INTEGRATED MANAGEMENT OF FIELD PEA (*Pisum sativum* L.) POWDERY MILDEW (*Erysiphe polygoni)* DISEASE IN NORTH SHOA ADMINISTRATIVE ZONE, AMHARA REGION, ETHIOPIA

MSc. Thesis Research Report

Belihu Haileye Woldeyohannis

(BSc in Plant Science)

June, 2021

Debre Berhan, Ethiopia

INTEGRATED MANAGEMENT OF FIELD PEA (*Pisum sativum* L.) POWDERY MILDEW (*Erysiphe polygoni)* DISEASE IN NORTH SHOA ADMINISTRATIVE ZONE, AMHARA REGION, ETHIOPIA

Debre Berhan University, College of Agriculture and Natural Resource Sciences, School of Graduate Studies, Department of Plant Science

In Partial Fulfillment of the Requirements for the Degree of

Master of Agriculture in Plant Protection

By

Belihu Haileye Woldeyohannis

(BSc in Plant Science)

Major Advisor: Estifanos Tsegaye (PhD)

Co-Advisor: Habtamu Kefelegne (MSc)

June, 2021

Debre Berhan, Ethiopia

Date: 29/06/2021

To: Department of plant sciences

Subject: Testimonial letter

This is to write testimonial letter in reference to Mr. Belihu Haileye Woldeyohannis who has conducted his MSc thesis research entitled **"Integrated management of field pea (*Pisum sativum)* powdery mildew (*Erysiphe polygoni*) Disease in North Shoa Administrative zone, Amhara Region Ethiopia"** has successfully defended his MSc thesis in (26/05/2021). I am a member of the advisory committee of his MSc thesis research, I went through the final thesis document and I found that the final document has incorporated the comment, suggestion and correction given by the board of examiner. He has prepared the thesis for final submission as to the standard, as per the CGS guidelines and to the satisfaction of me. Therefore, I kindly request the CGC to facilitate the final approval of Mr. Belihu Haileye MSc thesis and submission as final document.

Kind regards,

Negash Hailu (PhD)

CC:

Mr. Belihu Haileye

DEBRE BERHAN UNIVERSITY

EXAMINERS' APPROVAL SHEET – I

(Submission Sheet-1)

This is to certify that the thesis entitled: **"Integrated management of field pea (*Pisum sativum)* powdery mildew (*Erysiphe polygoni*) Disease in North Shoa Administrative zone, Amhara Region Ethiopia"** submitted in partial fulfillment of the requirements for the degree of Masters of Science with specialization in plant protection of the Graduate Program of the plant science, College of Agriculture and Natural Resource Sciences, Debre Berhan University and is a record of original research carried out by Mr Belihu Haileye Woldeyohannis, I.D: DBUPGR/165/2010, under our supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it to be accepted as fulfilling the thesis requirements.

______________________	________________	__________
Name of Major Advisor	Signature	Date
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Name of Co-Advisor	Signature	Date

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EXAMINERS' APPROVAL SHEET – I

(Submission Sheet-2)

We, the undersigned members of the Boarded of the Examiners of the final open defense by Belihu Haileye Woldeyohannis have read and evaluated his thesis entitled **"Integrated management of field pea (*Pisum sativum)* powdery mildew (*Erysiphe polygoni*) Disease in North Shoa Administrative zone**, **Amhara Region Ethiopia"**, and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of **Master of Science** in Agriculture, Plant science with specialization in **plant protection**.

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Dean, College of Graduate Studies (CGS)	Signature	Date

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Stamp of CGS Date_________

DEBRE BERHAN UNIVERSITY

College of Agriculture and Natural Resource Science

Department of Plant Science

FINAL THESIS APPROVAL FORM

(Submission Sheet-3)

As members of the board of Examiners of the final Masters open defense, we certify that we have read and evaluated the thesis prepared by **Belihu Haileye** under the title **"Integrated Management of Field Pea (*Pisum sativum)* Powdery Mildew (*Erysiphe polygoni*) Disease in North Shoa Administrative Zone**, **Amhara Region Ethiopia"**, and recommend that it be accepted as fulfilling the thesis requirements for the degree of **Master of Science** in Plant science with specialization in **plant protection**.

______________________	____________	__________
Name of Internal Examiner	Signature	Date
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Name of External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the CGS through the DGC of the candidate's department.

______________________	____________	__________
DGC	Signature	Date

Certification of the final Thesis

I hereby certify that all the corrections and recommendation suggested by the Board of Examiners are incorporated in to the final Thesis **"Integrated Management of Field Pea (*Pisum sativum)* Powdery Mildew (*Erysiphe polygoni*) Disease in North Shoa Administrative Zone**, **Amhara Region Ethiopia"** by **Belihu Haileye.**

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DGC	Signature	Date

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DEDICATION

This manuscript work is dedicated to Ethiopian's citizens who lost their life with pandemic corona virus (Covid-19) during my research time that makes interact on this thesis writing and this is to remind as memorial.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my genuine work, and that all sources of materials used for this thesis have been deeply acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Master of Science (MSc) in Plant Protection at Debre Berhan University and it is deposited at the University library to be made available for users under the rule of the library. 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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Name: Belihu Haileye Woldeyohannis **Signature**: ---------------------

Place: Debre Berhan University, Debre Berhan

Date of Submission: -----------------------------------

BIBLOGRAPHY

The author Belihu was born from his father Haileye Woldeyohannis and his mother Kelemua Estifo in North Shoa Zone Kewot District at Tabor *Kebele* in Amhara Regional State, Ethiopia, on December18, 1989 GC. When his age reached for school, he attended the elementary classes from 1994. – 1997 at Adokea Elementary School and from 1998 - 2001. Junior class he attended at Mezezo primary and secondary school. Finally, he attended his secondary education at Debresina Preparatory School from 2002 to 2003. After successful completion of his high school education, he joined Mertule Mariam Agricultural, Technical, Vocational and Educational Training (MTVET) College in 2005 to pursue higher education and graduated with Diploma in Plant Science in 2007. After graduation, he was employed at Ankober District Agricultural office as Development Agent on four *kebeles* and irrigation crop production expert at district level from 2008. – 2016. Then, he joined Debre Brehan Cluster Occupational Competence, Assessment and Certification Center (Db COCACC) as Agricultural Occupations Assessment tools preparation expert from 20017– 2021. After serving for ten years and two months, he joined Debre Berhan University School of Graduate Studies to pursue his MSc study in Plant Protection.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
ATVET	Agricultural Technical and Vocational Education and Training
AUDPC	Area under Disease Progress Curve
CSA	Central Statistical Agency
C V	Coefficient of variation
DAS	Days after flowering
E.C	Emulsified concentrate
EIAR	Ethiopian institute of agricultural research
GTP	Growth and Transformation Plan
IFPRI	International Food Policy Research Institute
LSD	Least Significant Difference
M.a.s.l	Metter above sea level
MOA	Ministry of Ethiopian Agriculture
MoARD	Ministry of Agriculture and Rural development
PDI	Percent of disease incidence
PSI	Percentage severity index
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
USA	United States of America
USD	United states dollar
WP	Wettable Powder

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By Belihu Haileye Woldeyohannis (BSc)

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ABSTRACT

Field pea with other food legumes covers about 11.54% of the total 1.3 million hectares of crop areas in Ethiopia and is the 3rd most important stable food legume among the highland pulses in rural Ethiopia. Field Pea powdery mildew affects the field pea production in the highland areas of Ethiopia and managing of it relies on planting resistant cultivars and applying fungicides. The general objective of this study was to determine the effect of integrated management of field pea powdery mildew, through host resistance and fungicide applications, on disease epidemics, yield and yield components. The experiment was conducted at ***Debre Brehan University Farm land*** *and at* ***Tare Maber District Debre Meaza Administration Farmers Training Center*** *farm land during the 2019 main season. The experiment consisted of 16 treatments, viz. four field pea varieties combined with three fungicides and control; in factorial arrangement. The experiment was laid out as randomized complete block design (RCBD) with three replications. The highest (46.19 qt/ha) grain yield was recorded from the Burkitu and Adi (46.08) varieties; whereas the lowest (36.51) grain yield per hectare were recorded from the local variety and improved varieties had shown significance difference over local varieties. Out of four entries, Burkitu and Adi varieties showed moderately resistant. Because of the per cent disease infection values of Burkitu (19%) and Adi (19.5%) are grouped under 10.1-25%_based on 0-5 scale of powdery mildew disease scoring. On the other hand, Bursa showed moderately susceptible and Local var. showed susceptible reaction to powdery mildew. Because the per cent disease infection values of Bursa (49.5%) and Local var. (59.5) are grouped under the scale 25.1-50% and 50.1-75 %, respectively. The highest (49.39) grain yield per hectare was recorded from the Deficonazole25% EC spray; whereas the lowest (34.07) grain yield per hectare was recorded on untreated treatments. Application of fungicide also has significant reduction in per cent disease severity with maximum reduction in Deficonazol25% (59.88%) and Tridemifon25% (52.03%). The maximum (ETB-114,272.6 ha^{-1}) net benefit also obtained from the Deficonazol25% EC fungicide. The minimum (79,723.8 ETB ha$^{-1)}$ net benefit indicated from the control plot with the minimum (0%) of marginal rate of return. Thus Deficonazole25%EC and Triadimefon25% WP spray were recommended as they gave the best protection against Powdery mildew.*

Keywords*: AUDPC, disease progress rate, Erysiphe polygoni, field pea, severity, yield loss*

1. INTRODUCTION

1.1. Background of the study

Field Pea (*Pisum sativum* L.) is an annual cool-season food legume that grows worldwide Teshome E, Tegegn A (2017). In Ethiopia, it is among the major food legume crops produced ranking third in terms of area of production and yield next to Faba bean and chick pea CSA(2008). It has a great economic merit in the livelihood of the agricultural societies of the country. It contains high protein content, favourable amino acids composition and low trypsin inhibitor levels and there by supply the essential nutrients to various age groups (Aysh *et al*., 2013). In Ethiopia, more than 15 cultivars of field pea, with superior yield potentials, seed size and seed colour and disease resistance have been released for different agro-ecological conditions (MoARD, 2008). Pea occupies a position of considerable importance because of its palatability in the form of vegetable curry along with other vegetables and also widely used as pulses in daily diet. Field pea with other food legumes covers about 11.54% of the total 1.3 million hectares of crop areas in Ethiopia and is the 3rd most important stable food legume among the highland pulses in rural Ethiopia (Basaiwala P, 2006). It also plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen and good source of cash to farmers and foreign currency to the country (Blen, 2017). It is also the major food legumes with a valuable and cheap source of protein having essential amino acids (23 to 25%) that have high nutritional values for resource poor households (Nawab *et al*., 2009).

Field Pea seed is also a source of vitamins A, B, C and contains 35 - 40% starch, 4 - 7% fiber and relatively high levels of lysine. This makes it an appropriate dietary complement to cereals (Dhama *et al*., 2010) addition to their ability to fix atmospheric N, Field Peas enhance soil structure, and provide breaks for disease control which means they have an important role in modern agricultural systems (Martin *et al*., 2008). Generally, it is a crop of manifold merits in the economic lives of the farming communities of high lands of Ethiopia. It is a rich source of protein (25%), carbohydrate (12%), vitamins A and C, calcium and phosphorus, apart from having a small quantity of iron. Peas being very rich in proteins are valuable for vegetable purposes. Even though the above facts clearly show the important role the crop plays in the country's agriculture, its average seed yield has remained very low in the highlands of Bale, Ethiopia (Benti, 2014). The crop has important ecological and economically advantages in the highlands of Ethiopia, as it plays a significant role in soil fertility restoration and also serves as a break crop suitable for rotation to minimize the negative impact of cereal based mono-cropping (Angaw and Asnakew, 1994). It is also used as a source of income for the farmers and foreign currency for the country (Girma, 2003).

Having all these multiple benefits in the economic lives of the farming communities, however, the average yield of the crop is only 1.24 tonnes ha^{-1} in Ethiopia which is far below the worldwide average yield of 1.7 tonnes ha^{-1} (Petr *et al*., 2012). Lack of improved high yielder varieties resistance to diseases, insects and abiotic calamities for specific location with appropriate agronomic recommendations can be cited as a major reason for this low productivity. The richness of legumes in N and P makes them attractive for insect pests and diseases (Sinclair and Vadez, 2012). From the total pulse crops in Ethiopia, field pea covers 212,530.56 ha of land with the total production of 348,144.631 tons and has the average yield of 1.638 tons (CSA, 2017). In Amhara region, field pea accounts 75,895.19 ha of land and the total production of 114,929.808 tons with the productivity of 1.514 tons per hectare (CSA, 2017). According to (CSA, 2017) in North Showa, there are 72,775 holders who produce field pea and the total area accounts 10,316.29 ha. The total production of the crop is 15,156.628 tons with the average productivity of 1.469 tons per hectare.

The powdery mildew fungi belong to the order Erysiphales and to its single family Erysiphaceae and sub division Ascomycotina. The Erysiphales cause a group of plant diseases commonly known as powdery mildews, so-called due to the enormous number of conidia produced on the surface of the host. The sexual stage of fungi in this order is a closed fruiting body called a cleistothecium. An obligate parasite, its development depends on the photosynthetic status of the host; this pathogen cannot develop on photo-synthetically inactive tissues (Caver and Jones 1988). *Powdery mildew caused by the obligate biotrophic fungus Erysiphe polygoni DC is an airborne disease of worldwide distribution, being particularly important in climates with warm dry days and cool nights* (Smith *et al*. 1996). Powdery mildew is one of the largest and the most important group affecting all parts of the plant of field pea (Nigussie *et al*., 2008). The disease can cause 25–50% yield losses (Warkentin *et al*. 1996), reducing total yield biomass, number of pods per plant, number of seeds per pod, plant height and number of nodes (Gritton and Ebert 1975). Severe pod infection leads to seed discoloration and downgrading of seed quality. It can also damage quality of processing pea giving tainted and bitter characteristics. Conidias and fungal debris from heavily infected crops can cause breathing and allergy problems for machinery operators. Powdery mildew is particularly damaging in late sowings or in late maturing varieties. The earlier the disease occurs the more severe the damage. Powdery mildew affects all green parts of pea plants. The first symptoms are small, diffuse spots on leaflets and stipules, usually first appearing on the lowest part of the plant. These lesions grow and became white to pale grey powdery areas that later coalesce and completely cover plant surfaces (Falloon and Viljanen Rollinson 2001). Current powdery mildew control methods include early planting, the use of fungicides and of resistant cultivars. According to (Nisar *et al*., 2006) Powdery mildew disease affects the yield potential, causing 86% loss in Field Pea germplasm growing in different parts of the world. Field pea yield reduction has been reported by powdery mildew disease in the mid-altitudes under moderate severity reaches 20-30%. 21.09% of yield losses have been reported due to powdery mildew severity on local field pea cultivar from plot without fungicide application at Sinana South Eastern Ethiopia (Teshome E and Tegegn A, 2017).

1.2. Statement of the problem

The most significant constraints facing pea production in Ethiopia include Powdery mildew, root rot, and lack of improved seed. Therefore, use of alternatives including using different varieties, bio-pesticides and different fungicides are essential to grow healthy pea crops. On the other hand in Ethiopian condition, farmers have low attention to use commercial fungicides and to identify resistant or tolerant varieties to manage powdery mildew of pea crops to enhance the production and productivity of field pea. So, in and around Debre Berhan area, research or studies should be conducted with the application of fungicides and use of resistance varieties have to be giving emphasis.

In a crop badly affected by powdery mildew, the reduction in number of pod per plant is estimated to be 28.6% (Rathi and Tripathi, 1994). The disease also reduces quality of harvested green pea crops, adversely affecting tender meter values, flavor and appearance of peas for canning or freezing (Gritton and Ebert, 1975). The significance of the study is to reduce the loss of field pea production due to powdery mildew by using the appropriate fungicide application in combinations of four varieties of field pea for the management of powdery mildew of pea. Therefore, the present study was conducted at Basona Warana

(Debre Brehan University) and Tar Maber (Debre Meaza *Kebele*) Districts in 2019 main or rainy cropping production season with the following objectives:-

1.3. Objectives

1.3.1. General objective

The general objective of this study was to contribute in increasing the yield of Field Pea by managing the Field Pea powdery mildew.

1.3.2. Specific objectives:

To determine the most effective fungicides with variety combination against field pea powdery mildew in the study area.

To evaluate the cost-benefit of the alternate fungicides application of Field Pea varieties in the management of field pea powdery mildew.

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2. LITERATURE REVIEW

2.1. Origin and domestication of field pea

Legumes constitute a critical component of the agricultural system in Ethiopia about 12 legume crops are grown in the country. Of these, faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), lentil (*Lens cultinaris* Medik.), grass pea (*Lathyrus sativus* L.), fenugreek (*Trigonella foenum-graecum* L.) and lupine (*Lupinus albus* L.) are categorized as highland legume crops and grown in the cooler highlands. On the other hand, haricot bean (*Phaseolus vulgaris* L.), soya bean (*Glycine max* L.), cowpea (*Vigna unguiculata* L.), pigeon pea (*Cajanus cajan* L.) and mung beans (*Vigna radiata* L.) are categorized as lowland legume crops and predominantly grown in the warmer and low land parts of Ethiopia (Getachew, 2019). That means vegetable pea belongs to the family (Fabaceae) Leguminosae "*Pisum sativum* L." sub species "Hortense" originated from common field pea. *Pisum sativum* sub species "arvense" is considered to be native of Ethiopia, the Mediterranean and Central Asia. It has chromosome number 2n=14 (Das and Kalloo., 1970). *Pisum sativum* comprises both the wild species (*P. fulvum* and *P. eratius*) and cultivated species (*P. abyssinicum*) originated from the Mediterranean region, primarily in the Middle East (Ellis *et al*., 2011). However, the exact centre of its diversity is not known yet due to significant change in the areas of origin and loss of passport data of the early accessions (Petr *et al*., 2012).

2.2. Botanical description of field pea

According to Inga, H. & Sue E. (1969) in volume three of flora of Ethiopia considers, field pea (*Pisum sativum*) is an herb about 2 m long plant. Its stipules are larger than the leaflets, up to 10 cm long. Racemes are 1-2 (1-3) flowered. Corolla is 15- 35 mm long and it has white to purple. Its pod is 3.5-9.5cm long and 1-1.8 cm wide, by containing 2-9 seeds. The seeds are 5-8 mm in diameter and it can be small, smooth or wrinkled, and globose or angled. Vines can be up to 9 ft long, however modern cultivars have shorter vines, about 2 ft long. The stem is hollow, and the taller cultivars cannot climb without support (Elzebroek and Wind, 2008). Inflorescences occur in the leaf axils, and consist of racemes with one to four flowers. Flowers have five green fused sepals and five white, purple or pink petals of different sizes. The top petal is called the „standard", the two small petals in the middle are fused together and called the „keel" (because of their boat-like appearance), and the bottom two petals taper toward the base and are called the „wings" (Elzebroek and Wind, 2008). Within the keel there are ten stamens; nine form a tube that surrounds the pistil, and there is one loose stamen. The ovary contains up to 15 ovules, and the fruit is a closed pod, 1 to 4 inches long that often has a rough inner membrane (L.S.Pavek, 2012). Ripe seeds are round, smooth or wrinkled, and can be green, yellow, beige, brown, red orange, blue- red, dark violet to almost black, or spotted. The flowers are primarily self-pollinating, which enables breeders to create true breeding lines.

