ADDIS ABABA UNIVERSITY

FACULTY OF NATURAL AND COMPUTATIONAL SCIENCES

GRADUATE STUDIES PROGRAM, DEPARTMENT OF ZOOLOGICAL SCIENCES

MSc THESIS

THE STATUS OF INSECT PESTS OF POTATO GROWN IN HADIYA ZONE, CENTRAL ETHIOPIA

BY

MATHEWOS KURCHO KOLASO

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A Research Paper Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Biology.

AUGUST 2024

ADDIS ABABA, ETHIOPIA

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As members of the Examining Board of the final MSc open defense, we certify that we have read and evaluated the Thesis prepared by: Mathewos Kurcho Kolaso entitled "The Status of Insect Pests of Potato Grown in Hadiya Zone, Central Ethiopia" and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Biology.

_____	_____	_____
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Examiner	Signature	Date
_____	_____	_____
Department chairperson	Signature	Date

Declaration

I declare that this thesis is my original work and that all sources of material used for this thesis have been duly acknowledged. I solemnly 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: _____

Signature: _____

Bibliography

The author, Mathewos Kurcho Kolaso was born in Lakole burkito kebele, Misrak badawacho woreda, Hadiya Zone, in 1982 and attended the primary school in Amburse Anjulo from 1989 - 1996, secondary and preparatory school in Shone from 1997-2000, BSc in Biology from Hawassa University from 2001-2003.I was started teaching profession in 2005, Keranso high school in Misrak badawacho woreda Hadiya zone up to 2016 and know attended Biology MSc in Addis Ababa University.

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LIST OF ABBREVIATIONS/ACRONOMYS

APR	Annual Progress Report
CIP	International Potato Improvement Center
CSA	Central Statistical Agency of Ethiopia
DAs	Developmental Agents
EBADO	East Badewacho Woreda Agricultural Development Office
EIAR	Ethiopia Institute of Agricultural Research
FAOSTAT	Food and Agriculture Organization Statistics
IPM MASL	Integrated Pest Management Meter Above Sea Level
PTM	Potato Tuber Moth
SPSS	Statistical Package for the Social Sciences
TPS	True Potato Seed
WBADO	West Badewacho Woreda Agricultural Development Office

ABSTRACT

Potato (Solanum tuberosum L.) can significantly contribute to food security improvement by increasing food availability and cash income of smallholder farmers. Ensuring the sustainable production of potatoes is an important challenge facing agriculture globally. Insect pests are major biotic constraints affecting potato yields and tuber quality. The current study was conducted to determine major insect pests and their management options on potato grown in Hadiya Zone, Central Ethiopia. A survey was undertaken in Hadiya Zone in two potential potato growing districts: East and West Badewacho districts. Data on the status of insect pest under field and storage conditions were collected through observations and interview. Field observation was made near potato harvesting time, while observation under storage condition was done in the middle and near the next planting season. Forty-eight respondents (36 farmers, 6 merchants and 6 Development Agents) from both study districts were randomly selected and interviewed. Data were collected and analyzed using descriptive statistics. The present result indicated that most of the fields were infested by potato tuber moth (Phthorimaea operculella). Among these pests, potato tuber moth and cutworm(*Agrotis ipsilon*) *were identified as major pests and caused high and moderate infestations respectively. Others were identified as minor pests of potato with low infestations. Potato tuber moth was found as the key pest in storage condition as compared to previous years . Currently, cutworm and aphid* (*Myzus persicae, Aphis gossypii*) *were more damaging insect pest of potato in field condition than previous infestation, and potato tuber worm was more damaging insect pest in storage. Insecticide spray is the most favorable pest control method among the potato growers. Surprisingly, most of the farmers only apply pesticides to control the pests infesting field. It can be understood that people are still unaware of the risk hazard of chemical application. So, it is necessary that the proper awareness program and planning should be given by the government ..*

Key words: *Field survey, Knowledge gap, Phthorimaea operculella, Potatoes, Storage,*

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is the world's fourth most widely cultivated food crop after wheat, rice and maize (Liu *et al*., 2022). It belongs to the family *Solanaceae* and an important food and cash crop as an income source globally (Esmael, 2017). It is also one of the fastest expanding food crops in Sub-Saharan Africa and a nutritionally balanced food, which provides a high calorie intake and a substantial number of vitamins (Haverkort *et al*., 2012). Ethiopia has considerable potential for potato cultivation, as 70 percent of its arable land is suitable - mainly highland areas above 1500 meters above sea level (Gelan and Bomas, 2017). Ethiopia is also one of the major producers of potato in Eastern Africa because of its suitable agro-ecology and its domestic consumption levels (Brasesco *et al.*, 2019).

Potato is an intensively managed crop, requiring irrigation, fertilization, and frequent pesticide applications in order to obtain the highest yields possible (Kumari 2012; Gelan and Bomas, 2017). Potato is grown throughout the world and originated in the high Andes of South America and started to be planted around Lake Titicaca in Peru (Halterman *et al*., 2016). However, the crop was first introduced to Ethiopia around 1858 by Schimper, a German botanist (Berga *et al.*, 1992). Ethiopia is endowed with great potential for potato production majorly because of good climatic and adapted conditions for higher potato production and productivity (Endale *et al.*, 2008). Potato is grown by approximately one million smallholder farmers in four major areas viz., the central, the eastern, the northwestern and the southern highlands of the country. According to Ethiopian central statistics agency (CSA, 2014/2015) survey report about 67,361.87 ha of land were used for potato production. The major constraints faced by potato producing farmers include the lack of improved variety, low yielding, and disease-resistant and good quality seed potato varieties (Schulte, 2013) and susceptibility to the major disease and insect pests (FAO, 2017).

Potato production is expanding rapidly in developing countries. Over the past decade, potato production in developing countries increased steadily by 5% per annum, while the crop's cultivated area rose by 3%. Potato has multiple benefits for low income households and where land shortage is a constraint ((Esmael, 2017). The crop grows quickly, has a high yield, and contains more energy and protein per unit area when compared to a cereal crop. Therefore, it

plays a vital role in ensuring food security, which is a major concern for the country (FAO, 2008). Potato is one of the stable food sources in the world, which have high carbohydrate and low fat content made it a better energy source than cereal for human consumption (Ayalew, 2014). Potato serves as food and income security to farmers; especially during seasonal food shortage or hunger as potato attain physiological maturity earlier than cereal crops (Sanginga *et al*., 2009). Potato is a valuable crop for smallholder farmers in Ethiopia, serving as both cash and food security crop. It is a nutritionally balanced food crop, which provides a high calorie intake and a substantial amount of vitamins (Brasesco *et al.,* 2019).

Potato is both an important tuber vegetable for local food security as well as a good cash crop for smallholder farmers in Ethiopia (FAO, 2017). It is mainly consumed as boiled, salad, stews and recently potato chips and crisps are getting attention from roadside vendor's who fries and sell it on the spot. Potato production in Ethiopia covers an area of about 1600, 000 ha. Potato average yield/ha (9 tones) in Ethiopia is much lower than the world average yield/ha (15 tones) (Ferdu *et al.,* 2009), not comparable with the world average yield. Reduced yield of potato per/ha have been indicating that there are still a lot of problems related to the production of potatoes that need to be addressed to realize the potential of the crop particularly in developing countries like in Ethiopia (Endale *et al.,* 2008; FAO, 2017).

Despite the presence of favorable environmental factor for potato production in Ethiopia a number of constraints limit the production and productivity particularly under smallholder farmer's condition (Lemma *et al*., 2018). Among the factors that contribute to low productivity of potato in Ethiopia are inadequate storage, lack of improved varieties (Ayalew, 2014), marketing facilities and biotic constraints such as fungal disease like late blight, early blight, bacterial wilt, and insect pests (Ferdu *et al.,* 2009). Therefore, potato crop production and storage is constrained by insect pests. Major insect pests of potatoes include cutworms (*Agrotis* and *Exigua* spp.), green peach aphid (*Myzus persicae*), metallic leaf beetle (*Lagria vilosa*), potato aphid (*Macrosiphum euphorbiae*), potato epilachna (*Epilachna hirta*), potato tuber moth (*Phthorimaea operculella*), red ants (*Dorylus* sp.), and red spider mite (*Tetranychus utricae*) (Bayeh and Tadesse, 1992; Ferdu *et al*., 2009; Muluken *et al.*, 2016). *P. operculella* received more attention than other insect pests affecting potatoes (Ferdu *et al*., 2009).

