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ORIGINAL ARTICLE

Effect of sowing date and fungicide frequencies for management of chocolate spot (*Botrytis fabae Sard.*) of Faba bean (*Vicia faba L.*) in Southern Ethiopia

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Faba bean (*Vicia faba L.*) is one of the major pulse crops grown in Ethiopia and many countries. However, the production and productivity of the crop is affected by several biotic and abiotic factors. Among these, chocolate spot caused by (*Botrytis fabae* Sard) is one of the most important destructive diseases hampering faba bean production. This work was carried out during the 2015 and 2016 cropping seasons to determinate the effect of sowing date and fungicide frequencies for management of chocolate spot of faba bean in potential growing areas of Silte and Hadya zone, southern Ethiopia. The treatments comprised three sowing date intervals and three fungicide frequencies. Unsprayed controls were also included to allow maximum disease severity for comparison. The trial was arranged in randomized completely block design (RCBD) in factorial arrangement with three replications. The trials clearly determined the appropriate sowing date and fungicide frequency for management of the disease. The statistical analysis showed significant differences ($p<0.05$) among the treatments for most of the parameters tested. The result of the study revealed that the maximum terminal severity of 64.7% at Alicho and 63.4% at Analimo were recorded on unsprayed plots of 2nd and 3rd sowing date respectively. The disease resulted in high grain yield loss of 52.1% at Alicho and 51.4% at Analimo on unsprayed plot of last sowing date. The maximum grain yield of 3649.4 kgha^{-1} at Alicho and 3557.1 kgha^{-1} at Analimo were obtained due to the interaction effect first sowing date and three-time application of fungicide. There was a significant strong negative correlation between disease incidence, severity and AUDPC to that of grain yield with correlation coefficient ranging from, r=-0.84** to r=-0.96**. The present research finding revealed that the combination use of first sowing (early sowing) and three-time application of Mancozeb 80% WP at the company rate of 2.5 kgha^{-1} can be recommended as the appropriate management option against chocolate spot in an area. However, further study should be necessary to come up with more inclusive recommendation and thereby increase production and productivity of faba bean in the region and elsewhere with similar agro ecological settings.

Keywords: Chocolate spot, Faba bean, Grain yield, Incidence, Severity.

Introduction

Faba bean (*Vicia faba* L.) is one of the most important pulse crops produced in Ethiopia and many countries of the world. It is the most important food legumes due to its high nutritive value both in terms of energy and protein contents (24-30%) and also an excellent nitrogen fixer (Metayer, 2004; Dagne et al., 2016). Faba bean is the leading and the earliest domesticated cool season food legumes grown in highlands of Ethiopia. Ethiopia is the second largest grower of faba bean in the world after the Peoples' Republic of China (FAOSTAT, 2017). The country is considered as one of the center of secondary diversity for faba bean (Yohannes, 2000). It is an important pulse crop grown in the highlands (1800-3000 m.a.s.l) areas where the soil and weather are considered to be congenial for better growth and development of the crop (Kubure et al., 2016). Faba bean is grown on 437,106 hectares in Ethiopia with an annual production of about 921,761.5 tons (CSA, 2018). Amhara and Oromia is the major faba bean producing regions in Ethiopia. The highland of Silte and Hadiya is the major faba bean producing area of Southern Nations Nationalities and Peoples' Regional State (SNNPRS).

Despite its wide cultivation, the national average yield of faba bean is 2.11 t/ha (CSA 2018), which far below the potential because of many biotic and abiotic constraints. Among these chocolate spot caused by *Botrytis faba* is the most widespread and highly destructive disease causing a yield loss of 34% on resistant and 61% on susceptible cultivars in Ethiopia (Tegegni et al., 2016). The production of the crop is enormously declining as the local faba bean cultivars are entirely attacked by chocolate spot and other diseases in southwest Ethiopia (Mesele et al., 2015). Chocolate spot occurs mainly on leaves, but stems and flowers may also be infected under sever conditions. The disease is very aggressive and spreads rapidly in warm humid conditions. Varied cropping systems and production situations can also influence disease occurrence, epidemic development and damage to crops.

Several approaches have been developed to reduce and manage the yield losses due to chocolate spot worldwide. These include adopting various cultural control strategies such as early sowing (Dereje, 1993), deep ploughing (Dereje, 1999), integration of genetic resistance (Stoddard et al., 2010), crop rotation, burying of crop residues and timely application of appropriate fungicides (El-Sayed et al., 2011).

Chocolate spot is most commonly controlled by the application of synthetic fungicides (Addisu et al., 2016). However, frequent use of synthetic fungicides may present several problems. Excessive use of chemicals may have hazardous effects on humans and the ecosystems. The contribution chemicals to environmental pollution and toxicity to non-target organisms are some of the major problems related to the use of synthetic chemicals (Isman, 2006). Adjustment of sowing date with appropriate chemical frequency contributed to the slowing of chocolate spot epidemics and increased yield of faba bean. Hence, this study was designed with the objective of identifying the best combination of sowing dates and different frequencies of fungicide application for the management of chocolate.

Materials and Methods

Description of the experimental areas

The present work was carried out in Werabe Agricultural Research center (WARC) at Alicho and Analimo district of southern Ethiopia under rain fed conditions during the 2015 and 2016 main cropping season. Both experimental sites are the major faba bean growing areas of southern region characterized by Dega and Woinadega agro ecology. Alicho is located at 07°56'96''N, 38°09'39"E and at 2870 m.a.s.l. The annual rainfall ranges from 750-1190 mm representing highland agro ecology. The mean annual minimum and maximum temperature is 8.1°C and 16.7°C, respectively. The dominant soil type is Clay soil (pellic vertisole). Analimo is located 07°40'23''N, 37°58'84''E and at 2119 m.a.sl. The annual rainfall of the area ranges from 560 to 870 mm. The mean annual minimum and maximum temperature is 12.7 and 19.6°C, respectively. The soil type is dominated by clay soil (Cromic Luvisole). Both locations are chocolate spot prone areas of southern regions and characterized by bimodal rainfall, the short rainy season extending from March to May and the main rainy season from June to September.

