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Title: Insect Pests Associated to Potato (*Solanum tuberosum L.*) Production and storage in the highland of Welmera district, Central Ethiopia.

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Declaration

I declare that this thesis is my original work and all the sources of materials used for this thesis have been duly acknowledged. I also declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Date of submission: _____

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This is to certify that the thesis prepared by Yirefu Belachew Gari entitled study on "Insect Pests Associated to Potato (*Solanum tuberosum L.*) Production and Storage in the Highland of Welmera District, Central Ethiopia" and submitted in fulfillment of the requirement for the degree of Masters in general Biology complies with respect to originality and quality.

Signed by examining committee:

Advisor: Emana Getu (PhD), professor of Entomology Sign_____ Date _____

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List of Abbreviations/Acronyms

CFC	Common Fund for Commodities
CSA	Central Statistical Agency of Ethiopia
EIARC	Ethiopian Institute of Agricultural Research Center
PTM	Potato Tuber Moth
SNNPRS	South Nations Nationalities and Peoples Regional State

Abstract

In Ethiopia, potato (Solanum tuberosum L.) is a potential food security and cash crop due to its high productivity and nutritional quality tuber. Due to these reason Welmera district farmers cultivated potato crops to fill full food security and also as cash crop to earn income from potato for different purpose. The major potato producing areas in the highlands of Shewa include Welmera district, West Shewa (Ginchi, Jeldu, Galessa), and North Shewa. Even if it is produced, it affected by different insect pests and needed proper storage system, so a study was carried out at Welmera district to assess the insect pests associated to potato under field area and in storage condition. Data were collected from farmers and Developmental Agents of the district using random sampling and purposive sampling technique to get actual primary data. The Primary data were analyzed, interpreted and put in frequency numbers and in percentage. The main constrains of potato production in this district were includes infestation of insect pests, diseases infestation, and weeds infestation.. However, several insect pests are associated to potato which contribute to the low yield of the crop. Among the insects P. operculella, potato aphid, green peach aphid, cutworms, red ants, potato epilachna, and leafhopper were a major pre-harvest problem and P. operculella and red ants are both pre and post-harvest problem of potato in Ethiopia. These insect pests reduced farmer's production capacity by large. Harvested tubers are stored on house floor or on bed like structure located under roof, and sacks. Some farmers keep the tubers un-harvested in the field area, but un-harvested potato were exposed to different animals such as cattle, rodents, and sheep. The stored potato tubers are infested by insect pests of potato such as, P. operculela and red ants are the most serious one. In addition to these insect pests aphids are another most serious by attacking potato and transmitting different viral diseases to potato during cultivation at the field or farm area. Farmers of Welmera district must use proper way of potato storage and concerned body should give awareness to the farmers of Welmera district on how the farmers cultivate and store potato properly.

Keywords/Phrases: Insect pests, potato production, Potato Storage

1. INTRODUCTION

1. 1.Background of the Study

From the *Solanaceae* plant family, potato (*Solanum tuberosum L.*) is an important food and cash crop globally (Fekadu *et al*., 2013). Potato is herbaceous annual crop that grows up to 100 cm tall and produces tubers. It is rich in starch, so it ranks as the world's fourth most important food crop, after maize, wheat and rice (FAO, 2008; Pandey *et al*., 2014). Although potato is an important food source globally (FAO and CFC, 2010), most of the part of the potato tuber that is enlarged to store nutrients is 80% water. Only 20% of the tuber constitutes the dry matter. Potatoes contain complex carbohydrates which are important for energy supply, but they are low in protein. Potato tuber contain large amounts of vitamins A, B (B1, B3 and B6) and C as well as minerals, such as ascorbic acid, potassium, phosphorus, magnesium, iron, phenolic, and free fat (Gumul *et al.,* 2011). Freshly harvested potatoes have higher quantities of vitamin C than stored potatoes (Gumul *et al.,* 2011). The vitamin C of potatoes can prevent the disease known as scurvy if a diet is lacking fruit (Amsel and Bishop, 2008; Gumul *et al.*, 2011). Umadevi *et al*. (2013) suggested that when we cook potatoes it is better to boil them with the skins still on, but washed well. That way you still have the benefits of these needed nutrients. Medium sized potatoes (of 150 g) provide nearly half of the daily adult requirement (100 mg) (FAO, 2008).

Potato is the most efficient tuberous crop in terms of time it takes to attain maturity. Potential tubers in potato can be harvested in 60 to 120 days after planting (Naz *et al*., 2011). There are four potato production systems which include: "belg" (short rain), "meher" (long rain), and residual crops and irrigated production in many areas of Welmera district were "belg" (January to June) crop supplemented with irrigation constituents the bulk of potato production (Adane *et al*., 2010).

In Ethiopia, potato is grown in four major parts of the country: central, eastern, north western and southern parts CSA (2017). The central part includes the highland areas surrounding the capital, Addis Ababa. In this part, the major potato growing zones are West Shewa and North Shewa. The eastern part of potato production mainly covers the eastern highlands of Ethiopia, especially the East Harerge zone. The Northwestern part of potato production is situated in the Amhara Regional State such as South Gonder, North Gonder, East Gojam, West Gojam and

Agew Awi. The southern part of Ethiopia in which potato is grown, is mainly located in the Southern Nations Nationalities and Peoples Regional State (SNNPRs) and partly in the Oromia Regional State. The major potato producing zones in this part are Gurage, Gamo Goffa, Hadiya, Wolyta, Kambata, Siltie and Sidama in the SNNPRS and West Arsi zone in Oromia. Together, they cover approximately 83% of the potato growers (CSA, 2017).

The Ethiopian potato industry is an important part of the country's agricultural economy. Some serious problems that affect potato production in the country are weather and pests. Too little rain and too much rain can reduce potato yields and quality. Pests such as late blight, bacterial wilt, weeds and potato tuber moth (PTM) were also mentioned by Ethiopian growers as serious risks in potato production (Guenthner, 2006). Potato tuber moth (PTM) is one of the most important constraints to potato production worldwide (Rondon 2007). In Ethiopia, it causes up to 42% yield loss in storage and on average 8.7% of the tubers were lost due to field infestation (Sileshi and Teriessa, 2001). PTM was known to damage potato only in the warmer areas, though major production areas mainly cover the highlands. The peak activity months of PTM were January, February, and June. Unlike the field situation, monitoring in the store showed no obvious peak record (Bayeh and Tadesse, 1992).

1.2 Statement of the problem

In Welmera district potato growing is well known agricultural activities and the farmers of the district cultivate potato to earn money by selling potato and for fulfillment of food security, but their cultivated potato affected by different insect pests under field and storage condition. Therefore assessing the status of insect pests associated to potato production under field and storage condition in the study area is needed. The finding of this study will help the local people, cultivator (farmers), and the whole potato user.

1.3. Significances of the study

The contribution of this study in the future is for the improvement in production of potato and storages of potato without infestation of insect pest that affect potato in the field and at storage in Welmera district Oromia regional states. The significance of the study can be stated as follows;

- It contributes to the assessment of insect pest that affect potato in the field and at storage
- It provides a hint to the farmers, Developmental agents (DA), and other concerned bodies, to find possible solution to the effect of insect pests of potato crops
- It uses as reference for further investigations for insect pests of potato at Welmera district
- It creates understanding and awareness on the effects of insect pests of potato at the field and in storage at Welmera district
- It helps as an input information for other researcher who wants to conduct further studies on similar issue

1.4. Objectives

1.4.1 General Objective

- To assess insect pest associated to potato production and at storage in highland of Welmera district, Oromia Special Zone, Central Ethiopia.

