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Effect of Intercropping and Compost Application for the Management of Common Bean Anthracnose (*Colletotrichum lindemuthianum)* in North Shewa, Central Ethiopia

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Abstract: Common bean is grown for its high nutritive, medicinal and market value in Ethiopia. Anthracnose is among the major production constraint within central common bean producing regions of Ethiopia. Field experiments were conducted on two common bean varieties Awash Melka and Mexican 142 at Shewarobit and Ataye in 2016 and 2017 main cropping seasons with the objective of evaluating the effects of row intercropping, compost plus their integration on disease severity of common bean anthracnose. Field experiments revealed maximum disease severity on highly susceptible variety Mexican 142 than Awash Melka at both locations and during both cropping seasons. Significantly, the lowest (26.9%) mean final anthracnose severity was obtained from the integration of intercropping with compost application at Ataye during 2017 and (562% day) mean area under disease progress curve was obtained from the integration of intercropping with compost application at Shewarobit during 2017. Whereas significantly the highest (39%) mean final disease, severity and (849% day) mean AUDPC were recorded from the sole planting control plots in 2016 at Shewarobit. Integration of intercropping with compost application as ecofriendly disease management option was the appropriate management option of common bean anthracnose in the study area. Further studies of integrating management options need to be conducted to reduce the residual effects of agrochemicals.

Keywords: Anthracnose; AUDPC, *Colletotrichum lindemuthianum*, Ecofriendly, Intercropping, Severity

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the important grain legume crop cultivated in different regions of Ethiopia [13, 14, 20, 21, 43]. Common bean is used as the fundamental source of income of foreign currency exchange and nutrition. Nutritionally, it provides a rich combination of carbohydrates (60 to 65%), proteins (21 to 25%) and fat (less than 2%), vitamins [11], some minerals like iron and zinc, have a low glycemic index and high fibers, contributing to the health conditions of human beings [3, 32]. In Ethiopia, common bean is used in intensifying crop production in space and species mixture (intercropping) and soil fertility management [1, 20, 43]. Common bean is extensively cultivated in low and mid altitude areas (1200 to 2000 masl) of eastern and many central parts of Ethiopia, with optimum temperature of about 24°C [12, 25, 43]. In Ethiopia, common bean ranked second next to faba bean at national level based on area and legume production [7, 20, 21]. High humidly and low temperature predisposes common bean to attack by various fungal and bacterial pathogens [1, 7, 17, 18, 21, 28, 34, 40, 47].

Anthracnose caused by *Colletotrichum lindemuthianum* is the most destructive common bean disease in the tropical and sub-tropical regions especially under cool and humid climates [1, 5, 23, 24, 26, 27, 37, 40]. Common bean is highly susceptible to the pathogen the whole lifespan of the crop depending on the occurrence of conducive ecological conditions necessary for commencement and disease progress of anthracnose [5, 23, 24, 25, 28, 34, 40, 41, 47].

In central part of Ethiopia, common bean anthracnose is the common recurrence with wide pathogenic variability [25, 34, 35, 40]. The local verities are susceptible to one or the other race of the pathogen [13, 17, 18, 25, 27, 38]. The pathogen causes losses both in terms of yield and quality [31, 37]. Comparing resistance and susceptible varieties, high yield loss (95%) has been reported in susceptible varieties of the crop [17, 18, 40]. Though different management aspects of bean anthracnose have been studied in different regions of the country, yet little is known about integrated field based strategies of crop disease management such as resistant varieties, intercropping and compost application in north shewa.

Considering the effect integrated field based strategies of crop disease management practices through vermicompost application [29, 31, 42] and species combinations [5, 12, 14, 20, 31, 44] on disease development help detection of the most important focus efforts in developing integrated disease management practices especial for ecofriendly integrated ones. The epidemic of the disease needs further assessment under sole and integrated field based management practices such as resistant variety, row intercropping and compost application [5, 44]. The objective of this study was, therefore, to assess the effects of the intercropping, compost application plus their integration on anthracnose epidemiology in central Ethiopia.

