Cogent Food & Agriculture

ISSN: (Print) (Online) Journal homepage: https://cogentoa.tandfonline.com/loi/oafa20

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

Daniel Wondimu Belay, Zemede Asfaw, Ermias Lulekal & Bekele Kassa |

To cite this article: Daniel Wondimu Belay, Zemede Asfaw, Ermias Lulekal & Bekele Kassa | (2021) Farmers' management of potato (*Solanum tuberosum* L.) late blight (*Phytophtora infestans* (Mont.) de Bary) and sprouting in Shashemene and West Shewa districts, Ethiopia, Cogent Food & Agriculture, 7:1, 1925432, DOI: 10.1080/23311932.2021.1925432

To link to this article: https://doi.org/10.1080/23311932.2021.1925432

Published online: 19 May 2021.

cogent food & agriculture

Received: 21 January 2021
Accepted: 30 April 2021

*Corresponding author: Daniel Wondimu Belay danwon401@yahoo.com Department of Horticulture, Selale University

Reviewing editor:
Manuel Tejada Moral, University of Seville, SevilleSpain

Additional information is available at the end of the article

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

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

Daniel Wondimu Belay[1,2]*, Zemede Asfaw[2], Ermias Lulekal[2] and Bekele Kassa[3]

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

ABOUT THE AUTHOR

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 starchy crop that has highly diverse landraces with a variety of tuber shapes and colors distributed and grown worldwide (Haverkort 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-Bamnolker (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 sprouting. 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 sprouting 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 Galessa-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 Shashmene 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

Table 1. Number of respondents based on age category in the studied areas (n = 464)

Age Category	Gender	Shashemene (n = 146)			West Shewa (n = 318)		
		Kebeles					
		Awasho-Dongu	Faji-Sole	Hurssa	Galessa-Dendi	Jeldu-Sariti	Wolmera-Choke
19–40	Male	16	32	25	22	51	27
	Female	2	8	2	3	7	-
41–60	Male	19	5	22	51	37	40
	Female	4	-	2	11	16	6
61–80	Male	9	-	-	11	12	10
	Female	-	-	-	2	3	5
>80	Male	-	-	-	-	4	-
	Female	-	-	-	-	-	-
Total		**50**	**45**	**51**	**100**	**130**	**88**

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

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	Jeldu-Seriti	Wolmera-Choke	Awasho Dongu	Faji Sole	Hurssa
Elevation (m.a.s.l)	2165	2952	2400	2061	2292	2296
Average Temperature (°C)	16	14	15	17	16	16
Average age (years)	49	45	46	47	37	41
Average farm size (ha)	0.77	1.32	0.97	0.82	0.61	0.47
Potato growers at field[a]	14	12	49	43	31	51
Potato growers at home-garden[a]	16	8	6	-	6	-
Potato growers at field and home-garden[a]	70	109	33	7	8	-
Potato cultivars under production[a]	6	6	5	5	2	6
Ware and seed potato production[a]	85	128	82	50	45	19
Late blight cited as a major problem (%)	100	96.6	100	97.8	100	100

respondents in Hursso had the lowest percentage (82.0) followed by Faji 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

