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Management of Faba Bean Gall Disease using Cultivars and Fungicides in North Showa Zone of Central Ethiopia

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Abstract – **Faba Bean Gall (FBG) disease has become a serious threat to faba bean production and productivity in major faba bean growing areas of the country causing a yield loss as high as 100%. Since the disease is new and recently reported in the country, information on its epidiomolgy disease intensity as well as its management methods. Therefore, the experiments were carried out to investigate its management using cultivars and fungicides with four spray frequencies. For the assesment of FBG disease management, a total of thirty treatments that included three cultivars (Gora, CS20DK and Local) and fungicides (Bayleton, Chlorothalonil and Ridomil MZ) with four spray frequencies were arranged in a split-split plot design with three replications on farmers' fields at Degem and Mush, North Shoa Zone in 2015 main cropping season. The statistical analysis showed that significant differences among treatments in the FBG incidence, severity and AUDPC value at both locations. On the final date of disease assessment, among the cultivars Gora cultivar recorded the lowest disease incidence of 40.69%, 25.42% and severity of 28.75%, 24.44% at Degem and Mush, respectively, whereas the highest disease incidence of 50.42 and 30.42% and severity of 33.3 and 29.68% were recorded on the local cultivar at Degem and Mush, respectively. The highest reduction on disease severity i.e. 71.69% at Degem and 67.12% at Mush were recorded on three times sprayed plots. At Degem the highest (3058.33%) and the lowest (1469.44 %-days) AUDPC were recorded from unsprayed plots of the local cultivar and Gora cultivar sprayed three times, respectively. Also at Mush, the highest (1916.67%-days) AUDPC value was calculated on unsprayed local cultivar, whereas; the lowest i.e. 902.78 and 916.67%-days AUDPC values were recorded from three times sprayed cultivars of CS20DK and Gora, respectively. The highest (7.57 at Dege and 3.59 at Mush) number of pods per plant were recorded on CS20DK and local cultivars sprayed with Redomil fungicide two and three times in the order mentioned. Also, the highest (2.40 at Degem and 2.68 at Mush) seeds per pod were recorded on local cultivar Redomil sprayed and on local cultivar three times sprayed plots were obtained respectively. At Degem, 1.216 t/ha yield was obtained on Gora cultivar sprayed with Chlorothalonil three times also at Mush 0.981 t/ha was obtained on same cultivar sprayed with Bayleton fungicide three times. The PDI, PDS and AUDPC values were correlated negatively and highly significantly with PP, SP, grain yield and HSW, at Degem but at Mush, they were correlated negatively and significantly with only grain yield while they were negatively and non-significantly correlated with PP, SP and HSW. At Degem, the highest net benefit (Birr 8,189) and marginal rate of return (777.5%) were obtained from three time's sprayed local and CS20DK cultivars, respectively, whereas, at Mush, the highest net benefit of Birr 6,943.5 and marginal rate of return 380.94%, were obtained from Gora cultivar sprayed three times with Bayleton and local cultivar sprayed two times with Redomil fungicide, respectively. The results of the present study provide some evidence on the response of faba bean cultivars, effect of fungicides and spray frequencies on disease intensity reduction and substantial increase on yield. Thus the improved cultivar Gora accompanied with three times spray with Bayeton fungicide could be recommended for the management of FBG disease. However, further evaluations of faba bean genotypes, fungicides and other disease control methods are important. In addition, for the development of sound and successful management, information regarding epidemiology of the disease in the country is a paramount. Thus any research towards this line could be highly appreciated/ recommended.**

Keywords – **AUDPC, Cost benefit, Cultivars, Faba bean, FBG disease, Fungicide, Spray frequencies, Yield.**

I. Introduction

Faba bean (*Vicia faba* L.) also called broad bean, horse bean, tic bean and field bean, is one of the earliest domesticated food legume in the world, probably in the late Neolithic period (Metayer, 2004) after chickpea and pea (Torres *et al*., 2006). It is known as a cultivated plant from the very onset of agriculture and is an important crop until the present (Hanelt, 1972; Zohary and Hopf, 2000). It is a cultivated species belonging to the wild pea genus *(Vicia)* of the Leguminosae family. Faba bean is assigned to the Central Asian, Mediterranean and South American centers of diversity and believe to be a native to North Africa, Southwest Asia and extensively cultivated elsewhere (Harllan, 1969; Zohary and Hopf, 2000). However, Cubero (1974) postulated a near Eastern center of origin, with four radii to Europe, along the North African coast to Spain, along the Nile to Ethiopia and from Mesopotamia to India. Secondary centers of diversity are postulated in Afghanistan and Ethiopia. It is believed that the crop was introduced to Ethiopia from the Middle East via Egypt around 5000 B.C (Asfaw *et al*., 1994).

Faba bean production in the world is concentrated in nine major agro-ecological regions: the Mediterranean Basin, the Nile Valley, Ethiopia, Central Asia, East Asia, Oceania, Latin America, Northern Europe and North America (Bond *et al*., 1985). The Chinese used it for food almost 5,000 years ago, and it was cultivated by the Egyptians 3,000 years ago, by the Hebrews in biblical times, and a little later by the Greeks and Romans (Mihailovic *et al*., 2005; Singh and Bhatt, 2012). In 2013, the worldwide production was 2.3 million metric tons

(Mt); China leads the world production in both area coverage and production. Other major production areas are Ethiopia (0.37 million ha, 0.45 Mt), Egypt (0.14 million ha, 0.44 Mt) and Australia (0.16 million ha, 0.27 Mt) (FOASTAT, 2004). In Europe, faba bean is the second legume crop in area and production, after pea. Europe accounts for 14% of the world area (0.37 million ha) and about 25% of world production (1.2Mt) (Torres *et al*., 2006). In Ethiopia, faba bean is grown as field crop throughout the highlands and is the most common in Woyna Dega (midlands) between the altitudes ranging from 1800-3000 m.a.s.l. where the environmental conditions are most favorable to the growth and productivity of the crop (Asfaw, 1985; Yohannes, 2000). Currently the crop is grown in several regions of the country where the annual precipitation is between 700-1000 mm (ICARDA2006). Faba bean is a grain legume used as a human food and animal feed and plays an important role in the national economy and has high nutritional value. Muehlbauer and Abebe (1997) stated that the whole dried faba bean seeds contain 344 calories per 100 g, 10.1% moisture, 1.3 g fat, 59.4 g total carbohydrate and provides a balanced diet of lysine rich protein, carbohydrates, fiber and phytochemicals (Burstin *et al*., 2011) and essential amino acids (Alghamdi, 2009. It has a potential as a meat substitute in many parts of the world where there is demand for non-animal protein sources. The crop produces the highest percentage of protein (20-41%) per unit land (Crépona *et al*., 2010) area as compared to all other temperate and tropical pulse crops, including lentil (*Lens culinaris*), common bean (*Phaseolus vulgaris*), chickpea (*Cicer arietinum*) and pea (*Pisum sativum*) (FAOSTAT, 2013). The mature seeds also used for feeding livestock, while stalks used as feed for animals and firewood for cooking (Gemechu and Mussa, 2002). From the economic standpoint, the crop is a source of cash to the farmers and foreign currency to the country. Ethiopian farmers are also cognizant of the role of the crop in improving soil health by fixing atmospheric nitrogen, and widely use it in rotation with cereals **(Samuel *et al.,* 2008**).

Despite the availability of high yielding varieties of the crop and its wide economic importance, the average national yield of faba bean under small-holder farmers is not more than 1.89 t ha^{-1} (CSA, 2014/15). The low productivity of the crop is attributed to susceptibility to biotic and abiotic stresses (Mussa *et al*., 2008). Among the biotic category, diseases are the most important factors limiting the production of food legume crops as a whole and faba bean specifically in Ethiopia (Berhanu *et al*., 2003 and Samuel *et al.,* 2008a). Among these, fungi are the largest and perhaps the most important groups affecting all parts of the plant at all stages of growth of faba bean (Nigussie *et al*., 2008). Diseases such as chocolate spot (*Botrytis fabae* Sardina), rust (*Uromyces fabae*), black root rot (*Fusarium solani* Mart.) and foot rot (*Fusarium avenaceum*) are among fungal groups that contributes to the low productivity of the crop (Berhanu *et al*., 2003).

Furthermore, in recent years, the crop is threatening by a new emerging disease known as Faba Bean Gall (FBG) locally known as “Kormid”, causing up to complete crop failure over wide areas within short period of time with disastrous economic consequences (Wulita, 2015). The distribution pattern of the disease was at escalating speed like fire-wood within short period of time (Teklay *et al.,* 2014).

Understanding of disease intensity and different management practices will help to develop an integrated and sustainable diseases management package for faba bean production (Rusuka *et al*., 1997). Faba bean gall is a new disease but being a new threat, information is lacking on its management aspects of the disease. As a result developing effective and economical management strategy must be devised to curb the progress of the disease and to manage it timely (Wulita, 2014). Therefore, this study was conducted with the following objectives:

1. General Objective

- To develop management strategies using cultivars and fungicides.

2 .Specific Objectives

(i) To determine the interaction effects of cultivar, fungicide and spray frequency

(ii) To evaluate the economic benefits driven from application of fungicides at different spray frequency for FBG disease management.

II. Literature Review

2.1. Origin of Faba Bean

Faba bean (*Vicia faba* L.) is one of the earliest domesticated food legumes originated from the Middle-East in the prehistoric period (McVicar *et al.,* 2013) and it is now widespread and cultivated in Europe, Africa, Central Asia, China, South America, the USA, Canada and Australia. It is believed that the crop was introduced to Ethiopia from the Middle East via Egypt around 5000 B.C., immediately after domestication and now considered as one of the centers of secondary diversity for faba bean (Asfaw *et al.,* 1994; Yohannes, 2000, Torres *et al.*, 2006).

2.2. General Characteristics of the Crop

Faba bean (*Vicia faba* L.*)* is an annual herb with coarse and upright stems, unbranched 0.3-2 m tall, with 1 or more hollow stems from the base (Bond *et al*., 1985; Heath *et al*., 1994). The leaves are alternate, pinnate and consist of 2-6 leaflets each up to 8 cm long and unlike most other members of the Genus; it is without tendrils or with rudimentary tendrils. Flowers are large, white with dark purple markings, borne on short pedicels in clusters of 1-5 on each auxiliary raceme usually between the 5th and 10th node; 1-4 pods develop from each flower cluster, and growth is indeterminate though determinate mutants are available. About 30% of the plants in a population are cross-fertilized and the main insect pollinators are bumblebees. It has a robust tap root with profusely branched secondary roots (Bond *et al*., 1985).

2.3. Importance of the Crop

The environmental benefits and impacts of faba bean can be seen from different perspectives. It is a multipurpose crop that plays an important role in the socio-economic life of farming communities (Agegnehu and Fessehaie, 2006). It is a grain legume grown worldwide as a source of protein for both human food and animal feed due to its high nutritive value both in terms of energy and protein contents (24-30 %) and is an excellent nitrogen fixer (Sahile *et al*., 2008a). The nutritional value of the crop is high, and in some areas is considered to be superior to peas or other grain legumes (Crepona *et al*., 2010). The most important organic components of faba bean seeds are proteins (20–41%) and carbohydrates (51–68%) of seed dry matter which depend on cultivars (Hossain and Mortuza, 2006). Faba beans intended for human consumption are harvested when immature. Mature seeds are roasted and eaten as snacks or ground to prepare falafel, sauces and various food ingredients such as meat extenders or skim-milk replacers (Muehlbauer *et al*., 1997). Faba beans have been suggested as an alternative protein source to soybean for livestock in Europe (Smith *et al*., 2013; Jezierny *et al*., 2010; Blair, 2007). In addition to protein, cropping faba bean benefits the ecosystem with renewable inputs of nitrogen (N) available to the next crops in the rotation and soil from biological N_2 fixation, and a diversification of cropping systems (Jensen *et al*., 2010). The principal agronomic advantage of faba bean is its ability to fix nitrogen by symbiosis with *Rhizobium* bacteria, and thereby substantially contribute to the supply of protein for human food and animal feed and greatly reduce dependence on energy consuming mineral N fertilizers. It is an advantage that in contrast to other legumes, faba bean can maintain high rates of biological nitrogen fixation in the presence of high amounts of available N in the soil (Turpin *et al*., 2002). It was deduce that faba bean may improve the structure of poorly structured soil by stabilizing soil aggregates. It can accumulate N both from soil and the atmosphere (Rajan and Singh, 2012).

It is also grown for green manure production or as a legume in cereal/legume rotations (Muehlbauer *et al*., 1997; McVicar *et al*., 2013). In Sweden, it was used as a lingocellulosic biomass to produce bio-ethanol and biogas (Petersson *et al.,* 2007). Enhanced fertility is of significant importance for the future capacity of the soil to sustain food production. Also faba bean green manuring play in increasing the risk of nutrient loss; especially losses of N via nitrate leaching to the ground water, or through denitrification and the production of the potent greenhouse gas N_2O. Supplying N inputs as fertilizer to grow non-legume biomass crops for bio-fuel purposes essentially negates the whole of energy cost and reduces the C neutrality because of the fossil fuels involved in fertilizer production and the emission of N_2O from N fertilizer (Crutzen *et al*., 2007; Peoples *et al*., 2009).

2.4. Faba Bean Production

Faba bean is a cool season pulse crop grown in the highlands (1800-3000 m.a.s.l.) of Ethiopia, where the need for chilling temperature is satisfied. It can be cultivated in places where annual rainfall is between 700 mm and 1000 mm and, ideally, evenly distributed during the growth season (ICARDA, 2006). Acidic soils with high levels of aluminum and manganese can be detrimental to growth (Matthews *et al*., 2003). It can tolerate water logging and temporary flooding and does better under such conditions than lentils, peas or common beans (McVicar *et al.,* 20013).

Faba bean is one of the most important food legumes both in acreage and annual production in Ethiopia. It occupies close to 443,107.88 ha making up 28.43% of the area under pulses with an annual production of 838,943.90 tones (CSA, 2014/15). Ethiopia is the 2nd among the top 5 producers viz. China, Australia, France and United Kingdom. These countries accounted more than 75% of world production. China alone produced 34% of all faba beans production (FAO, 2014). However, faba bean utilization and production has been declining in the last decades by 50% between 1960 and 2010 due to the replacement of traditional cropping systems by industrialized cereal-based systems (Jensen *et al*., 2010; McVicar *et al*., 2013). In the EU, faba bean ranks 2nd after field peas and is mostly used for animal feeding (FAO, 2014).

In Ethiopia, it takes the largest share of the area and production of the pulses grown and occupies 443,107.88 ha of land with annual production of about 838,943.90 ton and a productivity of 1.89 t ha^{-1} (CSA, 2014/15). Oromia, Amhara, Southern Nation Nationalities and Peoples (SNNP) and Tigray national regional States are the major faba bean producing regions in Ethiopia. These four regions cover almost all of the total faba bean production of the country. Oromia National Regional State take the largest faba bean area (42.98%) and contributes to the highest production (48.26%) of the country (Table 1) followed by Amhara national regional state that has 39.06% of the areas and contributes 36.34% to national production (CSA, 2014/15).

Table 1. Area, production and productivity of faba bean in major producing regions of Ethiopia (2014/15)

Regions/zones	Area (ha)	Production (kg)	Productivity (kg/ha)
Ethiopia	443,107.88	838,943,897	1,893
Region			
Oromia region	190,433.57	404,913,355	2,126
Amhara region	173,079.45	3,048,99111	1,762
SNNP region	66,590.48	1,091,41171	1,639
Tigray region	12,414.05	19,055,902	1,535
Zone			
North shoa	78,763.22	1,699,516.4	2,158
West shoa	8,329.33	15,105,396	1,814

Source: CSA, 2014/15.

