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RESEARCH ARTICLE

Factors for the Consideration to the Establishment of Commercial Fruit Orchards in the Mid-Hills of Nepal

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ABSTRACT

The mid-hill of Nepal has favorable agro-climatic conditions for temperate fruits like apple, pear, peach, plum, apricot, kiwi, walnut, etc. Despite their high potential, commercial orchards in the region often fail to deliver expected returns due to poor planning, limited technical knowledge, and weak market linkages. The objective of this study is to comprehensively review the major factors influencing the successful establishment and sustainability of commercial fruit orchards in mid-hill regions of Nepal. This review synthesizes information from secondary sources, including government reports, journals, extension manuals, articles, and technical reports. The fruit crops information was compared to highlight crop-specific requirements, management practices, and value-chain opportunities. The findings from the review reveal that the success of an orchard depends on matching crop choice with climate and soil suitability, adopting appropriate rootstocks, and designing the orchard with appropriate spacing, irrigation, and drainage. For long-term productivity, training, pruning, canopy management, and integrated pest and disease management are critical. Harvesting at the proper time and maturity indices, appropriate handling, and storage can reduce post-harvest losses. Furthermore, market research, value addition through processing and product diversification, and branding are equally important for enhancing returns. This study highlights the need for a holistic approach that integrates technical practices with market and value-chain planning, convincing the audience of its effectiveness in realizing the full potential of temperate fruit orchards in the mid-hills of Nepal.

Key words: Orchard establishment, Temperate fruits, Mid-hills, Commercial horticulture, Commercial fruit orchards, Agro-climatic regions

INTRODUCTION

Nepal primarily is an agrarian country, where 57.30% of the total population relies on agriculture as well as related activities, contributing 24.12% of the total gross domestic product (MoALD, 2022). Approximately 86% of the area of Nepal is occupied by mountains and hills, and the remaining 14% by the terai (Kafle, 2009). Nepal accommodates a wider biodiversity, and this also applies to the cultivation of diverse biotypes of fruit species. The horticulture sector contributes approximately 15% to the country's agricultural GDP, with nearly half of this contribution coming from fruits (Atreya, 2016). Mid-hills can support a range of fruit species, from subtropical to temperate (Devkota, 1999).The mid hills of Nepal, ranging from 700 to 2400m, provide diverse agroecological zones suitable for both subtropical and temperate fruits. In lower mid-hills ranging from 1000-1800m, there is potential for the cultivation of warm temperate fruit species, including pears, peaches, plums, and citrus. While higher mid-hills, ranging from 1800-2800m, are suitable for temperate fruits such as apples, walnuts, and vine fruits including kiwifruits. These fruit crops play a great role in rural livelihoods but establishing commercial orchards requires careful consideration of various factors such as agro-climatic, soil, and socioeconomic conditions to ensure long-term sustainability (Joshi et al., 2024).

The fruit cultivation in Nepal began with home gardens, which was formalized in 1952 with the introduction and evaluation of exotic germplasm by the government. This exotic germ plasm refers to plant materials such as seeds, cuttings, or other tissues that

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are collected from plants grown outside of Nepal, often from other countries, and then introduced into the local agricultural system. The systematic research started in 1967 with the establishment of the Department of Horticulture and regional farms, with strong government support from the Fifth Plan onward. Successive development plans prioritized orchard establishment, commercial fruit production, and poverty reduction, expanding in area, productivity, and impact on the fruit industries (Kaini, 2007).

Horticultural fruit orchards are of long-term investment, which takes 4 to 5 years or more for first commercial harvest, involving high upfront costs and risks. However, with proper management, they can be profitable. In Nepal, there are challenges such as poor soil, steep land slopes, and erratic rainfall, which demand sustainable practices. These practices, such as on-site selection, quality planting materials, soil and water conservation, low-cost irrigation, pest management, and efficient harvest to market planning, are essential for success (Pandey, 2017; Bajgain et al., 2024; Joshi et al., 2023). The commercial fruit production, which involves the cultivation of fruits on a large scale with the primary goal of selling the fruits in the market, rather than for domestic production, is a complex process. It comprises a wide range of activities, all aimed at producing high-quality fruit for profit. In Nepal, MoALD/FDD has identified major temperate fruits, development regions, and districts (Table 1).

Multiple factors are to be considered before establishing an orchard because an orchard is a long-term investment (often 20-50 years) and needs proper planning and expertise. An orchard has to face poor yields and losses if the site or crop is not well chosen. This review identifies and synthesizes information on practices of major fruits in mid-hill of Nepal, including Apple, Apricot, Citrus, Kiwifruit, Pears, Peaches, Plums, and especially major factors influencing the successful establishment and sustainability of commercial fruit orchards.

MATERIALS AND METHODS

The review article has been prepared in narrative form, searching key words with identification of research, extension manuals, and government reports on fruit cultivation, practices, pests and diseases management, harvesting practices, postharvest management of various fruits, including apple, pear, apricot, citrus, and kiwifruit in Nepal. Literature was searched in Google Scholar, Research Gate, NepJOL, FAO, Science Direct, CABI Library, and the Horticulture Society using keywords such as "Harvest Maturity", "Harvesting Practices", "Cultivation Practice", "Disease and Pest Management" on studies published from 1900 to 2024.