2. Materials and Methods

2.1. Experimental Sites

Field experiments were conducted at Shewarobit and Ataye at farmers' fields in 2016 and 2017 during main cropping seasons (June to November). Shewarobit is located 225-kilo meters from Addis Ababa at the northeastern part of the country between 09, 99' N latitude and 39, 89' E longitude at an altitude of 1288 meters above sea level [10, 36]. The area has an average annual rainfall of 1007 mm, with short rain between March and April and long rain between June and September and annual mean minimum and maximum temperatures of 16.5 and 31 ^{o}C, respectively [10, 36]. The location has varied soil types (from luvisol to vertisol) with pH range of 5.0-8.0 [36]. Ataye is located 290 kilometer from Addis Ababa at north eastern part of country between 10,21'N latitude and 39,56 ' E longitude at an altitude of 1458 meters above sea level (recorded by GPS in 2016). The area has an average annual rainfall of 1085 mm and annual mean minimum and maximum temperatures of 15.18 and 32.95 ^{o}C, respectively [8, 10, 36].

Simultaneous planting was used in row intercropping in which, a row of common bean was planted in the center of sorghum rows at 10 cm intra-row and 40 cm inter-row spacing [8, 44]. Similarly, in sole planting of common bean 40 cm inter-row and 10 cm inter-plant spacing with 7 rows per plot were used. The intra-block and intra-plot spacing were 1 m and 0.75 m respectively (on a plot size of 3 m x 4 m (12 m^2).

2.2. Experimental Procedures

Compost was applied a month before sowing at a rate of 8 tons per hectare, about half the rate recommended for cereals [9] for both plants. Sorghum seeds were sown on 20 June 2016 and 22 June 2017 at Shewarobit and on 14 June 2016 and 16 June 2017 at Ataye. Seeds were sown by hand drilling seeds at the rate of 5 kg ha^{-1}, and the plants were thinned of 25 cm intra-row spacing after emergence. Common bean seeds were sown on 21 July 2016 and 25 July 2017 at Shewarobit and on 16 July 2016 and 18 July 2017 at Ataye. The rows were thinned after emergency and establishment of seedlings. Plants were hand weeded three times and cultivated once during the growth periods in both cropping seasons.

2.3. Treatments and Experimental Design

Two field based management practices (intercropping and vermicompost application), their integration and a control were used as treatments. Row intercropping was used as crop diversification and vermicompost application was used as soil nutrient management. The treatments were common bean-sorghum row intercropping, vermicompost application, their combination and sole planting applied separately and in integration for both common bean varieties (Awash Melka and Mexican 142). The common bean varieties were obtained from Melkasaa Agricultural Research Center, Ethiopia. Awash Melka is moderately resistant while Mexican 142 is susceptible to CBB. Sorghum variety, Teshale (3442-2 OP) was used. Eight management combinations were set in factorial randomized complete block design (Table 1).

Table 1. *Management practices of common bean anthracnose disease for 2 common bean varieties at Shewarobit and Ataye, Ethiopia during 2016 and 2017 cropping seasons.*

S. No	Variety	Managements	Management practices description
1	Awash Melka	SP	sole planting
2	Awash Melka	CA	compost application
3	Awash Melka	RI	row intercropping
4	Awash Melka	RI + CA	row intercropping + compost application
5	Mexican 142	SP	sole planting
6	Mexican 143	CA	compost application
7	Mexican 144	RI	row intercropping
8	Mexican 145	RI + CA	row intercropping + compost application

2.4. Disease Data

All disease data were collected from three central rows. Disease severity (leaf area showing characteristic anthracnose symptom) was assessed five times at an interval of seven days during the experimental periods beginning from 48-52 days after planting (DAP) on both locations during both cropping seasons. Disease severity rating was performed on 10 randomly pre-tagged plants per treatment plot. Severity was rated with 1-9 scale ([4, 6, 30, 46] where 1 = no visible symptom and 9 = complete death of the foliar parts of the plant and the severity grades were converted into percentage severity index (PSI) for analysis using:

$$\text{PSI} = \frac{\text{Sum of numerical ratings X 100}}{\text{Number of plants scord X maximum score on scale}}$$

Disease progress rate (r) and area under disease progress curve (AUDPC) were calculated from the severity data. AUDPC was computed from PSI data calculated on each date of assessment as described by [26, 27].

