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Evaluation of Common bean Cultivars and Fungicide Spray Frequency for the Management of Anthracnose (Colletotrichum lindemuthianum) in Ambo, West Shewa Zone, Ethiopia

Ketema Hirpa[1] Thangavel Selvaraj[2]
1. Department of Plant Science, College of Agriculture and Natural resource, Assosa University, Ethiopia, Post Box No: 18, Assosa, Western Ethiopia
2.Department of Plant Science, College of Agriculture and Veterinary Science, Ambo University, Ethiopia Post Box No: 19, Ambo, Ethiopia

Abstract
Bean anthracnose caused by *Colletotrichum lindemuthianum* (Sacc. & Magnus) is one of the most devastating seed-borne diseases of common bean (*Phaseolus vulgaris* L.) in Ethiopia. Therefore, an experiment was conducted at Ambo University Experimental Research Farm during the main cropping season of 2014 to evaluate four common bean cultivars (Chercher, Awash Melka, Awash-1 and Mexican-142) and the efficacy of the fungicide, Folpan (80 WDG) at the rate of 2.6 kg/ha at four spray intervals (every one week, two weeks, three weeks and unsprayed-control) under field conditions for the management of bean anthracnose and their impact on yield and yield components. A total of sixteen treatments were laid out in a Factorial arrangement in Randomized Complete Block Design (RCBD) with 3 replications. The anthracnose severity, incidence, infected pods per plant and area under disease progress curve were the highest in susceptible cultivar Awash-1 followed by Mexican-142, Awash Melka and Chercher in unsprayed plots. The anthracnose severity was substantially reduced by 76.89% and resulted in increased seed yield (4 tons/ha) in Awash Melka when sprayed at weekly intervals compared to unsprayed plots. The anthracnose severity and area under disease progress were the recorded highest in unsprayed plots and reduced seed yield in susceptible cultivars Awash-1 and Mexican-142. Interaction effect of cultivars with spray intervals of fungicide showed significant variation in pods per plant, discolored seeds and seed yield and infected pods per plant; while it has no significant effect on seeds per pod and hundred seed weight. The relative yield loss of 51.89, 39.43, 27.5 and 22.97% were recorded from Awash-1, Mexican-142, Awash Melka and Chercher unsprayed plots, respectively. Economic analysis revealed that the highest net benefits were obtained from Awash Melka when sprayed at every one week and two weeks intervals (47,912 and 44,700 birr/ ha) followed by Chercher (42,662 and 41,373birr/ha) and the least was obtained from Awash-1 unsprayed plot (birr 10,935/ha). Highest marginal rate of return was obtained from Awash-1 sprayed at every three weeks interval (374.3%), but the lowest was obtained from Chercher with spray of fungicide at every three weeks intervals (Birr 10.88%). The relatively resistant cultivar Awash Melka with spray of fungicide at weekly intervals reduced anthracnose epidemic and increased seed yield, yield components and accrued higher net return. The results of the present study provide empirical evidences that the response of common bean cultivars to weekly and two weeks spray intervals of fungicide application found to be effective in reducing anthracnose severity, increased seed yield and reduced yield loss attributed to anthracnose in common bean cultivars under field conditions in Ambo University. Spraying Folpan fungicide at weekly and two weeks intervals had a favorable effect in reducing anthracnose epidemics. Further, cost effective and feasible integrated management options need to be developed for common bean anthracnose in the country.
Keywords: Common bean, cultivars, anthracnose, *Colletotrichum lindemuthianum,* management, fungicide, spray intervals, yield and yield loss.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important legume crop in the daily diet of more than 300 million of the world's population. For many households in the tropics, the crop is a good source of cash and food nutrients (Popelka *et al*., 2004, Hadi *et al*., 2006). Globally, common bean is cultivated on nearly 28 million hectares, producing about 20 million tons annually (FAOSTAT, 2008). In Ethiopia, common bean is mainly cultivated in the Eastern, Southern, South-western and Rift Valley Regions (Habtu *et al*., 1996). The crop is increasingly becoming important to the national economy and to the farmers as food and cash income. Between the years 2004-2010, income from the export of navy bean/common bean/haricot bean almost tripled from USD 18 to 50 million (EEPA, 2010).

The low yield of common beans could be attributed to various constraints like low adoption of improved agricultural technologies, drought, diseases and insect pests, and lack of improved cultivars, poor cultural practices and shortage of land and environmental degradation (Legesse *et al*., 2006, Kutangi *et al*., 2010). Common bean is generally cultivated during the rainy season in which the humid environment pre-disposes the crop to be attacked by various fungal, bacterial and viral pathogens. Anthracnose, (*Colletotrichum* *lindemuthianum* (Sacc. and Magnus), rust (*Uromysis appendiculatus*), angular leaf spot (*Phaeoisariopsis griseola*) and common bacterial blight (*Xanthomonas compestris pv. phaseoli*) are known common diseases of beans in Ethiopia (Habtu *et al*., 1996). Among these, anthracnose is one of the most wide spread and economically important seed borne diseases, mainly in the tropical and sub-tropical bean growing regions of the world including Ethiopia (Habtu *et al*., 1996; Tu, 1986).