2.5. Major Diseases of Faba Bean

The production of faba bean is constrained by several yield limiting constraints. Among these inherently low yielding ability of local land races, traditional production practices, poor soil conditions (water logging, low pH, etc) and diseases (Wuletaw, 1998), of which diseases are the major ones (Samia and zekaria, 2006). According to Yu Dafu 1979 a total of 102 faba bean diseases caused by fungi, bacteria and virus were recorded worldwide.

Among the reported diseases of faba bean, so far more than 17 pathogens have been reported from different parts of the country (Dereje and Tesfaye, 1994). In Ethiopia, though faba bean diseases caused by other pathogens were recorded, fungi are the largest and perhaps the most economically important disease causing groups affecting all parts of the plant at all growth stages (Nigussie *et al*., 2008).

Diseases such as chocolate spot (*Botrytis fabae* Sard.), rust (*Uromyces vicia fabae*), black root rot (*Fusarium solani*), and foot rot (*Fusarium avenaceum*) are among fungal groups that contribute to the low productivity of the crop (Berhanu *et al*., 2003; Nigussie *et al*., 2008). In recent years, in addition to the previous common diseases, the crop is threatening by new gall forming disease locally known as kormed.

2.5.1. Chocolate Spot (Botrytis Fabae)

Chocolate spot of faba bean, caused by *Botrytis fabae* Sardina, is the most prevalent and important disease in faba bean growing regions of Ethiopia as well as elsewhere in the world. In regions of Libya, Tunisia, Algeria and Morocco, losses due to this disease can reach 60-80% on susceptible cultivars (Bouhassan *et al*., 2004). It is the most important disease of faba bean worldwide and is capable of devastating unprotected and susceptible crops up to 67% (Bouhassan *et al*., 2004; Samuel *et al.,* 2010). Chocolate spot initially appears as reddish brown spots on leaves, which enlarge and even merge and subsequently lead to severe premature defoliation. Under favorable conditions, it appears on stems, flowers and pods, and this directly affects seed production. The pathogen infects the leaf tissues, petioles, stems, and seeds. It survives as sclerotia in infected plant debris for more than a year.

Different management options have been developed to reduce the yield losses in faba bean due to chocolate spot worldwide. These include the use of chemical fungicides, resistant/ tolerant varieties, use of certain cultural practices such as crop residue management and altering planting date (Dereje, 1999; Bretag and Raynes, 2004; Hawthorne, 2004) but integrated use of sowing date with fungicides provides a better control of this menace than using the two options individually (Harrison, 1988). In Ethiopia, growing of moderately resistant varieties, application of Chlorothalonil or Mancozeb and late planting have been recommended for the management of chocolate spot (Dereje, 1999; Samuel *et al*., 2008b)

2.5.2. Rust (Uromyces Vicia Fabae)

Rust is one of the most widely distributed diseases of faba bean around the world, but is more severe in humid tropical and sub-tropical areas (Hebblethwaite, 1983). It has been reported from all over West Asia and North Africa (Hawtin and Stewart, 1979). In general, rusty red pustules surrounded by a light yellow halo appears late in the season and causes an estimated 20% grain yield loss in faba bean production (Bekhit *et al.,* 1970; Mohamed, 1981). However, these losses could go up to 45% if severe infections occur early in the season, can cause almost a total crop loss (Williams, 1978). Cultural practices, such as field sanitation to remove the infected plant debris (Prasad and Verma, 1948), destruction of other host species and rotating faba bean with non-host crops (Conner and Bernier, 1981) play an important role in reducing chance of survival and primary infections in the field. Use of clean and contaminant free-seed is also recommended.

2.5.3. Black Root Rot (Fusarium Solani)

Black root rot, caused by the fungus *Fusarium solani,* is the second most important disease of faba bean (Liu, 1984). The disease exclusively occurs in clay black soils where water-logging are severe (Berhanu *et al*., 2003). Since the disease develops slowly, infected plants show chlorosis and dark black roots, which finally disintegrate (Abrham, 2008). Infected plants are easily pulled out and death of the plant follows severe infection. Cultural practices, such as planting crops that are not host to the pathogen in rotation with faba bean and proper drainage may reduce the inoculum level in the soil. Biological control by using *Bacillus* spp (Eshetu *et al*., 2015) and *Trichoderma viride* is also one of the appropriate methods to manage the disease.

2.5.4. Foot Rot (Fusarium Avenaceum)

Faba bean foot rot, caused by *Fusarium avenaceum*, is one of the most important diseases that reduce faba bean seed germination by 23%, germination energy by 35% and seedling emergence (stand establishment) by 55%. The disease may also decrease seed size and, if seeds from severely infected plants are used, emergence can be delayed (Abrham, 2008). The pathogen survives as a mycelium on diseased seed and infected plant debris. Development of foot rot is favored by acidic soils. Liming of acidic soil and rotation of faba bean with *Brassica* spp. would help in controlling the disease by reducing initial population density. Destroying volunteer faba bean plants and weeds belonging to the genera *Setaria, Phalaris, Cayluses, Polygonum, Spergulla*, and *Avena*, which serve as host plants to *Fusarium avenaceum*, could also help to reduce the risk of an early inoculum buildup (Abrham, 2008).

2.5.5. The Newly Emerged Faba Bean Gall Disease

In Ethiopia, faba bean gall disease was first reported in farmers' fields around Selale and Degem, North Shoa Zone highlands in July 2010 (Dereje *et al.,* 2012). However, after two years, in 2012 the occurrence increased to almost an epidemic level in the area and devastated almost all fields particularly in the red soils (Dereje, 2012). In a survey conducted on 2013 the disease becomes the most devastating and can cause up to 100% crop loss including North Shoa, Gojjam, Wollo, Gonder and Tigray (Endale *et al*., 2014). On this survey 100% and 91.7% disease prevalence were recorded in Awi and North Shoa zones of Amhara region, respectively. In Tigray region the disease was first reported in 2013 with an average prevalence of 66% and up to 100% disease severity. Most fields in the surveyed regions were re-plowed and re-sown by small cereals due to the epiphytotic appearance of the disease (Teklay *et al*., 2014). Average disease prevalence of 95.2% and 86.7% were recorded in North Shoa zone and South Wollo, respectively of Amhara region (Endale *et al*., 2014). The disease can completely destroy the above ground plant parts (stems, leaves, flowers and pods) within a short period regardless of the cultivars grown (Teklay *et al.*, 2014).

Even if it is not confirmed yet, a similar galls forming disease symptom was reported in 1970 in China provinces such as Gansu, Tibet and Shanxi on spring-sown faba bean in highland areas at an elevation of 2500-3400 m.a.s.l. The disease was getting serious since the 1970s and over 4000 ha of the crop have been affected by the disease (Lang Li-juan *et al*., 1993).

2.5.5.1. Host Range

The pathogen had a wide host range including faba bean and pea. It can also infect rapeseed, cabbage, cucumber, spinach and buckwheat (Lang Li-juan *et al,* 1993). According to Wulita (2014) the disease can also infect field peas. Xing (1984) first identified the pathogen of the disease as *Olpidium viciae* by means of microscopic examination, inoculation, symptom and host range determinations.

2.5.5.2. Disease Symptom

The symptom of the disease appears on leaves and stems and it also affects the petioles and the pods. The infection starts at the seedling stage and continues until flowering. At the initial stage of infection, on the back side or sometimes on the front side of the leaves, chlorotic galls are formed, and then progressively enlarged and become light brown, circular or elliptical rough spots (Figure 1). The spot immediately changes to brown lesion and it covers the whole lower leaves and stems and it changes from circular to slightly irregular shape. Mature leaves develop coalescing necrotic spots that are surrounded by white lesions. At the later stage, the galls turn black or brown, the tissues decay and a few galls break to form necrotic areas. There are 10 to 30, with a maximum of more than 50 small galls on one small leaf and 20-30 galls often coalesce adjacently to form huge galls, resulting in rolling up (cupping) and abnormal growth of leaves. In severely infected plants, circular to irregularly-shaped brown lesions or galls also appear on stems (Beyene and Wulita, 2012; Dereje *et al*., 2012). The disease becomes more sever especially 4-5 weeks after planting and the disease intensity gradually decreases (Dereje *et al*., 2012).

Fig. 1. Symptoms of faba bean gall on the upper (a) lower side (b, c, d and e) of the leaves and on all parts of the crop (f).

2.5.5.3. Importance of Faba Bean Gall

The disease can completely devastates the crop and causes up to 100% crop losses (Dereje *et al.,* 2013). According to Endale *et al*., 2014, survey conducted the disease has spread to the highlands of faba bean growing areas of Amhara, Tigray and Oromia regions. Similarly up to 100% disease severities have been reported in Tigray region in 2014 (Teklay *et al*., 2014). This indicated that the spread of the disease has been very fast and expanding from year to year in all faba bean growing areas of the country.

2.5.5.4. Epidemiology and Life Cycle

Olpidium viciae belongs to fungi kingdom of genus *Olpidium* of the family Olpidiaceae, Chytridiales, Mastigomycotina in taxonomy. The pathogen survives winter as cysts on debris of diseased plants in the soil. The cysts 3.5 cm deep in soil have the highest infection rate and those deeper or nearer the surface cause less infection to the plants. This indicates the association of the soil condition with the germination of cysts. The cysts can survive 1-2 years in the soil. The primary inoculum source is cysts from debris of the last infected crop in the field. The cysts germinate and discharge the single flagellum zoospores in the next spring. They penetrate the roots of the young seedlings of faba bean and form thin-walled zoosporangia in host cells to cause disease. Mature zoosporangia release zoospores to penetrate deeper layers of cells or to infect other healthy plants. Disease symptoms on plants usually appear 13-18 days after infection. In the late stage of crop growth, sporogenic (cystigerous) plasmodia and cysts are formed to complete the disease cycle (Lang Li-juan *et al.,* 1993).

The resting sporangium of *O.* viciae lives with sick plant residue through summer and winter together, which is the agent for early infection. The temperature range of germination of zoosporangium is from 0 to 18°C, it will be significantly inhibited below 18°C, and is unable to germinate at 20°C, 25°C and 30°C. PH also affects the germination of zoosporangium to some degree, and it was germinated at pH values from 5 to 8, with optimum value between 7 and 7.5. The swarming period of zoospores depend largely upon the temperature, gradually shortened with temperature increase. The zoospores are able to swim for 72 h between 0 and 5°C; for 24, 10, and 3 h below 10, 20 and 25°C, respectively; for only 5 min when temperature raised to 30 °C. Temperature apparently affects infection and morbidity of zoospores to plants. Infection and morbidity occur between10 and 25°C, no apparent symptom observe at 5°C although infection occur, and both are not observed at 30°C or above it. The optimum temperature for infection and morbidity is between 10 and 25°C. The time of keeping high humidity for infection and morbidity of zoospores is 12 h or longer. Zoospores liberated from resting sporangium would infect seedlings of faba bean in next spring, and then the symptoms of disease are found early. Zoosporangiums are constantly reproduced after the disease occurs in field, liberated zoospores with the presence of rain or dew for secondary infection. With highly repeated secondary infection, the disease spread quickly in the field and reached peak outbreak in flowering and pod formation stages, after that formed resting sporangium in following pod stage and then stopped gradually. This disease was able to spread in short distance by wind and rain. Continuous cropping and application of animal manure in which sick plant residue existed could cause this disease serious (Yan Ji Ming, 2012). The *Olpidium thallus* is spherical or cylindrical and there may be one or more in a host cell. The entire content of the thallus converts in to zoosporangium and cleaves into uniflagellate zoospores. The zoospores scape from the zoosporangium through one or more discharge tubes which penetrate the outer wall of the host cell and open to the exterior. The release of the zoospores takes place within a few munities of washing the roots free from soil (Mehrotra and Raneja, 2005).

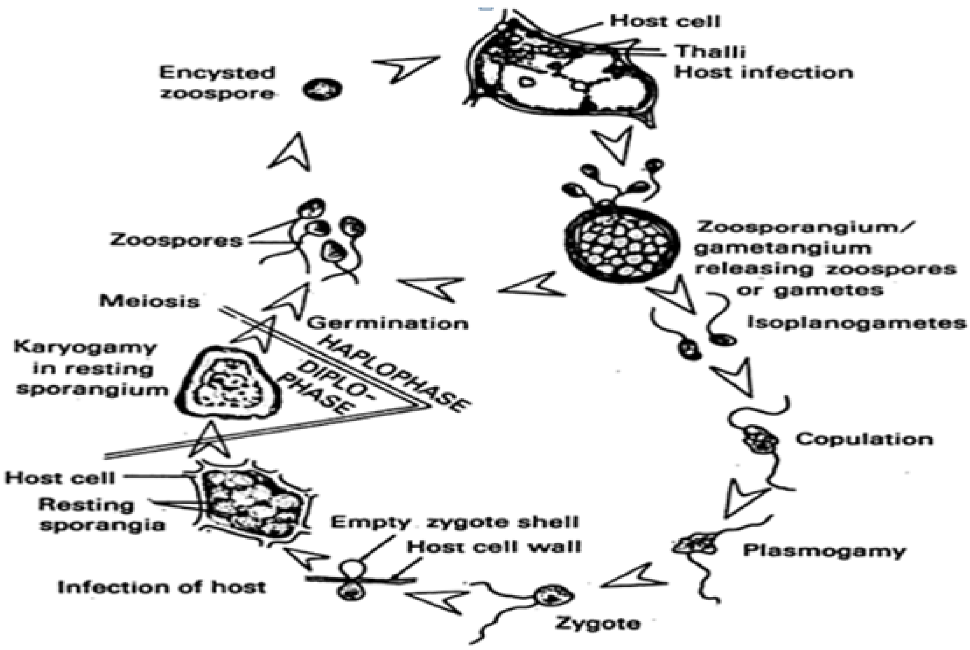

Fig. 2. Life cycle of *Olpidium viciae* (Source: Mehrotra and Raneja, 2005).

2.5.5.5. Management of FBG Disease

The disease is new and its causative agent is not well known in the country, no sound control measure was worked out yet. But reports in other countries of the like pathogen indicated that, cultural control involving crop rotation, reduce water logging and use of chemicals are important to reduce the inoculum (Xing Zhesheng, 1984). In Ethiopia, only chemical was suggested as a control measure for the disease. Dereje *et. al*. 2012, found that Redomil MZ reduces the diseases intensity as compared to the control. Fungicides like Triadimefon 250 g/l as foliar spray can also delay the disease development (Beyene B., 2015). Higher yield increment (77.92%) was obtained by foliar spraying of Metalaxyl 8% + Mancozeb 64% WP (Wulita, 2015).

III. Materials and Methods

3.1. Description of the Study Areas

The experiment was conducted at Mush and Degem. Mush site is 20 km far from Debre berhan and its found at an altitude of 2975 m.a.s.l. and receives average annual rain fall of 897.8 mm with mean minimum and maximum temperatures of 6.1 and 19.67^{0}C (Wulita, 2015). Degem district is located at an altitude of 3152 m.a.s.l and its mean annual rainfall is 916 mm and its temperature ranges from 6-24^{0}C, respectively. It is 150 km far from Addis Abeba. The soil types of the trial sites of Mush and Degem are characterized as Eutric vertisol and red soil, respectively.

