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RESEARCH ARTICLE

MECHANIZATION IN FRUIT CULTIVATION: PRESENT STATUS, ISSUES, CONSTRAINTS AND FUTURE ASPECTS OF NEPAL

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ABSTRACT

Around the world, increasing population is heightening the food and feed demand. Fruit production is playing vital role in augmented food availability, improved nutrition, livelihood, employment opportunities and economy of Nepal. Given the low mechanization in horticultural crops especially for fruits cultivation in nation, the production is by far based on physical labour source (human power). However, the rising cost and decreasing availability of farm labour has heightened interest in mechanization. There is no doubt that farm mechanization has substantial role in boosting the scale of farm operations, lessening the production cost, tumbling drudgery, enlightening the timeliness of operations, augmenting crop productivity and contributing to improve food security and rural livelihoods. This paper has attempted to give a short glimpse of fruit mechanization status and development of Nepal. It has focused more on fruit production and mechanization status, issues and research gaps, available machinery and tools of different farm operations, challenges and constraints along with way forward for fruit development. Although the country has some positive moves in fruit mechanization area (especially in tillage), the level of fruit mechanization is very poor with respect to mechanical power (especially in hills), effective tools and implements, irrigation, pest, and orchard management, harvesting and post-harvest technology areas. The physical constraints of rugged terrain and steep topography, small and fragmented turfs, lack of skilled manpower, poor facilities of spare parts, repair and maintenance, low investing capacity of the farmers, lack of awareness among farmers and non-availability of farm implements and machine based on gender and agroecology are some of the main bottleneck for low level of mechanization in the country. Despite various constraints, there is an enormous opportunity to integrate appropriate machines into most cultivation tasks in a way that optimizes productivity of land and farmer's life and economy. Making the best use of these machines requires a holistic approach that considers the ecological belt, topographical characteristics, fruit cultivar and equipment available. Therefore, a widespread participatory research method is required to test, validate and disseminate the fruit machinery and tools performance compared with traditional farming method. In fact, operation wise mechanization of orchard crops including nursery house, transplanting of saplings, pit making, spraying and weeding in tall crops and harvesting of fruits and post-harvest operations are prime intervention areas of current situation. Furthermore, immediate attention of the government and other bodies is required to strengthen and rejuvenate unproductive old orchards farm with proper tools and mechanism. Overall, this study highlights the need to prioritize and strengthen fruit mechanization research based on agro ecology and farmers need, improve credit access and spare parts, invest in technical human resources and agricultural machinery workshop, targeted subsidy for poor, women and youth friendly enterprises or real farmers following proper monitoring, incentivize local fabrication and, effective extension and custom hiring services to address the mechanization gaps and harness the potentiality of fruit development.

KEYWORDS

constraints, issues, fruit, farm operations, mechanization, migration, Nepal, status.

1. FRUIT STATUS IN NEPAL

Nepal is endowed with diverse agro ecologies, climatic and edaphic conditions favorable for the production of quality horticultural produces. The Mountain, Hills and Terai, respectively, covers 35%, 42%, and 23% of the total land area of the country (CBS, 2012). More than 80% of cultivated land in high and mid mountain regions is on sloping mountainous terrain where contour system of planting is followed. On very steep land, inward type sloped terraces are formed in order to prevent soil erosion. Fruit production is playing vital role in augmented food availability, improved nutrition, livelihood, employment opportunities and economy of nation. Due to the existence of large agro-ecological diversity within a short boundary ranging from flat lowlands and rivers basin to rugged mid hills and step mountain slopes, favorable soil conditions and ample water resources, different tropical, subtropical and temperate fruit crops are produced in different parts of the country (Table 1).

The contribution of the horticulture and cash crops commodities amounts to 15-20% of agriculture GDP (33% in nation GDP), of which fruits contributes 7.04 % (Panta and Dhakal, 2019; Atreya and Manandhar,

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2016; Acharya and Atreya, 2013). Table 2 shows the major fruits cultivation and production status of Nepal. According to table 2, the total fruit area, fruit productive area, production and productivity in the FY 2019/20 were 171318 ha, 119025 ha, 1249764 MT and 10.5 MT/ha, respectively (Khatri et al., 2021; MoALD, 2021). Citrus fruits have a total productive area of 27339 ha with 10.3 MT/ha productivity and 274140 MT production out of which mandarin contributing to productive area of 17,220 ha (60.62% acreage of the total citrus area) with 10.30 MT/ha productivity and 177,381 MT production during 2018/19 (MoALD, 2020). Likewise, sweet orange contributing to productive area of 4031 ha with 10.68 mt/ha productivity and 43061mt production during 2018/19 (MoALD, 2020). Similarly, apple farming is done in 11000 ha with the production of 32000 MT/ha. Currently, Citrus farming in mid-hill region having latitude: 26° 45'-29° 40'N and longitude 80° 15'-88° 12'E (Bhattarai et al., 2013; Timilsina and Tripathi, 2019) is becoming an attractive business proposition due to unique favorable topography and agro-climatic condition and demand in the national and international market (Khatri et al., 2021, Khatri et al., 2022).

Table 1: Fruit Types in Different Agro-Ecological Zones of Nepal

S.N	Zones	Features	Fruits
1.	Tropical	Temperature: greater than 24^{0}C Altitude range: less than 1000m Terai and low valleys of hills	Mango, Litchi, Banana, Jack fruit, Papaya, Pineapple, Coconut, Avocado etc.
2.	Sub-tropical	Temperature:17-24^{o}C Altitude:1000-1500m Lower mid hills and low high hills	Citrus fruits (Mandarin, Sweet orange, Lemon etc.), Guava, Pomegranate, Avocado, Kiwi, Strawberry, Grapes etc.
3.	Mid temperate	Temperature:10-15^{0}C Altitude: 1500-2000m High hills, mid hills, base of high hills	Peach, Pear, Plum, Apricot, Strawberry, Almond, Chestnut and mid deciduous fruits etc.
4.	Temperate	Temperature: less than 10 ^{0}C Altitude: 2000-3000m High hills and Mahabharat lekh	Apple, Pear, Peach, Walnut, Apricot and other temperate fruits etc.

