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Research Article

# Apple Production and Soil Fertility Management by Smallholder Farmers in Sentele Watershed in Southern Ethiopia

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## ABSTRACT

Production of apple (*Malus domestica* Borkh) has been promoted in Ethiopia owing to suitable agro-ecology in the highlands of the country with the aim of improving farmers' income and livelihoods. However, achievements from apple production have so far remained minimal due to a number of constraints. Low soil fertility and its management are major factors that constrain productivity of the crop in the country. Therefore, this research was conducted to understand the status of apple production and identify soil fertility problems as well as soil fertility management practices that apple producing smallholder farmer conduct in Sentele watershed of southern Ethiopia. A survey of 120 apple growing households (HHs) was conducted using a semi-structured questionnaire from three purposely selected villages in three districts of the region. The districts, villages, and apple growing farmers were sampled purposively. Furthermore, key informant interviews, focus group discussions, and field observations were used as the main tools of data collection. Descriptive statistics were used for analyzing the data. The results of study revealed that all farmers engaged in apple production perceived a deteriorating status of soil fertility and carried out some soil fertility management practices. They are using compost, mulch, and intercropping integrated or alone with any available recommendations. Accordingly, about 36% of the apple producing households practiced integrated compost, mulch, and intercropping; 23% used integrated compost and mulch; 14% used integrated compost and intercropping, and 5% used mulch and intercropping. Shortage of labor, money, composting materials, time consumption and access to extension service were major constraints to manage soil fertility for the crop. Similarly, apple diseases, lack of improved apple varieties, poor access to market, and lack of orchard equipment, poor soil fertility, and shortages of land and irrigation water are other problems that constrain apple production. Household characteristics, namely, sex, level of education, family size, and apple producing experience were positively and significantly correlated with soil fertility management practices whereas age, marital status, land size and area covered by apple trees were not associated with the practices. It is concluded that apple production is challenged by numerous constraints and farmers need access to evidence-based recommendations to sustainably manage soil fertility and improve productivity of apple trees, their incomes, and livelihoods.

**Keywords:** Compost; Households; Intercropping; Irrigation Water; Mulching

## INTRODUCTION

Agriculture is the mainstay of the Ethiopian population and a key sector of the country`s economy. It supports the livelihoods of 85% of the population, and accounts for around 46% of gross domestic product (GDP), 80% of exports by value and still remains a key growth sector, particularly in rural Ethiopia [1]. However, nutrient depletion remains a serious problem due to soil erosion and continuous Ethiopia [2]. Limited application of crop residues, competing uses of animal manure like household energy and animal feed, and restricted use of mineral fertilizers are major causes of nutrient depletion [3]. Thus, Ethiopia experiences the highest level of nutrient depletion which leads to declining per capita food production [4] (Table 1).

Soil fertility management is continuously modified and adapted practices that can be targeted by recognition of socio-economic and bio-physical factors [5]. Soil fertility management practices are obviously the management of soil services to increase the quality and durability of its services. Mowo et al. stated that, soil

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fertility managements practices are functions of socioeconomic processes and its management. The decision making of soil fertility management is governed by a complex framework of comparisons [6].

Although Ethiopia has a history of 70 years of introduction of apple during the 1940s, the production of the crop is still at its infancy. Some studies have been conducted on apple growing condition and improving some conditions hinders apple production [7-9]. However, no empirical study has so far been conducted to investigate particularly edaphic constraints of apple production in the country. Accordingly, farmers grow apples with little knowledge of soil fertility enhancement practices resulting in poor yield and quality. Therefore, evidence-based soil fertility management options that ensure sustainable apple production and enhance income of smallholder farmers have not yet been provided. The aim of this study was to identify farmers soil fertility management practices for apple production and to explore the practiced soil fertility management by apple growing smallholder farmers (Table 2).