2.3. Field Pea Production and productivity

Field pea Pea (*Pisum sativum*) is a popular leguminous vegetable in Bangladesh. It is cultivated in area of 38000 acre and annual production in about 13000 metric tons (Anonymous, 2005). It is an excellent food source used either as a vegetable or soup or canned, frozen or dehydrated and pea straw is also a nutritious fodder. It is great agronomic value and also a profitable crop (Kudan, 2008). Field pea is the most widely grown pluses crop in Ethiopia. Seven pulses are prioritized to be focused on the Ethiopian Agricultural Transformation Agency (ATA). They are faba bean, common bean, chickpea, field pea, lentils, soybeans and mung beans, in the order of their importance in terms of area coverage and volume of production. The criteria used for prioritizing these pulses were area coverage and economic benefits.

According to Atnaf *et al*. (2015), the production of grain legumes is mainly concentrated in the Oromia and Amhara regions which together account for 92% of chickpea production, 85% of faba bean production, 79% of haricot bean production, and 79% of field pea production. In wider, (Getachew, 2019) also indicated that Amhara and Oromia regions alone produce 83.17% of total grain legumes. In Ethiopia, more than 15 cultivars of field pea, with superior yield potentials, seed size and seed color and disease resistance have been released for different agro ecological conditions (MoARD, 2008). According to (Yayeh Bitew *et al*.,2014) 25 cm inter row with 15 cm intra row and 20 cm inter row with 5 cm intra row spacing, respectively can give the highest mean seed yield, and thereby increase the productivity of filed pea cultivars, under small scale farmers' conditions.

Globally, pea is grown in an area of 1.1 million ha with total production of 9.2 million tons and the productivity is 8.35 ton ha-1. Half of this production is used for livestock feed, and the remaining half for human consumption, mainly in developing countries (Martin-Sanz *et* *al*., 2011). The seed yield obtained by local farmers is quite low and variable. In Ethiopia, the national average yield of field pea is 1.2 ton/ha (Tilahun Tadesse *et al*., 2013).

2.4. Taxonomy of Powdery mildew and Distribution

Although Erysiphaceae are widely distributed throughout the world and have been known for some time. Powdery mildew (*Erysiphe polygoni*) is the major fungal diseases causing substantial yield loss (Adisu T and Ermiyas T (2017, Teshome E, and Tegegn A (2017). This disease is of less effect in high rainfall areas of Ethiopia where its spores are removed from the plant tissue by rain and cannot cause infection. However, late sown and off-season fields were reported to be severely affected by the disease. Areas like Adet, Denbi, Kulumsa, Bako, were considered to be hot-spot for powdery mildew in field pea. (Mussa Jarso *et al*., 2009). Their taxonomy is still rather confused. Linnaeus (1967) established a genus *Erysiphe*. De Candolle (1802) described many species of the genus. Salmon (1900), divided *Erysiphe* into eight species and one variety and grouped *E. pisi (E. martii)* into *E. polygoni* DC, which has 357 host species in 33 families. Homma (1937) adopted Salmon's system, but recognized more genera and introduced a narrower species concept than Salmon's. Blumer's (1933) monograph of the European powdery mildews became a standard in Europe. He combined morphology with host specialization in delimiting species and therefore came to a narrower species concept. He recognized 15 species within Salmon's *E. polygoni*, and considered *E. pisi* parasitic on *P. sativum* as the correct species concept of pea powdery mildew, as did Junell (1967) three decades later in Sweden. Braun (1987) based the species concept mainly on the morphological differentiations and divided *E. pisi* into two varieties, var. *pisi* and var. *cruchetiana* the latter differing from the former by 'frequently irregularly branched cleistothecial appendages'. According to Paul and Kapoor (1995) the species *E. polygoni* is an aggregate of many individual species.).

2.5. Morphology of fungus

The fungus is septate, ectophytic, obligate parasite producing whitish mycelium and hyaline conidia. Colonies amphigenous, mostly hypophyllous, also on petioles and stem, mycelium sub-persistent to persistent, white at first, turning brownish then to grayish color at maturity and the conidiophores arise vertically from the superficial hyphae on the host surface. Conidia solitary, vacuolated, granular, elongate or ellipsoidal and measures 31-38 x

17-21 (25-35 x 13-16) µm. Hyphal cells, cells of conidiophores, conidia and haustoria all are uni-nucleate (Singh and Singh, 1988).

2.6. The Infection

Powdery mildew is an obligate parasite which obtains nutrients from the plant through haustoria in epidermal cells (Agrios 1988). It is overwinters on infected pea debris or on alternative hosts (Falloon and Viljanen- Rollinson, 2001). Secondary spread occurs via airborne conidia (Warkentin *et al*., 1996). Conidia germinate producing a germ tube with a lobed primary appressorium. A penetration peg emerges and if it penetrates successfully through the host cuticle and cell wall, a primary haustorium forms within the epidermal cell. Nutrient uptake from the plant cell through the haustorium supports development of secondary hyphae that radiate across the host epidermis forming hyphal appressoria from which secondary haustoria are formed (Falloon *et al*., 1989). Finally; aerial conidiophores emerge from surface hyphae producing conidia capable of initiating a new cycle of infection (Falloon *et al*., 1989). Spore release also can cause breathing and allergic reactions in farm workers (Eklund M, *et al*., 2005).

2.7. Symptoms of powdery mildew

Morphologic signs of powdery mildew infection are usually apparent before symptoms appear. This is because the powdery mildews are obligate parasites which injure their hosts slowly and because the mycelium and conidiophores are so conspicuous. Powdery mildew is caused by the biotrophic, ascomycete fungus *Erysiphe polygoni*; which form colonies on leaves, stems and pods and the disease is severe in many areas of the world, particularly in climates with warm, dry days and cool nights (Ghafoor A, Mcphee K. 2012). White fungal colonies appear typically on the upper surfaces of leaves, and coalesce as the disease progresses. Symptoms appear later and include stunting and distortion of leaves, surface necrosis of invaded tissue, a general decline in the growth of the host, yellowing and chlorosis of leaves, and premature leaf fall (Yarwood, 1957). In severe infections, the foliage may wither and occasionally plant death occurs.

Histological changes in the host include collapse of the necrotic epidermal cells in case of sub-infections, collapse of tissue below the penetrated epidermal cells, and movement of the host nuclei towards the haustoria of the fungus. Physiology of the host is also affected.

There is increased transpiration, especially during night. Respiration is also increased and photosynthesis decreased (Singh, 2005).

2.8. Assessment of field pea varieties yield, yield components and disease reaction

Land races are the genetic wealth that a crop acquires over many years of its existence and have considerable breeding values as they contain valuable adaptive genes to different circumstances (Messiaen *et al*., 2006). The existing field pea germplasm in the country has phenotypic diversity and tolerance/resistance to diseases (Berhane Gebreslassie & Berhanu Abraha, 2016). There are two recognized subspecies, *Pisum sativum* var. *sativum* and *Pisum sativum* var. *abyssinicum* and the latter is endemic to Ethiopia (Haddis Yirga *et al*., 2013). The species *Pisum sativum* L. is known to dominate the production system in Ethiopia (Gemachu Keneni *et al*., 2007). Host resistance is one of the most widely used control measure for powdery mildew disease. There are reported sources of genetic resistance available, which were controlled by single recessive gene. Research reports also indicated that there is genetic diversity in resistance to powdery mildew in Ethiopian landrace collections (Mussa Jarso *et al*., 2009). According to (EIAR, 2018) the 1000 seed weight of Field pea varieties *i.e.* Bursa, Burkitu and Adi have 189, 208 and 209 gram, respectively and the days to maturity of these varieties reaches Bursa (134-157), Burkitu (110-160) and Adi (120-150) days after sowing. The total yield of Bursa (20-54 qt/ha), Burkitu (35-50qt/ha) and Adi (25-40 qt/ha) is on station, respectively (EIAR, 2018). Seed crops and dry grain types that mature later are more likely to become infected and have larger yield losses than crops sown for fresh pea markets (Falloon *et al.*, 1990). Generally 10% yield losses due to pea powdery mildew have been estimated (Dixon, 1978), but yield losses of over 70% have been reported (Singh *et al.*, 1978).

The powdery mildew is the major fungal disease of the crops by reducing yield and affecting nitrogen fixation (Singh and Mishra 1992). It is commonly known as pea powdery mildew but it can also infect *Medicago, Vicia*, *Lupinus*, *Lens* and *Lathyrus* (Sillero *et al*., 2006). It is an obligate parasite, its development depends on the photosynthetic status of the host; this pathogen cannot develop on photosynthetically inactive tissues (Caver and Jones 1988). According to (Nisar M, *et al.*, 2006) Powdery mildew disease affects the yield potential, causing 86% loss in field pea germplasm growing in different parts of the world. 20-30% of field pea yield reduction has been reported by powdery mildew disease in the mid-altitudes under moderate severity. Air currents spread the fungus locally and over long distances, whereas rain controls the disease by washing off spores and making them burst instead of germinating (Hargedorn, 1991). Powdery mildew is mostly damaging in late sowings or in late maturing varieties and can cause 25-50% yield losses, while management of pea powdery mildew relies on resistance cultivars, the use of fungicides and early planting (Fondevilla and Rubiales, 2012). The average yield of pea is quite low as compared to its yield potential. The crop is vulnerable to a large number of diseases. Among them powdery mildew and *Ascochyta blight* caused by *Erysiphe pisi* DC and *Ascochyta pinodes*, *Ascochyta pinodella*, *Ascochyta pisi* respectively are the major diseases occurring worldwide and can cause severe losses both in quality and quantity of fresh pods as well as dry seeds (Ek *et al*., 2005).

Yield loss on field pea due to powdery mildew were reported to be 50-75% in USA, 45% in England, 33% in Canada and 20-53% in Ethiopia (Dereje Gorfu, 2000). Infection of most powdery mildews increases with soil nitrogen availability due to its effect on host growth rate. On the contrary, phosphorous reduces the incidence of the disease (Jarvis *et al*. 2002). Severe infection may result in 24-27% reduction in pod weight, 21-30% reduction in pod number and up to 70% reduction in total yield (Prasad and Dwivedi, 2007). The pathogen causes up to 50 % losses and reduces pod quality (Nisar *et. al*. 2006). The disease can also hasten crop maturity and affects pea quality.

Uppal *et al*. (1935) observed heavy reduction in pod formation in pea due to severe infection of powdery mildew depriving even a single picking as compared to 6-7 picking in healthy crops. Vasudeva (1960) reported 23 percent loss in Field pea yield due to powdery mildew (*Erysiphe poligoni*) under field conditions. Shrivastava *et al*. (1973) noticed 39 percent loss in yield of pea due to powdery mildew. Munjal et al. (1963) conducted an experiment on the powdery mildew of pea and have indicated that the loss was proportional to the disease intensity between the limits: 50-100 percent. The loss in yield of even a 100 percent infected crop was 21-31 per cent in term of pod number and 26-47 per cent in term of pod weight. However, the above relation between disease intensity/ yield loss seemed to be valid for disease intensities observed at the time of first flush of pods started showing signs of maturity. The losses caused by the disease very considerably depending on the stage at which different disease intensities occur in the crop. Narasighani (1978) reported that infection of pea with *Erysiphe polygoni* lead to significant reduction in the yield because of less number of pods per plants and less number of seed per plant in the infected plants. Raut and Wangikar (1979) observed reduction of 34.50 percent in pod number, 42.3

percent in pod weight, and 31.81 percent in size of grain and 50.84 percent in weight of 100 grains of pea when the powdery mildew incidence was 100 percent. Krishna et al. (1989) observed consistently lesser losses in pod length, number of grains per pods, 1000 grains weight and total grain yield in slow mildewing cultivars of pea compared to fast mildews. Mahmood et al. (1983) noted 10.1-18 percent yield losses in 8 varieties of garden pea due to infection of *Erysiphe polygoni*. Cultivars; American and Alderman were relatively more tolerant than PN 25 and Alaska.

Nagaraju and Pal (1990) noticed no change in flowering time, rate of pod maturity, number of primary branches, plant height, pod length and sweetness of garden pea in powdery mildew resistant and susceptible lines. However, pods per plant, pod yield per plant and per plot, 100 green seed weight and seeds per pod were higher in resistant lines. Component characters adversely affected by the disease were number of pods per plant, number of seed per pod, number of seed per plant and pod yield per plot. Rathi and Tripathi (1994) found significant reduction in plant growth and yield parameters of pea due to powdery mildew. An increase in disease intensity led to a corresponding decrease in plant height, number of primary branches and yield. Reduction in the number of pods contributed to a major yield loss in all varieties. Shabeer *et al*. (2006) assessed yield loss due to powdery mildew in a susceptible pea variety "Meteor" planted under natural field conditions. 21.09% of yield losses have been reported due to powdery mildew severity on local field pea cultivar from plot without fungicide application at Sinana South Eastern Ethiopia (Teshome E, and Tegegn A (2017).

2.9. Comparative efficacy of Fungicides against powdery mildew

Current powdery mildew control methods include early planting, the use of fungicides and of resistant cultivars. Chemical control is feasible with a choice of protective and systemic fungicides. Chemical control of the disease has been reported to be effective if applied at proper time (Jarial and Sharma, 2005). The released varieties have moderate level of resistance to powdery mildew. Other control measures include early planting, sprinkler irrigation, chemical control with Benomyl 50% WP (Benlate 50% WP) 2 kg active ingredient per ha could be applied starting when 5% attack has been scored on the crop. However, this seems somewhat costly and unaffordable by poor farmers, as at least two sprays must be applied at 10 days intervals (Mussa Jarso *et al*., 2009). Maximum seed yield on mustard powdery mildew (*Erysiphe cruciferarum* Opiz ex. Junell) is found in hexaconazoleat 0.005 per cent concentration (2225 kg/ha) which remained statistically at par with penconazole (2160 kg/ha), difenoconazole (2130 kg/ha), dinocap (2117 kg/ha), wettable sulphur (2090 kg/ha) and azoxystrobin (2062 kg/ha). However, there was no significant yield difference between water spray control (1768 kg/ha) and no spray control (1711 kg/ha) treatments (Kanzaria1 and Dhruj, 2018). It was revealed that the minimum severity 17.80 per cent was recorded in the plots protected with Hexaconazole which was at par with Propiconazole (21.53%), followed by wettable sulphur (23.10%) and Tridemefon (23.58%), respectively. While, maximum disease severity 50.40 per cent was recorded in control plot. Similarly, the disease severity recorded after third spray (70 DAS) at the time of maturity was indicated statistically significance over control (Deshmukh *et al*. 2018).

Basandra *et al*., (2013) evaluated different fungicides and highest yield was recorded in tubeconazole followed by hexaconazole, propiconazole and mancozeb. According to (Girija *et al*., 2011) Triadimefon25%WP at 0.01percentage and mancozeb75%WP at 0.25 percentage were found significantly superior to Myclobutanil10% WP (Systhane) at all concentration in reducing the powdery mildew, leaf spot and fruit rot disease and enhancing the yield of chilli. Upadhyay and singh (1994) conducted spray trails with five fungicides on powdery mildew of pea during 1990-1992, the best control of powdery mildew and highest yield was obtained with 0.1 % Calixin (Tridemorph) applied 4 times at 15 days intervals. Kapoor and Sugha (1995) evaluated 12 fungicides to control *Erysiphe pisi* on susceptible pea cv. Lincoln. Spraying was taken up at 20 days interval and first spray was given 45 days after sowing. Spray of Triadimefon (Bayleton) was found effective against the disease. Once the disease had developed sulphur fungicides Dinocap (Karathane) did not control the disease effectively.

Sakr and Muehlbauer (1999) investigated the effect of genetic resistance, compared to chemical treatment due to powdery mildew on pea. The fungicide (Bayleton) treatment was applied at the rate of 0.15 kg a.i. /ha. Powdery mildew occurred naturally and caused serious damage in the non-treated plots of the susceptible lines. Resistant lines and chemically-treated lines remained free of the disease. Resistant near isogenic lines yielded 11 to 44% more than the susceptible lines. Disease resistance controlled powdery mildews as effectively as fungicide applications and was equivalent to chemical control in preventing yield losses.

Banyal and Rana (2003) determined the efficacy of fungicide spray schedule against pea powdery mildew. The treatments comprised single or combined applications of Triadimefon (Bayleton) (2 g/kg seed and 0.025% spray treatments), Hexaconazole (Contaf) (0.025% spray treatment), and Dinocap (Karathane) (0.05% spray treatment). To be effective, most fungicides need to be applied before disease occurs or at the first appearance of symptoms. Also, the damage caused by late blight on plants does not often go away, even if the pathogen is killed. Contact fungicides can only protect new uninfected growth from the disease. Generally, few fungicides are effective against pathogens after they have infected a plant (McGrath, 2004). According to Ateet, *et al (*2015) and Girija *et al*., (2011), area under disease progress curve (AUDPC) indicated that all fungicides are effective in reducing AUDPC when compared to untreated control that means the highest AUDPC from unsprayed plot and the lowest from fully controlled plot.

3. MATERIALS AND METHODS

3.1. Description of the study site

The experiments were conducted under rainy season at two locations that is Debre Berhan University farm field in Basona Warana district and Tar Maber District at Debre Meaza *Kebele* adminstration at North Showa Zone, Amhara Region, Ethiopia in 2019-2020. Debre Berhan is situated at about 120 km road distance from Addis Ababa (the national capital) and at about 696 km from Bahir Dar (the regional capital) on the main highway to Dessie and/or to Mekele (Dagne and Urgessa, 2017). Tarmaber District (Debresina) is located at about 190 km from Addis Ababa. Debre Berhan is situated at 09°35'45" to 09°36'45" North latitude and from 39°29'40" to 39°31'30" East longitude and an elevation of 2,840 meters above sea level. The x, y co-ordinate of Debre Meaza *kebele* administration FTC is 58° 28' 28" and 108° 59' 93" respectively (Dagne and Urgessa, 2017). The average annual rainfall of Debre Brehan is 965.25 mm.