Experimental design and treatments

The treatments were consisted of the combinations of three sowing date intervals and three fungicide frequencies. Sowing was done in ten-day interval and 1 June was arranged as the first, 10 June as the second and 20 June as the third sowing date. The faba bean variety used on the experiment was the susceptible cultivar, Motti. The seeds were sown by hand drilling at the recommended rate of 150 $kgha^{-1}$. Chocolate spot was allowed to develop naturally and chemical fungicide, Mancozeb 80% WP applied at a rate of 2.5 $kgha^{-1}$ at three different sprays schedules. The first spray was commenced immediately after the occurrence of disease symptom and the second and third sprays were continued within 10-day interval. During fungicide sprays, plastic sheets were used to protect the adjacent plots from fungicide drifts and plots with no fungicide treatment were also included in all sowing date interval as checks. Plots were arranged with distance of 1.5 m between block and 0.5m between plots. The plot size was 3 m x 2.4 m having six seedling rows with the spacing of 0.4 m and 0.1 m between rows and plant, respectively. The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement with three replications. Di-ammonium phosphate (DAP) and urea were applied at the time of planting and during weeding at the rate of 46 kg/ha and 18 kg/ha, respectively (Tamene and Tadese, 2013). Weeding and other cultural practices were carried out according to the recommendation of areas.

Data to be collected

Data on yield and yield component were collected on plot and plant basis from the grandmother trial. Plot based data were collected from four central rows (4.8 m^2 net areas) on each plot. Whereas individual plant-based data was taken from five plants selected randomly and pre-tagged with colored thread before disease symptom appearances from net areas on each plot and the mean of five plants were used for data analysis. Plant height (cm), numbers of pods per plant and number of seed per pod were recorded and their mean were used for data analysis. Thousands seed weight was counted carefully by adjusting to 10% moisture content and weighing seed on electronic balance. Grain yield was measured form each plot and converted to kilogram per hectare.

Disease incidence

Disease incidences were recorded in percentage from infected plant on each plot from total number of pant examined at ten day interval.

Diseases Incidenc=(Numberof diseased plants)/(Total number of plants examined) × 100

Diseases severity

Disease severity was recorded based on 1-9 scale (Bernier et al., 1993) four times at ten day interval starting from initial appearance of disease. The value of severity were given, i.e., 1=no diseases symptoms or very small specks, 3=few small discrete lesion, 5=some coalesced lesions, with some defoliation, 7=Large coalesced sporulating lesions 50% defolition and some dead plants, 9=Extensive heavy sporulation stem girdling blackening and death of more than 80% of plants.

Disease severity=((Area of plant tissue affected)/(Total area of plant tissue examined)) × 100

Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) separately according to Gomez and Gomez (1984) using SAS computer software package version 9.0 (SAS Institute, 2004). Data were not combined over the year due to heterogeneity on experiment. Means were separated by using least significant difference (LSD) at 5% probability level. Data on disease parameters and yield and yield components were correlated using the Proc-Corr Pearson's correlation of SAS computer software package.

Area under disease progress curve

Area under disease progress curve (AUDPC) was computed using severity percentage estimates according to Steffenson and Webster, (1992).

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

Relative yield loss

The relative losses in yield of each treatment were determined as percentage of that of the protected plots of the experiment. Losses were calculated separately for each of the treatment with different levels of disease based on the formula:

RL (%)=((YP-YT)/YP) × 100

Where, RL-relative loss (reduction of the yield parameter), YP-mean yield of the protected plots (plots with maximum protection-from Mancozeb sprayed at the specified time interval) and YT-mean yield in unprotected plots (i.e., unsprayed plots with varying level of disease).

Results and Discussion

The result from the experiment revealed that there is a variation between the treatment for various yield and yield component and disease parameters.

Diseases parameters

Diseases incidence

There was a significant difference (P<0.05) between treatments for chocolate spot incidence (Tables 1 and 2). The mean maximum chocolate spot incidence of 90% was recorded from the 3rd sowing date of untreated plots, whereas the lowest incidence of 38.5% was recorded from first sowing date plots that received three times application of fungicide (Table 2). The observed variation in disease level was due to the difference in sowing date and fungicide application frequencies. The highest chocolate spot mean disease incidence was recorded from untreated plots of third sowing date at both locations and years. This is probably because late planting and continuous production legume crop contribute for highest chocolate spot incidence in an area. Conducive environmental conditions were also play significant role for the development of disease during growing season. Similarly Villegas-Fernandez et al., (2010) reported that chocolate spot incidence is strongly influenced by climatic conditions.

Terminal severity

The finding of the present study revealed that terminal severity was significantly affected (P<0.05) by individual treatments and their combinations at both locations (Tables 1 and 2). The maximum disease severity of 59.6% at Alicho and 63.8% at Analimo were recorded on untreated plots of 3rd sowing date in 2015 crop growing season, while in 2016 about 64.7% at Alicho and 63.4% at Analimo were recorded from untreated plot of 2nd and 3rd sowing date, respectively. In 2016 main cropping season the lowest diseases severity of 18.3% at Analimo 17.6% at Alicho were recorded from first sowing date with 2nd and 3rd fungicide spraying respectively, whereas in 2016 the lowest disease severity of 18.2% at Analimo and 20.3% at Alicho where recorded from first sowing date with 2nd and 3rd fungicide spraying, respectively (Tables 1 and 2).