1.2. Statement of the Problem

Due its global geographical distribution, potato is affected by a wide range of insect pests (Lemma *et al*., 2018). Agricultural production in Ethiopia is largely rain-fed, where the rainfall is erratic and often insufficient. Therefore, the above constraints are important in all potato production areas of the country, with little variations across locations. Hadiya Zone is one of the potato production areas of southern Ethiopia facing these typical constraints. With the aim of setting up more rational approaches to control insect pests, Pucci *et al.*, (2003) noted that basic research is needed on the key factors regulating population dynamics of major deleterious insect pests; a number of phytophagous insects are known to feed on potato crops in the field and store. However, there is lack of precise and up-to-date comprehensive information on infestation of insect pests of potato and management options in Hadiya Zone, Central Ethiopia.

1.3. Objectives

1.3.1. General objective

- To determine major insect pests and their management options on potato grown in Hadiya Zone.

1.3.2. Specific objectives

1. To investigate major insect pests of potato in the study area.
2. To assess farmers, merchants and development agent's perception and beliefs on insect pests of potato in study area.
3. To know the management options of potato insect pest in the study area.

1.4. Research questions

Based on the objectives of the study the following research questions were formulated.

1. What are the major insect pests of potato in the study area?
2. How do farmers, merchants and development agents, perceive and believe on insect pests of potato in the study area?
3. What are the management options of potato insect pest in the study area?

1.5. The Significance of the study

The study contributes important information about the status of insect pests on potato grown in Hadiya zone. The study may provide a better understanding of thedamage caused by potato pests impacts of insect pests on potato damage. It also may serves as base line information to facilitate ideas among farmers, merchants and development agents, researchers and other stakeholders by creating awareness on how to manage insect pests' damage on potato effectively.

1.6. Scope of the study

The study was conducted on status of insect pests on potato grown on selected six sample kebeles from two districts of Misrak and Mirab Badewacho, in Hadiya zone Therefore, this study focused more on farming dependent segment of population rather than engaged in merchants and development agents. The study area was selected purposively based on the researcher's previous and current knowledge for the district and the sample kebeles were selected randomly.

2. LITERATURE REVIEW

2.1. Potato Production

Potato plants are herbaceous perennials that grow about 60 cm high, depending on variety, with the culms dying back after flowering, fruiting and tuber formation (FAO, 2013). They bear white, pink, red, blue, or purple flowers with yellow stamens. In general, the tubers of varieties with white flowers have white skins, while those of varieties with colored flowers tend to have pinkish skins (Tony, 2006). Potatoes are mostly cross-pollinated by insects such as bumblebees, which carry pollen from other potato plants, though a substantial amount of self-fertilizing occurs as well. After flowering, potato plants produce small green fruits that resemble green cherry tomatoes, each containing about 300 seeds. Like all parts of the plant except the tubers, the fruit contain the toxic alkaloid solanine and are therefore unsuitable for consumption. All new potato varieties are grown from seeds, also called "true potato seed-**TPS"**or "botanical seed" to distinguish it from seed tubers (Ferdu *et al.,* 2009). New varieties grown from seed can be propagated vegetative by planting tubers, pieces of tubers cut to include at least one or two eyes, or cuttings, a practice used in greenhouses for the production of healthy seed tubers. Plants propagated from tubers are clones of the parent, whereas those propagated from seed produce a range of different varieties (FAO, 2008).

Potato is a short duration vegetable crop as compared to cereals which, can attain in 3-4 months in Ethiopia (Endale *et al.,* 2008). Deciding appropriate date on harvesting time which cover the most important practices to maintain the quality and quantity of potato tuber yield (Ayalew *et al*, 2014). To reduce exposure time, harvest mature tubers as soon as possible and avoid leaving the tubes on the soil surface or on overnight. At harvest, tubers do not always show signs of damage, but may harbor eggs and early instars larvae. When foliage starts to decline, larvae move through stem or drop on the soil and enter the soil through soil cracks to find feed and egg lying on tubers (Rondon *et al.,* 2007).

2.1.1. Potato Harvesting

Potato is a short duration vegetable crop as compared to cereals which, can attain in 3-4 months in Ethiopia (Endale *et al.*, 2008). Deciding appropriate date on harvesting time which cover the

most important practices to maintain the quality and quantity of potato tuber yield (Ayalew *et al*, 2014b). To reduce exposure time, harvest mature tubers as soon as possible and avoid leaving the tubes on the soil surface or on overnight. At harvest, tubers do not always show signs of damage, but may harbor eggs and early instars larvae. *P. operculella* where prefer foliage and tubers for egg laying and feeding. When foliage starts to decline, larvae move through stem or drop on the soil and enter the soil through soil cracks to find feed and egg lying on tubers (Rondon *et al.,* 2007). Borgel *et al.* (1980) reported that the dates of harvesting vary depending on weather condition, storage facility, type varieties used, and the availability of labor. Moreover, small-scale farmers affected more by unavailability of appropriate storage methods and farmers forced to keep seed tubers in the ground for next planting season (Fuglie, K.O. 2007).

2.1.2. Seed Potato Storage System

In Ethiopia, there are two types of potato storage methods: traditional and improved storage methods (DLS). Farmers use different traditional potato storage methods such as leaving the tubers in the soil un-harvested (postponed harvesting), light place in the house, dark place in the house, raised beds and in sacks (Adane *et al*., 2010). These storage methods are very critical in affecting seed quality and yield loss. Hence potatoes that are leaving or unharvest in the field for any length of time and delay harvesting can act as a source of inoculums for disease and insect pests like *p. operculella* (Borgel *et al*., 1980; Endale *et al.*, 2008a; Rondon, S. I. 2010). A study by Tesfaye *et al.* (2008) in Gojam and Gonder, around 50% of potato yields loss by *P. operculella* when the tubers stored in traditional underground storage. Therefore, farmers due to shortage of storage facilities buy seed tubers at high prices during planting and forced farmers to sell their potato at low prices during harvesting. According to Ayalew Tewodros (2014) and Agajie *et al.* (2007) report better quality seed tubers are obtained with storage in DLS than in traditional dark storage, which can substitute alternative temperature - controlled storage system.

2.1.3. Potato Varieties and Seed Systems

Over twenty years later Medhin *et al*. (2001) reported that there is no institution in Ethiopia that multiplies and distributes potato seed tubers. Bogel *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 marketsand 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).

2.2. Potato Production in Ethiopia

Potato was introduced to Ethiopia in 1858 by a German immigrant, Wilhelm Schimper, adoption by Ethiopian farmers occurred very gradually for several decades (Berga *et al.,* 1992). The first available potatoes were probably of a very limited genetic base, hence vulnerable to diseases and pests. Cultivation was limited to potatoes growing voluntarily in fields in the colder highlands until wider adoption of the potato occurred at the end of the nineteenth century in response to a prolonged famine (Medhin *et al.,* 2001). In the 1980's IPM introduced the variety "Cara" to Ethiopia. Cara is still the only European variety being planted in some regions due to its great resistance to blight, robustness and yield potential (IPM, 2015).

Potato is one of the world most important crops and consumed for more than 8,000 years ago. Potato started widely cultivated and expanding around the world in the 16th century (FAO, 2008). 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). 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 Ethiopia, the main potato production season is from June to September which is called the rainy season (Emana and Nigussie, 2011).

Potato (*Solanum tuberosum*) is a valuable crop for smallholder farmers in Ethiopia, serving as both cash and food security crop. It is a nutritionally balanced food crop, which provides a high calorie intake and a substantial amount of vitamins (Brasesco *et al.,* 2019).In Ethiopia, potato can potentially play a great role in improving food security because of its high yielding ability, availability of suitable agro-ecological zones within the country, and the availability of labor for

its production on large areas of land (FAO, 2008). Potato gives the highest amount of energy per unit of land per day among the major arable crops like wheat, rice and maize (International Year of the Potato, 2008). Moreover, potato tubers are rich in vitamin C, a good source of vitamins B1, B2 and B6 and minerals such as potassium, phosphorous and magnesium, and a good source of high quality protein rich in S (Scott *et al*., 2000; International Year of the Potato, 2008). Potato can grow on 70% of the total arable land located in highland areas (from above 1500 to 3200 m asl with annual precipitation of 600 - 1200 mm, where about 90% of the Ethiopian population lives (FAO, 2008).