Highly susceptible cultivars to anthracnose, Mexican-142 and moderately susceptible Awash-1, which are preferred for their good canning quality and high market price, are still popular among farmers in the Central Region and some other parts of the country (Tesfaye, 1997; Kutangi *et al*., 2010). It has been confirmed that infection of such susceptible cultivars in favorable environmental conditions leading to an epidemic could result in 100% yield loss (Kutangi *et al*., 2010). In the past few decades, the frequency and severity of the disease have increased in many parts of the world including Ethiopia and have been a serious threat to bean production (Amin *et al.,* 2013). Management of the primary inoculum source has been reported as a key strategy in controlling bean anthracnose. Hall (1994), emphasized that the use of clean seeds could be a potentially powerful control measure in areas where strict standards of seed health can be maintained. Seed treatment is also an important measure for the control of anthracnose (Wilson *et al.,* 1993; Freeman *et al.,* 1997; Tesfaye, 2003). Seed treatment alone could be inefficient and would often require follow-up applications of contact or systemic foliar fungicides (Koch, 1996). Utilization of resistant cultivars has been the best way to manage the disease, it is one of the most economical and effective means of controlling anthracnose disease (Daniel *et al*., 2002).

The use of resistant cultivars not only ensures protection against diseases but also save the time, energy and money spent on other measures of control. In addition to these advantages, resistant varieties, if evolved, can be the only practical method of control of diseases as fungal, bacterial and viral diseases. The chemical control should form part of integrated disease management and applications of contact or systemic foliar fungicide are the most important for management of anthracnose (Amin *et al.,* 2013). The assessment of efficacy of seed dressing and foliar fungicides like benlate, difenoconazole, mancozeb and carbendazim has been carried out in Ethiopia (Freeman *et al.,* 1997; Tesfaye and Pretorius, 2005; Amin *et al.,* 2013a).

Folpan, a protective fungicide which is commonly applied for the control of a number of fungal diseases including anthracnose of cucumbers, melons, pumpkins, squash, tomatoes and common beans, has a multi-site activity, which provides an excellent management option (PMRA, 2008; Fitsum, 2014). Fitsum (2014) reported that the possibility of using folpan as foliar spray and *Pseudomonas fluorescens* as seed treatment, decreased anthracnose disease symptoms effectively in common bean plants and also recorded increased seed yield under field conditions. Recent studies showed that integrated management of crop diseases is getting increased attention as an environmentally sound approach. The resistant cultivars can be most simple, practical, effective and economical method of disease control.

But in Ethiopia, common bean resistant and moderate resistant cultivars integrated with spray of fungicides at different intervals has received comparatively little attention and not been studied so far. Therefore, the present study was carried out to evaluate the integrated management of common bean anthracnose using common bean cultivars and fungicide, Folpan at different spray intervals under field conditions in Ambo, West Showa, Ethiopia.

MATERIALS AND METHODS

Description of the study area

The experimental study on integrated management of common bean anthracnose was conducted under field conditions at Ambo University Experimental Research Farm, Ambo during the main cropping season of 2014. Ambo is located 120 km West of Addis Ababa at 8°98' North latitude and 37°83' East longitude. Ambo woreda has a total geographical area of 83,598.69 sq. km, with elevation of 2,068 meters above sea level. Annual rainfall ranged from 900-1100 mm and temperature ranged from 10-27^oC, with an average of 18^oC. The soil type of the study site is vertisol with a pH value of 6.8.

Experimental materials - Common bean cultivars and fungicide used

Four different cultivars of common bean viz., Mexican 142 (G-11239) and Awash-1 (Exrico-23) susceptible; Chercher (STTT-165-96) highly resistance and Awash Melka (PAN-182) moderately resistant were used for the study (Table 1) (NSIA, 2006). All of them are navy white in color and seed size is small, which are primarily used for **c**ommercial (canning) purposes in the country. All the four cultivars were released and obtained from Melkasa Agricultural Research Center and grown across bean growing areas of the country. The fungicide, Folpan (80 WDG) (contact and registered fungicide) was obtained from the Department of Plant Sciences, Ambo University, Ethiopia.

Field experimental design and their application

The treatments were arranged in a factorial Randomized Complete Block Design (RCBD) with three replications. The field trial consisted of four cultivars (one highly resistant, one moderately resistant and two susceptible) of common bean and one recommended fungicide, Folpan (80 WDG) which was applied at the rate of 2.6 kg/ha at four spray intervals (every one week, every two weeks, every three weeks and unsprayed check) using a Knap-Sack sprayer and forming a total of 16 treatments that were evaluated against common bean anthracnose during the main cropping season of 2014. Spacing between blocks measured 1 m and between adjacent plots 0.5 m. Each plot has a size of 2.4 m x 1.5 m and contained six rows (with four harvestable central rows) of the bean plants. Space between rows and plants was 0.4 m and 0.1 m, respectively. Planting was done on 1st July 2014 at Ambo University's Research Experimental Farm during the main cropping season of 2014 but the plots were free of common bean cultivation for many years. Seeds were planted at the rate of two seeds per hole and thinned to one plant, 15 days after sowing (DAS) to insure 90 plants per plot. Natural inoculation was relied up on in all experimental plots. All recommended agronomic practices were followed uniformly for all plots of each treatment. No fertilizer was applied for all the treatments. Weeding was performed twice, after 15 and 25 days after emergence. Disease assessment

Anthracnose Incidence and severity were assessed at 8 days' intervals starting from 48 to 96 days after planting from the 15 pre-tagged plants in the four central rows of each plot. The first anthracnose lesion was observed on upper and lower surface of the leaves, especially on leaf lamina and veins (Figure 2) of susceptible cultivars Awash-1. The number of plants showing symptoms of anthracnose was counted on 48 days after planting and Percentage of Disease Incidence (PDI) was calculated according to the formula by Wheeler (1969).

$$\mathrm{PDI} = \frac{\text{Number of infected plants}}{\text{Total number of plants inspected}} * 100$$

The severity of anthracnose on the leaves was scored using the standard disease scale 0-9, of Sharma and Pathania, 2010 (Table 3). The severity scores were then converted into Percentage Severity Index (PSI) according to the formula by Wheeler (1969).

$$\mathrm{PSI} = \frac{\text{Sum of individual numerical rating}}{\text{Total number of plants assessed} * \text{Maximum score in scale}} * 100$$

Area under disease progress curve and Disease progress rates

The Area under Disease progress Curve (AUDPC) was computed from the PSI data recorded at each date of assessment as described by Campbell and Madden (1990).