There was the development of the mass of black spot on the leaves (blighting), which is followed by defoliation and lodging. The occurrence of frequent rain fall distribution during both cropping seasons play significant role for disease pressure. Similarly Dereje et al., (1994) reported that prolonged rainfall is conducive for chocolate spot development leading to complete crop loss. There was substantial yield loss due to high disease severity especially on untreated plots in all sowing date. The result of the present study is in agreement with the work done by Ermiyas and (Addisu, 2013) who reported that the mean maximum chocolate spot severity of 51.89% from the first sowing date plot that received no fungicide treatment whereas, the least severity of 28.67% (based on 1-9 scale) from last sowing date plot which received four times fungicide spray. Disease's severity was associated with the management practices. The disease requires a minimum of two time sprays of Mancozeb at a rate of 2.5 $kgha^{-1}$ and early sowing in order to escape the epidemic to reduce the yield loss. On the other hand (AARC., 1996) reported that three to four sprays of Mancozeb at a rate of 0.7 $kgha^{-1}$ proved more effective for management of chocolate spot.

Area under diseases progress curve

Area under diseases progress curve (AUDPC) was significantly (P<0.05) affected by interaction of fungicide frequencies and sowing date at the two locations (Tables 1 and 2). The highest AUDPC was recorded on untreated plots of 3rd sowing date at both locations and years. The highest AUDPC of 1669% days and 1488% days were recorded from untreated plot of 3rd sowing date at Alicho and Analimo, respectively. The lowest AUDPC of 205% days and 120.7% days were recorded in 2015 cropping season from first sowing date with three-time fungicide frequency at Alicho and Analimo, respectively. The maximum variation of AUDPC (144.3-1843.5% days) was recorded at Alicho between untreated and second sowing date with twice fungicide application.

The grain weight loss was strongly associated with AUDPC at both locations and years. AUDPC is the result of all factors that influenced disease development such as environments, cultivars and population of the pathogen Pandy et al., (1989). As a result it gives a better indication on disease development over time, which is essential to predict yield losses. The result of the present finding indicted that higher frequency of fungicide application is needed particularly when the environmental conditions are favorable for the disease development based on resistance level of cultivar produced. If the weather condition was not favorable only 1 or 2 times spray is also enough whether the varieties are susceptible or moderately resistant. Therefore, it was clearly revealed that foliar sprayed of Mancozeb 80% WP with integration of first sowing (early sowing) had significantly reduced AUDPC. These results are in line with (Dereje, 1993) and (Ermiyas, 2013) who reported that early sowing integrated with fungicide application enable to the growers to effectively manage chocolate spot on faba bean in Central and South-Eastern Ethiopia.

Yield and yield component

Plant height

The finding of the present study showed that faba bean treated with different fungicide frequency and sowing date did not vary significantly in terms of plant height at both locations and years (Tables 1 and 2). The tallest plant 1.4 m at Alicho was obtained from first sowing date treated with three time spraying of fungicide at both years whereas, the shortest plant 1.27 m at both locations were obtained from unsprayed plots on 3^{rd} sowing date in 2016 (Tables 1 and 2). All sprayed plots revealed better plant height than the nil (unsprayed) plots but variation in plant height did not show significant difference between individual treatments because, plant height was not affected by interaction effect of sowing date and fungicide applications frequency.

Number of pod per plants

The interaction effect of fungicide frequencies and sowing date depicted significant difference ($P<0.05$) on number of pods per plants at both locations and years (Tables 1 and 2). The highest number of pods per plants 18.6 was obtained from first sowing date with three-time spray of fungicide in 2016 at Analimo while, the lowest number of pods per plants 8.4 was obtained from 3rd sowing date of unsprayed plots in 2015 at the same location. Among the two-test location the highest significant variation on number of pods per plant was obtained at Analimo which ranged from 8.4 to 17.2 and 8.4-18.6 between treated and untreated plots in 2015 and 2016 cropping seasons, respectively. The number of pods per plant was decreased due to chocolate spot in all sowing date of untreated plots. The disease was severe especially on 3rd sowing date of untreated plots at both locations. The pod development was affected by disease pressure and did not mature earlier in last sowing date. The result of the present study agrees with the work done by Sahile et al., (2008) who indicated that the pod setting/development stage of the crop is the most susceptible to attack by chocolate spot.

Number of seed per pod

The number of seed per pod revealed significantly ($P<0.05$) to the interaction effect of sowing date and fungicide application frequencies at both locations and years. The highest numbers of seed per pod 54.3 at Analimo and 52 at Alicho were obtained from first sowing date and 3rd fungicide application frequency whereas, the lost numbers of seed per pod 50.1 at Albazar and 50.5 at Alicho were obtained from untreated plots of 3^{rd} sowing date. Number of seeds per pod is one of the most important yield determining factors in pulse crops. Healthy and robust seed in each pod contribute to the overall grain yield. The reductions on the number of seed per pod due to chocolate spot contributed to the lowest grain yield. Therefore, three time application of Mancozeb 80% WP with integration of first sowing (early sowing) resulted the highest seed per pod and reduced chocolate spot. Similarly kora et al., (2017) who reported that management of chocolate spot with Mancozeb fungicide effectively control faba bean chocolate spot. In addition (Teshome and Tegegne, 2013) also reported that fungicide application increased yield and seed per plant about four times as compared to control.

