FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Farmers’ management of potato (*Solanum tuberosum* L.) late blight (*Phytophthora infestans* (Mont.) de Bary) and sprouting in Shashemene and West Shewa districts, Ethiopia

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Abstract: Potato is a potential crop for enabling smallholder farmers to attain food security. However, it is underutilized in Ethiopia due to late blight occurrences and management of sprouting. Understanding what farmers are doing in potato tubers storage and disease management is important to find alternative solutions for existing problems. The purpose of this research was to identify potato varieties currently grown in the study areas, to investigate their responses to sprouting ability and late blight as well as existing management for sprouting and late blight.

A survey was conducted with randomly sampled respondents in Shashemene (146) and West Shewa (318). Data were collected by interviewing farmers engaged in seed production and consumption. Farmers in the studied areas reported growing more than four potato local and improved varieties. Gudene variety earlier released as resistant to late blight was reported to be susceptible by 73.3% of the farmers. In the studied area, sprouting was controlled using diffused light storage and dark storage. However, chemical application was practiced by farmers to control late blight ranging from 82% to 94% and 93% to 99% at Shashemene and West Shewa, respectively. Since the application of chemicals raised the issue of health and environmental hazards, essential oils have been investigated and used to control late blight and sprouting in different parts of the world; however, it is not practiced

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The authors have pooled together knowledge from their qualifications and experiences on different aspects of the subjects that went into this article. On the one hand, Dr. Bekele and Mr. Daniel have applied their agricultural knowledge to plant pathology, crop physiology, agronomy, postharvest handling and related expertise. On the other hand, Prof. Zemede and Dr. Ermias brought their expertise in biodiversity, ethnobotany, environmental science principles and methods as well as related areas. Thus the authors tried to address the problems from diverse angles along the different relevant specialization areas.

PUBLIC INTEREST STATEMENT

This paper is of a great public interest as it deals with a very important food crop with economic importance and high market value, ease of consumption. Potato is produced twice a year in many highlands of Ethiopia and has been used as a source of food and nutrition toward achieving food security for smallholder farmers. This paper deals with the practices of indigenous knowledge on late blight disease and sprouting management. The results would be useful for individual potato farmers and researchers involving in potato production, protection and consumption. The management practices discussed in this paper will guide us to find alternative solutions to the problem of late blight and sprouting. Therefore, the paper combines agricultural knowledge, farmer’s knowledge, botanical knowledge to address its production and storage constraints and maximize yield.
in studied areas. Since Ethiopia has enormous plant species with essential oils, using essential oils as alternative is helpful to mitigate the existing problems.

**Subjects:** Horticulture; Agriculture and Food; Botany

**Keywords:** Chemicals; essential oils; late blight; potato cultivars; sprouting; storage methods

1. **Introduction**

Potato (*Solanum tuberosum* L.) is a crop of highland origin and has been domesticated in the high Andes of South America and has become a major crop in the cool highland areas of South America, Asia and Central and Eastern Africa (FAOSTAT, 1999). It is a solanaceous starch-y crop that has highly diverse landraces with a variety of tuber shapes and colors distributed and grown worldwide (Haaverkort et al., 2014; Machida-Hirano, 2015). Furthermore, it is the fourth most important food crop in the world in terms of production over 370 million metric tons produced in 2019; however, it is the third most important crop in terms of consumption after wheat and rice; as only 14% of maize produced is used for food (FAOSTAT, 2021). Relative to rice, wheat and maize, potato provides high productivity and generates more food per unit area as well as per unit time for ensuring long-term food security via sustainable production (Devaux et al., 2014). In the face of the world's growing population, global potato production needs to be increased since it is a potential crop for enabling smallholder farmers to attain food security (Devaux et al., 2020).