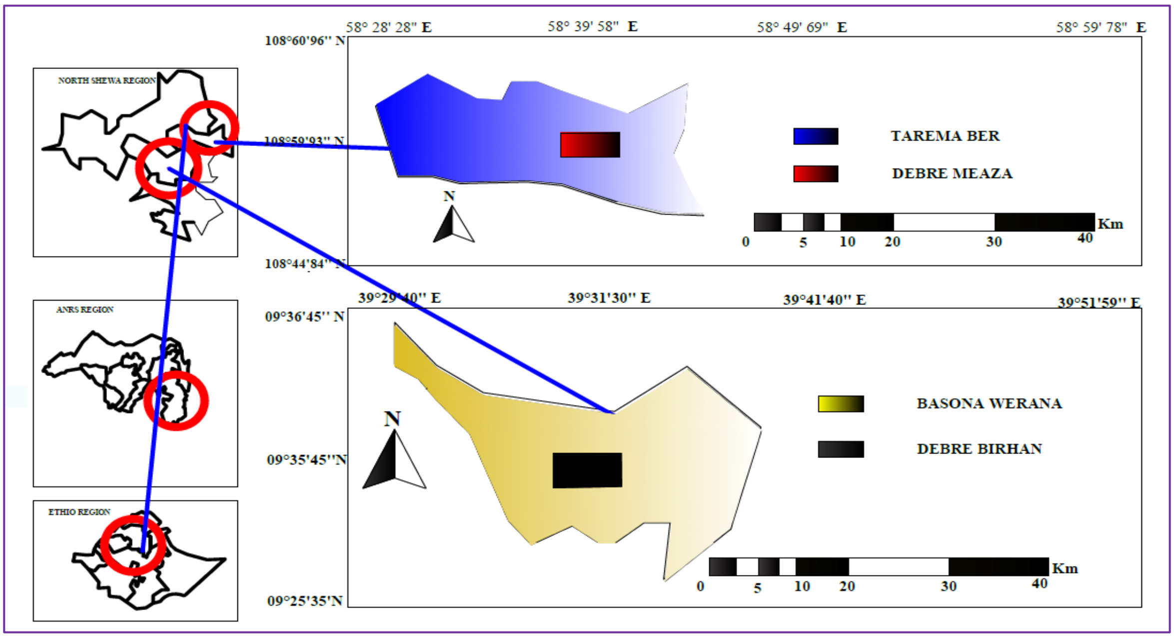

Figure 1 The Two Study sites Map

Basona Werana and Tar Maber districts are classified under *Dega*, *Woynadega* (*Mide-altitude*) and *Kola (Low altitude)* agro-climatic zones. With an average maximum temperature of 20.1^{O}C and average minimum temperature of 6.5 ^{O}C, the town has got mean annual temperature of 13.3 ^{O}C (2008 to 2013 G.C). This, though may be cold for some times (October, November and December), is favorable for human settlement and to undertake any developmental activities (Dagne and Urgessa, 2017). All varieties of Field Pea were sown on July 3/2019 G.C.

3.2. Materials Used

Materials that were used for implementation of the experiments were four varieties of field pea namely (Bursa, Burkitu, Adi and Local Var.) and four fungicides (Triadimefon25% WP, Metalaxyl8%+ Mancozeb64% WP, Deficonazole25% EC, and includes control.

Table 1: Description of field pea varieties used for field experiment

Name of Variety	Breeder/ maintainer Institute	Year of release (G.C)	Altitude (m.a.s.l.)	Rain fall (mm)	Required Days to harvest	Grain yield (qt ha-1)	
						Research Field	Farmer's Field
Bursa (EH05027-2)	Kulumsa (KARC/ EIAR)	2015	1900-3000	700-1000	134-157	20-54	20-40
Burkitu (EH99004-2)	Hollota (HARC/ EIAR)	2008	1800-3000	700-1000	110-163	35-62	20-38
Adi	Hollota HARC/ EIAR)	1995	2300-3000	800-1100	120-150	25-40	20-30
Local	-	-	-	-	-	-	-

Table 2: Fungicides used as treatment

Trts	**Trade name**	**Common name**	**Chemical family**	**Mode of action**
1	Bayleton25%WP	Triadmefon	Triazole	Systemic
2	Ridomil Gold MZ 68% WG	Metalaxyle + Mancozeb	Aclamine	Systemic and contact
3	Conazol 25% EC	Deficonazole	Triazole	Systemic
4	Control		-	-

3.3. Treatments, experimental design and application

The experiments were conducted under natural field condition (without any artificial inoculation) because the Powdery mildew disease development depends on the photosynthetic status of the host *i.e* this disease cannot be develop on photosynthetically inactive tissues and carried out during July- December 2019 G.C. The treatments were consist of 4 × 4 factorial RCBD that is, Bayleton (Triadimefon25% WP) (0.5-1 kg/ha - 150-400 liter H_2O), Sanchar (Metalaxyl8% + Mancozeb64%WP) (1.5kg/ha-200 liter H_2O), Conazole (Deficonazole10%EC) (0.5 lt/ha- 200 liter H_2O) and (Control/water also the four varieties (Bursa, Burkitu, Adi and Local-Variety).

Table 3: The treatments combinations look like the following

No Treatment Combinations	Treatment code
1. Triadimefon25% WP +Bursa	1
2. Metalaxyl8% + Mancozeb64% WP+ Bursa	2
3. Deficonazole25% EC + Bursa	3
4. Water (no fungicide application) + Bursa	4
5. Triadimefon25% WP +Burkitu	5
6 Metalaxyl8% + Mancozeb64% WP + Burkitu	6
7. Deficonazole25% EC + Burkitu	7
8. Water (no fungicide application) +Burkitu	8
9. Triadimefon25% WP +Adi	9
10. Metalaxyl8% + Mancozeb64% WP + Adi	10
11. Deficonazole25% EC + Adi	11
12. Water (no fungicide application) + Adi	12
13. Triadimefon25% WP +Local var.	13
14. Metalaxyl8% + Mancozeb64% WP + Local var.	14
15 Deficonazole25% EC + Local variety	15
16. Water (no fungicide application) + Local var. (Control)	16

Field Pea seeds were sown in plots (1.5 m × 4 m) during first week of July. The row to row distance was 20 cm and 5 cm apart between plants. Each treatment has three replications in Randomized Complete Block Design. The total area of the research site was 15m x 33.5 m

= 502.5 m^2 and the net plot area was 6 m^2 x 48 plots=288 m^2 for each research sites. The total plant population in each plot was 20 rows x 30plants = 600 plants and therefore, 600 plants x 48 plots = 28,800 plants have been in the total net plot area of in each study areas. Three fungicides viz., Triadimefon25% WP, Metalyxyl8% + Mancozeb64% WP and Deficonazole25% EC and these fungicides were applied 95 DAS to manage powdery mildew at its initial infection stage by using knapsack sprayer at fixed spray interval of every 15 days for two times due to systemic and curative action of the chemicals and application was started immediately after the development of the first observable disease symptom. Control plots were sprayed with the same volume of water. Ten randomly selected plants in each plot were tagged for the purpose of the clear observation. Crop observations data on different plant parts were recorded on weekly DAS but the observation was done daily. Observation on incidence and severity of powdery mildew disease was recorded from first appearance (September, 94 DAS) of the disease up to maturity and harvesting of the crop.

Disease severity was recorded at the first observation of disease sign and symptom (94DAS) and also after the beginning of first spray. Subsequent observations were recorded before each spray and finally disease severity was recorded ten times up to the plant harvest because the disease infection was continued until the plant harvesting time on its immature tip leaves and stems. The first powdery mildew symptom was observed at 94 days after the plant was sown. From the selected and tagged plot, number of pods, number of branches and total number of grains per pod were counted. Grain yield (kg/plot) was also recorded and finally converted in to ton/ha. Data was statistically analyzed. Numerical grades were assigned to the amount of disease observed applying 0-5 disease rating and further these scales were converted to per cent disease index using formula (Bernier CC *et al*., 1993). The drastic effect of the fungicides was controlled by fencing the plots with the plastic sheet during the application of fungicides.

3.3.1. Disease incidence and severity

The number of plants that showed symptoms of powdery mildew was counted and the percentage of disease incidence (PDI) was calculated according to the formula by Wheeler JB (1969). Appearance of the disease in the experimental plots was inspected six times (94 DAS, 102 DAS, 109 DAS, 116 DAS, 123 DAS and 130 DAS) in a week or every seven days. The randomly ten tagged plants infected from plots were recorded and their means were converted in to percentage as the total plant observation. Initial scoring for disease incidence was low when lesions were visible on the basal leaves of the plants. The lower average powdery mildew incidence was recorded during the first (94 DAS) and second (102 DAS) weeks of observation on each treatments. The average disease incidence on every treatment were highest and almost hundred per cent on the next successive five weeks (106 DAS, 109 DAS, 116 DAS, 123 DAS and 130 DAS) that is the disease has attained 100% incidence at 130 DAS in all plots.

$$\textbf{Percent Disease Incidence (PDI) \%} = \frac{\textbf{Number of Plants infected by disease}}{\boldsymbol{Total\ number\ of\ plants\ observed}} \textbf{*100}$$

Disease severity was recorded by visually estimating the percentage of leaf area diseased from 10 randomly take and pre-tagged plants in the middle two rows of each plot and rated using (Bernier CC et al., 1993) 0-5 scale for disease severity. Starting with the appearance of the first powdery mildew symptoms, each plant within each plot was visually evaluated for per cent foliar infection (severity). Powdery mildew (number of plants infected) and severity was assessed as of the disease onset at 7 days' intervals from the pre-tagged 10 plants/plot in the two central rows of each plot. The severity grades were converted into Percentage Severity Index (PSI) according to the formula by (Scott and Hollins, 1974).

$$\textbf{Percent Disease Severity (PSI) \%} = \frac{\sum \boldsymbol{Indvidual\ numerical\ rating}}{\boldsymbol{Total\ plants\ assessed * Maximum\ score\ in\ the\ scale}} * \mathbf{100}$$

3.3.2. Area under Disease Progress Curve and Disease Progress Rate

The percentage data obtained on disease incidence and severity was transformed using logistic transformation, loge [y (1-y)] (Van der plank, 1963) before statistical analysis. The transformed data was then regressed over time and the apparent infection rate was calculated for each plot. Area under disease progress curve (%-day) was calculated for each treatment from the assessment of disease severity using the following formula (Campbell and Madden, 1990).

$$AUDPC = \sum_{i=1}^{n} \mathbf{0.5}[(\boldsymbol{X_i} + \boldsymbol{X_{i+1}})](\boldsymbol{t_{i+1}} - \boldsymbol{t_i})$$

Where: xi = the cumulative disease severity percentage of infected plants at the i^{th} observation (day i), t_i = time (days) at the i^{th} observation, n = total number of symptom observations.

$$\% \text{ of number of leaves infected} = \frac{\text{Number of leaves infected x100}}{\text{Total number of leaves}}$$

AUDPC is better indicator of disease expression over time (Vander Plank, 1963) and also expressed in percent-days, because severity (x) was expressed in percent and time (t) in days (Shaner and Finney, 1977). AUDPC values were used in the analysis of variance to compare the amount of disease among plots with different treatments.

3.3.3. Yield loss Estimation

The relative loss in yield of each treatment was determined by percentage of that of protected plots of the experiment. Losses were calculated separately for each of the treatment and yield component of the field pea determined by a percentage of that of the protected plots and the yield loss must be calculated based on the formula of Robert and Janes, (1991):

$$RL\ (\%) = \frac{(Y_1 - Y_2)}{Y_1} * 100$$

Where, RL – relative loss (reduction of the parameters yield and yield component), Y1 mean of the respective parameter on protected plots (plots with maximum protection) and Y2 - mean of the respective parameter in unprotected plots (i.e. untreated plots or treated plots). Percent yield recovery will be calculated to compare the yield differences among fungicides and cultivars and other treatments using the formula:

$$YR\ (\%) = \frac{(PY - YUP)}{YSP - YUP} * 100$$

Where, YR is yield recovery in per cent, PY is plot yield, YUP is yield of unsprayed plot and YSP is maximum yield of sprayed plots.

The percentage disease control and the percentage deviation in yield were calculated with the help of the following formula (Mathur *et al*., 1971).

$$\text{Disease control}(\%) = \frac{(\text{PDI in check} - \text{PDI in treatment})}{\text{PDI in check}} * 100$$

$$\text{Yield increase}(\%) = \frac{(\text{Yield in treatment} - \text{Yield in check})}{\text{Yield in Check}} * 100$$

3.3.4. Cost Benefit Assessment

The cost and benefit of each treatment was analysed partially and marginal rate of return was computed by considering the variable cost available in the respective treatment. Variable cost include, fungicide cost and labour cost for chemical application. Yield and economic data was collected to compare the advantage of foliar spray in different treatment combinations. Economic data include input cost that varies; cost for chemical and labour during production time. Partial budgeting is employed to assess profitability of any new technologies (practice) to be imposed to the agricultural business. Marginal analysis is concerned with the process of making choice between alternative factor-product combinations considering small changes. It is a criterion which measures the effect of additional capital invested on net returns using new managements compared with the previous one (CIMMYT, 1988). It provides the value of benefit obtained per the amount of additional cost incurred percentage. The formula is as follows. Gross average marketable grain yield *(kg ha-1)* (AvY): It is an average yield of each treatment. Adjusted yield (AjY): It is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.
AjY = AvY- (AvY*0.1)

Gross field benefit (GFB) = AjY*field/farm gate price for the crop. Total cost: It is the cost of fungicide treatment for the experiment. The costs of other inputs and production practices, such as labour cost for land preparation, planting, weeding, and harvesting were considered remained the same or considered as insignificant among treatments. Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment.

NB = GFB – total cost

$$MRR(\%) = \frac{DNI}{DIC}$$

Where, MRR is marginal rate of returns, DNI, difference in net income compared with control, DIC, difference in input cost compared with control.

3.4. Yield contributing characters

3.4.1. Plant height

Physical measurement of the plant was recorded with Centimeter from ground level up to the growing tip with the help of a scale. The average height of ten tagged randomly selected plants of each treatment was calculated.

3.4.2. Length of pods

Physical length of pods on ten tagged plants per plots was taken and finally average lengths of pods per plant were calculated.

3.4.3. Pods per plant

Physical count of pods on ten tagged plants per plots was taken and finally an average number of pods per plant were calculated.

3.4.4. Grains per pods

Physical count of grains per pods on ten tagged plants per plots was taken and finally averages of grains per pods were calculated.

3.4.5. Grains weight per plant

Physical weight of grains was taken from ten tagged plants per plots and finally average of grains weight per plant was calculated.

3.4.6. Thousand (1000) seeds weight

Physical weight of randomly chose 1000 seeds were obtained from ten tagged plants per plots was taken and finally averages of 1000 seed weight of pods per plant was calculated.

3.4.7. Evaluation of field pea varieties against powdery mildew

The screening was under taken to assess the reaction of field pea varieties against *Erysiphe polygoni* under field condition in order to locate the resistant varieties.

Observation was taken at 7 days interval, after the first appearance of the disease. Zero to five scales was used for rating of powdery mildew (Anonymous, 1999).

Table 4: 0-5 Scale, of powdery mildew disease

Score	Percent disease infection	Reactions
0	0	Highly resistant
1	1-10	Resistant
2	10.1-25	Moderately resistant
3	25.1-50	Moderately susceptible
4	50.1-75	Susceptible
5	75.1- above	Highly susceptible

3.6. Data analysis

Analysis of variance (ANOVA) was to perform the disease parameters (Incidence, severity, AUDPC) and yields yield component parameters (grain yield per plant and yield loss) using the General Linear Model (GLM) of the SAS statistical package (SAS, 2007). T-test was conducted to compute the significant difference between treated and untreated means and among varieties. Least significant difference (LSD) at $p<0.05$ probability level was used to separate treatment means and among varieties. Correlation among parameters was calculated to explain the degree of relationship between parameters. Disease severity values recorded on the 10 tagged plants at weekly interval were correlated with grain yield, yield components of each cultivar and analysed. The coefficient of determination (R2) was computed to determine the proportion of the variation in yield loss explained by the disease variables (predictors) in the model (Gomez, K.A. and Gomez, A.A., 1984).

4. RESULTS AND DISCUSSION

Natural infection of the disease was allowed and the different yield contributing characters were recorded. The data of two sites were analysed separately but the result showed that there was no significant difference between the two site outputs in the experiments even if few data shows significant difference ($p \leq 0.05$) between treatments, so that the two site data were combined and analysed together.

4.1. Assessment of disease reaction

4.1.1 Powdery mildew Incidence and severity

Hundred per cent Disease incidence was recorded to all 16 treatments and this result is higher than the finding of (Alam *et al*. 2007), the lowest PDI of Powdery mildew (21.33%) disease was recorded from Sedozole fungicide treated plots. Disease incidence of powdery mildew was first noticed at the 1st week of September (94 DAS). The first disease severity was recorded in the same time during the first date of the disease incidence was shown. Gradual increase of Disease incidence (PDI) and severity (PSI) was continued up to last week of December (158 DAS) and before harvesting. Remarkable increase of disease severity (PSI) was recorded at the first week of December. The data of disease severity was recorded ten times from the first disease occurrence to harvesting for each treatment and it was started before the first application of fungicides. The time interval of data recording was maintained as seven days. First spray of fungicides as per treatment was taken up after initial appearance of disease in field pea crop and further sprays were given at seven days interval with knapsack sprayer at the rate of recommended litre of spray fluid per hectare for thorough coverage of foliage with spray fluid for each fungicide treatments. Data revealed that all three tested fungicide was found effective in controlling powdery mildew disease of field pea.

From the data, Burkitu variety (42.91%) shows that the superior result of disease severity reduction followed by Adi (40.58%), Bursa (30.6%) and Local variety (30.23%) (Table 8). Disease severity reduction showed significant differences ($P \leq 0.05$) among effects of the four field pea varieties and different types of fungicides application (Appendix Table 2). Data indicates from the mean of all fungicides and variety combinations that, the maximum powdery mildew severity was observed in Local variety (59.5%) followed by Bursa variety (49.5%), both of which were on par with each other. Minimum powdery mildew severity was observed in variety Burkitu (19.0%) and Adi (19.5%) (Table 8). The interaction effect of Local variety and Untreated (Control) was highly significant for total powdery mildew disease severity (85.33%) and similarly the highest relative yield loss (45.55) in per cent was recorded (Table 5). Application of T7 (Burkitu * Deficonazole25% EC), T11 (Adi * Deficonazole25% EC), T5 (Burkitu and Tridemifon25% WP), T9 (Adi * Tridemifon25% WP) and T10 (Adi * Metalaxyl8% + Mancozeb64% WP) were gave the lower powdery mildew disease severity *i.e* 12.67, 12.67, 13.33, 14.0 and 18.67 %., respectively and reduced the disease symptom and sign. Due to this reason these treatments were gave significant contribution to minimize (lowered) the relative grain yield loss of Field Pea. When T16 (Local * Untreated) interacted and was applied, the average powdery mildew disease severity was significantly higher than the other 15 treatments and grain yield was significantly lower ($P < 0.05$) *i.e* 2.53 ton/ha. The Current finding results are supported and similar with Teshome E and Tegegn A (2017) the highest powdery mildew disease severity (41.98%) was recorded from a plot without fungicide treatment, while lowest disease severity of 13.89% was recorded from plot sprayed at 7 days interval.

Symptoms & Severity on Metalaxyl8% + Mancozeb64% treated bursa variety

Generally, powdery mildew was recorded as the most important fungal disease on T16, T4, T2 and T14 due to its high symptoms and signs that have an average severity of 85% and 71% respectively than untreated Adi and Burkitu varieties with the mean average disease severity 33% and 29%, respectively (Table5 andFig. 2). Kapoor and Sugha (1995) Spray of Triadimefon (Bayleton) was found effective against the disease.