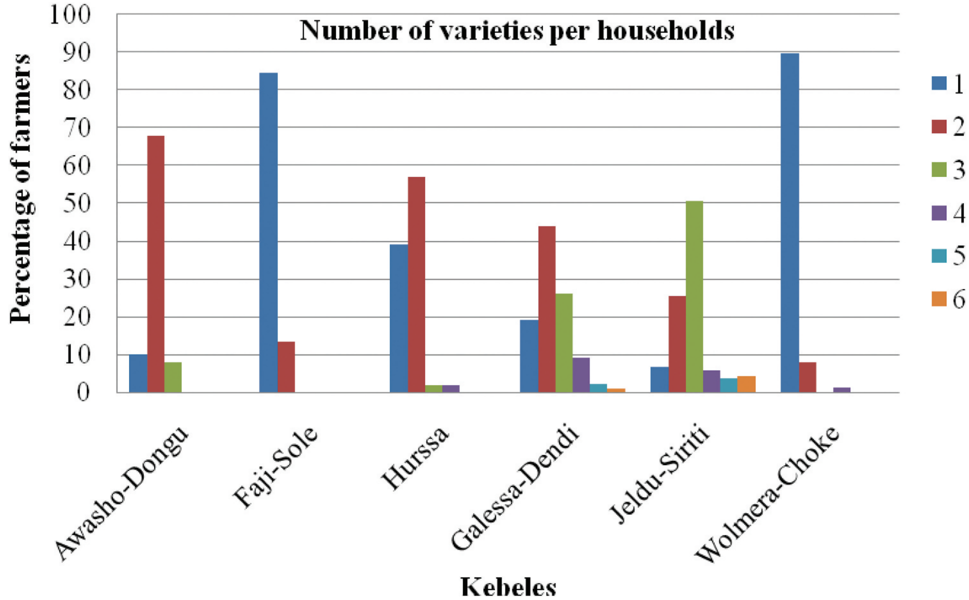

Figure 1. Number of varieties grown per household in the study kebeles expressed in percentage of farmers for the season prior to field survey.

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)		
		Awasho-Dongu	Faji-Sole	Hurssa	Galessa-Dendi	Jeldu-Siriti	Wolmera-Choke
Agazer[1]	%	12.0	31.1	7.8	-	-	-
	n	6	14	4	-	-	-
Belete[2]	%	-	-	2.0	13.0	20.0	4.5
	n	-	-	1	13	26	4
Gudene[2]	%	60.0	80.0	29.4	80.0	90.8	54.5
	n	30	36	15	80	118	48
Jalene[2]	%	44.0	-	3.9	26.0	60.8	3.4
	n	22	-	2	26	79	3
Menagesha[2]	%	-	-	-	100.0	92.3	1.1
	n	-	-	-	100	120	1
Neche Abeba[1]	%	82.0	-	33.3	-	-	-
	n	41	-	17	-	-	-

[1]Local varieties, [2]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-Dongu	Faji-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		1	2	9	15	11
Menagesha[2]	%	–	–	–	8.0	10.8	–
	n				8	14	
Neche Abeba[1]	%	32.0	-	33.3	-	-	-
	n	16	-	17	-	-	-

[1]Local variety, [2]Improved 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.

2012). 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
DLS[a]	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 soil[b]	-	4.4	3.9	1.0	0.8	12.5
DLS &leaving tubers in soil	6.0	4.4	-	2.0	-	2.3

[a]DLS-Diffused Light store. [b] Farmers 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)		
		Awasho-Dongu	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	99.0	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

Table 9. Percentage of farmers' who are using fungicides for late blight management

Shashemene (n = 146)				West Shewa (n = 318)	
Awasho-Dongu	Faji-Sole	Hurssa	Galessa-Dendi	Jeldu-Siriti	Wolmera-Choke
94.0	86.0	82.0	99.0	93.0	97.0

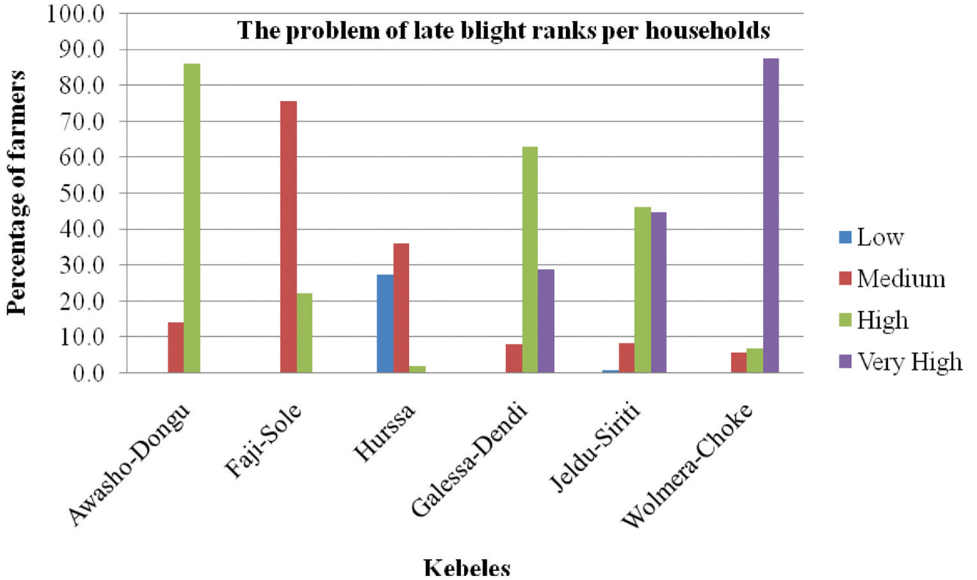

Figure 2. Problems of late blight ranks per household in study kebeles expressed in percentage of farmers for the season prior to field survey.