In Ethiopia, it has been cultivated since its introduction by German botanist, Wilhelm Schimper, in about 1858 (Pankhurst, 1964). The next-known introductions were in 1971–1972, when several Dutch cultivars were tested in the country (Hilemicheal, 1979) and after 1972, when additional cultivars were introduced (Berga et al., 1994; Gebremedhin et al., 2008). Since then, potato has gradually become staple crop in which almost every household allocates a fragmented land every year for achieving food security for consuming after cooking (to prepare “wet”) or boiling. According to Central Statistical Agency (CSA) (2016), potato is cultivated on more than 296, 000 ha of land which participates more than 3.7 million smallholder farmers and with an annual production of about 3.6 million tons. Though Ethiopia ranks ninth among the African countries in terms of potato production and harvested area in 2019, in terms of yield per hectare it is nineteen among the top Africa countries indicating that its productivity is less than desired (FAOSTAT, 2021). One strategy to increase the potato production is to understand constraints at the field level and identify the real problems together with the farmers.

Potato is a cheap source of nutrients that plays an important role in guaranteeing food security, income generation and employment opportunities (Devaux et al., 2020). Despite its potential, however, its productivity remains low in Ethiopia due to poor disease control measures and postharvest management, among others (Gildemacher et al., 2009a). For example, late blight, caused by oomycete fungus *Phytophthora infestans* (Mont.) de Bary, is one of the most destructive diseases which cause major losses in yield (Bekele & Eshetu, 2008; Demissie, 2019). It occurs throughout potato producing areas and farmers failed to grow potato during the main rainy season without chemical application (Shiferaw et al., 2011). In the absence of chemical application, the incidence of late blight was reported to be about 76.25% (White flowered cultivar) and 82.5% (cultivar Agazer) while for resistant cultivars Gudene and Jalene was reported to be 58% and 50%, respectively (Habetamu et al., 2012).

Moreover, farmers forced to sell their potatoes at low prices soon after harvesting due to postharvest handling problems (Endale et al., 2008b). Therefore, year-round availability of seed and ware potato tubers (fresh consumption) is a challenge in Ethiopia. In this context, preserving the quality of potato tuber after harvesting is vital for use as seed, fresh consumption and processing. Sub-optimal handling, poor tuber quality and deficient postharvest storage can lead to significant amount of waste due to premature sprouting and rotting during storage (Pritchard
et al., 2012). In nature, potato tuber couldn’t sprout immediately following harvesting due to dormancy which is a physiological phenomenon that is regulated by exogenous (environmental) and endogenous signals (Sonnewald & Sonnewald, 2014). The relative concentration of several biochemical compounds such as plant growth regulators and other compounds like carbohydrates and organic acids are believed to orchestrate the onset and further development in breaking the dormancy (Pasare et al., 2013). Longer dormancy and delayed sprouting (at desired time) would be best for ware potato tubers storage, while accelerated sprouting would be preferable for seed potato tubers. As reviewed by Eshel and Teper-Bammolker (2012), sprouting has been induced in seed potatoes by the application of “Rinditie” (commercial mixture of ethylene chlorohydrins, ethylene dichloride, and carbon tetrachloride), bromoethane, carbon disulfide and gibberlic acids (Sonnewald & Sonnewald, 2014). Recently, essential oils have been used to suppress and induce sprouting (Shukla et al., 2019). However, neither chemical nor essential oils have been used for managing potato sprout in the studied areas.

Research institutes have released different resistant improved varieties with major emphasis to a wide adaptability, high tuber yield and late blight resistant (Asefa et al., 2016). The resistances of released varieties, however, are reported to have been affected within short time due to the unstable nature of P. infestans (M. Shiferaw et al., 2011). Furthermore, chemical application does not always prove against pathogens and it has led to environmental pollution, pathogen resistance and increase risk for human (De Curtis et al., 2010; Haverkort et al., 2014; Wong et al., 2015). Therefore, using chemicals during potato production and consumption raised issues due to health and environmental hazards which demands alternative eco-friendly solutions. Thus it is a timely endeavor to keep searching for other biological control methods such as bio-control agents, essential oils and bio-pesticides. As results, effects on human and environment due to chemical application could be minimized.