Symptoms and Severity on Untreated Bursa variety

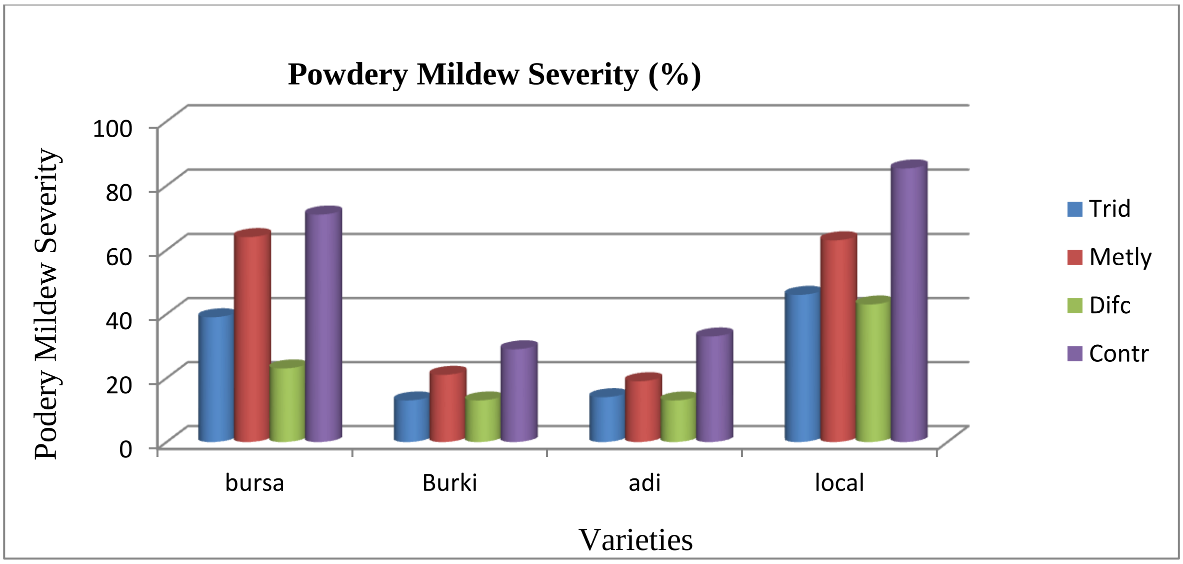

Figure 2: Effects of field pea varieties & fungicides on PDSI reduction

4.1.2. Area under Disease Progress Curve and Disease progress Rate

Data indicates from the mean of all fungicides and variety combinations that, the maximum AUDPC was observed in Local variety (1619.42) followed by Bursa variety (1592.75). Minimum AUDPC was observed in variety Burkitu (1221.5) and Adi (1273.4) (Table 8). It is evident from the data presented in Fig.3 from untreated Bursa variety, AUDPC was recorded ranged from 1592.75 to 1985. The maximum AUDPC was found in untreated control plot (1795) whereas, the minimum (1152.2) AUDPC also recorded from the Deficonazzol25% treated plot. Spraying of Tridemifon25% WP was also the second fungicide due to its minimum value of AUDPC (Table 9).

The interaction effect of Varieties * Fungicides have highly significant between treatments for total AUDPC and the highest (2334.7) but there was no yield recovery due to highest relative yield loss (45.55) in per cent as recorded (Table 5 and Fig.3). Application of T7 (Burkitu * Deficonazole25% EC), T3 (Bursa * Deficonazole25% EC), T6 (Burkitu and Metalaxyl8% + Mancozeb64% WP), and T11 (Adi * Deficonazole25% EC) were gave the lower AUDPC *i.e* 1061.7, 1122.7, 1148.3, and 1150.0, respectively (Table 5 and Fig.3). This result has supported with a finding of Ateet, *et al* (2015), when they found the highest AUDPC from unsprayed plot and the lowest from fully controlled plot and Girija *et al*., (2011), area under disease progress curve (AUDPC) indicated that all fungicides are effective in reducing AUDPC when compared to untreated control that means the highest AUDPC from unsprayed plot and the lowest from fully controlled plot. Whereas, Disease progress rate (r) of 0.2063 units day-1 to Tredimefon25%, 0.36 units day-1 to untreated plot, 0.1933 units day-1 to Deficonazzol25% and 0.2367 units day-1 to Metalaxyl8% + Mancozeb64% were calculated.

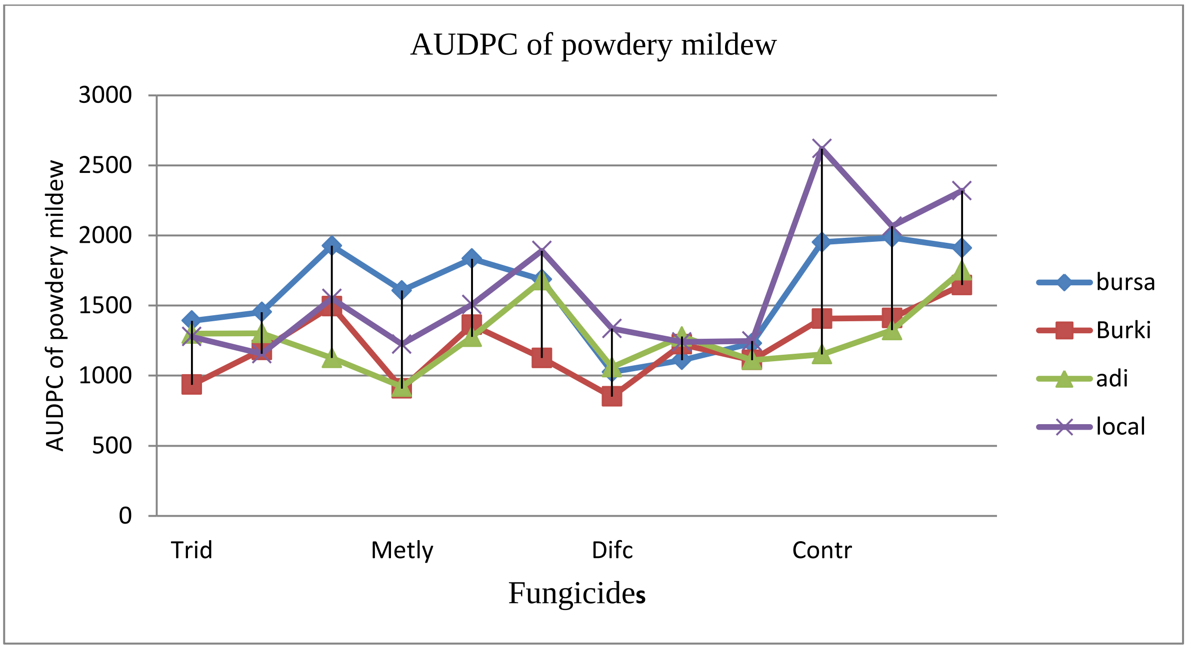

Figure 3: Interaction effects of fungicides and field pea varieties on AUDPC

4.2 Assessment of yield and yield components

Comparative yield contributing characters study was conducted during rainy season of 2019 by considering 4 cultivars evaluated against powdery mildew of field pea and the results which were obtained from both trial sites have been presented in Table 5**.** Three types of fungicides were applied in both trials and in addition to these three fungicides untreated treatment (Control) was also done. Natural infection of the disease was allowed and the different yield contributing characters were recorded. The combined analysis of variance over two locations were shown that there was statistically significant difference ($p \leq 0.05$) between treatments for parameters such as Powdery mildew disease severity, AUDPC, Disease Progress Rate (r), Number of pods per plant, Number of grains per plant, Thousand grain Weight (TGW) and Grain yield. However, these para-metres have shown statistically significant difference ($p \leq 0.05$).

4.2.1 Plant height (cm)

Combine analysis of variance (ANOVA) showed that the main effect of varieties significantly influenced the plant height. The present study also more clarify that the mean average highest (213.25 cm) plant height was recorded from the Bursa variety followed by Burkitu variety (193.8 cm) and Local variety (188.3 cm); whereas the lowest (186.03 cm) plant height was recorded from the variety of Adi (Table5). This is might be due to favourable environmental condition, cultivar difference and because of fast vegetative growth makes close spacing and similar findings were achieved by Derya Ozveren Yucel, (2013), who indicated that denser plant population of pea increased plant height due to competition among plants. Yayeh Bitew *et al*., (2014) findings are similar to the current results that planting Sefinesh cultivar in 5 cm intra row spacing and 25 cm inter row spacing (163-168.7 cm). Alam *et al*., (2007) also find similar results considering plant height of field pea and stated that the highest plant height was observed in propiconazole and lowest plant height was obtained from control plots. However, the present finding indicates that the plant height is numerically higher than the finding of Alam *et al*., (2007). This is because of the variety and fungicide difference and also during this research time, there was high rain fall throughout growing season and this makes better to the vegetative growth of the plant. However, varieties and fungicide spray did interact to pose significant difference ($P \geq 0.05$) on the average plant height (Table 5). The fungicide spray was significantly differing from each other in the average plant height. The highest (205.1cm) plant height was recorded from the Tridmefon25% WP followed by Deficonazole25%EC (202.3cm) and Metalaxyl8% + Mancozeb64%WP (193.2cm) sprays; whereas the lowest (180.6 cm) plant height was recorded on untreated plots (Table 7). The current result was supported with a finding of Ateet, *et al* (2015), similar result and considering plant height of Field pea and stated that highest plant height was observed in Conazole (propiconazol) and lowest plant height obtained from control plots when comparing Fungicides sprayed plots with control plots but, the current fungicides are different from fungicides which were used by Ateet, *et al* (2015).

4.2.2 Length of pods (cm.)

From the data, the maximum pod length was recorded from the treatment that was sprayed the Tredimefon25% (6.10) followed by both Deficonazole10% (5.74) and untreated (5.74) in equal amount. The minimum pod length was recorded from the Metalaxyl8% + Mancozeb64% (5.39) **(**Table 5 and Figure 4**).** The data showed that all the treatment were not significantly effective over control (Appendix Table 3) and this finding is opposed the findings of Alam *et al*., (2007) that considering length and breadth of pod that untreated control plots recorded shorter and thinner pods with mean measure of 3.88 cm and 0.98 cm, respectively. The present finding was supported by Alam *et al*., (2007) only on the Bursa variety. All possible interactions of main effects that is each varieties * each fungicide treatments, were significant at ($p < 0.05$) (Table 5 and Fig.4). Interactions effects of variety with Fungicide treatments, and Fungicide treatments with variety were significantly differed among 16 treatments and the highest length of pods were obtained from T6 (Burkitu * Metalaxyl8% + Mancozeb64%), T1 (Bursa * Tredimefon25%) and T5 (Burkitu * Tredimefon25%WP) 6.42, 6.37 and 6.36, respectively. However, the lower length of pods in centimetre were obtained from T14 (Local variety * Metalaxyl8% + Mancozeb64%), and T4 (Bursa * Unsprayed) *i.e* 5.39and 5.49, respectively (Table 5 and Fig.4).

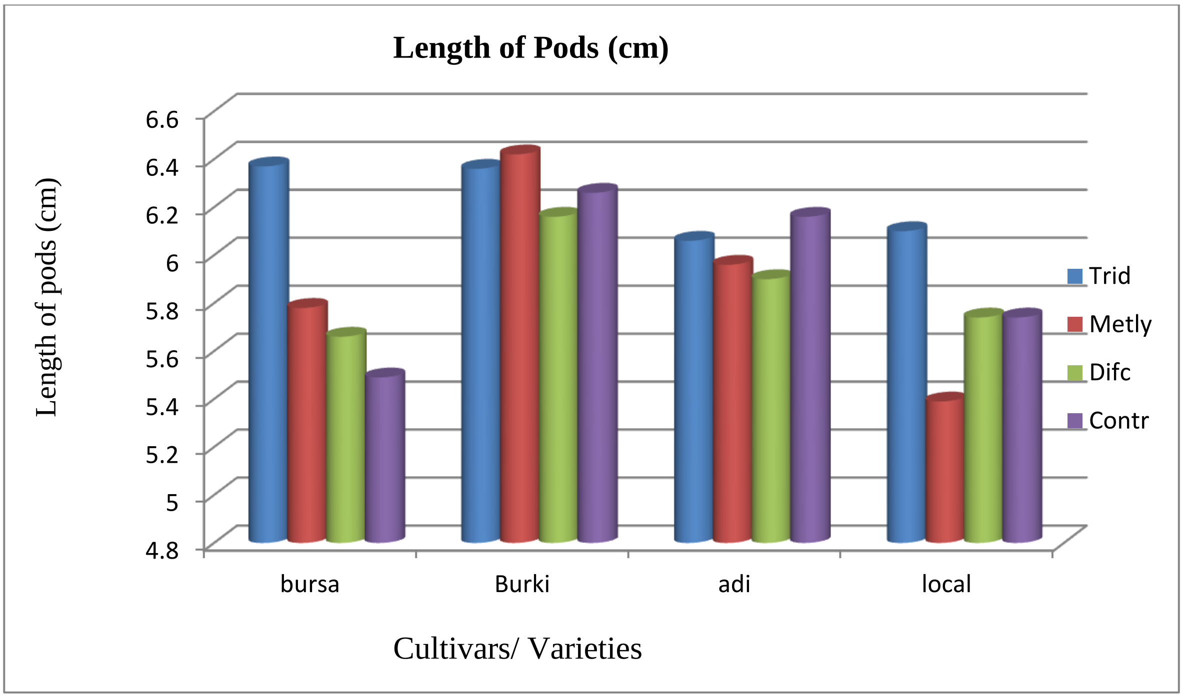

Figure 4: Length of Pod (cm) different pea cultivars combined with fungicides

Table 5: Interaction effects of fungicide application and field pea varieties

Var.	Fung.	PH	LP	PPP	GPP	GPPt	HD	TSW	GYPH(tonn)	YR(%)	RGYL%
Bursa	Tr	222.0a	6.37a	21.87abc	5.2abcd	137.8abcde	162.0a	278.6 ab	4.89ab	69.42abc	6.83cde
	M+M	218.0ab	5.78ab	17.57bcd	4.49bcde	109.5bcdefg	161.0a	256.2cd	3.62cd	-5.54d	30.77ab
	Def	214.67abc	5.66ab	23.53a	5.45ab	140.8abcd	162.0a	282.1a	4.72abc	80ab	8.57bce
	UP	198.0abcd	5.49b	15.50d	3.99fe	89.53efg	161.0a	229.7ef	3.62cd	0.0dc	23.8abcd
Burkitu	Tr	204.0abcd	6.36a	22.67ab	5.86a	132.8abcdef	150.0b	260.1bcd	5.1a	94.29ab	1.367de
	M+M	188.3bcd	6.42a	20.37abcd	5.367abc	107.3cdefg	150.0b	252.5cd	4.5abc	28.2bcd	12.93bcde
	Def	208.0abc	6.16ab	24.433a	6.140a	154.7a	150.0b	286.3a	5.1a	84.14ab	2.067 de
	UP	174.67d	6.26ab	19.97abcd	4.32cdef	101.03efg	150.0b	256.3cd	3.82bcd	33.3abcd	25.97abc
Adi	Tr	192.7abcd	6.06ab	24.033a	5.480ab	142.5abc	150.0b	256.3cd	4.83ab	75.0ab	9.37 bcde
	M+M	199.7abcd	5.96ab	21.517abc	5.31abcd	132.8abcdef	150.0b	243.4de	4.5abc	58.3abcd	15.6bcde
	Def	175.67d	5.90ab	23.17ab	6.0167a	146.97ab	151.7b	266.1abc	5.33a	100 a	0.0e
	UP	201.7abcd	6.16ab	20.00abcd	4.087ef	103.6defg	150.0b	246.9cde	3.77bcd	0.0cd	29.37abc
Local Var.	Tr	190.3bcd	6.10ab	20.48abcd	5.0abcde	115.2bcdefg	143.33c	214.3fg	4.22abcd	78.64ab	9.10bcde
	M+M	187.0cd	5.39b	16.73cd	4.213def	97.60fg	140.0c	202.9gh	3.21de	32.6abcd	30.93ab
	Def	183.67bc	5.74ab	21.68abc	5.653a	123.6abcdefg	140.00c	216.87gf	4.64abc	100a	0.0e
	UP	174.0d	5.74ab	15.10d	3.383f	85.50g	141.7c	190.43h	2.53e	0.0dc	45.6a
LSD(0.		25.66	.73ns	4.835	0.980	33.12	3.274	18.86	9.69	60.77	19.97
C.V (%)		7.899	7.29	14.154	11.782	16.588	1.3055	4.606525	13.627	70.569	76.16

Means within the same column followed by the same letter(s) are not significantly different, LSD (0.05) = Least significant difference at P≤0.05, Defi.25%EC = Deficonazole25%EC, Tredi.25%WP = Tredimefon25%WP Met.l8%+Man.64%WP=Metalaxyl8% + Mancozeb64% applied with the indicated spray interaction. PH=average plant height, PPP= pods per plant, GPP=grains per pod, GPPt=grains per plant, TSW=thousand seeds weight, GYPH=grain yield per hectare, YR=yield recovery (%), GYL= relative grain yield loss (%), PDSI= Percent disease severity index, and AUDPC=area under disease progress curve

4.2.3 Pods per plants

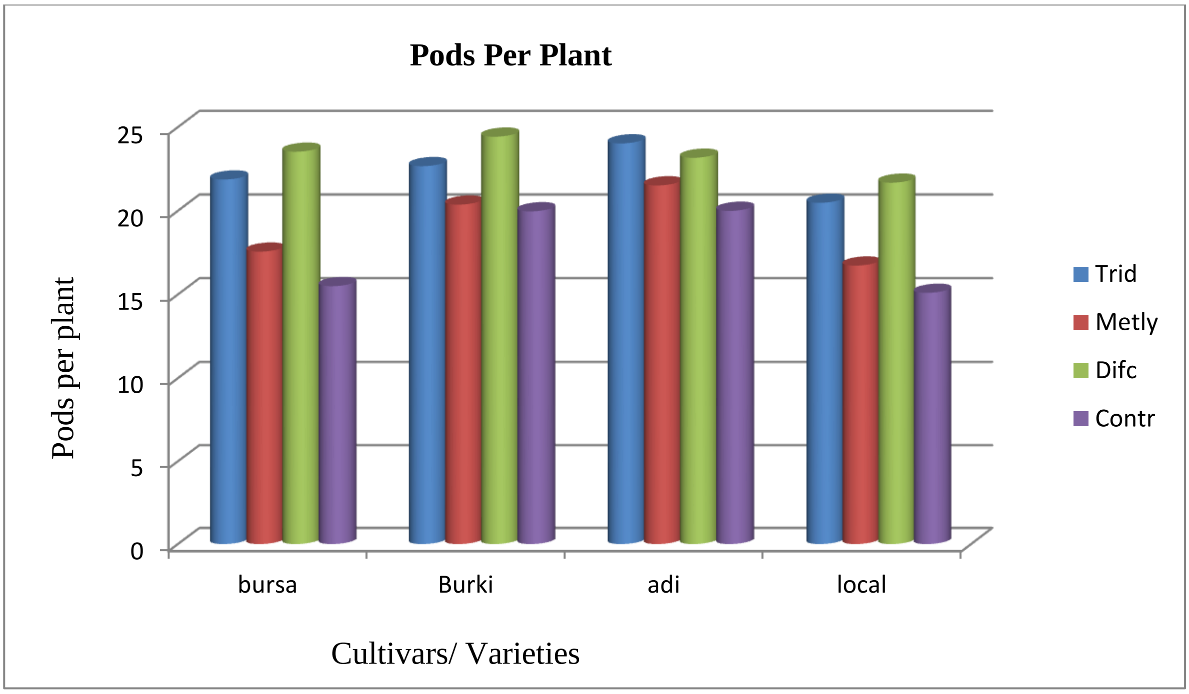

Figure 5: Pods per plant of different pea varieties combined with fungicides

From the data there is significance difference among fungicide treatments and among the varieties that bring in pods per plant **(**Table 6, Figure 5 and Appendix Table 1**)**. Combine analysis of variance (ANOVA) showed that the main effect of varieties significantly influenced the average pods per plant. However, there was also numerical difference in the average pods per plant. The highest (22.18) mean average pods per plant were recorded from the Adi variety followed by Burkitu variety (21.86) and Bursa variety (19.62); whereas the lowest (18.5) pods per plant were recorded from the local variety (Table 6). However, varieties and fungicide spray did not interact to pose significant difference (P≥0.05) on the average pods per plant (Appendix Table 1). The fungicides spray was highly significant differing from each other in the average pods per plant. The highest (23.2) pods per plant were recorded on the Deficonazole25% EC spray; whereas the lowest (17.64) pods per plant were recorded on untreated treatments (Table 7). This result is exactly in agreement with Ateet, *et al* (2015), and Teshome E, Tegegn A (2017) findings when they found the highest number of pods/plant from treated plot while the least number of pods/plant was recorded from Control plot. All possible interactions of main effects that is each varieties * each fungicide treatments, were significant at ($p < 0.05$) (Table 5 and Fig.5). This implies that each variety responded differently to fungicide applications, hence their effects were presented separately. T7 (Burkitu integrated with Deficonazole25% EC) and twice foliar sprays gave higher mean number of pods per plant of 24.43, 24.03 and 23.53, from T9 (Adi integrated with Tredimefon25%WP), T3 (Bursa integrated with Deficonazole25% EC), respectively and these treatment combinations were significantly differed from T16 (Local variety integrated with control) and T4 (Bursa integrated with control) (15.1 and 15.5), respectively (Table 5 and Fig.5).