1.4.2 Specific Objectives

- To assess the status of insect pest associated to potato production under field and storage condition
- To determine farmers' seed potato storage methods versus insect pest infestation.

2. LITERATURE REVIEW

2.1. Potato Production

Potato is a starchy, tuberous crop belonging to the family Solanaceae. The word "potato" may refer either to the plant itself or the edible tuber. It is the world's fourth-largest food crop, following maize, wheat, and rice. Following centuries of selective breeding, there are now over a thousand different types of potatoes. Over 99% of the presently cultivated potatoes worldwide descended from varieties that originated in the lowlands of south-central Chile, which have displaced formerly popular varieties from the Andean highlands. It remains an essential crop in Europe (especially eastern and central Europe) where per capita production is still the highest in the world, but the most rapid expansion over the past few decades has occurred in southern and eastern Asia. China now leads the world in potato production, and nearly a third of the world's potatoes are harvested in China and India.

According to FAO report (2008), potato is one of the world most important crops and consumed for more than 8,000 years. Potato widely cultivated and expanded around the world in the 16th century. The crop is introduced to Europe and Asia in the 17th century and in Africa in the 19th century by Spanish from South America and Andes (Pliska, 2008). Now a days, the annual world potato production is estimated to 300 million tons (FAO, 2008). Among this, Asia and Europe are the major potato producing countries, which cover more than 80% of the world production. Today, China is the biggest potato producer in the world which, covered, about 20% of the world potato production (Pliska, 2008). Potato had been imported and grown in Africa for many years. According to the report of South Africa, Egypt and Morocco are the highest producers with productivity ranges 24.2 tons/hectare to 34 tons/hectare, while Nigeria and Kenya are the least producer with the productivity ranges 3.1 tons/hectare to 6.7 tons/hectare (FAO, 2008). Also in Ethiopia potato productivity in the same year was 7.2 tons/hectare, which was similar to the least producer countries (FAO, 2008). In Ethiopia, the main potato production seasons are from June to September which is called the rainy season. About 70% of the country's available agricultural lands are located at an altitude range of 1800-2500 meter above sea level, which is suitable for seed and ware potato production (FAO, 2008; Emana and Nigussie, 2011). Potatoes are usually grown in Ethiopia in a multi cropping or rotational cropping system which rotate with cereal and legume crops, followed by potatoes (Medhin *et al.*, 2001).

In the past three decades vast differences between developed and developing countries in production of potato were seen. Developed countries like Canada and the common wealth of independent states decreased on average by one percent per year, developing countries increased by five percent per year. So, developing countries are now the world biggest potato producers, importers, and consumers (FAO, 2008). In Ethiopia, potato production also has increased considerably through the 20th century. In 1975, the area of cultivation was estimated at 30,000 hectares, with an average yield of approximately five tons per hectare. The area of cultivation had reached 50,000 hectares by the mid 1980's and 2001 production area raised up to 160,000 hectares, with average yields around eight tons per hectare. The average yield of potato in Ethiopia is 8- 9 tons/hectare which is much lower than the African continent average of 10.8 ton/hectare and the world average yield of 16 tons/hectare (FAO, 2008; Ferdu *et al*., 2009).

There has been a dramatic increase in potato production and demand in Asia, Africa and Latin America, where output rose from less than 30 million tons in the early 1960s to more than 165 million tons in 2007 (Bezabih and Hadera, 2007). The total world potato production is estimated at 364,808,768 ton in 2013. China is now the biggest potato producer, and almost one third of all potatoes are harvested in China and India (FAOSTAT, 2014). China, India, Ukraine, Russian, and United States of America are the top five world potato producing countries (FAOSTAT, 2015). Europe and Central Asia produced 144 million tons of roots and tubers. They mostly account 18 percent of the world potatoes output in 2011. The total Indian potato production during 2014-15 has increased by 10.7 percent from 41.5 million tons in 2013-14 to 45.9 million tons in 2014-15 (FAO STAT, 2014). The area under potato production in Ethiopia in the year 2013/14 was about 66,745 hectares with an average national yield of 11.7 tons/hectare for the main cropping season (CSA, 2014). The area under potato production was 70,132 hectares and the total production of potato was 946,782 tons with an average productivity of 13.5 tons/hectare in the main cropping season (CSA, 2016).

The main potato exporters are the Netherlands, France and Germany, while Spain and Belgium import most. The Netherlands is responsible for 22 percent of the world's potato exports (FAO STAT, 2012). Eastern Hararghe (Haramaya and Kombolcha Woredas) is one of the major potato producing areas in Ethiopia (Bezabih and Hadera, 2007). This zone produced an average yield of

19.3 tons/hectare higher than the average national production in the year 2013/14 of 11.7 tons/hectare (CSA, 2014). In addition to satisfying domestic demand, the potato produced in the region is being exported to regional markets like Djibouti and Somalia, Middle East countries and the western European countries (EHDA, 2011). For instance, out of the total volume of potato marketed to Somalia, 75 percent is supplied from East Hararghe and about 25 percent from the Central part of Ethiopia (Bezabih, 2008).

2.2. Origin and distribution of potato

Globally, potatoes are one of the most important crops in terms of production as well as consumption and ranks first among root and tuber crops followed by Cassava, Sweet potatoes and Yams (FAO, 2008). It was originated in the high Andean mountain of South America about 8000 years ago (Pandey *et al*., 2014) and it was first cultivated in the vicinity of Lake Titicaca near the present day border of Peru and Bolivia. More than 320 million tons of potato is being cultivated annually on 20 million hectares of land (FAO and CFC, 2010). It was first introduced into Europe towards the end of 16^{th} century through Spanish conquerors. There, the potato developed as a temperate crop and was later distributed throughout the world largely as a consequence of the colonial expansion of European countries (Pandey *et al*., 2014) and to Africa in the 19^{th} century (Pliska, 2008). Ethiopia has good climatic and edaphic conditions for higher potato production and productivity. It has the potential to grow in the 70% of the 10 million hectares of arable land in Ethiopia. It was introduced to Ethiopia in 1859 by the German botanist Schimper (FAO, 2008). It is the second most important tuber crop grown in Ethiopia next to Enset in terms of area coverage (Solomon, 1985).

2.3 Global distribution of insects that attack potato

Wireworms are one of the most destructive insect pests in the Pacific Northwest. Nearly 40 species from 12 genera attack potato, but only a few are economically important (Hoy *et al.*, 2008). Wireworms are the larval stage of click beetles. Adult wireworms are slender, reddish brown to black that are 0.25 to 0.5 inch long (Hoy *et al.,* 2008) Wireworms can cause damage to potatoes by feeding upon potato seed pieces and sprouts in the spring, facilitating infection by pathogens or other insect pests. The latter damage can result in reduction in yield and/or rejection

of the entire crop. In the U.S. there is zero tolerance for live larvae in tubers. Wireworms tend to be most damaging in potatoes that follow corn or small grains (wheat, barley) and on ground just entering cultivation. Potatoes, corn, wheat and grass are hosts for several species of wireworms in the Pacific Northwest (Hoy *et al.,* 2008) Also, beans, carrots, peas, and other annual crops may be infested; while melons, beet roots, and strawberry fruits are affected less frequently.