Several researchers have sought alternatives to chemicals, of low toxicity to control late blight and potato spraying. Among the potentially useful practices, the use of essential oils against oomycetes (Bi et al., 2012; Lee et al., 2008) and to control potato sprouting has already been demonstrated (El-Awady et al., 2014; Shukla et al., 2019). Hence, understanding what farmers are doing in potato production and postharvest management is important for finding alternative solutions in Ethiopia. To find potential essential oils as alternatives, the practices of farmers to manage late blight and sprouting should be studied. Therefore, the main objectives of this study are: 1) identifying available cultivars currently grown in the study area according to their response to sprouting and late blight, 2) assessing the existing management methods for potato spraying and late blight. As a result, communities involved in potato consumption and production can benefit through minimizing the losses due to potato late blight and sprouting.

2. Materials and methods

2.1. Agro-ecology of potato

In Ethiopia, the agro-ecological zones suitable for potato growing classified as semi-arid, sub-humid and humid conditions with an average altitude of 1340–3298 m a.s.l. (Tilahun et al., 2017). Researches had been conducted to develop improved variety since 1975 with the objectives of developing high-yielding, late blight resistant and wide adaptability cultivars. From 1987 to 2015 about 37 improved varieties were released which are adaptable to the range of altitudes from 1650 m to 3350 m with on-farm yielding ability from 17.5 to 54 tons ha⁻¹ (MANR (Ministry of Agriculture and Natural Resources), 2016 and personal communication at Holetta Agricultural Research Center).

2.2. The study area

The survey was carried out in 2019 “Meher” season (main rainy season from June to September) in major potato growing areas in Shashemen (Awasho-Dengo, Fajo-Sole, Hurssa) and West Shewa (Jeldu-Sariti, Wolmera-Choke, Galessa-Dendi) districts, Ethiopia. According to Central Statistical
Agency (CSA) data of 2015/16, the total area used for potato in Jeldu-Sariti, Wolmera-Choke and Shashemene was 300.78, 51.90 and 2,808.42 ha, respectively, whereas the area used in Galesso-Dendi had not been included. The altitude ranges from 2165 m to 3380 m in West Shewa while the altitude of Shashemene is from 2061 m to 2296 m. The average temperature and relative humidity is 16°C/65% and 15°C/63% in Shashemene and West Shewa, respectively. Bimodal rainfall is common in the studied areas. The peak rainy seasons in Shashemene is in May followed by a second peak in August, where as in West Shewa the peak is in April followed by a second peak in July–August.

2.3. Selection of study areas and farmers
The farmers in Shashemene and West Shewa districts are known as the suppliers of potato tubers. Shashemene, for example, is considered the main trade hub that provides ware potatoes to the capital city of Ethiopia (Bezabih & Mengistu, 2011; Tesfaye et al., 2011). According to agricultural offices data, all farmers in the districts are engaged in potato production. The farmers in studied areas were seed producer cooperatives, commercial seed producer as well as consumers. Therefore, total sample sizes of 464 households were randomly selected from registered list obtained from the respective agricultural offices in the study areas based on the formula by Yamane (1967). Using proportionate sampling determination with 95% confidence level and 5% margin of error, the population sample per district was determined.

2.4. Data collection and analysis
A structured questionnaire was used to collect the data and pretested for consistency. Data were collected after securing official permission from the districts agricultural offices. Experienced enumerators were recruited among the development agents and trained both theoretically and practically on how to fill in the questionnaire by interviewing the selected farmers. The informed consent was obtained from each informant after being informed that the results will be used for academic purpose with no commercial interest and that positive outcomes may be extended to the farmers to improve the potato situation. The data collected included practices related to disease management, postharvest handling, organic management as well as use of chemicals to manage late blight disease and sprouting. Furthermore, open-ended questions were included to get an overview of potato production and consumption constraints. To process the household survey data, descriptive statistics (frequency, percentage, cross tabulation) were computed using SPSS. Pearson Chi-square was used to test the significance.