3.2. Evaluation of Cultivars, Fungicides and Spray Frequencies for the management of FBG Disease

The field experiment for evaluation of faba bean gall di-

-sease using cultivars, fungicides and spray frequency was conducted in 2015 main cropping season at two locations i.e. at Mush and Degem on farmers fields which are found in Amhara and Oromia administrative regions of North Shoa zone, respectively. These two locations are considerd as hot spot areas of the disease.

3.2.1. Faba Bean Cultivars

Three cultivars of faba bean viz. Gora, CS20DK and Local were used for the study in both locations. The two improved cultivars were selected based on their high yield potential/ performance and wider adaptation (Table 2) and local varieties of the locations (Degem and Mush) were included as test material.

Table 2. Faba bean cultivars used for the experiment

No.	Cultivars	Seed source	Altitude range (m.a.s.l)	Year of Release	Productivity qt/ha
1	Gora	HARC/ EIAR	2000-2800	2013	37-43
2	CS20DK	HARC/ EIAR	2300-3000	1977	45-58
3	Local	Farmers	-	-	-

Source: Ethiopian Institute of Agricultural Research (EIAR), 2014.

3.2.2. Fungicides

Three fungicides viz. two systemic fungicides (Triadimefon and Metalaxyl), and a contact fungicide, Chlorothalonil were used singly in different spray frequency to test their efficacy against FBG disease. Spray frequency was scheduled at 10 days interval for contact fungicide and 15 days interval for systemic fungicides with their recommended dose. Bayleton and Redomil MZ fungicides were applied at the rate of 2 kg ha^{-1} each, and Chlorothalonil fungicide at the rate of 2.5 kg ha^{-1}. Spraying of fungicides was started when the first symptoms of the disease appeared and continued according to spray schedule designated for each treatment (Table 3). Control plots were kept unsprayed during the experiment. Spraying of the fungicides was performed using knapsack sprayers with 300 liters of water ha^{-1}. The plants were shielded with polyethylene sheets during spraying to avoid fungicidal drift and thereby interplant interference.

Table 3. Fungicides and spray frequency used for FBG disease management.

Common Name	Rate (kg/ha)	Fungicide spray frequency	Time of spray
Triadimefon (Bayleton)	2.0	1 time spray	Disease onset
		2 times spray	Disease onset and once after 15 days
		3 times spray	Disease onset and two times at 15 days interval.
		Control	Unsprayed plots
Chlorothalonil	2.5	1 time spray	Disease onset
		2 times spray	Disease onset and once after 10 days.
		3 times spray	Disease onset and two times after 10 days interval.
		Control	Unsprayed plots
Redomil MZ (Metalaxyl)	2.0	1 time spray	Disease onset
		2 times spray	Disease onset and once after 15 days
		3 times spray	Disease onset and two times at 15 days interval.
		Control	Unsprayed plots

3.2.3. Experimental Design

The experiment was arranged in split-split plot design using three cultivars, three fungicides and four spray frequencies with three replications with a plot size of 3.2 m^2 (2m x 1.6m). A total experimental area of 288 m^2 was used. Cultivars were used as a main plot while fungicides as a sub plot and spray frequency of fungicides as a sub sub-plot forming a total of 30 treatments combinations including the control. For each treatment of fungicides and spray frequencies only one cultivar was used as a control. Four rows per plot each accommodating 20 plants were used and an inter-row and intra-row spacing of 40 cm and 10 cm, respectively, were used. Ways of 0.5 and 1 m were used between plots and replications, respectively. Planting were carried out in June 2015 on both locations on farmer fields. Fertilizer were applied as recommended (100 kg ha^{-1} DAP) during planting and other agronomic practices were practiced as recommended.

3.2.4. Assessment of the Disease

The disease incidence and severity were recorded from ten pre-tagged plants in the two cental rows of each plot. Disease assessment was taken every ten days interval starting from the first appearance of the disease. **Disease incidence (%)** of FBG was assessed by counting the number of diseased plants per total number of plants inspected and expressed as percentage of total plants. Percent disease incidence was competed according to the following equation.

$$\text{Disease incidence \%} = \frac{\text{Number of diseased plants}}{\text{Total number of plants inspected}} \text{x } 100$$

Disease Severity (%):

It was recorded by estimating the percentage of leaf and stem area diseased using the 0-9 disease scoring scales (Ding *et al*, 1993) (Appendix Table 2). The severity grades were then converted into percentage severity index (PSI) for analysis (Wheeler, 1969).

$$\text{PSI} = \frac{\text{Snr}}{\text{Npr x MSC}} x\ 100$$

Where, Snr is the sum of numerical ratings, Npr is number of plant rated, Msc is the maximum score of the scale. Means of the severity from each plot were used in data analysis.

Area under disease progress curve

Area under disease progress curve (AUDPC): was calculated for each plot using the formula of Shaner and Finney (1977) and was expressed in %-days as follows.

$$AUDPC = \sum_{i=1}^{n-1} 0.5\left(x_{i+1} + x_i\right)\left(t_{i+1} - t_i\right)$$

Where Xi is the cumulative disease severity expressed as a proportion at the ith observation, ti is the time (days after planting) at the ith observation and n is the total number of observations.

Additional Data Collected Were: -

Number of Pods Per Plant:

The average number of pods per plant was determined from five randomly taken plants out of the 10 pre-tagged plants.

Number of Seeds Per Pod:

The mean number of seeds per pod was obtained from five taken plants per plot at harvest.

100 Seed Mass (g):

The mass of 100 randomly taken seeds from the yield of each plot was recorded.

Yield per plot (g):

The grain yield per plot was recorded from the two central rows.

Yield (t/ha):

The yield was recordeded from the middle two rows for each treatment and converted to yield ton per hectare.

3.2.5. Relative Yield Loss (%)

Percent relative grain yield loss was calculated as follows:

$$RYL\ (\%) = \frac{(\text{Yp} - \text{Yt})}{\text{Yp}} \text{x}100$$

Where, RYL = relative yield loss in percent, Yp = yield from the maximum protected plots (sprayed three times) and Yt = yield from other plots.

3.2.6. Cost - Benefit Analysis

Price of faba bean seeds, Birr/kg was assessed from local market in each location, taking into account the total price of one quintal (100 kg) obtained from a hectare bases and total sale from one hectare was computed. Price of Redomil kg^{-1} was Birr 150, Bayleton Birr 250 kg $^{-1}$ and Chlorithalonil was Birr 500 kg $^{-1}$ and total price incurred to spray one hectare of faba bean fields at different spraying frequencies were calculated. Labor to spray chemicals and to manage the experiment was computed. Payment for labor was Birr 50 days^{-1} at both locations. Cost of spray and spray equipment to spray once, twice and three times the treatments was calculated. Based on the data obtained from field, the cost-benefit analysis was performed using partial budget analysis. The difference between treatments, the option economic data was subject to analysis using the partial budget analysis method (CIMMYT, 1988). Marginal rate of return was calculated using the formula.

$$\text{MRR}\ (\%) = \frac{\Delta NI}{\Delta \text{IC}} x100$$

Where, MRR- is marginal rate of returns,
ΔNI – change in net income compared with control, and
ΔIC – change in input cost compared with control.

The following points were considered during cost benefit analysis using partial budget.

- Costs for all agronomic practices were uniform for all treatments within sites.
- Price of grain yield per tons for each treatment was the same within each locality.
- Costs of labor and spray equipment were taken based on the price in the locality.
- Costs, return and benefit were calculated per hectare basis.

3.2.7. Data Analysis

Survey data were summarized using descriptive statistics. The mean disease prevalence, incidence and severity data were analyzed by using descriptive statistical analysis (means) over districts, altitude range and variety. While, for field experiment, incidence and severity assessment of FBG in each cultivar, fungicides and spray frequiencies were examined. Analysis of variance was performed for disease parameters (incidence, PSI, AUDPC), seed yield and yield components (pod per plant, seed per pod and HSW) using Statistical Analysis System (SAS) version 9.1.3 software (SAS Institute, 2002). Least significance difference (LSD) and Standard Error (SE), were used to separate treatment means ($P < 0.05$) from each assessment date, area under disease progress curve, yield and yield components were subjected to analysis of variance by using the methods descibed by Gomez and Gomez (1984) using SAS computer soft ware (Michigan State University, 1991).

IV. Results and Discussions

4.2.1. Disease Incidence and Severity

4.2.1.1. Disease Incidence

The analysis of variance (ANOVA) indicated that interaction effects of cultivars, fungicides and spray frequencies, didn‟t show any significant variations in reducing disease incidence at all dates of diseases assessment at both locations. At Degem, except cultivars with fungicides and fungicides with spray frequencies at 79 DAP of assessment date, no significant (P<0.05) differences were observed in reducing disease incidence at Degem in all dates of assessment. While, at Mush, interaction effect of both, cultivars with spray frequencies and fungicides with spray frequencies showed significant variations in reducing disease incidence on 76 DAP, and also cultivar with spray frequency showed significant variation at 96 DAP. Effect of cultivars and spray frequencies as a main factor had a highly significant (P<0.01) difference on disease incidence at both locations but no significant variation was observed between fungicides at the final date of assessment at both locations (Appendix table 3 & 4).

At Degem, the lowest disease incidence was recorded on Gora variety at all DAP assessments, which were also significantly different from the other two cultivars. But at mush significant variation was observed at 66

DAP assessment date also Gora recorded the lowest (51.31) disease incidence. At the final date of assessment (99 DAP) at Degem and Mush the highest (50.42% and 30.42%) and the lowest (40.69% and 25.42%) disease incidence was recorded on Local and Gora variety in the order mentioned. Although at both locations, on the last date of assessment the highest disease incidence was recorded on Local cultivar, no significant variation was observed between CS20Dk variety and Local cultivar on 39, 69, 79 and 89 DAPs of assessment date. While, at Mush no significant variations was observed between CS20DK variety and Local cultivar only on 66 DAP and 76 DAP of assessment dates. At Degem, on Gora and CS20DK varieties, 19.30% and 10.75% disease incidence reduction over local cultivar was recorded at the final date of assessment, respectively. Also, at Mush, 16.44% and 7.76% reduction in disease incidence was recorded on Gora and CS20DK varieties in the ordered mentioned as compared to Local cultivar. The disease incidences in tested cultivars peaking the highest at 59 DAP and 66 DAP in all cultivars at Degem and Mush, respectively, and reduced after the proceeding assessment dates which indicate that, the disease becomes more prevail at vegetative and flowering stages of the crop (Table 6 & 7). Similarly Dereje et al. (2012) reported that, the disease is more sever especially 4-5 weeks after planting and then after the intensity gradually decreases.

Table 6. FBG disease incidence on different faba bean cultivars under field conditions at Degem during the main cropping season of 2015.

Cultivars	Mean disease incidence (%) on different assessment dates at Degem						
	39DAP	49DAP	59DAP	69DAP	79DAP	89DAP	99DAP
Gora	50.97b	64.86c	70.00c	56.51b	54.31b	49.17b	40.69c
CS20DK	55.28a	79.44a	86.67a	66.53a	64.58a	56.25a	45.00b
Local	51.11b	69.44b	79.58b	59.58b	52.91b	53.33ab	50.42a
Mean	52.45	71.25	78.75	60.97	57.27	52.92	45.37
LSD(0.01)	2.98	3.71	4.99	3.36	4.50	4.18	3.31
CV (%)	12.03	11.01	13.40	11.66	16.63	16.70	15.43

DAP: Days after Planting, Means followed by the same letter are not significantly different.

Table 7. FBG disease incidence on different faba bean cultivars under field conditions during the main cropping season of 2015 at Mush.

Cultivars	Mean disease incidence (%) on different assessment dates at Mush					
	46 DAP	56 DAP	66 DAP	76 DAP	86 DAP	96 DAP
Gora	21.53a	30.97a	51.31b	35.97b	26.11a	25.42c
CS20DK	20.56a	29.31a	58.89a	40.42a	26.67a	28.06b
Local	20.69a	30.28a	60.00a	42.08a	27.50a	30.42a
Mean	20.93	30.19	57.73	39.49	26.76	27.96
LSD(0.05)	1.68	1.78	3.90	2.86	2.08	2.10
CV (%)	16.95	12.45	14.31	15.35	16.41	15.89

DAP: Days after Planting, Means followed by the same letter are not significantly different.

Also, at the final date of assessment significant variation (P<0.05) was recorded on disease incidence at both locations between sprayed and unsprayed control plots (Appendix 3 & 4). At both locations, on the final assessment date the highest and significantly different disease incidence was observed on unsprayed control plots. However, at this assessment date, three is no significantly variation observed among the fungicides applied at both locations. Application of Bayleton, Chlorothalonil and Redomil reduced disease incidence by 48.83%, 49.62% and 48.32% at Degem, and 49.78%, 45.57% and 48.94%, at Mush as compared to unsprayed plots, respectively (Table 8).

Table 8. Initial and final percentage of disease incidence of FBG as influenced by different fungicides under field conditions during the main cropping season of 2015.

Fungicides	Mean disease incidence (%)					
	Degem at 99 DAP (%) over		Reduction in PDI	Mush at 96 PDI (%) over		Reduction in PDI
	39 DAP	99 DAP	control	46 DAP	96 DAP	control
Bayleton	55.19a	36.67b	48.83	20.00	22.04b	49.78
Chlorothalonil	52.41ab	36.11b	49.62	20.56	23.89b	45.57
Redomil	51.11b	37.04b	48.32	21.48	22.41b	48.94
Control	51.11b	71.67a	0.0	21.67	43.89a	0.0
LSD (0.05)	3.44	3.82		1.94	2.43	
CV (%)	12.03	15.43		16.95	15.89	

DAP: Days after planting, Means followed by the same letter are not significantly different.

Fungicides application frequencies showed highly significant variations in disease incidence at both locations on the last date (Appendix 3 & 4). At Degem, on the final assessment date (99 DAP), the highest (71.67%) and lowest (21.85%) disease incidence were recorded from the unsprayed control and three times spayed plots, respectively. Accordingly, at this assessment date, spraying of fungicides three and two times reduced disease incidence by 69.51% and 45.73% as compared to the unsprayed control plots, respectively and significant variations was observed between them (Table 9). Also at Mush on the final assessment date (96 DAP), the lowest incidence (13.15%) was recorded from the plots sprayed three times, whereas, the highest (43.52%) disease incidence was observed on the unsprayed control plots. At this assessment date spraying of fungicide three and two times reduced disease incidence by 69.78% and 44.26% as compared to the unsprayed control plots in that order and significant variations was observed between them regardless of the type of fungicides. One time spraying reduced disease incidence by 28.93% as compared to the unsprayed control plots and plots (Table 9).

Table 9. Initial and final percentage of disease incidence of FBG as influenced by spray frequencies of fungicides under field conditions during the main cropping season of 2015.

	Mean disease incidence (%)					
Spray frequencies	Degem		Reduction in PDI at 99 DAP (%) over	Mush at 96 PDI (%)		Reduction in PDI
	39 DAP	99 DAP	control	46DAP	96 DAP	over control
One time	51.85	49.07b	31.53	20.37ab	30.93b	28.93
Two times	53.33	38.89c	45.73	19.44b	24.26c	44.26
Three times	53.52	21.85d	69.51	22.22a	13.15d	69.78
Control	51.11	71.67a	0.0	21.67a	43.52a	0.0
LSD (0.05)	3.44	3.82		1.94	2.43	
CV (%)	12.03	15.43		16.95	15.89	

DAP: Days after planting, Means followed by the same letter are not significantly different.