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), first described in 1824 by Thomas Say, is associated with potato plants and its solanaceous relatives such as nightshade. It is the most important defoliating insect pest of potato. Its remarkable ability to develop insecticide resistance, incredible reproductive potential and sustained feeding by larvae and adults, makes the management of this pest challenging (Hoy *et al.,* 2008). The Colorado Potato Beetle (CPB) is a yellow and black striped beetle, about 1.3 cm long and 0.6 cm wide. They can be found in almost all U.S. potato regions. This beetle can cause complete defoliation and nearly complete crop loss if allowed to reproduce unchecked. Both larvae and adults feed on potato foliage throughout the season. Potatoes and other solanaceous plants such as eggplant, nightshade, horsenettle and buffalobur are preferred hosts of this pest.

The aphid population in western North America, north of Mexico, is comprised of 1,020 species in 178 genera in 15 subfamilies (Pike *et al.,* 2003). Several aphid species are known to be pests of potatoes, but the green peach aphid, *Myzus persicae* (Sulzer), and potato aphid, *Macrosiphum euphorbiae* (Thomas), are two of the most important vectors of diseases in the Pacific Northwest. Aphids are important due to their ability to transmit viruses. According to Hoy et al., (2008) there are six commonly found potato viruses transmitted by aphids: Potato leafroll virus (PLRV), multiple strains of Potato virus Y (PVY), Potato virus A (PVA), Potato virus S (PVS), Potato virus M (PVM), and alfalfa mosaic virus (AMV). PLRV and PVY are transmitted by several species of aphids but primarily by green peach aphid. The potato aphid transmits PVY and PVA. In general, aphids injure plants directly by removing sap juices from phloem tissues. They also reduce the aesthetic quality of infested plants by secreting a sugary liquid called "honeydew" on which a black-colored fungus called "sooty mold" grows. The “sooty mold” reduces the photosynthetic potential of the plant. Most importantly, aphids transmit plant diseases, particularly viruses. Aphids on potato are serious pests because of their ability to transmit several plant diseases such as PLRV (transmitted mainly by green peach aphid) and PVY (transmitted by

several species of aphids). The green peach aphid, also known as tobacco or spinach aphid, survives the winter in the egg stage on peach trees. They can also overwinter on various perennial, biennials, and winter annual weeds, besides potatoes and peaches, other hosts include lettuce, spinach, tomatoes, other vegetables and ornamentals (Dickson and Laird, 1967; Wallis, 1967; Tamaki *et al.,* 1980; Barry *et al.,* 1982). Among the species of aphids known to transmit potato leaf roll virus (PLRV), the most important virus diseases of potato, only the bean aphid (*Aphis fabae*), the potato aphid (*Macrosiphum euphorbiae*) and the green peach aphids (*Myzus persicae*) were commonly recorded in potato fields in Ethiopia.

The beet leafhopper, *Circulifer tenellus* Baker, is the carrier of the beet leafhopper-transmitted virescence agent (BLTVA) phytoplasma (a.k.a., Columbia Basin potato purple top phytoplasma) that causes significant yield losses and a reduction in potato tuber quality.

Beet leafhoppers must feed in the phloem of the plant. Direct feeding can cause relatively minor damage ("hopperburn"); however, BLTVA is a very destructive and detrimental disease affecting potatoes. BLTVA can cause a wide range of symptoms in potatoes, including leaf curling and purpling, aerial tubers, chlorosis, and early senescence. Most BLTVA infection occurs early in the season, during May and June (Munyaneza, 2003; Munyaneza and Crosslin, 2006). Potato is not a preferred host for BLH and will not spend much time on the crop (however it does spend enough time to transmit BLTVA) (Schreiber *et al.,* 2010). They also thrive on radishes, sugar beet (Meyerdirk and Hessein, 1985), and carrots (Munyaneza, 2003).

The potato tuber moth, *Phthorimaea operculella* Zeller, is one of the most economically significant insect pests of cultivated potatoes worldwide. The first significant economic damage to potato crops in the Columbia Basin region occurred in 2002, when a field in Oregon showed high levels of tuber damage associated with potato tubeworm. By 2003, the pest was a major concern to all producers in the region after potatoes from several fields were rejected by processors because of tuber damage. Since then, potato tubeworm has cost growers in the Columbia Basin millions of dollars through increased pesticide application and unmarketable potatoes (Rondon, 2010). Tubeworm larvae behave as leaf miners. They can also live inside stems or within groups of leaves tied together with silk.

The most important damage is to tubers, also a food source for the larvae, especially exposed tubers, or those within centimeters of the soil surface. Larvae can infest tubers when foliage is vine killed or desiccated right before harvest (Clough *et al.,* 2010). Tunnels left by tuber worms in tubers can be full of droppings or excrement that can be a potential source for secondary infections. Although the potato tubeworm host range includes a wide array of Solanaceous crops such as tomatoes, peppers, eggplants, tobacco, and weeds such as nightshade, the pest has been found only on potatoes in the Pacific Northwest region (Rondon, 2010). The two-spotted spider mite, *Tetranichus urticae* Koch, is the most abundant mite species found in potatoes in the Pacific Northwest. They can occasionally be considered pests of potatoes when crops such as beans, corn, and alfalfa or clover seed are planted nearby (Hoy *et al.,* 2008).

Cutworms, armyworms and loopers are the immature stages of lepidopteran moths. These are several species of moth larvae that affect potato crops. Moths' typically have four defined life stages: egg, larva, pupa and adult. The most common species in the Pacific Northwest regions are cutworms feed on potato seeds, cut stems, and foliage; armyworms and loppers feed on foliage throughout the season. Potato leaf miner, *Liriomyza huidobrensis* has been a serious problem in the Sandveld, USA since 2000 and has spread to other potato production regions soon after. Once the leaf miner has become established in a potato field, it will spread within a few days and is then almost impossible to control. The management process must therefore start even before the first signs of damage and for it to be truly effective chemical, cultivation and biological measures must be integrated. Mines or tunnels are created as the larvae feed on the mesophyll tissue between the two epidermal layers of the leaf. Flies tend to lay their eggs in punctures situated close to the leaf veins, especially the main vein. The tunnels then spread to the leaf blades. With heavy infestation tunnels can interlink, thus destroying large portions of the functional leaf surface. This can result in serious damage, since photosynthesis is insufficient to meet the plant's energy requirements. Tunnels can also appear in the leaf petioles.

According to Crow and Shitaye (1977) and Crow *et al.* (1977) reported that the red ant (*Dorylus* sp.) was a very serious pest on vegetable crops grown at high altitudes. Red ants damage potato plants by scraping the phloem tissues of the roots and destroy root hairs. Such potato plants wilt and die. If the insect appears late in the cropping season, they bore hole and eat out the starch from the developing tubers. Thus, the insect causes direct loss as such kind of damaged tubers

are unmarketable. However, the insect has not been reported in major potato growing areas such as Awassa, Shashemene and Shamena, which are situated at altitudes of 1680, 1800 and 2120 m above sea level, respectively. Most of the farmers in Walmera, Degem, Jeldu and Dandi Woredas who were interviewed during a survey responded that the pest is more serious in dry soils. However, most of the farmers in Degem responded that the pest is problematic in wet conditions.

2.4. Insect pests of potato in Ethiopia

Potato is attacked by a number of insect pests. In the last two decades or more, the major insect pests that stay on potato include: cutworms (*Agrotis* spp. and *Euxoa* spp.), red ants (*Dorylus spp.),* potato aphid (*Macrosiphum euphorbiae*), green peach aphid (*Myzus persicae*) and the potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) (Bayeh and Tadesse, 1992). Among these insects, potato tuber moth (PTM), cutworms, and aphids were the most important. Research has been made to inform management options against these economically important insect pests. Many survey reports indicated that PTM was known to damage potato only in the warmer areas, though major production areas mainly cover the highlands.

