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ORIGINAL RESEARCH ARTICLE

Apple production systems and post-harvest management across selected locations of North Shewa Zone, Ethiopia

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ABSTRACT

Apple farming is a new production venture across the North Shewa Zone. Its production, harvest, postharvest handling, and marketing status are not well known. This study was conducted to assess the above-lined situations across the district. Four representative locations, Asabahir, Tsigereda, Tengego, and Godnamamas were selected based on their apple production status. Then, a total of 88 respondents were randomly selected and interviewed by a structured questionnaire. The data were analyzed by descriptive statistics of percentage, standard deviation, and chi-square tests. A larger percentage of farmers are male (82.9%), in their active production age (41.7%), and produce apples in their backyard (85.25%). The agronomic management of fertilization, pruning, training, and plant spacing deviate from the recommended practices of apple farming. Whereas varietal distribution, irrigation, and post-harvest treatments are better practiced. Loss of fruits by fruit drops and discrimination on the market due to small fruit size are serious problems across the locations. Regarding apple farming, the farmers think of it as a productive venture and got a better price per kg and single fruit sale. They sell mainly in local collectors (60.2%) and nearby cities. As for institutional support, the farmers got apple seedlings, training, and capacity buildings by Agriculture Offices and NGOs, even if the farmers are still in higher need of better support. Therefore, it can be concluded that if not outwaited by poor tree management, destructive product transportation, and higher loss of fruits from trees and in the market, the attitude of the farmers can be capitalized in better production of apples.

Keywords: Agronomic Management; Apple; Marketing; Post-harvest Handling; Production

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1. Introduction

Apple (*Malus domestica* B.) is one of the very popular, widely produced, and highly consumed fruits in the world[1]. It belongs to the Rosaceae family which includes fruits and berries. The plant is widely found in wild form in temperate regions of North America. But its primary center of diversity is believed to be around Asia Minor and western China[2,3].

Apple is important in the human diet as it supplies minerals (calcium, phosphorus, iron, potassium, and magnesium), proteins, vitamins (C, K, B6), carbohydrates, fiber, and different phenolic compounds. It has the health benefits of controlling chronic diseases like diabetes, cardiovascular diseases, and cancer. Apples have higher contents of phenolic compounds and oxygen radical scavenging antioxidants. It has been served in different dishes in different forms like rows, snacking, salads, baking, sauces, pies, juices, and cooking[4–6].

The world average area coverage of apples is 4,822,226 hectares of land with a production of 9,314,4358 tonnes. The top five apple pro-

ducers are China (45,983,400 tonnes), Turkey (4,493,264 tonnes), USA (4,467,206 tonnes), Poland (4,067,400), and India (2,276,000 tonnes). The world's average production is 19.3 tonnes per hectare[7].

Apple tree is introduced to Ethiopia by British Protestant Missionaries in the year 1950s. Since its introduction, the crop has been produced in different parts of the country[8]. But the progress of its production is restricted to small-scale farmers. However, due to increased market demand, the country is importing apples from other countries. In 2018, Ethiopia imported 1,007 tons of apples valued at 2 million USD[9].

According to some survey studies, cool highland areas of Ethiopia have favorable climatic conditions for the production of apple fruit. The more accessible areas which are in proxy to local markets in the center of the country are considered suitable for apple production which makes good competent to move from imported fruits products[10,11].

In the North Shewa Zone, apple fruit farming has been practiced for the last 10–15 years. The cool highland parts of the zone mainly produce apples on a small scale as well as large-scale farming in some investments. Angolela Tera district is one of the parts of the North Shewa Zone in which apple farming has been known to the community in recent years. According to the information of the office of agriculture of Angolela Tera district, more than 35,000 seedlings have been distributed to farmers and are planted across different locations in the district. Different governmental and non-governmental institutions are involved in the supply of seedlings to farmers. Even if the number of seedlings distributed is very high, its production, productivity, status, opportunities, and challenges of production are not well known. Therefore, this study was conducted to assess the production status, the challenges of production, harvest, and post-harvest handling as well as the marketing systems of apples across the district.

2. Material and methods

2.1 Description of the study area

The study was conducted in the Angolela Tera district of the North Shewa Zone (**Figure 1**). The district is 111 km away Northeast of Addis Ababa the central city of Ethiopia. It comprised locations, which are categorized as lowland, highland, and

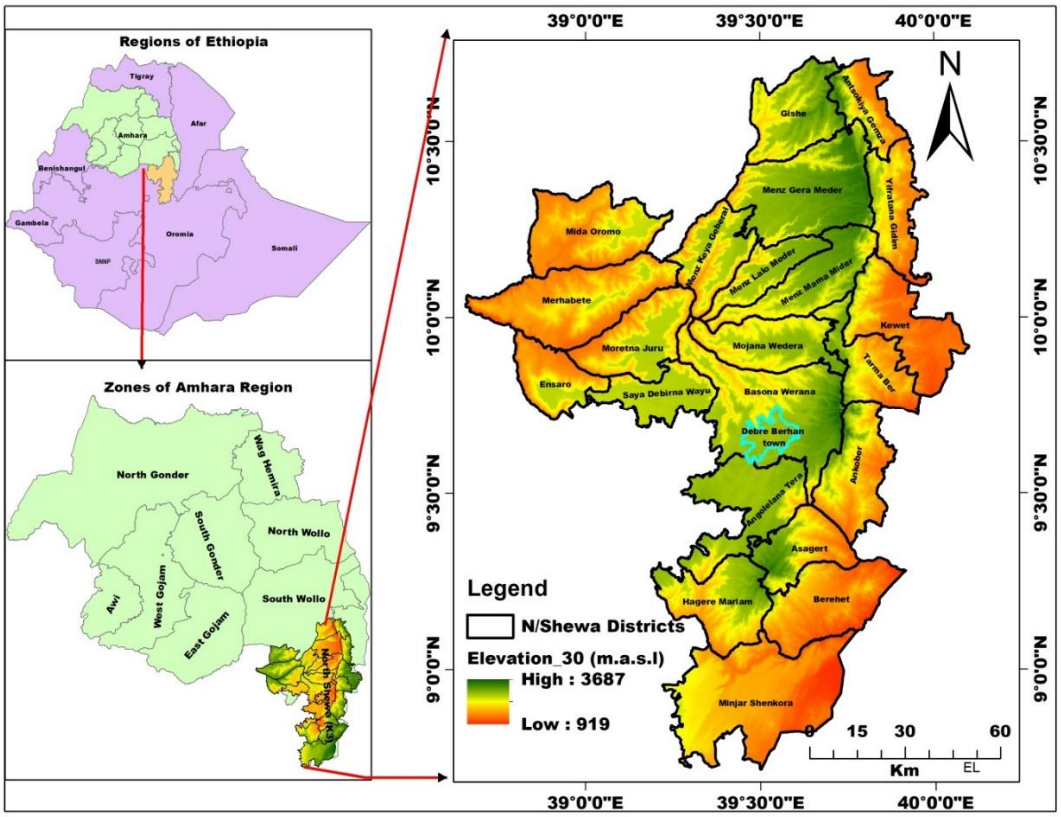

Figure 1. Study location map.

mid-altitude agroecology zones. It has an average monthly rainfall of 25 mm and an average monthly minimum temperature of –0.1 ℃, the maximum average temperature is 22.9 ℃. It is located at 9°28'51" N latitude and 39°21'51" E longitude. It has an altitude ranging from 1,600 to 3,030 m above sea level[12].