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

The rates of disease progress were obtained from regression of PSI data fit to Logistic Model ln [Y/1-Y))] with dates of disease assessments.

2.5. Data Analysis

Disease severity at different days after planting (DAP) and AUDPC were analyzed with analysis of variance using the PROC GLM procedure of Statistical Analysis System or SAS version 9.2 [16, 39] to determine the treatment effects. Treatment means were separated with least significant difference (LSD) test at 5%. Since the collected data were heterogeneous with regard to location and season, disease data were analyzed separately.

3. Results

3.1. Disease Severity

The epidemics of anthracnose were appeared on both varieties at both locations and during both cropping seasons varied among management practices significantly (Table 2). Disease severity was consistently less on the integrated plots than sole planted plots. Appearance of disease in both years and both locations were significantly different ($P<0.01$) among management practices and between varieties. During both cropping seasons, the management practices significantly ($P<0.01$) affected disease severity (Table 2) throughout the whole disease recording dates while significant difference ($P<0.01$) of disease severity between the two varieties were at late disease recording days.

Considering the range of disease severity and percentage of disease severity reduction, the solely applied management practice had higher disease severity and lower reduction compared to integrated and row intercropping plots. The integrated management practice: row intercropping + compost application and row intercropping caused higher anthracnose severity reduction. They reduced the mean final disease severity from 21.9-27% (mean 13.7%) during 2012 (Figure 1A) and from 29-35.7% (mean 18.8%) during 2013 (Figure 1b).

At Shewarobit, the highest mean initial disease severity (19.6%) and (16.9) at 48 days after planting (DAP) were recorded from sole planted plots, during 2016 and 2017 cropping season respectively while the lowest (14.2%) and (13%) were recorded in row intercropping integrated with compost applied plots (Figure 1a and 1b), during 2016 and 2017 cropping seasons respectively. Similarly, at 76 DAP, the highest mean final disease severity (39 % and 37.3%) were recorded from sole planning plots and the lowest (27.1% and 28.1%) were recorded from row intercropping + compost application in 2016 and 2017 cropping seasons respectively (Figure 1a and 1b). RI+CA has reduced the initial disease severity index by 27.9 % and 23.1% during 2016 and 2017 cropping seasons respectively while 30.5% and 24.7% of finial disease severities were reduced by RI+CA during 2016 and 2017 cropping seasons respectively at Shewarobit. All of the disease management practices had similar trends of disease reduction during both years in the entire disease recording dates ((Figure 1a and 1b). The integrated management practice: row intercropping + compost application and row intercropping caused higher anthracnose severity reduction. They reduced the mean final disease severity from 15.5-27.9% (mean 17.8%) during 2016 (Figure 2A) and from 9.1-23.1% (mean 12.8%) during 2017 at Shewarobit (Figure 1a and 1b).

At Ataye, the highest mean initial disease severity (17.93%and 18.5%) at 51 days after planting (DAP) were recorded from sole planted plots, during 2016 and 2017 cropping season respectively while the lowest (15.6%) was recorded in row intercropping integrated with compost applied plots (Figure 1a and 1b), in 2017 cropping seasons respectively. Similarly, at 79 DAP, the highest mean final disease severity (36.7 % and 34.5%) were recorded from sole planning plots and the lowest (27.7% and 26.9%) were recorded from row intercropping + compost application in 2016 and 2017 cropping seasons respectively (Figure 1c and 1d). Row intercropping has reduced the initial disease severity index by 25.2 % during 2016 and RICA has reduced initial disease severity index by 15.7% in 2017 cropping season while 24.5% and 22% of finial disease severities were reduced by RI+CA during 2016 and 2017 cropping seasons respectively at Ataye. All of the disease management practices had similar trends of disease reduction in both cropping seasons in the entire disease recording dates ((Figure 1c and 1d). The integrated management practice: row intercropping + compost application and row intercropping caused higher anthracnose severity reduction. They reduced the mean final disease severity from 10.7-25.2% (mean 12.9%) during 2016 (Figure 2A) and from 6.3-15.7% (mean 9.3%) during 2017 at Ataye (Figure 1c and 1d).