Thousand seed weight

Thousand seed weight (TSW) significantly responded to sowing date and fungicide application frequency at both locations (Tables 1 and 2). The highest TSW of 736.2 g at Alicho and 733.4 g at Analimo were obtained from first sowing date with three-time application of fungicide in 2015, whereas in 2016 the highest TSW of 736.1 g at Alicho and 731.1 g at Analimo were obtained from first sowing date with twice spraying and from first sowing date with three-time fungicide application frequency, respectively. The lowest TSW of 667 g at Alicho and 671 g at Analimo were obtained from untreated plots of 3rd sowing date. The result of study revealed the remarkable difference on thousand seed weight at both locations. The seed harvested from unsprayed plots were shrunked and had lower seed weights. Large proportion of grain yield reductions could be attributed to the reductions in TSW due to chocolate spot disease. Therefore, TSW measure is probably the best indicator to estimate the effect of chocolate spot on grain yield and quality.

Grain yield

The finding of the present study revealed that significant variation was noticed ($p<0.05$) for the grain yield due to the interaction effect of sowing date and fungicide frequencies at both locations (Tables 1 and 2). The maximum grain yield of 3649.4kgha-1 was obtained from first sowing date treated with three times spray of fungicide in 2015 at Alicho while in 2016 the minimum grain yield of 1423kgha-1 was harvested at Analimo from untreated plots of the last sowing date.

The highest yield reduction was recorded on untreated plots in all sowing date. The disease was severe in all leaves of the plant including the flag leaves and branch on untreated plots. There was the spread of the pathogens from the flowers into the developing pods. Disease infections at flowering stage cause them to abort without forming pods especially on 3rd sowing date. These phenomena contributed to the great yield difference and losses at both locations. The highest grain yield loss of 52.1% at Alicho and 51.4% at Analimo were recorded on untreated plots 3rd sowing date, whereas 53.5% of grain yield loss was also recorded from untreated plots of 2nd sowing data. This is due to prolonged rainfall distribution in areas which was favorable for the development of the chocolate spot. Yield losses as high as 90% and total crop failure in severe epidemics of *Botrytis fabae* have been reported from areas where extended periods of wet weather conditions prevail Singh et al., (2013). Similarly (Richardson, 2013) also reported that the disease can reduce yields by 30-50% in unprotected crops under conditions favorable for disease development.

The grain yield was much lower in the last sowing date compared to the first and second sowing date. This is because late sown crops had not enough time and resource to develop enough crop biomass. In addition to disease pressure moisture stress, low temperature and shorter grain filling duration contributed for small pod and seed during the last sowing date. Considerable grain yield was obtained from the first sowing date sprayed from one to three times. This might be since the early sown crop had a better chance to obtain important resource to develop enough crop biomass than late sown crop. Early planting contributed extended period of vegetative growth which resulted in the improvement of the several agronomic characters. The present research finding clearly determined first sowing (1 June or early sowing) as integrated disease management options against chocolate spot in the study areas. However, in most faba began producing area of Ethiopia sowing date is recommended from mid-June to early July. This is because the first shower of rain is started during this time in most mid and highland areas. It is important to consider the beginning of rainfall since our most of agricultural production is rain fed. Sowing time also depends on the type of crop cultivar. Late flowering/long season cultivars need to be sown early, while early flowering (short season cultivars) are sown late to escape the chocolate spot, frost, and cold temperature during the flowering period. Therefore, optimizing sowing date is crucial through considering the type of faba bean cultivar, locations, and availability of soil moisture within the soil.

The combination use of early sowing (1 June) with three time spraying of Mancozeb 80% WP is the best option for management of disease. The interaction effect of both management options greatly reduced the disease incidence, severity, AUDPC and thereby increased faba bean grain yield. The result of this study was in agreement with the previous work by Dereje and Tesfaye (1993) and Sahile *et al.,* (2008b) which found that the Mancozeb at the rate of 3 kgha^{-1} active ingredient every week at threshold level was effective against chocolate spot and accordingly recommended for use in Ethiopia.

Table 1. Effect of sowing date and fungicide spray frequency on disease and yield component of faba bean in 2015.