While screening, only peer-reviewed articles, open-access papers, and credible reports were considered, ensuring the highest level of reliability and trustworthiness. The text includes a description of the various dimensions to be considered while establishing commercial orchards including climatic factors, topography, conditions of the field, availability of the infrastructures and resources like accessibility of roads, schools, markets, banks, water resources, availability of electricity, disease and pest infestation in the area for the particular fruit crops, harvesting season, maturity indices, and postharvest handling. Furthermore, duplicated and unrelated studies were excluded from

Table 1: Prioritized districts for commercial fruit production in Nepal

Fruits	Development Region	Potential Districts
Citrus	Eastern	Taplejung, Panchthar, Terhathum, Sankhuwasabha, Dhankuta, Khotang, Bhojpur, Okhaldhunga, Udayapur, Solakhumbu and Illam
	Central	Ramechhap, Kathmandu, Lalitpur, Bhaktapur, Makawanpur, Nuwakot
	Western	Gorkha, Lamjung, Tanahun, Kaski, Syangja, Parbat, Baglung, Myagdi, Palpa, Gulmi, Arghakhanchi
	Mid-Western	Salyan, Rolpa, Rukum, Dailekh, Pyuthan
	Far-western	Achham, Doti, Baitadi, Dadeldhura
Apple	Western	Mustang
	Mid-western	Dolpa, Humla, Jumla, Mugu, Kalikot, Rolpa, Rukum
	Far-western	Baitadi, Bajhang, Bajura, Darchula
Walnut	Western	Mustang
	Mid-western	Humla, Jumla, Dolpa, Mugu, Kalikot
	Far-western	Baitadi, Bajhang, Bajura, Darchula
Pear	Eastern	Panchthar, Terathum, Dhankuta
	Central	Kathmandu, Bhaktapur, Lalitpur, Kavre, DhadhingandMakawanpur
	Western	Gorkha, Tanahun, Syangja, Palpa
Apricot	Mid-western	Jumla, Humla, Dolpa, Kalikot
Kiwi	Eastern	Illam, Dhankuta, Pakhribas
	Central	Dolakha, Kavre, Lalitpur, Makwanpur, Sindhupalchok, Nuwakot
	Western	Solukhumbu
	Mid-western	Jumla
	Far-western	Dadeldhura

(FDD 2015, Year Book, 2071/72).

the analysis. Relevant data were extracted, compared across different crops, and summarized in a table. All sources were cited using the APA 7th edition format to ensure accuracy.

Major factors to be considered for commercial orchard establishment in the mid-hills of Nepal

Agro-climatic considerations

The success of any fruit orchard begins before planting a single tree; it starts with choosing the right location. In agriculture drama, temperature plays a starring role. It's like each fruit tree has its own thermostat preference, and ignoring this can lead to poor fruit production or even tree death. Similarly, rainfall pattern and humidity levels are another important considerations (Table 2).

Site Selection and Land Preparation

Site selection and land preparation are crucial for commercial fruit production in mid-hills of Nepal.

Climate and Topography

The mid-hill zone is of generally rugged mountain topography, so the altitude can vary considerably within a short horizontal distance. The climate and the vegetation show great variation over a very short distance, and give rise to great ecological diversity and complexity (Rawat and Negi ,2021). The area of mid-hill rises towards the north and upto 30% of these slopes are worked traditionally into innumerable terraces and are extensively cultivated. This and some highly productive valleys around Kathmandu, Pokhara and Banepa, are only arable land in this region.

Crop suitability in the mid-hills is influenced by aligning the needs of different cultivars such as chilling hours, heat tolerance, and frost resistance with local environmental conditions. The fruits like mandarins and oranges thrive at lower elevations, while apples and pears require cooler sites with sufficient chilling hours. Similarly low-chill apricots do well in the lower mid-hills, and kiwifruit flourishes in moist, cool areas, provided that frost is controlled and monitoring climate conditions, utilizing chill hour and growing degree day (GDD) assessments can assist in matching crops to appropriate sites (Bajgain et al., 2024).

Rainfall is concentrated during the monsoon (June–September), with an annual average of 1,200-2,500 mm. Winters are cool and dry, with temperatures ranging from 5°C to 20°C, while summers are warm which is shown in Table 3 that summarize the climate requirement for citrus, apple, pear, apricot and kiwifruit cultivation in Nepal.

Table 2: Table showing agro-climatic requirements of different temperate fruits.