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

Where 'n' is the total number of assessments,' t_i' is the time of the i^{th} assessment in days from the first assessment date, 'x_i' is percentage of disease severity at i^{th} assessment. AUDPC was expressed in percent-days because the severity (x) was expressed in percent and time (t) in days. The rates of disease progress in time was determined by recording the severity of anthracnose at 8 days interval right from the appearance of the first disease symptoms till the maturity of the crop in the different treatments.

Assessment of yield and yield components

The total number of pods per plant, infected pods per plant and seeds per pod was recorded from the 15 pre-tagged plants. The harvested pods were sun dried and the respective seed yield of the different treatments was measured. Bean yield data was adjusted at 10% moisture content after measuring with a moisture tester. Seed yield per plot was converted into yield in tons per hectare. The weight of 100 randomly selected seeds was also measured. Amount of shriveled or discolored seeds were counted from randomly selected hundred seeds and converted to percentage. The relative yield loss due to common bean anthracnose was assessed using the following formula:

$$\text{Relative Yield loss (\%)} = \frac{\mathrm{PY} - \mathrm{AY}}{\mathrm{PY}} * 100$$

Where, PY=potential yield (the highest yield in every one week sprayed treatment), AY= Actual yield (every two week sprayed, every three week sprayed and untreated control) and the relative hundred seed weight losses were similarly calculated.

Statistical analysis

Incidence and severity of anthracnose disease in each cultivar and each spray interval of Folpan fungicide at all frequencies were analyzed. Analysis of variance was performed for disease parameters (incidence, PSI, AUDPC, disease progressive rate), seed yield and yield components (pods per plant, infected pods per plant, seeds per pod, 100 seed weight and discolored seeds) using Statistical Analysis System (SAS) version 9.1.3 software (SAS Institute, 2002). Least significant difference (LSD) was used to separate treatment means (P<0.05).

RESULTS AND DISCUSSION

Disease incidence

The incidence data on anthracnose showed highly significant difference among unsprayed cultivars at 48, 64 and 80 DAP but there was no significant differences at 54, 72, 88 and 96 DAP. The incidence in the cultivars increased with time, the peak being at 96 DAPS (Table 1). This indicated that, the disease increased with the plant age and prevalence of favorable environmental conditions. In Awash-1, all spray intervals showed significant variations at initial and final day of incidence assessment. The recorded mean incidence was highly varied in cultivars of common bean at final day of assessment after weekly, every two weeks, every three weeks spray intervals and unsprayed plots (Table 1). At every one week, two weeks and three weeks spray intervals, the spray of fungicide was recorded highly reduced disease incidence in Chercher (38.11, 29.83 and 20.98%) followed by Awash Melka (33.89, 8.99 and 2.16%), Awash-1 (31, 6.89 and 2.33%) and Mexican-142 (33, 4.44 and 2.22%) as compared to unsprayed plots at final day of incidence assessment, respectively (Table 1). The difference in disease incidence among spray frequencies and cultivars could be due to the fact that frequent fungicide spraying could reduce spreading of secondary inoculum of anthracnose and differential resistance of bean cultivars to pathogen. Pastor-Corrales and Tu (1989) reported that the spraying of systemic fungicides like maneb, zineb, benomyl, carbendazim, and fentin hydroxide at foliage stage, flower initiation, late flowering and pod-filling stages which have been used to control and protected bean anthracnose in common bean cultivars.

Anthracnose incidence generally increased throughout the assessment days, which showed the spread of the disease in time. Although natural inoculation was relied up on in all experimental plots, anthracnose symptoms started to appear from 48 DAP without heavy seedling infection. Araujo *et al*. (1994) predicted the possible Occurrence of a marked susceptibility phase at the early stage of pod formation when no heavy seedling infection is observed. Common bean anthracnose is highly favored by cool and wet weather conditions (Bost, 2013). The main cropping season of 2014/2015 Mexican -142 in this the growing season. Table 1. Initial and final percentage disease incidence of common bean anthracnose as influenced by different cultivars and fungicide spray intervals under field conditions during the main cropping season of 2014

Treatments interactions		Mean disease incidence (%)		Reduction in PDI at 96(DAP) over unsprayed control plots (%)
Cultivars	Spray intervals	Initial 48 (DAP)	Final 96 (DAP)	
Chercher	Every one week spray	32.33a	59d	38.11
	Every two weeks spray	33.11a	66.9b	29.83
	Every three weeks spray	35.11a	75.3b	20.98
	Unsprayed control check	32.00a	95.3a	0
	Mean	33.14	74.13	
	CV (%)	11.09	2.9	
	LSD (5%) for C*SI	7.34	4.4	
Awash Melka	Every one week spray	32.22a	64.7c	33.89
	Every two weeks spray	32.66a	88.9b	8.99
	Every three weeks spray	33.99a	95.6ba	2.16
	Unsprayed control check	32.33a	97.a	0
	Mean	32.80	86.69	
	CV (%)	2.94	4.8	
	LSD (5%) for C*SI	1.93	8.4	
Awash-1	Every one week spray	47.22a	69c	31
	Every two weeks spray	47.66a	93.1b	6.89
	Every three weeks spray	47.00a	97.7a	2.33
	Unsprayed control check	48.03a	100a	0
	Mean	47.54	89.95	
	CV (%)	2.29	2.2	
	LSD (5%) for C*SI	2.17	3.9	
Mexican-142	Every one week spray	45.78a	67b	33
	Every two weeks spray	45.67a	95.6a	4.44
	Every three weeks spray	46.55a	97.8a	2.22
	Unsprayed control check	46.00a	100a	0
	Mean	46.00	90.08	
	CV (%)	1.31	4.1	
	LSD (5%) for C*SI	1.21	7.4	

LSD=Least significant difference at ($P<0.05$), CV=Coefficient of variation, DAP= Days after planting, PDI= Percentage disease incidence, the mean values in the column with the different letters represent significant variation and the mean values with the same letters are not significantly different, C = Cultivar, SI=Spray interval.