Table 2: Status of Fruits Cultivation in Nepal for Fiscal Year 2019/2020 (MoALD, 2021)

S.N	Fruits Type	Total Area (ha)	Productive Area (ha)	Total Production (mt)	Productivity (mt/ha)
1.	Citrus fruits	46715	27339	274140	10.3
2.	Winter fruits	31940	16318	116802	7.16
3.	Summer fruits	92664	75368	858822	11.40
Total		171318	119025	1249764	10.50

Citrus fruits: mandarin, sweet orange, lemon etc., winter fruits: apple, pear, walnut, peach, plum, pomegrate, kiwi etc., summer fruits: mango, banana, litchi, papaya, guava, jackfruits, pineapple, coconut etc.

2. Status of Fruit Mechanization

Agricultural mechanization formally started in the 1970s with the advent of two and four-wheel tractors in Nepal (Takeshima, 2017). Mechanization during the early period typically referred to as tractorization (especially tillage), instead of encompassing whole sets of manually operated, animal drawn equipments and smaller machines (2-wheel tractors, water pump sets etc.) in Nepal. The mechanization level was relatively low and poor until a few decades ago. Consequently, animate power is the main source of power in Nepalese agriculture. For instance, upto 2011/12, human power and animal power occupies 36.3 and 40.5%, respectively of the total farm power available in the country. The available mechanical power in the country is only 23% out of which most of the mechanical power (92.28%) is concentrated in Terai belt of Nepal (FBC, 2006; AED, 2013; Shrestha, 2012). Until the development of agricultural development strategy (ADS) by government, agricultural mechanization was neglected and not included in any policies, but ADS highlighted the importance of agriculture and rural mechanization (ADS, 2013).

Policymakers in Nepal have recognized mechanization as an important intervention for addressing agricultural labor scarcity. As a result, the Government of Nepal promulgated an agricultural mechanization policy in 2014, subsequently following the formulations of several other related promotion policies which also increased its priority in agricultural sector. Furthermore, increasing road connectivity, improved accessibility of electricity and other infrastructure in rural hills and mountains is slowly changing the people's life pattern and agricultural scenario of these parts in recent years. Many green revolutions have come about in Nepalese mechanization due to the spread of larger 4WT and combine harvesters, shallow tube wells, power tiller in Terai periphery and smaller scale equipment such as two-wheel hand tractors (mini tiller), drip and sprinkler irrigation, small threshers, sheller, harvesters, sprayers and smaller-scale water pump in hills. In the last 10 years, there have been some encouraging movement to enhance the fruit mechanization work in mid and high hill areas. Likewise, there is an increasing attraction of returned migrant youth in commercial agriculture and use of modern machineries.

Most district headquarters are connected by roads. For instance, remote districts (Manang, Mustang, Kalikot and Jumla) are also connected by road. It has opened new avenue for the promotion of high value horticultural products such as apple, walnut, almond, saffron, etc. for both export and import substitution (Pradhan et al., 2022). In addition, agricultural machinery was often heavily subsidized (50-75%) with capital grants and low-interest loans by different governmental bodies (Biggs and Justice, 2015). Government also prioritizes the mechanization by imposing very liberal import policy with tax exemption for agricultural machinery and equipment such as tractors, harvesters, agricultural water pumps, secatures, power weeder, chain saw, earth auger etc. Recently, Nepal has progressed significantly in developing fruit plant propagation technologies with different methods of grafting including stone grafting in mango, shoot tip grafting in citrus, etc. Biotechnology such as tissue culture is contributing to produce disease free saplings in banana and citrus. Water harvesting and multiple use water system like drip and sprinkler irrigation technology are contributing to efficient utilization of water in nursery and orchards (NHPC, 2017).

Importantly, the spread of small horsepower 2-wheel hand tractors or mini tiller in rural and mountainous areas is a relatively new entrant onto the mechanization scene of Nepal where power tiller is too large for the small and narrow terraces, and difficult access condition. However, most of the tillers were used for plowing purpose only. Different attachments such as bed former, digger, seed drills, irrigation pumps, spraying pump and trolley are introduced recently in Nepal to diversify the use of mini tiller and to increase its annual working hours. In addition, various agricultural machineries and equipment are increasingly being used in the horticultural, poultry, dairy and animal feed industries mainly through private sector initiatives based on agricultural and other rural resources (Gauchan and Shrestha, 2017; Gauchan and Shrestha, 2014). As a result, overall agricultural mechanization status of Nepal reached 40% in which terai, mid hills and mountains constitutes 61, 15 and 2% respectively (Agricultural Mechanization Promotion Operational Strategy) (Ghimire, 2021). The ultimate goal of operational strategy is to reach mechanization level upto 70% by 2025. Likewise, the total farm power availability on Nepalese farms has increased from 0.22 kW/ha in 1990 to 0.67 kW/ha in 2016/17 and targeted to reach 1.19 by the 2025.

The total number of four and two-wheel tractors (power tiller) registered in Department of Transport Management had reached 163126 in F/Y 2020/21 (DOTM, 2021). But not all of these are used in agriculture because a large percentage of the registered tractors are used in non-agricultural purposes such as construction material and other goods transportation. Additionally, the total number may vary as power tiller operating only in agriculture are not registered. In a similar way, there is no provision for small mini tiller to register in transport department, so it is actually difficult to state the exact current population of mini tillers in

Nepal. However, there is an approximate population of more than 50,000 mini tiller in Nepal with 90% mini tiller adopted in hills and mountain (Ghimire, 2021).

In recent year, approximately 20000 to 25000 mini tillers are imported yearly from different countries such as China, India and other countries to Nepal (personal communication with Krishna Sharma, SKT company). It is also estimated that about 30 % of the registered tractors and above 80% of registered power tillers and 100 % mini tillers are actually used in agriculture in which most of the power tiller are solely concentrated on Terai and plain flat lands of hills (Gauchan and Shrestha, 2017; Shrestha, 2012). Moreover, in Nepal, mechanization is mostly concentrated on cereals-based crops such as rice, wheat and maize. In contrast, the fruit cultivation seems very less mechanized with respect to different operations. As far, soil tillage/land preparation operation seems more mechanized than other operations that are still awaiting proper mechanized tools.