## MATERIALS AND METHODS

### Study area

Sentele Watershed is located in Southern Ethiopia at 7°36'30" to 7°39'30" N and 37°48'00" to 37°50'30" E. It has an elevation of 2270 to 2680 m.a.s.l. and encompasses different land use types, and covers a total area of 1883 ha (Figure 1). As the area is located in the south-central highlands of Ethiopia, it enjoys temperate climate with three distinct seasons. Bega, Belg, and Kremt characterized with an average annual rainfall of 1178 mm and the mean annual maximum and minimum temperatures of 22.8°C and 9.2°C, respectively.

**Table 1:** Household land size and average landholding under apple production.

| Villages | Average HH land size (Ha) | Minimum (Ha) | Maximum (Ha) | Apple Trees Planted (N0) | Land occupied by Apple tree/HH | |
|---|---|---|---|---|---|---|
| | | | | | Ha | % |
| Lambuda | 0.55 | 0.25 | 1 | 1228 | 0.02 | 3.90% |
| Lenchecho | 0.58 | 0.25 | 1.25 | 903 | 0.02 | 3.40% |
| Santo-Ambeka | 0.62 | 0.25 | 1 | 750 | 0.02 | 3.20% |

**Table 2:** Types of livestock owned by apple producing households in Sentele Watershed.

| | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| No livestock | 23 | 19.2 | 19.2 |
| Cow only | 12 | 10 | 29.2 |
| Poultry only | 7 | 5.8 | 35 |
| Horse/donkey only | 7 | 5.8 | 40.8 |
| Cow+poultry | 23 | 19.2 | 60 |
| Cow+donkey+poultry | 18 | 15 | 75 |
| Poultry+horse/donkey | 12 | 10 | 85 |
| Cow+Poultry+horse/donkey | 18 | 15 | 100 |
| Total | 120 | 100 | |

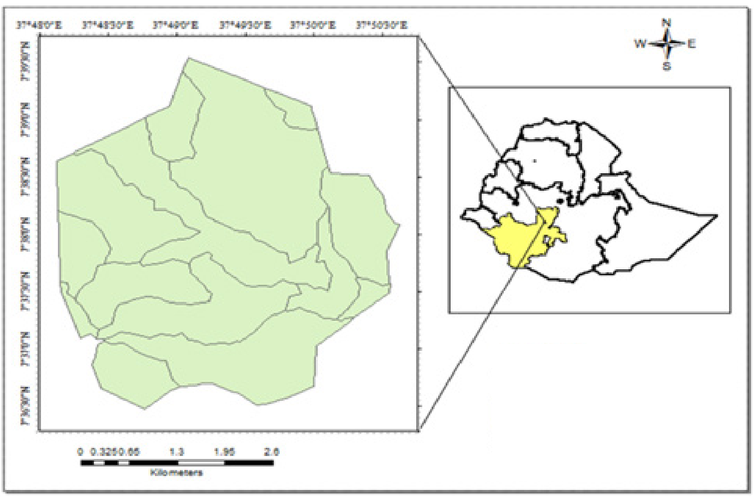


**Figure 1:** Location map of study area. Note: ( ) Sentele_Watershes, ( ) SNNP_region, ( ) Ethiopian_regions.

### Source of data and method of data collection

The sources of data for the research are both primary and secondary sources. The major primary source of data is field visit, interviewing households' heads, development agents and experts, and focus group discussion. While, secondary data was collected mainly from reports and documents of NGO, Central Statistical Agency (CSA) and village level field offices. The questionnaire was developed and translated into local language (Hadiyssa), and was pre-tested with seven respondents and modifications were made according to the pre-test. Discussions were held with governmental experts, NGOs staffs and key informants associated with field visits. Focus group discussions (FGD) were conducted with purposely selected 8 to 10 participants including village leaders, DAs, elders, women, youth groups and apple growing farmers [10-15].