With respect to mean initial and final disease severity of two varieties during both cropping seasons and both locations, higher mean initial disease severity was obtained from variety Mexican 142 and lower mean initial disease severity was obtained from variety Awash Melka throughout the whole disease recording periods of time (Figure 2).

At Shewarobit, using resistant variety Awash Melka reduced the mean final disease severity by 20.9% in 2016 cropping season and by 25.7% in 2017 when compared to susceptible variety Mexican 142 (Figure 2a). Similarly, Awash Melka reduced the mean final disease severity by 26.6% in 2016 cropping season and by 26.8% in 2017 when compared to susceptible variety Mexican 142 at Ataye (Figure 2b).

Table 2. *Mean squares analysis value for percentage of disease epidemiology of common bean anthracnose at Shewarobit and Ataye during 2016 and 2017 main cropping seasons (n=24).*

Location	Year	Source	DF	Days After Planting				
				48	55	62	69	76
		Treat	3	40.62***	53.80***	145.11***	145.28***	181.36***
		Variety	1	92.09***	233.54***	414.17***	402.44***	368.78***
	2016	Treat. Variety	3	2.64ns	13.79**	24.06**	28.31*	38.33**
		Error	14	3.89	1.79	4.22	7.94	6.96
		CV (%)		12.2	6.6	7.3	9.1	7.8
Shewarobit		Treat	3	18.44***	29.05***	102.57***	119.41***	130.14***
		Variety	1	53.98***	213.41***	560.24***	549.6***	487.15***
	2017	Treat* Variety	3	6.98**	12.14**	15.12**	8.95ns	15.72**
		Error	14	1.44	2.19	2.56	3.43	4.13
		CV (%)		8.1	8.2	6.2	6.7	6.2
				51	58	65	72	79
		Treat	3	21.25***	28.77**	73.04***	112.25***	102.45***
		Variety	1	60.943***	290.74***	567.45***	584.11***	574.31***
	2016	Treat*Variety	3	4.11ns	1.65ms	6.61ns	17.90*	15.90*
		Error	14	1.61	4.35	3.65	3.37	4.28
Ataye		CV (%)		8.1	10.2	7.6	6.7	6.5
		Treat	3	11.76*	16.92**	70.975***	83.56***	82.96***
		Variety	1	64.63***	266.44***	494.39***	532.25***	531.571***
	2017	Treat*Variety	3	4.45ns	4.64ns	10.15*	5.20ns	5.203ns
		Error	14	2.89	2.67	1.87	3.97	5.915
		CV (%)		10.1	8	5.7	7.6	8

DAP= Days after planting, CV= Coefficient of Variation; *, **, ***, are significant at p ≤ 0.05, P<0.01and p ≤ 0.001 probability levels, respectively, ns is non-significant, *= interaction.