3. Issues and Need of Mechanization in Fruit Production

Agricultural labor scarcity is one of the utmost problems in Nepalese agricultural sector due to rapidly increasing trends of male out-migration to city and abroad (especially gulf countries) in search of better employment opportunities and income which also increased wage rates in rural areas. The number of draft animals and the labor force in Nepal is decreasing due to the labour out migration, feminization and increasing trend of keeping milking cattle overdraft animals because of an emerging dairy industry. Furthermore, in hilly regions of Nepal, bullocks are only used to plow land, and the opportunity cost of raising them is much higher due to lack of feed, fodder, grazing land, small landholdings, and labor shortages. This in turn ultimately resulted difficulty in getting agricultural laborers and draft animals in right time as well as additional burden to women, elderly and children creating imbalance in family and social lives.

Women increasingly have multiple roles and responsibilities, including additional agricultural work in the absence of their male partner. Female headed households have also doubled in last 15 years from 13% in 1995 to 26 % in 2010 (CBS, 2012; Gauchan and Shrestha, 2014). In hilly regions, most of the cultivable land has been converted to fallows due to rapid migration, increasing labor costs, labor scarcity as well as a reduction in animal traction. In this circumstances, agricultural mechanization could be a worthwhile option to counterbalance the effects of labor scarcity and enhance agricultural productivity. The shortage of agricultural laborers, primarily due to male out migration has been the driver of farm mechanization in Nepal (Paudel et al., 2020). Agricultural mechanization is a crucial input to improve efficiency in agricultural production as well as to emerge farmers from subsistence farming. Primarily, it includes small hand tools to more sophisticated or powered machines and equipment.

Various farm operations such as land preparation, planting, weeding and interculture, irrigation, fertilization, pruning and training, spraying and harvesting, shares more than half of production cost. In addition, the labor scarcity in agriculture, coupled with escalating wage increases have forced to find alternative means through mechanization to help reduce our current reliance on a physical labor force. Thus, mechanization is needed in Nepalese horticulture (fruit cultivation) to minimize production cost, reduce women drudgery, obtain timeliness of an operation, increase labour productivity, enhance horticulture production, productivity and quality as well as generate favorable atmosphere for the competitive market value of the produced commodities.

Though area and production of fruits have increased, fruit yield is hovering around 10 mt/ha in average. Thus, there is still a lot to be done to enhance fruit productivity. For instance, supply of quality planting material and inputs, application of agri tools and machines in proper orchard management (manuring, irrigation, plant protection, training and harvesting) and post-harvest management engineering techniques, have been found as major areas for intervention. Despite the potential of horticulture, horticultural productivity remains low mainly due to the lack of access to information, technology, inputs (seeds, fertilizers, machines, agri tools, post-harvest techniques, credit) and reliable market.

4. Agricultural Machinery and Tools for Fruit Cultivation

Mechanized tools and equipment are used for different types of cereals and horticulture crop cultivation and management practices. The most common operations in fruit cultivation include nursery plantation and grafting/budding, land preparation, digging and planting, weeding and intercultural operations, plant protection, irrigation and fertigation, harvesting and post-harvest management.

4.1 Nursery House

Different kinds of nursery houses are being used in Nepal for growing or producing saplings of different fruits and spices. The type and design of nursery house mainly depends on latitude of site of construction, agro climatic parameters (sunlight, soil, temperature, relative humidity etc.) and crop requirements. Basically, Plastic tunnel type poly house, bamboo tunnel, local-type greenhouses, naturally ventilated polyhouse, shade net house-tubular structure and insect proof net house were major types of nursery house technology adopted by farmers in Nepal. Protected cultivation green house or Hitech plastic house (Fan and cooling pad system) is also being started to construct in different areas through subsidies program by different stakeholders such as agricultural knowledge center and municipalities in Nepal. For instance, Prime Minister Agriculture Modernization Project (PMAMP) is constructing different protected structures through its pockets, blocks, zones and super-zones area in different part of Nepal. Since, the Hitech greenhouse technology is still in its preliminary stage in Nepal, intensive efforts in the form of feasibility study, extensive research on location specific design and model prioritization along with financial aspects or benefits in different ecological belts, demonstrations and sensitization are needed to properly adopt this technology.

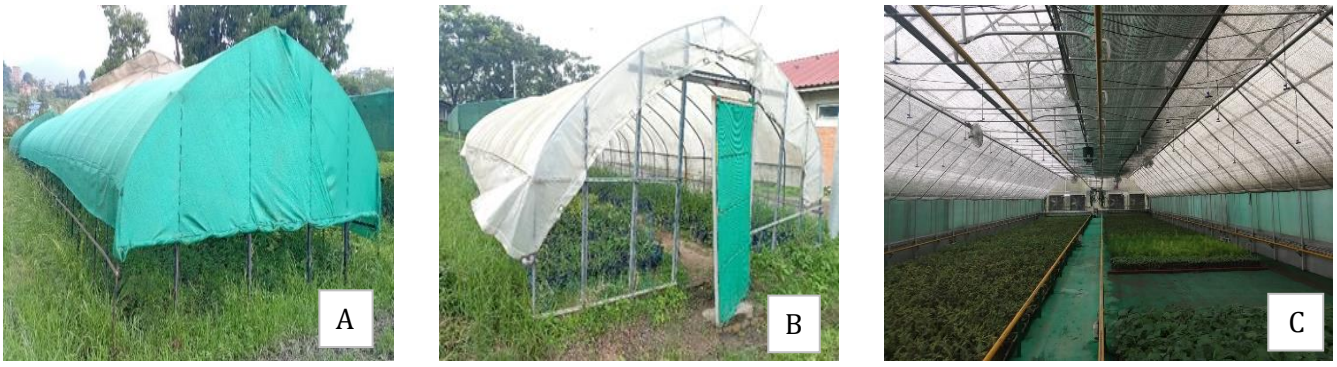

Figure 1: Normal Nursery House (A and B) and Hitech Nursery house (C)

4.2 Grafting and Budding

Grafting and budding are horticultural techniques used in fruit cultivation to asexual or vegetative methods of plant propagation. The upper part (scion) of one plant grows on the root system (rootstock) of another plant during grafting process while a bud is taken from one plant and grown on another in the budding process. Presently, grafting and budding operations of fruit plant are performed using hand knives that are designed specifically for these purposes. The blade of these knives is beveled on only one side. Grafting tape can be used to tie in any graft onto the rootstock for fruit trees. Nowadays, different types of professional grafting tools are also available in Nepal to do grafting. But the use of this tool seems very less which need operational and promotional activities within nursery farmers.