A total of 120 apple producing farmers were selected from three villages (Lambuda, Lenchecho and Santo-Ambeka) of Lemo and Misha districts in Southern Ethiopia. A multi-stage sampling method was used to identify the area and households. In the first stage, we selected two districts and three villages purposively on the basis of apple production potential. The second stage involved selection of apple producing households in the three villages based on their involvement in apple production to achieve the objective. The final stage involved purposive selection of apple producers on the basis of minimum number of trees grown. In the studied villages, 175 apple producers were found growing 20 and more apple mother trees. The sample size was determined by the formula given by Kothari to find out the sample size of finite population:

$$n = \frac{x^2.p.q.N}{c^2(N-1)+z^2.p.q}$$

Where, N=population; n=sample size; z=the value of standard variate at a given confidence level and to be worked out from table showing area under normal curve; p=sample proportion, q=1-p, e=given precision rate or acceptable error.

### Data analysis

The collected data were analysed using simple descriptive statistics like frequency, mean, and percentage using SPSS (version 22.0) package software and data were coded for analysis. Descriptive statistics was used to describe quantitative factors. Frequency and percentage were used for describing qualitative factors. Linear regression model was used to show relationships between variables and factors influencing farmers' soil fertility management practices and apple productivity in the area (Table 3).

## RESULTS

### Demographic characteristics

Of the 120 interviewed smallholder households from the three villages 43%, 32% and 25% were from Lambuda, Lenchecho and Santo-Ambeka villages, respectively. The majority of the respondents were male (73%) whereas, the rest (27%) were female. Respondents` age ranged between 25 and 60 (Figure 2) with the average age of 41 years. The survey result indicated that about 37.5% of the respondents had no formal education, 33.3% were attended primary education, 27.5% attended secondary education, and about 1.7% were attended tertiary level of education. Generally, about 62.5% of the interviewed respondents acquired formal education (Figure 2). Majority of the respondents (84.2%) was couples, 8.3% was single, 4.2% was divorced and 3.3% was widowed. Regarding size of the households, the overall average family size was 6 persons with a minimum of 3 persons and a maximum of 11 persons [16-19].

**Table 3:** Soil fertility management practices in apple production by farmers.

| | Soil fertility management practices | | | | | | |
|---|---|---|---|---|---|---|---|
| | M | I | C | MI | CI | CM | CMI |
| | 4 | 2 | 4 | 4 | 7 | 10 | 21 |
| | 2 | 3 | 2 | 2 | 3 | 11 | 15 |
| | 3 | 2 | 4 | 0 | 7 | 7 | 7 |
| Total | 9 | 7 | 10 | 6 | 17 | 28 | 43 |

**Note:** TM=Mulch; I=Intercropping; C=Compost; MI=Mulch and intercropping; CI=Compost and intercropping; CM=Compost with mulch; CMI=Compost with mulch and intercropping