4.1.1.2. Disease Severity

The analysis of variance (ANOVA) revealed that only cultivars and spray frequencies as a main factor revealed a highly significant difference (P< 0.01) in disease severity at the final date of assessment at both locations. But, none of the interactions showed significant difference on the final date of assessment. However, interaction effects of cultivars with fungicides on 79 DAP, cultivars with spray frequencies on 89 DAP, and fungicides with spray frequencies on 79 and 89 DAP of assessment date showed significant variations at Degem. At Mush among the interactions only cultivar x spray frequencies showed significant variation at 56 and 86 DAP of assessment date (Appendix Table 5 & 6). At Degem and Mush, on the final assessment date the highest PSI (33.33%, 29.89%) was recorded on Local cultivar, respectively. At both location on the last date of assessment the lowest PSI (28.75%) at Degem, and (24.44%) at Mush, was recorded on Gora cultivar. Accordingly, at Degem, on the final assessment date, the cultivar Gora reduced disease severity by 13.04% and 13.74% as compared to CS20DK and local cultivars, respectively. Also this cultivar reduced the disease severity by (18.15%) as compared to Local cultivar in the ordered mentioned. Similarly, this result agrees with the finding of Wulita (2015) that the highest and significantly different disease severity was recorded on Local cultivar, as compared to the other improved cultivars. The significant difference observed among cultivars, indicated that the faba bean gall epidemic level varies among cultivars (Table 10).

In general, though the newly emerged disease of faba bean occurred in both locations, it was more severe at Degem than Mush. This might be due to the presence of more favorable environmental conditions at Degem during the main crop growing season. Rhaïem *et al.,* (2002) and Tivoli *et al.,* (1992), illustrated that disease resistance level shown by some genotypes in the field could be broken under certain environmental conditions, which may make these varieties susceptible.

Table 10. FBG disease severity on faba bean cultivars under field conditions during the main cropping season of 2015
A) Degem

Cultivars	Mean disease severity (%) at different assessment dates						
	39 DAP	49 DAP	59 DAP	69 DAP	79 DAP	89 DAP	99 DAP
Gora	22.36b	37.64b	31.94c	33.33c	29.58b	31.11b	28.75b
CS20DK	24.31a	43.61a	39.44a	43.75a	34.31a	34.31a	33.06a
Local	21.89b	34.58c	35.56b	38.33b	32.50a	36.53a	33.33a
Mean	22.85	38.61	35.65	38.47	32.13	33.98	31.71
LSD (0.01)	1.81	2.61	2.81	2.67	2.56	2.37	2.01
CV (%)	16.83	14.32	16.66	14.67	16.83	14.76	13.40

B) Mush

Cultivar	Mean disease severity Index (%)					
	46DAP	56 DAP	66 DAP	76 DAP	86 DAP	96 DAP
Gora	20.83ab	22.64b	20.97b	26.81b	23.89b	24.44c
CS20DK	19.44b	23.61b	21.25b	29.86a	24.03b	27.08b
Local	22.08a	25.14a	26.25a	30.14a	29.03a	29.86a
Mean	20.78	23.80	22.82	28.93	25.65	27.13
LSD (0.05)	1.80	1.43	1.88	1.84	2.05	2.04
CV (%)	18.27	12.68	17.43	13.44	16.88	15.90

DAP: Days after planting, PSI: percentage severity index, Means followed by the same letter are not significantly different.

Spray frequencies revealed that significant (P<0.05) and highly significant (P<0.01) variations of percentage severity index were recorded at Degem and Mush, respectively (Appendix 5 & 6). At Degem, on the first date (39 DAP) of assessment, no significant variations was observed between spray frequencies while, after the receipt of different fungicides spray frequencies, significantly different disease severity was recorded in all the cultivars. At this location on the final date of assessment, disease severity was reduced on plots received one, two and three times sprayed by 36.21, 46.60 and 71.69%, respectively, when compared to unsprayed control plots. At Mush, from the initial (46 DAP) up to the final (96 DAP) dates of assessment, unsprayed control plots showed the highest disease severity while the lowest disease severity was recorded on three times sprayed plots. At the initial date of assessment the lowest (17.96%) and the highest (24.44%) disease severity were recorded on three times sprayed plots and unsprayed plots, respectively. At the final date of assessment (96 DAP) at Mush, application frequencies i.e. one time, two times and three times spray reduced PSI by 27.12%, 45.33% and 67.12% as compared to control plot, respectively (Table 11).

The disease was more severe at Degem than Mush; this might be due to the difference between environmental conditions. The Degem experimental site was located slightly on higher altitude than mush. This result illustrates the findings of Endal *et al.,* (2014), that the disease becomes more savior as altitude increases.

Table 11. Severity of FBG disease on different spray frequencies at Degem under field conditions during the main cropping season of 2015

Spray Frequencies	Degem: Mean PSI 39 DAP	Degem: Mean PSI 99 DAP	Degem: Reduction of PSI at 99 (DAP) over unsprayed	Mush: Mean PSI 46 DAP	Mush: Mean PSI 96 DAP	Mush: Reduction of PSI at 96 (DAP) over unsprayed
One time	23.33	32.96b	36.21	20.00bc	30.37b	27.12
Two times	23.52	27.59c	46.6	20.74b	22.78c	45.33
Three times	22.78	14.63d	71.69	17.96c	13.70d	67.12
Control	21.11	51.67a	0	24.44a	41.67a	0
LSD (0.05)	2.08	2.32		2.07	2.35	
CV (%)	16.83	13.4		18.27	15.9	

DAP = Days after Planting, Means with the same letters are not showed significantly difference.

At Degem, interaction of effects of cultivars and spray frequency showed significant variations at only (89 DAP) of assessment date. Unsprayed CS20DK cultivar showed the highest and significantly different (51.67%) PSI followed by unsprayed Local cultivar (45.00%) and unsprayed Gora cultivar (41.67%). While, the lowest PSI (20.00%) was recorded on CS20DK cultivar that received three times spray but this value did not show significant variations from plots of Gora cultivar (23.89%) that received three times spray. At this assessment date spraying of fungicides three times on each variety reduced disease severity by 42.67%, 61.29% and 38.27% on Gora, CS20DK and Local cultivars associated with unsprayed control plots of each cultivar, respectively (Table 12 & Figure 4).

Table 12. Severity of FBG on cultivars and fungicide spray frequencies at Degem under field conditions during the main cropping season of 2015

Treatments		Mean disease severity (%)						
Cultivars	**Frequencies**	**39DAP**	**49 DAP**	**59 DAP**	**69 DAP**	**79DAP**	**89 DAP**	**99 DAP**
Gora	**One time**	24.44	38.33	41.67	33.33	31.11	30.56ef	30.56
	Two times	23.89	40.00	32.22	28.33	23.33	28.33fg	23.89
	Three times	21.11	35.00	30.00	25.00	19.44	23.89gh	13.89

Treatments		Mean disease severity (%)						
Cultivars	**Frequencies**	**39DAP**	**49 DAP**	**59 DAP**	**69 DAP**	**79DAP**	**89 DAP**	**99 DAP**
	Control	20.00	37.22	23.89	46.67	44.44	41.67bc	46.67
CS20DK	One time	23.89	42.78	38.33	41.11	34.44	35.56d	35.00
	Two times	23.89	45.56	36.67	38.89	28.33	30.00ef	28.89
	Three times	26.11	39.44	27.78	33.33	22.78	20.00h	13.33
	Control	23.33	46.67	55.00	61.67	51.67	51.67a	55.00
Local	One time	21.67	35.56	37.22	38.33	34.44	38.89cd	33.33
	Two times	22.78	33.89	32.78	35.00	26.67	34.44de	30.00
	Three times	21.11	32.22	25.56	26.67	22.22	27.78fg	16.67
	Control	20.00	36.67	46.67	53.33	46.67	45.00b	53.33
	SE	1.27	1.84	1.98	1.88	1.80	1.67	1.42

DAP = Days after Planting, Means with the same letters are not significantly difference among spray frequencies

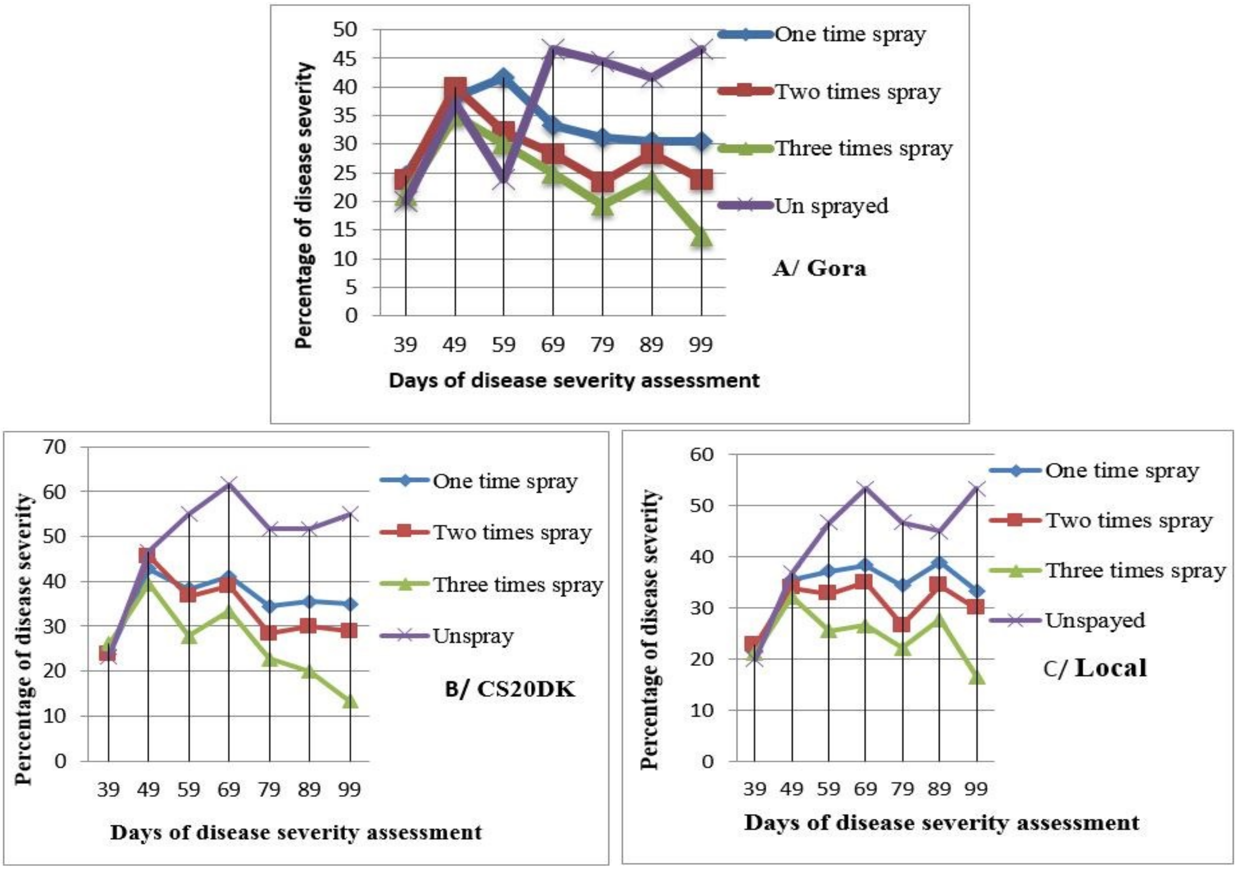

Fig. 4. Severity of faba bean gall on different faba bean cultivars sprayed with different spray frequency in 2015 at Degem.

Likewise, at Mush interaction effects of cultivars and spray frequencies showed significant difference on disease severity at 46, 56 and 86 DAP date of disease assessment but not on the other assessment dates (66, 76 and 96 DAP) (Appendix Table 6). At this location, on 86 and 96 DAPs the highest PSI (43.33%, 46.67%) was recorded on unsprayed local cultivar in the ordered mentioned. On 89 DAP assessment date, the lowest PSI (14.44%) was recorded on cultivar CS20DK sprayed three times whereas not significant variations on cultivar Gora (17.22%) sprayed three times (Table 13 & Figure 5). At this assessment date, three times spraying on each cultivar reduced PSI by 50.80%, 56.68% and 52.55% on Gora, CS20DK and local cultivars as compared to control plots of each cultivars, respectively.

Table 13. Severity of FBG on cultivars and fungicide spray frequencies at Mush under field conditions during the main cropping season of 2015

Treatments		Mean disease severity (%)					
cultivars	**frequencies**	**46 DAP**	**56 DAP**	**66 DAP**	**76 DAP**	**86 DAP**	**96 DAP**
Gora	**One time**	21.11b	25.56bc	21.11	23.89	24.44de	27.22
	Two times	21.67b	19.44d	18.33	25.00	18.89fg	20.56
	Three times	18.89bc	18.89d	17.78	21.67	17.22gh	13.33
	Control	21.67b	26.67b	26.67	36.67	35.00b	36.67
CS20DK	**One time**	20.00b	25.00bc	21.11	30.00	25.56cd	30.00
	Two times	20.00b	22.78c	20.00	24.44	22.78def	23.33
	Three times	16.11c	18.89d	18.89	23.89	14.44h	13.33
	Control	21.67b	27.78b	25.00	41.67	33.33b	41.67
Local	**One time**	18.89bc	26.67b	26.11	27.22	28.89c	33.89
	Two times	20.56b	22.78c	21.67	28.89	23.33de	24.44
	Three times	18.89bc	17.78d	22.22	22.78	20.56efg	14.44
	Control	30.00a	33.33a	35.00	41.67	43.33a	46.67
	SE	1.27	1.01	1.33	1.30	1.44	1.44

DAP = Days after Planting, Means with the same letters are not significantly difference among spray frequencies

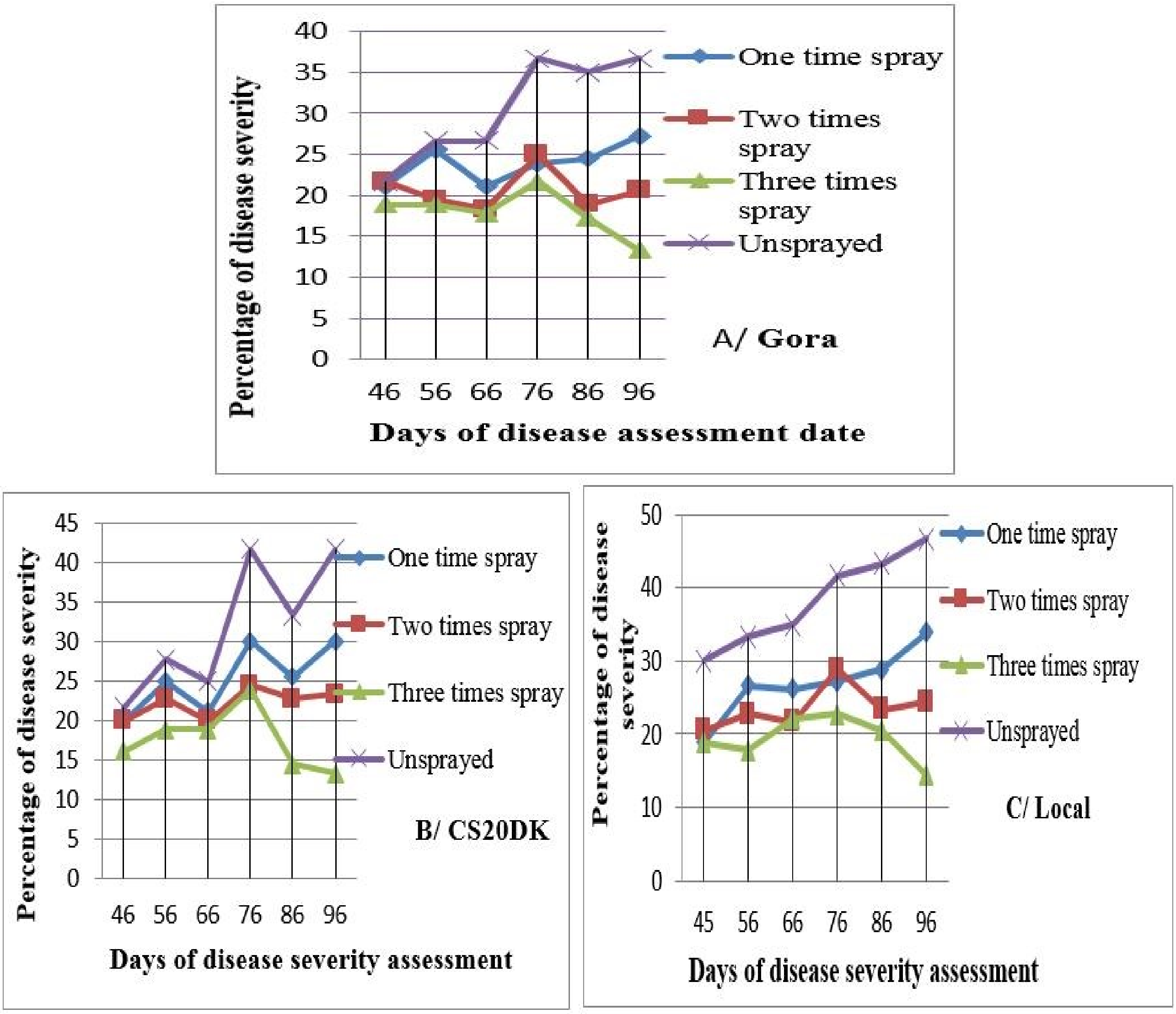

Fig. 5. Percentage of faba bean gall disease on different faba bean cultivars sprayed with different fungicide frequency at 2015 Mush.