Disease severity

The percentage of disease severity index showed highly significant variation at (P<0.01) among cultivars as well as fungicide spray intervals at all the days of assessment. At final day of assessment, PSI was reduced in Chercher sprayed at every one week, two weeks and three weeks intervals by 61.53, 36.03 and 13.91%, respectively when compared to unsprayed control (Table 2 and Figure 1A). The significant differences observed among all cultivars were indicated that the different anthracnose epidemic occurred at initial stage in all cultivars. Similarly, Shao and Teri (1985) also found that highly significant differences in disease severity levels between the resistant and susceptible cultivars of common bean and between fungicides sprayed and unsprayed plots. In the present study, in Awash-1 fungicide treated plots at every week, every two weeks and every three weeks spray intervals, the PSI was reduced by 69.39, 36.20 and 24.99% respectively compared to unsprayed at final assessment (Table 2 and Figure 1C). The effect of fungicide spray in reducing PSI was significant at all dates of assessment.

Regardless of cultivars, the percentage of severity index at initial stage (48 DAP) remained high in unsprayed plots, the highest being in Awash-1 (12.21%) followed by Mexican-142 (10.96%), Awash Melka (8.06%) and the least in Chercher (7.00%) (Figure 1 A, B, C, D). After the receipt of fungicide spray at weekly interval, the percentage of severity index reduced significantly in all the cultivars compared with sprays at two weeks interval and three weeks interval, indicating the effectiveness of fungicide spray. Before this study, Awash-1 cultivar was reported to be moderately susceptible, but in this study a given cultivar was found to be highly susceptible to anthracnose and severity recorded was considerably high as compared to the susceptible cultivar, Mexican-142.

The main reason of less resistant cultivars is the possible breakdown of resistance due to the race change of the pathogen to the host resistance (McDermott, 1993). The lowest PSI (9.13%) was obtained from Chercher treated at every one week spray intervals compared to any other treatments at final day of PSI assessment.

Area under Disease Progress Curve (AUDPC)

By and large, irrespective of variety, AUDPC exhibited a trend similar to disease severity index. Analysis of variance for AUDPC showed significant difference among cultivars as well as fungicide spray intervals. Lowest area under disease progress curve was recorded from Chercher sprayed at every one week (281.5%-days) compared to unsprayed plots (805.3%-days). This could be due to lower percentage of severity index recorded in Chercher sprayed at every one week during severity assessment days. Although, the highest area under disease progress curve was recorded from Awash-1 unsprayed (1797.5%-days) followed by Mexican-142 unsprayed (1440.3%-days) compared to every one week sprayed plots (Table2).

This result brings out the fact that Awash-1 and Mexican-142 cultivars though all highly susceptible to anthracnose due to the favorable environment for the pathogen and variability of the pathogen virulence respond better to weekly fungicidal spray favorably in terms of reducing disease severity index. Kelly *et al.,* (1994) reported that genetic diversity and variability of the fungus with frequent appearance of new races remain to be the major limiting factor for effective control of bean anthracnose. Every three weeks fungicide sprays resulted in less area under disease progress curve in all cultivars, as compared to every one week and two weeks spray in the cultivars (Table 2).

Every week spray has been recorded highly effective in reducing area under disease progress curve in all the cultivars. Interaction effects of cultivars and spray intervals of fungicide was highly significant at P<0.01 on AUDPC. Area under disease progress curve 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 area under disease progress curves between treatments is the most commonly used tools for evaluating practical disease management strategies. The result attained confirmed that the overall disease development was significantly influenced by the cultivars used and fungicide spray intervals.

Table 2. Percentage severity index and area under progress curve of common bean anthracnose as influenced by different cultivars and fungicide at different spray intervals under field conditions during the main cropping season of 2014.

Treatments interactions		Mean PSI		Reduction of PSI at 96 DAP over unsprayed control plots (%)	AUDPC (%)
Cultivars	Spray intervals	Initial 48 (DAP) (%)	Final 96 (DAP) (%)		
Chercher	Every one week	7.49a	9.13d	61.53	255.83c
	Every two weeks	7.04a	15.18c	36.03	513.55b
	Every three weeks	7.53a	20.43b	13.91	611.89b
	Unsprayed control	7.00a	23.73a	0	805.38a
	Mean	7.26	18.03		546.41
	CV (%)	4.93	9.32		13.79
	LSD (5%) for C*SI	0.72	3.35		150.58
Awash Melka	Every one week	8.11a	9.87d	76.89	351.12c
	Every two weeks	8.10a	16.79c	60.69	529.98cb
	Every three weeks	8.40a	25.92b	16.79	625.06b
	Unsprayed control	8.06a	42.71a	0	1099.55a
	Mean	8.17	23.83		651.43
	CV (%)	2.96	6.84		8.3
	LSD (5%) for C*SI	0.48	3.26		108.02
Awash-1	Every one week	12.04ba	17.53d	69.39	683c
	Every two week	12.00b	36.54c	36.20	1134.8b
	Every three week	12.55a	42.96b	24.99	1442.9b
	Unsprayed control	12.21ba	57.27a	0	1797.5a
	Mean	12.20	38.58		1264.6
	CV (%)	2.25	4.35		12.46
	LSD (5%) for C*SI	0.54	3.35		314.95
Mexican-142	Every one week	10.99a	18.27d	65.58	513.9c
	Every two week	10.80a	29.38c	44.65	937.5b
	Every three week	10.71a	38.51b	27.45	1211.7ba
	Unsprayed control	10.96a	53.08a	0	1440.3a
	Mean	10.86	34.81		1025.86
	CV (%)	2.65	2.71		17.28
	LSD (5%) for C*SI	0.58	1.88		354.3