2.2 Sampling technique and method of data collection

A multistage sampling technique was used. First, four locations of Angolela Tera district namely Asabahir, Tsigereda, Godnamamas, and Tengego that produce apples were purposively selected. Second, the farm households in each location were stratified into apple producers and non-producers since the interest of this study was apple producers. Finally, a total of 88 sample respondents (apple producers) were randomly selected from each stratum, i.e., 22 producers from each location. The primary data necessary for the quantitative study was collected from sampled households by conducting a formal survey using a structured interview schedule. Data were collected in 2018/19 years.

Before the actual data collection, enumerators who are familiar with the culture and practice of the society were recruited and trained. The training was focused on the purpose and contents of the questionnaire and techniques on how to approach and interview the respondents and collect the data using the questionnaire. Next, the interview schedule was pretested on five randomly selected farm households from each location before conducting the formal survey. Necessary improvements were made based on the feedback from the pre-test. The data were collected by eight development agents of the Agricultural Development office with the assistance of a district subject matter specialist who has better knowledge and experience in the farming system of the study area. The researcher was visiting each enumerator for cross-checking at the end of each day. All questionnaires were checked with the enumerators and clarifications were made. Qualitative data were also collected using group discussions among selected apple producers and extension development agents who were working in the respective locations.

The primary data generated were focused on the socio-economic characteristics of respondents, household income, farming experience and landholdings, apple orchard size, apple planting system, types of apple varieties under production, agronomic practices of production, harvest and post-harvest handling, marketing and institutional support on production.

The data collection was conducted in close communication with the Debre Berhan University governing body. The participant farmers were informed about the content of the data and they verbally agreed to give the interview without any hesitation. The data collection process did not breach the WMA Declaration of Helsinki as it is not medical research involving human subjects. Rather it is surveying the farming practice of the farmers across study areas.

2.3 Data analysis

Data collected through questionnaires were organized and summarized for analysis. Data were analyzed using descriptive statistics with SPSS (SPSS, 2015). Depending on the nature of the data, the chi-square test and ANOVA were employed to compare variables among the study locations. Pearson's chi-square (χ^2) test was used for categorical variables to assess a statistical significance of a particular comparison. One-way analysis of variance was applied for quantitative dependent variables.

3. Result and discussion

3.1 Socio-economic characteristics of households by districts

The production and productivity of crops are highly influenced by the socio-economic factors of the producer farmers[8]. As indicated in **Table 1** in all four locations of the district, the male apple producers are higher than their female counterparts. Even if there was no significant difference ($p > 0.05$) between those areas, the higher male producers are found at Tsigereda (95.5%) and higher female producers are from Godnamamas (22.7%) locations. In areas where the participation of females is high, it is indicated that the production of crops is also higher. Hence, the imbalance between male and female producers could negate the production of apples across

Table 1. Socio-economic characteristics of apple producers in the Angolela Tera district

Parameters	Variables	Districts				Overall (n = 88)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Sex (%)	Male	81.8	95.5	77.3	77.3	82.9	
	Female	18.2	4.5	22.7	22.3	17.1	0.327
Family size (Mean ± SE)	Males	3.41 ± 0.328	2.91 ± 0.328	2.77 ± 0.328	2.73 ± 0.328	2.95±	>0.01
	Females	3.05 ± 0.29	2.45 ± 0.29	1.95 ± 0.29	2.50 ± 0.29	2.48±	>0.01
Farmers' age	(Mean ± SE)	44.90 ± 1.78	40.80 ± 1.82	40.10 ± 1.54	41.25 ± 1.38	41.7±	>0.05
Age category (%)	18–25	0.0	0.0	13.6	0.0	3.4	<0.001
	26–35	0.0	4.5	22.7	22.7	12.5	<0.001
	36–50	40.9	59.1	45.5	77.3	55.7	<0.001
	>50	59.1	36.4	18.2	0.0	28.4	<0.001
Education level (%)	Illiterate	4.5	22.7	50	45.5	30.67	
	Read and write	77.3	63.6	22.7	54.5	54.5	
	< Grade 6	13.6	13.6	4.5	0	7.9	
	Grades 7–12	4.5	0	4.5	0	2.25	<0.001
	> Grade 12	0	0	18.2	0	4.55	
Marital status (%)	Married	100	100	86.4	100	96.6	<0.05
	Unmarried	0.0	0.0	13.6	0.0	3.6	
Working power (Mean ± SE)	Male	2.18 ± 0.31	1.36 ± 0.10	1.18 ± 0.14	1.64 ± 0.15	1.59 ±	<0.05
	Female	1.77 ± 0.26	0.95 ± 0.04	1.55 ± 0.24	1.59 ± 0.16	1.46 ±	<0.05
Household income	Low	45.5	77.3	77.3	40.9	60.2	<0.05
	Medium	54.5	22.7	22.7	59.1	39.8	<0.05
	High	0.0	0.0	0.0	0.0	0.0	>0.05
Income source (%)	Livestock	9.1	0.0	77.3	13.6	25	<0.001
	Horticultural crops	18.2	0.0	9.1	4.5	7.95	>0.05
	Cereal crops	100	100	77.3	90.9	92.05	<0.05
	Trade	0.0	0.0	13.6	0.0	3.6	<0.05

the study locations.

Similarly, with an increase in the age of farmers, apple farming experience could be developed. On the other hand, farmers who are young and at their active working age are more productive than older farmers. In all the study areas, most apple producer farmers are in the age category of 36–50 and >50 years. The better percentage of younger ages was recorded from Godnamamas areas in which nearly one-third of the population are between 18–35 years on average. Even if there were no significant differences ($p > 0.05$) in farmers' age, there was a highly significant difference ($p < 0.001$) between different age groups across apple producer areas (**Table 1**). In areas where the age of farmers is at an active stage higher working hours, better working efficiencies, and better production are expected. Hence, in those study areas, the productivity of apples could be positively altered by the farmer's age, as most of the farmers in the study locations are at a younger stage of their life. In agreement with this study, Emana *et al*.[13] and Sarker *et al*.[14] reported that farmers who are more experienced and at their active age are more productive and could make better decisions in their farming.