	Alicho								Analimo							
TR	**INC (%)**	**TS (%)**	**AUDPC (% days)**	**PH (m)**	**NPO**	**NSP**	**TSW (g)**	**GY (Kg)**	**INC (%)**	**TS (%)**	**AUDPC (% days)**	**PH (m)**	**NPO**	**NSP**	**TSW (g)**	**GY (kg)**
SD1 Ch0	80.0^{ab}	52.4^{b}	1675^{b}	1.32^{d-f}	12.0^{cd}	2.6^{ef}	674^{fg}	2095^{g}	77.5^{ab}	55.6^{b}	1505.4^{b}	1.31^{c-e}	10.6^{f}	2.1^{gh}	678.1^{fg}	1628^{gh}
SD1 Ch1	65.0^{de}	35.0^{d}	1185.5^{e}	1.33^{de}	13.7^{b}	3.2^{cd}	694^{de}	2867.2^{d}	65^{cd}	32.8^{e}	1337.5^{d}	1.34^{bc}	15^{b-d}	3.0^{c-e}	701.2^{c-e}	$2493d^{e}$
SD1 Ch2	55.0^{ef}	19.4^{gh}	375^{i}	1.40^{a}	15.9^{a}	3.9^{ab}	733.5^{ab}	3578.2^{ab}	47.4^{ef}	15.8^{i}	235.6^{i}	1.37^{ab}	17.2^{a}	3.53^{ab}	731.2^{a}	3367.2^{a}
SD1 Ch3	50.0^{f}	17.6^{h}	205.5^{j}	1.38^{ab}	16.5^{a}	4.03^{a}	736.2^{a}	3649.4^{a}	43.3^{f}	18.4^{hi}	120.7^{j}	1.39^{a}	16.1^{ab}	3.7^{a}	733.4^{a}	3429.1^{a}
SD2 Ch0	83.3^{a}	55.7^{ab}	1735^{ab}	1.30^{e-g}	11.8^{cd}	2.5^{f}	668.6^{g}	2015.2^{g}	83.7^{a}	58.7^{b}	1585.4^{b}	1.28^{de}	8.9^{g}	1.8^{hi}	674^{g}	1590^{h}
SD2 Ch1	70^{b-d}	43.4^{c}	1605^{c}	1.32^{d-f}	13.1^{bc}	3.0^{de}	683.1^{eg}	2389.2^{f}	70^{bc}	41.5^{d}	1410^{cd}	1.32^{b-e}	13.4^{de}	2.8^{d-f}	689.9^{ef}	1852.1^{fg}
SD2 Ch2	60^{d-f}	27.8^{ef}	950^{f}	1.35^{b-d}	14.1^{b}	3.7^{ab}	703.2^{cd}	3168.4^{c}	54.6^{d-f}	23.9^{g}	458.1^{h}	1.37^{ab}	15.7^{ab}	3.4^{a-b}	706.3^{c-e}	2584^{cd}
SD2 Ch3	55.2^{ef}	23.6^{fg}	650.3^{h}	1.37^{bc}	14.1^{b}	3.8^{ab}	717.2^{bc}	3445.3^{b}	50^{ef}	21.6^{gh}	620^{g}	1.35^{a-c}	16.4^{ab}	3.2^{b-d}	715^{b}	3032^{b}
SD3 Ch0	85.0^{a}	59.6^{a}	1765^{a}	1.27^{g}	10.4^{d}	2.3^{f}	667g	1972.1	85.5^{a}	63.8^{a}	1612^{a}	1.27^{e}	8.4^{g}	1.5^{i}	671^{g}	1560.1^{h}
SD3 Ch1	77.6^{ab}	44.8^{c}	1545.2^{c}	1.29^{fg}	12.6^{bc}	2.7^{ed}	680.8^{eg}	2451.6^{ef}	73^{a-c}	46.3^{c}	1454.5^{bc}	1.3^{c-e}	12.5^{e}	2.5^{fg}	692^{e}	2011^{f}
SD3 Ch2	67.6^{cd}	40.9^{c}	1395.3^{d}	1.34^{cd}	12.6^{bc}	3.2^{cd}	689.1^{df}	2607.3^{e}	63.3^{cd}	39.6^{d}	1125.4^{e}	1.31^{c-e}	14^{cde}	2.7^{ef}	694^{de}	2310^{e}
SD3 Ch3	66.6^{cd}	31.5^{de}	765.4^{g}	1.32^{d-f}	13.8^{b}	3.5^{bc}	701.2^{cd}	3058^{c}	57.5^{de}	28.5^{f}	823.7^{f}	1.33^{b-d}	15.7^{ab}	3.0^{c-e}	709.2^{bc}	2777^{c}
CV (%)	9.96	8.32	3.84	1.93	7.31	7.49	3.53	3.42	11.3	6.68	4.93	2.21	6.85	9.85	2.55	5.96
$LSD_{0.05}$	11.4	5.3	65.1	0.03	1.66	0.4	18	160.6	12.3	4.2	75.9	0.05	1.57	0.4	13.6	240.9

$LSD_{0.05}$=List significant difference at 5%, CV (%)=Coefficient of variation at (%). Means in same column followed by the same letters are not significantly different. SD1, SD2, and SD3=Sowing date interval from 1-3 time and Ch0, Ch1, Ch2, Ch3=Chemical spray frequencies from 0 times spray to 3, TR=Treatments, INC=Incidence, TS=Terminal severity, AUDPC=Area under disease progress curve, PH=Plant height, NPO=Number of seed per pod, TSW=Thousand seed weight, GY=Grain yield.

Table 2. Effect of sowing date and fungicide spray frequency on disease and yield component of faba bean in 2016.