4.3 Land and Seed Bed Preparation

Land preparation is the basic phase of fruit planting. Most of the land preparation tools and equipment are common in both cereals and horticulture crops. Previously, draught animals were the main source of farm power for land and seed bed preparation. Animal drawn implements such as indigenous plough harrow and soil stirring plough are employed

for land preparation activities. These days in Terai belt, land preparation is mostly done through power tiller and four-wheel tractor with different tillage attachments such as MB plough, disc plough, harrow, cultivator, clod crushers, bund former, levelers, bed former, trenchers and rotavator. Most of the farmers in this belt used required farm machinery in custom hiring basis. In contrast, different models of small mini tiller are started to be used for the purpose of tillage work in the hilly regions. Besides, small and marginal farmers still use the manual tillage tools such as spades, hoes, shovels, sickle, hand forks for land preparation etc.

4.4 Digging and Planting Operation

The fruits plants are usually planted in pits. Digging is the most labour intensive and laborious operation. Mostly, farmers dig holes to construct nursery tunnel or planting purpose by simple hand tools such as hand auger, hoe, spades etc. These days mechanical and hydraulic type post hole digger such as four-wheel tractor PTO driven type are also started to dig holes in terai. In hilly areas, gasoline engine powered small earth augers are also being used to plant tree saplings or to set up posts for fences and different kinds of fruit such as dragon fruit, grapes, kiwi etc.

4.5 Weeding and Intercultural Operations

Weed management is an important component in fruit crop production as it negatively affects fruit yield and quality. In addition, weeds compete directly with fruit crops for needed nutrients, water, light, fertilizers, and space during the growing season. Manual (hand) weeding is the most common practice in Nepal. Surface digging with hand tools at the time of inter-cropping is the only way of working the soil in orchards. Most of the farmers still manually remove weeds through the help of small hand tools such as spades, different kinds of hand hoe (kuto, kodalo, kodali) and sickle etc. from the orchard land. Manual weeding is labourious, tedious, and time-consuming process. Currently, different kinds of agricultural machines such as light weight gasoline engine operated multipurpose brush cutter and small power weeder (2-5HP engine) are available for the cutting and weeding purpose in Nepalese orchard fields.

Brush cutter can be used to cut grasses and weeds from the orchard fields with help of ploughing, weeding, and cutting blade attachment in front shaft of machine. Likewise, power weeder (2-5 HP gasoline engine operated self-propelled machine having tilling blades) is suitable in sloppy land and small terraces, lesser row spacing crops and weeding activity below fruit tree plants. Attempts have been made by different organization to use different machinery for weeding purposes which yet need detail research and dissemination work. Thus, inter-row spaces of the pits can be tilled with power tiller/tractor drawn tillage machinery to destroy the weeds, increase aeration and conserve moisture. Likewise, small power tillers can be used in terraced fields of hills to do tilling and weeding.

4.6 Plant Protection

Spraying and dusting is an important plant protection operation during the fruit production. Farmers mostly used foot sprayers to spray insecticides, pesticides and fungicides in tall tree such as mango and avocado for the control of insects, pests and diseases. Small hand sprayer and Knapsack (battery operated or manually operated) sprayer is massively used in fruit sapling nursery house by farmers. These days, portable power sprayer (engine or electric motor operated) are also available for spraying purposes. Different kinds of high efficiency sprayers such as aero blast tractor sprayers, power operated mist blower and dust sprayers, and electrostatic sprayers are being researched and practiced for fruits in the other countries that are rarely researched in Nepal. Thus, researcher needs to focus their research on these kind of orchard sprayers by considering viability, acceptability and economical aspects in our country. Fogging machines and mist blowers can also have opportunity to be used in the green houses and for covered crop cultivation.

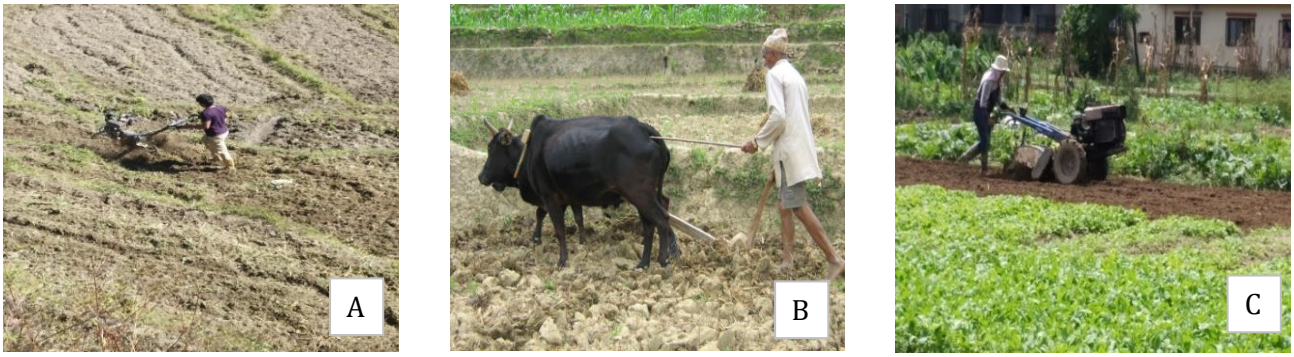

Figure 2: Land Preparation: - Mini Tiller (A), Animal Drawn Wooden Plough (B) (Pradhan and Shrestha, 2009) and Power Tiller (C)