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4.1.1.3. Area Under Disease Progress Curve (AUDPC)

The interactions effects cultivars, fungicides and spraying frequencies did not showed significant variations on AUDPC value at both locations. At Degem, the interactions, only cultivars and spray frequencies and cultivars, fungicides and spray frequencies as a main effect showed significant variation on AUDPC value (Appendix table 7). Thus, among the interactions of cultivar and spray frequencies the highest and significantly difference AUDPC (3058.33%-days) value was recorded from the unsprayed control plot of CS20DK cultivar while three times sprayed Gora cultivar exhibited the lowest AUDPC (1469.44%-days) value. On each spraying frequencies of corresponding cultivars the lowest AUDPC was recorded on Gora cultivar (Table 14).

This result showed that, CS20DK and Local cultivars recorded the highest AUDPC and disease PSI, and this finding is in line with Wulita (2015), faba bean cultivars showed different level of resistance for the disease. Three times fungicide sprays resulted less area under disease progress curve in all cultivars of this study, compared to two times and one time spray and also from the control. Three times spray has been recorded highly effective in reducing area under disease progress curve in all the cultivars.

AUDPC is generally used to make comparison between treatments (Xu, 2006) and to evaluate the resistance of plant species to a pathogen (Mikulova *et al*., 2008). Jerger (2004) indicated that comparison of AUDPC values between treatments is the most commonly used tools for evaluating practical disease management strategies. From the result obtained, it was confirmed that the overall disease development was significantly influenced by the cultivars used, fungicide spray frequencies as well as the type of fungicides.

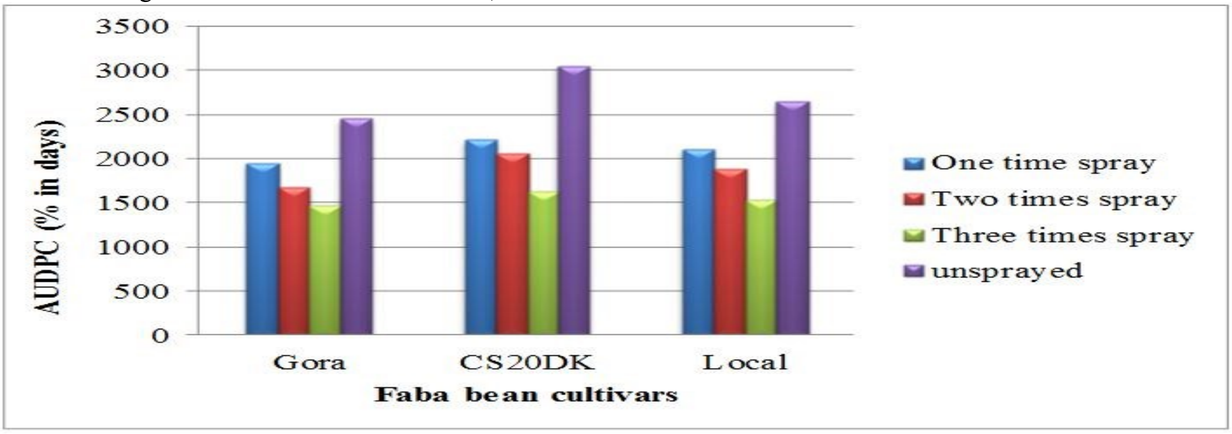

Fig. 6. AUDPC of faba bean gall disease in relation to cultivars of faba bean treated with different spraying frequencies at Degem.

Also, at Mush, among the interaction effects, only cultivar by spray frequencies showed significant variation on AUDPC values. The highest (1916.67%-days) AUDPC value was calculated on unsprayed local cultivar, whereas; the lowest i.e. 902.78%-days AUDPC values were recorded from three times sprayed CS20DK cultivar. The next highest i.e. 1594.44%-day AUDPC value was calculated from unsprayed CS20DK cultivar (Table 14). Three times sprayed CS20DK cultivar reduced the AUDPC value by 9.72% as compared to three times sprayed local cultivar. However, the AUDPC value of the three times sprayed cultivars didn't show significant variations among them.

Table 14: The AUDPC values of the FBG disease on cultivars and spray frequencies at both locations

Treatments		Mean disease AUDPC (%-days)	
Cultivars	**Spray frequencies**	**Degem**	**Mush**
Gora	One time	1947.22ef	1191.67de
	Two times	1688.89g	1027.78fg
	Three times	1469.44h	916.67hi
	Control	2461.11c	1541.67b
CS20DK	One time	2216.67d	1266.67d
	Two times	2058.33def	1116.67ef
	Three times	1630.56gh	902.78i
	Control	3058.33a	1594.44b
Local	One time	2119.44de	1352.78c
	Two times	1891.67f	1191.67de
	Three times	1533.33gh	1000.00gh
	Control	2650.00b	1916.67a
	SE	60.92	29.54
	CV (%)	8.87	7.08

AUDPC: Area under disease progress curve, Means with the same letters are not significantly different.

In general, AUDPC values varied among the faba bean cultivars depending on the resistance levels of the cultivars and it is known that AUDPC is directly related to the yield loss (Singh, 1989). Therefore, selection of faba bean cultivars having low AUDPC value is acceptable for practical purposes.

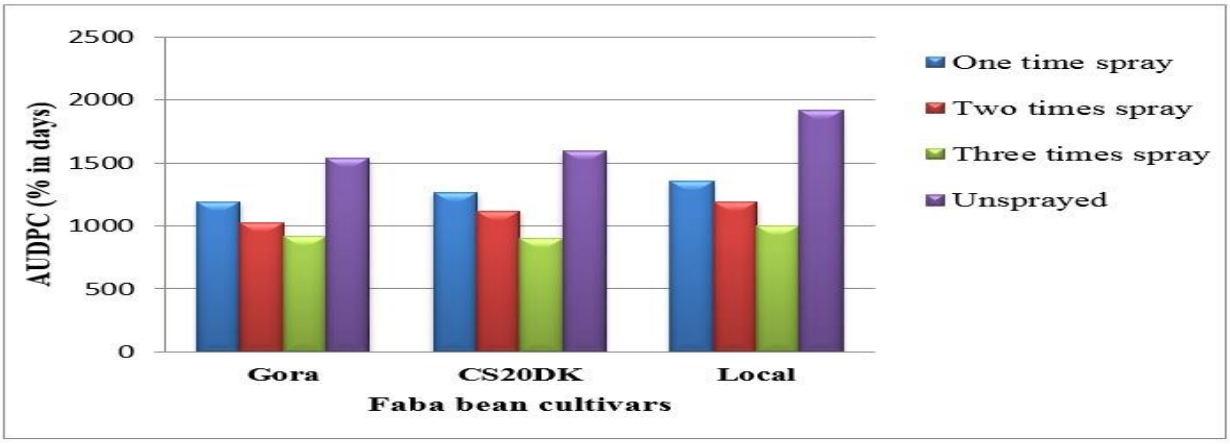

Fig. 7. AUDPC of FBG disease in relation to cultivars of faba bean treated with different spraying frequencies of fungicides at Mush.

Yield and Yield Components

Yield Components

Interaction of cultivars, fungicides and spray frequencies showed significant variations on the number of pods per plant and seed per pod at Degem but only on the number of pod per plant at Mush (Appendix Table 7 & 8). At Mush, neither of the interactions nor of the main effects showed significant variations on the number of seeds per pod except the fungicides applied. At Degem, the highest number of pods per plant (7.57) and the lowest (3.17) were obtained from CS20DK cultivar sprayed with Redomil fungicide two times and unsprayed local cultivar, respectively. At this location on Gora cultivar, the lowest (3.24) and the highest pod per plant (4.76) were recorded on plots sprayed with chlorothalonil fungicide one time and three times, respectively. On CS20DK and Local cultivars the lowest pods per plant were recorded on unsprayed plots. Among the control plots of each cultivar the highest pods per plant (4.57) and the lowest (3.17) were obtained from Gora and local cultivars in the same order. Whereas, at Mush the highest number of pods per plant (3.59) was obtained on Local cultivar sprayed Redomil fungicide three times and 1.67 lowest, was obtained from Gora cultivar sprayed Bayleton fungicide once. On Gora cultivar, the highest and the lowest pods per pod (3.53, 1.76) were recorded from plots sprayed Bayleton fungicide three times and once in that order. At this location also, among the unsprayed plots, Gora cultivar recorded the highest pods per plant (2.29) than others. At Degem the highest and significantly different number of seeds per pod (3.14) was recorded on Local cultivar sprayed with Redomil fungicide three times followed by (2.69) CS20DK cultivar sprayed Redomil fungicides three times. The least mean seeds per pod (1.81) were obtained from unsprayed CS20DK cultivar. On Gora cultivar, the highest and the least numbers of seeds per pod (2.42, 1.82) was obtained from plots sprayed Redomil fungicide two times and Chlorothalonil fungicide only once, respectively. Similarly, on CS20DK cultivar, the highest (2.69) and the least (1.81) numbers of seeds per pod were recorded from plots sprayed with Bayleton fungicide three times and unsprayed control plots in the order mentioned. On Local cultivar, the second highest seeds per pod (2.65) were recorded from plots sprayed Redomil fungicide two times (Table 15).

Table 15. Effect of cultivars, fungicides and spray frequencies on pods per plant at Degem and Mush in 2015 main cropping season.

Treatments			Degem		Mush	
Cultivar	**Fungicide**	**spray frequency**	**Pod/plant**	**Seed/pod**	**Pod/plant**	**Seed/pod**
Gora	**Bayleton**	1 time spray	3.66g…k	1.84hijk	1.76j	1.75
		2 times spray	3.98g...k	1.99fghi	1.86ij	2.22
		3 times spray	4.65e…i	2.19defg	3.53a	2.11
	Chlorothalonil	1 time spray	3.24jk	1.82ijk	2.39e…j	2.07
		2 times spray	4.20f…k	2.00fghijk	2.19hij	1.87
		3 times spray	4.76efghi	2.05efghi	2.61c…i	1.9
	Redomil	1 time spray	4.64efghi	2.12efgh	2.34f…j	1.95
		2 times spray	4.72efghi	2.42bcd	3.16a…d	2.48
		3 times spray	3.49ijk	2.23defg	2.13hij	1.96
		Control	2.57efghij	1.91hijk	2.29ghi	1.92
CS20DK	**Bayleton**	1 time spray	6.45abc	2.31cde	3.03a…g	2.09
		2 times spray	4.54e…k	2.27def	3.05a…f	1.69
		3 times spray	4.90d…h	2.69b	3.55a	1.7
	Chlorothalonil	1 time spray	4.80e…i	2.04efghij	3.13a…e	1.79
		2 times spray	4.92defg	2.60bc	2.32fghij	1.89
		3 times spray	3.66g…k	2.27def	2.50d…j	2.29
	Redomil	1 time spray	6.62abc	2.16defg	3.33abc	1.99

Treatments			Degem		Mush	
Cultivar	Fungicide	spray frequency	Pod/plant	Seed/pod	Pod/plant	Seed/pod
		2 times spray	7.57a	2.32cde	2.97a…g	2.48
		3 times spray	3.92g…k	2.08efghi	3.07a…f	2.1
		Control	3.50hijk	1.81jk	2.04e…j	1.78

Table 15. (Continued)

Local	**Bayleton**	1 time spray	6.12bcd	2.11efgh	3.03a…g	2.05
		2 times spray	7.13ab	2.23defg	3.44ab	1.64
		3 times spray	6.23abcd	2.63b	3.21abcd	1.83
	Chlorothalonil	1 time spray	3.84g…k	1.74k	3.37ab	2.18
		2 times spray	5.59c…f	2.00fghijk	2.05e…j	1.85
		3 times spray	6.89abc	2.27def	3.03a…f	2.26
	Redomil	1 time spray	4.34e…k	1.95ghijk	3.41ab	2.07
		2 times spray	5.73cde	2.65b	3.32abc	2.33
		3 times spray	6.67abc	3.14a	3.59a	2.27
		Control	3.17k	1.84ijk	1.92hij	2.23
	SE		0.49	0.10	0.27	0.19
	CV (%)		17.88	11.76	16.59	16.45

Values in the column with the same letters are not significantly different.

At Mush, neither of the interactions nor of the main effects showed significant variations on the number of seeds per pod except between fungicides applied (Appendix Table 8). Among the fungicides applied, the highest (2.20) and significantly different numbers of seeds per pods were recorded on Redomil fungicide sprayed plots regardless of the type of cultivar and spraying frequencies. The second highest (2.01) numbers of seeds per pod were recorded on chlorothalonil sprayed plots but it didn't show significant variations from plots sprayed with Bayleton (1.90) and unsprayed plots (1.94) (Table 16).

Table 16. Effect of fungicide on seeds per pod in 2015 main cropping season at Mush

Fungicides	Seeds/Pod
Bayleton	1.90b
Chlorothalonil	2.01b
Redomil	2.20a
Control	1.94b
LSD (%)	0.15
CV (%)	16.45

Values in the column with the same letters are not significantly different.

Analysis of variance (ANOVA) revealed that interaction of cultivars and spraying frequencies and cultivars as a main factor showed highly significant difference (P<0.01) in HSW at Degem (Appendix table 7). However interaction effects of cultivars, fungicides and spray frequencies showed non-significant variations. In this study, the highest HSW (74.67 g) and the least (39.0 g) were obtained from Gora cultivars received three times spray and unsprayed local cultivar, respectively (Table 17). However, the HSW obtained from Gora cultivar of one time (69.89), two times (72.22) sprayed and unsprayed (68.89g) plots had no significant difference between them. Likewise, on cultivar CS20DK the highest (47.67 g) hundred seed mass were recorded from the plots sprayed three times but it didn't show significant variations from plots received once and two times spray except the unsprayed. Similarly, on local cultivar a HSW of 41.78, 42.78, 42.89 and 39.0 g were recorded from once, two times, three times sprayed and unsprayed plots, respectively. Generally, HSW recorded from Gora cultivar was much higher than the weight of other cultivars corresponding to spraying frequencies.