	Alicho								Analimo							
TR	**INC (%)**	**TS (%)**	**AUDPC (% days)**	**PH (m)**	**NPO**	**NSP**	**TSW (g)**	**GY (kg)**	**INC (%)**	**TS (%)**	**AUDPC (% days)**	**PH (m)**	**NPO**	**NSP**	**TSW (g)**	**GY (kg)**
SD1 Ch0	85.1^{ab}	58.8^{b}	1635^{b}	1.3^{e-g}	11.9^{e}	2.4^{gh}	675^{gh}	1598.1^{g}	71.9^{cd}	55.2^{b}	1719.7^{bc}	1.34^{ab}	12.2^{f}	3.54^{cd}	678^{d-f}	1794.3^{g}
SD1 Ch1	65.0^{de}	39.6^{d-f}	865.0^{f}	1.35^{b-d}	14.2^{b-d}	3.1^{c-e}	690.2^{ef}	2698^{d}	58.5^{ef}	35.6^{ef}	1265^{e}	1.36^{ab}	16.1^{b-d}	3.7^{a-d}	699^{b-d}	2669^{d}
SD1 Ch2	40.0^{g}	23.4^{gh}	144.3^{j}	1.37^{a-c}	16.3^{a}	3.9^{a}	736.1^{a}	3373.1^{a}	48.5^{g}	18.2^{h}	286.6^{i}	1.38 a	18.3^{a}	3.89^{ab}	728.3^{a}	3513.1^{a}
SD1 Ch3	50.0f^{g}	20.3^{h}	255.5^{i}	1.40^{a}	15.6^{ab}	3.7^{ab}	734.1^{ab}	3341^{ab}	38.5^{h}	24.6^{g}	185.0^{i}	1.38 a	18.6^{a}	4.0^{a}	731.1^{a}	3557.1^{a}
SD2 Ch0	87.6^{ab}	64.7^{a}	1843.5^{a}	1.29^{fg}	10.7^{e}	2.0^{hi}	669^{h}	1490^{gh}	86.8^{a}	61.2^{ab}	1785.5^{ab}	1.33^{ab}	10.1^{g}	2.67^{fg}	674^{ef}	1633.4^{gh}
SD2 Ch1	77.6^{bc}	44.6^{cd}	1523.5^{c}	1.33^{c-f}	14.0^{cd}	2.9^{d-g}	684.3^{fg}	1967.8^{f}	78.5^{bc}	47.3^{c}	1615^{c}	1.32^{ab}	15.1^{de}	3.49^{d}	690^{c-f}	2186^{f}
SD2 Ch2	60^{d-f}	36.2^{ef}	680.0^{g}	1.38^{ab}	15.1^{a-c}	3.6^{a-c}	702^{de}	2719^{cb}	61.9^{ef}	29.8^{fg}	790.0^{g}	1.36^{ab}	16.9^{a-c}	3.6^{b-d}	703.3^{bc}	2811.2^{d}
SD2 Ch3	53.3^{f}	27.6^{g}	495.2^{h}	1.34^{b-e}	15.4^{a-c}	3.4^{a-d}	720.1^{bc}	3203.3^{b}	56.8^{f}	24.4^{g}	585.0^{h}	1.32^{ab}	17.1^{ab}	3.8^{a-c}	713.1^{ab}	3219.1^{b}
SD3 Ch0	90.0^{a}	61.2^{ab}	1715^{b}	1.28^{g}	11.1^{e}	1.8^{i}	673^{gh}	1423^{h}	86.6^{ab}	63.4^{a}	1850.6^{a}	1.3^{b}	9.30^{g}	2.56^{g}	672^{f}	1610^{h}
SD3 Ch1	83.3^{ab}	46.2^{c}	1618b^{c}	1.32^{d-g}	13.6^{d}	2.7^{fg}	684.2^{fg}	2108^{f}	81.1^{ab}	45.8^{cd}	1650.5^{c}	1.3^{b}	13.5^{ef}	2.91^{ef}	694^{b-e}	2360.7^{ef}
SD3 Ch2	70.0^{cd}	41^{c-e}	1384.4^{d}	1.32^{d-g}	14.7^{b-d}	2.8^{e-g}	687^{e-g}	2347^{e}	81.1^{ab}	39.8^{de}	1465.7^{d}	1.34^{ab}	15.2^{c-e}	3.11^{e}	696^{b-d}	2479^{e}
SD3 Ch3	56.6^{ef}	35.3^{f}	1123.3^{e}	1.35^{b-d}	14.8^{b-d}	3.3^{b-e}	706.3^{cd}	2868^{c}	65.1^{de}	25.7^{g}	980.7^{f}	1.34^{ab}	16.2^{b-d}	3.56^{cd}	711^{a-c}	3020.5^{c}
CV (%)	9.36	7.7	5.5	2.11	6.27	10.2	2.28	4.05	7.1	9.08	7.2	3.32	6.8	5.06	1.82	4.01
$LSD_{0.05}$	10.8	5.24	103.1	0.04	1.48	0.5	15	166.5	8.2	6.03	115.9	0.06	1.71	0.29	21.5	174.9

$LSD_{0.05}$=List significant difference at 5%, CV (%)=Coefficient of variation at (%). Means in same column followed by the same letters are not significantly different. SD1, SD2, and SD3=Sowing date interval from 1-3 time and Ch0, Ch1, Ch2, Ch3=Chemical spray frequencies from 0 times spray to 3, TR=Treatments, INC=Incidence, TS=Terminal severity, AUDPC=Area under disease progress curve, PH=Plant height, NPO=Number of seed per pod, TSW=Thousand seed weight, GY=Grain yield.

Correlation analysis between disease and agronomic variables

Analysis of the data revealed a strong negative correlation between disease parameters and yield components at both locations (Tables 3-6). There were strong negative correlations (r=-0.97**) between terminal severity and grain yield. This implies that when there is an increase in disease parameters there was a decrease in yield parameters and vice versa. The correlation was strong indicating that severity had high negative impact on thousand seed weight and grain yield reduction. There were strong positive correlations between pod per plant, seed per pod, and thousand seed weight to that of grain yield. The numbers of seed per pod strongly correlated negatively (r=-0.91**) with grain yield. This indicates that number of seed per pod contributed significant effect on grain yield increment of faba bean.

Table 3. Correlation between disease parameters and yield and yield Components at Alicho in 2015.

	INC	TS	AUDPC	PH	NPO	NSP	TSW	GY
INC								
TS	0.88^{**}							
AUDPC	0.85^{**}	0.94^{**}						
PH	-0.14^{ns}	-0.19^{ns}	-023^{ns}					
NPO	-0.74^{**}	-0.78^{**}	-0.77^{**}	0.15^{ns}				
NSD	-0.85^{**}	-0.92^{**}	-0.90^{**}	0.19^{ns}	0.71^{**}			
TSW	-0.86^{**}	-0.90^{**}	-0.92^{**}	0.21^{ns}	0.78^{**}	0.87^{**}		
GY	-0.90^{**}	-0.97^{**}	-0.96^{**}	0.24^{ns}	0.81^{**}	0.91^{**}	0.94^{**}	

** refers to mean values Significant @=0.01, * refers mean square values Significant at @=0.05, ns: refers mean square values not significant at @=0.05, INC=Incidence, TS=Terminal severity, AUDPC=Area under disease progress curve, PH=Plant height, NPO=number of pod per plant, NSP=Number of seed per plant, TSW=Thousand seed l weight, GY=Grain yield.