Fruit	Growing season temp (°C)	Chill hours (Dormant season)	Humidity	Annual rainfall	Key refs.
Apple	10-25 (Cool nights help quality)	600-1500hr (Depending on cultivar)	Moderate (Very high RH increases fungal disease risk)	1200-1500mm (In absence or irrigation)	(Adhikari et al.,2023; Thapa et al.,2024)
Citrus	20-30 (growth slows <12 °C)	No true chill requirement (evergreen tropical)	Moderate (60-70%), very high RH predisposes to citrus canker and fungal rot	1000-2000mm (sensitive to prolonged drought or waterlogging)	(Paudyal et al., 2016.)
Pear	10-25	800-1200hr	Moderate RH	750-1000mm + irrigation	(Devkota ,1999)
Apricot	15-28	300-900hr	Prefer drier air	500-1000mm	(Temnani, 2023)
Walnut	12-28	400-1000hr	Moderate RH	Need good soil moisture avoid waterlogging	(Sharma et al.,2022)
Peach	15-30	600-1000hr	Moderate RH	>700-1000 mm (needs irrigation in dry season)	(*Devkota 1999*)
Plum	12-28	500-1000+ hr	Moderate RH	Irrigation in dry month needed	(Kafle, 2009)
Kiwi	10-25 (frost sensitive at flowering)	600-800hr depending on cultivar	Requires high humidity (70-80%) for vine health, avoid very dry winds	1200-1800 mm, irrigation essential in dry mid-hill winter/ spring	(Pandey and Sharma,2000,**Rai 2025**)

Table 3: Climatic and topographical requirement of major fruits.

Fruit	Climate Zone	Altitude	Temperature	Soil	Rainfall	References
Apple	Temperate	1800-2800	Cool winter and moderate summer	Loamy, well drained	Moderate	Subedi, 2019
Citrus	Sub tropical	650-1450	Warm and frost free	Slightly acidic	Moderate	Sapkota, et al., 2023
Pear	Warm temperate	1450-2100	Mild winter, Warm summers	Fertile, well drained	Adequate	Atreya, 2020
Apricot	Temperate, rain shed	2100-3000	Cold winter ,dry	Slightly alkaline	Low annual rainfall	Kaini et al.,2016
Kiwifruit	Mid temperate	Varies; emerging areas	Warm summer warm winter	Fertile, well-drained, slightly acidic	Moderate - high rainfall	Rajan et al., 2024,Rai and Rai 2024a,2024b

Soil Testing

Soil testing is a crucial factor to be considered for establishment of commercial fruit orchard as it identifies soil properties such as pH, nutrient levels, texture, compaction and drainage necessary for fruit tree survival and productivity. A fertile loam soil with good drainage capacity, pH ranging from 5.5-7.5 (slightly acidic to neutral) is preferred for fruit cultivation (Table 4).

Table 4: Table showing optimum soil pH requirement of temperate fruits in mid-hill

Fruit	Optimum soil pH (Mid-hill)
Apple	6.0-7.0
Citrus	5.5-6.5
Kiwi	5.5-7.0
Apricot	6.0-7.5
Walnut	6.0-7.5
Pear	6.0-7.0
Peach	6.0-7.0
Plum	6.0-7.5

Land Clearing

Effective land clearing involves removing existing vegetation including weeds, rocks, and debris and preparing the land for tree planting. Land clearing for fruit orchards in Nepal's mid-hills involves creating terraces and planting on contour lines to prevent soil erosion on sloping terrains, a practice essential for long-term success (Devkota, 1999).

Soil Fertility

Based on the soil test recommendations, incorporate the organic matter and necessary fertilizer. Traditional manuring practices adopted in mid-hills to maintain the soil fertility are no longer sufficient to meet the nutrient demands of crop. There exist a possibilities for improving the soil status within the existing system itself, one of which would simply be to encourage better management practices while preparing and applying compost (Kaini et al., 2016).

Nursery Establishment

Seedling Production

To get quality seedlings, the establishment of nursery is important. Select suitable fruit varieties which can thrive in the mid-hill climate, acquiring certified, disease-free rootstock, and propagating them through grafting (Table 5).

Infrastructure

A screen house for rootstock production and a callusing house for grafted sapling is essential in nursery for commercial orchard establishment in Nepal's mid-hill. Nursery tools and equipment, proper irrigation facilities, and effective pest management systems are equally important.

Training

Training on nursery management, including grafting, pest management, irrigation technique, soil quality management, establishment of screen house etc is essential for the success of commercial fruit orchard. To get training, farmers should contact government bodies like the National Centre for Fruit Development (NCFD) and the Department of Agriculture (DoA), and local or international NGOs (Nepal Horticulture Society (NHS) involved in agriculture. Programs and projects, like the Horticulture Development Program (HDP) or the Nuts and Fruits in Hilly Areas Project, often provide training and technical support.

Table 5: Table showing seedling production method of temperate fruits

Fruit	Seedling production method
Apple, Pear, Apricot, Peach, Plum	Seedling rootstock + grafting/ budding
Citrus	Budding on specific rootstock
Kiwi	Seedling rootstock + grafting/ cutting (dioecious)
Walnut	Seed (difficulty in grafting)

Orchard Layout and Planting

The layout of the orchard is made at least one month before planting by marking and pegging planting points at appropriate spacing. Mid-hill should adopt contour farming system or terraced farming on slopes.