Kolech *et al*., 2015 result indicated that, in Ethiopia, potato is grown in a wide range of agro-ecological zones, throughout the year using different growing practices and is considered a "hunger breaking crop" because it can be grown and harvested when cereals don't mature for consumption other crops fail. Indeed, potato is the only food crop grown to any large extent in the dry season where rain-fall is erratic and unpredictable in the months of March through May. Ethiopia has the most potential of potato production because of the highlands comprises 70% of the country and home to higher percent of the population (Egata, 2019). Exploiting these production potentials will make the potato crop to play a key role in ensuring national food security (FAO, 2008). It is an important food crop after cereals, inhuman diet in developed as well as in developing countries (Kushwaha *et al*., 2014).

In Ethiopia, potato is among the major root and tuber crops. It is grown on about 0.164 million ha (CSA, 2002) by about 1.3 million smallholder farmers (CSA, 2012). Data over the period 2006-2010 from the Central Statistical Agency (CSA) show that potato covers about 30% of the total area allocated to root and tuber crops and accounts for 28% of total production. It is grown mainly in two seasons: *meher*– long rain season – June to October, and *belg*– short rain season – February to May. Potato is also grown in off-season (October to January). The *meher* and the *belg* seasons vary in the level of disease pressure. There is more diseases pressure in *meher* than in *belg* and the area of production and total yield of potato are larger in *belg* than in *meher*. According to CSA (2002), of the total land cultivated under potato, about 77% is cultivated in *belg.* Two types of potato varieties are grown in Ethiopia: local and improved. The majority of potato growers grow local potato varieties. The local varieties are mostly grown in the *belg*

because of low level of disease incidence in this season and improved varieties are more often grown in the *meher* because of their high level of disease resistance (Lemaga, 2010).

2.3. Ecology of Potato

2.3.1. Climatic requirements

Potato is normally a temperate crop and it requires cool climate. But it is also adapted to wide range of climatic conditions. It grows well in temperatures range 15-250C**.** High day temperatures of 20-250C are good for vegetative growth while temperatures between 15-200C are suitable for tuber formation. Tuber formation stops totally when the temperature exceeds above 300C (FAO, 2006).

Soil temperature is also important for grow and development of potato. Optimum soil temperatures for normal tuber growth are 15 to 18°C. Cool conditions at planting lead to slow emergence of seed tubers which may extend the growing period of potato plant. Early varieties bred for temperate climates require a day length of 15 to 17 hours while the late varieties produce good yields under both long and short day conditions. For tropical climates, varieties which tolerate short days condition are required (FAO, 2013).

2.3.2. Soil requirements

Potato can be grown on any soils which are rich in organic matter. For better yield, the soils should be well drained and aerated. Potatoes grown in light or porous soil require relatively higher amount of fertilizer. Loam or sandy loam soils are most suitable for proper tuber development. Potato is moderately sensitive to soil salinity. The yield of potato decreased with increasing soil salinity (FAO, 2013). Potato prefers slightly acidic soils with the pH values of 5.2-6.4. Potato cannot tolerate alkaline soil. It is grown on ridge or flat seed bed depending on the moisture condition available. For rain fed production in dry conditions, flat planting tends to give higher yields due to soil water conservation measures. Under irrigation condition potato is mainly grown on ridges.

2.4. Potato Production Constraints

The most important constraints responsible for the low yield of potato production in Ethiopia include, poor agronomic practices, shortage of good quality seeds, absence of well adapted varieties, in sufficient and high quality seed potatoes, sufficient storage and marketing facilities, problems of diseases and insect pests (APR, 1979/80; Medhin *et al*., 2001). In Ethiopia different authors identified potato production affected by different insect pests among these: cotton aphids, pepper and potato aphid, green peach aphid, death's head halok moth, cutworms, red ants, potato epilachna, Teff epilachna, Metallic leaf beetle and potato tuber moth (Bayeh and Tadesse 1992; Emana, and Amanuel, 1992; Bayeh *et al.*, 2008), but in Ethiopia *P. operculella* and red ant merit close attention. In Ethiopia, *P. operculella* was recognized as important pests in the warmer areas where potato is grown, but now a day's *P. operculella* has been an important pest in high land in major potato growing areas. Alvarez *et al.* (2005) stated that the damage caused by *P. operculella* is a very severe case of significant economic loss of potato ranging from 50% to 100% under potato storage in the world. Adhanaom *et al*. (1985) reported that, *P. operculella* is the most damaging pest of potato in Ethiopia, where the damage due to this pest could reach up to 91%. It is distributed to other places at the time of seed tuber transportation from one place to another (Bayeh *et al*., 2008; Tekalign Zeleke *et al.,* 2015).

2.5. Major Insect Pests of Potato

The most important constraints responsible for the low yield of potato production in Ethiopia include poor agronomic practices, shortage of good quality seeds, absence of well adapted varieties, in sufficient and high-quality seed potatoes, sufficient storage and marketing facilities, problems of diseases and insect pests (Medhin *et al*., 2001; Bayeh *et al.,* 2008). In Ethiopia, different authors identified potato production affected by different insect pests among these: cotton aphids, pepper and potato aphid, green peach aphid, death's head halok moth, cutworms, red ants, potato epilachna, Teffepilachna, Metallic leaf beetle and potato tuber moth (Bayeh and Tadesse 1992; Emana, and Amanuel, 1992; Bayeh *et al.*, 2008), but in Ethiopia *P. operculella* and red ant merit close attention. Several insect pests and diseases are associated with potatoes in field and storage conditions. Ahad (2003) reported that cutworm (*Agrotis ipsilon*), aphid (*Myzus*

persicae, *Aphis gossypii*), potato tuber worm (*Phthorimaea operculella*) and potato leafhopper (*Empoasca fabae*) may inflict heavy damage to the growing crop.

2.4.1. Potato Tuber Moths

P. operculella is an oligophagous pest (i.e., an insect feeding on a restricted range of food plants) of vegetable crops that belong mainly to the family Solanaceae: potato (*Solanum tuberosum* L.), tomato (*Lycopersicon esculentum* Mill.), and tobacco (*Nicotana tabacum* L.).

P. operculella is one of the major potato pests worldwide (Rondon *et al*., 2007a). It is a host specific pest of solanaceous crops, high adaptability to daily and seasonal changes, high reproductive potential, resistance to some insecticides and high potential to destroy potatoes in storage (Chumakov and Kuznetsova, 2009; Binyam, 2015). Moawad and Ebadah (2007) reported that *P. operculella* causes serious damage to stored potato through its larval tunneling and feeding, which lead to partial or complete rotting by subsequent infection of fungi and bacteria. This insect pest causes significant crop losses in almost all tropical and sub-tropical potato production systems in Central & South America, Asia and Africa (Rolot, 2001). It is zero tolerance for the presence of *P. operculella* larvae in the raw processing product because they are classified as foreign material. Thus, the problem is very critical in affecting seed quality and subsequent performance sprouting of the crop in the field (Endale *et al*., 2008).

The potato tuber moth is a major insect pest of potato affecting potato yield through infestations of leaves, stems, and harvested tubers. Harvested tubers infested by PTM often initiate tuber infestation in stores causing losses of stored tubers of up to 70 % (Raman and Radcliffe, 1992; Kroschel and Schaub, 2013). *P. operculella* attacks potato by mining the leaves and stems and by feeding on the tuber. Mines are the typical symptoms of leaf damage caused by the larvae eating the mesophyll without damaging the upper and lower epidermis. When the foliage dies, the larvae enter the soil through cracks where they may eventually find and feed upon tubers. Larvae enter potato tubers via the eyes and continue to bore or tunnel through the tuber just below the skin. Larval excreta are pushed out through the holes, which can be observed immediately after larvae start their mining activity (Kroschel *et al*., 2020). The potato tuber moth (PTM), *Phthorimaea operculella,* originated in the tropical mountainous regions of South America. Today, it has a worldwide distribution and is considered the most damaging potato pest in the

developing world. It is present in almost all tropical and subtropical regions of the world, in North, Central, and South America, Africa, Asia, Australia, and Europe.