A higher percentage of farmers at Asabahir (77.3%), Tsigereda (63.6%), and Tengego (54.5%) can read and write. Whereas the illiterate farmer's percentage at Godnamamas (50%) is higher than the other categories. Similarly, the education level above Grade 12 is very low in all the study areas (**Table 1**). In areas where farmers are educated, they have a better chance of understanding technological packages and it may create a conducive atmosphere for the transfer of knowledge. Evidence by Bai *et al*.[15] indicated that the education level of farmers significantly affects fertilizer use efficiency. As a large percentage of farmers from the study area can read and write it could be an opportunity to transfer the skill and knowledge of apple production. This result conforms with the study of Sarker *et al*.[14] and Dannehl[16] who indicated that educated farmers exhibit better farming efficiency than the illiterate ones.

The percentage of married apple producers was very high in all three study areas. It can be concluded that almost all apple producers are married as the overall percentage indicated that 96.6% of the

farmers are in this category. The *F*-stat result also indicated that there were significant differences in education level and marital status among apple producer farmers. As per research reports, marital status is also among the factors which affect farming systems. Married farmers exhibited better production and productivity than single ones. Furthermore, being married could increase the working hands in the farming activity. Similar to this research, Omobolanle[17] and Oluwatusin and Shittu[18] reported that most respondents in their research areas are married and exhibited better productivity than single farmers.

The household income of farmers has a significant ($p < 0.05$) impact on producing fruits. Farmers who have better incomes have the freedom to try different plant types. On the other hand, producer farmers who have lower levels of income focus on annual and immediate crops rather than longstanding fruit crops. As indicated in **Table 1**, the apple producer farmers in the district of Angolela are in the categories of low and medium income. A higher percentage of farmers from Tsigereda (77.3%) and Godnamamas (77.3%) responded that their household income is low. Whereas a larger percentage of farmers from Asabahir (54.5%) and Tengego (59.1%) areas have medium levels of household income. The chi-square test result also indicated that there is a significant difference ($p < 0.05$) in the level of income across districts.

The overall income level indicated that a higher percentage of farmers have a lower level of income. The major source of income for the farmers is cereal crop production. This is verified by an overall percentage which is 92.05% of the farmer's income source is cereal crops farming. The second most source of income across districts is from the livestock sector. The involvement of farmers in trade and horticultural farming is rare except in some locations. This could indicate that the farmers across the study area are mainly cereal crops and animal producers but rarely involved in trade and horticultural crop production which is in agreement with the report of Gizaw *et al*.[19].

3.2 Year of farming experience and apple orchard size

Most of the farmers across the study locations have experience in apple farming which is less than 5 years. All of the farmers from Tengogo and Godnamamas have apple farming experience below five years. In Asabahir and Tsigereda, a higher percentage of farmers have below 5 years of experience, but 36.4% of the farmers from Asabahir, and 27.3% of farmers from Tsigereda have farming experience of 5–10 years. In addition, 18.2% of farmers from Asabahir and 31.8% of farmers from Tsigereda have farming experience of above ten years. The *F*-test result also indicated that there is a significant difference in farming experience across locations. This result indicated that apple farming has been introduced recently in two locations Godnamamas and Tengego and it is more known in the other two locations Asabahir and Tsigereda which have farming experience of above 10 years (**Table 2**). Hence, the farmers could have a lower level of experience in apple farming, which could indicate it fruit crops are recently introduced across the area. It is expected that the lower level of farming experience in years could negate the productive potential of farmers on apple fruit. In conformity to this, research results indicated that farming experience plays a significant role in the success of crop production. The longer the experience of farming, the higher it has a positive impact on production and productivity. It is also indicated that an increase in farming experience enhances the ability to be receptive to technological improvements, enhanced ability to farm wisely, and better utilization of inputs[20,21].

The land holding across locations amplified that all the respondents from Asabahir, Tsigereda, and Tengego have their land. Exceptionally, 13.6% of farmers from Godnamams use rented land. It can be concluded that the apple producer farmers in the study locations use their land for apple production. This in turn could be evidenced by the overall percentage of 96.6% of respondents having their land. Even if the farmers are using their land, the result of this study indicated that the average land size across Asabahir, Tsigereda, Godnamamas, and Tengego was 0.25, 0.49, 0.43, and 0.05 ha, respectively. The chi-square test result also verified that there is a significant difference across locations in the land holdings of farmers (**Table 2**). In all the locations, it is

well below half a hectare which is lower than the national average land holding of 1.8 ha[22]. It can be concluded that lower land availability could limit the production and expansion of apple fruits across the study area. This is because, apple fruit trees require a large area of land and could stay for many years, which substantially could alter the income of small-scale farmers. Research reports confirmed that small landholding could negatively alter the production of profitable crops like fruits[23,24].

Regarding the number of trees per household, 63.6% of farmers from Tengego and 68.2% of respondents from Asabahir have apple trees in the range of less than ≤5. In these areas, some farmers have apple trees above 40, even if their percentage is very low (4.5%). Whereas at Tsigereda, a higher percentage (45.5%) of the farmers have apple trees in the range of 5–10. The exceptional case is found in Godnamamas, 40.9% of respondents have apple trees in the range of 0–5 and 5–10 in number. Some farmers have apple trees of 20–40 in those locations (**Table 2**). As the overall percentage indicated, it can be concluded that across the study locations, the farmers have less or equal to 5 apple trees. As some of the farmers have had apple trees above 20, it could be a very good indication of the need of the farmers in involvement of apple production. In conformity with this research, other research reported that above 80% of apple farmers at Chencha are known to have less than 10 mother trees per household[8].