DAP =Days after planting, PSI=Percentage severity index, CV = Coefficient of variation, AUDPC= Area under disease progress curve, LSD=Least significant difference at (P<0.05), the mean values in the column with the different letters represent significant variation and the mean values with the same letters are not significantly different, C = Cultivar, SI=Spray interval.

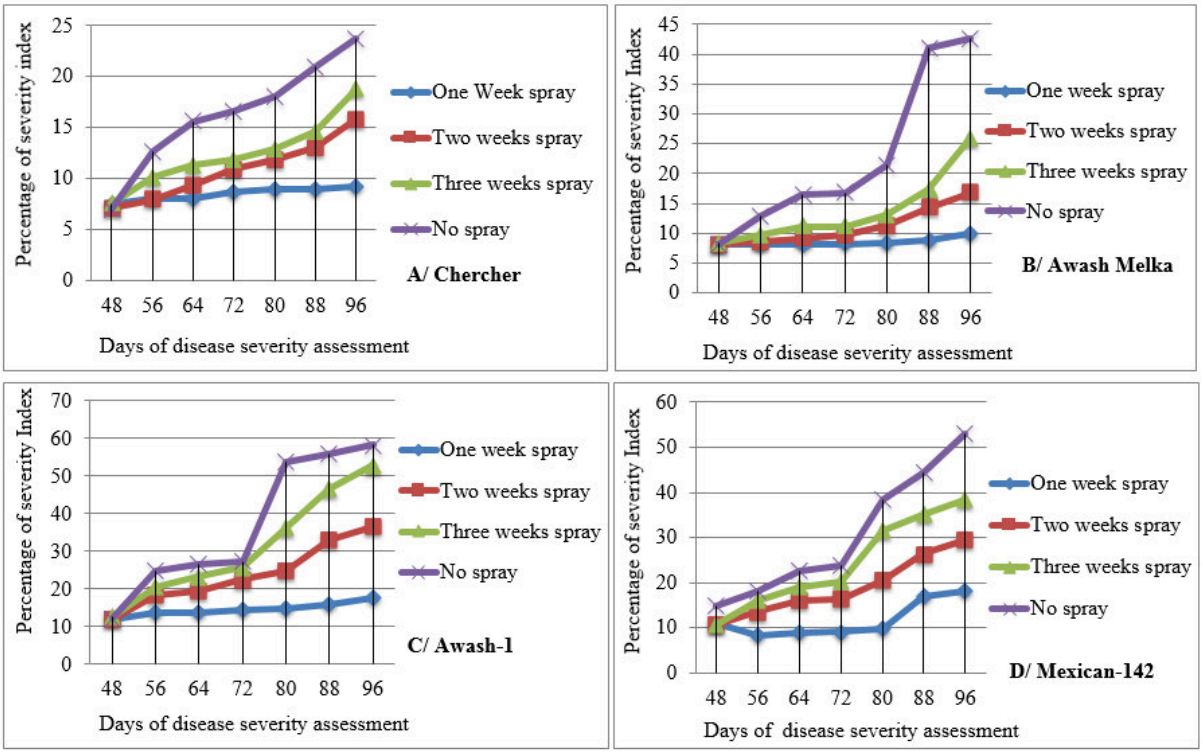

Figure 1. Percentage severity index of anthracnose on different common bean cultivars at different days of assessment under field conditions during the main cropping season of 2014 Yield components

Number of pods per plant, infected pods per plant, seeds per pod, discolored seeds and hundred seeds weight were highly significantly varied among cultivars. In Awash Melka every one week sprayed (16.82) had higher number of pods per plant than Awash Melka every two weeks sprayed (13.55), every three weeks sprayed (13.15) and unsprayed control (12.06). Higher number of seeds per pod (5.43) was recorded from Awash Melka every one week sprayed than Mexican-142 (5.00), Awash-1 (4.7) and Chercher (4.17) when sprayed every week, respectively (Table 3). The highest number of pods per plant and seeds per pod recorded in Awash Melka, could be due to every week application of fungicide which reduced the spread of anthracnose infection at the critical time of common bean flowering and podding stage. It could also contribute to the highest seed yield in Awash Melka (4 tons/ha) every one week sprayed.

In this study, foliar sprays of fungicide Folpan at weekly interval reduced PSI at final day of severity assessment and increased seed yield and yield components. This corroborates with the findings of Selamawit (2004) who indicated spray interval of 5 days increased yield over unsprayed one. Also, Conneret *et al.* (2001) indicated that application of the foliar fungicide could reduce losses in seed yield and quality from bean anthracnose disease. In this study, the significant variation was observed among fungicide spray intervals in producing pods per plant, infected pods per plant, seeds per pod, percent discolored seeds and seed yield. The least mean pods per plant (3.69), seed yield (1.4 tons/ha) and highest infected pods per plant (6.55) was obtained from Awash-1 unsprayed plot (Table 3). The decrease in number of pods/plant, seed yield and increased infected pods per plant was due to early pod infection leading to pod death and drop seems to be the cause of reduction in seed yield of susceptible bean cultivars.