Spacing

Rectangular and hexagonal layouts gives better spacing and light penetration. Spacing should be even closer in case of high density planting using dwarf rootstock (Table 6). A standard spacing of 6 x 6 meters (approximately 20x20 feet) is often recommended for most deciduous fruit trees (Kaini et al,2016).

There are different planting system based on the fruit as per topography in mid hill of Nepal.

Citrus

Citrus which are found in Nepal's mid hills are cultivated on terrance with 4m*4m spacing and trained to vase or central leader system for better light (Paudyal et al., 2016; Acharya et al., 2024). Similarly, pollination depends on natural pollination and intercropping legumes or vegetables in young orchards improves soil fertility (Curriculum Development Centre, 2019). Sustainable irrigation system including micro irrigation is recommended to enhance fruit size and prevent decline though many farmers still use ring irrigation (Bajgain et al., 2024).

Applying regular farmyard manure (15–25 kg per plant) along with a balanced NPK fertilizer is important due to the low organic matter content in mid-hill soils. The major threats to citrus crops include citrus greening (HLB), root rots, and pests such as psyllids. Emphasizing integrated pest management (IPM) and using disease-free planting materials are key strategies for success. Recommended varieties include mandarins ("Khoka"), sweet oranges ("Junar"), and acid lime ("Thapa thali") (Paudyal et al., 2016).

Table 6: Table showing spacing and planting system of temperate fruits

Fruit	Spacing (m*m)	Layout system (Mid-hill)
Apple	4.5-6*4.5-6 (seedling rootstocks) 3*3 (HDP) (**Subedi , 2023)**	Square, contour. terrace
Citrus (Mandarin/orange)	4.5-6*4.5-6 (Kaini et al., 2016)	Square, contour
Kiwi	4*6 (trellis) R=6, P=4 (S**apkota, 2021)**	Trellis, pergola
Apricot	6*6	Square, contour
Walnut	10*10 (seedling trees) 8*8 (semi-vigorous rootstock)	Square, terrace
Pear	6*6 (seedling rootstock) 4.5*4.5 (semi-dwarf/quince)	Square, contour
Peach	5*5	Square
Plum	6*6(vigorous) 5*5 (semi-vigorous)	Square, contour

Apple

Apples are planted in mid hill to high mountains in most of the districts of Nepal like Jumla, Mustang and Dolpa with some areas adopting high density planting (HDP) to enhance returns and optimize labor management on terrace. A case study in Jumla and Mustang have shown that productivity improves when HDP is combine with careful site selection (Thapa et al., 2024). Nepalese apple growers plant trees or sapling in various planting system from modified central leader (vertical axis) to slender or tall spindle design with practices such as; minimal first year pruning, single or multi-wire trellis and pilot planar cordon layouts, the trails are in row spacing 0.6-1.2 m and inter-row widths of 3-4m adjusted for slope and mechanization (Subedi et al., 2019). Similarly dwarf or semi-dwarf rootstocks from certified nurseries are recommended for system like spindle or vertical system. High density planting should be paired with proper irrigation and nutrient management to prevent stress and pest issues (Subedi, 2023).

Pears

Pears are found cultivated in mid hill and warm temperate areas including introduced cultivar and recent phonological trails helps to localize pruning and flowering calendars (Dhakal et al., 2021). The pears in orchard are now planted at wide spacing, central leader to intensive system like slender spindle and espalier, trail of multi leader V or bi-axis aims to improve light capture and mechanization that align with cold chain for value retention (Gotame et al., 2015).

Apricot

Apricots hold cultural significance and are grown in mid to high-hill areas and trans-Himalayan regions, to minimize frost damage and improve ventilation, pruning methods like open vase or central leader are used, although only a few introduced cultivars perform well in Nepal (Devkota, 1999).

Trellis systems, such as V-shaped and planar walls, can boost early yields on protected terraces, but require careful thinning, frost management, and site selection for success (Angmo et al., 2017; Hussain et al., 2017).

Kiwifruit

Kiwifruits are now a days gaining popularity in mid-hill in Nepal. Dolakha, Chitlang, Kavre and related hill rapidly due to high market value and suitability for sloping land, Kiwi is attracting more farmers over the past decade (Sharma et al., 2020). In Nepal T-bar or pergola with a single main stem and horizontal fruiting, for high vine load pergola and T-bar system are used by smallholder (Poudel, 2022) with the spacing of 4-6m x3-5m and 1:8 or 1:12 male: female ratio using sturdy timber or cemented posts on slopes (Sherpa, 2013).

Planting time

In Nepal's mid-hills, the best time to plant a commercial orchard is during the dormant season, which is from late winter to early spring (February to April) for the majority of deciduous fruits, such as apples, pears, apricots, peaches, and plums, after the ground has thawed but before the buds have fully broken. Walnut and citrus trees may have slightly different ideal seasons, but it is also advantageous to plant when the trees are less stressed, which is frequently in the early spring or during this dormant phase.

Planting Depth

Dig hole twice the width of the root ball to encourage root spread. Fruits like apple, pear, peach, plum, apricot, and walnut should be planted at same depth as they were in the nursery condition, citrus and kiwi require slightly deeper planting with later soil mounding for drainage (Table 7). The plant should be planted in such a way that the bud union remain slightly above the soil surface.