Table 2. Year of farming experience and orchard size of an apple in Angolela Tera district

Parameters	Variables	Districts				Overall (n = 88)	*p*-value
		Asabahir (n = 22)	Tsigereda (n=22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Apple farming experience (%)	≤5 year	45.5	40.9	100	100	71.6	
	5–10 year	36.4	27.3	0.00	0.00	15.9	<0.001
	>10 year	18.2	31.8	0.00	0.00	12.5	
Landholding (%)	Own land	100	100	86.4	100	96.6	<0.05
	Rented land	0.0	0.0	13.6	0.0	3.4	<0.05
	Other land	0.0	0.0	0.0	0.0	0.0	<0.05
Average landholding (ha)	(Mean ± SE)	0.25 ± 0.03b	0.49 ± 0.05a	0.43 ± 0.03a	0.05 ± 0.01c	0.30	<0.001
Number of apple trees (%)	0–5	68.2	31.8	40.9	63.6	51.1	<0.05
	5–10	9.1	45.5	40.9	13.6	27.2	
	10–20	13.6	13.6	13.6	18.2	14.75	
	20–40	4.5	9.1	4.5	0.0	4.52	
	>40	4.5	0.0	0.0	4.5	2.25	

3.3 Apple planting and production systems

Apple like other trees has recommended practices of planting and management systems. Effective application of this recommendation enhances the productivity of the fruit. From the main management systems, planting hole depth and width, plant spacing, production systems, and orchard site are considered as a factor that affects the success of apple farming. As indicated in **Table 3**, the average hole width and depth the farmers used to plant the apple tree across study locations was 60 × 60 cm at Asabahir, 58.18 × 54.5 cm at Tsigereda, 55.68 × 55.68 cm at Godnamamas, and 55 × 53.64 cm at Tengego. In the Assabahir location, the planting hole depth and length the farmers applied was similar to the recommendation (60 × 60 cm) by the Angolela Tera district Agriculture Office, but in other locations, it was well below that (**Table 3**). The most commonly used apple planting hole size and plant spacing across different locations in Ethiopia are 60 × 60 × 60 cm[25]. Accordingly, the planting hole size of the area is near to these recommended diameters and depth of planting hole.

The plant spacing between plants and rows was variable across locations. The *F*-test result also indicated that there was ($p < 0.05$) significant difference in spacing between rows across locations. The average spacing between plants and rows at Asabahir was indicated 2.95 × 9.05 m. This indicated that the farmers are using very wide plant spacing between rows. The next higher plant spacing is recorded at Godnamamas which is 4.20 × 4.27 m of spacing between

plants and rows. These plant spacings are well beyond the recommendation and indicate that the farmers are using large areas of land for very few plants. The lower spacings between plants were found at Tsigereda which is 2.72 × 2.77 m and Tengego at 2.90 × 2.91 m between plants and rows (**Table 3**). The spacing at these two locations is better than the other two and the farmers could have an optimum number of apple trees per given area. It can be concluded that the spacing between trees and plants from Godnamamas and Asabahir is far from the commonly used apple plant spacing of 3 × 3 m[25]. Whereas in Tengego and Tsigereda, it is close to the recommended levels.

In three locations of Asabahir, Tsigereda, and Tengego, a higher percentage of farmers are using sole planting systems of apple trees. In Godnamamas, 72.3% of farmers planted their apples in a mixture with other crops. The farmers from Asabahir (100%), Tsigereda (100%), and Godnamamas (95.5%) also revealed that their orchard is placed in the backyard. Whereas at Tengego, the percentage of farmers placing their orchard at their main field (54.5%) is higher than backyard producers (45.5%). There was also a significant difference ($p < 0.05$) in production systems across locations (**Table 3**). This could be associated with the fact that the farmers allocated their main field for cereals and other crops as their major source of income is from cereal products as indicated in **Table 1** above.

The responsibility of the management of apples is also placed on housewives as a higher percentage of respondents from Asabahir (77.3%), Tsigereda (100%), and Godnamamas (95.5%) responded (**Table 3**). Whereas at Tengego, the responsibility is laid on husbands rather than women[1,4] and children. Their reason could be that at this location, the apple trees are cultivated in the main field rather than backyard. In Ethiopian, rural women spend most of their time at home, which could be the reason the responsibility is on them to manage apples in their backyard. The very good thing across locations is that all the family members are involved in managing the apple trees. In conformity with this research result, Feyisa and Megersa[26] and Mohammed and Abdulquadri[27] reported that the involvement of women in fruit crop production is paramount ranging from harvesting to marketing.

Table 3. Apple planting systems across locations in Angolela Tera district

Parameters	Variables	Districts				Overall (n = 88)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Planting hole length and depth (cm)	Hole width	60	58.18	55.68	55.0	57.2	>0.05
	Hole depth	60	54.5	55.68	53.64	55.9	<0.05
Plant spacing (m)	Between row	9.05	2.77	4.27	2.91	4.75	<0.001
	Between plant	2.95	2.72	4.20	2.90	3.19	>0.05
Production system	Sole	95.5	63.6	4.5	54.5	54.25	<0.001
	Mixed with horticultural crops	0.0	13.6	13.6	9.1	9.07	>0.05
	Mixed with other crops	4.5	27.3	72.7	36.4	35.2	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05
Placement of the orchard	Backyard	100	100	95.5	45.5	85.25	<0.001
	Main field	0	0	4.5	54.5	14.75	<0.001
Responsibility	Husbands are responsible	27.3	31.8	59.1	77.3	48.8	<0.001
	Housewife is responsible	77.3	100	95.5	45.5	79.5	<0.001
	Children are responsible	4.5	22.7	63.6	13.6	26.1	<0.001

3.4 Apple varieties under production and source of seedlings

Since its introduction to Ethiopia, there have been different varieties of apples grown across the country. The distribution of those varieties is dependent on the altitude and climatic conditions of the areas. As revealed by respondents of the Asabahir location, the varieties of apple they are growing are Ana (100% of respondents), Crispin (50% of respondents), Princisa (36.4% of respondents), Dorset (22.7%) and CP–92 (4.5%) (**Table 4**). The varieties which the farmers at Godnamamas grow are Ana (86.4% of respondents), Crispin (40.9% of respondents), Dorset (27.3%), and Jona Gold (50% of

respondents). Whereas at Tengego, the respondents said that they grow three varieties Dorset (18.2% of respondents), CP–92 (77.3% of respondents), and Ana (100% of respondents). All the respondents from Tsigereda revealed that they didn't know what kind of variety of apples they were growing. Based on the overall percentage of respondents, it can be concluded that the Ana variety is widely grown across study areas followed by CP–92, Crispin, Dorset Golden, and Jona Gold apple varieties (**Table 4**). Furthermore, the result of this study also revealed that there is a better distribution of varieties across locations and most farmers grow more than one variety in their field. All of the varieties grown across the research locations are low chill. Hence, they require chilling hours of 500–1000 h of chilling for good yield and production[28,29]. As the study areas are mid-altitude agroecology, they could be fitted to these verities.

The source of seedlings for the farmers in the study areas was the government office, research center, and non-governmental organizations (NGOs). In all four locations, a higher percentage of respondents got their seedlings from Government offices. Whereas the involvement of NGOs in supplying apple seedlings at Godnamamas (45.5%) and Tengego (31.8%) was higher than in other locations. The overall percentage of seedling sources also indicated that the first seedling source for farmers is from the Agriculture Office (95.4%) followed by NGOs (22.7%) (**Table 4**). The result of this research is in contrast to the report by Fetena *et al*.[11] who reported that the role of the Agriculture Office in supplying grafted seedlings across the Chencha district is lower than NGOs and their sources.