In Ethiopia, *P. operculella* was recognized as important pests in the warmer areas where potato is grown, but now a day's *P. operculella* has been an important pest in high land in major potato growing areas. Alvarez *et al.* (2005) stated that the damage caused by *P. operculella* is a very severe case of significant economic loss of potato ranging from 50% to 100% under potato storage in the world. Adhanaom *et al*. (1985) reported that, *P. operculella* is the most damaging pest of potato in Ethiopia, where the damage due to this pest could reach up to 91%. It is distributed to other places at the time of seed tuber transportation from one place to another (Bayeh *et al*., 2008; Tekalign Zeleke *et al.,* 2015).

P. operculella. Under heavy field infestation, potato foliage can be destroyed, which can result in substantial yield loss of up to 70%. High infestations early in the season can directly affect tuber yield. Strong correlation exists between leaf and consequent tuber infestation, which suggests that reducing *P. operculella* population density during the growing period is key to reducing potato tuber infestation at harvest. Infested tubers are unsuitable not only for human consumption but also for use as seed. Infested tubers produce fewer yields and initiate a fast development of a new field *P. operculella* population (Kroschel and Schaub, 2013).

2.4.2. Aphids

Aphids are extremely polyphagous, being capable of feeding on several hundred-plant species (Blackman and Eastop 2000). The potato aphid is highly adaptable and is currently cosmopolitan in distribution. The potato aphid (*M. euphorbiae*) originated in North America but has spread to the temperate parts of Europe and Asia and is found in all potato growing areas globally (CABI, 2017).

Aphids can damage potato plants directly by feeding on sap, and indirectly by transmitting various viral diseases. *Direct damage*. Continuous sucking of sap by large numbers of aphids considerably weakens and slows plant development (Salazar 1995). *Indirect damage*. The most important damage caused by aphids in potato is virus transmission. Symptoms of virus infestation vary depending on the virus transmitted (Larrain *et al*., 2003).

2.4.3. Cutworms

Cutworms are polyphagous and have been reported as a pest on nearly all vegetable crops and some cereals. It's a pest in potato, maize, alfalfa, clover (*Trifolium* L.), cotton, rice, sorghum, strawberry, sugar beet, and tobacco. Cutworms are larvae of several noctuid moth species which are cosmopolitan. Most widely distributed are the black cutworm (*Agrotis ipsilon*), the variegated cutworm (*Peridroma saucia*) and the turnip moth (*Agrotis segetum*).

The cutworm larvae remain in the soil at the base of the plant during the day. At night, some species cut down the stems of young potato plants, while other species climb the plants and feed on their leaves. Old instar larvae can occasionally tunnel into potato stems disrupting plant growth. Tubers closer to the ground surface may suffer occasional damage. In a single night, single larva can cut down several potato plants.

2.6. Geographical Distribution of Potato Insect Pests

Due its global geographical distribution, potato is affected by a wide range of insect pests. a total of 49 species: nine major species occurring in tropical and subtropical regions; two major species affecting potato in temperate regions; six major and 32 minor species of temperate, subtropical, and tropical regions. Farmers in tropical and subtropical countries must contend with a higher number of pest species, and with some exceptions, a minimum of 2–4 pests often reach pest status requiring the application of control methods (Kroschel *et al*., 2012). Many pests have evolved in the center of potato origin, and farmers in the Andean region are confronted by a higher number of pests than farmers in Africa or Asia. Some species such as the potato tuber moth, *Phthorimaea operculella* (Zeller), and the leafminer fly, *Liriomyza huidobrensis* (Blanchard) have become invasive and occur today as serious pests in many tropical and subtropical regions (CABI, 2017).

2.6. Impacts of Climate Change on Potato Insect Pests

Climate, especially temperature, has a strong and direct influence on the development and growth of insect pest populations. Herbivorous insects—as all other arthropods—are exothermic organisms that cannot internally regulate their own temperature (Orlandini *et al*., 2017). Their

development depends on the temperature to which they are exposed in the environment. A rise in temperature due to climate change may both increase or decrease pest development rates and related crop losses. Hence, an increase in temperature can potentially affect range expansion and outbreaks of many insect pests including pests of potato (Kroschel *et al*., 2020).

Potato production systems of tropical countries are highly susceptible to pest infestations due to often year-round favorable climatic conditions for pest population growth and host plant availability. Even smaller changes in temperature predicted for tropical regions compared to temperate regions will have stronger consequences on pest development due to already higher existing metabolism rates of organisms such as insects (Dillon *et al*., 2010). This does affect not only the general life cycle of an insect pest but also all other biological processes, including feeding rates, plant growth, and activity of biotic antagonist (Quiroz *et al*., 2018).

2.7. Pathogen Transmission

Many insect pests are potential vectors of potato pathogens. This association can be casual with the insect serving as a mechanical vector or providing entry for invasion by pathogens present in the environment. Of greatest importance are instances in which the insect is the principal or sole means of pathogen transmission. Aphid-transmitted viruses probably cause greater economic loss in potato production than all other insect related damage. Some 40 virus species are known to infect potato, and of these, 13 are aphid-transmitted (Salazar, 1996).

2.8. Potato Insect Pest Control Methods

Potatoes are affected by a number of insect pests causing both direct and indirect yield losses. Weekly scouting for caterpillars during the first 30 days after planting; throughout the vegetative phase scouting for whiteflies, aphids, and thrips; and during tuber bulking scouting for millipedes and tuber moths is important for prompt initiation of a better control strategy (Yanggen *et al*., 2004). Potato is attacked by a number of insect pests (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. 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).

To manage the pest, farmers may use family labor to physically collect and kill cutworms from the fields. This should be done in the morning or evening when the temperature is low and pest is actively feeding. This practice could be aided using rice brans placed strategically in the field to attract the worms which are then collected and killed. The crops could also be sprayed continuously with neem leaves or neem seed extract for eco-friendly control (Bayeh *et al.,* 2008; Esmael, 2017).

2.8.1. Cultural control methods

Cultural pest control involves changing or modifying cultivation practices which directly or indirectly reduce the insect pest population. Cultural practices, such as elimination of cull piles and volunteers (sanitation), soil moisture at and after vine clearing, length of time between skin hardening and harvest, rolling or covering hills, crop rotation, etc., were the earliest control measures advocated for reducing PTM (Rondon *et al.,* 2007). Hanafi (1999) indicated that many cultural practices that are used by farmers to improve the yield and quality of potato can also limit the development of PTM and minimize damage to tubers.

Cultural controls means a good practice for the support and reduces *P. operculella* damage to potato tubers and improve the yield and quality of potato (Hanafi, 1998). Weeds and any volunteer plants can act as alternate hosts for *P. operculella*, and should be eliminated from fields and surrounding areas (Rondon *et al.*, 2007; Gill *et al.,* 2014). Moth populations are maintained in plant and tuber debris in the field in the absence of the main crop. Therefore, timely field cleanliness and discard infested tuber seeds are an important preventive measure. Alvarez *et al. (*2005) and Chumakov and Kuznetsova (2009) outlined healthy seed tubers planting and good coverage of potato seeds with soil 1 to 2 inches of which, significantly reduces tuber infestation by *P. operculella*. Cull piles should be destroyed to reduce overwintering stages of *P. operculella*. After harvesting tubers soon transported overnight in the field as to prevent

these potatoes could act as egg laying for *P. operculella* (Raman, 1980; Alvarez *et al.,* 2005; Rondon *et al*., 2007; Anonymous, 2013). Continuous cropping of host plants increases infestation levels, which provide more favorable conditions for the reproduction of *P. operculella* linked with that particular host. Therefore, crop rotation helps to reduce and disturb the population buildup of *P. operculella* in the field and preventing it from attacking the following year's crop (Baldwin Keith R. 2006; Adane *et al.,* 2010). The rotation of crops has proved to be the most cultural control measure against those pests which are mono phagous or restricted feeders, slow breeder and having a longer duration of feeding phase (Shukla, G. S and Upadhyay,V.B. 2007).

2.8.2. Chemical control methods

Chemical pest control has resulted in more than 500 insect species becoming resistant to one or more pesticides and almost without exception; attempts to eradicate insect pests have failed (Van Lenteren, 2005). As far as insecticidal control is concerned, there are many chemicals registered for use. These include systemic granules applied at planting and foliar sprays. The commonly used chemicals have mostly been from the organophosphate and carbamate groups, but newer and less harsh insecticides are steadily replacing these (Anonymous, Undated). Susceptibility of potatoes to the potato tuber moth as well as to important diseases such as the late blight and bacterial wilt attracts large-scale use of chemical pesticides making it the second highest consumer of agricultural pesticides worldwide, after cotton (Das *et al*., 2007). Insecticides remain the chief means of control for potato tuberworm (Alvarez *et al*., 2005).