4.2.4 Grains per pod

Combine analysis of variance (ANOVA) showed that the main effect of varieties significantly influenced the average grains per pods. The highest (5.42) mean average grains per pods were recorded from the Burkitu variety followed by Adi variety (5.22) and Bursa variety (4.79); whereas the lowest (4.57) grains per pods were recorded from the local variety (Table 6).

The current findings are similar with (Knott, 1987), there are normally 5 - 6 seeds contained in a pea pod but this depends on the cultivar and the growing conditions. Alam *et al*., (2007) also find similar results considering yield contributing characters (plant height, pods per plant, length of pod and breadth of pod and seed per pod) of field pea. According to Yayeh *et al*., (2014) findings, among the field pea varieties, Megeri (4.7-5.2) gave the mean highest number of seeds per pod as compared to Sefinesh (3.8-4.8) and his result supports the current finding, which means that the significance difference of grains per pod resulted due to varieties of cultivars. However, varieties and fungicide spray did interact to pose significant difference ($P \geq 0.05$) on the average pods per plant (Table 5 and Fig.6). The fungicides spray was highly significant differing from each other in the average grains per pods. The highest (5.82) mean average grains per pods were recorded on the Deficonazole25% EC spray; whereas the lowest (3.95) mean average grains per pods were recorded on untreated treatments (Table7). This result indicates that, fungicides have their own effect on a variety of field pea grains per pod.

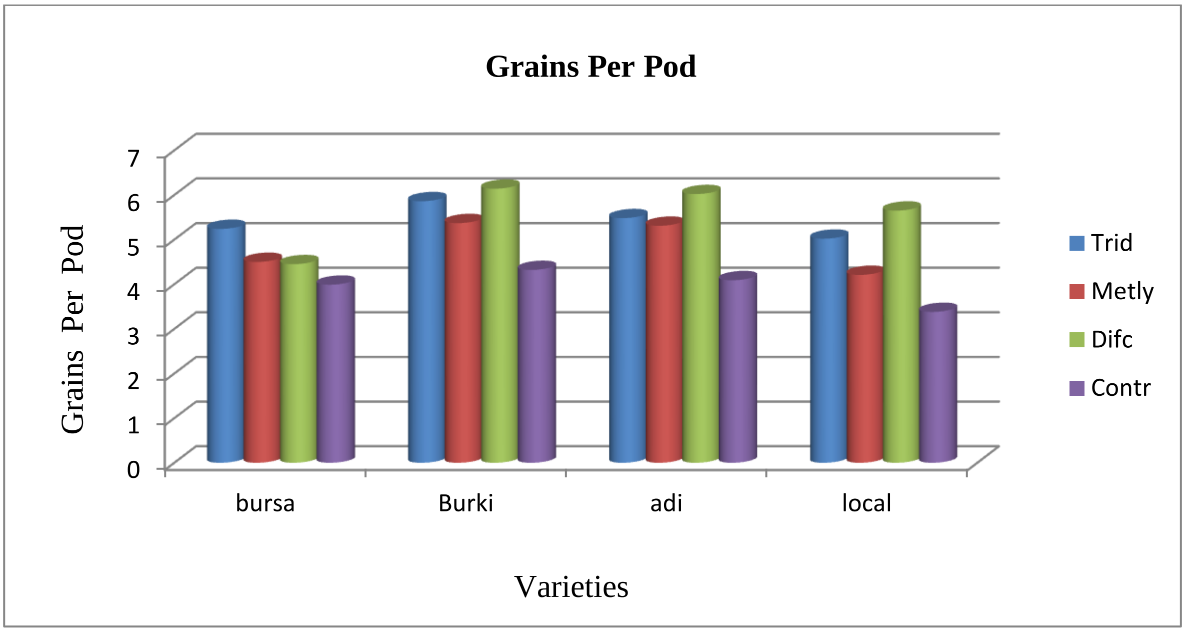

Figure 6: Grains per pod of field pea varieties combined with fungicides

Effects of interactions of variety with Fungicide treatments, and Fungicide treatments with variety were significantly differed and the highest grains per plant were obtained from T7 (Burkitu * Deficonazole25% EC), T11 (Adi * Deficonazole25% EC), T5 (Burkitu * Tredimefon25%WP) and T15 (Local variety * Deficonazole25% EC) *i.e* 6.14, 6.02, 5.86 and 5.65, respectively. However, the lower number of grains per pod were obtained from T16 (Local variety * Untreated), T4 (Bursa * Unsprayed), T12 (Adi * Unsprayed) *i.e* 3.38, 3.99 and 4.09, respectively (Table 5 and Fig.6).

4.2.5 Grain per plant

The combined analysis of average grains per plant showed highly significant differences ($P \geq 0.05$) among the four field pea varieties and also have highly significance difference among fungicides (Table 6 and Appendix Table 1). The highest (132.5) average grains per plant were recorded from the Adi variety followed by Burkitu variety (123.8) and Bursa variety (119.4); whereas the lowest (105.5) grains per plant were recorded from the local variety (Table 6). However, varieties and fungicide spray did not interact to pose significant difference ($P \geq 0.05$) on the average grains per plant (Appendix Table 1). The fungicides spray was highly significant differing from each other in the average grains per plant. The highest (141.51) mean average grains per plant were recorded on the Deficonazole25% EC spray; whereas the lowest (94.92) grains per plants were recorded on untreated treatments (Table 7). From all 16 treatment combinations of fungicide sprays and the Field Pea varieties interaction results were statistically significance difference and the highest (154.7) number of grains per plant were recorded from treatment interaction of T7 (Burkitu*Deficonazole25%. However, the lowest number of grains per plant were obtained from the interaction effects of T16 (Local variety*unsprayed), and T4 (Bursa*unsprayed) *i.e* 85.5 and 89.5, respectively in number (Table 5 and Fig. 7).

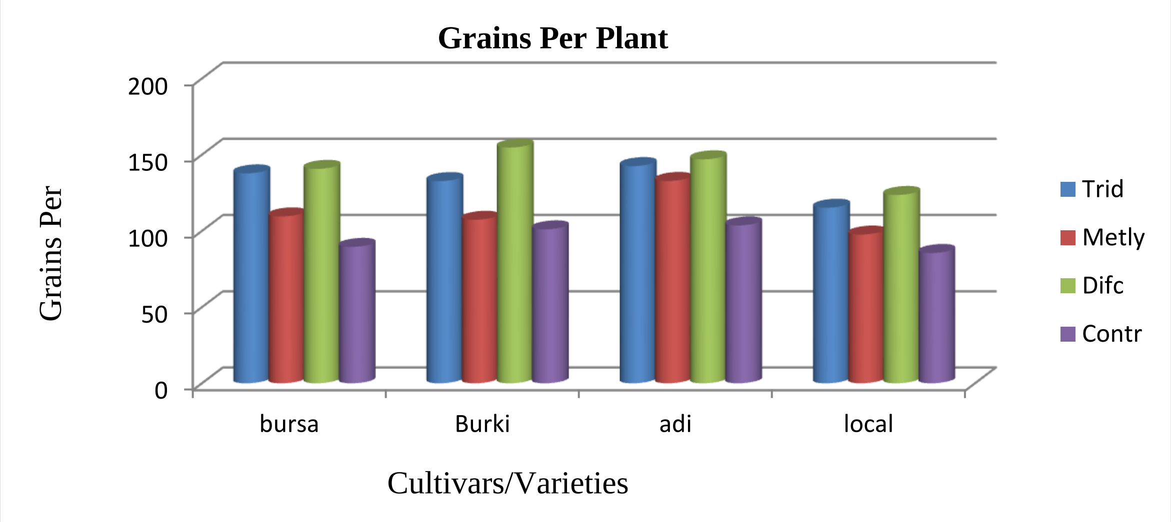

Figure 7: Grains per plant of different pea varieties combined with fungicides

4.2.6 Thousand seeds weight

The combined analysis of average thousand seeds weight showed significant differences ($P \leq 0.05$) among the four field pea varieties and fungicide application. The highest (263.8) thousand seeds weight were recorded from the Burkitu variety followed by Bursa variety (261.67) and Adi variety (252.94); whereas the lowest (206.14) thousand seeds weight were recorded from the local variety (Table 6). However, varieties and fungicide spray did not interact to pose significant difference ($P \geq 0.05$) on the thousand seeds weight (Appendix Table 1). The fungicides spray was highly significant differing from each other in the thousand seeds weight. The highest (262.0) grains per plant were recorded on the Deficonazole25% EC spray; whereas the lowest (237.5) grains per plants were recorded on untreated treatments (Table7). According to (EIAR, 2018) the 1000 seed weight of Field pea varieties *i.e.* Adi, Burkitu and Bursa have 209, 208 and 189 gram, respectively but according to the current finding, the average mean thousand seed weight of Field pea varieties was recorded *i.e*. Burkitu, Bursa, Adi and Local variety have 263.8gm, 261.67gm, 252.94gm, and 206.14gm respectively and this result is relatively higher than the finding of

EIAR, 2018. The current pragmatic finding also indicates that Deficonazole25%WP, Tredimefon25%EC, Metalaxyl8% + Mancozeb64%WP and untreated treatments have 262.01gm, 252.33gm, 238.77gm and 230.61gm average mean thousand seed weight and this is different from the finding of EIAR, 2018. The values of mean average 1000 seeds weight recorded in the present finding are higher than the findings of (Sharma *et al.*, 2017), two fungicidal treatments, azoxystrobin + difenoconazole and azoxystrobin + benzovindiflupyr recorded significantly mean heavier 1000 seed weight (139.51 g and 135.32 g, respectively) than untreated control (132.84 g). This is because of seed weight is the most stable yield component (Littleton *et al.*, 1979; Saxena, 1980; Saxena and Sheldrake, 1980; Saxena *et al.*, 1983). Pea seeds differ in size and shape, with size ranging from about 90 mg seed-1 to 400 mg seed-1 (Knott, 1987). However, the current finding is supported by (Sharma *et al.*, 2017) findings, because both findings are indicates fungicides have significantly superior over control on thousand seeds weight of field pea.

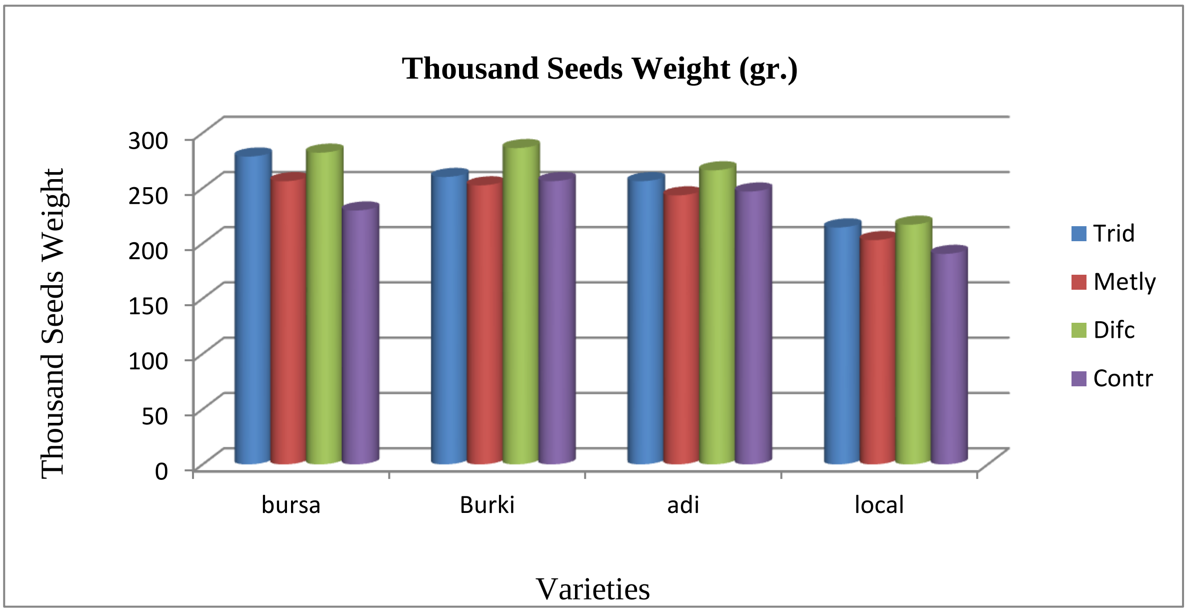

Figure 8:1000 seeds weight (gr.) of varieties combined with fungicides

Interaction between varieties and fungicides (varieties * fungicides) combinations were revealed that, irrespective significance difference of thousand seeds weight were observed between treatments which were Burkitu*Deficonazol25% (286.27) and Bursa* Deficonazol25% (282.1), produced highest TSW (Table5). However, the lowest TSW were also recorded from both treatment combinations of Local variety*water sprayed (control) (190.43) and Local variety* Metalaxyl8% + Mancozeb64% WP (202.93) in gram (Table 5).

Table 6: Effects of field pea varieties on yield and yield components

Var.	PH	GPP	PPP	TSW	HD	GPPt	GYPH(ton)	RGYIn %
Bursa	213.2**a	4.79bc	19.62bc	261.67 **ab	161.5 a	119.4ab	4.21a	17.09b
Burkitu	193.8 b	5.42a	21.86ab	263.8 **a	150.0 b	123.8a	4.62a	25.99b
Adi	186.0b	5.22ab	22.18a	252.9 **b	150.4 b	132.5a	4.61a	23.78b
Local	188.3b	4.57c	18.50c	206.1 **c	141.3 c	105.5b	3.65**b	45.6**a
CV%	7.899	11.78	14.15	4.607	1.305	16.59	13.627	79.82
LSD	12.83	0.49	2.42	9.43	1.637	16.56	0.484	18.95

PH= plant height, GPP= grains per pod, PPP= pods per plant, TSW= thousand seeds weight, GPPt= number of grains per plant, GYPH= grain yield per hectare (ton), PSI%= severity, AUDPC= area under disease progress curve, RGY In%= relative grain yield increase, DSR%= disease severity reduction, L=locations, and Var =varieties

4.2.7 Grain Yield per hectare (GYPH ton/ha)

The combined analysis of average grain yield per hectare showed significant differences ($P \leq 0.05$) among both the four field pea varieties and fungicides (Appendix Table 1). The highest (4.62ton) mean average grain yield per hectare were recorded from the Burkitu variety followed by Adi variety (4.61ton) and Bursa variety (4.21ton); whereas the lowest (3.65 ton) grain yield per hectare were recorded from the local variety (Table 6). The current findings oppose with Yayeh *et al*., (2014) findings although, the mean effect of variety was statistically non-significant, Megeri (1.06 ton/ha) gave the highest grain yield as compared to Sefinesh (90.95ton/ha), because in the current findings Burkitu (4.62ton), Adi (4.61tonn) and Bursa (4.21ton) showed significant difference over the local variety (3.65 ton). However, varieties and fungicide spray did not interact to pose significant difference ($P \geq 0.05$) on the grain yield per hectare (Appendix Table 1). The fungicides spray was highly significant differing from each other in the grain yield per hectare. The highest (4.94ton/ha) grain yield per hectare was recorded on the Deficonazole25% EC spray; whereas the lowest (3.41ton) grain yield per hectare was recorded on untreated treatments (Table 7).

Significantly higher Field Pea grain yield was obtained when Adi interacted from Deficonazole25% EC, Burkitu interacted from Tredimefon25% WP and Burkitu interacted from Deficonazole25% EC *i.e* 5.3, 5.10 and 5.06 ton/ha, respectively as compared to Local variety interacted from water (control) and Local variety interacted from Metalaxyl8% WP+ Mancozeb64% WP that is 2.53 and 3.22 ton/ha grain yield, respectively were obtained (Table 5 and Fig. 9). The most likely reason for lower grain yield when Local variety combined with water (control) and also Local variety combined with Metalaxyl8% WP+ Mancozeb64% WP as compared to Adi variety interacted from Deficonazole25% EC fungicide, Burkitu variety interacted from Tredimefon25% WP fungicide and Burkitu variety interacted from Deficonazole25% EC fungicide were due to the relatively high Powdery mildew severity that adversely affected Field Pea photosynthetic activities by limiting access for solar radiations especially during its flowering stage. In general, there was significant difference recorded among the interaction effects of fungicides and varieties over control (Table 5and Fig.9).