Interaction effect of cultivars and spray of fungicide showed significant variation in producing pods per plant, seed yield and discolored seeds, while it showed no significant variation in seeds per pod and hundred seeds weight but it showed significant variation in infected pods per plant.

Table 3. Yield and yield components of common bean as influenced by different cultivars and fungicide at different spray intervals under field conditions during the main cropping season of 2014

Cultivars	Spray intervals	Pods per plant	Infected pods per plant	Seeds per pod	100 seed weight (g)	Dis-Colored seeds (%)	Seed Yield (tons/ha)	Yield increase over un sprayed (%)
Chercher	Every one week	13.38a	1.62b	4.17a	23.88a	0.66c	3.7a	29.82
	Every two weeks	12.84a	2.11ba	3.83ba	23.40a	1.66b	3.41ba	19.65
	Every three weeks	10.35b	2.64a	3.54ba	23.20a	1.66b	3.03ba	6.32
	Unsprayed control	9.37b	2.68ba	3.34b	23.10a	3.00a	2.85b	0
	Mean	11.49	2.27	3.72	23.38	1.75	3.25	
	CV (%)	7.10	23.3	10.5	2.87	28.6	12.9	
	LSD (5%)	0.67	1.05	0.78	NS	0.99	0.83	
Awash Melka	Every one week	16.82a	1.57b	5.43a	21.36a	1.00b	4.0a	37.93
	Every two weeks	13.55b	2.02b	5.30a	21.26a	1.00b	3.6ba	24.14
	Every three weeks	13.15cb	2.22b	5.00a	20.76a	1.33b	3.2ba	10.34
	Unsprayed control	12.06c	3.39a	4.55a	20.73a	2.00a	2.9b	0
	Mean	13.9	2.3	5.1	21	1.3	3.43	
	CV (%)	5.1	19.1	12.8	3.12	21.7	11.85	
	LSD (5%)	1.4	0.88	NS	NS	0.57	0.81	
Awash-1	Every one week	14.40a	1.85c	4.78a	20.63a	2.66b	2.91a	107.86
	Every two weeks	8.62b	2.33c	4.31a	19.86a	3.33b	2.38a	70
	Every three weeks	6.97b	5.08b	3.67ba	19.46a	4.00b	2.17a	55
	Unsprayed control	3.69c	6.55a	3.03b	19.06a	6.33a	1.4b	0
	Mean	8.42	4.0	3.69	19.8	4.08	2.21	
	CV (%)	11.29	14.9	9.61	4.9	11.5	17.03	
	LSD (5%)	1.89	1.41	0.75	NS	0.94	0.75	
Mexican-142	Every one week	14.51a	1.47c	5.00a	18.33a	0.66a	3.17a	65.10
	Every two weeks	12.38b	2.38b	4.44ba	17.46a	2,33b	2.62ba	36.46
	Every three weeks	9.73c	3.68b	4.09ba	17.43a	4.33c	2.23bc	16.15
	Unsprayed control	8.82c	4.10a	3.64b	17.23a	5.66d	1.92c	0
	Mean	11.4	2.9	4.29	17.6	3.25	2.5	
	CV (%)	7.43	14.8	12.2	3.7	10.25	11.97	
	LSD (5%)	3.52	0.86	1.04	NS	0.66	0.60	

CV =Coefficient of Variation, LSD=Least Significant Difference, the mean values in the column with different letters are significantly different where as the mean values with the same letters are not significant different, NS=Not significant difference.

Yield loss

The computed relative yield losses showed prominent differences among treatments. Yield losses were reduced in Chercher with every two weeks and every three weeks spray with Folpan fungicide (7.84% and 18.11%) compared to Chercher unsprayed plot (22.97%), this corresponds to the gain of additional yield (0.56 to 0.18 tons/ha) over unsprayed plot in Chercher. As reported by Conneret *et al.,* (2001) application of the foliar fungicide could reduce losses in seed yield and quality from bean anthracnose disease. About 1.22 tons/ha additional yield was obtained in Awash Melka every two weeks sprayed compared with Awash-1 every two weeks sprayed. The highest yield loss was observed in Awash-1 unsprayed plot (51.89%) followed by Mexican-142 unsprayed plot (39.43%). This high yield loss in moderately susceptible and highly susceptible cultivars could be due to high initial inoculum of disease in both cultivars and its persistence for prolonged period.

The present findings are in agreement with the results of Tesfaye (1997) who evaluated severity of bean anthracnose and its effect on yield of common bean and found that high disease severity ranging between 17.2 to 76.6 % resulted in mean yield loss of 67.2%. Similarly, Sharma *et al.,* (2008) reported that pod infection had direct effect on seed yield and indicated that the pod development stage is the most vulnerable stage of common beans for quick disease progress. As reported by Sartorato *et al.,* (1998) yield losses due to anthracnose in susceptible cultivars vary from 38-100 % under different situations.

The least yield loss was obtained from Chercher every two weeks and every three weeks sprayed (Table 4). This could be due to genetic resistance of Chercher cultivar to the virulence of pathogen. In Awsah-1 sprayed at every two weeks and every three weeks spray intervals, yield loss was reduced by 18.21 and 25.43% compared with unsprayed (51.89%) and in Mexican-142 sprayed at every two weeks and every three weeks spray intervals, yield loss was reduced by 17.35 and 29.65% compared with Mexican-142 unsprayed (39.43%). Pyndji (1991) has estimated that 43.9 % yield loss in French bean was due to anthracnose infection, and found that pod infection had direct effect on seed yield, however, the extent of losses varied with severity level. The present study indicated that the maximum relative yield loss was recorded from susceptible cultivar Awash-1 and Mexican-142 unsprayed plots than the remaining cultivars treated at different intervals of fungicide spray.