Commercial fruit farming is increasing due to market demand where government focus on horticulture income generation (Fruit Development Project 2016). But challenges such as; poor planting material soil erosion and water scarcity affects quality seedlings, agro-ecological management and climate adaptation (FAO 2012; Poudel et al., 2019).

Table 7: Table showing planting time and planting depth of temperate fruits

Fruit	Planting time (Mid-hill)	Pit size and depth
Apple	Dec-Feb	1*1*1 m
Citrus	Jun-Aug	60*60*60 cm
Kiwi	Dec-Feb	1*1*1 m
Apricot	Dec-Feb	1*1*1 m
Walnut	Dec-Feb	1*1*1 m
Pear	Dec-Feb	1*1*1 m
Peach	Dec-Feb	1*1*1 m
Plum	Dec-Feb	1*1*1 m

Depending upon the species ,landform and in hilly region the rectangular system are common in level terraces, while contour and triangular system are suited for sloping lands to prevent runoff fertile loam soils , south facing aspects to reduce frost risk (Gotame, 2020). The spacing for different fruits varies: critrus required 4to 6 m, pears and apple is planted around 6 to 8 m whereas kiwifruit need trellis system with 1:6, male to female ratio for pollination (Poudel et al., 2019). According to Fruit Development Project, high density planting system is tested for citrus and apple which requires intensive inputs. Similarly certified seedlings and integration of mulching, intercropping and rainwater harvesting improves productivity and resilience (MoALD, 2019).

Irrigation and Water Management

Water sources

Reliable water source, such as a nearby river, spring, or constructed pond, should be ensured.

Irrigation system

Orchard and vineyard irrigation should manage the water supply efficiently, ensuring that trees and vines receive enough water while minimizing waste (Table 8). Options such as drip irrigation, micro-sprinklers, and soil moisture sensors can be commonly used to achieve this.

Water conservation

Applying organic mulches, such as compost, wood chips, or straw, around the trees in a mid-hill commercial fruit orchard can help conserve water by lowering soil runoff and evaporation. For hilly regions, use the strip mulching technique, in which mulch is spread out in rings or strips around the trees to let water in while reducing resource competition and erosion. Make sure the mulch layer is sufficiently thick to inhibit weed growth and enhance the soil's ability to retain water, both of which will ultimately aid in the survival and growth of the young trees (Bakshi, 2015).

Fertilization and Soil Management

For the sustainable management of soil and to get the optimum production and appropriate income from the fruit orchards, test soil before planting. And every 2–3 years thereafter; test for pH, organic matter, available N, P, K, Ca, Mg, and texture appears to be a mandatory and regular task. Similarly, leaf analysis is the most accurate way to monitor tree nutritional status during the growing season for perennial fruit trees, perform annual leaf tests at the standard sampling date for each crop. As orchards are long-term investments, rates and frequency depend heavily on soil supply, rootstock/crop, and cropping intensity. Before starting the establishment of the orchard, reclamation of the soil is necessary, incorporate lime if pH < 5.5 (pome fruits prefer ~6.0–6.8; many stone fruits tolerate slightly lower). Apply lime 2–6 months before planting and re-test. It is compulsory to carry out the deep ripping and subsoil work on compacted sites; ensure 60-80cm of workable, well-drained rooting zone. Apply well-rotten Farm-Yard Manure (FYM) or compost @ 10–20 t/ha in the planting row or pit (typical mid-hill Nepal practice) and incorporate recommended starter dose of P (DAP) based on soil test. Mix amendments into the planting pit (Pilbeam et al., 2005).

Table 8: Table showing critical irrigation stage of temperate fruits

Fruit	Critical Irrigation Stage
Apple	Flowering to fruit set (Mar-Apr)
	Fruit enlargement (Apr-Jun)
Citrus	Flowering (Mar-Apr)
	Fruit set & marble stage (May-Apr)
	Fruit enlargement (Aug-Sep)
Kiwi	Bud burst & flowering (Mar-Apr)
	Fruit set & enlargement (Apr-May)
Apricot	Flowering & fruit set (Feb-Mar)
	Fruit development (Apr-May)
Walnut	Flowering & nut set (Apr-May)
	Kernel filling (Jun-Aug)
Pear	Flowering to fruit set (Mar-Apr)
	Fruit enlargement (Apr-Jun)
Peach	Flowering & fruit set (Feb-Mar)
	Fruit enlargement (Apr-May)
Plum	Flowering & fruit set (Feb-Mar)
	Fruit growth & enlargement (Apr-May)

(A) Basal Application

1. Base applications on soil + leaf tests, tree age, crop load, and tree vigor.
2. Split N applications (early spring + mid-season or via fertigation) improve uptake and reduce leaching.
3. Apply P and K mostly as basal/top-dress; micronutrients are often applied as foliar sprays or soil banding.