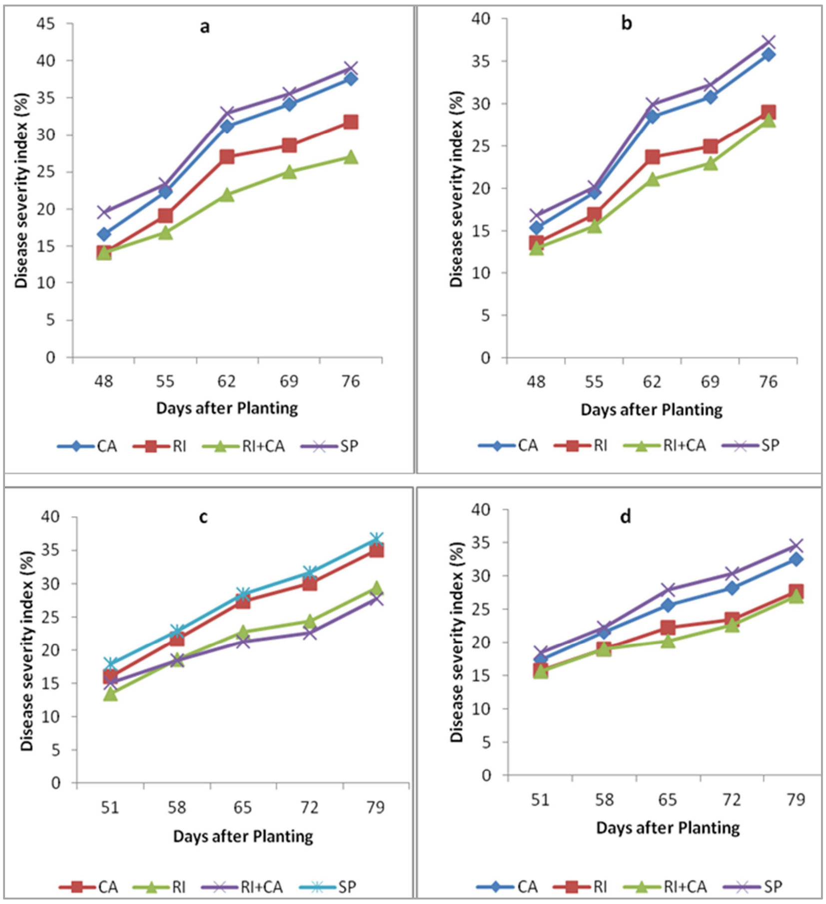

Figure 1. *The mean disease progress curve of common bean anthracnose Awash Melka and Mexican 142 varities (a) in 2016 and (b) in 2017 at Shwarobit and (c) in 2016 and (d) in 2017 at Atayet. RI + CA row intercropping + compost application; RI, row intercropping; CA, compost application; SP, sole planting.*

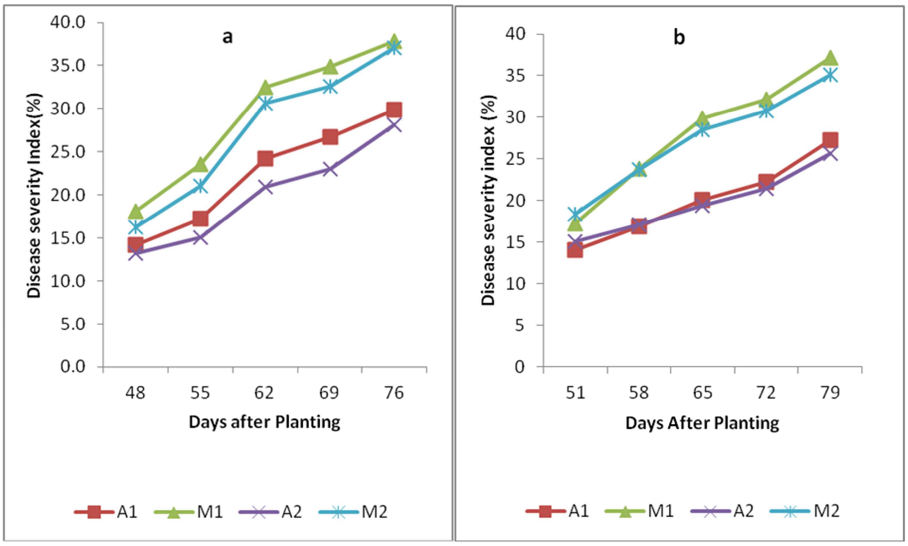

Figure 2. *The mean disease progress curve of common bean anthracnose Awash Melka (A1 and A2 during 2106 and 2017 respectively) and Mexican 142 M1 ans M2 during 2016 and 2017 respectively) (a) at Shewarobit and (b) at Ataye obtained from four management practices.*