Table 4. Seed yield, hundred seed weight and relative yield loss of common bean due to anthracnose as influenced by different cultivars and fungicide at different spray intervals under field conditions during the main cropping season of 2014

Treatments		Seed yield	Relative Yield loss	100 seed weight	Relative Seed weight
Cultivars	Spray intervals	(tons/ha)	(%)	(g)	Loss (%)
Chercher	Every one week	3.70	0.00	23.88	0.00
	Every two weeks	3.41	7.84	23.40	2.01
	Every three weeks	3.03	18.11	23.20	2.85
	Unsprayed-control	2.85	22.97	23.10	3.27
Awash Melka	Every one week	4.0	0.00	21.36	0.00
	Every two weeks	3.6	10	21.26	0.47
	Every three weeks	3.2	20	20.76	2.80
	Unsprayed-control	2.9	27.5	20.73	2.95
Awash-1	Every one week	2.91	0.00	20.63	0.00
	Every two weeks	2.38	18.21	19.86	3.73
	Every three weeks	2.17	25.43	19.46	5.67
	Unsprayed-control	1.4	51.89	19.06	7.61
Mexican-142	Every one week	3.17	0.00	18.33	0.00
	Every two weeks	2.62	17.35	17.46	4.75
	Every three weeks	2.23	29.65	17.43	4.91
	Unsprayed-control	1.92	39.43	17.23	6.00

Correlation between disease parameters and yield and yield components.

The correlations among the disease parameters with the yield and yield components showed a significant negative correlation in PSI, DPR and AUDPC with seed yield, pods per plant, seeds per pod and hundred seed weight, but positively correlated with infected pods per plant and discolored seeds. Similarly, significant positive correlation was observed among PSI, DPR, AUDPC, IPP and DS (Table 5). Sharma *et al.,* (2008) reported highly significant correlation between anthracnose severity and percentage reductions in the number of seeds per pod and seed weight due to anthracnose. The disease progress rates and percentage of pod infection showed non-significant negative correlations with seed yield. Similarly, the disease progress rates showed non-significant positive correlations with the percentage of pod infection and terminal disease severity. Marcinkowska and Borucka (2001) also found significant positive correlation between the incidence of *C. lindemuthianum* in *P. vulgaris* seeds and leaf, pod and stem infection by the pathogen under natural field conditions.

Non significant variation and positive correlation was observed in hundred seed weight with seed yield and pods per plant while negative correlation and non significant variation was observed in hundred seed weight with mean seeds per pod. The disease parameters such as, PSI, DPR and AUDPC and seed yield and yield components such as, seed yield, PP,SP and HSW showed highly significant positive correlations with each other (Table 5). The area under disease progress curve showed highly significant positive correlations with the percentage of disease severity index and mean pod infection per plant and permanent disease severity. The results suggest that reliable yield loss estimates could be made on the basis of the severity level by engaging regression equations. Especially, for crops growing under epidemic conditions, Percentage severity value recorded during flowering and podding stage of common bean would be a good prediction of the yield that could be obtained.

Table 8. Correlation coefficient (r) among disease parameters and yield and yield components in different common bean cultivars and fungicide at different spray intervals under field conditions during the main cropping season of 2014

	Correlations									
Correlations	Yield (tons/ha)	PP	IPP	SP	HSW (g)	DS (%)	PDI	PSI	DPR	AUDPC (%)
Yield (tons/ha)	1									
PP	0.871**	1								
IPP	-0.811**	-0.887**	1							
SP	0.711**	0.833**	-0.685**	1						
HSW (g)	0.614ns	0.286ns	-0.404ns	0.043ns	1					
DS (%)	-0.848**	-0.853**	0.865**	-0.680*	-0.602*	1				
PDI	-0.625**	-0.682**	0.671**	-0.353ns	-0.545*	0.693*	1			
PSI	-0.852**	-0.824**	0.881**	-0.542*	-0.636**	0.882**	0.824**	1		
DPR	-0.816**	-0.815**	0.906**	-0.548*	-0.594*	0.856**	0.764**	0.986**	1	
AUDPC	-0.913**	-0.874**	0.916**	-0.596*	-0.626**	0.933**	0.798**	0.974**	0.959**	1

PP=Pods per plant, IPP=Infected pods per plant, SP= Seeds per pod, HSW=Hundred seed weight, DS= Discolored seeds PDI=Percentage disease incidence, PSI=Percentage severity index, NS=Not significant, DPR= Disease progress rate, AUDPC=Area under disease progress curve, *= Correlation is significant at (P< 0.05), **=Correlation is significant at (P< 0.01).

Cost benefit analysis From the data analyzed, the highest variable cost of input and labor cost (22,088Birr/ha) was computed for all cultivars treated at every one week spray intervals, with high net profit compared with unsprayed treatments (Table 6). In Chercher every one week, every two week and every three weeks spray provided higher net benefit of Birr 42,662, 41,375 and 36,619/ha, respectively over unsprayed (Birr 36,310/ha); and the corresponding values of marginal rate of return were 74.53, 106.9 and 10.88%, respectively. The change in input cost of all treatments varied from 2,841(unsprayed plots) to 8,523Birr/ha (every one week sprayed).

At every one week spray of fungicide increased net benefit to Birr 47,912/ha with 125.56% marginal rate of return in the Awash Melka. Similarly every two weeks spray of fungicide increased net benefit to Birr 44,700/ha with 158.71% marginal rate of return and the least variable (input and labor) cost compared with Chercher every one week spray of fungicide which provided net benefit of Birr 42,662/ha. The highest net benefit was obtained from Awash Melka every one week spray of fungicide (Birr 47,912) and the least from Awash-1 unsprayed (Birr 10,935/ha).