2.8.3. Biological control methods

Biological control is one of the first assessments for a successful integrated pest management program, following establishment of a monitoring program, should be to determinate the role of natural enemies (Rondon *et al*., 2007). Biological control means the use of parasitoids and predators and the use of microorganisms pathogenic to insect pests. It is the most successful, most cost effective and environmentally safest way of pest management (Van Lenteren, 2005). Rondon *et al.* (2007) pointed out that one of the first assessments for a successful integrated pest management program, following establishment of a monitoring program, should be to determinate the role of natural enemies. Minimal insecticide usage allows numbers of parasitic

wasps and predators to build up. This requires choosing insecticides that preserve natural enemies (Douches *et al*., 2002).

2.8.4. Resistant variety selection

Varietals resistance is the cheapest pest control strategy with various advantages. It is easy to introduce, low cost, safe to the natural enemies, and is compatible with other control measures such as biological, cultural and chemical methods (Panda and Khush, 1995). Varietals selection offers some opportunity to reduce PTM damage (Rondon *et al.*, 2007a). In agreement with this the relative rates of potato tuber damage due to *P. opercullela* were assessed in 30 varieties of potato grown at Alemaya, eastern part of Ethiopia by Sileshi and Teriessa (2001), result indicated that there were significant differences observed amongst genotypes with range of 6%-62% field infestation in tubers (Sileshi and Teriessa, 2001). Varietal differences in susceptibility to PTM damage may be due to differential feeding by larvae or to adult egg-laying preferences (Rondon *et al.,* 2007). This resistance provides an important genetic trait potentially useful for management of PTM in cultivated potatoes (Malakar and Tingey, 2000).

The cultivation of resistant varieties could reduce the chemical treatments and increases the effectiveness of alternative methods of control. It is known that some cultivar trials, such as earliness and deep tuberization can hinder field infestation. But not factor of resistance in the tubers of *s. tubersum* varieties proved efficacious (Arnone *et al*., 1998). Resistant clons were selected from primitive cultivars and wild solanum species are at the International Potato Center of Lima (Peru) and were used as parents in a breeding program giving rise to genotypes with tuber resistance to the Peruvian population of potato tuber moth (PTM) (Ortiz *et al*., 1990).

The uses of resistant varieties are a key component of an integrated pest management (IPM) program for *P. operculella*. Varietal selection and using natural host plant resistance is the first line of defense in the control of *P. operculella* damage (Lagnaoui *et al*., 2000). The cultivation of resistant varieties could reduce the chemical application and increases the effectiveness of alternative control methods (Golizadeh and Esmaeili, 2012). Varietal differences in susceptibility to *P. operculella* damage may be due to differential feeding by larvae or to adult egg - laying preferences. According to (Rondon *et al*., 2007), planting potato in shallow depth setting results more susceptible than varieties that set tubers deep against *P. operculella* infestation in the field.

2.8.5. Integrated pest management (IPM)

Integrated Pest Management is a pest population management system that utilizes all suitable pest control techniques in a compatible manner to reduce pest populations and maintains them at levels below those causing economic injury (Smith and Reynolds, 1966). IPM is the smart approach to managing insect pests because it uses observation, knowledge and thinking instead of the brute force of toxic synthetic insecticide sprays alone. IPM in potatoes is similar to that of other crops: understanding the components and maintaining a balance within an ecosystem and the environment to produce high yields. This implies biological control is a major player while chemical insecticides are utilized as a last resort so that the balance of the agro-ecological system is maintained for as long as possible (FAO, 2008).

Integrated Pest Management is a broad-based approach that integrates a range of practices for economic control of pests with, least possible hazard and environmentally sounds. Before applying IPM program comprehensive information on the life cycles of pests, ecology and plant pest interaction required (Binyam, 2015). It uses all suitable pest control techniques in a compatible manner to reduce pest populations below economic injury levels. In IPM a variety of complementary pest control measures: cultural practice, host resistance varieties, biological control, bot and the last option chemical control which should be both economic control and environmentally sound (Fuglie *et al.,* 1991). IPM in potatoes is similar to that of other crops and there are beneficial species used for biological control that occur in potato crops worldwide (Horne and Page, 2009).

3. MATERIALS AND METHODS

3.1. Descriptions of the Study Area

The study was conducted in two districts of Hadiya Zone, Central Ethiopia namely East and West Badewacho Districts.

East Badewacho district is located in Hadiya Zone, Central Ethiopia. It is 95 Km away from south of Hosanna and 360 Km south of Addis Ababa. Topographically, it is located at an altitude range of 1150-1650 meter above sea level. Geographically, it is located 07 ^{o}90 and 8^{0}15' North latitude and 35^{0} and 40^{0}15' East latitude. The average temperature is 14-30^{0}c with lower temperature fluctuation. According to East Badawacho agricultural statistics information, the production system of the district is mixed type (EBADO, 2019).

West Badewacho district is located in Hadiya zone, Central Ethiopia. It is 60Km from south of Hosanna and 325 Km south of Addis Ababa. Topographically, it is located at an altitude range of 1650-2050 meter above sea level. Geographically, it is located 07^{o}80 and 8^{0}95' North latitude and 45^{0} and 45^{0}' East latitude. The average temperature is 16-27^{0}c with lower temperature fluctuation climatically. According to West Badawacho agricultural statistics information, the production system of the district is mixed type (WBADO, 2019).

Figure 1. Map of Study area (Daniel, 2018).

3.2. Sampling and Sample Size Determination

Hadiaya zone from the central Ethiopia regional estate was purposively selected as the study zone because its potential for potato production. From the zone two districts: East and West Badewacho were purposively selected and surveys were conducted. The districts were known for their potential in potato production. Moreover, they were accessible. From each district, three administrative Kebeles (PAs) were selected based on their seed potato production potential and storage. From these kebeles, a total of 36 households (6 from each kebele) were selected randomly and questionnaire were distributed to them. From the total sample households, 12 households were randomly selected for fields assessment (observation by the researcher). Totally, forty-eight respondents (36 farmers, 6 merchants and 6 Development Agents) were randomly selected from all the study areas. Focal group discussions were made with 18 households (3 from each Kebele) who have good history in potato production (purposive

sampling). Interviews were conducted with Agriculture Beauro Offices, Developmental agents and Merchants (Key informants). Secondary data were also collected from reports of the Ministry offices.

3.3. Data Collection

The study was conducted from November 2022 to June 2023 and data were collected from January and April at field and in the storage. Data on the infestation level of insect pests under field and storage conditions were collected through observations and interview with farmers, merchants and DAs.

3.3. 1. Field observations

Field observations were made at potato harvesting, after mid storage in January and at the time of next planting season in April.

3.3.2. Interviews

Using a questionnaire, individual interviews were conducted in the different study sites as recommended by Munyuli (2011). Forty-eight respondents (36 farmers, 6 merchants and 6 Development Agents) were randomly selected from all the study areas and were interviewed. Data were collected using semi-structured questionnaire to know about the current insect pest infestation on potato in selected areas in relation to seed potato production, management methods and challenges they face in potato production. Interviews were conducted in local languages translation in Hadiya language. Overall, several insect pests known to attack potato were mentioned by farmers in local languages. Within each study site, farmers were randomly selected for individual interviews using the list of local authorities. Respondents were randomly selected from the lists to cover at least 30% of total number of potato growers on the list of local authorities (Munyuli 2011). The household heads were the targeted respondents, although any adult in the household who was familiar with potato production was interviewed if the head of the household was absent. Structured questionnaires were focus on importance of insect pests, knowledge of farmers, merchants and development agent's about infestation of insect pest and management options used to control insect pest of potato.

3.4. Data Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 16.0. All data were summarized using descriptive statistics.

3.5. Ethical Consideration

The selected kebeles were contacted with a formal letter written from the Addis Ababa University and asked for permission to continue the data collection. The study participants (householders') were selected randomly. The study participants were also asked for verbal consent (ethical consideration). Data was collected after their full consent and their confidentiality was kept by not mentioning their names in any communications.