3. Results

3.1. Demographic information of studied areas
Farmers in the studied areas were in the age range from 19 to 95, the majority (87.9%) were between 20 and 60 years old. Most of the interviewed were male headed households with 87.7% and 83.3% at Shashemene and West Shewa districts, respectively (Table 1). This might be related to the fact that suitable workers who are known to possess the physical strength required for crop production. The results imply that potato has been used as a means of employment and source of income for a range of age categories in the studied areas. An overview where potato used to grow in the studied areas, the number of potato under production, its use, land size and major disease is given in Table 2.

3.2. Potato varieties grown in the studied areas
The number of varieties grown per household in each kebele is shown in Figure 1. Farmers used to grow from one to six potato local and improved varieties per kebele. Among the total farmers surveyed, at least 63% grew two or more potato varieties during the growing season prior to survey period. Almost all farmers in the studied areas were engaged in producing ware and seed potato tubers both local and improved varieties (Table 2). Predominantly, the improved variety Gudene and Jalene were grown in all studied areas while Menagesha was grown only in West Shewa and the local varieties Agazer and Neche Abeba grown only in Shashemene (Table 3). The dominant variety grown in Shashemene was Gudene followed by Neche Abeba and Agazer. Similarly, the dominant variety grown in West Shewa
was Gudene followed by Menagesha and Jalene. Furthermore, more number of potato varieties were found in West Shewa (Galessa, Jeldu and Wolmera) relative to Shashemene (Awasho, Faji and Hurssa).

3.3. Sprouting management
As indicated in Table 4, the improved variety named Gudene was mentioned as one that sprouts fast during storage in terms of duration relative to the other potato varieties under production which is suitable for the areas that grow more than one growing seasons per year. Besides, it was found that there was a highly significant relationship between the capacity to sprouting faster and storage methods used (diffused light storage and dark storage) at 95% confidence level and 5% margin of error in the studied areas (Table 5). Diffused light storage was indicated as better methods to store seed potato tubers. Respondents were asked whether they grow potato at home-garden, field and at both. Among the respondent farmers 49% mentioned that they used to grow using both farm types while 43% grow on field. Those farmers growing on field involved in large amount of potato production with the objective of providing their potato for market outlets. However, most farmers (95.5%) mentioned that there was a lack of market information that forces them to sell their product at lower price during peak production season and unable to quantify the losses due to sprouting.

Moreover, the results indicated that the relation between storage and growing conditions used by farmers is highly significant at 95% confidence level and 5% margin of error (Table 6). In this study, farmers were asked where they grow and store potato. It was found that farmers who grow at field store more while those who grow at home-garden store less. Moreover, farmers used different storage methods to control sprouting: diffused-light store (DLS), dark storage and leaving the potato tuber in the soil until harvesting (Table 7).

Characteristics with b expressed in number.

3.4. Late blight disease and its management
All farmers mentioned that late blight is the major constraint among other factors in potato production and consumption. Potato varieties grown in the studied areas were susceptible to late blight (Table 8). The occurrence and effects of late blight have been rated as high and very high in the studied areas. The problems posed due to late blight were higher at West Shewa for the potatoes grown during the field survey with the highest percentage at Wolmera-Choke (Figure 2). The majority of the potato producers are dependent on fungicides to manage the disease (Table 9). The results showed that

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\text{Table 1. Number of respondents based on age category in the studied areas (n = 464)}
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| Age Category | Gender | Shashemene (n = 146) | West Shewa (n = 318) |
|--------------|--------|----------------------|-----------------------|
|              |        | Kebeles              |                       |
|              |        | Awasho-Dongu         | Faji-Sole             |
| 19–40        | Male   | 16                   | 32                    |
|              | Female | 2                    | 8                     |
| 41–60        | Male   | 19                   | 5                     |
|              | Female | 4                    | -                     |
| 61–80        | Male   | 9                    | -                     |
|              | Female | -                    | -                     |
| >80          | Male   | -                    | -                     |
|              | Female | -                    | -                     |
| Total        |        | 50                   | 45                    |