Table 4. Apple varieties under production and seedling source across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 88)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Varieties under production	Ana	100	0.0	86.4	100.0	71.6	<0.001
	Jona Gold	0.0	0.0	50.0	0.0	12.5	<0.001
	Crispin	50	0.0	40.9	0.0	22.7	<0.001
	Princisa	36.4	0.0	0.0	0.0	9.1	<0.001
	Dorset Golden	22.7	0.0	27.3	18.2	17.05	>0.05
	CP92	4.5	0.0	0.0	77.3	30.05	<0.001
	I don't know	0.0	100	0.0	0.0	25	<0.001
Seedling source	Agriculture Office	100	95.5	86.4	100	95.4	>0.05
	Research centres	9.1	4.5	9.1	4.5	6.8	>0.05
	NGO	4.5	9.1	45.5	31.8	22.7	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05

3.5 Agronomic management of apple trees

3.5.1 Fertilizer management

Fertilization is one of the prominent factors which determines the yield and productivity of plants. Apple is one of the fruit plants[30] which is significantly affected by fertilization. Across different parts of the world, fertilization from different sources and kinds are used in growing apples. In the research areas, there is a use of both organic and inorganic fertilizers. The use of organic fertilizer farmyard manure (FYM) is higher than other types of fertilizers. Respondents from Asabahir reported that they don't use inorganic fertilizer and all of them (100%) reported the use of farmyard manures (FYM) (**Table 5**). However, a larger percentage of farmers (86.4%) applied the FYM only at the time of planting. A small percentage of farmers apply once per year (4.5%) and three wise per year (4.5%). The method of application is dominated by broadcast applications (95.5%).

Out of the total respondents of the Tsigereda location, 63.6% of them use FYM and the remaining 36.4% didn't apply any fertilizer at all (**Table 5**). They apply the FYM once per year in broadcast (68.2%), side dress (18.2%), and top dressing (13.6%) methods. Farmers from Godnamamas indicated that 4.5% of them use DAP which is applied once at planting in broadcasting methods. FYM is also used by the farmers from this area in which 100% of

them use it in broadcast methods. The frequency of application of FYM fertilizers at Godnamams was once per year (18.2%), three wise per year (9.1%), every three month (40.9%), and once at planting (31.8%). At Tengego, the use of UREA (4.5%), FYM (77.3%) and DAP (18.2%) is very common. The frequency of application is variable as a larger percentage of farmers apply UREA once at planting, DAP before planting, and FYM once at planting. From the method of applications, the broadcast application takes larger proportions. From this research result, it can be concluded that the farmers across the Angolela Tera district apply FYM as the main source of fertilizer in the broadcast method once per year. Furthermore, the application of inorganic fertilizers is very low and even the organic fertilizer application is below the required level in amount and frequency. Similar results were found in the study of Fetena *et al*.[11] and Ntakyo *et al*.[31] who reported that the use of organic fertilizer in apple production is lower than the need of the plant.

Table 5. Agronomic management practices for apple across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 88)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Type of fertilizers used	DAP	0.0	0.0	4.5	18.2	5.67	<0.05
	UREA	0.0	0.0	0.0	4.5	1.12	>0.05
	FYM	100	63.6	95.5	77.3	84.1	<0.01
	Microelements (Fe, Zn, Mn, etc.)	0.0	0.0	0.0	0.0	0.0	>0.05
	I didn't apply	0.0	36.4	0.0	0.0	9.1	
DAP application	Once at planting	0.0	0.0	100	9.1	22.27	>0.05
	Before planting	0.0	0.0	0.0	90.9	22.72	>0.05
	Frequently	0.0	0.0	0.0	0.0	0.0	>0.05
UREA application	Split application	0.0	0.0	0.0	0.0	0.0	>0.05
	Once at planting	0.0	0.0	0.0	100	25	<0.05
FYM application	Once at planting	86.4	0.0	31.8	45.5	30.67	<0.001
	Once per year	4.5	100	18.2	13.6	34.07	<0.001
	Three wise a year	4.5	0.0	9.1	32.8	11.6	>0.05
	Every three month	0.0	0.0	40.9	9.1	12.5	<0.001
Method of application	Broadcasting	95.5	68.2	100	81.8	86.37	<0.001
	Side dressing	0	18.2	0.0	0.0	4.55	>0.05
	Top dressing	4.5	13.6	0.0	18.2	9.07	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05

3.5.2 Irrigation, pruning, and training

As indicated in **Table 6**, the irrigation frequency across study areas showed a significant difference ($p < 0.05$). The percentage of farmers who irrigate once a week is 68.2% from Asabahir and 50% from Godnamamas. A higher percentage (81.8%) of farmers at Tsigereda irrigate their apples once a month. The percentage of farmers who irrigated once in 15 days was higher than other irrigation frequencies applied at Tengego. The irrigation frequency result indicated that it is very variable across locations. The overall percentage indicated that the farmers in the study area irrigate at least once a week. As proper irrigation enhances vegetative growth[32], fruit quality[33,34] and frequent irrigation in the study locations could enhance apple production in the future.

All the farmers at Asabahir, 90.9% of farmers at Godnamamas and Tengego pruned their apples. Whereas a larger percentage of farmers from Tsigereda (77%) doesn't prune their apple. All farmers at Tsigereda, 90% from Asabahir, and 68.2% from Tengego prune their apples any time they want to prune. About 40.9% of farmers from Godnamamas, which is the largest proportion of other pruning, prune their apples in summer. Regarding the part of plant pruned, 77.3% of farmers from Godnamamas and 90.9% from Tengego pruned the criss-crossed branches. Whereas 90.9% of farmers from Asabahir and 54.6% of farmers from Tsigereda prune whatever they wanted from the apple trees (**Table 6**). Pruning enhances light distribution, yield, and disease control in apple trees[35,36]. The result from the

study areas is mixed in that some farmers don't prune at all; some others prune at any time and others in summer. Furthermore, the branches pruned are also very variable across locations. This could indicate that the farmers did not follow the recommended period, recommended pruning practice or they are not familiar with pruning practices at all.

Near to all farmers at Asabahir, Godnamamas, and Tengego train their apple trees. Approximately, 90.9% of farmers from Tsigereda doesn't train their apple. There are different methods of training apple trees. From the selected method like training by using wires and staking, 90.9% and 95.5% of farmers from Asabahir and Tengego use training by wires. Even if a very small portion of farmers from Tsigereda apply training, all of them and 63.6% from Godnamams prefer to train their apple trees by staking (**Table 6**). The overall percentage of training systems indicated that a larger portion of the farmers across the three locations uses training by wire as a mechanism. Likewise, a higher percentage of farmers across all study areas train the apple branches horizontally. However, nearly 40.9% of farmers from Tengego train their apples vertically, which is against the recommendations[37,38].