4. RESULTS AND DISCUSSION

4.1. Demographic Characteristics of the Respondents

The current findings revealed that demographic characteristics of respondents were grouped into different age groups, gender, education level and occupational status (Table 1). The total sample size of farmer respondents handled during the study was 48 (14.6% of them were female). This may indicate that the majority of potato producers were male headed household taking part in crop production and management activities in the district. Among the respondents 75% of them were farmers, 16% merchant and 16% development agents. Merchants play crucial role in potato supply chain in the area by facilitating potato transaction through linking producers with retailers and producers with consumers and wholesalers with retailers. As far as age was concerned particularly from 30-50 years old was dominating as the percentage was 68.7%. About 60.4% of the interviewed farmers said that they had no formal education. The present result is in line with Emana *et al*. (2008) who reported farmer's background determines how effective they are in producing crops. However, better educational status has ability to easily understand and interpret the information transferred to them from Development Agents (Getahun *et al.*, 2000).

Table 1. Demographic characteristic of the study participant

Variables		**Frequency**	**Percentage**
Sex	Male	41	85.4
	Female	7	14.6
Age	18-29	7	14.6
	30-50	33	68.7
	Above 50	8	16.7
Grade level	No formal education	29	60.4
	Primary school (1-8)	6	12.5
	Secondary school (9-12)	5	10.4
	Above secondary school	8	16.7
Occupational status	Farmer	36	75
	Business man/Merchant	6	12.5
	Development agent	6	12.5
	Total	48	100

4.2. The purposes for which potatoes are grown

The purposes for which potatoes are grown in the study areas revealed that the highest proportion (62.5%) of farmers grows potatoes for consumption. Only few farmers grow potato for market for seed purpose (Figure 1). Ayalew *et al., (*2014) found that due to lack of improved storage facility, farmers forced to sell their products immediately after harvest in low price, especially in Beso kebele. From field and respondents' observation the seed source is a major factor affecting getting good quality seed tubers like free of insect pests. The results of this study showed that from the farmers who stored seed tubers under traditional storage methods was highly infested by *insect pests* than improved storage facilities.

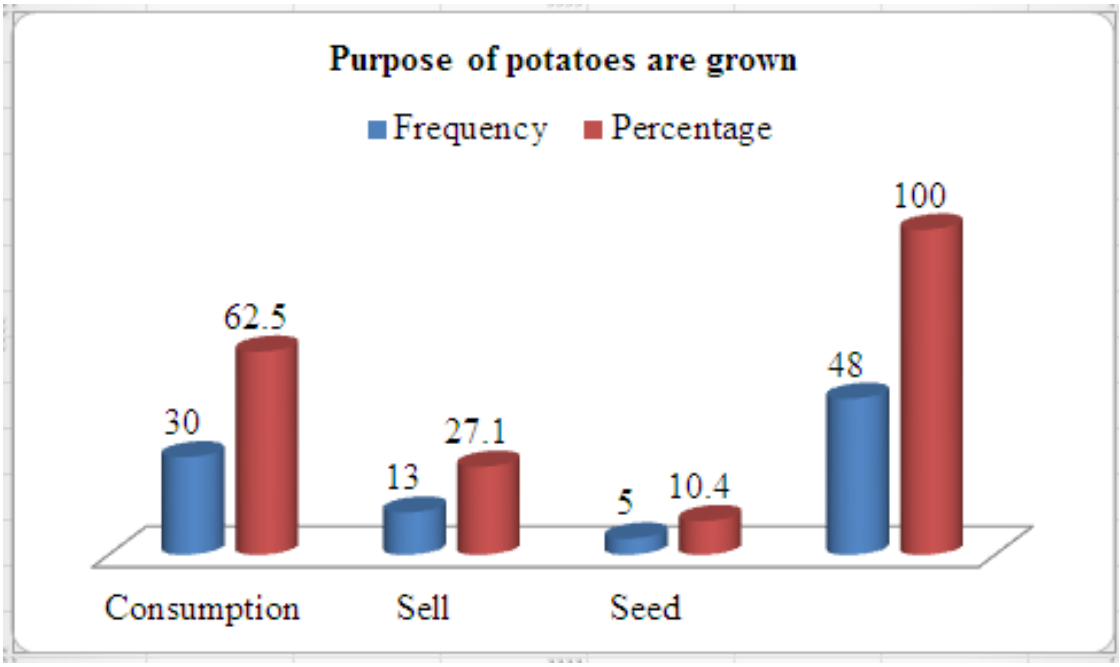

Figure 2: The purposes for which potatoes are grown in the study area

4.3. Source of potato seeds for cultivation

The respondents mentioned that they obtain seeds of potato varieties from different sources for cultivation (Table 3). Among the potato farmers, most of the farmers (50%) used seed potatoes from their own seeds. Other important sources were neighbor's seed, private local seed producer and merchants. Potato seed producers in the highlands of Ethiopia are supported by Ethiopian Institute of Agricultural Research (EIAR) and the Association for Strengthening Agricultural

Research in Eastern and Central Africa (ASARECA) (Medhin *et al.*, 2001). These organizations have formed a monitoring and evaluation body to supervise seed production in Ethiopia, which is recognized by the Ethiopian government.

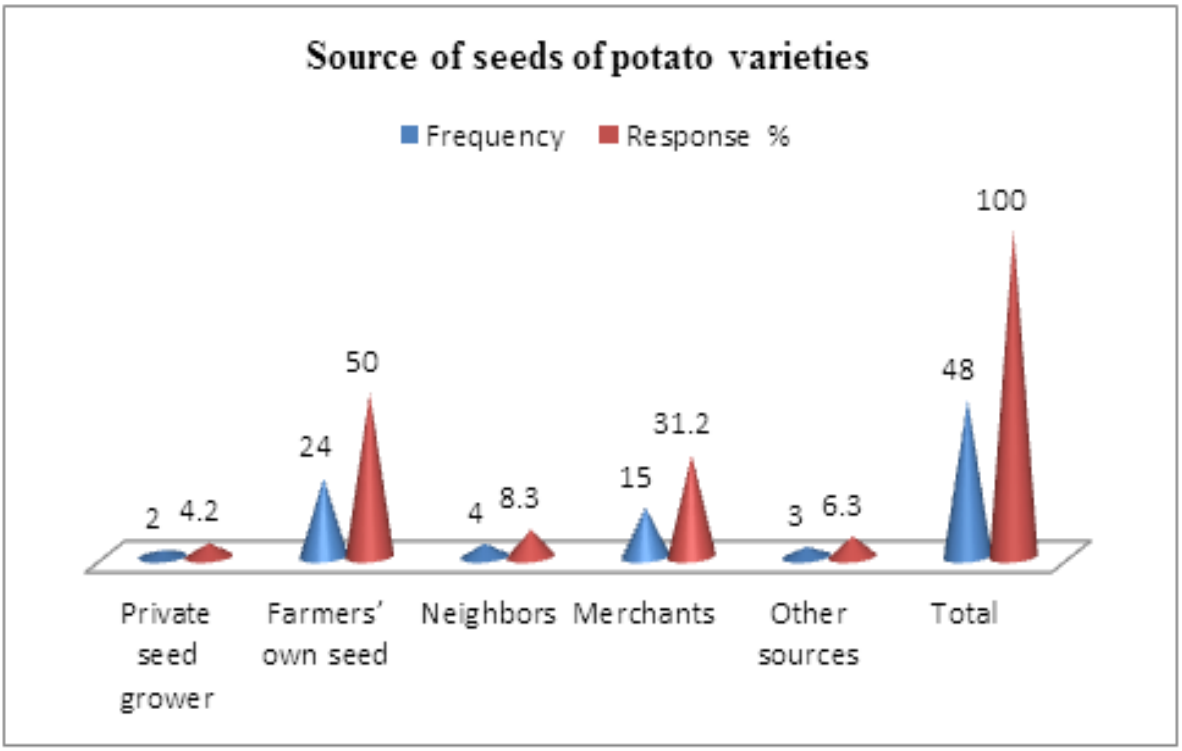

Figure 3: Sources of seed potatoes usually used for cultivation

4.4. Commonly used potato varieties

In response of the respondents (48) in the field study; the maximum (44.5%) of farmers used Gudene variety of potato for cultivation in their field, whereas 30.6% reported that farmers used Local variety. This was followed by Jalene variety (16.6%) and only 8.3% farmers used Belete potato variety to cultivate in their field (Figure 2).From respondent's information and field observation, insect pest infestation on potato tubers were not economically important for most of the study sites surveyed on the main season planted seed tubers. There was infestation observed in West Badewacho district in small number at harvest due to the fact that farmers use a susceptible variety known as Belete. This variety is more susceptible may be due to its big seed size. This result agrees with Lacey *et al*. (2008) who reported that economic damage occurs towards the end of the growing season when tubers were exposed. The majority of the farmers

were growing Gudene potato variety which has small tuber sizes and less infestation as compared to Belete variety. Rondon *et al.* (2007) reported that shallow setting varieties are generally more susceptible to insect pest than varieties that set tubers deeper in the ground.