b = expressed in number.
Table 2. Potato used to grow in studied areas, disease and postharvest management and its use (n = 464)

| Characteristics                                      | West Shewa (318) | Shashemene (146) |
|------------------------------------------------------|------------------|------------------|
| **Kebeles**                                          |                  |                  |
| Galessa-Dendi                                        | 2165             | 2952             |
| Jeldu-Seriti                                         | 2400             | 2061             |
| Wolmera-Choke                                        | 2292             | 2296             |
| Awasho-Dongu                                         | 16               | 16               |
| Foji-Sole                                            | 49               | 47               |
| Hurssa                                               | 41               | 37               |
| Elevation (m.a.s.l)                                  | 49               | 47               |
| Average Temperature (°C)                            | 0.77             | 0.82             |
| Average age (years)                                 | 1.32             | 0.61             |
| Average farm size (ha)                              | 0.97             | 0.47             |
| Potato growers at field (%)                         | 49               | 43               |
| Potato growers at home-garden (%)                   | 16               | 31               |
| Potato growers at field and home-garden (%)          | 14               | 51               |
| Potato cultivars under production (%)                | 16               | -                |
| Ware and seed potato production (%)                  | 109              | 41               |
| Late blight cited as a major problem (%)             | 100              | 100              |

respondents in Hurssa had the lowest percentage (82.0) followed by Foji Sole (86.0) who are using fungicides to manage the disease. Potato farmers in West Shewa are also dependent on fungicides and the majority of the respondents (93.0, 97.0 and 99.0 %) said that fungicides are the main late blight management component.

In general, 78.7% of the farmers reported that the benefits from potato production are low since the potato in their hand is susceptible to late blight due to two main reasons. First, the cultivars are local. Second, the improved varieties are out dated so that it cannot resist the disease without fungicides. Besides, 95.5% and 75.4% of the respondents mentioned the problems related to market information and accessibility of fungicides as major constraints for the potato production sector.

4. Discussion

4.1. Potato varieties grown in the studied areas
The current study identified potato varieties grown in the studied areas at both household and kebele levels to guide future alternative management options for sprouting in storage and late blight. Farmers in the studied areas were involved in production of both ware and seed potato using up to six local and improved varieties. The current study further indicated that there were similarities and differences in potato varieties grown in the studied areas. The local varieties Agazer and Nech Abeba were grown only in Shashemene while the variety Menagasha grew only in West Shewa. But, both Gudene and Jalene varieties were grown in all studied areas. Gumataw et al. (2013) and Semagn et al. (2015) also reported that Agazer and Nech Abeba are widely grown in Shashemene district while different authors indicated that Gudene and Jalene
grown in all studied areas. One of the reasons for growing Agazer and Neche Abeba by framers in Shashemene is due to the nature of short dormancy that can be used as a seed source in two consecutive growing seasons (Semagn et al., 2019).

Few numbers of varieties were grown by interviewed farmers relative to the released improved varieties so far while potato varieties released to farmers from 1987 to 2015 were about 37 varieties (MANR (Ministry of Agriculture and Natural Resources), 2016). The reasons for the low number of varieties associated with the lack of access to improved varieties and occurrence of late blight disease which is in line with previous study by Haverkort and Struik (2015). Moreover, mismatch between the selection criteria that breeders and farmers use resulted in low number of improved varieties grown by farmers (Semagn et al., 2019). Releasing new improved varieties had been used as an option to minimize the losses due to late blight and to improve the quality of potato tubers in storage (Asefa et al., 2016). However, breeders in Ethiopia are not seen developing new varieties within short period since breeding for creating a new potato variety is slow and difficult (Stokstad, 2019). Hence, there should be some mechanism to sustain the existing varieties to minimize the losses due to the existing problems. Therefore, researchers should find alternative solutions via incorporating farmers’ indigenous knowledge while releasing new varieties. The use of essential oils could be an option to sustain the existing varieties in the production system via minimizing the losses from late blight and to improve the quality of potato tubers as a seed and ware.