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 gibrellic 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-Bamnolker 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 *Phytophtera 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 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 (moderately 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.

Acknowledgments
We would like to thank the Ethiopian Ministry of Education for financing this research. We also would like to thank the Department of Plant Biology and Biodiversity Management, Addis Ababa University for facilitating the research. We also thank the supervisors at agricultural offices who facilitated the survey activities.

Funding
The authors received no direct funding for this research.

Author details
Daniel Wondimu Belay[1,2]
E-mail: danwon401@yahoo.com
ORCID ID: http://orcid.org/0000-0002-6918-8705
Zemede Asfaw[2]
ORCID ID: http://orcid.org/0000-0002-2469-8808
Ermias Lulekal[2]
Bekele Kassa[3]
[1] Department of Horticulture, Selale University.
[2] Department of Plant Biology and Biodiversity Management, Addis Ababa University Addis Ababa Ethiopia.
[3] Ethiopian Institute of Agriculture Research, Holetta Agricultural Research Center.

Citation information
Cite this article as: Farmers' management of potato (*Solanum tuberosum* L.) late blight (*Phytophtora infestans* (Mont.) de Bary) and sprouting in Shashemene and West Shewa districts, Ethiopia, Daniel Wondimu Belay, Zemede Asfaw, Ermias Lulekal & Bekele Kassa, *Cogent Food & Agriculture* (2021), 7: 1925432.

References

Abbasi, K. S., Masud, T., Ali, S., Khan, S. U., Mahmood, T., & Qayyum, A. (2015). Sugar-starch metabolism and antioxidants potential in potato tubers in response to antisprouting agents during storage. *Potato Research*, *58*, 361–375. https://doi.org/10.1007/s11540-015-9306-4

Abebe, C. (2010). *Effect of Gibberellic acid on tuber dormancy breaking, subsequent growth, yield and quality of potato (Solanum tuberosum L.)*. M.Sc. thesis presented to School of Graduate Studies of Haramaya University, Haramaya, Ethiopia.

Adane, H., Meuwissen, M. P., Agajie, T., Lommen, W. J., Lansink, A. O., Admasu, T., & Struik, P. C. (2010). Analysis of seed potato systems in Ethiopia. *American Journal of Potato Research*, *87*, 537–552. https://doi.org/10.1007/s12230-010-9164-1

Asefa, G., Wassu, M., & Tesfaye, A. (2016). Evaluation of potato (*Solanum tuberosum* L.) Genotypes for Resistance to Late blight at Sinana Southeastern Ethiopia. *International Journal of Agricultural & Innovation Technology*, *6* (1), 21–25. doi: https://doi.org/10.22004/ag.econ.305398

Azad, A. K., Kabir, H., Eaton, T. E.-J., & Soren, E. B. (2017). Storage Potentialities of some exotic potato varieties at farmers' conditions in Bangladesh. *Agricultural Sciences*, *8*, 183–193. https://doi.org/10.4236/as.2017.82013

Bhattacharyya, A., Chandra, S., Goswami, D. A., Das, S. K., Mandal, T. K., Chakraborty, A. K., et al. (2006). Toxicokinetics, metabolism and microsomal studies of chloropropham in rats. *Toxicological and Environmental Chemistry*, *88*(3), 527–539. https://doi.org/10.1080/02772240600741528

Bekele, K., & Eshetu, B. (2008). Potato disease management. In W. Gebremedhin, G. Endale, & L. Berga (Eds.), *Root and tuber crops: The untapped resources* (pp. 53–78). Ethiopian Institute of Agricultural Research.

Berga, L., Gebremedhin, W., Teressa, J., Bereketshi, T., & Yayinu, H. (1994). Potato agronomic research in Ethiopia in: Horticulture research and development in Ethiopia. *Proceeding of the 2nd National Horticulture workshop*. December 1-3, 1992, Addis Ababa, Ethiopia. E. Herath & D. Lemma (eds); 101–119. IAR/FAO

Bezabih, E., & Mengistu, N. (2011). Potato value chain analysis and development in Ethiopia. International Potato Ceneter (CIP-Ethiopia).