Monitoring of PTM was conducted using PTM sex pheromone trap at Holetta. The result showed that the peak months were January, February, and June. Unlike the field situation, monitoring in the store showed no obvious peak record (Bayeh and Tadesse, 1994). Aphids in potato, though, were more important as vectors of virus diseases than as pests. Monitoring work was conducted using yellow water traps at Holetta, and during the monitoring different aphid species were recorded. The peak months were January, April, and November– December. The dominant species were Brassica aphids, green peach aphids, and potato aphids (Bayeh and Tadesse, 1994).

2.5. Seed Potato Storage System

In all potato producing areas of Ethiopia, potato seed storage is a common practice. According to

(Endale *et al*. 2008b) farmers of ethiopia store seed potato by leaving the tubers in the soil un-harvested (postponed harvesting); by other traditional storage methods like in a local granary, on bed-like structures or the floor in their house; or by diffused-light storage (DLS),Because of

storage and other post-harvest problems Ethiopia loses 30– 50% of its potato production. Types of storage are described in more detail below.

2.5.1. Postponed harvesting as storage mechanism

Postponed harvesting is the most commonly used storage method for ware potatoes in the highland and northwestern areas of the country to extend piece-meal consumption and also to wait for a better price (Endale *et al.* 2008b). According to these authors, tubers can be kept up to 4 months without major quality loss in cool highlands. This storage method is also used to store seed potatoes. According to authors survey they revealed that about 37% of the farmers in Banja in the northwestern area of Ethiopia left the potato tubers for seed un-harvested in the field, whereas only 1% (Jeldu) to 3% (Degem) of the farmers in the central area used this method. In a study undertaken in the central and northwestern areas of Ethiopia, Gildemacher *et al.,* (2009b) found that 47% of the potato farmers leave seed potatoes in the soil unharvest. This storage method was not reported in seed potato studies in the eastern area of Ethiopia. There is also no information on the presence of this storage type in the southern area of Ethiopia. Postponed harvesting as storage mechanism has been creating problems in potato production for it could allow more accumulation of tuber-borne diseases than early harvesting (Endale *et al.* 2008a). In ground storage of potato is also associated with large losses: in the Gojam and Gonder areas of the northwest losses of up to 50% have been reported caused by tuber moth and ants (Tesfaye *et al.,* 2008).

2.5.2. Other traditional storage methods

Farmers also store seed potatoes in bags stacked on the floor in untidy places in the house where there is no ventilation, heaped loosely or put on a bed-like structure. Forty seven percent of the farmers in the district Degem and 46% of the farmers in district Jeldu in the central area of Ethiopia and 73.6% in the eastern area of Ethiopia (Mulatu *et al.,* 2005a) used bags to store their seed potatoes. About 45% of the potato farmers of Jeldu district in the central area of Ethiopia and 21% of the farmers of Banja district in the northwestern area of Ethiopia heap their seed potatoes loosely while 33% of the farmers of Banja district in the northwestern area of the country use a bed-like structure. Mulatu *et al.* (2005a) also found that about 26.4% of the farmers in the eastern area of Ethiopia piled up their seed potatoes in an open place or in a corner of their

house. However, there are also farmers who store their potatoes in a better place. In a study made in the central and northwestern areas of Ethiopia, about 18% of the farmers were found to use light spaces in the house to store their seed potatoes (Gildemacher et al., 2009b). In the southern area farmers store seed potatoes in their home or in a store constructed for this purpose. Seed and ware potatoes are stored side by side in the same store or home. In the Shashemene district of the southern area, farmers cover stored ware and seed tubers with teff straw to protect the tubers from sun light (Adane *et al*., 2010). They use a thicker cover for the seed than for the ware. The farmers increase the thickness of the seed tuber cover a few weeks before planting. The farmers believe that an increase in the thickness of the cover will help the seed tubers to break dormancy and thereby encourage sprouting.

2.6. **Potato Varieties Grown and the Seed Systems in Ethiopia**

Over twenty years (20) later (1980-2001) Medhin *et al*. (2001) reported that there is no institution in Ethiopia that multiplies and distributes potato seed tubers. Borgal *et al* (1980) reported that very little imported or certified seed is available to farmers. Thus, farmers are forced to use inferior-sized tubers from different sources such as neighbor farmers, local markets and previous harvests (Almekinders *et al*., 1994). Hence, this practice has contributed to the build-up of diseases and pests, which leads to low yield. According to Kidane-Mariam (1980) and Lemaga (1983) local varieties are not free of insect pests, diseases and viral infection. Lack of available seed can be a major factor in determining whether farmers continue to grow potatoes, or to rely only on cereals (Medhin *et al.,* 2001). In Ethiopia, currently, 29 potato varieties were released officially and the most from the EIAR-CIP breeding program (Mekonen *et al.,* 2011).

2.7. Potato production in Ethiopia

Potato is grown in most parts of Ethiopia, with the major production regions located in the central, eastern, northwestern and southern which cover approximately 83% of the potato farmers (CSA 2008/2009). In the central highland area the major potato growing Zones are West Shewa and North Shewa in Oromia regional state.

From West Shewa Ginchi, Jeldu, Galessa and Holetta are one of the major potato producing areas. Potato is produced mainly in the short rainy, season starting from February to May and long rainy, season from June to September. It is a major potato growing area in the country. Both seed and ware potato and farmers grow about seven local varieties includes Jalane, Gudane, Belete, Tolcha, Digemegn, Sisay and Menagesha, eight improved varieties and six clones (CSA 2008/2009).

The eastern area of potato production mainly covers the eastern highlands of Ethiopia, especially the East Harerge zone. Only about 3% of the total number of potato growers is situated in this area (CSA 2008/2009), but the area is identified specifically because the majority of the potato farmers in this area produce for the market and there is also some export to Djibouti and Somalia. Potato is mainly grown under irrigation in the dry season (December to April). This season is characterized by low disease pressure and relatively high prices (Mulatu et al. 2005b). Potato is also produced in the belg (February to May) and the meher (June to October) seasons. Most farmers grow local potato varieties. However, some farmers in the vicinity of Haramaya University in the eastern area and farmers who are targeted by NGO seed programmes have access to improved varieties (Mulatu et al. 2005a).

The northwestern area of potato production is situated in the Amhara region. It is the major potato growing area in the country that included South Gonder, North Gonder, East Gojam, West Gojam and Agew Awi are the major potato production zones (CSA 2008/2009).

The southern area of Ethiopia in which potato is grown, Nationalities and Peoples' Regional State (SNNPRs) and partly in the Oromiya region. The major potato producing zones in this area are Gurage, Gamo Goffa, Hadiya, Wolyta, Kambata, Siltie and Sidama in the SNNPRS and West Arsi zone in Oromiya (CSA 2008/2009). Potato tubers are produced under rainfall conditions and under irrigation. Productivity usually ranges from 7 to 8 Mg ha−1, whereas in some places potato productivity is even below 7 Mg ha−1. About six varieties are grown, of which four are local and two are improved (Endale et al. 2008a).

2.8. Potato production in Oromia

Oromia is the major potato producing region that constitutes 51% of the national potato production (CSA, 2015). According to the Bezabih and Mengistu (2011) West Arsi is a major potato producing zone in Oromia National Regional state that smallholder farming has diversified from staple food subsistence production into more market oriented and high value commodities. Potato is a major food and cash crop produced in Shashemene district (Bariso Bati, 2018).

In Ethiopia, potato is grown in four major areas: the Central, the Eastern, the North-Western and the Southern regions, which together constitute approximately 83% of the potato farmers in the country CSA 2008/2009).