Table 17. Effect of cultivars and spray frequencies on hundred seed weight in 2015 main cropping season at Degem

Treatments		
Cultivars	Frequencies	Hundred seed Weight
Gora	1 time spray	69.89b
	2 times spray	72.22ab
	3 times spray	74.67a
	no spray	68.89b
CS20DK	1 time spray	45.22cd
	2 times spray	45.00cd
	3 times spray	47.67c
	no spray	41.00ef
Local	1 time spray	41.78def

2 times spray	42.78d
3 times spray	42.89de
no spray	39.00f
SE	1.28
CV (%)	7.29

Values in the column with the same letters are not significantly different.

At Mush, analysis of variance (ANOVA) revealed that interaction effects of cultivars, fungicides and spray frequencies showed significant variations on HSW (Appendix Table 8). The highest HSW (62.33g) and the lowest (35.0 g) were recorded from Gora cultivar sprayed three times with Bayleton fungicide and local cultivar sprayed two times with Chlorothalonil fungicide and from plots, Chlorothalonil fungicide once, respectively (Table 18). On this cultivar, three times sprayed plots with either of the fungicides didn't show significant variations. Similarly, on CS20DK cultivar the highest HSW (49.67 g) was recorded from three times sprayed plot with Bayleton fungicide. While the lowest (41.0 g) hundred seed weight was recorded from untreated control plots. However on local cultivar, the highest (57.0g) hundred seed weight was recorded on plots received Chlorothalonil fungicide three times spray. On this cultivar (Local), unsprayed plots of Bayleton and Redomil did not show significant variations from unsprayed control plots of each. Among unsprayed control plots the highest (60.0 g) and the lowest (41.0 g) HSW were recorded on Gora and CS20DK cultivars in the order mentioned (Table 18).

Table 18. HSW of faba bean as influenced by different cultivars, fungicide and spray frequencies under field conditions during the main cropping season of 2015.

Treatments			**HSW**	
Cultivars	**Fungicides**	**Spray frequencies**	**Mush**	**Degem**
Gora	Bayleton	1 time spray	62.00a	70.33
		2 times spray	44.00d…i	72.33
		3 times spray	62.33a	74.67
	Chlorothalonil	1 time spray	41.00e…i	69.00
		2 times spray	62.00a	68.67
		3 times spray	60.33ab	75.67
	Redomil	1 time spray	53.33ab	68.67
		2 times spray	60.00ab	70.67
		3 times spray	60.00ab	72.67
		no spray	60.00ab	46.00
CS20DK	Bayleton	1 time spray	48.67c…h	43.33
		2 times spray	48.67c…h	50.00
		3 times spray	49.67b…f	46.00
	Chlorothalonil	1 time spray	41.00e…i	41.67
		2 times spray	41.67e…i	44.33
		3 times spray	44.33d…i	43.67
	Redomil	1 time spray	43.00d…i	45.00
		2 times spray	44.67d…i	48.67
		3 times spray	41.00e…i	41.000
		no spray	41.33efghi	43.67
Local	Bayleton	1 time spray	43.00fghi	41.33
		2 times spray	43.33d…i	42.33
		3 times spray	49.67b…f	43.67
	Chlorothalonil	1 time spray	35.00i	40.00
		2 times spray	41.00e…i	43.00
		3 times spray	57.00abc	42.33
	Redomil	1 time spray	38.33ghi	42.00
		2 times spray	37.67hi	44.00
		3 times spray	43.33de…i	43.67
		no spray	40.00fghi	39.00
		SE	3.99	2.21
		CV (0.05%)	14.39	7.29

HSW: Hundred seed weight, Means with the same letters are not significantly different.

4.1.1.4. Grain Yield

Interaction effect of cultivars, fungicides and spray frequencies showed significant variations in producing seed yield at both locations (Appendix 7 & 8). At Degem, the highest mean seed yield (1216 kg ha^{-1}) was recorded on Gora cultivar sprayed three times with Chlorothalonil fungicide but it didn't showed significant variations from plots of this cultivar sprayed with Bayleton (1152 kg ha^{-1}) and Redomil (1127 kg ha^{-1}) three times each. The least mean seed yield (575 kg ha^{-1}) was recorded from unsprayed plots of cultivar CS20DK (Table 19). At this location on cultivar CS20DK, sprayed three times with Redomil gave 989 kg ha^{-1} mean grain seeds which was significantly differed from unsprayed plots (575 kg ha^{-1}). Also on local cultivar, the highest (1114 kg ha^{-1}) mean grain yield was obtained on three times sprayed plots with Redomil fungicide than unsprayed plots (692 kg ha^{-1}).

Similarly at Mush, the highest grain yield of 981 kg ha^{-1} was obtained on Gora cultivar from plots sprayed three times with Bayleton fungicide. Furthermore, the next highest (928 kg ha^{-1}) grain yield was obtained on local cultivar sprayed Redomil fungicide three times. On CS20DK cultivar, the highest 850 kg ha^{-1} and 849 kg ha^{-1} was obtained on Bayleton and Redomil sprayed plots of three times each respectively. But on Local cultivar, the highest (928) and the lowest (601 kg ha^{-1}) grain yield was recorded on plots sprayed Redomil fungicide three times and unsprayed plots respectively. On this location on unsprayed plots, the least (547 kg ha^{-1}) and (601 kg ha^{-1}) grain yield was obtained on CS20DK and local cultivars in the order mentioned (Table 19). This result in line with the result of Wulita (2015) explained that spraying of fungicides reduced disease intensity and hence increases the yield potential of the crop.

4.1.1.5. Yield Loss

Relative grain yield loss due to faba bean gall disease showed prominent differences among treatments at both locations. At Degem, among unsprayed control plots an additional yield of 3.56 and 2.39 kg/ha were gained on Gora cultivar as compared to CS20DK and local cultivars, respectively. The highest yield loss (41.86%) was observed on unsprayed plot of cultivar CS20DK as compared to plots sprayed Redomil fungicide three times while, the lowest (4.05%) yield loss was recorded on local cultivar sprayed Bayleton fungicide two times. Similarly, Wulita *et al*., (2015) reported that application of the foliar fungicide reduced losses in seed yield and quality from faba bean gall disease. On Gora cultivar the lowest (6.83%) yield loss were recorded, on plots sprayed with Redomil fungicide two times as compared to Bayleton and Chlorothalonil sprayed plots. On this cultivar, three times sprayed plots with Chlorothalonil fungicide gave additional yield of 64 and 89 kg ha^{-1} as compared to Bayleton and Redomil fungicides sprayed plots three times each, respectively. On CS20DK cultivar, additional yield of 237 and 128 kg ha^{-1} was harvested on three times sprayed plots of Redomil fungicide as compared to Chlorothalonil and Bayleton fungicides sprayed three times each, respectively. On this cultivar, two times sprayed plots with Redomil fungicide recorded the least (5.36%) yield losses relative to Bayleton (17.54%) and Chlorothalonil (14.10%) fungicides two times sprayed plots. Unsprayed CS20DK cultivar recorded the least (575 kg ha^{-1}) yield loss as compared to unsprayed Gora (931 kg ha^{-1}) and local (692 kg ha^{-1}) cultivars; this could be due to the genetic make of the variety susceptibility to the pathogen. In addition, on local cultivar the maximum (37.88%) and the minimum (4.05% kg ha^{-1}) relative yield loss were recorded on unsprayed control plots as compared to three times sprayed plots with Redomil fungicide and on plots received Bayleton fungicide two times as compared to three times sprayed plot with Bayleton plots in the order mentioned. On this cultivar, additional yield of 14 and 3 kg $ha^{-1}$was gained due to spraying of Redomil fungicide three times rather than spraying of Chlorothalonil and Bayleton fungicides three times each, respectively.

At Mush, the maximum relative yield (39.78%) loss was recorded on unsprayed local cultivar as compared to three times sprayed plots with Redomil fungicide (Table 19). On this location, on Gora cultivar, the highest (981 kg ha^{-1}) and significantly difference grain yield was recorded on plots sprayed with Bayleton fungicide three times. A relative yield loss of 37.21% was recorded on unsprayed plots of this cultivar as compared to plots three times sprayed with Bayleton fungicide. On this cultivar, spaying Bayleton fungicide three times gave an additional 179 and 298 kg ha^{-1} grain yield than sparing three times with Chlorothalonil and Redomil fungicides. Also, the yield obtained from plots sprayed two times with Bayleton fungicide gave higher yields than spraying of other fungicides two times.

On CS20DK cultivar, two times Bayleton sprayed plots gave the highest (850 kg ha^{-1}) grain yield but it did not showed significant variations from three times sprayed plots with Redomil (849). Whereas except the above two treatments the other treatments did not showed significant variations among them. The relative lower 8.22% and 11.22% kg ha^{-1}, grain yield loss were recorded on plots sprayed Bayleton and Redomil once each (Table 19). On local cultivar 35.24% highest yield loss was recorded on unsprayed control plots of Redomil fungicide followed by (33.70% kg ha^{-1}) one time sprayed plot of Chlorothalolin fungicide. On this cultivar the lowest (4.53% kg ha^{-1}) yield loss was calculated on plots of Bayleton fungicide sprayed two times.

Table 19. Yield and RYL of faba bean as influenced by different cultivars, different fungicides and different spray frequencies under field conditions during the main cropping season of 2015.

Treatment			Degem			Mush		
Cultivar	Fungicide	Spray frequencies	YLD (kg/ha)	YIOUP %	RYL %	YLD (kg/ha)	YIOUP (%)	RYL (%)
Gora	Bayleton	1 time spray	973ghij	4.51	15.54	665e…k	7.96	32.21
		2 times spray	1019c…h	9.45	11.55	842b…f	36.69	14.17
		3 times spray	1152ab	23.74	0.00	981ab	59.25	0.00
		no spray	931hijkl	0.00	19.18	616ijk	0.00	37.21
	Chlorothalonil	1 time spray	872ijklm	4.62	19.9	707d…k	14.77	11.85
		2 times spray	967ghij	3.87	20.48	772c…j	25.33	3.74
		3 times spray	1216a	30.61	0.00	802b…i	30.2	0.00
		no spray	931hijkl	0.00	23.44	616ijk	0.00	23.19
	Redomil	1 time spray	982fghij	5.48	12.87	612ijk	0.65	10.40
		2 times spray	1050b…h	12.78	6.83	682e…k	10.71	0.15
		3 times spray	1127abc	21.05	0.00	683e…k	10.88	0.00
		no spray	931hijkl	0.00	17.39	616ijk	0.00	9.81
CS20DK	Bayleton	1 time spray	667op	16.00	22.53	578jk	5.67	32.00
		2 times spray	710nop	23.48	17.54	595jk	8.78	30.00
		3 times spray	861jklm	49.74	0.00	850bcde	55.39	0.00
		no spray	575q	0.00	33.22	547k	0.00	35.65
	Chlorothalonil	1 time spray	691opq	20.17	8.11	615ijk	12.43	4.65
		2 times spray	646pq	12.35	14.1	588jk	7.5	8.84
		3 times spray	752mnop	30.78	0.00	645f…k	17.92	0.00
		no spray	575q	0.00	23.54	547k	0.00	15.19
	Redomil	1 time spray	835klm	45.22	15.57	637ghijk	16.45	24.97
		2 times spray	936hijkl	62.78	5.36	678e…k	23.95	20.14
		3 times spray	989e…i	72	0.00	849bcde	55.21	0.00
		no spray	575q	0.00	41.86	547k	0.00	35.47
Local	Bayleton	1 time spray	1016c…h	46.82	8.55	759c…i	26.29	8.22
		2 times spray	1066b…g	54.05	4.05	622hijk	3.49	24.79
		3 times spray	1111a…e	60.55	0.00	827b…g	37.60	0.00
		no spray	692opq	00.00	37.71	601jk	0.00	27.33
	Chlorothalonil	1 time spray	776mno	12.14	29.46	602jk	0.17	33.70
		2 times spray	946ghijk	36.71	14.00	820b…h	36.44	9.69
		3 times spray	1100a…f	58.96	0.00	908abcd	51.08	0.00
		no spray	692opq	00.00	37.09	601jk	0.00	33.81
	Redomil	1 time spray	823lmn	18.93	26.12	724d…k	20.47	21.98
		2 times spray	10.01d…h	44.65	10.14	886abcd	47.42	4.53
		3 times spray	1114abcd	60.98	0.00	928ab	54.41	0.00
		control	692opq	00.00	37.88	601jk	0.00	35.24
		SE	0.43			0.71		
		CV (%)	8.41			17.34		

YLD: Yield, RYL: Relative yield loss, HSM: Hundred Seed Mass, YIOUC: Yield increase over unsprayed control

4.1.1.6. Correlation between Disease Parameters, Yield and Yield Components

The correlations among the disease parameters with yield showed a highly significant negative correlation in PDI, PDS and AUDPC at both locations (Table 20). At Degem, grain yield showed a highly significant positive correlation with PP and SP while at Mush, only SP showed significant positive correlation. Similarly, highly significant positive correlation was observed among PDI, PDS, and AUDPC at both locations.

At Degem, a highly significant variation and positive correlation was observed in hundred seed weight with grain yield but it showed a highly negative correlation with PDI, PDS and AUDPC and non-significant variation with PP and SP. Similarly, severity and AUDPC had highly significant negative correlation coefficients of r = -0.595 and r = -0.599 with yield, respectively, while AUDPC and severity themselves were even highly and positively (r = 0. 998) correlated with each other. There is existence of strong positive correlation (r = 0.998) between percent severity and AUDPC indicates that treatments which were severely infected revealed high AUDPC values (Table 20).

At Mush, hundred seed weight showed non-significant correlation with disease parameters and yield and yield components. At this location, severity values and the AUDPC had highly significant (P <0.01) and negatively correlated with coefficients of r = -0.316** and r = -0.317** with grain yield, respectively. AUDPC had a strong positive (r = 0.998) correlation with the final disease severity. At this location disease parameters showed highly positive correlation between them while seeds per pod showed non-significant correlation with pods per plant and hundred seed weight (table 20).

This finding agrees with the finding of Wulita, (2015), who stated that disease severity showed higher positively and negatively correlations with AUDPC and seed yield respectively and positive correlations with AUDPC and seed yield. El-Sayad (2011), also reported that the higher AUDPC values were accompanied by lower yields. AUDPC is an integral descriptive for the epidemic, which is comparable to the multiple point models to measure crop losses; however, AUDPC can't distinguish between early and late occurring epidemics, which result in the same areas under the curve without applying weighting factors to assessments at different growth stages.

Also, Su1 *et al*., (2006), stated the terminal disease severity and AUDPC were very important in determining the extent of losses in yield and yield components and the observed levels of the disease had a considerable adverse effect on grain yield of the crops.