Table 6. Training and pruning practices for apples across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Irrigation frequency	Once a week	68.2	4.5	50.0	9.1	32.95	
	Twice a week	13.6	0.0	36.4	36.4	21.6	<0.001
	Once in 15 days	18.2	9.1	13.6	54.5	23.85	
	Once a month	0.0	81.8	0.0	0.0	20.45	
	Other	0.0	4.5	0.0	0.0	1.12	
Do you prune your apple	Yes	100	22.7	90.9	90.9	76.12	<0.001
	No	0.0	77.3	9.1	9.1	23.88	
When do you prune	Before rainy season	0.0	0.0	18.2	18.2	9.1	<0.05
	Summer	4.5	0.0	40.9	4.5	12.47	<0.001
	Winter	4.5	0.0	63.6	9.1	19.3	<0.001
	Anytime	90	100	4.5	68.2	65.6	>0.05
Branches pruned	Crisscrossed	4.5	22.7	77.3	90.9	48.85	<0.001
	Vertical	4.5	22.7	13.6	4.5	11.3	<0.05
	What I want	90.9	54.6	0.0	0.0	36.37	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05
Training apple	Yes	95.5	9.1	86.4	95.5	71.62	<0.001
	No	4.5	90.9	13.6	4.5	28.38	
Training methods	Wire	90.9	0.0	27.3	95.5	53.4	<0.001
	Staking	9.1	100	63.6	4.5	44.3	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05
How you train	Vertically	27.3	0.0	13.6	40.9	20.45	<0.001
	Horizontal	72.7	100	77.3	54.5	76.12	<0.001
	In any direction	0.0	0.0	0.0	0.0	0.0	>0.05

3.6 Fruiting and harvesting

Fruit drops could be a common problem for apple growers. Across the study areas, 45.5% of farmers reported a 50% fruit drop, 90.9% of farmers from Asabahir reported a 25% fruit drop, 95.5% of farmers from Tsigereda reported a 75% fruit drop, and 72.7% of farmers from Tengego indicated 25% of fruit drop (**Table 7**). This indicated that there is a huge amount of loss of production due to fruit drop, which in turn could be associated with poor handling of the plants. The common causes of fruit drop are mainly poor nutrition, diseases attack, poor tree pruning, and inaccurate irrigation[39–42]. As indicated above in **Tables 5** and **6**, poor nutrition, and tree management are the most common futures across the study locations.

Around 72.7% of farmers from Godnamams indicated that their harvesting criteria are by market price. However, 50.1% from Asabahir, 54.5% from Tsigereda, and 90.9% of farmers from Godnamamas indicated that they harvest their apples by looking at their maturity. A large percentage of farmers from

Asabahir and Tsigereda indicated that they harvest their apples while at the full ripe stage, and at any time of the day. On the other hand, 63.6% of farmers from Godnamamas indicated that the harvest was at half ripe stage, and 77.3% of them were at any time of the day. Whereas a larger portion of farmers from Tengego (59.1%) indicated that they harvest their apples at the half-ripe stage, they harvest it in the noon part of the day (**Table 7**). The overall percentage indicated that immature, half-ripe, and full ripe stage share to equal percentage of farmers. This indicated that the harvesting is judged by the gut filling of the farmers without considering the market, customer preferences, and climacteric nature of the apple plant. Most of the farmers across locations use the harvesting criteria of maturity and market price. In agreement with this study, it was evidenced by Erkan and Dogan[43], maturity is one of the best indices of harvesting fruits.

Table 7. Pre-harvest and harvesting practices for apples across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Fruit drop	0	0.0	4.5	0.0	0.0	1.125	<0.001
	25	27.3	0.0	90.9	72.7	47.7	<0.001
	50	45.5	0.0	4.5	27.3	19.3	<0.001
	75	27.3	95.5	4.5	0.0	31.8	<0.001
	All	0.0	0.0	0.0	0.0	0.0	
Harvesting criteria	Maturity	50.1	54.5	27.3	90.9	55.6	<0.001
	Market price	40.9	45.5	72.7	9.1	42.05	<0.001
	No criteria	0.0	4.5	4.5	00	2.25	>0.05
Stage of harvesting of fruit	Green stage	0.0	0.0	13.6	4.5	4.52	>0.05
	Immature	31.8	41	4.5	36.4	28.4	<0.001
	Half ripe	27.3	4.5	63.6	59.1	38.6	<0.001
	Fully ripe	40.9	54.5	27.3	0.0	30.6	<0.001
Harvest time of the day	Morning	45.5	0.0	18.2	0.0	15.9	<0.001
	Afternoon	0	41	0.0	90.9	32.9	<0.001
	Evening	0	4.5	9.1	0.0	3.4	<0.001
	Anytime	54.5	54.5	77.3	9.1	48.85	<0.001

3.7 Post-harvest handling

Post-harvest handling is one of the main causes of the loss of fruits in developing countries. According to some reports, above 60% of the loss of fruits is due to poor post-harvest-handling. More than 90% of respondents from Asabahir and Tengego store the apple fruit first and sell it after that. Regarding farmers from Tsigereda and Godnamamas, higher percentage of farmers, 63.7% and 54.5%, respectively, directly sell the harvested fruit. The *F*-test result indicated that there is a significant difference between locations in post-harvest handling. In the case of post-harvest treatment, 13.6% of farmers from Asbahir, 95.5% of farmers from Godnamams, and 45.5% from Tengego use post-harvest handling treatments. Washing with clean water is the major postharvest treatment at Asabahir (90.9%), Godnamamas (81.8%), and Tengego (59.1%). The *F*-test result indicated that there is a significant difference in washing and packing postharvest treatments across locations (**Table 8**). It can be concluded that the respondents across the study locations first store their products and sell them after that. Similarly, the farmers use washing by clean water system of post-harvest handling treatment. As for different reports, the practices the respondents used as post-harvest systems are common in fruit and vegetables[44,45].