In the Central area, potato production includes the highland areas surrounding the capital, Addis Ababa. In this area the major potato growing zones are West Shewa and North Shewa About 10% of the potato farmers are located in this area (CSA, 2008/2009).

The Eastern area of potato production mainly covers the Eastern highlands of Ethiopia, especially the East Harerge zone. Only about 3% of the total number of smallholder potato producing farmers in Ethiopia grow potato inhabit in this area (CSA, 2008/2009). However, the area is identified specifically because the majority of the potato farmers' in this region produce potatoes for the market and the farmers have also access to export markets in Djibouti and Somalia. Potato is mainly grown under irrigation in the dry season (December to April). This season is characterized by low disease pressure and relatively high prices (Mulatu *et al., 2005b)* Potato is also produced in the belg (February to May) and the meher (June to October) seasons. Most farmers grow local potato varieties. However, some farmers in the vicinity of Haramaya University in the Eastern area and farmers who are targeted by NGO seed programmes have access to improved varieties (Mulatu *et al.*, 2005a). Despite the use of local varieties, the productivity of potato in this area is equivalent to the productivity in the Central area. This might be due to good farm management practices triggered by the farmers' market orientation (Adane *et al.*, 2010).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Welmera is one of the districts found in Oromia special zone surrounding Finfine, in the Oromia Regional states of Ethiopia. It is bordered by the Sebeta Hawas in the South, in the West by West Shewa Zone, in the North by Mulo, in the Northeast by the Sululta, and in the East by Burayu town. Towns in Welmera include Menagesha and Holeta.

The survey was conducted in some selected major potato growing kebele of Welmera districts namely Watabicha Minjaro, Ade Simbirit Kotu and Kolobo kebele. I select these three kebeles because they cultivate potato in large quantities and qualities and highly populated kebeles.

The highest point in this district is Mount Wechacha (3191 meters), located in the Southern part of the districts. The Menagesha National Forest covers the Southern and Western slopes of this mountain; it is 2500 hectares in size. Other notable peaks include Mount Menagesha (between 2800 and 2900 meters). (// en.m.wikipedia.org/w/index.php)

Crop rotation and climate of the study area

The main crop plants cultivated in the study area are potato, Wheat, Barley, chickpea teff, and lentil. The districts are characterized with the average maximum and minimum temperatures are 24 °C and 8 °C, respectively, and average relative humidity of 60.6% Agricultural office of Welmera district (2019). The area receives an annual rainfall of above 1,100 mm. The climate is characterized by bimodal rainfall consisting of a long rainy season (June- September), short rainy season (February - April) and a dry season (October - January. Farmers rotate cereals with legumes and potato at two to three year intervals.

Agro-ecology

Potato is a temperate or cool season crop which needs a low temperature, low humidity, less wind, and bright sunny days. Humidity and rains are not conducive to potatoes as these lead to insect pests and disease attacks (United States Department of Agriculture, 2010). Also potato offers a wide flexibility in planting to the cultivator. The crop can potentially be grown on about 70% of the 10 Million hectare of arable land in the country (FAO, 2008) located within altitude

ranging from 1800-2500m above sea level and receiving an annual rainfall of more than 600 mm. As a highland country located in the tropics, Ethiopia has very conducive edaphic and climatic conditions for the production of high quality seed potato (Emana and Nigussie, 2011).

3.2. Study design and Sampling techniques

To achieve the intended objectives of the study descriptive survey design was used. The survey of the study was conducted in three (3) major potato growing kebeles of the highland of Welmera district. This three kebeles were selected because, this kebeles cultivate potato highly. A total of 382 (376 farmers and 6 Developmental Agents) respondents were selected as a representatives, and potato grower farmers from each kebele were interviewed, namely Watabicha Minjaro, Ade Simbirit Kotu and Kolobo through pre-designed questionnaire (**Appendix 1**). Thus, a total of 376 selected potato growers were interviewed from 3 sampled kebeles. On the other hand, a total of 6 Field Level Officers (FLO) of DA were (2 officers from each kebele) also interviewed through pre-designed questionnaire (**Appendix-2).**

Face to face interviews were conducted among 376 potato farmers and they filled up a set of pre-designed questionnaire (**Appendix-1)** and face to face interview was also conducted among 6 DA and they filled up a set of pre-designed questionnaire (**Appendix-2).** These questionnaires distributed for the respondents by random sampling technique and purposive sampling technique were used to get the representative or the participant of the study.

Population of the study area

The total number of population in Welmera district are about 127084. From these population about 51342 were male and 75742 were female. The population of the study area were restricted three kebele of Welmera district. In general with the 8257 population in the three kebeles of welmera district. Among this population 382 were selected by random sampling techniques. To determine the sample size, the researcher were used proportionate random sampling techniques after dividing into three kebele. Accordingly, 382 household were selected.

That is: - $n=\frac{N}{1+Ne^2}$ Use confidence level 95%, Margin of error = 0.05

Where, n= the sample size

N= the population size

e= the margin of error

$n=\frac{8257}{1+8257(0.05)^2}$

$n=\frac{8257}{21.64}$

n=382

In other opinions, to define proportion $\frac{n}{N}$the sample size required is 382. ($\frac{382}{8257}$=0.046) Therefore, n=382, was multiplied by the number of Sample size in each section by the obtained proportion, that is, 0.046 in order to determine the sample size.

Table 1: Sample size of the farmers including Developmental Agents

N	Kebele	Population	Proportion	Sample
1	Watabicha Minjaro	3420	3420*0.046	158
2	Kolobo	2504	2504 *0.046	116
3	Ade Simbirkotu	2333	2333*0.046	108
	Total	8257	8257* 0.046	382

3.3. Source of Data

The researcher used only primary data to gather information from the specified population to conduct the study. Primary sources of data were collected from respondents' interview and observation researcher

3.4. Data gathering tools

According to the sample design, 382 (376 farmers and 6 Developmental agents) respondents were covered under the study of which 382 respondents participated for face-to face interview and the selection of respondents were made on a simple random sampling technique within the sampled kebeles. Two types of questionnaire prepared for two types of data collection such as (a) respondents' survey for potato growing farmers and (b) respondents' survey for field level officers of Developmental Agents and these were given below:

- Questionnaire
- Observation and
- Interview will be used in these study

3.4.1. Questionnaire

Semi-structured questionnaire were prepared in English language and distributed to all Developmental Agents. Moreover, the questions were translated to Afan Oromo for farmers in order to avoid the presumably misunderstanding of the message conveyed with the questions. The researcher validated the instruments that were developed as follows: before the actual data collection was started; the instruments were given to colleagues so as to get valuable comments and criticisms on the strengths and weaknesses of the items. Based on the comments obtained, necessary modifications were made.

3.4.2. Observation

The researcher applied observation to gather information relevant to the study. The farm area (field) and storage system were observed to get the relevant information about insect pest associated to potato cultivation and at storage place.

3.4.3. Interview

Semi-structure interview was conducted with three kebeles' farmer to each interview; a schedule was prepared with suggested questions. The location for an interview was organized in advance and was in a quiet place so that the interview can concentrate on the questions but also in an open place where neither the researcher nor the interview can be compromised.

Interview was selected as appropriate data gathering tool for this study as it provides the opportunity for the participants to explain about insect pests associated to potato. Interviews also gave the researcher opportunity to clarify his/her interpretation of the participants‟ ideas, as produced in the interviews. By undertaking interviews every participant had the opportunity to share their personal view and perspective toward the research topic. The researcher conducted interview with six (6) field level officers or Developmental Agents (DA) and one hundred fifty (376) farmers.

