also perform same under these situations. For raising ultra-high densitiesthe spur types may be raised on semi-dwarfing rootstocks for attaining the sustainable production under these agro-ecological situations. Due to lack of any type of recommendations for apple HDP under Kinnaur region, these reckoning studies may be followed in consultation with the experts while planning any new apple HDP in the Kinnaur region. For translating these reckoning findings into absolute recommendations, further validation

through location specific research will be done in the due course of time for the varied agro-ecological situations of the Kinnaur region.

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