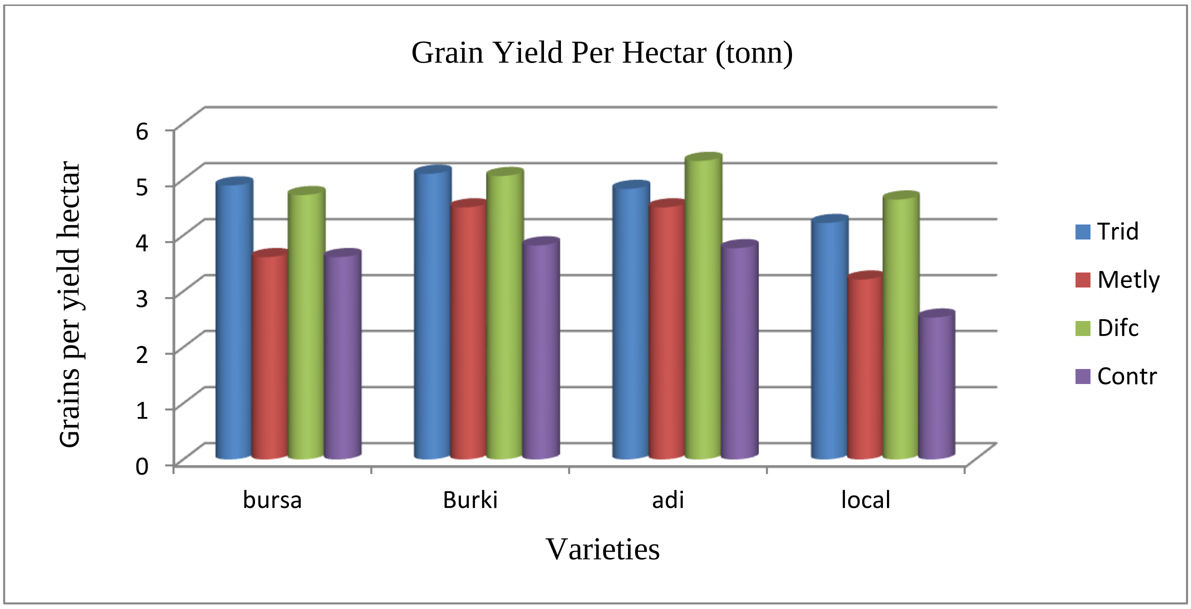

Figure 9: Grain yield (ton/ha) of field pea varieties combined with fungicides

Table 7: Effect of fungicides on yield and yield components

Fungicides	PH	GPP	PPP	TSW	GPPt	HD	GYPH (ton)	RGY In%
Tr.25% WP	205.1a	5.397a	22.3a	252.3b	131.92a	151.3a	4.76a	44.02a
M+M	193.2ab	4.85b	19.05b	242.5c	111.8b	150.3a	3.96b	17.86b
Defi.25 % EC	202.3a	5.816a	23.2a	262.0a	141.5a	150.9a	4.94a	50.04a
UP	180.6b	3.946c	17.64b	237.5c	94.92b	150.7a	3.43c	0b
CV%	7.90	11.78	14.15	3.89	16.589	1.30544	13.627	79.82
LSD	12.83	0.49	2.417	8.061	16.56	1.637	0.484	18.67

PH= plant height, GPP= grains per pod, PPP= pods per plant, TSW= thousand seeds weight, GPPt= number of grains per plant, HD=harvesting date, GYPH= grain yield per hectare (ton), PSI%= severity, AUDPC= area under disease progress curve, RGYIn%= relative grain yield increase, Tr.25% WP= Tredimefon25% WP, M+M = Metalaxyl8%+Mancozeb64%WP, Def.25%= Deficonazol25% EC and UP = Untreated plot

4.3. Evaluation of field pea varieties against powdery mildew

Screening of four field pea entries was carried out for powdery mildew reaction under natural field conditions. Out of these entries, Burkitu (19%) and Adi (19.5%) varieties showed moderately resistant (Appendix Figure 8 and 12) because the per cent disease infection values of Burkitu 19% and Adi 19.5% are grouped under 10.1-25 percent based on (Anonymous, 1999) 0-5 scale, of powdery mildew disease scoring, Bursa (49.5%) showed moderately susceptible and Local var. (59.5) showed susceptible reaction to powdery mildew (Table 6). The present finding is similar with Kedir (2020) findings, supports the present finding that Adi and Megeri were moderately resistant to disease Severity. Among varieties, there was no free from powdery mildew infection but the data indicates above board sign difference on leaves and stems.

In Burkitu and Adi field pea varieties had low disease severity score and symptom (Table 5**,** Appendix Fig.8 and 12), than that of untreated plots (59.5%) and (49.5%) with only small white specks more scattered on the leaflets and stipules. In contrasts, varieties Bursa showed moderately susceptible and local variety showed high score or susceptible reaction respectively with the whole plant being covered with white powdery mass of mycelium and conidia that was recorded from untreated plots. Disease development on Burkitu and Adi appeared to be slower at all the stages of the infection as compared with the susceptible varieties. Resistance and susceptibility were readily distinguishable under the prevailing field conditions. The maximum disease severity reduction 42.9 % was recorded from Burkitu variety followed by Adi (40.58%) and Bursa (30.6%). The minimum disease severity reduction 33.74 was also recorded from the local variety (Table 8 Appendix Fig.16). Data indicates from the mean of all fungicides that, the maximum powdery mildew severity was observed in untreated (54.67%) followed by Metalaxyl8% + Mancozeb64% WP (41.67%) and Tredimefon25%WP (28.17%). Minimum powdery mildew severity was observed in fungicide Deficonazole25%EC (23%) (Table 9). Therefore, the higher disease severity reduction was recorded from Deficonazole25%EC (59.88%) followed by Tredimefon25%WP (52.03%) and Metalaxyl8% + Mancozeb64% WP (29.08%).The minimum powdery mildew disease severity reduction was recorded from untreated plots (Table 9).

Table 8: Effects of field pea varieties on powdery mildew disease

Varieties	PSI%	DSR%	AUDPC	rAUDPC	RGYIn%
Bursa	49.50b	30.60b	1592.75a	0.2483a	17.09b
Burkitu	19.00c	42.91a	1221.50b	0.1875b	25.99b
Adi	19.50c	40.58ab	1273.42b	0.1983b	23.78b
Local	59.50a	30.23b	1619.42a	0.2492a	45.63**a
CV%	15.38	33.74	15.65	15.575	79.82
LSD	4.715	10.12	186.13	0.0287	18.95

4.4. Comparative efficacy of fungicides against powdery mildew

The data revealed that all fungicides were significantly reduced the powdery mildew severity in tested field pea varieties. The disease severity recorded at one day before first spray ranged from 2 to 8 % which was very low. The powdery mildew severity increased from its first appearance until the first and second spray which was later significantly reduced and continued in a constant level until 15 days after second spray. At the final observation the disease severity reduced significantly over unsprayed control in all the fungicides tested. Application of fungicide showed significant reduction in per cent disease severity with maximum reduction in Deficonazzol25% (59.88%) followed by Tridemifon25% (52.03%) and Metalaxyl8% + Mancozeb64% (29.08%) (Table 9). The mean disease severity was reached with respect to different fungicides and including the control ranged from 23.0 to 54.67 per cent. As far as effect of fungicide spray, Metalaxyl8% + Mancozeb64% was least significantly effective on disease severity as compared to other tested fungicides, and recorded 41.67 per cent powdery mildew severity, respectively (Table 9).

Among the fungicides tested, Deficonazole25%EC and Tredimefon25%WP were found the most effective fungicides with least disease sign and symptoms and average disease severity 23 % and 28.17% which were 41.67% and 54.67% lesser than Metalaxyl8% + Mancozeb64% WP and control, respectively (Table 9 and Fig 10). This current result was supported by the findings of Tripathi *et al.* (2003), Hifsa and Shabeer (2005), Shivanna *et al.,* (2006) and Prasad and Dwivedi (2007). Yield obtained in these treatments were 4.94 and 4.76 tonn/ha. Deficonazole25%EC and Tredimefon25%WP also proved to be very effective which were increased the yield recovery by Deficonazole25%EC 91.04% and Tredimefon25%WP 79.34% and had reduced yield loss by reduced the disease severity (Table 10).

Result (Appendix Table 4) obtained on the economics (Cost: Benefit ratio) of the fungicides tested, revealed that all the treatments were effectively and significantly reduced the powdery mildew disease severity and gave better yield over unsprayed control. However, among all the treatments, Deficonazole25%EC and Tredimefon25%WP were found most economical with highest Cost: Benefit ratio (Appendix Table 4). However, all fungicides were statistically significance different over control. Several workers also reported the effectiveness of Triadimefon against the powdery mildew pathogen on different crops. Naik and Nagaraj (2000) revealed that Carbendazim, Penconazole, Tridemorph, and Triadimefon were effective in reducing powdery mildew and this support the present finding. Among different treatments, application of Triadimefon showed the highest increase in the yield over untreated control.

Table 9: Effects of fungicides against powdery mildew disease

Fungicides	PSI%	DSR%	AUDPC	rAUDPC	RGYIn%
Tr.25% WP	28.17c	52.0a	1341.42b	0.209b	44.023a
M+M	41.67b	29.1b	1418.5b	0.221b	17.863b
Defi.25% EC	23.00d	59.9a	1152.17c	0.178c	50.036a
UP	54.67a	3.3c	1795.0a	0.276a	0b
CV%	15.38	33.74	15.647	15.575	79.82
LSD	4.715	10.12	186.13	0.0288	18.67

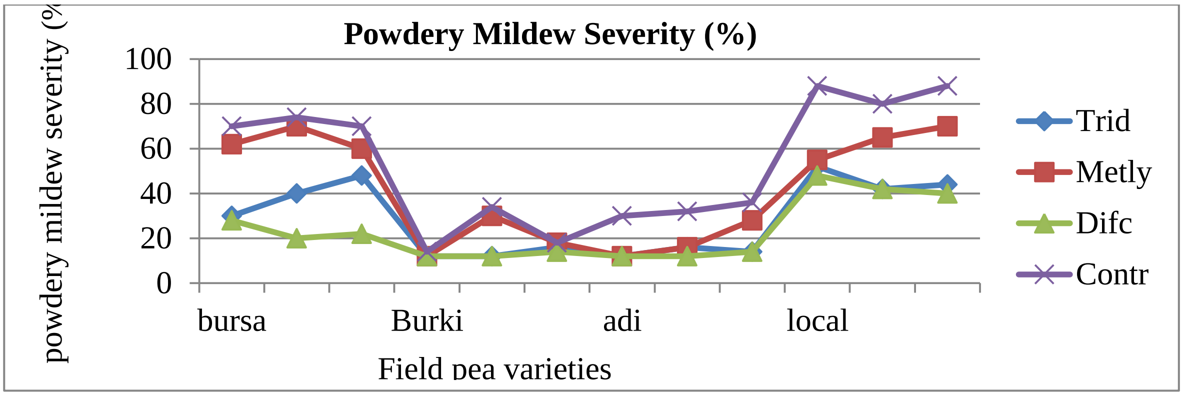

Figure 10: Interaction effects of fungicides & varieties on disease severity

The yield loss that was incurred for each of the fungicide were calculated relative to the yield of maximum protected plots i.e. from Deficonazol25%EC fungicide spray the minimum average yield loss were recorded (2.66%) followed by Triadmefon25%WP (6.67%) and Metalaxyl8%+Mancozeb64%WP (22.57%) in the increasing order (Table 10). The highest levels of yield loss 31.18% occurred in the unsprayed treatment as compared to the best protected plots sprayed with Deficonazol25%EC and Triadmefon25% WP fungicides. The current finding was supported by Jarial and Sharma (2005) chemical control of the disease has been reported to be effective if applied at proper time (Jarial and Sharma, 2005), Shabeer *et al*. (2006) data on disease severity and yield parameters were recorded and percent loss in grain yield 16.3, Girija *et al*., 2011) Triadimefon25%WP and mancozeb75%WP were found significantly superior to Myclobutanil10% WP (Systhane) in reducing the powdery mildew and Teshome and Tegegn (2017) the maximum loss in grain yield (21.09%) was obtained from plots without any fungicide treatment while the lowest loss of 8.53% was recorded from plot received a fungicide treatment at every 14 days interval; where loss of 17.61% was recorded from plot treated with a fungicide.

Table 10: Loss in yield and yield components as a function of fungicides

Fungicides	LPH %	LPPP %	LGPP %	LGPPt %	LTSW %	RGYL %	RGY In%	YR (%)
Tr	4.49b	4.83c	7.81c	8.2c	4.33b	6.67b	44.0a	79.3a
M+M	13.11a	16.24b	19.6b	21.8b	9.73a	22.57a	17.9b	28.4b
Def	5.93ab	1.08c	0.83d	1.52c	0.93b	2.66b	50.0a	91.0a
UP	14.19a	23.61a	33.6a	32.8a	12.46a	31.18a	0b	8.3b

PH= plant height, GPP= grains per pod, PPP= pods per plant, TSW= thousand seeds weight, GPPt= number of grains per plant, GYPH= grain yield per hectare (qt), RGYL%= relative grain yield loss, YR=yield recovery, DSR%= disease severity reduction, Tr = Tredimefon25% WP, M+M = Metalaxyl8%+Mancozeb64%WP, Def = Deficonazol25% EC and UP = Untreated plot.

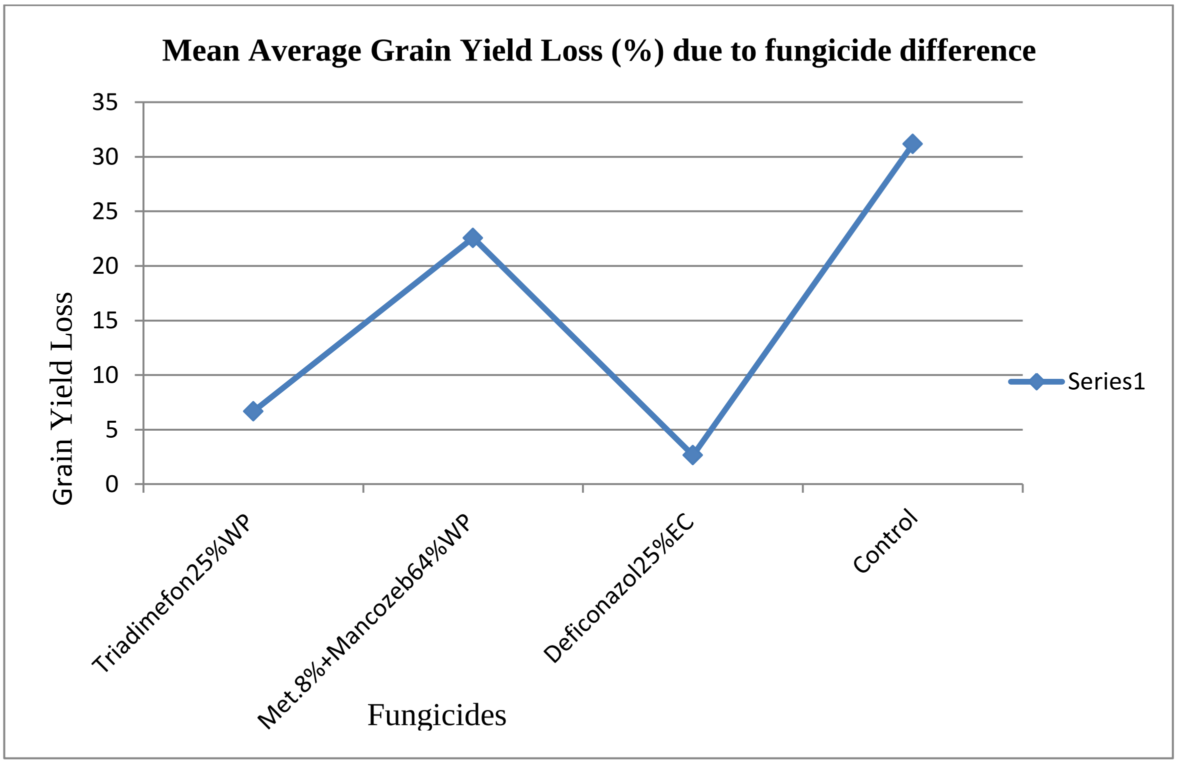

Figure 11: Mean average grain yield loss (%) due to differenct fungicides

As shown in the present study, yield loss due to field pea varieties was recorded from 10.58% to 21.41% and this is similar with the findings of Amare and Beniwal, (1988), Powdery mildew has been reported to be the major field pea disease in the mid-altitudes and may reduce yields by 20-30% under moderate severity. The maximum average yield loss was recorded from local variety (21.41%) followed by Bursa (17.49%) and Adi

(13.59%) in the decreasing order (Table 11 and Fig 12). Similar findings (Teshome and Tegegn, 2017) insured that 21.09% of yield losses have been reported due to powdery mildew severity on local field pea cultivar from plot without fungicide application at Sinana South Eastern Ethiopia. The current finding was supported by Dereje Gorfu, 2000, Vasudeva, 1960, Doxon, 1978, Shabeer *et al*, 2006, Mhamood *et al*, 1983 and similar findings were achieved by (Munjal *et al*. 1963), who indicated that the disease affects pea plants in several ways: it has a negative influence on plant weight and height and may cause plant death, thus reducing yield by as much as 25-30%.

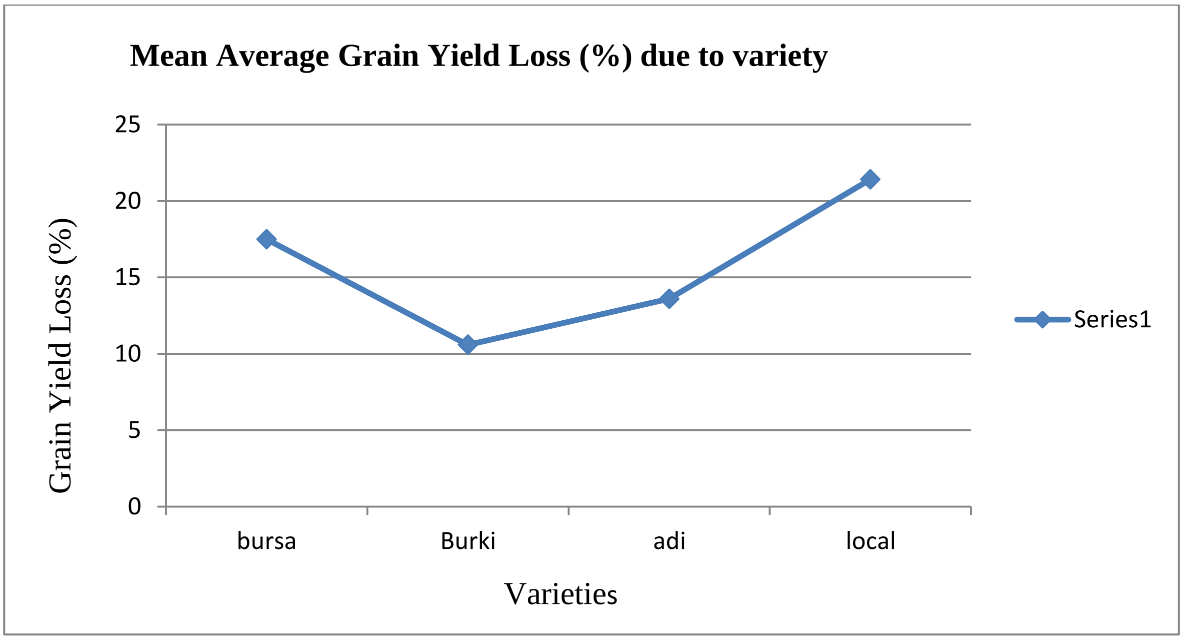

Figure 12: Grain yield loss (%) due to field pea varieties difference

The minimum loss of plant height was recorded from Triadmefon25% WP (4.5%) followed by Deficonazol25%EC (5.9%) and Metalaxyl8%+Mancozeb64%WP (13.18%). The highest loss of plant height was recorded from the control (14.19%) (Table 10). This result is supported by Alam *et al*., (2007) also find similar results considering plant height of field pea and stated that the highest plant height was observed in fungicide treated plots and lowest plant height was obtained from control plots.