Table 4. Correlation between disease parameters and yield and yield Components at Analimo in 2015

	INC	TS	AUDPC	PH	NPO	NSP	TSW	GY
INC								
TS	0.89^{**}							
AUDPC	0.86^{**}	0.91^{**}						
PH	-0.17^{ns}	-0.21^{ns}	-0.24^{ns}					
NPO	-0.85^{**}	-0.94^{**}	-0.80^{**}	0.15^{ns}				
NSP	-0.80^{**}	-0.89^{**}	-0.83^{**}	0.23^{ns}	0.86^{ns}			
TSW	-0.84^{**}	-0.88^{**}	-0.90^{**}	0.16^{ns}	0.84^{ns}	0.86^{**}		
GY	-0.88^{**}	-0.94^{**}	-0.92^{**}	0.20^{ns}	0.88^{ns}	0.84^{**}	0.92^{**}	

** refers to mean values Significant @=0.01, * refers mean square values Significant at @=0.05, ns: refers mean square values not significant at @=0.05, INC=Incidence, TS=Terminal severity, AUDPC=Area under disease progress curve, PH=Plant height, NPO=number of pod per plant, NSP=Number of seed per plant, TSW=Thousand seed l weight, GY=Grain yield.

Table 5. Correlation between disease parameters and yield and yield Components at Alicho in 2016

	INC	TS	AUDPC	PH	NPO	NSP	TSW	GY
INC								
TS	0.86^{**}							
AUDPC	0.88^{**}	0.90^{**}						
PH	-0.18^{ns}	-0.23^{ns}	-0.24^{ns}					
NPO	-0.82^{**}	-0.88^{**}	-0.77^{**}	0.22^{ns}				
NSP	-0.84^{**}	-0.88^{**}	-0.85^{**}	0.20^{ns}	0.85^{**}			
TSW	-0.81^{**}	-0.88^{**}	-0.88^{**}	0.18^{ns}	0.73^{**}	0.75^{**}		
GY	-0.92^{**}	-0.95^{**}	-0.94^{**}	0.23^{ns}	0.84^{**}	0.86^{**}	0.86^{**}	

** refers to mean values Significant @=0.01, * refers mean square values Significant at @=0.05, ns: refers mean square values not significant at @=0.05, INC=Incidence, TS=Terminal severity, AUDPC=Area under disease progress curve, PH=Plant height, NPO=number of pod per plant, NSP=Number of seed per plant, TSW=Thousand seed l weight, GY=Grain yield.

Table 6. Correlation between disease parameters and yield and yield Components at Alicho in 2016.

	INC	TS	AUDPC	PH	NPO	NSP	TSW	GY
INC								
TS	0.80^{**}							
AUDPC	0.89^{**}	0.89^{**}						
PH	-0.32^{*}	-0.27^{*}	0.21^{ns}					
NPO	-0.79^{**}	-0.88^{**}	-0.85^{**}	0.31^{*}				
NSP	-0.88^{**}	-0.76^{**}	-0.75^{**}	0.29^{*}	0.81^{**}			
TSW	-0.72^{**}	-0.80^{**}	-0.82^{**}	0.23^{ns}	0.75^{**}	0.67^{**}		
GY	-0.84^{**}	-0.94^{**}	-0.94^{**}	0.29^{*}	0.88^{**}	0.76^{**}	0.88^{**}	

** refers to mean values Significant @=0.01, * refers mean square values Significant at @=0.05, ns: refers mean square values not significant at @=0.05, INC=Incidence, TS=Terminal severity, AUDPC=Area under disease progress curve, PH=Plant height, NPO=number of pod per plant, NSP=Number of seed per plant, TSW=Thousand seed l weight, GY=Grain yield.

Plant height had correlated negatively with all disease parameters and correlated positively with yield components, but the correlations were non-significant. Correlation analysis also showed a strong positive correlation between disease parameters. There was strong positive correlation (r=0.94**) between terminal severity and AUDPC. The overall results of the correlation analysis suggest strong negative association between chocolate spot and yield component.

Conclusion

Faba bean is one of the most important cool season leguminous crops grown in the highland of Ethiopia. It is the least expensive source of protein for the people in Ethiopia. In the highlands of Silte and Hadya faba bean grows potentially but is threatened by tremendous development of chocolate spot disease. This research revealed that adjustment of sowing date and appropriate fungicide application frequency were considered to enhance chocolate spot control and reduced grain yield losses. Reduction in disease levels were observed in all fungicide sprayed plots compared with the corresponding unsprayed plots in this study. The disease resulted significant reduction in number of pods per plant, number of seed per pod, thousand seed weight and grain yield on untreated plots. The current study also revealed strong and significant correlation between disease parameters on one hand and yield and yield components on the other.

The interaction effect of sowing date and fungicide application frequencies significantly reduced disease incidence, severity, AUDPC increased number of seed per pod, TKW, grain yield and reduced yield loss. The present study indicate that the application of Mancozeb 80% WP for three times with the recommended rate of 2.5kgha-1 consistently reduced chocolate spot disease level with the combination of first sowing date (early sowing). During chemical application it is important to consider the costs of productions. The application cost should be equal to or is less than the returns gained. The use of any two or more control measures that are compatible to the farming systems and each other are advisable to manage the disease and for better economic return especially under subsistence farming conditions in the country. Therefore, it can be concluded that the combination of early sowing with appropriate fungicide application frequency is the compatible management option against chocolate spot with integration of relatively resistant and moderately resistant of faba bean variety to reduce disease pressure and yield loss.

Recommendations

Evident from the finding of this study is that adjustment of sowing date and appropriate fungicide frequency will be an effective strategy to control chocolate spot. Therefore, three times spraying of Mancozeb 80% WP from the onset of disease development with the combination of early sowing should be the appropriate recommendation for management of chocolate spot in the study areas. However, further studies under different agro ecological zones should be carried out with integration of host resistance to develop more effective, sustainable, and affordable chocolate spot management strategies.

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References

Annicchiarico, P., Iannucci, A. (2008). Breeding strategy for faba bean in Southern Europe based on cultivar responses across climatically contrasting environments. Crop Science, 48:983-991.