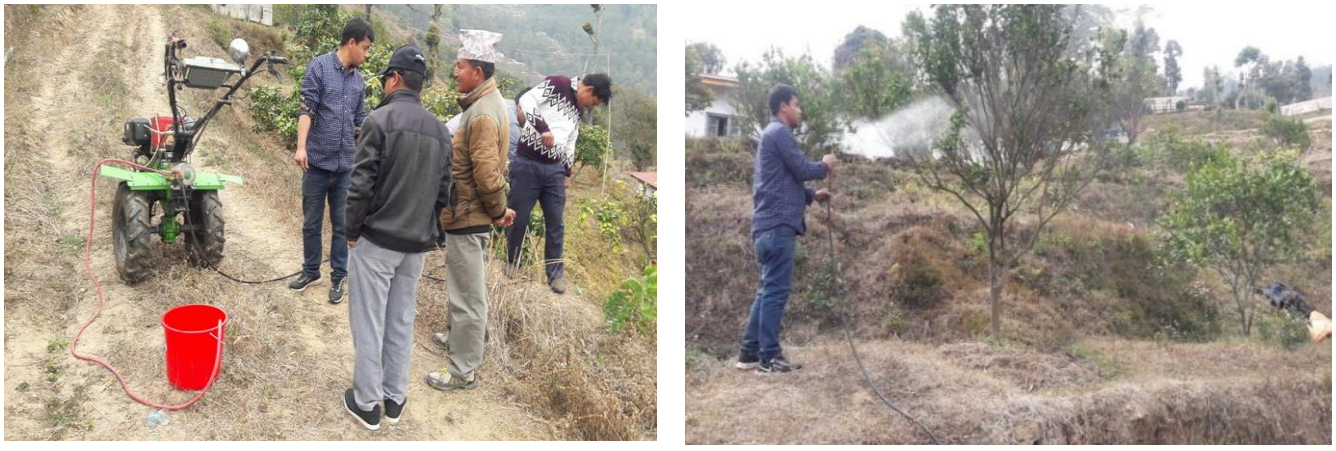

Figure 3: Mini Tiller Attached Sprayer

4.7 Irrigation and Fertigation Practices

In Nepal, irrigation is mostly done by ring basin flooding system where ample water is available and fertilization through manual broad casting method. Drip irrigation seems more effective in horticultural crops. Sprinkler irrigation is suitable for almost all crops (except rice and jute) and in various soils and topographic conditions. Nowadays, drip irrigation and sprinkler irrigation is also being started to use in fruits cultivation such as grapes, kiwi, dragon fruits etc. in different part of the country. Fertigation can also be applied through the drip irrigation system. Different types of pumps which includes centrifugal, turbine, submersible, axial flow, mixed flow pumps, mini tiller attached pump etc. are available in market for lifting irrigation water.

4.8 Orchard Farm Management Tools (Pruning and Training Tools)

Pruning and training is one of the important operations for fruit tree

canopy management as it retains a balance between vegetative and reproductive growth in plants and safeguards higher fruit quality. Earlier farmers use locally made traditional hand tools such as axe, wooden handle saw and sickle for pruning and training purposes. Today, lopping shear, pruning shear, hedge shear and engine powered or electric chain saw are started to use for training and pruning in horticultural fruit crops of Nepal. In addition, telescopic handles can be used for the pruning of the twigs and branches, that are not in the reach of human hand.

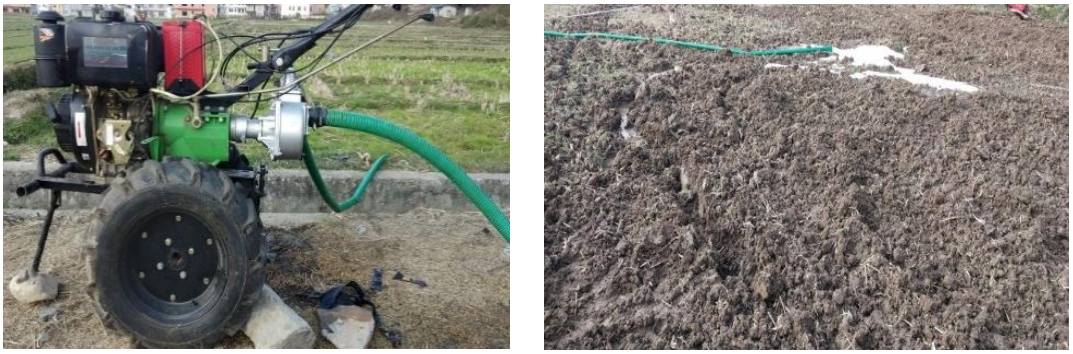

Figure 4: Mini Tiller Operated Water Pump

4.9 Harvesting

Harvesting is considered as one of the crucial and critical tasks in fruit production, handling and storage and market cycle due to possible damage to the fruits and musculo skeletal stress on the worker. Traditional picking (hand plucking, tree shaking) and post-harvest practice are responsible for deteriorating the fruit quality and shortening the postharvest shelf-life. Generally, fruit harvesting is done by hand pulling using ladder and collecting bag. Moreover, conventional methods such as tree climbing, tree shaking and hitting by sticks are also commonly applied by farmers (Khatri et al., 2022). These methods are risky, labour and time intensive practices as well as affects market quality and nutritive value of the fruits. Mechanized harvesting is recognized as the most promising area of intervention to tackle increasing phenomena of labour scarcity and costs and to fuel farm prosperity and entrepreneurial opportunity in the rural part of the country (Rickman et al., 2013; Khatri et al., 2021).

Around the world, mechanical harvesters like limb shaker, air blasting, canopy shaker and trunk shaker, particularly for citrus fruits have been investigated and practiced improving profitability and efficiency of citrus farming. However, there are major issues such as the flexibility, the fruit selection ability, the damage to the fruit and trees, the layout of the grove design for mechanical harvester and topographical constraints which still limits the investment capability and application of the mechanical harvesters in developing countries like Nepal (Kassim et al., 2020; Li et al., 2011; Khatri et al., 2022). Recent studies by Khatri et al. (2021) and Khatri et al. (2022) evaluated performance of different models of manual fruit harvester along with storage trials on fruit physiochemical attributes on sweet orange and mandarin in Nepal and reported higher harvesting output and improved storability and extended shelf-life of fruits in stored condition than traditional farmers practice (Khatri et al., 2021; Khatri et al., 2022). Thus, these kinds of appropriate and effective small scale harvesting tools suitable for smallholder farmers to replace the manual picking of fruits need to be promoted in Nepal that has an immense potentiality to raise the quality fruit production and productivity.

4.10 Post-harvest Management

In Nepal, most of the fruit grading and sorting work was done manually based on visual observation. Attempts have been made by NAERC to develop manual fruit graders for multi fruits such as apples, mandarin, lemon, pears and sweet orange, which are still in research phase and yet to be commercialized (NAERC, 2021). Few imported high capacities Chinese or Indian grader are also presently seeming to be used in cooperatives farm through subsidy program. However, this type of grader has issues of higher initial investment cost, economic return and acceptability aspects by farmers which need detailed adaptive research before promotion of the model. Regarding packaging, crop specific sizes of corrugated cardboard boxes (for apple and mandarin) and plastic trays/crates (for tomato, mandarin) suitable to local conditions are standardized and locally available wrapping/cushion materials are recommended (Bhattarai, 2018). However, traditional methods of packaging (wooden boxes, gunny sacks and bamboo baskets) are still broadly practiced.