(B) Young, Establishing trees (years 1–3)

1. Nitrogen (N): Small starter dose then gradually increase. Example: 10–50 g N/tree/year in first year rising to 50–100 g N/tree by year 3 (split into 2 applications: early spring + after fruit set).
2. Phosphorus (P_2O_5): Apply a small basal dose at planting (e.g., 50–150 g/plant DAP or equivalent depending on soil P).
3. Potassium (K_2O): Apply 50–200 g/tree/year in bands, depending on soil K.

(C) Bearing, Mature Trees (varies by species & cropping intensity)

1. Nitrogen: typical range 50–250 g N/tree/year for many pome and stone fruits; intensive, high-yield orchards may need more. Use trunk-diameter/leaf analysis to refine. Apply N as split doses (spring + mid season).
2. Phosphorus: maintain soil Olsen-P at sufficiency; top-dress 20–50 kg P_2O_5/ha/year if soil test low.
3. Potassium: many fruit trees strongly require K for fruit quality 50–150 kg K_2O/ha/year where K is low; split applications and apply near the root zone/drip line.
4. Micronutrients: Boron (B), Zinc (Zn) are commonly needed in Himalayan/mid-hill soils. Apply as foliar or soil-based on leaf test; boron often as a small periodic soil/foliar application every 2–3 years for pome and stone fruit.

Organic Amendments, Compost & Green Manures

1. Use FYM/compost regularly (e.g., 10 t/ha/year or an equivalent schedule adjusted by availability) to build organic matter, structure and slow-release nutrients, common and effective in Nepal's mid-hills.
2. Green manures and cover crops (legumes) in alleyways reduce erosion, add N and improve soil biology. Incorporate before planting or during early growth phases.
3. Compost quality matters well-matured compost avoids nitrogen tie-up and phyto-toxicity. FAO and Nepal studies show organic methods are vital for long-term soil health in mountainous agro-ecosystems.

Soil Structure, Erosion Control and Mulching

1. Mulch orchard rows with straw/leaf mulch (5–10 cm) to conserve moisture, moderate soil temperature and add organic matter as it decomposes.
2. Contour terraces, grass strips, stone bunds and maintaining permanent cover in inter-rows control erosion in steep mid-hill orchards. Soil conservation is as important as fertilizer on slopes (Pilbeam et al., 2005).

ph, Ca/Mg Balance and Salinity

1. Many fruit trees need nearly neutral pH. If pH < 5.5 apply lime (quantity from soil test). If pH > 8 or saline, choose tolerant rootstocks and manage irrigation water quality.
2. Calcium applications (soil or foliar) improve storage quality (important for apple/pear). Applying at late fruit development can reduce storage disorders.

Micronutrients (monitor & correct)

Common deficiencies in Nepal

Boron and zinc show up frequently for pome and stone fruit. Do leaf tests and apply foliar sprays of B or Zn at recommended doses rather than blanket a heavy soil applications. Over-application of micronutrients can injure trees.

Prepare and follow the seasonal calendar

1. Pre-season (late winter/very early spring): soil test follow-up, apply lime (if needed), basal P + K if soil is low P and K, first N top-dress just before bud break.
2. Early season (flowering to fruit set): small foliar feeds for micronutrients if leaf tests show deficiency; avoid heavy N during bloom.
3. Post fruit set (late spring): second N application (split) and K top-dress. Monitor shoot growth; prune to balance vigor.
4. Pre-harvest (summer): foliar calcium sprays to improve storage quality (apples/pears). Reduce N in late season to promote fruit quality.
5. Post-harvest (autumn): apply potash and organic manure/compost to rebuild reserves before winter dormancy.

Pest and Disease Management

Fruit orchards in Nepal face a range of pests and diseases that significantly impact both yield and quality across various crops (Table 9). In apple orchards, the codling moth (Cydia pomonella) is a major fruit borer, causing substantial losses of marketable fruit and remaining one of the most significant pests in pome production (Živković et al., 2011; Akroute et al., 2023). Apple scab (Venturia inaequalis) is also prevalent, producing lesions on leaves and fruits that greatly reduce both yield and quality (Jha et al., 2010). Fire blight (Erwinia amylovora), although less common, poses a severe threat due to its potential to trigger destructive outbreaks in apple and pear orchards (Aćimović et al., 2015; Adhikari, 2022).

Pear orchards are similarly affected by fire blight, which can lead to rapid tree death and significant yield losses (Sharma et al., 2024). Additionally, pear cultivation faces challenges from scab and various arthropod pests, including aphids, mites, and leafrollers, along with codling moths and other lepidopteran borers. These factors all negatively impact fruit quality and tree health (Sharma et al., 2024).

Plum production is threatened by brown rot (Monilinia spp.), which damages flowers and fruits while mummified fruits act as sources of infection during the winter. Other concerns include bacterial spot, canker, blossom blight, and insect pests such as fruit borers, fruit flies, and mites, which vary by region and cultivar (Rungjindamai et al., 2014).

Kiwifruit orchards are notably at risk from bacterial canker (Pseudomonas syringae pv. actinidiae, Psa), a global issue that has led to severe epidemics and is increasingly problematic in Nepal (Santo et al., 2024; Wan et al., 2025). Additionally, soil nematodes, including Meloidogyne and Pratylenchus species, have been reported in local kiwifruit orchards, impairing root health and overall vine vigor (Chhetri et al., 2019).