4.2. Sprouting management
Sprouting can be inhibited and/or enhanced depending on the intended final usage. In the case of ware potatoes, sprout inhibition is beneficial whereas for seed potato sprout enhancement is crucial to use tubers after a short period of storage as a seed to coup with the planting date. The data from the survey showed that farmers used different storage methods for both ware and seed tubers to manage sprouting but they were unable to quantify the losses due to the lack of awareness about its effect on the production and consumption of potato tubers. In countries that have better technology to manage sprouting (e.g., the United Kingdom), losses of 770,000 tons were recorded in 2012 due to premature sprouting and rotting during storage (Pritchard et al.,
Table 3. Percentage and number of farmers who used to grow different potato varieties

| Varieties                | Shashemene (146) | West Shewa (318) |
|--------------------------|-------------------|------------------|
|                          | Awasa-Dongu       | Faji-Sole        | Hurssa | Galessa-Dendi | Jeldu-Siriti | Wolmera-Choke |
| Agazer<sup>1</sup>       | %                 |                  |        |              |              |                |
|                          | n                 | 6                | 14     | 4            | -             | -              |
| Belete<sup>2</sup>       | %                 | -                | -      | 2.0          | 13.0          | 20.0           |
|                          | n                 | -                | -      | 1            | 13            | 26             |
| Gudene<sup>2</sup>       | %                 | 60.0             | 80.0   | 29.4         | 80.0          | 90.8           |
|                          | n                 | 30               | 36     | 15           | 80            | 118            |
| Jalene<sup>2</sup>       | %                 | 44.0             | -      | 3.9          | 26.0          | 60.8           |
|                          | n                 | 22               | -      | 2            | 26            | 79             |
| Menagesha<sup>2</sup>    | %                 | -                | -      | -            | 100.0         | 92.3           |
|                          | n                 | -                | -      | -            | 100           | 120            |
| Neche Abeba<sup>1</sup>  | %                 | 82.0             | -      | 33.3         | -             | -              |
|                          | n                 | 41               | -      | 17           | -             | -              |

<sup>1</sup> Local varieties, <sup>2</sup> Improved variety
Table 4. Percentage and number of farmers who mentioned potato tubers sprout within 120 days after harvest in storage

| Varieties         | Shashemene | West Shewa |
|-------------------|------------|------------|
|                   | Awasho-Dengu | Foji-Sole | Hurssa | Galessa-Dendi | Jeldu-Siriti | Wolmera-Choke |
| **Agazer**¹      | %           | 6.0        | 13.3   | 29.4          | -            | -            |
|                   | n           | 3          | 6      | 15            | -            | -            |
| **Gudene**²      | %           | -          | 75.6   | 27.5          | 99.0         | 83.1         | 88.6         |
|                   | n           | -          | 34     | 14            | 99           | 108          | 78           |
| **Jalene**²      | %           | -          | 2.2    | 3.9           | 9.0          | 11.5         | 1.1          |
|                   | n           | -          | 3       | 2             | 9            | 15           | 11           |
| **Menagesha**²   | %           | -          | -      | 8.0           | 10.8         | -            |
|                   | n           | -          | -      | 8             | 14           | -            |
| **Neche Abeba**¹ | %           | 32.0       | -      | 33.3          | -            | -            |
|                   | n           | 16         | -      | 17            | -            | -            |

¹Local variety, ²Improved variety
Table 5. Chi-square tests for variety easily sprout * storage

|                      | Value       | df  | Asymp.Sig. (two-sided) |
|----------------------|-------------|-----|------------------------|
| Pearson Chi-Square   | 1.678E3*    | 960 | .000                   |
| Likelihood Ratio     | 656.455     | 960 | 1.000                  |
| No. of Valid Cases   | 464         |     |                        |

*Highly significant at 5% margin of error.

Moreover, a significant amount of weight loss in stored potato due to sprouting reported by Azad et al. (2017). The current methods used by farmers could not minimize the effects of sprouting in potato production sector since farmers could not recognize the losses due to sprouting.