Bi, Y., Jiang, H., Hausbeck, M. K., & Hao, J. J. (2012). Inhibitory effects of essential oils for controlling *Phytophthora capsici*. *Plant Disease*, *96*, 797–803. https://doi.org/10.1094/PDIS-11-11-0933

Central Statistical Agency (CSA) (2016). Agricultural sample survey report on area, production and farm management practice belg season crops private peasant holdings Vol. V statstical bulletin.

De Curtis, F., Lima, G., Vitullo, D., & De Cicco, V. (2010). Biocontrol of *Rhizoctonia solani* and *Sclerotium rolfsii* on tomato by delivering antagonistic bacteria through a drip irrigation system. *Crop Protection*, *29*, 570–663. https://doi.org/10.1016/j.cropro.2010.01.012

Demissie, Y. T. (2019). Integrated potato (*Solanum tuberosum* L.) late blight (*Phytophthora infestans*) disease management in Ethiopia. *American Journal of BioScience*, *7*(6), 123–130. https://doi.org/10.11648/j.ajbio.20190706.16

Devaux, A., Goffart, J. P., Petsakos, A., Kromann, P., Gatto, M., Okello, J., Suarez, V., & Hareau, G. (2020). Global food security, contribution from sustainable potato agri-food systems. *The Potato Crop*, 1–35. doi: https://doi.org/10/1007/978-3-030-28683-5_1

Devaux, A., Kromann, P., & Ortiz, O. (2014). Potatoes for sustainable global food security. *Potato Research*, *57*, 185–199. https://doi.org/10.1007/s11540-014-9265-1

El-Awady, A., Moghazy, A. M., Gouda, A. E. A., & Rewaa, E. S. A. (2014). Inhibition of sprout growth and increase storability of processing potato by antisprouting agent. *Trends in Horticulture Research*, 4, 31–40. https://doi.org/10.3923/thr.2014.31.40

Endale, G., Gebremedhin, W., & Berega, L. (2008a). Potato seed management. In W. Gebremedhin, G. Endale, & L. Berega (Eds.), *Root and tuber crops: The untapped resources* (pp. 53–78). Ethiopian Institute of Agricultural Research.

Endale, G., Gebremedhin, W., Bekele, K., & Berega, L. (2008b). Postharvest management. In W. Gebremedhin, G. Endale, & L. Berega (Eds.), *Root and tuber crops: The untapped resources* (pp. 113–130). Ethiopian Institute of Agricultural Research.

Eshel, D., Orenstein, J., Tsror, L., & Hazanovsky, M. (2008). Environmentally friendly method for the control of sprouting and tuber-borne diseases in stored potato. *Acta Horticulture*, *830*, 363–368.

Eshel, D., & Teper-Bamnolker, P. (2012). Can loss of apical dominance in potato tuber serve as a marker of physiological age? *Plant Signaling & Behavior*, *7*(9), 1158–1162. https://doi.org/10.4161/psb.21324

FAOSTAT. (1999). *Production year book* (Vol. 53). Food and Agriculture Organization.

FAOSTAT. (2021). World food and agricultural organization data of statistics. Food and Agricultural Organization. Avaialble at http://www.fao.org/faostat/en/#data

Gebremedhin, W., Endale, G., & Berga, L. (2008). Root and tuber crops: The untapped resources. Addis Ababa: Ethiopian Institute of Agricultural Research

Gemeda, M., Wassu, M., Nigussie, D., & Dandena, G. (2017). Effects of different dormancy-breaking and storage methods on seed tuber sprouting and subsequent yield of two potato (Solanum tuberosum L.). *varieties.Open Agriculture*, *2*, 220–229. https://doi.org/10.1515/opag-2017-0023

Gildemacher, P., Demo, P., Barker, I., Kaguongo, W., Gebremedhin, W., Wagoire, W., Wakahiu, M., Leeuwis, C., & Struik, P. C. (2009b). A description of seed potato systems in Kenya, Uganda and Ethiopia. *American Journal of Potato Research*, *86*, 373–382. https://doi.org/10.1007/s12230-009-9092-0