Table 9: Table showing major pest and disease with their preventive management.

Fruit	Major pest	Major disease	Prevention
Apple	San Jose scale, Codling moth, Aphids	Apple scab, Powdery mildew, Fire blight	• Select scab-resistant varieties/rootstocks. • Avoid low-lying humid areas • Quarantine nursery plants against San Jose scale
Pear	Psylla, Fruit fly, Codling moth	Fire blight, Pear scab, Rust	• Avoid highly fire blight region (warm and humid) • Use of resistant rootstock • Ensure orchard sanitation and pruning practices
Peach	Fruit fly, Aphids, Borers	Leaf curl, Brown rot, Bacterial spot	• Avoid high humid sites • Select tolerant varieties and resistant rootstocks • Ensure good drainage to avoid rot
Plum	Plum fruit moth, Aphids, Fruit fly	Brown rot, Leaf spot, Plum pox virus	• Use virus free planting stock • Maintain orchard hygiene and remove infected trees • Prefer resistant cultivars to reduce brown rot
Apricot	Fruit borers, Aphids, Fruit flies	Brown rot, Bacterial canker, Shoot hole	• Select well-drained, less humid sites to reduce brown rot • Avoid waterlogging soils • Use resistant/tolerant varieties if available
Walnut	Codling moth, Aphids, Walnut husk fly	Bacterial blight, Crown gall, Anthracnose	• Choose blight-tolerant cultivars (Chandler) • Avoid planting in heavy soils prone to waterlogging • Use crown gall-free planting stock
Kiwi	Thrips, Mites, Fruit fly	Bacterial canker	• Select canker-tolerant cultivar • Ensure good drainage to prevent root rot • Avoid sites with frequent frost (Favors bacterial canker)

Monitoring

Inspect the trees frequently in the growing season. It helps accessing the growth status and general health of the crops and determining the presence and intensity of pest infestations or the potential for future pest problems.

Integrated Pest Management (IPM)

Some IPM practices should be performed in anticipation of future pest problems. These include pruning and shaping the tree to improve air circulation and prevent disease, selecting cultivars resistant to various pests (Shrestha et al., 2025).

Record Keeping

Maintain the detailed record from monitoring, IPM and treatment applied for future reference.

Pruning and Canopy Management

Training

Support a heavy crops and facilitate early production by developing a strong tree structure.

- Central leader: Apple, Pear, Walnut
- Modified central leader: Apricot, Plum
- Open center (Vase): Peach, Apricot
- Trellis or Pergola: Kiwi vines (Deng, 2023)

Pruning:

Dormant season pruning: Conduct in late winter or early spring (Feb-March in mid-hill) before bud break to shape trees and remove dead or diseased wood. For apple, pear, peach, plum, apricot, walnut, kiwi.

Summer pruning: Control tree size and improve light penetration, especially for stone fruits like peach and plum (Lakso et al.,1989).

Canopy Management

a. Apple and Pear: Maintain conical shape for light penetration, thin fruit clusters to improve size and quality
b. Peach: Maintain open canopy to reduce disease risk, control height for easier harvesting
c. Plum, Apricot, Walnut: Ensure good air circulation to prevent fungal disease, thin fruit to prevent limb breakage
d. Kiwi: Ensure male and female vines are properly spaced for pollination, maintain canopy height for ease of management(Deng, 2023).

Harvesting and Post-Harvest Handling

Horticultural crops, including apples, pears, kiwifruits, and apricots, are highly perishable and have a short shelf-life, leading to significant post-harvest losses between harvest and consumption (Adhikari and G.C., 2021). In Nepal, post-harvest losses for fruits and vegetables range from 20-50%, potentially exceeding 50% under adverse conditions.

Harvesting Practices

Fruit color is major maturity indicator, though it varies by varieties as shown in Table.10. For kiwifruit SSC and flesh firmness are reliable maturity indices (Crisosto et al., 1984). Harvest time also affects storage behavior, respiration, ethylene production and overall sensory quality (Khodifad et al., 2016). Similarly careful handling is important as mechanical damage and bruising especially in apples, significantly reduces quality and shelf life (Subedi et al., 2016).

Post-Harvest Handling Techniques

For fruit a proper temperature and humidity is required in order to limit respiration and transpiration