Different kinds of cellar storage and zero energy storage structures are being used to store fresh fruits. Most of the rural villages in hills and mountain still lack fruit storage amenities which induce post-harvest losses and decrease income. For such areas, cellar storage can be a profitable option due to supply season extension by storing the produce in glut season. Recently, different cost centers of NARC such as National Horticulture Research Centre and National Citrus Research Centre is also conducting research of fruits and vegetables in cool bot storage technology to have an outlook on feasibility and economical aspects of technology in Nepalese context.

In case of drying, various models of solar dryers (multi rack solar dryer, low-cost solar dryer and solar tunnel dryer) have been developed and promoted by NAERC, NARC that are appropriate for drying fruits and vegetables in isolated and remote area. The dryers are especially useful for the farmers of such areas to make dried apple and mandarin slices that can fetch better market price. Solar tunnel dryer is silpouline plastic covered type made of GI pipe or bamboo structure while multi rack solar dryer is glass covered one with MS iron and sheet metal frame. NAERC developed dryers are also being promoted by different government and nongovernment organizations in remote areas of Nepal in subsidized rate.

Regarding transportation of fruits, farmers mostly use bamboo basket (Doko) and crates for fruit from orchard field to nearby market or storage place on foot. After then, fruits transported to the market in crates and cartoon using animal cart, four-wheel tractor trolley, power tiller trolley, mini trucks etc. Recently, NAERC has developed portable wheel trolley (figure 7c.) to carry crates from field to nearby storage place. This kind of wheel trolley need small plain pavement to run wheel properly in the field.

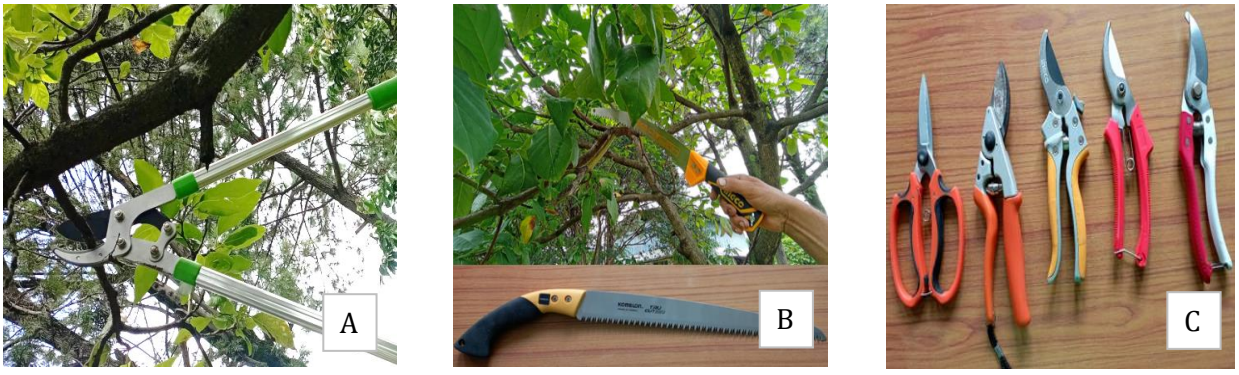

Figure 5: Shear (A), Pruning Saw (B) and Secateurs (C)

*A) Farmer practice-hand picking, B) Farmer practice tree climbing, C) Secateurs, D) Secateur +tree climb, E) Pole mounted cut and hold type picking shears, F) Telescopic long reach fruit picker, G) Fruit picker harvester with basket and cushion, H) Metal fruit picker with cotton bag, I) Hand shaking of the tree branch.

Figure 6: Different Models of Manual Fruit Harvesters (Khatri et al., 2021)

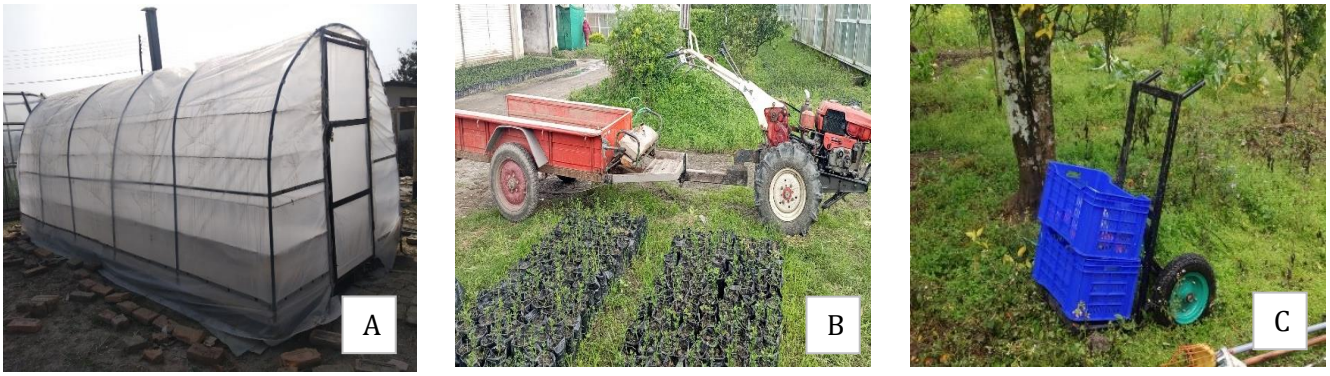

Figure 7: NAERC Developed Solar Tunnel Dryer (A), Power Tiller with Trailer Attachment (B) and Portable Wheel Trolley (C)

5. Fruit Mechanization Institutes in Nepal

Different organizations are playing vital roles to enhance fruit mechanization in Nepal. Some of the institutes and organization are mentioned below:

- National Agricultural Engineering Research Centre, Nepal Agricultural Research Council, Khumaltar, Lalitpur
- National Citrus Research Program, Paripatle, Dhankuta
- Horticulture Research Station, Jumla
- National Centre for Fruit Development, Kirtipur, Kathmandu
- Nepal Agricultural Machinery Entrepreneurs Association (NAMEA) and other Machinery Entrepreneurs
- Local Agri Machine and Tools Fabricators
- Local Bodies such as Municipalities and Rural Municipalities
- Agricultural Knowledge Centers
- Different INGOs and NGOs, Development Organization
- Government projects

6. Challenges and Constraints of Fruit Mechanization

6.1 Small Scale Land Holdings

The National average size of farm holding is less than 0.79 ha of which mountains, hills and Terai has 0.73, 0.65 and 0.94 ha, respectively. Likewise, the national average parcel size is 0.24 ha and average no. of parcel holding is 3.27 (Shrestha, 2012). Smallholder subsistence and rainfed farming system, small farm size, split land holding, lack of agricultural roads to most farmlands, physical constraints of steep and rugged terrain and narrow terraced farm topography in hills and mountains limits the foreign machinery introduction and promotion as compared to the terai plain.