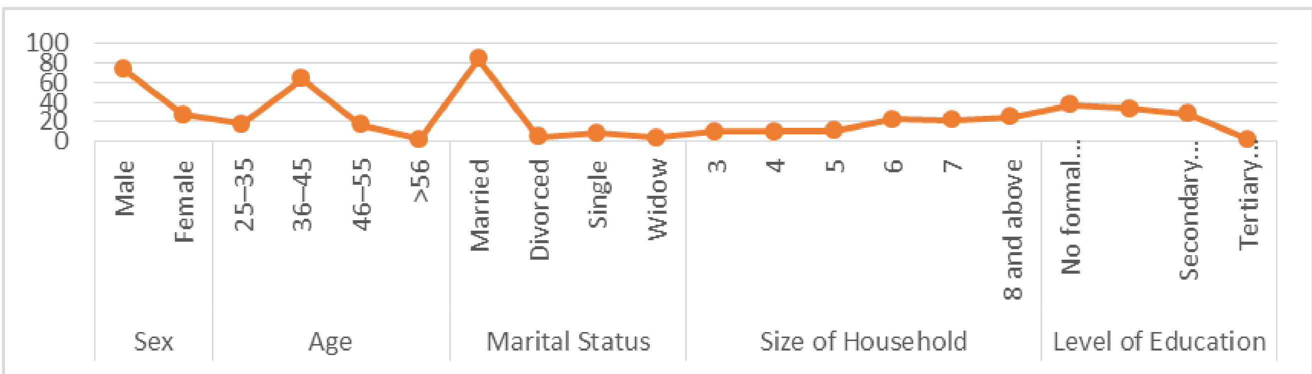


**Figure 2:** Demographic characteristics of smallholder apple producing farmers in Sentele Watershed. Note: (—●—)%

## Farming system

Smallholders in the study area practicing crop-livestock integrated farming system. Intensively managed with land sizes ranging between 0.25¬–1.25 ha with the average of 0.54 ha. In Table 1, about 23.3% of the respondents owned 0.25 ha of land and 3.3% owned about 0.3 ha of land; 35.8% owned 0.50 ha of land and 4.2% owned 0.6 ha of land and 20% owned 0.75 ha of land, 9.2% owned 0.8 ha of land and the remaining 3.2% owned 1–1.25 ha of land. Out of the total average of 0.54 ha of land, the surveyed households allocated on average 0.02 ha (3.4%) of land to apple production.

The mean number of apple mother trees planted by the surveyed households were 24 with a minimum 20 and maximum 30. Out of the total respondents, 35% had 4-6 years, 29% had 7-9 years, 23% had 10-12 years, and 13% had 13-14 years of experiences. Regarding the type of apple variety planted by farmers, 16.7% two varieties, 42.5% three varieties, and 40.8% four varieties. Apple Anna and Princess as a common variety. Next to them Dorset Golden and CP-92 were planted.

Livestock are managed as free grazing and cut-and-carry system. Household data revealed that, out of the total respondents 80.8% owned at least one type of livestock unit, while the rest 19.2% did not own any type of livestock. This indicated that apart from crop cultivation, the majority of the households kept livestock, and the farming system in the area is a subsistent mixed crop-farming as a source of income and home consumption.

## Farmers soil fertility management practices for apple production

Apple producing farmers in the study area seem to understand the importance of soil fertility management practices well. Therefore, all surveyed apple growing households practiced soil fertility management (Table 3). As shown in the table, about 35.8% respondent practiced integrated compost, mulch and intercropping, 23.3% integrated compost and mulching, 14.2% compost and intercropping, and 5% integrated mulch and intercropping. However, 8.3% practiced compost alone, 7.5% mulch alone and 5.8% intercropping alone. Regarding frequency of fertilizer application, about 59.2% applied twice year$^{1}$ and 28.8% once year$^{1}$ and 12.5% more than two times year$^{1}$. The respondents revealed that, per apple tree at a time, about 28.3% of them applied about ≤5 kg of compost, while 35.8% applied 5–10 kg of compost, 30.8% 10–15 kg, and the rest 5% applied 15–20 kg per tree. The data showed that smallholder farmers used only organic sources fertilizer due to an unavailability and unaffordability of mineral fertilizers.

Framers that applied integrated organic fertilizer at the rate of ≤ 5 kg tree$^{-1}$ earned on average 9.2 t ha$^{-1}$, whereas 5–10 kg tree$^{-1}$ earned on average 10.8 t ha$^{-1}$, 10–15 kg tree$^{-1}$ earned on average 13.4 t ha$^{-1}$ and those who applied at the rate of 15–20 kg tree$^{-1}$ earned 15.2 apple fruit ha$^{-1}$, which was about 39.5% higher yield when compared with the apple fruit yield obtained from the application rate of ≤ 5 kg tree$^{-1}$. Similarly, farmers who applied integrated organic fertilizers at the rate of 5–10 kg tree$^{-1}$ once in a year earned on average 9.2 t ha$^{-1}$, farmers who applied the same rate (5–10 kg tree$^{-1}$) two times year$^{-1}$ earned on average 11.7 t ha$^{-1}$, and who applied the same rate (5–10 kg tree$^{-1}$) year$^{-1}$ earned on average 14.7 tha$^{-1}$ which was higher by 59.8% than farmers who applied once year$^{-1}$ and 27.2% than who applied twice year$^{-1}$. This implies that higher rate of organic fertilizers application can yield more apple fruit when compared with low rate less frequency.