3.5. Data collection

Personal interview approach was adopted for collection of primary data. The researcher personally contacted with the potato growing farmers in the respective Walmera district of selected sampled potato growing kebeles. When the target respondents were found, the researcher started the interview by explaining the objectives of the study to the respondents. After getting respondents, the researcher filled up each question of the questionnaire one by one and obtained desired information. The field level data collection was conducted for a period of potato growing season starting from May 2020 to December 2020. After the completion of data collection, all filled up questionnaires were preserved according to the category of respondents for processing and data analysis.

3.6. Data Analysis

The primary data collected from respondents by questionnaire, interview and observation were arranged and put in table for statistical analysis. Then the quantitative data was analyzed by descriptive method in percentage and frequency distribution by computer software SPSS.

4. RESULTS

4.1 Farmers and Developmental Agents response on insect pest associated to potato in the field and in the storage system

The results obtained from the studies were presented below sequentially in various forms and thus interpreted and discussed as to extract the findings systematically in line with the objective of the study.

4.2. Commonly used potato varieties

Table 2 demonstrated potato variety utilization of the farmers. All farmers 382 (100%) of potato growers in Welmera districts used Gudane variety of potato for cultivation in their field, whereas next to Gudane 334 (87.43%) of respondents responded that as they used Jalane variety. This was followed by Jalane variety which was cultivated 304(79.58%) Belete variety of potato and next to Belete variety Tolcha 171(44.76%) was grown by farmers and the last choice of farmers for cultivation was Sisay variety 106(27.74%). This indicates that almost all farmers used to grow varieties of potato at the same season simultaneously this means that an individual farmers grow variety of potato varieties in different farm area. As they responded to the researcher they used varieties of potato to identify varieties which was the most resistant to insect pest that associated to potato or feed on potato in the farm area. The researcher observed the farm area to identify types of potato varieties that farmers cultivated and asked why the farmers used multi-cultivation and prefer Gudane varieties. The farmers responded that as Gudane varieties mostly available in Welmera district and most resistant to insect pests associated to potato and weeds, due to these reason farmers prefers Gudane varieties. Similarly Developmental Agents of the district verify as the farmers preferred Gudane and Jalane due to its availability and resistivity to insect pests. This research finding is agreed with that of (Mekdes Nega 2015) stated that Gudane and Jalane did not susceptible due to their size.

Table: 2 commonly used potatoes varieties cultivated by farmers and Developmental Agents

Potato varieties	Response on potato variety cultivation			
	Frequency		% response	
	Yes	No	Yes	No
Jalane	334	48	87.43	12.57
Gudane	382	0	100	0
Belete	304	78	79.58	20.42
Tolcha	171	211	44.76	55.24
Sisay	106	276	27.74	72.26

4.2 Major problems farmers face in potato cultivation

Major potato production constrains that farmers faced are shown in **Table 3** This study showed that potato production constrains included insect pests that feed on potato 319 (83.50%), followed by disease infestations was the major problem 311 (81.41%) whereas weeds infestation was 280 (73.30%) and followed by insect pest that attack potato at storage 245 (64.13%). As it indicated in the table 3 the most problem that contributed to reduce the potato cultivation was insect pest associated to potato or insects that feed on potato at the field area. The response of the respondents indicated that as almost all farmers faced different constrains of potato production. The field observation made by researcher confirmed that the respondents' responded in below table as farmers exposed to different constrains of potato production.

Table: 3 Major problems faced farmers during potato cultivation

Major problems	Response on major problem (N= 382)			
	Frequency		% response	
	Yes	No	Yes	No
Insect pests associated to potato	319	63	83.50	16.5
Weed infestation	280	102	73.30	26.7
Diseases infection	311	71	81.41	18.59
Insect Pests attack potato in storage	245	137	64.13	35.87

4.3. Occurrences of potato insect pests at potato cultivation field

As the potato farmers and Developmental Agents expressed their opinion in the below **Table 4** out of 382, all (100%) of farmers (374) responded that the potato was infested in the field by potato tuber worm, which was followed by red ant infestation were reported 83.5% (319). The next insect occurred at Welmera district that affect potato was aphids 79.58% (304) whereas; cutworm was also insect that occurred in Welmera district in the farm area of potato by 75.13% (287) as the farmers and Developmental Agents reported. While leafhopper 63.61% (243) and the farmers and Developmental Agents reported as the insect pests associated to potato and occurred in the field attack their potato. This report shows that potato tuber worm, red ants, aphids, cut worms, and leafhopper were the most serious insect pests associated to potato that occur in the field and attack potato respectively. These showed that as all these types of insect pest associated to potato occurred in all potato farm area of Welmera district.

Table: 4 Types of potato insect pests occurred at potato cultivation area

Major insect pests	Response on major insect pests (N= 382)			
	Frequency		% response	
	Yes	No	Yes	No
Aphids	304	78	79.58	20.42
Potato tuber worm	382	0	100	0
Leafhopper	243	139	63.61	36.39
Potato Cutworm	287	95	75.13	24.87
Red ants	319	63	83.50	16.5

4.4 Infestation status of insect pests of potato in field condition

Table 5 shows clearly the infestation status of insect pests of potato in the field. According to the opinion expressed by the farmers and Developmental Agents all the farmers and Developmental agents (100%) responded that the major insect pest associated to potato damaged in the field condition is potato tuber worms. In other ways all farmers observed this insect pests in their field. This was followed by red ants stated that 90.05% of farmers responded as this pest attack their crop product seriously. Next to red ants, aphid 84.81% was major insect pest associated to potato in attacking potato in the field as the farmers and Developmental Agents reported. Additionally, the major insect pest that damaged potato product were leafhopper, and cutworm

as stated by 66.75%, and 62.82% crops of farmers respectively. The field observation revealed that as these all types of insect pests attack potato at different stages of potato and this infestation reduced the potato product by large.

Table: 5 Infestation status of insect pests of potato in field condition

Name insect pests	Response on infestation status of insect pest of potato in the field (N=150)			
	Frequency		% response	
	Yes	No	Yes	No
Potato tuber worm	382	0	100	0
Leafhopper	255	127	66.75	33.25
Cutworm	240	142	62.82	37.18
Red ants	344	38	90.05	9.95
Aphids	324	58	84.81	15.19

4.5 Infestation status of insect pests of potato at storage condition

As shown in Table 6 potato tuber worm and red ants were the two insect pests' species that affect potato in the storage place. These insect affect tuber of potato underground in the soil and were it stored at home. As the farmers and Developmental Agents responded that 96.86% of storage place were invaded by Potato tuber worms. Similarly 93.72% of storage place were invaded by red ants so these two types of insect pests were the most serious pest that affect potato in storage condition.

Table: 6 Infestation status of insect pests of potato at storage condition

Name of insect pest	Response on Infestation status of insect pests of potato at storage			
	Frequency		% response	
	Yes	No	Yes	No
Potato tuber worm	370	12	96.86	3.14
Red ants	358	24	93.72	6.28

4.6. Production loss due to insect pests

The reduction of potato production due to the presence of insect pest's infestation is described in the below Table 7 According to the interviewed farmers and Developmental Agents around 75% of farmers responded that insect pests contributed to 25%, whereas about 76.67% of farmers mentioned as their crop product damaged by 33.33% and about 80% of farmers responded that as their yielding capacity were reduced by 20%. These respondents mentioned that in average the yielding capacity of the farmers reduced by 26.11 percent including infestation under field and storage condition.