Table 6. Chi-square tests for growing conditions * storage

|                      | Value       | df  | Asymp.Sig. (2-sided) |
|----------------------|-------------|-----|----------------------|
| Pearson Chi-Square   | 2.872E2*    | 90  | .000                 |
| Likelihood Ratio     | 297.984     | 90  | .000                 |
| No. of Valid Cases   | 464         |     |                      |

*Highly significant at 5% margin of error.

Table 7. Farmers used storage methods for sprout control (%)

| Storage Types            | Shashemene | West Shewa |
|--------------------------|------------|------------|
|                          | Awasho-Dongu | Faji-Sole | Hurssa | Galessa-Dendi | Jeldu-Siriti | Wolmera-Choke |
| DLSa                     | 14.0        | 28.9       | -      | 92.0          | 99.2         | 67.0         |
| Dark Storage             | 54.0        | 60.0       | 96.1   | 5.0           | -            | 3.4          |
| Leaving tubers in soilb  | -           | 4.4        | 3.9    | 1.0           | 0.8          | 12.5         |
| DLS & leaving tubers in soil | 6.0        | 4.4        | -      | 2.0           | -            | 2.3          |

aDLS-Diffused Light store. bFarmers practice, leaving the potato tuber in the field as a means of storage.

For example, leaving potato tuber in the soil until harvesting was indicated as one of the storage methods to minimize the losses due to sprouting in the current-studied areas. However, this method was reported as one of the causes for potato tuber losses (Gebremedhin et al., 2008). Moreover, it allows more accumulation of tuber-borne diseases than early harvesting (Endale et al., 2008a). Hence, controlling of potato sprouting using chemicals such as chlorophropham and maleic hydrazide remained as an option to inhibit sprouting in >8°C storage conditions (Raigond et al., 2018). However, they are not environmentally friendly and can cause some complication to human health (Abbasi et al., 2015). Therefore, finding alternative sprouting management technology is mandatory to ensure year-round availability of potato tubers for fresh consumption.

Even if different methods were used to enhance potato sprouting, farmers in the studied areas indicated the lack of quality potato tuber seed which is in agreement with the findings of Gildemacher et al. (2009b). Seed potato storage is a common practice by farmers in all potato
Table 8. The percentage and number of farmers affected by late blight for potato under production

| varieties        | Shashemene (n = 146) | West Shewa (n = 318) |
|------------------|----------------------|-----------------------|
|                  | Awasha-Dengu | Faji-Sole | Hurssa | Galessa-Dendi | Jeldu-Siriti | Wolmera-Choke |
| Agazer\(^1\)     | %          | 42.0      | 82.2   | 21.6         | -            | -            |
|                  | n          | 21        | 37     | 11           | -            | -            |
| Gudene\(^2\)     | %          | 6.0       | 35.6   | 25.5         | 990          | 94.6         | 97.7         |
|                  | n          | 3         | 16     | 13           | 99           | 123          | 86           |
| Jalene\(^2\)     | %          | 8.0       | -      | -            | -            | 7.7          | -            |
|                  | n          | 4         | -      | -            | -            | 10           | -            |
| Neche Abeba\(^1\)| %          | 100.0     | -      | 17.6         | -            | -            | -            |
|                  | n          | 50        | -      | 9            | -            | -            | -            |

\(^1\)Local, \(^2\)Improved variety

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producing areas (Adane et al., 2010) which demands the process of priming to sprout soon after harvesting to be planted (Van Ittersum & Scholte, 1992). This is especially important for the areas that grow potato more than once per year like the current-studied areas. Application of different dormancy-breaking chemicals and storage methods has been proposed as one of the most effective methods to promote tuber sprouting (Abebe, 2010; Shibairo et al., 2006). Application of gibberellic acid has been rarely used to enhance sprouting for research purposes in Ethiopia (Gemeda et al., 2017). Moreover, different authors had shown the potential of essential oils to control sprouting (Eshel et al., 2008; Shukla et al., 2019; Teper-Bammolker et al., 2010). However, the use of essential oils as an option to control sprouting have not been practiced in the current-studied areas; therefore, research should be designed to test the potential of essential oils as alternatives to control potato sprouting. As results, potato tubers will be available in sufficient quantity and quality for the intended purposes.