Table 10: Harvesting protocol and practices of fruit

Fruit	Harvest season and maturity index	Harvesting Practices	References
Apple	Late August-October depend upon altitudes TSS(12-14 °Brix) Starch degradation index Background color change	Hand picking gentle twist or clippers which avoid stem tearing. After 7-10 days intervals multiple picking. Fruit placed in padded crates and kept shaded before transport.	(Chalise et al., 2023)
Pear	July-September Maturity judged by change in skin color from green, yellow, brownish, ease of separation from spur, firmness and sweetness.	Hand or using clippers when fruit detaches easily with upward twist. Pick in cool hours, harvest in 2-3 stages as maturity is uneven	(Gotame et al., 2015)
Apricot	June-July Ground color turns from green to yellow shows maturity and fruit soften slightly	Early morning by hand harvest avoiding picking wet fruits, separate for fresh market Vs. drying	Devkota, 1999
Peaches	May-July Fruit size, surface, colour (green to yellow to red blush)	Hand-pick with gentle twist, multiple picking to avoid over ripe, shallow crates use to avoid pressure damage.	Devkota, 1999
Citrus	November to January for mandarin, December to March for Orange. Peel color fron green to orange shows maturity Similarly TSS, acid ratio and juice content also determine maturity	Hand harvest using clippers to leave short stalk avoid pulling oil gland rupture sort and grade before pecking	Ojha et al., 2024
Kiwifruit	October-November in mid hills. Maturity Judged by TSS (≥6.5 °Brix at harvest, ripening to ≥14 °Brix), firmness and black seed colour, brown hair fall from outer layer	Hand pick to avoid puncturing skin, collecting in padded crates ,store in cool ,ventilated space and precooling is done before marketing	Sapkota et al., 2020

that can long the storage life and preserv marketable quality (Adhikari and G.C., 2021). Low temperature inhibit fungal pathogen growth that can cause fruit rot (Holb et al., 2011). Similarly packaging and cushioning helps maintaining freshness during storage and transport, where cushioning material like grass and woolen shawls reduces bruising in apple during transportation and bamboo baskets without liners results in higher fruit damage (Subedi et al., 2016).

Cold storage is one of the most effective method for storing fruits like mandarins, apples, pears and kiwifruits which maintains optimal temperatures, humidity and gas composition to reduce post harvest losses, but can reduces aroma and flavor due to decreased volatile production (Lamsal et al., 2024). In hilly areas in Nepal, cellular storage is adopted for apples and citrus, offering a low cost solution for extending shelf life.

MAP (Modified atmosphere packaging) active and intelligent packaging and controlled atmosphere storage enhances shelf life and quality retention (Adhikari and G.C., 2021). Value addition also reduces post harvest losses by converting raw fruits into products like wine, pickles, juice, jam, marmalades, brandy and ciders which are used in remote regions where fresh fruit marketing is difficult. Nepal's fruit processing industries encounter challenges, including limited access to processing varieties, which sometimes leads them to rely on imports to satisfy demand. However, product diversification such as transforming custard apples into beverages, ice cream, squash, and toffee can create new markets and harness their nutritional potential (Khodifad et al., 2016) .

Marketing and Value Addition

The fruits of Nepal, including apple, apricot, citrus, peach, plum, pear, walnut, and kiwifruit; hold great potential for income generation if systematic marketing and value addition strategies are adopted (Table 11). Investments in cold-chain, farmer cooperatives, processing industries, branding, and certification can significantly enhance their domestic and export market value. There are various cross – cutting issues in Marketing and value addition.

a. Post-Harvest Losses: A major problem due to a lack of cold storage, grading, and proper packaging.
b. Market Linkages: Dependence on middlemen reduces farmers' bargaining power.
c. Value Chain Development: Limited processing industries and a lack of certification (organic, GAP) restrict premium market access.
d. Export Potential: India and China are primary markets, but strict quality standards and weak infrastructure remain challenges.
e. Policy Support: Government initiatives like PMAMP (Prime Minister Agriculture Modernization Project) and cooperative-based marketing have helped, but need scaling.

The crop specific marketing and value addition are listed below (Table 11).

Conclusions

In Nepal, mid-hill have strong potential for commercial fruit production with a favorable climate and emerging market opportunities for fruits such as mandarin, kiwifruit, pears, apricot and apple. Similarly realizing the opportunity required needs careful attention to site selection, quality planting material,

Table 11: Table showing market research, value addition and branding of temperate fruits

Fruit	Market Research	Value Addition	Branding/ Marketing
Apple	• High domestic demand • Off-season imports-market gap	• Grading • CA storage • Juice • Jam • Chips	Brand by variety and mid-hill origin
Pear	• Stable local demand; potential if graded/ exported	• Canning • Juice • Dried chips	Variety based and geographic branding
Peach	• Seasonal fresh fruits • Short shelf-life; need processing	• Canning • Jam • Dried slices	Fresh seasonal + artisan processed goods
Plum	• Local fresh demand; prune industry potential	• Prunes • Jam • Juice	Healthy dried plum (prune)
Apricot	• Small fresh market but strong dried product demand	• Drying • Jam • Kernal oil	"Sundried mid-hill apricot", organic niche
Kiwi	• Emerging high-value crop; growing export	• Cold storage • Juice • Jam • Puree • Frozen slice	Nutritional branding, local origin
Walnut	• Import substitution • Export markets	• Drying • Shelling • Kernels • Oils	"Mid-hill walnut", premium oil

orchard design etc. while integrating scientific knowledge with local practices can enhance productivity, fruit quality and profitability. Crop specific management practices with proper care will help create sustainable and investment ready orchard addressing current knowledge gaps through research and extension will further accelerate the growth of profitable fruit farming in Nepal's mid-hills.

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