## Challenges faced by the apple farmers in soil fertility management practices

Agricultural production frequently depends on soil fertility management practices. In the study area, soil fertility management practices of apple orchards influenced by a number of factors (Figure 3). Out of 120 respondents, 28% was influenced by labor shortage, 23% by money, 20% by composting material, 18% by poor extension service, and 11% time constraint. Extension service and training included workshops, demonstration and on-farm advice plays an important role to aware of farmers on farm management practices (EKHC Projects Annual Report) [20-22].

According to the respondents, about 66% did not obtained any extension service concerning soil fertility management practices for apple production in a year. In contrast, 91% apple growing households trained in advance of receiving seedlings on soil fertility management. Group discussion confirmed that, the extension service requirement of the apple producers was not addressed and farmers' awareness of soil fertility management practice decreased after the Ethiopia Kale Heywet Church Project phased out. The government extension system did not provide the farmers with sufficient advices on sustainable soil fertility management practices for apple production. Improving the knowledge and skills of smallholder farmers in horticultural production may address some of the production challenges (Table 4).

## Major challenges of apple production

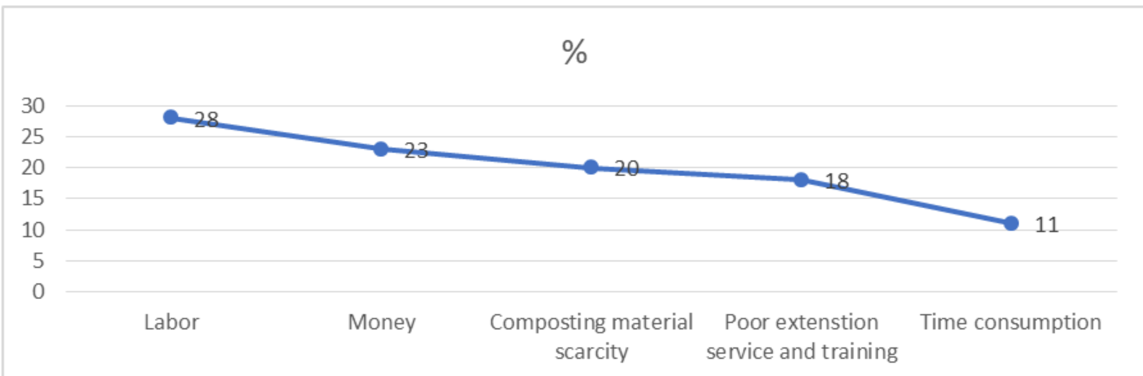


**Figure 3:** Factors affecting soil fertility management.

**Table 4:** Challenges Faced by Farmers in Apple Production.

| Challenges of Apple Production | Percentage of Farmers Response |
|---|---|
| Low soil fertility | 85 |
| Disease and lack of improved varieties | 81 |
| Market access | 77 |
| Lack of orchard equipment and farming skills | 61 |
| Labor availability | 57 |
| Land and irrigation water | 54 |

As indicated in Table 4, factors that limiting apple production, low soil fertility, apple diseases, low access to market, lack of orchard equipment and poor farming skills, scarcity of labor, land, and irrigation water. The majority of the respondents stated that soil fertility reduction was a major cause of yield reduction. Similar findings were also reported by (Sanchez) who stated that soil fertility decline is considered as an important cause for low productivity in many soils. In addition, apple diseases such as apple scab *(Veturia inaequalis)*, powdery mildew *(Podosphaera leucotricha)*, leaf curl *(Taphrina deformans)*, collar rot *(Phytophthora cactorum)* and wooly apple aphid *(Eriosoma lanigerum)* were found to be serious challenge. Similarly, Gebrerufael et al. Seifu et al. reported that occurrence of diseases and insect pests as a serious constraint for apple production in Chencha area.

Lack of secured marketing channels, poor infrastructure and limited transport facility constrain apple production in the study area. Thus, the farmers have a few alternatives and were selling the product for passengers and neighborhood consumers at low prices. This result agrees with the finding reported by Slender et al. that lack of market outlet limited farmers ability to sell apple fruit to passers-by in streets and in retail shops. Lack of orchard equipment and farming skills were also the challenge of apple producers. Earlier study by Ferree and Schupp stated that apple tree pruning and training improved tree growth, flowering and fruitfulness, and fruit quality.