Table: 7 production loss due to insect pests

production loss due to insect pests	Response of the respondents	
	Frequency	Percentage
¼	286	75
1/5	306	80
1/3	255	76.67

4.8 Storage structures and practices

As it indicated in T**able 8** majority of Welmera district farmers uses the system of late harvesting of potato storing system for seeds to grow in the next cultivation season or 93.45 percent of farmers used this storing method this means that potato tuber remain (stayed) in soil until it needed for seeds to be cultivated, then when it required for seeds it harvested and sold or sow by the farmers, the next most favorable system of storing potato was storing on the floor 309(80.89%) of farmers and the third favorable system was storing of potato in sack 288(75.39%) whereas the last method of storing system that Welmera district farmers used were storing potato in the bed like structures 227(59.42%), but scientifically storing potato in bed like structure is the most favorable method. Farmers of Welmera district have experience of potato storing system for a long period of time at least ten years. The observation was made by the researcher to identify storing methods of Welmera districts' farmers, then the researcher saw that

as farmers were used four types of storing system of potato for seeds. It include that storing on the floor, leaving un-harvested for three to four months, storing potato in sacks and in bed like structures were storing structures and practices of farmers of Welmera district.

Table: 9 Storage structures and practices

What types of storage system do you use	Response of the respondents			
	Frequency		Percentage	
	Yes	No	Yes	No
Store in sack	288	94	75.39	24.61
Store on floor	309	73	80.89	19.11
Store in bed	227	155	59.42	40.58
Late harvesting	357	25	93.45	6.55

a. Storing in bed like structure c. storing on the floor

Figure 1. Method of potato storage systems in Welmera district, 2021.

b. Storing in sacks d. leaving un-harvested

Figure 2. Method of potato storage systems in Welmera district, 2021.

4.9. Potato storing experience of farmers and their experience by year

Most of Welmera district farmers (90.84%) have experience to store potato for seed purpose this indicated that they have cultivated potato for a long period of time, But some (9.16%) of the farmers of Welmera district have no experience of storing potato for seed so these non-experienced farmers always buy potato seeds from the experienced neighbor. Experienced farmers stored their potato in average for three to four months then they used for cultivation in their farm area and sold the left seed to the neighbor.

As it shown in table 10 most of Welmera district farmers have above ten years' experience of storing potato seed in percent (55.24). As it expressed in table 9 they use storing system like storing on the floor, storing in bed like structure, storing in sacks and late harvesting system of storing potato for seed purpose. The next most experienced farmers were only 6-10 year experienced which is 24.34% of the farmers while about 20.42% were1-5 years experienced.

Table: 10 Potato storing experience of farmers and their experience by year

Do you have the experience of storing potato storing system	Frequency	Percent
Yes	**347**	**90.84**
No	35	9.16
Total	382	100
Experience of storing system of potato by farmers in years	**Frequency**	**Percent**
1-5 years	78	20.42
6-10	93	24.34
Above ten years	**211**	**55.24**
Total	382	100

5. DISCUSSION

As this research result indicated that Welmera district farmers were cultivated different varieties of potato includes (Jalane, Gudane, Belete, Tolcha and Sisay). Among the varieties of potato, their best choices to cultivate were Jalane and Gudane varieties, because these varieties have small tuber size and less infestation as compared to Belete variety (Mekdes Nega 2015). They cultivated Belete as the third choice of their cultivation in the farm area if there were no seeds of Gudane and Jalane, because Belete variety is more susceptible to insect pest may be due its big seed size (Mekdes Nega 2015). This result agrees with Lacey *et al*. (2008) who reported that *P. operculella* economic damage occurs towards the end of the growing season when tubers were exposed. As it indicated in **Table 2** when it put in percentage 382 (100%) of potato growers farmers used Gudane variety for cultivation in their field, whereas next to Gudane about 334(87.43%) of farmers used Jalane variety. Following of Jalane variety Belete variety of potato was cultivated 304(79.58%) and next to Belete variety Tolcha 171(44.76%) was grown by farmers and the last choice of farmers for cultivation was Sisay variety 106(27.74%).

The research findings identified the major constrains of potato production were infestation of insect pests at cultivation (field), and in storage place, weeds infestation and diseases infestation at different stages of potato. This constrains contributed to the reduction of the yielding capacity of the farmers, as a result of this farmers of Welmera district needs the assistance of Developmental Agents and advice that assist them in practical way. This finding is clearly identified that the major insect pests associated to potato and adversely affect the production of potato at Welmera district were included aphids, red ants, cutworms, potato tuber worms, and leafhopper. Similarly the Developmental Agents of Welmera district verified as this insect pests adversely affect the production of potato. The researcher analyzed farmer's and Developmental Agents response and put in percentage, potato tuber worms found in all over the Welmera districts 100%, Red ants and Aphids were found in most farm area of farmers in percentage 90.05% and 84.81% respectively then Leafhopper and cutworms were found in some farm area of the farmers as a result of these insects infestation contributed the reduction of the yielding capacity of the farmers by 26.11% in average. From field observation and respondents responded most of the storage place were infested by insect pests such as potato tuber worms and Red ants.

The results of this study showed that from the farmers who stored seed tubers in floor, in sack and staying un-harvested in field (leaving un-harvested in soil) storage methods was highly infested by p. operculella and red ants. Therefore, due to lack of improved storage facility, farmers forced to sell their products immediately after harvest in low price, and these result is similar to (Tewodros *et al.,* 2014). Moreover, these traditional storages are not able to store for long period without insect pests or disease damage, bulk storage and reduced the farmers housing safety for those who store in the house (Tewodros *et al*., 2014). According to (Agajie *et al.,* 2007) report better quality seed tubers is obtained with storage in DLS than in traditional dark storage. So the recent finding agree with this statements and recommended that the farmers must be improve storing mechanisms of potato for seeds and for food values. The field observation of the researcher confirmed that what the farmers and Developmental Agents responded as P. opercullela and red ants affect potato at storage condition.

Alvarez *et al. (*2005), Chumakov and Kuznetsova (2009) reported that hilling of potato with 2 inch thick soil significantly reduces potato tuber damage by *P. opercullela*. Rondon *et al.* (2007) reported that shallow setting varieties are generally more susceptible to *P. operculella* than varieties that set tubers deeper in the ground. This indicated that the shallower tuber can be eaten by cow, sheep, horses and goats if it leaved un-harvested in soil.

According to Sileshi and Teriessa, (2001) the infestation of seed tubers by PTM was found to be significantly higher in Welmera followed Jeldu, while no damaged was observed in Dandi and Dagem. As Silashi and Teriessa on average, 8.7% of the potato tubers were lost due to field infestation of insect pests. According to the current findings, the infestation status of insect pest in Welmera districts by potato tuber moth and red ants under storage condition were by large. It means that according to the response of farmers and Developmental Agents of Welmera district about 26.11% of their potato products were lost due to the presence of these insect pests. Similarly the infestation of seed tubers by PTM was found to be significantly higher in Walmera Ferdu *et al* (2009) report. Also farmers and developmental Agents of Welmera districts confirm that as insect pests attack potato in the field and deteriorated potato tuber at storage place.

According to Bayeh and Tadesse, (1994) the major insect pests that associated to potato were include: cutworms (*Agrotis* spp. and *Euxoa* spp.), red ants (*Dorylus spp.),* potato aphid

(*Macrosiphum euphorbiae*), green peach aphid (*Myzus persicae*) and the potato tuber moth, *Phthorimaea operculella* (Zeller), but in this recent finding cutworms (*Agrotis* spp. and *Euxoa* spp.), red ants (*Dorylus spp.)*, potato aphids, potato tuber worms *Phthorimaea operculella* (Zeller), and leafhoppers are insect pests that associated to potato in Welmera district and these four type of insect pests are infect potato at farm area, and red ants and potato tuber worm are infects potato both at farm area and at storage place.