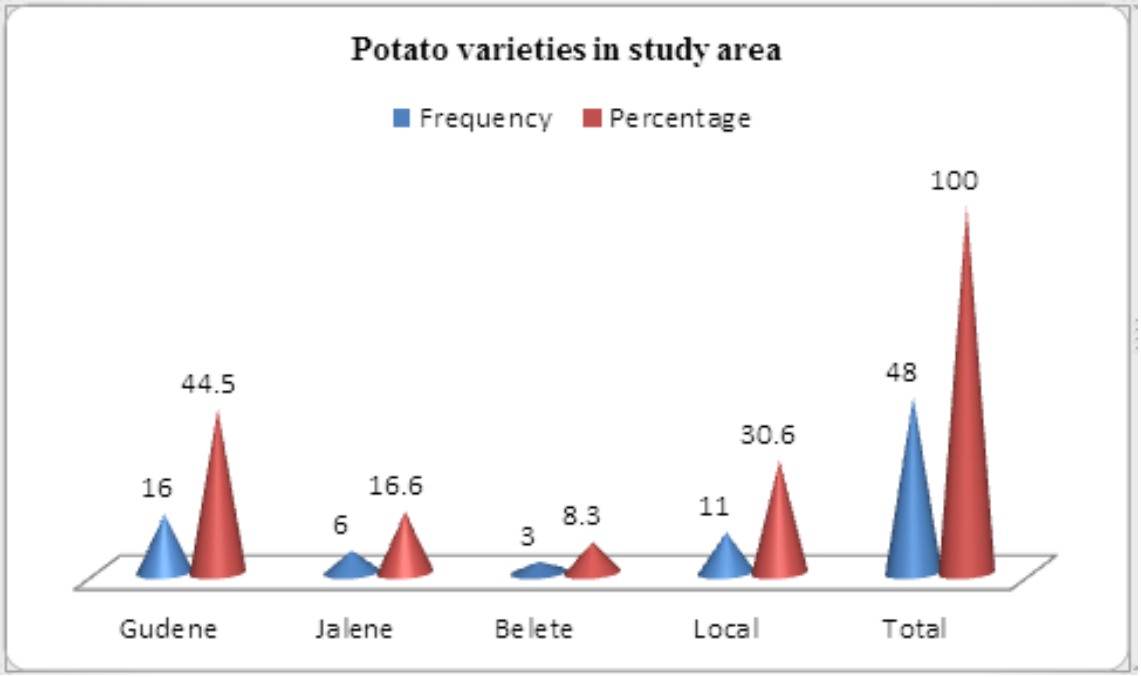

Figure 4: Commonly used potato varieties by farmers in the study area.

4.5. Major Problems in Potato Farming

The most important problems that hindered further potato production in the study district include high input cost (unaffordable price of clean newly released potato seed tubers), pre harvest disease, postharvest disease, problem of storage pests, lack of modern storage, problem of unavailability of transport means (in time and capacity) and shortage of seed supply that for the reason that of high input cost when compared to improved seed demand. The findings indicated that all of the respondents faced problems of pre harvest disease and unavailability of transport means. Majority (62.5%) of the respondents have problems of storage pests and absence of modern storage of potato after harvesting, while 85.4% have a problem of high input costs whereas pre harvest diseases and problem of postharvest spoilage due to ageing and mechanical damage respectively. Postharvest losses generally occur due to improper use of storing and transportation from farm area to storage and markets. Storage losses due to pests such as rodents and the potato tuber moth are most common. Insect pest can Couse severe problem in potato

field (Figure 5). This leads to low market value from production in the season. In addition, data from Farmers' interview showed that the shortage of extension service there is no specialized extension services for potato growers except that potato is considered as just one of the vegetables. Application of knowledge of general agriculture is not sufficient for potato production especially kebele's that far from the district because kebele's that near to the district get advisory service from different supporting organizations. The suppliers of inputs prefer to buy on farm to avoid or minimize the possibility mixing of varieties and to get advantage of packing in bulk in large sacks for later resell it in smaller sacks. However major problem they encounter is that the road is not conducive for use the accessible transportation means (carts). Other means available include back of donkey and horse but not suitable to transport in bulk. This was in line with the study that found means of transportation in Ethiopia varies among producers depending on the amount of area of production but predominately on pack of animals (donkey) (Mulatu et al 2005).

Figure 5: Insect pest infestations on leaves of potato

4.6. Respondents Response on Potato Insect Pests

4.6.1. Occurrence of insect pests of potato

Most of the farmers reported that potato was infested in the field by Potato tuber worm, which was followed by cutworm, red ant and aphid infestation ((Table 2). The potato was attacked by different insect pest in the study area. This result is in line with still remain drawbacks to attain maximum yield of potato (Siddique *et al*., 2015). Farmers also indicated that late coming of the rainfall (prolonged drought) induced high insect pest attacks and high yield loss due to insects, could be observed (Munyuli, 2016). From the respondents interviewed and field observation insect pests were severe problems in the study areas. Therefore, 89.6 % of respondents result revealed that *P. operculella* was problems on the potato production in Hadiya zone. These respondents result agrees with the research results reported by (Bayeh, 2004) *P. operculella* was problem in Welmera and Jeldu before 10 years in potato production.

Table 2: Respondents response on occurrence of insect pests of potato vulnerable, stages, parts of potato plants to insect pests, infestation status and severity in field and storage condition

No	Insect pest	Occurrence of Insect Pest (N=48)		Response on pest status (%)		Response on infestation severity (%)		
		Frequency	Response %	Major pest	Minor pest	Low	Moderate	High
1	Potato tuber moth	43	89.6	83.7	16.3	16.3	23.3	60.4
2	Aphid	24	50	33.3	66.7	62.5	20.8	16.7
3	Cut worm	38	79.2	73.7	26.3	10.6	71	18.4
5	Red ant	27	56.3	25.9	74.1	55.6	29.6	14.8

4.6.2. Infestation status of insect pests of potato

Out of 48 respondents, the major insect pest of potato in field condition was potato tuber worm, followed by cut worm. On the other hand, the minor insect pests of potato were red ant and aphid (Table 2). These species of insect pest is now present in all potato growing districts. This result is

agreed with (Rondon, 2010) in many regions potato tuber moth is the insect responsible for the largest potato losses.

4.6.3. Infestation severity of potato crops by insect pests

Most of the respondents expressed that potato tuber moth caused damage potatoes with high infestation intensity. Furthermore, cutworm caused damage potato plants with moderate to high infestation severity. On the other hand, red ant and aphid caused damage potato plants with low infestation severity. From field and respondents' observation the seed source is a major factor affecting getting good quality seed tubers like free of insect pests. The results of this study showed that from the farmers who stored seed tubers under traditional storage methods was highly infested by insect pest than improved storage facilities. Therefore, due to lack of improved storage facility, farmers forced to sell their products immediately after harvest in low price and this result is similar to (Ayalew *et al.*, 2014).

The field observation and interview in the study areas indicated that low potato tuber damage by insect pest (Figure 6) this could be due to continuous rainfall up to mid-October, which minimized soil cracking and prevent larvae entry to the ground for damage tubers. Potato grew in the main season in the study areas faces a low temperature which, delay developmental period of insect pest that has a negative impact on its density.