6.2 Inadequate Research, Development and Extension Activities on Fruit Mechanization

In Nepal, work on fruit mechanization research is inadequate and

extension program is very general and cereal crop dominated. Institutions for research, extension and educational program are very weak and have less prioritized fruit mechanization work. Fruit mechanization research related institutes such as NARC (NAERC-Khumaltar, AMTRC-Nawalpur, AIRS- Ranighat, NCRP-Dhankuta, HRS-Jumla etc.) lack adequate resources, expertise and infrastructure facilities for proper work on fruit mechanization and technology generation. Coordination among research, education and extension seems very poor in Nepalese context. Major agricultural extensions and educational institutions also lack well established fruit mechanization disciplines and manpower. In addition, to promote sustainable agricultural mechanization programs there is also need to recruit trained manpower (Agricultural engineers) in the institutions related to agricultural mechanization/ modernization in Nepal.

6.3 Poor Availability of Spare Parts, Repair and Maintenance Facility

Although there is some motivational attempt by machinery dealers on spare parts and repair service, Nepalese rural farmers are still suffering from problems such as unavailability of spare parts and mechanic, well equipped, proper and easy repair and maintenance service facilities in the rural area, expensive spare parts and service etc. A high cost of spare parts for agricultural machinery is the result of high import duty and value added tax (VAT). One of the major issue is agricultural machines being dumped as junk scrap in rural areas due to unavailability or high cost of spare parts. Additionally, repair and maintenance facilities are limited primarily in urban centres in Terai and Kathmandu.

6.4 Import Tax on Spare Parts and Raw Materials

The encouraging move by the government is that there is a provision of tax and vat free to the imported assembled agricultural related machines. Tractors are imported with low custom duties and taxes in the name of agricultural mechanization. Currently, these are more frequently seen carrying construction raw materials rather than being used in agriculture. In contrast, the heavy duty (15-45%) on importing raw materials for locally manufacturing agricultural machines has created a disincentive to all local engineering firms to engage in local production and sales of machinery, tools and equipment as the production cost will be higher than the imported one. There is also need to differentiate, categorize and target import duty for raw materials, spare parts, machineries etc. related to agriculture production.

6.5 Accident and Injuries

The haphazard distribution of agriculture machinery and tools without proper research work on topography suitability, machinery performance and safety features as well as effective training to the operator or end user massively increases accident and injuries. Although there is no categorized data on agricultural machinery accident, according to accident report provided by traffic department, the tractor accident was 605 in F/Y 2076/77 (2019/20) which increased to 993 in F/Y 2077/78 (2020/21). Thus, Agricultural Machinery Testing and Research Centre, NARC need to prioritize their work on this area. It is necessary to promote quality standards, safe use (both operators' safety and environmentally safe) of farm machineries.

6.6 Agricultural Machinery Fabricators, Industries (Local Trade Person and Enterprise), and Importer

The sustainability of traditional artisans (blacksmiths) is becoming harder and at the verge of extinction due to older and traditional workshop facilities, expensive raw materials and lack of appropriate technical and capital support to upgrade their occupational skill and size of business. Also imported tools and machines reduces the demand of tools developed by them. The bitter truth is there is no any governmental factory like Agriculture Tool Factory (ATF), Birgunj (was collapsed in 1996) which can commercially produce small agri tools and machines in nation. Small and medium sized enterprises do not have sufficient financial and technical backstopping to fabricate sophisticated agricultural machines and equipment. Thus, these kinds of actual entrepreneurs need protection from government through favorable policy related to agricultural machinery fabrication related raw materials. Private sectors are emerging in agri machinery business, particularly in import, marketing and supply. But most of them have concentrated mainly urban centres of Terai and in limited hill areas.

6.7 Limited Custom Hiring Service and Poor Monitoring of Subsidized Machines

Although custom hiring business is somehow effective in Terai belt still there is poor state of rental markets for agricultural machineries in hills. Custom hiring service is provided by very limited private sectors till now. As the custom hiring service providers are operating informal basis, the farmers did not find any authority to complain about the service quality. Also, there is still lacking of proper field level monitoring and evaluation of use of imported subsidized and domestically developed and promoted agri machineries.

6.8 Poor and Difficult Access to Institutional Credit and Insurance Schemes

Although there is positive move by government (formulation of fruit insurance policy) towards the agricultural insurance schemes and loan facility to the farmer, it is not yet effectively applied and still beyond the reach of rural poor farmers. The reason might be due to tedious loan and insurance procedure, lack of adequate awareness to the uneducated farmers and subsistence nature of farming. Limited access to credits as well as high credit interest rates for tractors and other agriculture machineries increases farmer's unwillingness in machine use.

6.9 Inappropriate Protected Horticulture Structures (Plastic House), Machinery and Tools for Different Agro Ecological Zones

As, country has no sophisticated agricultural manufacturing industries, farmers have to rely totally on imported machines that were based on foreign topography. In addition, imported machinery and tools are being attempted to use in Nepalese varying topography without proper study on suitability to local condition. This ultimately resulted operation and production inefficiency, accident, injuries and financial loses which in turn leads to the technology negativity or mechanization failure.

6.10 Lack of Fruit Related Policies and Act

Specific policy for fruit development (Orchard establishment and management policy, Fruit processing policies, Fruit nursery policy, Fruit export and import policies etc.) are still lacking in the country (NHPC, 2017).