Bernier, C.C., Hanounik, S.B., Hussein, M.M., Mohamed, H.A. (1993). Field manual of common faba bean diseases in the Nile Valley. Aleppo: International Center for Agricultural Research in the Dry Areas (ICARDA). Information Bulletin.

Denekea, S., Shiferawa, D., Fininsa, C., Yesuf, M. (2018). Integrated management of faba bean chocolate spot (*Botrytis fabae* Sard.) through host resistance, intercropping and fungicide applications in arsi, Ethiopia. DNA, 109:1-10.

Dereje, G. (1993). Studies on the epidemiology of chocolate spot (*Botrytis fabae* Sard.) of faba bean (Vicia faba L.) (Doctoral dissertation, M.Sc. Thesis, Alemaya University of Agriculture. Alemaya, Ethiopia).

Gorfu, D., Beshir, T. (1994). Faba bean diseases in Ethiopia. In: National Cool-season Food legumes Review Conference, Addis Abeba (Ethiopia), ICARDA/IAR.

Gomez, K.A., Gomez, A.A. (1984). Statistical procedures for agricultural research. John Wiley and Sons.

Gorfu, D. (1999). Survival of *Botrytis fabae* Sard. between seasons on crop debris in field soils at Holetta, Ethiopia. Phytopathologia Mediterranea, pp:68-75.

Hassen, H., Chauhan, S.S. (2003). Effect of rate of maize leaf defoliation at various growth stages on grain, stover yield components of maize and undersown forage production. Indian Journal of Agricultural Research, 37:136-139.

Kora, D., Hussein, T., Ahmed, S. (2017). Management of chocolate spot (*Botrytis fabae* L.) on faba bean in Bale Highlands, Ethiopia. Journal of Plant Sciences, 5:120-129.

Kubure, T.E., Raghavaiah, C.V., Hamza, I. (2016). Production potential of faba bean (*Vicia faba* L.) genotypes in relation to plant densities and phosphorus nutrition on vertisols of central highlands of West Showa Zone, Ethiopia, east Africa. Advances in Crop Science and Technology, 4:2-9.

Leur, J.V., Gebre, H. (1996). Barley research in Ethiopia: Past work and future prospects. Institute of Agricultural Research.

Mitiku, M. (2017). Integrated management of chocolate spot (*Botrytis fabae*) disease of faba bean (*Vicia faba* L.) In Ethiopia: A Review. International Journal of Research-Granthaalayah, 5:195-205.

Pandey, H.N., Menon, T.C.M., Rao, M.V. (1989). A simple formula for calculating area under disease progress curve. Barley and Wheat Newsletter.

Reise, S.P., Waller, N.G. (2009). Item response theory and clinical measurement. Annual Review of Clinical Psychology, 5:27-48.

Sahile, S., Ahmed, S., Fininsa, C., Abang, M.M., Sakhuja, P.K. (2008). Survey of chocolate spot (*Botrytis fabae*) disease of faba bean (Vicia faba L.) and assessment of factors influencing disease epidemics in northern Ethiopia. Crop Protection, 27:1457-1463.

Sahar, A., El-Shennawy, R.Z., Ismail, A.I. (2011). Fungicidal management of chocolate spot of faba bean and assessment of yield losses due to the disease. Annals of Agricultural Sciences, 56:27-35.

Anil, K.S., Naresh, C., Ra, M., Anitha, P. (2013). An assessment of faba bean (*Vicia faba* L.) current status and future prospect. African Journal of Agricultural Research, 8:6634-6641.

Steffenson, B.J., Webster, R.K. (1992). Pathotype diversity of *Pyrenophora teres* f. teres on barley. Phytopathology, 82:170-177.

Stoddard, F.L., Nicholas, A.H., Rubiales, D., Thomas, J., Villegas-Fernández, A.M. (2010). Integrated pest management in faba bean. Field Crops Research, 115:308-318.

Tegegn, A., Egigu, M.C., Hundie, B. (2016). Efficacy of pepper tree (*Schinus molle*) extracts to suppress growth of *Botrytis fabae* and manage chocolate spot severity on faba bean (*Vicia faba*) at Sinana, Bale zone, Southeastern Ethiopia. East African Journal of Sciences, 10:111-118.

Tesfaye, D., Yilma, G., Achenif, G., Sefera, T., Temesgen, T., Abo, T. (2020). Faba bean variety development for quality and disease resistance for potential areas (Registration of a Faba Bean Variety Named 'Numan').

Teshome, E., Tagegn, A. (2013). Integrated management of Chocolate spot (*Botrytis fabae* Sard.) of Faba bean (*Vicia faba* L.) at highlands of Bale, south eastern Ethiopia. Research Journal of Agricultural and Environmental Management, 2:11-14.

Van Loon, M.P., Deng, N., Grassini, P., Edreira, J.I.R., Wolde-Meskel, E., Baijukya, F., van Ittersum, M.K. (2018). Prospect for increasing grain legume crop production in East Africa. European Journal of Agronomy, 101:140-148.

Villegas-Fernández, A.M., Sillero, J.C., Emeran, A.A., Winkler, J., Raffiot, B., Tay, J., Rubiales, D. (2009). Identification and multi-environment validation of resistance to *Botrytis fabae* in Vicia faba. Field Crops Research, 114:84-90.

Yitayih, G., Azmeraw, Y. (2017). Adaptation of faba bean varieties for yield, for yield components and against faba bean gall (*Olpidium viciae Kusano*) disease in South Gondar, Ethiopia. The Crop Journal, 5:560-566.

Yohannes, D. (2000). Faba bean (*Vicia faba*) in Ethiopia. Institute of Biodiversity, Conservation and Research (IBCR). Addis Ababa, Ethiopia, p:43.

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