Figure 6: Insect pest observation at field condition (Captured by researcher, April 2023)

4.7. Farmers' pest management practices

Most (75%) of them reported that they applied insecticides in potato fields to control insect pests of potato. This control option was followed by application cultural methods particularly for controlling cutworm (Figure 4). For short-term storage before cooking, temperatures of about 7 to 10°C (45 to 50°F) are preferred (Kohli, 2009). Farmers indicate that potato tuber moth, cutworms, red ants and aphids were the species causing yield loss, especially when no pesticide is applied. The confusion of insect pest names by farmers, or the damage caused, is reported elsewhere in Africa (Sinzogan*et al*., 2004). A list of local names of different potato pest species can be found in the literature for the region (Munyuli 2016). The description of local names of insect pests is expected to help entomologists, extension workers, and others who work with rural communities to better understand pest occurrence and appreciate local knowledge (Midega*et al*., 2012). The most common argument given by farmers for massive application of pesticides was that pesticides were reliable control methods for pests. Farmers indicated that they were experimenting different pesticide effects in their gardens because they lacked technical advice (extension service) in their villages. Farmers reported that yield losses were recorded in the absence of pesticide application across all study sites (Figure 7). Farmers indicated that it was

not possible to grown potato without applying pesticides. High yield losses were reported by farmers when potato was grown without pesticides. Farmers also indicated that late coming of the rainfall (prolonged drought) induced high insect pest attacks and high yield loss due to insects, could be observed (Munyuli, 2016).

Most of farmers 36 (75%) were use chemical to control potato insect pests from their crop grown followed by cultural mechanism 5 (10.42%) while 4 (8.33%) of respondents were use biological method to control key potato insect pest (Table 3). In the other hand, 3 (6.25%) of respondents were use early cropping method for their potato grown on field. This finding is in line with the investigation of (Tefera *et al.,* 2011) to control insect pest various control mechanisms have been evaluated including chemical, cultural, host plant resistance and biological in different parts of Africa.

Table 3: Potato Insect pest control methods under practice in Hadiya zone on potato based on questionnaire

Control methods	No. of respondents	Percentage (%)
Chemical use	36	75
Cultural use	5	10.42
Biological use	4	8.33
Early cropping	3	6.25

Potato pest control methods under practice in Hadiya zone mainly use chemicals based on interview. Table 4 shows 15(31.25%) of respondents were agreed and 28(53.33%) of respondents were strongly agreed. However, 3(6.25%) of respondents were disagreed with the given idea. Moreover, 2(4.17%) of the respondents were strongly disagreed. This implies that the most respondents were agreed and strongly agreed with the idea in the study area.

Table 4: Potato pest control methods under in Hadiya zone mainly use chemical methods based on interview.

Response	Frequency	Percentage
Agree	15	31.25
Strongly agree	28	58.33
Disagree	3	6.25
Strongly disagree	2	4.17
Total	48	100

Commonly used potato varieties by farmers in the study area based on focal group discussion. Table5.Shows 8(44.44%) of focal group participants were agreed that most farmers grown Gudene and 5(27.78%) were grown local potato. Moreover, 3(16.67%) of farmers were grown Jalene and 2(11.11%) of farmers were grown Belete. This implied that in the study area most farmers grown Gudene and Local potato.

Table 5: Commonly used potato varieties by farmers in the study area based on focus group discussion.

Item	Frequency	Percentage
Gudene	8	44.44
Local potato	5	27.78
Jalene	3	16.67
Belete	2	11.11
Total	18	100

Figure 7: Farmers' pest management practices in study area (Captured by researcher, May, 2023)

5. CONCLUSION AND RECOMMENDATION

Potatoes are attacked by numerous pests in the farmer fields with high potential to cause low to high yield losses. The direct and indirect nature of impacts and the ability to attack at the fields and stores make potato tuber moth the most important pest in the region. Insect pest is not an important pest at the study areas under field condition on rain fed potato production but, infestation that existed under field condition on Belete potato varieties. Insect pest is an economic pest under storage condition at the study sites though the infestation level varies with the type of storage structure and methods. In all type of storage methods, insect pest infestation increases with the increase of storage period. Farmers have little or no knowledge of insect pest damage symptom and its importance in the potato production. Surprisingly, most of the farmers only apply pesticides to control the pests infesting field. It can be understood that people are still unaware of the risk hazard of chemical application. So, government should take proper steps to help out this problem.

Therefore, based on above conclusive remarks the following recommendations are forwarded:

- ✓ In order to reduced insect pest spread and development farmers should adopt good agronomic practice, seed store in proper storage methods and use improved varieties.
- ✓ Awareness creation and training should be given to farmers and developmental agents in order to identify damage symptoms of insect pest.
- ✓ Integrated Pest Management of on stored potato tubers should be given research priorities.
- ✓ Knowledge of the impact, dynamics and ecology of the pest is essential before effective control strategies can be developed.
- ✓ Survey should concentrate on quantitative observation to map the relative distribution and importance of major migratory and non-migratory insect pest in different agro-ecological zones.

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7. APPENDICES

ADDIS ABABA UNIVERSITY

FACULTY OF NATURAL AND COMPUTATIONAL SCIENCES

GRADUATE STUDIES PROGRAM DEPARTMENT OF ZOOLOGICAL SCIENCES

Dear respondents! This questionnaire is prepared to determine the types of insect pest of potato grown in HadiyaZone, Central Ethiopia.

- ✓ **The questionnaire has three parts.** The first parts is the back ground of the respondents and the second and third part is the major points to identify the insect's pest on stored and field potato, to find out the insect's pest management practice that damage on potato and the insects pest management techniques used by local communities in study area.

Therefore, you are expected to provide your response correctly as your response has a great value on the finding of this study. So feel free and answer it.

Thanks you a lot for your cooperation in advance.

- ❖ Respondent_____
- ❖ District _____ Village_____ Kebele _____
- ❖ Interviewer _____Location _____
- ❖ The interview takes place on the farm and in the house of selected interviewee in individual bases.
- ❖ **The type of questionnaires**
  - Multiple choice
  - Open end

Part I. Socio-Demographic Profile

1. Sex: A) Male B) Female
2. Age: A) 18-29 B) 30-50 C) Above 50
3. Educational status A) Illiberal (0) B) Primary school (1-8)
   C) Junior secondary school (9-10) D) senior secondary school (11-12)
4. Occupational status:- A) Farmer B) Business man C) Development agent D) Others-----

Part II. Typical production system to grow potato on your farm

5. For what purpose can the farmers cultivate the potato?

   A. Consumption B. Source animal feed C. Commercial use D. Others…….

12. What type of potato varieties planted in your area?

    A. Gudene B) Belete C) Jalene

13. What cropping pattern do you follow?

    A. Potato-Fallow B) Potato-potato C) Potato- other vegetable D) Potato-Other crops

14. why you select the cropping patter_____

15. Typical time of potato planting range

    A. April B)May C) June

16. Typical time of potato harvest range

    A) September B) October C) November D) October - January E) October - March

Part III. Farmers' knowledge on potato insect pest infestation both at field and storage conditions

17. What pest(s), if any, did you face in your potato field in last year cropping season? _____

18. Specify the pests, if any, caused the biggest damage to your potato crop last cropping season?_____

19. What is your second most important pest problem? _____

20. How did you control these major pests last season?

    i. Apply pesticides B) Cultural control method

    ii. Biological control D) Non E) Other (specify) _____

21. Do you have the knowledge on the damage potential of insect pest?

    a. Yes B) No

22. Why is necessary using any control mechanism for insect pest_____

23. How important is insect pestin your village?

    a. Serious problems B) Low problem C) Before two years

    b. No problems

24. When would insect pest occur in your surrounding (Specify month etc.)

A. Beginning of September B) October - April C) None

25. In which temperature zones does insect pest occur?

A. Lowland B) Mid-attitude C) Highland

26. Knowledge on insect pest occurs in field & storage.

A.YesB) No

27. Can you distinguish the damage stage of insect pest and can you identify insect pestlarva from another? How? _____

28. Tuber-feeding insects cause severe damage to the seed potato crop.

A. Agree B) Disagree C) No opinion

Part IV. Seed potato storage methods and sources

29. Which types of seed potato tuber storage method used?

A. Diffuse light store B) Dark store C) in the field, not harvested D) The dark place in the house E) Light place in the house F) Underground pit G) Potato in the bags H) Put warm place in the house I) Cover with crop residues G) other methods (specify)

30. Which storage methods are best to prevent insect pest infestation on the seed tuber? _____

31. What is your source of seed potato?

A. Private seed grower B) Ministry of Agriculture C) Own D) Neighbor E) Research center F) other (specify) ___

32. Of which the above source of seed potato provide free from insect pest?

A. Private seed grower B) Ministry of Agriculture C) Own D) Neighbor E) Research center F) other (specify) ___

33. What is the consequence of storing infested tubers without proper precautions? _____

34. What is your suggestion concerning potato production in this area.

A) High change B) Medium change C) No change

35. List major insect pest of potato and its severity?

36. List minor insect pest of potato and its severity?