Table 20. Correlation coefficient (r) among disease parameters, yield and yield components in different faba bean cultivars, fungicides and spray frequencies under field conditions at Degem and Mush during the main cropping season of 2015

A) Degem

	PDI	PDS	AUDPC	PP	SP	Yield	HSW
PDI	1						
PDS	0.907**	1					
AUDPC	0.907**	0.998**	1				
PP	-0.279**	-0.310**	-0.305**	1			
SP	-0.486**	-0.438**	-0.426**	0.419**	1		
Yield	-0.561**	-0.595**	-0.599**	0.406**	0.272**	1	
HSW	-0.331**	-0.260**	-0.273**	-0.158^{ns}	-0.131^{ns}	0.438**	1

B) Mush

	PDI	**PDS**	**AUDPC**	**PP**	**SP**	**Yield**	**HSW**
PDI	1						
PDS	0.865**	1					
AUDPC	0.870**	0.998**	1				
PP	-0.100**	-0.127^{ns}	-0.127^{ns}	1			
SP	-0.087^{ns}	-0.020^{ns}	-0.021^{ns}	-0.002^{ns}	1		
Yield	-0.286**	-0.316**	-0.317**	0.160^{ns}	0.190*	1	
HSW	-0.055^{ns}	-0.042^{ns}	0.042^{ns}	-0.157^{ns}	-0.015^{ns}	-0.120^{ns}	1

PP = Pods per plant, SP = Seeds per pod, HSW = hundred seed weight, PDI = Percentage disease incidence, PSI = Percentage severity index, ns = Non-significant, *, ** and ^{ns} indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively. AUDPC = Area under disease progress curve.

4.1.1.7. Cost Benefit Analysis

Variation in the net benefit was recorded among the interaction effects of cultivars, fungicides and spraying frequencies at both locations (Table 21 & 22). Partial budget analysis was calculated based on cost of variable inputs of the year 2015 cropping season and net benefit estimated based on mean of local market price when most of farmers supplied the produce to the market. At both locations, the highest input and labor cost of 9,900 birr/ha was computed for all cultivars treated with Chlorothalonil fungicide three times. However, the highest net benefit of ETB 8189 and 6943.5 was recorded at Degem and Mush, respectively. At Degem on Gora cultivar, the highest net benefit of ETB, 8164.5 was recorded on plots sprayed with Redomil fungicide three times followed by ETB, 7902 was gain on plots sprayed with Bayleton fungicide three times. On this cultivar the lowest net benefit of ETB, 4504.5, 4572 and 6516 was gained plots sprayed with Chlorothalonil fungicide once, twice and three times, respectively over unsprayed plots (ETB 6,718.5). On this cultivar, the change in input cost of all treatments varied from 5850 (unsprayed) to 9900 Birr (three times sprayed). On the other hand on CS20DK cultivar, the highest net benefit of 6301.5 birr was obtained from plots sprayed with Redomil fungicide three times and increased net benefit with 365.75% marginal rate of return. On this cultivar, plots sprayed three times with Bayleton, Chlorothalonil and Redomil fungicides recorded MRR of 114.5%, (-41.0%) and 365.75%, respectively but, the highest (777.50%) and the least (-64.5%) marginal rate of return was recorded on plots sprayed one time with Redomil fungicide and two times with Chlorothaonil in the order mentioned.

On local cultivar the highest; 8164.5 and 7348.5 net benefit was obtained from plots sprayed with Redomil and Bayleton fungicides three times each with 391.42% and 214.25 marginal rate of return correspondingly. Among two times sprayed plots with Bayleton, Chlorothalonil and Redomil fungicides 7341, 4,421 and 7,063.5 net profit with marginal rate of return i.e. 320.75%, 34.41% and 446.44% was gained, respectively. On this cultivar the lowest net benefit of -16.0 and (-1.19%) marginal rate of return was recorded on plots sprayed once with Chlorothalonil fungicide (Table 21).

From the disease, yield and yield components data of Gora cultivar; three times sprayed plots had protected the cultivars from severe epidemic and increased yield and yield components. Partial budget analysis using marginal rate of return revealed that sprayed this cultivars three times provided higher marginal rate of return than the remaining fungicide spray frequencies.

Table 21. Data of partial budget analysis for the management of faba bean gall using cultivars, fungicides and spray frequencies under field conditions during the main cropping season of 2015 at Degem.

Treatments			Cost benefit data							
Cultivar	**Fungicide**	**Spray frequencies**	**Yield (kg/ha)**	**Sale (ETB 100 kg^{-1})**	**Sale revenue (ETB Birr)**	**Total Input and Labor cost (birr/ha)**	**Marginal cost (birr/ha)**	**Net profit (birr/ha)**	**Marginal benefit (birr/ha)**	**Marginal rate of return (%)**
Gora	**Bayleton**	**1 time**	973	1350	13135.5	6450	600	6685.5	-33	-5.50
		2 times	1019	1350	13756.5	7050	1200	6706.5	-12	-1.00
		3 times	1152	1350	15552	7650	1800	7902.0	1183.5	65.75
	Chlorothalonil	**1 time**	872	1350	11772	7200	1350	4572.0	-2146.5	-159.00
		2 times	967	1350	13054.5	8550	2700	4504.5	-2214	-82.00
		3 times	1216	1350	16416	9900	4050	6516.0	-202.5	-5.00
	Redomill	**1 time**	982	1350	13257	6250	400	7007.0	288.5	72.13
		2 times	1050	1350	14175	6650	800	7525.0	806.5	100.81
		3 times	1127	1350	15214.5	7050	1200	8164.5	1446	120.50
		control	931	1350	12568.5	5850	0	6718.5	0	0.00
	Bayleton	**1 time**	667	1350	9004.5	6450	600	2554.5	642	107.00
CS20DK		**2 times**	710	1350	9585	7050	1200	2535.0	622.5	51.88
		3 times	861	1350	11623.5	7650	1800	3973.5	2061	114.50
	Chlorothalonil	**1 time**	691	1350	9328.5	7200	1350	2128.5	216	16.00
		2 times	646	1350	8721	8550	2700	171.0	-1741.5	-64.50
		3 times	752	1350	10152	9900	4050	252.0	-1660.5	-41.00
	Redomil	**1 time**	835	1350	11272.5	6250	400	5022.5	3110.0	777.5
		2 times	936	1350	12636	6650	800	5986.0	4073.5	509.19
		3 times	989	1350	13351.5	7050	1200	6301.5	4389.0	365.75
		control	575	1350	7762.5	5850	0	1912.5	0.0	0.00
Local	**Bayleton**	**1 time**	1016	1350	13716	6450	600	7266	3774	629
		2 times	1066	1350	14391	7050	1200	7341	3849	320.75
		3 times	1111	1350	14998.5	7650	1800	7348.5	3856.5	214.25
	Chlorothalonil	**1 time**	776	1350	10476	7200	1350	3476	-16	-1.19
		2 times	946	1350	12771	8550	2700	4421	929	34.41
		3 times	1100	1350	14850	9900	4050	5150	1658	40.94
	Redomil	**1 time**	823	1350	11110.5	6250	400	5060.5	1568.5	392.13
		2 times	1001	1350	13513.5	6650	800	7063.5	3571.5	446.44
		3 times	1114	1350	15039	7050	1200	8189	4697	391.42
		control	692	1350	9342	5850	0	3492	0	0

Likewise, at Mush, the highest (6943.5) ETB ha^{-1} net benefit was obtained on Gora cultivar sprayed Bayleton three times followed by 6,423 ETB obtained from plots sprayed with Redomil fungicide three times, whereas (-1539) ETB loss was recorded from plots sprayed with Chlorothalonil fungicide three times. On this location on Gora cultivar, 6943.5, ETB ha^{-1} highest net benefit was recorded from plots sprayed Bayleton fungicide three times with a marginal rate of return 248.75% followed by 4317 ETB ha^{-1} net benefit and 154.25 % marginal rate of return was recorded on plots sprayed Bayleton fungicide two times. On this cultivar, application of Chlorothalonil once, twice and three times recorded 2,344.5, 1892 and 927 net profit, respectively. In Redomil fungicide sprayed plots, except twice sprayed, the other sprayed plots (once and three times) gave lower net profit than untreated control plot.

On cultivar CS20DK, Chlorothalonil sprayed plots recorded lower net benefit as compared to the control. On this cultivar the highest (ETB 4411.5) net profit with Marginal rate of return (239.75%) was obtain on plots Redomil fungicides three times. Spraying Redomil fungicide once, twice and three times gave higher net benefit ETB of (2503.0, 2349.5 & 4411.5) than unsprayed control (1534.5) with a marginal rate of return 203.75%, 121.06% and 239.75%, respectively.

On local cultivar, the highest net benefit was recorded from plots receiving Redomil fungicide three times (ETB, 6423 ha^{-1}) and the second highest net benefit was obtained from two times sprayed with Redomil fungicide (ETB 5311.0) ha^{-1}. On this cultivar, Chlorothalonil sprayed plots, recorded greater net benefit than control plots except plots received one time spray. On this location, the maximum calculated value of marginal rate of return (380.94) was obtained from local cultivar on plots received Redomil fungicide two times. Also, spraying of this fungicide three times on local cultivar, resulted the maximum marginal rate of returns (346.63%) compared to unsprayed control plots. In addition 315.13% and 248.75% of marginal rate of return were resulted on local cultivar sprayed Redomil fungicide once and on Gora cultivar sprayed Bayleton fungicide three times. This result agrees with the result of Wulita (2015), that application of different fungicides result higher rate of marginal return than unsprayed plots. Also, Rechcing (1997), stated that fungicides are used because they provide effective and reliable disease control, deliver production in the form of crop yield and quality at an economic price and can be used safely. The lowest marginal rate of return (-113.5%) was recorded on Gora cultivar received one time spray with Redomil fungicide (Table 22).

Table 22. Data of partial budget analysis for the management of faba bean gall using cultivars, fungicides and spraying frequencies under field conditions during the main cropping season of 2015 at Mush.

Variety	Fungicide	Spray frequencies	Yield (kg ha^{-1})	Sale (ETB 100 kg^{-1})	Sale revenue (ETB Birr)	Total input and labor cost (birr/ha)	Marginal cost (birr/ha)	Net profit (birr/ha)	Marginal benefit (birr/ha)	Marginal rate of return (%)
Gora	Bayleton	1 time	665	1350	8977.5	6450	600	2527.5	61.5	10.25
		2 times	842	1350	11367	7050	1200	4317	1851	154.25
		3 times	981	1350	14593.5	7650	1800	6943.5	4477.5	248.75
	Chlorothalonil	1 time	707	1350	9544.5	7200	1350	2344.5	-121.5	-9
		2 times	772	1350	10442	8550	2700	1892	-574	-21.26
		3 times	802	1350	10827	9900	4050	927	-1539	-38
	Redomil	1 time	612	1350	8262	6250	400	2012	-454	-113.5
		2 times	682	1350	9207	6650	800	2557	91	11.38
		3 times	683	1350	9220.5	7050	1200	2170.5	-295.5	-24.63
		control	616	1350	8316	5850	0	2466	0	0
CS20Dk	Bayleton	1 time	578	1350	7803	6450	600	1353	-181.5	-30.25
		2 times	595	1350	8032.5	7050	1200	982.5	-552	-46
		3 times	850	1350	11475	7650	1800	3825	2290.5	149.27
	chlorothalonil	1 time	615	1350	8302.5	7200	1350	1102.5	-432	-32
		2 times	588	1350	7938	8550	2700	-612	-2146.5	-79.5
		3 times	645	1350	8707.5	9900	4050	-1192.5	-2727	-67.33
	Redomil	1 time	637	1350	8599.5	6250	400	2349.5	815	203.75
		2 times	678	1350	9153	6650	800	2503	968.5	121.06
		3 times	849	1350	11461.5	7050	1200	4411.5	2877	239.75
		control	547	1350	7384.5	5850	0	1534.5	0	0

Table 22. (*Continued*)

Variety	Fungicide	Spray frequencies	Yield (kg/ha)	Sale (ETB ha^{-1})	Sale revenue (ETB Birr)	Total input and labor cost (birr/ha)	Marginal cost (birr/ha)	Net profit (birr/ha)	Marginal benefit (birr/ha)	Marginal rate of return (%)
Local	Bayleton	1 time	759	1350	10246.5	6450	600	3796.5	1533	255.5
		2 times	622	1350	8397	7050	1200	1347	-916.5	-76.38
		3 times	827	1350	11164.5	7650	1800	3514.5	1251	69.5
	chlorothalonil	1 time	602	1350	8127	7200	1350	927	-1336.5	-99
		2 times	820	1350	11070	8550	2700	2520	256.5	9.5
		3 times	908	1350	12258	9900	4050	2358	94.5	2.33
	Redomil	1 time	724	1350	9774	6250	400	3524	1260.5	315.13
		2 times	886	1350	11961	6650	800	5311	3047.5	380.94
		3 times	928	1350	13473	7050	1200	6423	4159.5	346.63
		control	601	1350	8113.5	5850	0	2263.5	0	0

V. Summary and Conclusions

Ethiopia is the world's second largest producer of faba bean next to China. The low productivity of the crop in the country is attributed to susceptibility to biotic and abiotic stresses. Faba Bean Gall (FBG) disease has become a serious threat to faba bean production and productivity in major faba bean growing areas of the country causing a yield loss as high as 100%. Since the disease is new and recently reported in the country, information is lacking on disease intensity as well as its management methods. The present study was carried out to assess the intensity of FBG disease and to evaluate the combinations of three faba bean cultivars (Gora, CS20DK and local) and fungicides (Bayleton, Chlorothalonil and Redomil) with four spray frequencies (one time spray, two times spray, three times and unsprayed) for the management of faba bean gall disease, and also to assess their yield and yield components.

- The field survey was carried in 14 districts of North Shoa of Oromia and Amhara regions, whereas the field experiment was carried out at Degem and Mush, North Shoa under natural infection.
- Among the total number of fields (126) surveyed, the disease was observed in 103(81.75%) of the surveyed fields with mean incidence and severity of 46.52 and 39.17%, respectively.
- The disease intensity was variable with altitude, location and type of cultivar.
- The highest mean diseases severity (44.74%) was recorded on altitude above 2800 m.a.s.l while the least (28.96%) was recorded at altitudes below 2600 m. a .s .l.
- The FGD disease was observed on improved as well as local cultivars with more or less similar disease intensity.
- For the assesment of FBG disease management, a total of thirty treatments that included three cultivars

(Gora, CS20DK and Local) and fungicides (Bayleton, Chlorothalonil and Ridomil MZ) with four spray frequencies were arranged in a split-split plot design with three replications on farmers' fields at Degem and Mush, North Shoa Zone in 2015 main cropping season.