3.2. Area under Disease Progress Curve

There were significant (P<0.001) differences among the management practices in both seasons and both locations in mean AUDPC (Figure 3). At Shewarobit, the highest AUDPC values (662%-days and 943%-days) were recorded form Awash Melka and Mexican 142 varieties respectively, combined with sole planting in 2016 cropping season (Figure 3A). Minewhile the slowest AUDPC vales (557%-days and 624%-days) were recorded from Awash Melka and Mexican 142 varieties respectively, combined with row intercropping integrated with compost application in the same year. Other management practices reduced AUDPC values from 7.3 to 22% (mean 11.6%) in Awash Melka and from 4.2 to 36.6% (mean 15.6%) in Mexican 142 variety (Figure 3A). The highest AUDPC values (629%-days and 906%-days) were recorded form Awash Melka and Mexican 142 varieties respectively, combined with sole planting in 2017cropping season. Minewhile the slowest AUDPC vales (489%-days and 635%-days) were recorded from Awash Melka and Mexican 142 varieties respectively, combined with row intercropping integrated with compost application in 2017 cropping season. Other management practices reduced AUDPC values from 6.8 to 22.2% (mean 11.2%) in Awash Melka and from 3.3 to 29.9% (mean 14.3%) in Mexican 142 variety.

At Ataye, the highest AUDPC values (635%-days and 911%-days) were recorded form Awash Melka and Mexican 142 varieties respectively, combined with sole planting in 2016 cropping season (Figure 3B). Minewhile the slowest AUDPC vales (503%-days and 672%-days) were recorded from Awash Melka and Mexican 142 varieties respectively, combined with row intercropping integrated with compost application in the same year at Ataye. Other management practices reduced AUDPC values from 7.4 to 20.7% (mean 11.8%) in Awash Melka and from 3.9 to 26.3% (mean 13.1%) in Mexican 142 variety at Ataye during 2016 (Figure 3B).

The highest AUDPC values (611%-days and 885%-days) were recorded form Awash Melka and Mexican 142 varieties respectively, combined with sole planting in 2017 cropping season. Minewhile the slowest AUDPC vales (495%-days and 668%-days) were recorded from Awash Melka and Mexican 142 varieties respectively, combined with row intercropping integrated with compost application in 2017 cropping season at Ataye (Figure 3B). Other management practices reduced AUDPC values from 6.7 to 19% (mean 6.8%) in Awash Melka and from 5.8 to 24.5% (mean 13.1%) in Mexican 142 variety at Ataye during 2017 (Figure 3B).

3.3. Disease Progress Rate

Comparisons of disease progress rates for management practices were made with Logistic regression model by fitting severity data with dates of assessment (Table 3). The rates of disease progress were significantly different among treatments and between seasons. During 2016 cropping season, the highest disease progress rate (0.02-logit day^{-1}) was on Mexican 142 variety and (0.01 logit day^{-1}) from Awash Melka variety treated with sole planting and compost application while the lowest epidemic rate (0.008 logit day^{-1}) was recorded from row intercropping + compost application of both common bean varieties at Shewarobit (Table 3). During 2017 cropping season the highest rates (0.01 and 0.019 logit day^{-1}) were recorded from Awash Melka and Mexican 142 varieties respectively at Shewarobit while the lowest rates (0.005 logit day^{-1}) was recorded from Awash Melka variety treated with row intercropping integrated with compost application at Shewarobit during 2017 cropping season (Table 3).

At Ataye, during 2016 cropping season, the highest disease progress rate (0.017-logit day^{-1}) was on Mexican 142 variety and (0.009 logit day^{-1}) from Awash Melka variety treated with sole planting and compost application while the lowest epidemic rate (0.006 logit day^{-1}) was recorded from row intercropping + compost application on Awash Melka variety at Shewarobit (Table 3). During 2017 cropping season the highest rates (0.008 and 0.015 logit day^{-1}) were recorded from Awash Melka and Mexican 142 varieties respectively at Ataye while the lowest rates (0.004 and 0.008 logit day^{-1}) were recorded from Awash Melka and Mexican 142 varieties respectively, treated with row intercropping integrated with compost application at Ataye during 2017 cropping season (Table 3).

At Shewarobit, application of row intercropping + compost application reduced disease progress rate by 26% and 62% on Awash Melka and Mexican 142 respectively compared to sole planting in 2016 cropping season (Table 3). Row intercropping + compost application also reduced disease progress rate by 50% and 43% on Awash Melka and Mexican 142 respectively compared to sole planting in 2017 cropping season.