The losses of pods per plant recorded that treated by different fungicides were presented in (Table 10). The mean number of losses of pods per plant ranged from 1.08% to 23.61% due to the difference of fungicides and also the loss of pods due to variety difference ranged from 10.58% to 21.41%. From the untreated, Metalaxyl8%+Mancozeb64%WP, Triadmefon25% WP and Deficonazol25%EC treatments, 23.61%,16.24%, 4.83% and

1.08% loss of average pod per plant was recorded respectively. The maximum loss of pods per plant 23.61% was recorded from the untreated. The minimum number of loss of pods per plant (1.08%) was counted from Deficonazol25%EC (Table 10). This result is similar with (Munjal, and Hora, 1963) findings who have recorded the losses in number of pods/plant from 100% infected crops were estimated to about 21% to 31%. Similarly, the highest loss in number of seeds per plant (36.29%) was from a plot without fungicide treatment; while the lowest (10.60%) was from plot treated with a fungicide and followed by Metalaxyl8% + ancozeb64% (16.24%) treated plots. Deficonazol25% and Tredimefon25% shows low in loss of pods per plant (1.075% and 4.83%), respectively due to the effective disease severity reduction ability of both fungicides *i.e* Deficonazol25% (59.88%) and Tredimefon25% (52.03%) respectively than Metalaxyl8% + ancozeb64% (29.07%) and untreated plots (3.33%) (Table 9). In addition to (Munjal, and Hora, 1963) the current finding was also supported by Teshome and Tegegn (2017) that the highest loss in number of pod per plant (31.59%) was recorded from plot with no fungicide spray while the lowest loss (11.91%) was from plots treated with fungicides, but this Finding has high result numerically than the current result, and this is because, there was high moisture content due to sufficient rain fall to full growing season of field pea. So, this makes unfavourable condition to the fast development rate of powdery mildew. Shabeer *et al*. (2006) data on yield parameters were recorded and percent increase in disease severity was 18.37, and percent loss in number of pods/plant 22.6% and this result is similar with the current findings. Similarly, this result agrees with (Prasad and Dwivedi, 2007) severe infection may result in 21-30% reduction in pod number. The loss of pods per plant was incurred for each of the varieties were calculated relative to the pods per plant of maximum protected plots i.e. from local variety, the maximum average loss of pods per plants were recorded (14.48%) followed by Bursa (14.31%) and Burkitu (9.1%) in the decreasing order (Table 11). The lowest levels of loss of pods per plant 7.92% recorded from Adi variety as compared to the listed varieties (Table 11**)**.

The current finding consistent with (Prasad and Dwivedi, 2007) severe infection may result in 21-30% reduction in pod number and up to 70% reduction in total yield and the disease can cause 25–50% yield losses (Munjal *et al*. 1963; Warkentin *et al*. 1996). Hence, the second highest yield loss was recorded from plots sprayed with Metalaxyl8%+Mancozeb64%WP application. Therefore, overall use of new released cultivars would potentially reduce losses due to powdery mildew, reduce the cost of crop protection and reduce the risks of fungicide resistance strain appearance in field pea production. The losses of grains per pods recorded that treated by different fungicides were presented in Table 10). The mean number of losses of grains per pods ranged from 0.83% to 33.63% due to the difference of fungicides and also the loss of grains per pods due to variety difference was ranged from 11.58% to 19.27%. The loss of grains per pods was incurred for each of the varieties were calculated relative to the grains per pods of maximum protected plots i.e. from local variety, the maximum average loss of grains per pods were recorded (19.27%) followed by Bursa (17.78%) and Adi (13.25%) in the decreasing order. The lowest levels of loss of grains per pods 11.6% recorded from Burkitu variety as compared to the other varieties (Table 11). From treatments of untreated, Metalaxyl8%+Mancozeb64%WP, Triadmefon25% WP and Deficonazol25%EC treatments, 33.63%,19.61%, 7.81% and 0.83% loss of average grains per pods was recorded respectively. The maximum loss of grains per pods 33.61% was recorded from the untreated. The minimum number of loss of grains per pods (0.83%) was counted from Deficonazol25%EC (Table 10).

Table 11: Yield and yield component loss due to field pea varieties

Var.	LPH %	LPPP %	LGPP %	LGPPt %	LTSW%	PSI%	DSR%	RGYL %	YR (%)
Bursa	8.5a	14.3	17.8a	20.74a	8.3a	49.5b	30.6b	17.49a	35.97
Burkit	7.2a	9.1a	11.6b	19.5a	7.8a	19.0c	42.9a	10.58a	59.99
Adi	8.7a	7.9a	13.3ab	10.05b	4.9a	19.5c	40.6ab	13.59a	58.33
Local	13.4a	14.5a	19.3a	14.05ab	6.4a	59.5a	30.2b	21.41a	52.80a

Var. = varieties, LPH= Loss of plant height, LGPP= loss of grains per pod, LPPP= loss of pods per plant, TSW= thousand seeds weight, GPPt= number of grains per plant, GYPH= grain yield per hectare (qt), PSI%= severity, AUDPC= area under disease progress curve, RGYL%= relative grain yield loss and DSR%= disease severity reduction

The highest (20.74%) losses of grains per plant were recorded from the Bursa variety followed by Burkitu variety (19.45%) and local variety variety (14.05%); whereas the lowest (10.05%) losses of grains per plant were recorded from the Adi variety (Table11). The fungicides spray was highly significant differing from each other in the average losses of grains per plant. The highest (33.63%) losses of grains per plant were recorded on the untreated (no sprayed treatments) followed by Metalaxyl8%+Mancozeb64%WP (19.61%) and Triadmefon25%WP (7.81%); whereas the lowest (0.83%) losses of grains per plant were recorded on Deficonazole25% EC treated plots due to the effective disease severity reduction ability of both fungicides *i.e.* Deficonazol25% (59.9%) and Tredimefon25% (52.03%) respectively than Metalaxyl8% + ancozeb64% (29.1%) and untreated plots (3.33%) (Table 9). The current finding was supported by Shabeer *et al*. (2006) data on yield parameters were recorded 16.7 percent loss in number of grains/pod when the disease severity reaches on 18.37%.

The highest (8.33%) losses of thousand seeds weight were recorded from the Bursa variety followed by Burkitu variety (7.8%) and local variety (6.4%); whereas the lowest (4.9%) losses of thousand seeds weight were recorded from the Adi variety (Table 11). The varieties were not significant differing from each other in the average losses of thousand seeds weight. The highest (12.46%) losses of thousand seeds weight were recorded on the untreated (no sprayed treatments) followed by Metalaxyl8%+Mancozeb64%WP (9.73%) and Triadmefon25%WP (4.33%); whereas the lowest (0.93%) losses of thousand seeds weight were recorded on Deficonazole25% EC treated plots and had significance difference among fungicides(Table 10). The result of this study supported by the finding from different experiments; the disease can cause 25% to 50% yield losses (Munjal *et al*. 1963; Warkentin *et al*. 1996).], A finding from (Dixon, 1987) also supports this result, he found from his study that from a heavily infested plot with powdery mildew disease and with no any treatment; the pathogen has caused up to 50% yield losses and reduced pod quality significantly. In the same manner, (Teshome and Tegegn, 2017) the maximum loss in grain yield (21.09%) was obtained from plots without any fungicide treatment while the lowest loss of 8.53% was recorded from plot received a fungicide treatment at every 14 days interval. In general, on the parameters from data were indicate that Deficonazol25%EC and Triadmefon25%WP (systemic fungicides) at the company recommendation rate (0.5kg/ha) were effective with two times spray. Whereas, Metalaxyl8%+Mancozeb64%WP (systemic fungicide) depending on the company recommendation rate (1.5kg/ha) would have less efficacy to reduce the powdery mildew epidemics. Mahmood *et al.* (1983) noted 10.1-18 percent yield losses in 8 varieties of garden pea due to infection of *Erysiphe polygoni*. Dereje Gorfu, (2000) Yield loss on field pea due to powdery mildew were reported to be 50-75% in USA, 45% in England, 33% in Canada and 20-53% in Ethiopia. Prasad and Dwivedi, (2007) severe infection may result in 24-27% reduction in pod weight, 21-30% reduction in pod number and up to 70% reduction in total yield. Nisar *et. al*. (2006) the pathogen causes up to 50 % losses and reduces pod quality.

Table 12: Loss in yield and yield components as a function of disease

Varieties	Fungicide	LPH%	LPPP%	LGPP%	LGPPt%	LTSW%	LGYPH%	YR%
Bursa	Tr	7.433ab	11.57bcd	6.53c	9.33de	1.93e	6.83cde	69.42abc
	M+M	11.03ab	15.07abcd	28.2ab	27.0abc	10.87abcd	30.77ab	5.54d
	Def	12.20ab	0.0d	3.3c	6.07de	2.17def	8.57bbcde	80ab
	UP	3.433b	30.60a	33.07ab	40.57a	18.37a	23.80abcd	0.0dc
Burkitu	Tr	2.50b	2.03cd	4.70c	13.73cde	8.97bcde	1.37de	94.29ab
	M+M	9.63ab	16.70abc	12.27c	30.27abc	11.70abc	12.93bcde	28.2bcd
	Def	0.47b	0.0d	0.0c	0.0e	0.0f	2.07de	84.14ab
	UP	16.0ab	17.47abc	29.37ab	33.80ab	10.33abcde	25.97abc	33.33abcd
Adi	Tr	5.70ab	0.23d	8.83c	3.167de	3.70cdef	9.37bcde	75.0ab
	M+M	13.33ab	10.87bcd	11.83c	9.93de	8.47bcdef	15.63bcde	58.33abcd
	Def	1.97b	4.3cd	0.0c	0.0e	0.0f	0.0e	100a
	UP	13.80ab	16.27abc	32.33ab	27.10abc	7.57bcdef	29.37abc	0.0d
Local variety	Tr	2.33b	5.47cd	11.17c	6.37de	2.70def	9.10bcde	78.64ab
	M+M	18.80ab	22.33ab	26.13b	20.17bcd	7.90bcdef	30.93ab	32.57abcd
	Def	9.10ab	0.0d	0.0c	0.0e	1.57ef	0.0e	100a
	UP	23.53a	30.10a	39.77a	29.67abc	13.57ab	45.60a	0.0cd

Means within the same column followed by the same letter(s) are not significantly different, LSD (0.05) = Least significant difference at P≤0.05, Def= Deficonazol25% EC, Tr=Tredimefon25%WP, M+M= Metalaxyl8%+Mancozeb64%WP, UP=untreated plots, applied with the indicated the three fungicide sprays, LPH%=loss of plant height, LPPP%= loss of pods per plant, LGPP%= loss of grains per pod, LGPPt = loss of pods per plant, LTSW%= loss of thousand seed weight, LGYPH% = loss of grain yield, YR%= yield recovery and DSR% = disease severity reduction

4.5. Correlation among Disease Parameters, Yield and Yield Components

Disease severity values assessed on plots treated with different fungicide treatments had highly significant ($P \leq 0.01$) and negative correlation ($r = -0.7934$) with total grain yield per hectare, ($r = -0.7397$) pods per plant and ($r = -0.723$) with grains per pod, respectively (Table13). This indicates that the observed levels of the disease had a considerable adverse effect on total grain yield per hectare, pods per plant and grains per pod of the crop. Thousand-seed weight was also significantly ($P \leq 0.05$) and negatively associated ($r = -0.6923$) and had moderate down-hill relation-ship with powdery mildew severity. Depending on the result, due to the negative association of powdery mildew severity, with the parameters of yield traits (pods per plant, grains per pod, grains per plant and thousand seeds weight) had contribution to the losses of grain yield. However, strong down-hill correlation relation-ship (-0.7934) was observed between disease severities and grain yield per hectare. Disease severities ($r = -0.7934$), AUDPCs ($r = -0.7603$) and infection rates ($r = -0.7522$) in general had higher negative correlations with grain yield per hectare. Likewise, correlations between pods per plant values with the disease severity ($r = -0.7397$), AUDPC ($r = -0.7368$) and rAUDPC ($r =-0.7378$) were highly significant and negatively correlated that shows strong down-hill relationship. The association between grains per pod with disease severity ($r = -0.723$), AUDPC ($r = -0.7593$) and rAUDPC ($r = -0.7551$) were also strong down-hill (negative) linear relationship. In general, the correlation coefficients observed to disease severity with crop yield relationship were higher than that of the relation-ship between AUDPC and crop yield. This result supported by Alam *et al*., (2007) found a significant negative correlation between PDI of powdery mildew and yield (kg ha-1), which indicated that with the increase of PDI of powdery mildew there was a progressive fall in the yield. Since grain yield per hectare had highly significant positive correlation (strong up-hill relation-ship) (r = 0.8373 and 0.7139) with grains per pod and pods per plant, $P \leq 0.01$) respectively grain yield with each other.

Thousand seed weight (r = 0.6671) had moderate up-hill (positive) relationship with grain per pod. The strong negative correlation observed between disease parameters and total grain yield and other yield parameters would indicate the extent to which the disease may affect grain yield of the crop. Kim and Brewbaker (1976) reported that grain yield is significantly correlated with thousand-grain weight. Thus a significant effect of the disease on thousand-grain weight can result in a considerable reduction in grain yield of the crop. On the other hand, the correlations observed between disease parameters (severities, AUDPC values and infection rates) were positive (strong up-hill) relation-ship. This means correlation coefficient (r = 0.8351) between severity and AUDPC was highly significant and strong positively related at $P \leq 0.01$ (Table 13). This indicates that although the area under the disease progress curve was steadily increasing, the rate of infection is expected to slow down after disease has reached higher severity levels. It is a well-established fact that the availability of healthy plant tissue for infection limits the further development of epidemics; as epidemics progresses less plant tissue will be available for further infection and the rate of epidemic development trails off (Freedman and Mackenzie, 1992).

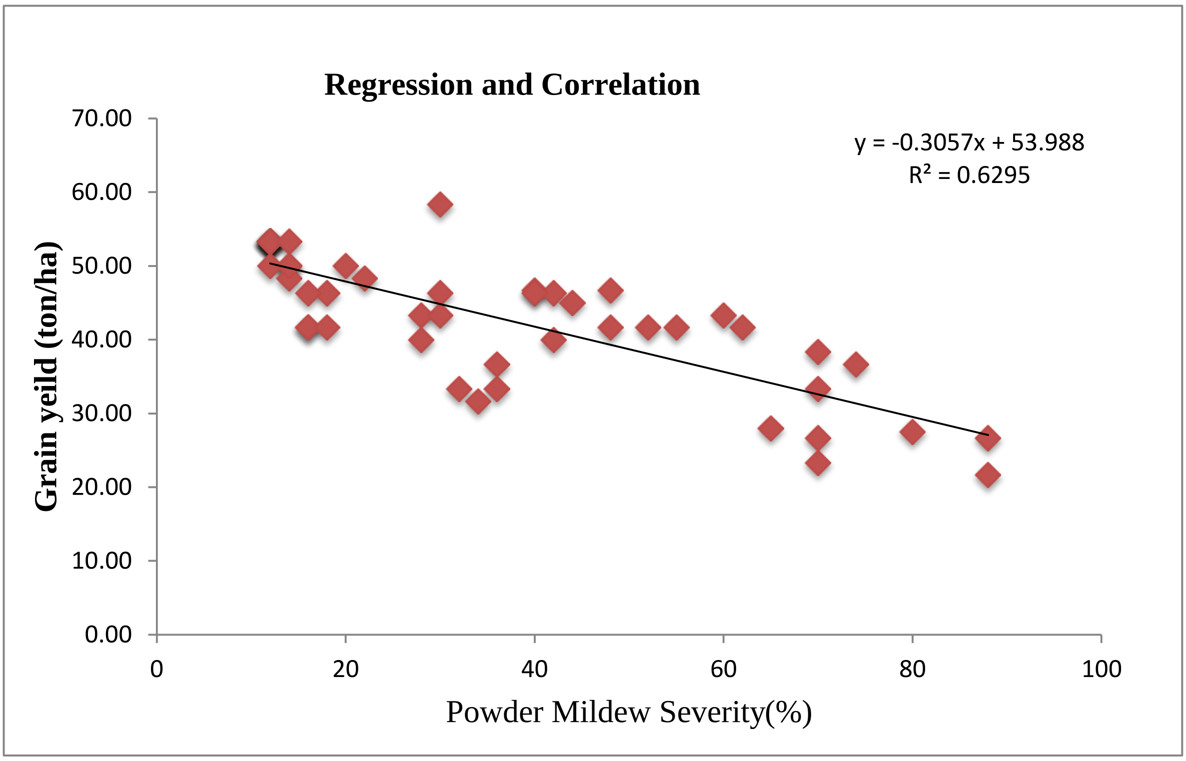

Figure 13: Regression and Correlation chart

Table 13: Correlation coefficients (r) of yield, yield components & disease

	PH	*PPP*	*GPP*	*TSW(gr)*	*HD*	*GYPH (t/ha)*	*PSI*	*AUDPC*	*rAUDPC*	*RGYI (%)*	*DSR (%)*	*RGYL%*	*GPPt*
PH	1												
PPP	0.1487	1											
GPP	0.2014	0.671	1										
TSW(gr)	0.4421	0.576	0.532	1									
HD	0.4659	0.098	0.057	0.639	1								
GYPH(t/ha)	0.277	0.714	0.837	0.667	0.186	1							
PSI	-0.056	-0.740	-0.723	-0.693	-0.1094	-0.7934	1						
AUDPC	-0.142	-0.737	-0.759	-0.530	-0.0038	-0.7603	0.835	1					
rAUDPC	-0.127	-0.738	-0.755	-0.518	0.018	-0.7522	0.836	0.998	1				
RGYI (%)	0.253	0.346	0.4802	0.014	-0.327	0.572949	-0.306	-0.4807	-0.4798	1			
DSR (%)	0.312	0.732	0.769	0.48842	0.0147	0.799704	-0.732	-0.7443	-0.7403	0.6409	1		
RGYL%	-0.279	-0.602	-0.7684	-0.5436	-0.0727	-0.92438	0.657	0.6807	0.6731	-0.636	-0.775	1	
GPPt	0.2526	0.739	0.8086	0.5553	0.1603	0.767564	-0.645	-0.6392	-0.637	0.3355	0.7079	-0.632	1

**Correlation is significant at the 0.05 level (one tailed; ** Correlation is significant at the 0.01 level (one tailed); ns refers to non-significant level at P < 0.05; PH = plant height; PPP= pods per plant; GPP= grains per pod; HSW= hundred seed weight; TGYPH= total grain yield in quintal; PSI= disease severity; AUDPC = area under disease progress curve; RGYL% = relative grain yield loss; DSR= disease severity reduction; GPPt = grains per plant.*

4.6. Cost-Benefit Analysis

Partial budget analysis indicated that the systemic fungicide Metalaxyl8% + Mancozeb64% WP had the highest total cost but the unsprayed plots had the lowest cost. On variety Bursa the computed value for partial cost benefit showed that the highest (ETB 112,687ha-1) net profit with marginal rate of return (MRR) 1,659% obtained from plots sprayed with Tridemefon25% WP. The lowest (ETB 81,589.6 ha-1) net profit with marginal rate of return (MRR) -100% obtained from plots sprayed with Metalaxyl8% + Mancozeb64% WP (Appendix Table 4). On the field pea variety Burkitu the highest (ETB 117,632.2ha^{-1}) net profit with marginal rate of return (MRR) 2,120% obtained from plots sprayed with Tridemefon25% WP. The lowest (ETB 89,427 ha^{-1}) net profit obtained from unsprayed plots (Appendix Table 4). The field pea variety Adi sprayed with Deficonazol25% EC gave the highest (ETB123, 494.8 ha^{-1}) net profit with marginal rate of return (MRR) 2,230% compared to other fungicides. The lowest (ETB 94,629.6 ha^{-1}) net profit obtained from the variety unsprayed plots (Table 14 and Appendix Table 4). On local field pea variety sprayed with Deficonazol25% EC gave the highest (ETB107, 369.6 ha-1) net profit with marginal rate of return (MRR) 3,707.6% compared to other fungicides. The lowest (ETB 59,170.8 ha-1) net profit obtained from the variety unsprayed plots (Appendix Table 4). Generally Deficonazol25% EC and Tridemefon25% WP fungicide application were gave highest net profit for the respective field pea varieties and they are economical than Metalaxyl8% + Mancozeb64% WP.