- The statistical analysis showed that significant differences among treatments in the FBG incidence, severity and AUDPC value at both locations.
- On the final date of disease assessment, among the cultivars Gora cultivar recorded the lowest disease incidence of 40.69%, 25.42% and severity of 28.75%, 24.44% at Degem and Mush, respectively, whereas the highest disease incidence of 50.42, 30.42% and severity of 33.3, 29.68% were recorded on the local cultivar at Degem and Mush, respectively. All the fungicides were reduced FBG incidence however, significance difference were not recorded among them at the final date of assessment at both locations.
- Three times sprayed plots recorded the lowest (21.85% and 13.85%) disease incidence, whereas the highest disease incidence (71.67% and 43.52%) was recorded on control plots at Degem and Mush.
- None of the interactions showed significant variations in reducing disease severity except cultivar with fungicide on 79 DAP and cultivar x spray frequencies on 89 DAP of assessment date at Degem.
- At Degem on the final disease assessment date, unsprayed plots of the cultivar CS20DK showed the highest (51.67%) disease severity followed by the local cultivar with severity of 53.33% while, the lowest (13.33%) was recorded on three times sprayed plots of the cultivar CS20DK followed by13.89% were recorded on the Gora Cultivar..
- Likewise, at Mush also interaction effects of cultivars and spray frequencies showed significance difference on disease severity at 86 DAP date of disease assessment and the highest (43.33%) and the lowest (14.44%) disease severity was recorded on unsprayed and three times sprayed plots of Local and CS20DK cultivar, respectively.
- The highest i.e. 3058.33 and 1916.67%-days AUDPC values were recorded on unsprayed plots of CS20DK and on control local cultivars at Degem and Mush in the same order mentioned. While, the lowest AUDPC values of 1469.44 and 902.78% - days were recorded on three times sprayed plots of Gora and CS20DK cultivars regardless of fungicides at Degem and Mush.
- Interaction effects of cultivars, fungicides and spraying frequencies showed significant variation for pods per plant and grain yield at both locations and also it was significant on hundred seed weight only at Mush. The highest number of pods per plant i.e. 7.57 at Degem and 3.59 at Mush were recorded on CS20DK and local cultivars sprayed with Redomil fungicide two and three times in the order mentioned.
- At Degem the highest seeds per pod (3.14) were recorded on local cultivar sprayed three times with Redomil fungicide. While, the lowest (1.81) number of seeds per pod were recorded on unsprayed plots of CS20DK cultivar. At Mush, except the fungicides neither of the interactions nor the main effects showed significant variations on seeds per pod. Among the fungicides, the highest (2.20) and the lowest (1.940) seeds per pod were recorded on Redomil sprayed and unsprayed plots.
- The highest grain yield was recorded on Gora cultivar that was sprayed three times with Chlorothalonil at Degem but Redomil at Mush. At Degem on Gora cultivar, the highest relative yield losses of 23.44, 19.18 and 17.19% were incurred from unsprayed plots of Chlorothalonil, Bayleton and Redomil, respectively. While on this location, on CS20DK and local cultivars, relative yield loss of 41.86% and 37. 88% were recorded on control plots of Redomil fungicide, respectively.
- At Mush, the highest relative yield loss of 37.21% and 35.65% was recorded from unsprayed plots of Gora and CS20DK cultivars, respectively.
- There was significance correlation between yield and yield components with disease severity. The PDI, PDS and AUDPC value were correlated negatively and highly significantly with PP, SP, grain yield and HSW, at Degem. At Mush, they were also correlated negatively and significantly with grain yield while negatively and non-significantly correlation was observed with PP, SP and HSW.
- At Degem, the highest net benefit of ETB 8,189 and 8, 164 were obtained from the local and improved Gora cultivars, respectively that was sprayed three time's with Ridomil fungicide and the least (ETB 171.0) was obtained from cultivar CS20DK that were sprayed with Chlorothlonil fungicide two times. On the other hand, the highest marginal rate of return (777.5%) was obtained from CS20DK cultivar that was one time sprayed with Redomil and the lower marginal rate of return (ETB -159.0%) was recorded on Gora cultivar sprayed with Chlorothalonil once, whereas, at Mush, the highest (ETB 6,943.5) and the lowest (ETB -1,192.5) net benefit were obtained from Gora and CS20DK cultivars that were sprayed with Bayleton and Chlorothalonil fungicide three times each, respectively. At this location, the highest (380.94%) and lowest (-113.5%) marginal rate of return were recorded on local and Gora cultivar sprayed with Redomil fungicide two times and once in the ordered mentioned.

VI. Recommendations

- ✓ From this study, the improved cultivar Gora accompanied with three times spray with Bayeton fungicide could be recommended for the management of FBG disease at Degem and Mush, North Shoa Zone, Ethiopia.
- ✓ However, further evaluations of faba bean genotypes, fungicides and other disease control methods are important.
- ✓ FBG disease was reported recently in the country, its spreads at alarming rate in most of the major faba

bean growing areas of the country. Thus further management/control of this new disease should be aimed at reducing the crop losses and also check the spread of the disease to new areas.

- ✓ For the development of sound and successful management, information regarding on epidemiology of the disease in the country is paramount. Thus any research towards this line could be highly appreciated/ recommended.

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APPENDICES

Table 2. Ding Ascochyta blight scoring scale of

Index	% of plant infected tissue	Nature of infection
0	0	No disease symptom observe
1	< 2%	A few, very few small (2 mm^2) lesion on leaves
2	2-5%	Very small (<2 mm^2) lesion
3	6-10%	Many small lesions (2-5mm^2)
4	11-25%	Many small lesions, a very few large (>mm2)
5	26-50%	Many large lesions
6	51-75%	Lesions coalescing
7	76-90%	Lesions coalescing
8	91-99%	Plants darken, stem breakage
9	100%	plants totally dead

Table 3. ANOVA of percentage of incidence of faba bean gall at different days of assessment in experimental plots under field Conditions during the main cropping season in 2015 at Degem.

		Mean square of percent incidence						
Source of variation	**df**	**DAP 39**	**DAP 49**	**DAP 59**	**DAP 69**	**DAP 79**	**DAP 89**	**DAP 99**
Replication	2	133.57	92.36	446.53	1009.03	41.9	75	594.68
Cultivar	2	215.51**	2002.08**	2518.75**	902.78**	1462.25**	456.25**	854.40**
Error	4	50.93	129.86	989.24	205.56	81.48	145.83	220.72
Fungicide	2	87.73ns	21.53ns	21.52ns	42.36ns	422.45*	317.36*	4.40ns
Cul x Fun	4	72.80ns	85.07ns	173.61ns	49.31ns	315.16*	135.07ns	31.48ns
Error	12	9.38	84.03	213.19	80.32	138.43	80.56	40.16
Fre	3	36.65ns	49.00ns	1069.37**	756.40**	3403.94**	7984.18**	11703.09**
Cul x Fre	6	41.74ns	85.11ns	123.07ns	92.28ns	123.15ns	114.28ns	26.93ns
Fun x Fre	6	27.86ns	33.26ns	68.21ns	44.83ns	220.60*	57.79ns	2.86ns
Cul x Fun x Fre	12	22.18ns	48.19ns	148.30ns	21.68ns	66.55ns	68.09ns	41.98ns
Error	54	39.82	61.5	111.27	50.54	90.66	78.09	49.00
CV (%)		12.03	11.01	13.4	11.66	16.63	16.7	15.43
R^2 (%)		51.41	69.41	76.63	77.21	80.47	87.53	93.82
Mean		52.45	71.25	78.75	60.97	57.27	52.92	45.37

*, ** and ns indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively.
DAP: Days after planting Cul: Cultivar, Fung: Fungicide, Fre: Spray Frequency.

Table 4. ANOVA of percentage of incidence of faba bean bean gall at different days of assessment in experimental plots under field conditions during the main cropping season in 2015 at Degem.

		Mean square of percent incidence					
Source of variation	**Df**	**DAP 46**	**DAP 56**	**DAP 66**	**DAP 76**	**DAP 86**	**DAP 96**
Replication	2	21.07	237.73	1934.95	412.73	153.01	277.08
Cultivar	2	9.95ns	25.23ns	328.01*	359.26**	12.04ns	200.69**
Error	4	18.63	105.09	471.76	90.86	61.34	86.11
Fungicide	2	11.34ns	4.40ns	343.29**	312.73**	30.79ns	19.44ns
Cul x Fun	4	13.08ns	29.05ns	107.18ns	84.61ns	6.83ns	15.97ns
Error	12	10.07	27.08	113.31	28.7	7.87	8.45
Fre	3	42.59*	1.85ns	196.53*	1380.48**	1557.41**	4460.19**
Cul x Fre	6	17.36ns	9.49ns	65.97ns	88.58*	34.26ns	49.77*
Fun x Fre	6	9.49ns	21.99ns	71.07ns	151.31**	17.82ns	7.41ns
Cul x Fun x Fre	12	8.91ns	7.76ns	23.84ns	30.59ns	23.50ns	12.73ns
Error	54	12.58	14.12	68.21	36.73	20.76	18.52
CV (%)		16.95	12.45	14.31	15.35	16.97	15.34

R^2 (%)	51.74	68.83	74.19	82.21	84.28	93.88
Mean	20.93	30.19	57.73	39.49	26.85	28.06

*, ** and ^{ns} indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively.
DAP: Days after planting, Cul: Cultivar, Fung: Fungicide, Fre: Spray frequency.

Table 5. ANOVA of percentage of severity of faba bean gall at different days of assessment in experimental plots under field conditions during the main cropping season in 2015 at Degem

		Mean square of percent severity						
Source of variation	**df**	**DAP 39**	**DAP 49**	**DAP 59**	**DAP 69**	**DAP 79**	**DAP 89**	**DAP 99**
Replication	2	78.01	109.03	362.73	419.44	69.68	94.68	84.26
Cultivar	2	79.40**	759.04**	506.48**	977.08**	157.18**	266.90**	237.73**
Error	4	25.58	208.68	45.72	198.61	34.61	112.04	155.09
Fungicide	2	25.23^{ns}	6.25^{ns}	34.95^{ns}	77.08^{ns}	147.45**	225.93^{ns}	69.68*
Cul x Fun	4	5.09^{ns}	46.53^{ns}	20.02^{ns}	10.42^{ns}	113.43**	20.37^{ns}	28.01ns
Error	12	22.57	53.94	51.74	49.65	51.51	39.24	15.51
Fre	3	32.41^{ns}	90.43*	2264.51**	3245.29**	3721.30**	2334.26**	6376.78**
Cul x Fre	6	17.36^{ns}	38.35^{ns}	44.14^{ns}	34.18^{ns}	12.73^{ns}	116.90**	35.57^{ns}
Fun x Fre	6	14.12^{ns}	19.83^{ns}	37.42^{ns}	54.55^{ns}	78.94*	76.85*	37.89^{ns}
Cul x Fun x Fre	12	7.41^{ns}	25.39^{ns}	27.12^{ns}	25.39^{ns}	35.65^{ns}	28.24^{ns}	42.52^{ns}
Error	54	14.58	30.56	35.26	31..87	28.16	25.15	18.06
CV (%)		16.83	14.32	16.66	14.67	16.42	14.76	13.4
R^2 (%)		59.01	72.46	84.4	89.68	90.26	88.72	95.72
Mean		22.69	38.61	35.65	38.47	32.32	33.98	31.71

*, ** and ^{ns} indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively.
DAP: Days after planting Cul: Cultivar, Fung: Fungicide, Fre: Spray frequency.

Table 6. ANOVA of percentage of severity of faba bean gall at different days of assessment in experimental plots under field conditions during the main cropping season in 2015 at Mush

		Mean square of percent severity					
Source of variation	**df**	**DAP 46**	**DAP 56**	**DAP 66**	**DAP 76**	**DAP 86**	**DAP 96**
Replication	**2**	6.48	57.18	1562.73	14.12	157.18	526.62
Cultivar	**2**	62.73*	59.95**	317.59**	123.15**	308.57**	264.12**
Error	**4**	13.77	102.32	140.86	121.07	21.41	89.47
Fungicide	**2**	6.48^{ns}	21.07^{ns}	17.59^{ns}	11.34^{ns}	5.79^{ns}	23.84^{ns}
Cul x Fun	**4**	5.44^{ns}	3.70^{ns}	30.09^{ns}	15.16^{ns}	5.44^{ns}	116.90^{ns}
Error	**12**	7.18	22.34	45.02	7.18	4.51	14.01
Fre	**3**	197.76**	558.64**	494.68**	1568.13**	1963.27**	3789.20**
Cul x Fre	**6**	62.11**	38.97**	29.63^{ns}	31.79^{ns}	44.99*	33.87^{ns}
Fun x Fre	**6**	16.05^{ns}	8.41^{ns}	8.33^{ns}	20.91^{ns}	9.80^{ns}	25.08^{ns}
Cul x Fun x Fre	**12**	20.69^{ns}	12.35^{ns}	10.65^{ns}	22.42^{ns}	14.08^{ns}	17.67^{ns}
Error	**54**	14.43	9.11	15.82	15.12	18.75	18.6
CV (%)		18.27	12.73	17.43	13.44	16.88	15.9
R^2 (%)		70.13	86.22	88.93	88.42	88.1	93.38
Mean		20.79	23.7	22.82	28.94	25.65	27.13

*, ** and ^{ns} indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively.
DAP: Days after planting, Cul: Cultivar, Fung: Fungicide, Fre: Spray frequency.

Table 7. ANOVA for three faba bean cultivars for their reaction to faba bean gall disease under yield and yield components at Degem, 2015 main cropping season.

		Mean square				
source of variation	**df**	**AUDPC**	**PPP**	**SPP**	**YLD**	**HSW**
Replication	**2**	126283.9	0.18	0.25	0.43	12.58
Cultivar	**2**	539893.09**	7.72	0.27*	72.16**	9663.86**
Error	**4**	26007.21	0.12	0.13	21.77	117.4
Fungicide	**2**	59358.06*	2.78*	0.34**	5.16**	1.44^{ns}
Cul x Fun	**4**	15987.37^{ns}	1.86*	0.25**	3.52**	4.93^{ns}
Error	**12**	37147.17	0.57	0.19	0.75	15.41
Fre	**3**	3259806.63**	13.55**	1.64**	39.44**	18.31^{ns}
Cul x Fre	**6**	44326.14*	10.78**	0.24**	3.98**	69.79**
Fun x Fre	**6**	26511.24^{ns}	2.14**	0.11^{ns}	3.67**	12.85^{ns}
Cul x Fun x Fre	**12**	20697.34^{ns}	1.64*	0.10**	1.10*	15.15^{ns}
Error	**54**	16362.06	0.72	0.06	0.56	14.7
CV (%)		8.87	17.88	11.76	8.41	7.29
R^2 (%)		93.41	81.67	80.02	93.62	96.32
Mean		1442.51	4.75	2.13	8.89	52.58

*, ** and ^{ns} indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively.
AUDPC = Area under Disease Progress Curve, PPP = Pod per plant, SPP = Seed per pod, YLD = Yield, HSM = Hundred seed mass, Cul, Cultivar, Fung: Fungicide, Fre: Spray frequency.

Table 8. ANOVA for three faba bean cultivars for their reaction to faba bean gall disease under yield and yield components at Mush, 2015 main cropping season.

		Mean square				
Source of variation	**DF**	**AUDPC**	**PPP**	**SPP**	**YLD**	**HSW**
Replication	**2**	248992.6	0.33	0.02	12.46	69.62
Cultivar	**2**	232446.59**	4.20**	0.18ns	9.47**	1829.62**
Error	**4**	75463.69	0.98	0.11	4.46	41.41
Fungicide	**2**	8654.40ns	1.14**	0.57**	1.37ns	57.18ns
Cul x Fun	**4**	6548.93ns	0.24ns	0.08ns	5.50*	37.55ns
Error	**12**	5983.22	0.14	0.09	1.35	22.15
Fre	**3**	1879530.92**	1.05**	0.07ns	18.02**	90.90ns
Cul x Fre	**6**	2870.38**	0.42ns	0.14ns	4.64*	122.37*
Fun x Fre	**6**	2102.16ns	1.00**	0.21ns	1.38ns	23.82ns
Cul x Fun x Fre	**12**	6490.33ns	0.42*	0.08ns	5.47**	176.42**
Error	**54**	4827.22	0.21	0.11	1.5	47.72
CV (%)		7.16	16.59	16.45	17.34	14.39
R^2 (%)		96.54	75.18	70.34	76.16	75.08
Mean		971.09	2.77	2.01	7.06	48.02

*, ** and ^{ns} indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively.
AUDPC = Area under Disease Progress Curve, PPP = Pod per plant, SPP = Seed per pod, YLD = Yield, HSM = hundred seed mass, Cul: Cultivar, Fung: Fungicide, Fre: Spray frequency.