Higher marginal rate of return of 374.3% was obtained from Awash-1 every three week sprayed plots. The lower marginal rate of return was obtained from Chercher every three week sprayed (10.88%). From the disease, yield and yield components data; every one week spray interval had protected the cultivars from severe epidemic and increased yield and yield components. The aim of disease control is to assess reduction in economic gain from a crop and if the control measures fail to increase economic gain, even if disease epidemic is reduced no grower is likely to accept the recommendation for the plant disease control (Chaube and Singh, 1991). Economics are variable and depend on the prevailing price of the products and costs of input, but difference between treatments in disease parameters as well as yield may stay constant in each cultivar. This trend holds true for other cultivars at same time, where higher seed yield and net benefit was obtained from every one week spray intervals than every three weeks spray intervals with higher marginal rate of return. Therefore, effectiveness in epidemic reduction, difference in yield and net return should be considered while recommending integrated management options.

Table 5. Data of partial budget analysis for the management of common bean anthracnose using different cultivars and fungicide under field conditions during the main cropping season of 2014

Cost benefit data	Treatments			
Cultivars	One week spray interval	Two weeks spray interval	Three weeks spray interval	No spray (control)
Chercher				
Common bean yield (tons/ha)	3.70	3.41	3.03	2.85
Bean sale (Birr/tons)	17,500	17,500	17,500	17,500
Sale revenue (Birr)	64,750	59,675	53,025	49,875
Total Input and Labor cost (Birr/ha)	22,088	18,300	16,406	13,565
Marginal cost (Birr/ha)	8,523	4,735	2,841	0
Net profit (Birr/ha)	42,662	41,375	36,619	36,310
Marginal benefit (Birr/ha)	6,352	5,065	309	0
Marginal rate of return (%)	74.53	106.9	10.88	0
Awash Melka				
Common bean yield (tons/ha)	4.0	3.6	3.2	2.9
Bean sale (Birr/tons)	17,500	17,500	17,500	17,500
Sale revenue (Birr)	70,000	63,000	56,000	50,750
Total Input and Labor cost (Birr/ha)	22,088	18,300	16,406	13,565
Marginal cost (Birr/ha)	8,523	4,735	2,841	0
Net profit (Birr/ha)	47,912	44,700	39,594	37,185
Marginal benefit (Birr/ha)	10,727	7,515	2,409	0
Marginal rate of return (%)	125.86	158.71	84.79	0
Awash-1				
Common bean yield (tons/ha)	2.91	2.38	2.17	1.4
Bean sale (Birr/tons)	17,500	17,500	17,500	17,500
Sale revenue (Birr)	50,925	41,650	37,975	24,500
Total Input and Labor cost (Birr/ha)	22,088	18,300	16,406	13,565
Marginal cost (Birr/ha)	8,523	4,735	2,841	0
Net profit (Birr/ha)	28,837	23,350	21,569	10,935
Marginal benefit (Birr/ha)	17,902	12,415	7,134	0
Marginal rate of return (%)	210.04	262.19	374.3	0
Mexican-142				
Common bean yield (tons/ha)	3.17	2.62	2.23	1.92
Bean sale (Birr/tons)	17,500	17,500	17,500	17,500
Sale revenue (Birr)	55,475	45,850	39,025	33,600
Total Input and Labor cost (Birr/ha)	22,088	18,300	16,406	13,565
Marginal cost (Birr/ha)	8,523	4,735	2,841	0
Net profit (Birr/ha)	33,387	27,550	22,619	20,035
Marginal benefit (Birr/ha)	13,352	7,515	2,584	0
Marginal rate of return (%)	156.66	158.71	90.95	0

RECOMMENDATIONS AND CONCLUSIONS

The primary goal of this study was to evaluate the combinations of four common bean cultivars (Chercher, Awash Melka, Awash-1 and Mexican-142) and the efficacy of the fungicide, Folpan at the rate of 2.6kg/ha with four spray intervals (every one week, two weeks, three weeks and unsprayed) under field conditions for the management of bean anthracnose and their impact on yield and yield components. All fungicide spray intervals in cultivars reduced anthracnose incidence and severity compared to unsprayed control checks at final day of disease assessment. The anthracnose incidence, severity, infected pods per plant and area under disease progress curve was observed highest in susceptible cultivar Awash-1 followed by Mexican-142, Awash Melka and Chercher in unsprayed plots.

The maximum seed yield in Awash Melka with spray at weekly interval could be due to reduction of fungal spores spread from infected leaf to healthy leaf apart from genetic resistance of the cultivar to virulence of anthracnose. Highest anthracnose disease severity was observed in highly susceptible cultivar Awash-1 in unsprayed control plots could be the reason for highest yield loss in the cultivar. The highest yield loss was incurred from highly susceptible cultivar, Awash-1 unsprayed plot (51.89%) followed by moderately susceptible cultivar, Mexican-142 unsprayed (39.43%).

Higher marginal rate of return was obtained from Awash-1 sprayed at every three weeks interval (374.3%) but the lowest marginal rate of return was obtained from Chercher with spray of fungicide at every three weeks intervals (10.88%). The results of this study provide an empirical evidences that the response of common bean cultivars to weekly and two weeks spray intervals of fungicide application found to be effective in reducing anthracnose severity, increased seed yield and reduced yield loss attributed to anthracnose in common bean cultivars under field conditions in Ambo University Experimental Research Farm. To ensure maximum protection, resistant cultivars could be raised supplemented with different spray intervals of fungicide to reduce fungal spore spread from diseased to healthy plants. Spraying Folpan fungicide at weekly and two weeks intervals had a favorable effect in reducing anthracnose epidemics.

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