6.11 High Post-Harvest Losses

There is still a high postharvest loss (20-30%) of fruits due to lack of proper harvesting, grading, storing, inappropriate packaging techniques and materials, and means of transportation.

6.12 Unproductive Old Orchards Farm

Most of the old orchard's farm such as mandarin farm in Kavre district (visited by authors) are suffering from wilting of tree, unproductive tree, less production etc. due to poor orchard input management such as nutrient, training and pruning or might be due to global warming or climate change effect (need detail study by concern stakeholders/bodies such as National Environment Research Centre, NARC, Lalitpur). Farmers are destroying their farm and shifting to other crops such as cultivation of potatoes which leads to decrease in machinery use and fruit productivity.

7. Future Aspects, Way Forward and Recommendation

The agricultural sector is increasingly feminized as women alone constitute 64% of the total human workforce in agricultural activities due to the recent phenomenon of men leaving agricultural jobs and taking non-agricultural jobs (mostly outside the country). Thus, environment friendly and gender responsive fruit mechanization such as hand tools, mini tiller and other equipment need to be introduced, developed, modified, promoted in rural orchard farm of nation for enhancing production, reducing drudgery and minimizing the accidents in agricultural and allied activities. Because of the great range of fruit farming conditions in Nepal, diverse irrigation technologies including plastic pond (for dry season irrigation), small scale pumps, drip and sprinkler irrigation system need to be promoted in more effective ways to improve agricultural intensification.

Appropriate machinery suitable for different fruit cultivation operations are still not widely available in Nepalese local markets, therefore, a widespread participatory research method is required to test, validate and disseminate the developed or imported tools performance compared with traditional farming method. In fact, operation wise mechanization of orchard crops including transplanting of saplings, pit making, spraying and weeding in tall crops and harvesting of fruits etc. are prime need of current situation. Adoption and validation on different models of nursery house based on agro ecological zones, climatic parameters, farmer's acceptability and economical aspects need to be given priority in applied or adaptive research. Training and wider dissemination work on orchard farm management machinery tools is needed to have proper training of fruit plants and pruning of older trees which is very important operation to increase quality production.

Detailed research work on mulching technology around the fruit trees is recommended to have proper vision on technical, environmental and financial benefits of technology before promoting and recommending to farmers or fruit growers, but in practice (except in a few cases) it is rarely followed. There is no doubt that manual harvesting/picking of fruit is highly labour intensive and demanding a huge seasonal workforce in rural areas. Primarily, in the beginning, major focus on promotion of NAERC verified manual fruit harvesters is needed in hilly and terai region's orchard farm. Later, in terai flat belt, there is opportunities of using mechanical or powered harvesters as well as robotic harvesting systems after testing and verifying by the research mandated centers based on the fruit type, land topography, technical and economic viability of the technology.

Due to the ecological imbalance and mass household migration from hill, most of the land became fallow and barren as a result the monkey and wild boar menace in farm land is becoming one of the major problems of the farming community in the hills of Nepal. Thus, there is opportunity of changing cropping pattern from monkey's palatable crop to non-palatable crops such as planting different fruits plants such as walnuts, macadamia nut, lemon, garlic, turmeric, medicinal and aromatic plants to avoid or minimize crop damage from monkey menace. Importantly, the abandoned or fallow land in the hills and degraded forest and public land, if brought under fruit cultivation, could contribute to revive hill agriculture and carbon sequestration.

Importantly, there is urgency to establish accredited laboratory facilities of international standard to promote export. Likewise, Hi-tech cold storage and chilling van for safety measures of fruits at export point is also necessary to meet international standard. The adoption of farm mechanization in hill production ecologies is challenged by rugged terrain as well as small and often terraced plots that also provides opportunities for planning and operation of small scale mechanization. Application of proper screen house especially for the production of citrus saplings construction and management of high tech screen house for qualitative and quantitative citrus fruits saplings production is one of the important sector need to be prioritized by government. Smallholder farmers, land limitation, fragmented and scattered plots is also a limiting factor for big orchard establishment and commercial farming. Thus, land lease and contract farming in the hills need to be focused to use appropriate machinery.

The concept of custom hire which has immense potential in the country as the majority of farmers are small holders need to be seriously prioritized. This strategy lets them to get the benefit of cultivation, handling and transport machinery on payment basis thereby increasing production and productivity. Thus we need to focus on small scale mechanization and promotion of custom hiring of agricultural equipments and machineries. In addition, it is very much important to target subsidy for poor, women and youth friendly enterprises or real farmers, activities as well energy efficient, labor saving technologies and machineries. As there is no doubt that labor is the largest element of cost in fruit production, every means need to be exploited to reduce, facilitate, or eliminate hand labor. Considering the long gestation periods of fruits, government and concerned stakeholders should provide easily accessible soft loan or credit facilities to those farmers who are willing to purchase the machinery individually or cooperative basis.

Farming such as contour, terrace, and bund farming need to be prioritized to check the menace of hill's soil erosion. Major future intervention areas in post-harvest management to minimize the post-harvest losses and challenges include the following: a) Enhancing farmers' capacity on appropriate harvesting and cracking and extracting techniques, b) Improving packaging materials and packaging techniques, c) Enhancing farmers' capacity on fruit grading (apples, mandarins), packaging (apples and pears) and transportation facilities d) Promoting multi-chambered cold storage facilities for fruits in the major consumption market centers. Establishment and encouragement of small-scale machinery manufacturing units and small service centres at local markets for easy accessibility of spare parts, and repair and maintenance facilities. Extension network should be strong to create awareness among the farmers for improved fruit mechanization technologies through effective village exhibition (krishak mela), demonstrations, field dissemination and media (Newspaper, Radio, TV, etc.).

The Agricultural Mechanization Policy 2071 (2014) need to be revised to streamline it in the present context of national federalism. The agricultural machinery related organizations are needed to be strengthened for the modernization of agriculture for the sustainable development of Nepal. In this context, there is a need to revisit our policy and program for promotion of sustainable agricultural mechanization with transfer of appropriate technology addressing all the component of fruit supply chain (not only mere distribution of machine). Rejuvenation tools of unproductive old orchards farm: old unproductive orchards need to be appropriately rejuvenated by severe pruning in winter and nutrient management for production of new shoots. Unwanted shoots need to be removed for proper growth of new canopy for which pruning tools and power operated saw are the potential agricultural tools for rejuvenation of orchards.

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