At Ataye, application of row intercropping + compost application reduced disease progress rate by 27% on Awash Melka compared to sole planting in 2016 cropping season (Table 3). Row intercropping + compost application also reduced disease progress rate by 49% and 45% on Awash Melka and Mexican 142 respectively compared to sole planting in 2017 cropping season.

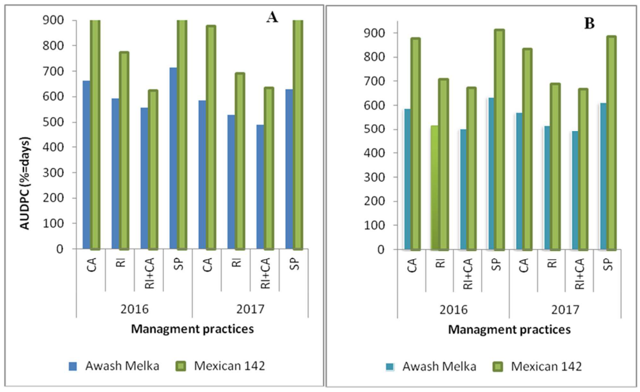

Figure 3. *AUDPC Values of bean anthracnose against management practices on Awash Melka and Mexican 142 varieties of common beans at Shewarobit (A) and at Ataye (B).*

Table 3. *Common bean anthracnose disease progress rate (r) in logit per day and adjusted coefficient of determination (R2) on common bean varieties of Awash Melka and Mexican 142 at Shewarobit and Ataye in 2016 and 2017 cropping seasons.*

Location	Management Practices	2016				2017			
		Awash Melka		Mexican 142		Awash Melka		Mexican 142	
		Rate (r)	R^2	Rate (r)	R^2	Rate (r)	R^2	Rate (r)	R^2
Shewarobit	SP	0.011	87.5	0.020	90.5	0.010	86.9	0.019	93.4
	CA	0.011	85.7	0.020	78.1	0.010	76.7	0.018	82.1
	RI	0.009	90.2	0.013	82.9	0.007	82.7	0.010	88.9
	RI + CA	0.008	87.9	0.008	88.2	0.005	69.8	0.011	90.3
Ataye	SP	0.008	83.6	0.008	70.3	0.008	84.7	0.015	92.1
	CA	0.009	92	0.017	94.1	0.007	87.3	0.013	82.5
	RI	0.007	88.3	0.011	88.3	0.005	73.7	0.009	85.6
	RI + CA	0.006	87.3	0.008	70.3	0.004	72.2	0.008	88.9

4. Discussion

Common bean anthracnose epidemics were significantly varied among the management practices, between common bean varieties, the cropping seasons and over locations. The variety Mexican 142 had higher disease severity and higher area under disease progress curve (AUDPC) than Awash Melka variety, which is due to the higher resistance level of Awash Melka variety against common bean anthracnose than the variety Mexican 142. The result of this study is in agreement with the findings of Fininsa and Tefera [15] who described the variety Awash Melka as a moderately resistant variety to Common bean anthracnose and halo blight while the variety Mexican 142 was considered as a susceptible variety. Higher disease epidemic was recorded in 2016 cropping season than in 2017 cropping season in both locations. This was because of higher relative humidity and relatively lower maximum temperature were recorded in post flowering and podding stage in 2016 cropping season, which could have created suitable environment for common bean anthracnose.

Row intercropping + Compost application as management practices had lowered final disease severity (22-31%) and AUDPC values by 22.3-30.4% compared to the values for sole planting on both common bean varieties in both cropping seasons and both locations. The variation in final severity was based on the application of management practices and their integration, resistance level of common bean, conduciveness of location and weather variables for common bean anthracnose in both cropping seasons.

Intercropping common bean with sorghum significantly lowered the severity level of common bean anthracnose compared with sole planting. Row intercropping + compost application and row intercropping showed significantly lower common bean anthracnose severity than the sole plantings during both cropping seasons at both locations. Row intercropping whether applied solely or in combination, significantly reduced the final disease severity by 19.5-30.1% compared to sole planted plots in both seasons. Similarly, Fininsa, [14] reported reduction of common bacterial blight severity 17-40% in bean-maize intercropping than sole cropping. Ihejirika et al. [22] experimental result revealed that there was about 36% reduction in early leaf spot of groundnut with melon intercrops when compared to controls. In sorghum-common bean intercropping, common bean anthracnose disease epidemics might have been reduced because the sorghum might have served as physical barrier against the fungal inoculum from reaching the common bean.