4.3. Late blight management
Researchers tried to release different resistant varieties to late blight though the problems have still not been fully addressed in Ethiopia. For example, Gudene was released as resistant cultivar to late blight in 2006 by Holetta Agricultural Research Center and grown in the studied areas. However, the current findings indicated that Gudene became susceptible variety to late blight which is in agreement with the results found by Asefa et al. (2016). This may be due to the changing behavior of the pathogen strains since many resistant varieties have been overcome by Phytophthora infestans in the past. As results, smallholder farmers still grow local varieties (Adane et al., 2010; Gildemacher et al., 2009b; Semagn et al., 2019) and largely depend on application of

| Table 9. Percentage of farmers’ who are using fungicides for late blight management |
|-------------------------------------------------|---------------------------------|
| Shashemene (n = 146)                             | West Shewa (n = 318)            |
| Awasho-Dongu                                    | Foji-Sole                       |
| 94.0                                            | 86.0                            |
| Foji-Sole                                       | 82.0                            |
| Hurssa                                          | 99.0                            |
| Galessa-Dendi                                   | Jeldu-Siriti                    |
| 93.0                                            | 97.0                            |
| Wolmera-Choke                                   |                                 |

Figure 2. Problems of late blight ranks per household in study kebeles expressed in percentage of farmers for the season prior to field survey.
fungicides (T. Shiferaw et al., 2018). Therefore, researchers must continue to search for new technologies since the earlier released varieties are facing problems as they are susceptible to late blight.

In Ethiopia, the major potato growing areas known with the occurrence of late blight disease during the main rainy season in which farmers failed to grow potato in the absence of chemical application (Asefa et al., 2016; T. Shiferaw et al., 2018). Some Ethiopian farmers are using integrated disease management (moderate resistant variety, early planting and low fungicide frequency two to three times) to minimize the losses due to late blight. Hence, chemical application remains the preferred method to reduce the prevalence of late blight due to lack of resistant cultivars which is in line with current studied areas. However, chemical application is always under debate because of the negative effect they can have on the environment and humans working with them (Abbasi et al., 2015; Haverkort et al., 2008). Furthermore, the application of chemicals incurs high costs and raised issues due to contaminating food and water (Lesa & Wageh, 2019). Even if study that indicates the negative effects of fungicide are lacking in Ethiopia, searching for other biological control methods such as bio-control agents and essential oils is vital to give farmers management option.

Globally, sprouting and late blight are managed using chemicals. In Ethiopia, however, sprouting is managed using different storage methods while chemicals are remained as prevailing and classical method for controlling late blight. Recently, because of the public concern over the health and environmental hazards associated with the increased levels of chemical use has led to the development of safe, alternative and natural methods of postharvest disease control (Lesa & Wageh, 2019; Lopez-Reyes et al., 2013). Furthermore, chemical application during postharvest stages raised issues following the studies which described toxic and carcinogenic properties of chemical application (Bhattacharyya et al., 2006; El-Awady et al., 2014; Rather et al., 2017). Due to this fact, there has been a great interest in the use of essential oils as possible natural substitutes for chemicals to manage sprouting and late blight.

5. Conclusions
In the studied areas, potato production and consumption sector is hampered by lack of improved variety, the occurrence of late blight disease and insufficient sprout managements. The existing methods used to manage potato late blight and sprouting could not minimize the losses. Besides, the chemical application used to control late blight may pose pollutions to human and environment. Therefore, finding eco-friendly solutions will be crucial for management of potato late blight and sprouting. Recently, attention has been given for the application of essential oils for potato late blight control and sprouting management in some countries of the world. Since Ethiopia have diverse plant species of which some of which have essential oils that could be exploited and helped to manage the disease and the sprout of tubers.

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