Gildemacher, P., Kaguongo, W., Ortiz, O., Agajie, T., Gebremedhin, W., Wagoire, W., Kakuhenzire, R., Kinyae, P., Nyongesa, M., Struik, P. C., & Leeuwis, C. (2009a). Improving potato production in Kenya, Uganda and Ethiopia. *Potato Research*, *52*, 173–205. https://doi.org/10.1007/s11540-009-9127-4

Gumataw, A., Bijman, S., & Pascucci, O. S. (2013). Adoption of improved potato varieties in Ethiopia: The role of agricultural knowledge and innovation system and smallholder farmers' quality assessment. *Agricultural Systems*, *122*, 22–32. https://doi.org/10.1016/j.agsy.2013.07.008

Habetamu, K., Alemayehu, C., Bekele, K., Pananjay, G. B. G., & Tiwari, K. (2012). Evaluation of different potato variety and fungicide combinations for management of potato late blight (*Phytophthora infestans*) in southern Ethiopia. *International Journal of Life Science*, *1*, 8–15.

Haverkort, A. J., Boonekamp, P. M., Hutten, R., Jacobsen, E., Lotz, L. A. P., Kessel, G. J. T., Visser, R. G. F., & Van Der Vossen, A. E. G. (2008). Societal costs of late blight in potato and prospects of durable resistance through cisgenic modification. *Potato Research*, *51*, 47–57. https://doi.org/10.1007/s11540-008-9089-y

Haverkort, A. J., De Ruijter, F. J., Van Evert, F. K., Conijn, J. G., & Rutgers, B. (2014). Worldwide sustainability hotspots in potato cultivation. 1. Identification and mapping. *Potato Research*, *56*, 343–353. https://doi.org/10.1007/s11540-013-9247-8

Haverkort, A. J., & Struik, P. C. (2015). Yield levels of potato crops: Recent achievements and future prospects. *Field Crop Research*, *182*, 76–85. https://doi.org/10.1016/j.fcr.2015.06.002

Hilemicheal, K. (1979). Preliminary assessment of the responses of potato genotypes in the eastern, southern and central regions of Ethiopia. *Ethiopian Journal of Agricultural Science*, *1*, 41–47.

Lee, Y. S., Kim, J., Shin, S. C., & Lee, S. G. (2008). Antifungal activity of Myrtacea essential oils and their components against three Phytopathogenic fungi. *Flavour and Fragrance Journal*, *23*, 23–28. https://doi.org/10.1002/ffj.1850

Lesa, A. T., & Wageh, S. D. (2019). Environmental chemical contaminations in food: Review of global problems. *Journal of Toxicology*.

Lopez-Reyes, J. G., Spadaro, D., Prelle, A., Garibaldi, A., & Gullino, M. L. (2013). Efficacy of plant essential oils on postharvest control of rots caused by fungi on different stone fruits in vivo. *Journal of Food Protection*, *76*, 631–639. https://doi.org/10.4315/0362-028X.JFP-12-342

Machida-Hirano, R. (2015). Diversity of potato genetic resources. *Breeding Science*, *65*, 26–40. https://doi.org/10.1270/jsbbs.65.26

MANR (Ministry of Agriculture and Natural Resources). (2016). Crop variety release, protection and seed quality control directorate, Issue number 19, Addis Ababa, Ethiopia

Pankhurst, R. (1964). Notes on the history of Ethiopia agriculture. *Observer*, *7*, 210–240.

Pasare, S. A., Ducreux, L. J., Morris, W. L., Campbell, R., Sharma, S. K., Roumeliotis, E., Kohlen, W., Van Der Krol, S., Bramley, P. M., Roberts, A. G., Fraser, P. D., & Taylor, M. A. (2013). The role of the potato (Solanum tuberosum) CCD8 gene in stolon and tuber development. *New Phytologist*, *198*(4), 1108–1120. https://doi.org/10.1111/nph.12217

Pritchard, S., Lee, J., Tao, C. W., Burgess, P., Allchurch, E., & Campbell, A. (2012). Reducing supply chain and consumer potato waste (RBC820-004) Available at: http://www.wrap.org.uk/sites/files/wrap/Amcor%20project%20report%20final%2C%2003%20Jan%202012.pdf

Raigond, P., Mehta, A., & Singh, B. (2018). Sweetening during low-temperature and long-term storage of Indian potatoes. *Potato Research*, *61*(3), 207–217. https://doi.org/10.1007/s11540-018-9369-0