3.8 Transport and marketing

The main types of transportation systems of the apple fruits across the study area were reported as animal carts, vehicles, head or back loading, and animal carriers. The result of this survey indicated that 95.5% of farmers from Asabahir uses animal cart as the main means of transportation for their apple products. Whereas in Tengego and Tsigereda districts, the main means of transport of their apple fruit is by head or backloading. The exception is that 45.9% of farmers from the Godnamamas district use an animal carrier for the transport of produce (**Table 9**). This could indicate that different types of

Table 8. Postharvest practices for apple across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
After-harvest handling	Store and sell	90.9	13.6	36.4	90.9	57.95	<0.001
	Direct cell	9.1	63.7	54.5	9.1	34.1	<0.001
	Consume all	0.0	13.6	22.7	0.0	9.07	<0.05
Do you use post-harvest treatment	Yes	13.6	0	95.5	45.5	38.65	<0.001
	No	86.4	100	4.5	55.5	61.35	
Kind of treatment	Chemical	0	0.0	9.1	0	2.275	>0.05
	Washing with clean water	90.9	0.0	81.8	59.1	57.95	<0.001
	Packing	9.1	0.0	77.3	39.9	31.57	<0.001

Table 9. Transportation and marketing systems for apple across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Transportation system	Animal cart	95.5	13.6	31.8	31.8	43.17	<0.001
	Vehicle	0.0	18.2	0	0.0	4.5	<0.01
	Head/backloading	0.0	68.2	22.3	50.0	35.12	<0.001
	Animal carrier	22.7	0.0	45.9	22.7	22.8	<0.05
	Other	0.0	0.0	0.0	0.0	0.0	>0.05
To whom you usually sell	Rural collector	90.9	68.2	63.6	18.2	60.2	<0.01
	Wholesaler	0	0	9.1	9.1	4.55	>0.05
	Cooperatives	0	0	9.1	0	2.275	>0.05
	Retailers	0	9.1	4.5	0	3.4	>0.05
	Local consumers	9.1	22.7	45.5	86.4	40.9	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05
Buyer preference criteria	Better price	90.9	18.2	36.4	72.7	54.55	<0.001
	Customer	9.1	9.1	63.6	22.7	26.12	<0.001
	No quality discrimination buyer	0.0	81.9	18.2	22.7	30.7	>0.05
	Large volume buys	0.0	4.5	22.7	4.5	7.92	<0.05
	other	0.0	4.5	0.0	4.2	2.17	>0.05

transportation systems for apple products are utilized across the study areas. In those areas where the vehicle is not accessible, what they use is other options for transport. Meanwhile, if the amount of produce is very low, they even use backloading. The result of this research conforms to other research in which in rural and small-scale countries the transport systems of fruits and vegetables are either by animal carriers or human backloading[46–48].

Buyer preference is based on different factors which could be variable from place to place. The main criteria could be if the buyer offers a better price per kg, if the buyer couldn't discriminate by quality if the buyer takes in bulk, and if it is a long-term customer. Hence, the farmers from the Asabahir district prefer buyers by offering better prices (90.9%) (**Table 9**). This conforms to the research result of Ahmed[30] who described that a better price is the best price setting in fruit marketing in Ethiopia. Based on this criterion, the buyer they selected is the rural collectors who collect the apple by going to their local market or their homes. The buyer preference at Tsigereda is mainly governed by no quality discrimination criteria (81.9%), but in the Godnamamas district, it is by long-term customer status. Based on those criteria, those two locations also prefer to sell to collectors. In contrast to this, farmers from Tengego sell their apples to consumers at the local location and in other nearby towns as they offer them better prices. The overall percentage of this study indicated that rural collectors are preferred over the other buyers and better price is the major criterion in selecting buyers. This is in confinity with the research result of Ahmed[30]. In contrast to this research result, their research done on apple fruit market analysis in Chencha, by Tamirat and Muluken[49] described that a higher preference for selling by farmers is towards cooperatives.

3.9 Marketing and loss

Some common market problems, customer preferences, and post-harvest handling problems could force the loss of harvested fruit without generating income. Of all the respondents from Godnamamas (36.4%) and Tengego (86.4%), the main cause of the market problem is fruits are discarded due to their small size. Whereas, for 36.4% of farmers from Asabahir, the main cause of market loss is physical damage while transportation. Farmers from Tsgereda reported that the main cause of the marketing problem is the loss of fruits due to mechanical damage at harvesting and marketplace (**Table 10**). In agreement with this research, the result indicated that physical and mechanical damage during transportation and other handling systems are the main causes of loss in different fruits and vegetables[46–48]. According to a rough estimation of the percentage of loss of harvested apple fruit across study areas, 37.8%, 5.8%, 25.9%, and 22.4% average loss is estimated from Asabahir, Tsigereda, Godnamams, and Tengego, respectively (**Table 10**). The result of this study could indicate that the main causes of market losses across locations are discarded due to small-sized fruits and poor transportation. Similarly different research reports indicated that fruit size and transportation are causes of market loss[14,50,51].

Table 10. Loss and market problems in apple across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Main quality problems in selling	Immature fruit	13.6	18.4	9.1	18.2	14.8	>0.05
	Over ripen fruits	0.0	0.0	9.1	0.0	2.275	>0.05
	Discarded due to small fruit size	31.8	22.7	36.4	86.4	44.3	<0.001
	Mechanical damage at harvest and marketplace	18.2	35.6	9.1	0.0	15.7	<0.05
	Sunburn	4.5	0.0	4.5	0.0	2.25	>0.05
	Poor transport loss	36.4	23.3	31.8	0.0	22.8	<0.05
Average loss percentage (%)	Loss	37.8	5.8	25.9	22.4	22.9	<0.05

The market place of fruit commodities could be governed by different factors. Of those better access to the market and better price per product could be the main determinants. According to this study, 50% of farmers from Godnamamas and all respondents from Tengego prefer to sell in local markets. Whereas 95.5% of farmers from Asabahir prefer to sell to a major city, and 45.5% of respondents from Tsigereda nearby city is their main marketplace (**Table 11**). In agreement with this research result, the review study by Yeshiwas and Tadele[52] indicated that the main market for mango fruit in Ethiopia is the local market.

The way of selling is also variable across locations. The *F*-test result indicated that there is a significant difference between locations in between weighting and single fruit way of selling. A higher percentage of farmers from Godnamams, Tengego, and Asabahir prefer selling by single fruit method. Even if selling by single fruit is higher than weighting in these locations they also use selling by weighting. This preference for selling single fruit could be associated with a lack of customers buying by weighting from the local areas. In contrast, farmers from Tsigereda prefer to sell by weighting. The chi-square test result also indicated that there is a significant ($p < 0.05$) difference in cost per kg and per single fruit across locations. The highest cost per kg and per single fruit which is 47 and 3.27 ETB is recorded from Godnamams, and the lowest is 14.5 and 0.77 ETB from Tsigereda (**Table 11**). The farmers from Asabahir and Godnamams think that apple farming is a productive venture, whereas, in the other two locations, the reverse is reported. All the costs per kg of apple fruit are better than the reported cost of apple selling from Chencha by the study result of Tamirat and Muluken[49].