The microclimate created by intercropping may also retard proliferation and spread of the fungus between plants because of non-host nature of the component crop sorghum. In addition to disfavoring common bean anthracnose severity, intercropping can maintain soil fertility and provide balanced nutrition that might enhance physiological and morphological fitness of the crop to build resistance to common bean anthracnose. The result of this study is in line with the report of [33] who reported that intercropping is used for improving soil fertility and diseases control.

Compost application reduced the final common bean anthracnose disease severity by 3.6-5.8% when applied solely and reduced disease severity by 19.5-30.5% when integrated with row intercropping in both cropping seasons. The result of this experiment is in agreement with the findings of [45] who reported similar results on foliar plant diseases, found that compost showed 34-65% disease symptom reduction in bacterial speck *Pseudomonas syringae* pv. *tomato* of *Arabidopsis thaliana* compared with non-amended soil. Hassan et al. [21] reported that compost application resulted in the highest reduction (44.4%) in anthracnose of chili over the control. Hassan et al. [21] also reported that disease management with compost has been attributed to successful competition for nutrients and activation of disease-resistant genes in common beans. This result is consistent with the findings of Barker and Bryson [2] who reported that using compost could supply plant nutrients, could increase tolerance and/or resistance to diseases, and would retain soil moisture. Moreover, beneficial microorganisms in compost might have activated the crop's disease defenses mechanisms against the fungus by thickening of the cell walls in roots and foliage to make it more difficult for penetration (Hassan et al. [21].

When the management practices are integrated, their synergetic effect significantly reduced disease severity, AUDPC and disease progress rate. Row intercropping + compost application showed significant difference in disease severity reduction compared to singly applied and the sole planted plots. Compost application aggravated common bean anthracnose severity on the susceptible variety Mexican 142 when applied solely during both cropping seasons. This might be that compost application could have enhanced the growth of the variety Mexican 142 at a faster rate and created more closed canopy earlier than plots without compost, consequently increased temperature and increased humidity, which sequentially could create favorable condition for common bean anthracnose development and spread. Generally, there were higher disease progress rates on the variety Mexican 142 than on Awash Melka in both seasons over both locations.

High disease rates were observed compost application that had lower disease severity. This could be due to high density of initial inoculum from the infected seeds, infested debris or infested soil that might have increased the initial disease severity. The plots with higher initial disease severity resulted in higher disease progress rate even though there was lower final disease severity.

Generally, common bean anthracnose severity was reduced due to the reduction in inoculum dispersal and inhibition of inoculum proliferation by cultural management practices, creating disfavoring conditions for the fungus. Such management practices are therefore, suitable as disease management options, cheaper, sustainable and could be easily adopted by smallholder farmers in central regions of Ethiopia. The results obtained from this study suggest the importance of cultural management practices applied singly and/or in combination as management options for common bean anthracnose and other common bean diseases in the study area and in areas with similar agro-ecological conditions.

5. Conclusion and Recommendation

Application of cultural management practices in field experiments reduced common bean anthracnose severity and AUDPC values compared to singly applied management practices and sole planting in common beans across seasons and over locations. In addition, row intercropping + compost application, showed promising results in maintaining soil temperature and moisture. Thus, it could be concluded that farmers in central Ethiopia should design a strategy to promote common bean production through the application of row intercropping and compost application to improve the physico-chemical properties of soil and sustain enhanced production and productivity of common bean. It is strongly believed that the management practices through reduction in common bean anthracnose epidemics would serve as ecofriendly disease management option and would enhance soil fertility management, contribute substantially to the efforts of increase in food production in the study area.

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Conflict of Interest

The authors declare that they have no competing interests and the research was conducted by keeping the ethics of scientific research methods and approaches.

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