Rather, I. A., Koh, W. Y., Peak, W. K., & Lim, J. (2017). The sources of chemical contaminants in food and their health implications. *Frontiers in Pharmacology*, *8*, 830. https://doi.org/10.3389/fphar.2017.00830

Semagn, A. K., Donald, H., Walter, D. J., Keith, P., David, W., Fentahun, M., & Steffen, S. (2015). Potato variety diversity, determinants and implications for potato breeding strategy in Ethiopia. *American Journal of Potato Research*. https://doi.org/10.1007/s12230-015-9467-3

Semagn, A. K., Walter, D. J., Donald, H., & Steffen, S. (2019). Understanding farmer needs and unlocking local genetic resources for potato improvement: A case study in Ethiopia. *African Journal of Food, Agriculture, Nutrition*, *19*(1), 13883–13905. https://doi.org/10.18697/ajfand.84.BLFB1012

Shibairo, S. I., Demo, P., Kabira, J. N., Gildemacher, P., Gachango, E., Menza, M., Nyankanga, R. O., Chemining'wa, G. N., & Narla, R. D. (2006). Effects of gibberellic acid (GA) on sprouting and quality of potato seed tubers in diffused light and pit storage conditions. *Journal of Biological Sciences*, *6*(4), 723–733. https://doi.org/10.3923/jbs.2006.723.733

Shiferaw, M., Tameru, A., Bekele, K., & Forbes, G. (2011). Evaluation of contact fungicide spray regimes for control of late blight (*Phytophthora Infestans*) in southern Ethiopia using potato cultivars with different levels of host resistance. *Tropical Plant Pathology*, *36*(1), 21–27. https://doi.org/10.1590/S1982-56762011000100003

Shiferaw, T., Elias, D., Van Mierlo, B., Lie, R., Bergga, L., Sharma, K., Leeuwis, C., & Struik, P. C. (2018). Farmers' knowledge and practices of potato disease management in Ethiopia. *NJAS-Wageningen Journal of Life Sciences*.

Shukla, S., Pandey, S. S., Chandra, M., Pandey, A., Bharti, N., Barnawal, D., Chanotiya, C. S., Tandon, S., Darokar, M. P., & Kalra, A. (2019). Application of essential oils as a natural and alternative method for inhibiting and inducing the sprouting of potato tubers. *Food Chemistry*, *284*, 171–179. https://doi.org/10.1016/j.foodchem.2019.01.079

Sonnewald, S., & Sonnewald, U. (2014). Regulation of potato tuber sprouting. *Planta*, *2239*, 27–38. https://doi.org/10.1007/s00425-013-1968-z

Stokstad, E. (2019). The new potato. Breeders seek a breakthrough to help farmers facing an uncertain future. *Science*, *363*, 6427, 574–577. 0036-8075

Teper-Bamnolker, P., Dudai, N., Fischer, R., Belausov, E., Zemach, H., Shoseyov, O., & Eshel, D. (2010). Mint essential oil can induce or inhibit potato sprouting by differential alteration of apical meristem. *Planta*, *232*(1), 179–186. https://doi.org/10.1007/s00425-010-1154-5

Tesfaye, L., Ermias, S., & Hoekstra, D. (2011). Status and capacity of farmer training centers (FTCs) in the improving productivity and market success (IPMS) pilot learning woredas (PLWs). International Livestock Research Institute (ILRI), Addis Ababa, Ethiopa

Tilahun, A., Christopher, A., Jean-Marco, B., John, D., Thilak, M., Mandi, R., & Tilaye, T. (2017). A farming system framework for investement planning and priority setting in Ethiopia. ACIAR Technical Reports Series No. 92. Australian Center for International Agricultural Research: 52

Van Ittersum, M. K., & Scholte, K. (1992). Shortening dormancy of seed potatoes by storage temperature regimes. *Potato Research*, *35*(4), 389–401. https://doi.org/10.1007/BF02357595

Wong, A. O., Ko, F., Tweddell, Q., Antoun, R. T., Avis, H., & T.j.. (2015). Antifungal effect of compost tea microorganism on tomato pathogens. *Biological Control*, *80*, 63–69. https://doi.org/10.1016/j.biocontrol.2014.09.017

Yamane, T. (1967). *Statistics: An Introductory Analysis* (2nd ed). Harper and Row.