Table 11. Marketplace and profitability of apple across locations of Angolela Tera district

Parameters	Values	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Market place	Local area	4.5	4.5	50	100	39.75	<0.001
	Nearby city	4.5	45.5	27.3	13.6	22.7	<0.05
	Major city	95.5	27.3	22.7	0.0	36.37	<0.001
Way of selling	weighting	9.1	86.4	77.3	77.3	62.5	<0.001
	Single fruit	90.9	13.6	81.8	95.5	70.45	<0.001
Cost per kg (ETB)	(Mean ± SE)	22.27 ± 2.27	14.54 ± 6.075	47.0 ± 5.29	30.2 ± 4.14	23.2	<0.001
Cost per single fruit (ETB)	(Mean ± SE)	3.27 ± 0.69	0.77 ± 0.43	3.06 ± 0.41	3.59 ± 0.35	4.1	<0.001
Apple farm profitability	Yes	90.9	40.9	90.9	18.2	60.2	<0.001
	No	9.1	59.1	9.1	89.8	39.8	

3.10 Institutional support and capacity-building needs

3.10.1 Institutional support and capacity building status

Apple farming is a recent production venture across the study areas. Similar to other technologies, different capacity-building programs by different institutions could have paramount importance. As indicated in **Table 12**, the largest portion of respondents from all the districts indicated that the main kind of capacity building they received was training. With an overall percentage of 17.5%, booklets were the second most kind of support the farmers received. According to the source of capacity building, with an overall percentage of 89.7%, the Agriculture Office is the main source of support. The support by NGOs is the next source with an overall percentage of 17.05% (**Table 12**). In conformity with this research result, Mossie *et al.*[53] revealed that different stakeholders mainly government offices and NGOs give support to farmers in terms of training and other capacity-building strategies.

Table 12. Type of support and supporters of apple production across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Types of capacity building received	Training	95.5	66.3	95.5	45.5	75.7	<0.001
	Field demonstration	0.0	0.0	9.1	4.5	3.4	>0.05
	Experience sharing	4.5	4.5	4.5	40.9	13.6	<0.001
	Booklet	0.0	24.7	0.0	45.5	17.5	<0.001
	Other	0.0	4.5	0.0	0.0	1.12	>0.05
Source of capacity building	Agriculture Office	100	63.6	95.5	100	89.7	<0.001
	Research Center	0.0	0.0	4.5	0.0	1.12	>0.05
	NGO	0.0	36.4	31.8	0.0	17.05	<0.001
	Other	0.0	0.0	0.0	0.0	0.0	>0.05

3.10.2 Farmer's training and capacity-building support needs

Growing an apple tree requires knowledge, skill, and understanding of agronomic management, harvesting, postharvest handling, and marketing of the products. As a new technology and production venture to the district, the farmers need to be supported by different stakeholders on those skill sets. The result of this research study indicated that with an overall percentage of 75%, 64.7%, 61.3% and 55.6% knowledge and skill on site selection, land preparation, chilling requirement, and planting system respectively are the most needed across the locations (**Table 13**). Meanwhile, farmers from Asabahir prioritized training on chilling requirements (100%), site selection (100%), harvest and postharvest handling, tree training (86.4%), and seedling establishments (81.8%). Regarding Tsigereda, the main needs rely on fertilization, planting system, land preparation, and site selection. Except for a small percentage of training needed for harvesting, marketing, and food preparation, the farmers from

Godnamamas need other training topics above 77.3%. As compared to other locations, the farmers from Tengego showed a low level of need for training and other capacity buildings. But, chilling requirements, land preparation, and site selection are the main needs of training in this district (**Table 13**). It can be concluded that the farmers in the study locations are in high demand for training and capacity building from different institutions. Capacity-building supports have a high impact on production, productivity, and adoption success[53,54].

Table 13. Type of capacity building and training needs of farmers across locations of Angolela Tera district

Parameters	Variables	Districts				Overall (n = 160)	*p*-value
		Asabahir (n = 22)	Tsigereda (n = 22)	Godnamamas (n = 22)	Tengogo (n = 22)		
Training and capacity-building topics	Chilling requirement of apple	100	0.0	100	45.5	61.3	<0.001
	Site selection	100	59.1	100	40.9	75	<0.001
	Land preparation	54.5	59.1	100	45.5	64.7	<0.001
	Seedling establishment	81.8	0.0	100	36.4	54.5	<0.001
	Planting system	54.5	59.1	100	9.1	55.6	<0.001
	Irrigation	40.9	54.5	77.3	31.8	51.12	<0.001
	Fertilization	27.3	76.4	100	22.7	56.6	<0.001
	Pruning systems	45.5	13.6	100	13.6	43.1	<0.001
	Tree training	86.4	0.0	95.5	0.0	45.4	<0.001
	Harvesting and postharvest handling	90.9	27.3	59.1	0.0	44.3	<0.001
	Marketing of apple	50	0.0	45.5	0.0	23.8	<0.001
	Food preparation	50	0.0	40.9	0.0	22.7	<0.001

4. Summary and conclusion

The production of apples in the study areas is a new venture. Hence, this study analyzed the socioeconomic, production, marketing, harvesting, postharvest handling, and needs of institutional support of apple produce across the Angolela Tera district. The result revealed that the main farmers producing apples are males, even if most of the management of the apple trees is the responsibility of females. The farmers are also in their active farming stage. Regarding the apple orchard size and placement of the orchard, it is revealed that most of the farmers have apples with less than 10 trees and placed them in backyards. The management of apple trees is characterized by non-recommended practices of plant spacing, fertilizer application, pruning, and training. On the other hand, better practices regarding variety distribution, harvesting stage, irrigation frequency, and post-harvest handling were recorded. According to marketing and post-harvest loss results, most of the farmers from study locations prefer the local market, and higher postharvest loss was reported due to the impact of poor transportation, small fruit size, and mechanical damages. The farmers across the study areas get a better price per kg and per fruit of apple. It might be due to this that most of the farmers think apple farming is a productive venture. As the result revealed, there is a higher need for farmers for institutional support in training and capacity building. Hence, if they are supported very well, apple farming could be one of the good farming systems in the coming years across the study locations.

Author contributions

Conceptualization, GA and BD; methodology, GA; software, GA, BD, NT and KM; validation, GA, BD and NT; formal analysis, GA; investigation, BD; resources, GA, BD, NT and KM; data curation, GA and BD; writing—original draft preparation, GA; writing—review and editing, BD; and all authors involved in visualization, supervision, project administration, and funding acquisition. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The datasets generated and analyzed during the current study are not publicly available to protect the privacy of respondents. Furthermore, the authors need to confirm that the data is used in the right way

and for the right purposes. Therefore, data presented in this study will be available upon request from the corresponding author.

Conflict of interest

The authors declare no conflict of interest.

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