Labor, land and water availability is a key production factor in agriculture. As indicated in Table 4, shortage of labor (57%), and land and irrigation water (54%) was found to be important apple production challenges faced respondents. In apple orchard management, composting task is the labor-intensive practice [8]. The land in the study area is fragmented and some of the water points dry up in the dry season. Effective watering (irrigation) influences the entire growth processes of the plant and flowering and fruit bearing. Kopytko et al. stated that availability of water is the main limiting factor of apple productivity.

# DISCUSSION

## Demographic characteristics

The result on sex suggests that apple production and soil fertility management in the study area was to a large extent related to gender differences. Results in Figure 2 indicated that male respondents had greater participation in apple production and soil fertility management practices (73.3% of male and 23.7% of female). This perhaps could be a reflection of the reality that resources like land are owned and easily accessed by male and majority of female cannot access the resources that would permit them to do otherwise. This implies that gender bias towards land resources for men is the cause of poor performance of women in agriculture [9]. However, the revised Family Law of Ethiopia has improved the right of women to manage common marital property along with their husband [9].

The survey result shown that respondents` level of education has significant ($P<0.01$) effect on apple orchard soil fertility management practices. This shows that education helps farmers to make appropriate decision in agricultural production. Knowledge and information obtained through education enables farmers to adopt new technologies and access to inputs [10]. The positive and significant relation of family size with soil fertility management practice suggests that households with many family members contributing to the labor force for soil fertility management tasks. This finding agrees with Chidi et al. who reported that households with increased family size supplied additional labor force to perform agricultural works and obtained more yields. Age and marital status of the households did not influence soil fertility management practices. It can be explained that the farmers practiced soil fertility management for apple production regardless of age and marital status. Thus, differences in age and marital status were not affected the practices of apple production and soil fertility management in apple production.

## Farming systems

The type and number of livestock possessed have shown a positive and significant relationship with soil fertility management practices. This means farmers who keep a large number of heads of livestock have access to farmyard manure which is a vital source of nutrients for soil fertility management. This result is in agreement with that of Dereje reported that farmers who owned a large number of heads of livestock were more likely to practice soil fertility management. However, there was no significant difference in soil fertility management practices due to land size and area occupied by apple trees. This means that the current soil fertility management practice in apple production was not seems to be influenced by households` land size owned and area covered by apple trees.

Soil fertility management practice for apple production was associated with apple farming experience of the households. Households with more years of apple farming experience have enhanced skills and experiences for better soil fertility management. Farmers with more years of farming experience tend to adopt more soil fertility management practices than those with few years of experience [11].

The majority of respondents (95%) consumed less than 15 kg $tree^{-1}$ organic fertilizer, 87.5% applied two times or one time in a year and about 22% non-integrated sources of organic fertilizers. This implies that among apple growing households only 5% consumed above 15 kg $tree^{-1}$ organic fertilizer, 12.5% applied more than two times and 78% integrated organic fertilizer. Respondents who applied integrated organic fertilizer at the rate of 15–20 kg tree$^{-1}$, and more than two times in a year earned better apple fruit yield. Consistent with these results, Aura reported that integrated soil fertility management practices using optimum rates of the fertilizers restored soil fertility and improved crop productivity.

### Challenges faced in soil fertility management practices

The shortage of labor and money were serious challenges faced respondents. Major source of labor for soil fertility management practice was family. This implies that larger family size makes enough labor available for soil fertility management practices. Limited availability of labor directly limited the soil fertility management effort by organic sources [12]. Labor is not always provided from family, but may be also rented need money for different stages of compost preparation. If smallholder farmers do not have alternative sources of income to invest in soil fertility management, maintaining soil fertility to apple orchards becomes a serious challenge.