Bayeh and Tadesse (1992) stated that a peak period of insect infestation in Welmera district were January, February, and June in the field. This finding also confirms these statement, but it is happen when the farmers use late harvesting methods of storing system. Postponed harvesting system exposed potato to be affected by insect pests, cattle, rats, sheep, and rodents, as a result of this farmers lost the benefit that they gain from potato production, so the farmers must harvest the cultivated potato as soon as it matured.

The Developmental Agents and farmers of Welmera districts indicated that cutworms, potato tuber moth, aphids, red ants and leafhoppers are the potential or major insect pests that damaged potato in every years of cultivation. These insect pests associated to potato and damaged the cultivated potato seriously at farm area and at storage place. If these insects did not controlled or managed at proper time during cultivation some insect pests such as potato tuber moth and red ants are harvested with potato and attacked potato at storage place due to these reason the yielding capacity of crop reduced and the produced crop deteriorated, so the farmers must use method of insect control before harvesting potato.

The Developmental Agents of Welmera districts and farmers of the kebeles mentioned that as there were no new species of insects that invaded the farm area, but they mentioned that as the previously existed insect pests seriously affected their crop products, so the current finding revealed that as there is no newly emerged insect pests of potato in Welmera districts.

6. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Potato cultivation is common practice of agricultural activity that grow as cash crop and to fill full food security in Welmera district. Welmera district farmers grow different types of potato varieties in their farm area especially their favorable choice were Gudane and Jalane varieties. These types of varieties are most resistant to disease and insect pests associated to potato as a result of this reasons Gudane and Jalane varieties are mostly expanded in Welmera district. However the most important insect pests associated to potato in Welmera district are potato tuber worms, cutworms, red ants, potato aphids, green peach aphid, and leafhopper. Among these insect pests, potato tuber moth (PTM), cutworms, leafhopper, red ants, and aphids were the most important insects that attack potato at field condition, while potato tuber moth and red ants are types of insects that affect potato both under the field and at storage condition. Farmers of Welmera district use different methods of storing system of potato for seeds purpose included storing in sacks, on the floor, in bed like structure and late harvesting system for three to four months, even if they use these system of potato storage system potato tuber can be affect by insect pests that associated to potato.

Generally insect pests associated to potato is the main constrain that reduced the production capacity of Welmera district farmers. So the current finding indicated that the yielding capacity of Welmera district farmers reduced due to the presence of insect pests associated to potato.

5.2. RECOMMENDATION

1. Farmers of Welmera district must use proper way of potato storage.

2. Concerned body should give awareness to the farmers of Welmera district on how the farmers cultivate and store potato properly.

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Appendix 1:
Questionnaire for potato farmer

Addis Ababa University Department of Biology and zoological science

Insect pest associated to potato production and storage in the highland of Welmera districts

Prepared by: Yirefu Belachew Gari

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Set-1: questionnaire for farmer

Instruction: - show your answer by making √ symbol in the box provided.

1. Sex: Female ☐ male ☐
2. Age 18-20 ☐ 20-30 ☐ 31-40 ☐
   41-50 ☐ 51-60 ☐ 61 &above ☐
3. Marital status:- Married ☐ Single ☐
   Divorced ☐ Window ☐
4. Educational Status: 1-4 ☐ 10-12 ☐
   5-10 ☐ Above ☐
5. Nationality - Ethiopian ☐ Foreign ☐
6. Name of the variety that you cultivated this year?

Name potato varieties	Types of answer (code 1 =yes, code 2= no)	
Belete		
Gudane		
Jalane		
Tolcha		
Sisay		
Gera		
Guasa		

Why you prefer these varieties. _____

7. Insect occurrence in potato field

Name insect pest	Types of answer (code 1 =yes, code 2= no)	
Aphids		
Potato tuber worm		
Beet Leafhoppoer		
Cutworm		
Leafminer		
Whitefly		
Field cricker		
Mole cricker		
Red ants		

Other insect type you know _____

8. Infestation status of insect pests of potato in field condition

Name insect pest	Types of answer (code 1 =YES, code 2= NO)	
Aphids		
Potato tuber worm		
Beet Leafhoppoer		
Cutworm		
Leafminer		
Whitefly		
Field cricker		
Mole cricker		
Red ants		

10. Infestation status of insect pests of potato at storage condition

Name insect pest	Types of answer (code 1 =yes, code 2= no)	
Aphids		
Potato tuber worm		
Beet Leafhoppoer		
Cutworm		
Leafminer		
Whitefly		
Field cricker		
Mole cricker		
Red ants		

11. By how much the production reduced due to insect infection?

A. ¼ B. 1/5 C. 1/3 D. ½ E. other _____

12. What types of storage system do you use

A. Late harvesting B. store in sack C. store on floor D. store in bed E. other

13. Do you have the experience of storing system A. Yes B. No

14. If yes for how long? A.1-5 B. 6-10 C. above

Appendix 2:

Questionnaire for field level officer or DA of Welmera districts

Addis Ababa University of Department zoological science

Insect pest associated to potato production and storage in the highland of Welmera districts

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Set-1: for field level officer or DAE of Welmera districts

INFORMATION ABOUT INSECT PESTS OF POTATO

1. Name of the variety that farmers cultivated this year?

Name potato varieties	Types of answer (code 1 =yes, code 2= no)	
Belete		
Gudane		
Jalane		
Tolcha		
Sisay		
Gera		
Guasa		

Why they choose varieties? _____

2. Insect occurrence in potato field

Name insect pest	Types of answer (code 1 =yes, code 2= no)	
Aphids		
Potato tuber worm		
Beet Leafhoppoer		
Cutworm		
Leafminer		
Whitefly		
Field cricker		
Mole cricker		
Red ants		

3. Infestation status of insect pests of potato in field condition

Name insect pest	Types of answer (code 1 =major, code 2= minor)	
Aphids)		
Potato tuber worm (*Phthorimaea operculella* (Zeller)		
Beet Leafhoppoer		
Cutworm		
Leafminer		
Whitefly		
Field cricker		
Mole cricker		
Red ants		

4. Infestation status of insect pests of potato at storage condition

Name insect pest	Types of answer (code 1 =yes, code 2= no)	
Aphids		
Potato tuber worm		
Beet Leafhoppoer		
Cutworm		
Leafminer		
Whitefly		
Field cricker		
Mole cricker		
Red ants		

5. By how much the production reduced due to insect infection?

   B. ¼ B. 1/5 C. 1/3 D. ½ E. other _____

6. What types of storage system do you farmers use?

   A. Late harvesting B. store in sack C. store on floor D. store in bed E. other

7. Do you have the experience of storing system A. Yes B. No
8. If yes for how long? A.1-5 B. 6-10 C. above

Set-2 please read the following questioners and gives the response to question below

1. What are the major insect pests that cause potential damage to potato in Welmera districts (kolobo kebele, watabicha minjaro or ade simbirit kotu)? _____ _____ _____
2. What are the key insect pests associated to potato production that cause potential damage in every year in Welmera district /your area? _____ _____
3. What are the minor insect pests that may harm potato in the field and at storage area if not to be controlled? _____ _____
4. What are the insect pests of potato, which incidences are being seen in recent years, but not seen earlier in your area? _____ _____
5. What are the effective options to control the insect pests that are found in the potato field or at storing place in your area? _____ _____
6. Give your suggestions for the better management of the insect pests of potato in your area? _____