Table 14: Cost-benefit analysis of spray fungicides and field pea varieties

SF	Yield ton/ha	AjY (ton/ha)	P(ETB/qt	GFB (ETB/ha)	TC (Br/ha)	ΔC (Br/ha)	NP (Br/ha)	ΔNB(Br/ha)	MRR (%)
Tr25% WP	4.76	4.29	2600	111,540	1700	1700	111,370	31,646	1862
M8%+ M64%	3.98	3.58	2600	93,132	2900	2900	90,232	10,508	362.4
Def25 %EC	4.94	4.45	2600	115,572.6	1300	1300	114,272	34,549	2658
UP	3.41	3.01	2600	79,723.8	0	0	79,724	0	0

SF = Spray Fungicide; GFB = Gross field benefit; TC = total cost; ΔC =change in cost; NP=net profit; ΔNB = change in net benefit; MRR = marginal rate of return: Def25%EC =Deficonazole25%EC,Tr25%WP=Tredimefon25%WP,Met.l8%+Man.64%WP=Metalaxyl 8% + Mancozeb64% applied;

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

Field pea is the major pulse crop grown in the highlands of North Showa next to Faba bean. However, Powdery mildew (*Erysiphe polygoni*) has put field pea productivity under question. This study will better contribute towards the management of field pea diseases, particularly of powdery mildew, which is most important disease of field pea at highlands of North Showa, Ethiopia but no one who give attention to control of this disease in the past years. The types of fungicides have made a statistically significant difference on field pea productivity. For the better management of field pea powdery mildew disease, based on disease pressure and the prevailing environmental condition two times spray of fungicides of Triadmefon25%WP and Deficonazol25% EC within 7 days interval after the disease development was recommended.

The two fungicides *i.e* Deficonazol25% EC and Triadmefon25%WP have exhibited better role to disease severity reduction and also proved to be very effective which were increased the yield recovery . Due to this result, fungicides improve the plant height, pods per plant, grains per pod, grains per plant, thousand seeds weight and grain yield per hectare by reducing the impacts of powdery mildew on the field pea varieties. Field pea varieties under Deficonazol25% and Triadmefon25%WP could withstand infestation better than both of the Metalaxyl8% + Mancozeb64% WP and untreated varieties and all fungicide treated plots were highly significantly superior ($p<0.05$) to that of the untreated (control) plots.

On the other hand, the density (invasion) of powdery mildew and level of infestation were higher on local variety plots and on Bursa. Generally, Burkitu and Adi varieties have more or less numerically nearby due to their ability of disease severity reduction. This result shows statistically highly significantly difference at ($p<0.05$) among the all field pea varieties on powdery mildew disease severity. Therefore, the local verity was susceptible and also Bursa was moderately susceptible whereas Burkitu and Adi were moderately resistant varieties. The higher grain yielder varieties with powdery mildew infection were Burkitu and Adi ultimately by reducing the disease infestation. The highest mean total grain yield obtained from both the varieties of Burkitu, and Adi, as compared to local variety. The maximum net benefit obtained from the varieties of Adi, and Burkitu, respectively. This is due to their better productivity and the ability of disease tolerance.

5.2. Conclusion

In this study, four varieties and four fungicides (including control) were compared. Results have revealed that the two varieties (Burkitu and Adi) and fungicides application consistently reduced powdery mildew severity increased the yield correspondingly. Powdery mildew is fully capable of causing significant reductions in yield and grain yield parameters. Powdery mildew can be controlled with resistance varieties or fungicides. The types of fungicides application required to manage powdery mildew in the most economical manner are important for efficient control of the disease. Generally, fungicides may not be accessible or affordable for small-scale farmers of Ethiopia. However, fungicide application may be imperative for hybrid seed producing companies and in areas with high powdery mildew disease pressure. Variety selection is a major disease management decision as well, because it determines the potential for diseases to reach various levels of severity under favourable conditions. This study revealed that Burkitu and Adi were moderately resistant to powdery mildew and had good yields exceeding the yields of local field pea variety tested. Use of these resistant varieties may reduce or eliminate the need for fungicides control and this should be a prime consideration whenever possible. The performance of Bursa and local varieties tested in the present study was not satisfactory and varieties with moderately susceptible to powdery mildew and other desirable features should be sought for the specific purpose they are utilized for.

The result of this study showed that, high powdery mildew disease epidemics (AUDPC values) of 2334.67, 1942, 1487.67and 1408.67-%unit-days) exhibited on unsprayed plots of the varieties of Local, Bursa, Burkitu and Adi, respectively. Thus it caused considerable yield loss (45.55%, 26.13%, 25.06% and 24.17%) on unsprayed plots of the varieties Local, Bursa, Burkitu and Adi, respectively, as compared to the best protected plots sprayed with Deficonazol25% EC and Triadmefon25%WP. Therefore, production of field peas in all studied varieties including Burkitu and Adi which were previously reported as moderately resistant and should be supplemented with fungicide spray. Thus the use of application of Deficonazol25% EC and Triadmefon25%WP fungicides are recommended as it gave the best protection against powdery mildew and the best monetary benefit as compared to the other treatments *i.e* the maximum net benefit also obtained from the fungicides Deficonazol25% EC (ETB-114,272.6 ha^{-1} and Triadmefon25%WP (ETB-111,370 ha^{-1}) in descending order, respectively.

5.3. Recommendations

As a result of the data the distribution and occurrence of powdery mildew infection levels varies treatment to treatment, and season to season, as a result more survey in different locations at different seasons may be very important. In the present study, the infection of powdery mildew has already generated. Two powdery mildew management strategies can be developed to manage *Erysiphe polygoni* infection in the field. The use of resistant field pea varieties to *Erysiphe polygoni* and environmentally adapted different stress has been considered as an economical and effective means of reducing powdery mildew infection. The use of resistant varieties is simple, cheap, environmentally safe, and can also be readily adopted by the small scale Farmers rather than using fungicides. Depending on the present findings, the fungicides used to control powdery mildew disease by small scale farmers are expensive and some of them are not effective to the target disease as Metalaxyl8% + Mancozeb64% WP. Environmental and residue problems are also other drawbacks of fungicides. Farmers should be advised to implement all possible powdery mildew disease control methods such as use the two best moderately resistant varieties (Burkitu and Adi) before use of the two best fungicides (Deficonazol25% EC and Triadmefon25%WP) as the present research finding to minimize the drawback of fungicides on environment. To do this, farmers should be get advice from researchers and agriculture extension workers to implement resistant variety selection to control powdery mildew before using fungicides. The following recommendations for future work:-

- The biology, distribution and pest status of *Erysiphe polygoni* should be studied.
- Surveys species compositions of powdery mildew in other field pea growing areas should be conducted.
- To develop sound IDM against field pea powdery mildew other control alternatives, which can be integrated with the use of fungicides and resistance varieties should be developed.
- The use of fungicides and variety selection as powdery mildew control should be communicated to field pea growers through extension systems such as stalk-holders training.
- Further studies on the effect of fungicides and varieties should be made.
- Epidemiological studies on powdery mildew disease should be carried out for the future.

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7. APPENDIX

7.1 Appendix I. Analysis of Variance Table

Appendix Table 1: ANOVA for powdery mildew antagonists on yield & yield components

Source	Df		Sum of mean squares of different yield and yield trait					
		PH	PPP	GPP	TSW	HD	GPPt	GYPH (ton/t)
var	3	1831.3 **	37.8 *	1.8**	8796.3***	825.9***	1429.0*	249.1***
fug	3	1465.3 **	82.8 ***	7.8** *	2451.6***	2.47ns	5204.1 ***	595.8***
V*F	9	132.3n	3.4n	0.1ns	256.14ns	2.75ns	139.9ns	20.54 ns
Eror	30	237.98	8.5	0.35	128.56	3.875	396.5	33.97
CV		7.9	14.2	11.78	4.607	1.305	16.59	13.64

PH = plant height, PPP = pods per plant, GPP = grains per pod, TSW = thousand seeds weight, HD = harvesting date and GYPH = grain yield per hectare (qt) of field pea

Appendix Table 2: ANOVA for powdery mildew severity on field pea yield

Source	DF		Sum of mean squares of ;				
		PSI%	AUDPC	rAUDPC	RGYI (%)	RYL (%)	DSR (%)
Var.	3	5170.75 ***	521260.47 ***	0.0127 ***	1804.26*	265.6	524.2 ***
Fug.	3	2431.42 ***	861250.0 ***	0.0209 ***	6388.1 ***	2154.2	7769 ***
V* F	9	200.67* **	116793.45 *	0.0029*	450.50ns	132.0	199.3*
Error	30	32.146	50460.94	0.0012	503.99	144.2	148.2
CV%		15.376	15.744	15.575	79.82	76.16	33.74

Df = Degree of freedem, PSI = Per cent severity index, AUDPC = area under disease progress curve, rAUDPC = Rate of diseas infection,RYL = Relative yield loss, RYI = relative yield increase and DSR =Disease severity reduction

Appendix Table 3: Mean square of variance for disease, yield & yield components

D/Brehan						D/Meaza FTC					
Variabl	Variety	Fungicide	V*F	Error	CV (%)	Variety	Fungicide (F)	V*F	Error	CV (%)	EMS
DF	3	3	9	30		3	3	9	30		
PH	1831.3**	1465.3**	132.34ns	237.98	7.8992	749.92ns	178.58ns	257.0ns	274.8	9.55	256.38
PPP	37.76*	82.79***	3.399*	8.4504	14.154	3.375ns	2.1806ns	4.194ns	4.0934	9.69	6.272
GPP	1.8298**	7.8345***	0.116*	0.3472	11.782	0.228ns	0.078ns	0.218ns	0.407	11.98	0.377
TSW	8796.3***	2451.6***	256.1*	128.56	4.6065	141.60ns	109.20ns	230.2ns	205.3	6.70	166.95
HD	825.92***	2.4722ns	2.750*	3.8750	1.3054	813.0***	13.021ns	13.02ns	12.15	2.77	8.0139
GPPt	1429.02*	5204.1***	139.87*	396.49	16.589	1970.7***	1798.8***	721.0*	166.4	5.32	281.42
GYPH	249.08***	595.8***	20.54ns	33.966	13.644	28.289ns	12.94ns	8.471ns	25.84	12.14	29.904
ANB	0.1953ns	0.06088ns	0.0476ns	1.8344	15.231	0.1463ns	0.1547ns	0.091ns	0.10	13.07	0.9675
PSI%	5170.8***	2431.4***	200.7***	32.146	15.376	-	-	-	-	-	-
AUDP	521260.46	861250.02	116793.4	50460.94	15.744	-	-	-	-	-	-
RGYL	265.606	2154.208	132.032	144.23	76.161	-	-	-	-	-	-
DSR%	524.18***	7769.0***	199.34ns	148.18	33.739	-	-		-	-	-

Appendix Table 4: Cost-benefit analysis of fungicides & field pea varieties

Variety	SF	AjY (qt/ha)	P(ETB/qt	GFB (ETB/ha)	TC (Br/ha)	ΔC (Br/ha)	NP (Br/ha)	ΔNB(Br/ha)	MRR (%)
Bursa	Tredi.25% WP	43.992	2600	114,387	1700	1700	112,687	28,197.4	1,659
	Met.l8%+Man.64%WP	32.508	2600	84,489.6	2900	2900	81,589.6	-2,900	-100
	Defi.25% EC	42.498	2600	110,494.8	1300	1300	109,194.8	24,705.2	1,900
	Untreated plot	32.508	2600	84,489.6	0	0	84,489.6	0	0
Burk.	Tredi.25% WP	45.891	2600	119,332.2	1700	1700	117,632.2	28,205.2	1,659
	Met.l8%+Man.64%WP	40.500	2600	105,300	2900	2900	102,400	12,973	447
	Defi.25% EC	45.495	2600	118,294.8	1300	1300	116,994.8	27,567.6	2,120
	Untreated plot	34.398	2600	89,427	0	0	89,427	0	0
Adi	Tredi.25% WP	40.497	2600	106,594.8	1700	1700	104,894.8	10,265.2	604
	Met.l8%+Man.64%WP	40.491	2600	105,294.8	2900	2900	102,394.8	7,765.2	268
	Defi.25% EC	47.997	2600	124,794.8	1300	1300	123,494.8	28,865.2	2,220
	Untreated plot	33.894	2600	94,629.6	0	0	94,629.6	0	0
Local Var.	Tredi.25% WP	37.998	2600	98,794.8	1700	1700	97,094.8	37,924	2,230
	Met.l8%+Man.64%WP	28.896	2600	75,129.6	2900	2900	72,229.6	13,058.8	450
	Defi.25% EC	41.796	2600	108,669.6	1300	1300	107,369.6	48,198.8	3,707.6
	Untreated plot	22.758	2600	59,170.8	0	0	59,170.8	0	0

Appendix Table 5: Mean rain fall and temperature from 2010 to 2019

				Altitude M asl	
Year (G.C)	T min (^{0}C)	T max (^{0}C)	RF (mm)	DARC	DBU
2010	4.8	25.1	739.2	2814	2840
2011	5.1	21.5	1056	2814	2840
2012	2.6	22.8	1367.31	2814	2840
2013	3.2	22.8	1241.77	2814	2840
2014	2.7	21.8	1052.1	2814	2840
2015	2.8	24.7	918.2	2814	2840
2016	6.4	23.8	859.42	2814	2840
2017	4.8	23.9	751.42	2814	2840
2018	4.5	26.1	898.2	2814	2840
2019	3.9	24.7	767.31	2814	2840
Total	40.7	237.1	9650.9	2814	2840
Average	4.068	23.71	965.09	2814	2840

Source: Debre Berhan Agricultural Research Centre, 2020

7.2. Appendix II. List of figures in the appendix

Appendix Figure 1: Bursa variety and Triadmefon25% WP fungicide sprayed plots

Appendix Figure 2: Bursa variety and Metalaxyle8%+Mancozeb64% WP sprayed plots

Appendix Figure 3: Bursa variety and Deficonazol25% EC sprayed plots

Appendix Figure 4: Bursa variety and untreated plots with fungicides

Appendix Figure 5: Burkitu variety and Triadmefon25% WP treated

Appendix Figure 6: Burkitu variety and Metalaxyl8%+Mancozeb64% WP sprayed plots

Appendix Figure 7: Burkitu variety and Deficonazol25% EC treated plots

Appendix Figure 8: Burkitu variety and untreated plots with fungicides

Appendix Figure 9: Adi variety and Triadmefon25% WP treated plots

Appendix Figure 10: Adi variety and Metalaxyl8%+Mancozeb64% fungicide treated plots

Appendix Figure 11: Adi variety and Deficonazol25% EC treated plots

Appendix Figure 12: I Adi variety and untreated plots with fungicides

Appendix Figure 13: Local variety and Triadmefon25% WP fungicide treated plots

Appendix Figure 14: Local variety and treated with Metalaxyl8%+Mancozeb64% WP fungicide

Appendix Figure 15: Local variety and treated with Deficonazol25% EC fungicide

Appendix Figure 16: Local variety and untreated with fungicides (Control plots)

Appendix Figure 17: Fungicide drift control method during spraying field trial

Appendix Figure 18: layout and sowing of field pea in spacing

7.3. Appendix III. Field layout of the experimental site

R-I	R-II	R-III
P1= Tr25%WP, BURSA	P32=Control/H_2O, Local	P33= Tr25%WP, BURSA
P2= Defico.EC, Local var.	P31= Control/H_2O, BURKITU	P34= Defico.EC, BURSA
P3= Tr25%WP, BURKITU	P30= Defico.EC, ADDI	P35= Defico.EC, Local Var.
P4= Tr25%WP, ADI	P29= Defico.EC, BURKITU	P36= Defico.EC, ADI
P5=Me8%+ Ma64%, Local	P28= Tr25%WP, Local Var.	P37=Me8%+ Ma64%, BURKIT
P6=Tr25%WP, Local Var.	P27= Defico.EC, BURSA	P38= Tr25%WP, Local Var.
P7= Control/H2O, ADDI	P26= Defico.EC, Local Var.	P39= Tr25%WP, BURKITU
P8= Defico.EC, BURSA	P25=Me8%+Ma64%, Local	P40= Me8%+ Ma64%, BURSA
P9= Control/H_2O , BURKITU	P24= Me8%+ Ma64%, BURSA	P41=Tr25%WP, ADI
P10= Me8%+ Ma64%, ADI	P23= Tr25%WP, BURSA	P42= Control/H_2O, ADI
P11= Control/H_2O, BURSA	P22= Control/H_2O /, BURSA	P43= Control/H_2O, BURKITU
P12= Me8%+ Ma64%, BURSA	P21=Me8%+Ma64%, BURKIT	P44= Me8%+ Ma64%, ADI
P13=Me8%+ Ma64%, BURKIT	P20=Tr25%WP, ADI	P45= Control/H_2O Local v.
P14= Control/H_2O, Local	P19= Tr25%WP, BURKI	P46= Control/H_2O, BURSA
P15= Defico.EC, BURKITU	P18= Control/H_2O ADI	P47=Me8%+Ma64%, Local
P16= Defico.EC, ADI	P17= Me8%+ Ma64%, ADI	P48= Defico.EC, BURKITU

33.5m

16m

Appendix Figure 19: Field layout of the experimental site