Competition of composting material with other uses was another reason to the limited soil fertility management practices in apple production. This means that low availability of composting materials constrains apple growers. Hailu et al. reported that animal manure used for composting is used for household energy [3]. Therefore, strategies for managing soil fertility should consider the use of composting materials and manure for competing ends [6]. Time is another bottleneck for using organic fertilizers (FAO, 2010). The result of this study is consistent with the report of Weldegebrial et al. who stated that composting is not a rapid stabilization process and, depending upon techniques used, and could take several weeks to achieve stable compost.

Respondents stressed that their soil fertility management tendency was continuously decreased due to lack of technical advice and sensitization training. This may be due to less extension workers to farmers` ratio at the study area or the extension workers assigned to other duties by governmental officials out of their duty [13]. This showed that the number of extension workers contact made with the apple growing farmers might not be enough to educate and technically support soil fertility management practices. Based on the results of the survey, farmers who were kept close contacts with extension agents were likely to practice soil fertility management practice by 28% higher than farmers that had no any content with the agents. This implies that households that often visited by extension workers gained better knowledge and skills to practice soil fertility management.

### Major challenges faced in apple production

Constraints that are originated from different sources and could have the potential to influence apple productivity mentioned by farmers; such as low soil fertility was major challenge to apple production. Nabhan et al. reported that low soil fertility is one of the major causes for poor crop performance. Disease and lack of improved varieties was another constraint stated by respondents. Our focus group discussion confirmed that apple diseases and lack of improved varieties hinders apple production seriously. Diseases of the apples are the huge problems for farmers growing apples [14]. Apple production also directly influenced by lack of improved variety. Similarly, Seifu and Berhanu mentioned that appropriate varieties need to be selected in terms of resistance to disease and fruit shelf life.

Market access was a serious challenge faced by smallholder apple farmers. Consistent with this suggestion, Sieber reported that the intensity of agricultural production decreases with increasing distance of plot from the market. Market access needs supportive policies and regulations to provide with the services that help to produce quality fruits and join the market. Unlike other fruit trees, apple requires annual training and pruning [15]. Lack of apple pruning equipment and farming skills were also challenging apple production. Due to the absence of apple pruning equipment and carrying out skills, the majority farmers unable to prune apple trees. It suggests that the respondents were less experienced, and have fear to undertake pruning apple trees. Thus, apple growing households should be ready to improve their skills in orchard management.

Labor, land and irrigation water availability were mentioned as the limiting factors to apple production with full potential in the area. This implies production of apple is labor intensive, and land and water source demanding activity. Apple production system is intensively labor demanding [16]. Households with large families may constitute family members to perform apple orchard. Therefore, government institutions and other supporting organization should support these smallholder apples producing farmers to address land and water scarcity. Researches on apple production system should therefore be redirected towards the discovery of less labor-intensive technologies specifically for soil fertility management processes.

In general, the above results confirmed that smallholder apple growing farmers thriving may lack complete package of technology when apple production introduced to the area. Therefore, apple growing smallholder farmers and other supporting actors may understand sustainable, low cost and efficient integrated soil nutrient management practices to enhance apple production. To provide effective extension service and to train the farmers, the extension agents need to spent fulltime on agricultural extension related activities.

## CONCLUSION

Production of apple (*Malus domestica* Borkh) has been promoted in the study area in the garden of smallholder farmers, and they are practiced organic soil fertility management like; compost, mulch, and intercropping. However, there are many production and soil fertility management constraints remained minimal the achievements. Labor, money, composting materials, time consuming and low extension service were found to be major constraints of apple orchard soil fertility management practices. Likewise, low soil fertility, apple diseases, access to market and orchard equipment, management skills, scarcity of land and irrigation water are serious hindrances to apple production. For sustainable apple production, integrated soil fertility management practice should be promoted. Capacity building and awareness creation as well as providing various farm tools and water harvesting schemes are required to realize maximum potential of apple production. Government and other relevant institutions should work to facilitate the market for produce. Future research should focus on socio-economic factors influencing farmers' decision on integrated soil fertility management practices, opportunities and limitation of apple production in the area, determinants of scientifically recommended soil fertility management practices.

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