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Management of Common bean anthracnose (*Colletotrichum lindemuthianum* Sacc and Magn.) through integration of intercropping and compost application at Haramaya, eastern Ethiopia

Negash Hailu*

Department of Plant Sciences, Debreberhan University, P.O. Box 445, Debre Berhan, Ethiopia

***Corresponding Author:** Negash Hailu, Department of Plant Sciences, Debreberhan University, P.O. Box 445, Debre Berhan, Ethiopia.

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Abstract

Common bean (*Phaseolus vulgaris* L.) grown for its high nutritive, medicinal and market value in Ethiopia. Anthracnose caused by Colletotrichum lindemuthianum is among the major diseases of common bean production constraint in central and eastern highlands of Ethiopia. Field experiments were conducted on two common bean varieties Gofta (G2816) and Mexican 142 (11239) at Haramaya university research station in 2012 and 2013 main cropping seasons with the objective of evaluating integrated effects of intercropping, compost application and compost application + compost application on disease development of common bean anthracnose. The four management options used were compost application, intercropping, intercropping + compost application and sole planting. The treatments were laid out in a randomized complete block design in factorial arrangements. Significantly ($P < 0.01$) the lowest (23.82%) mean final anthracnose severity and (390.6% day) mean area under disease progress curve (AUDPC) were obtained by integration of intercropping with compost application whereas significantly the highest (33.04%) mean final disease severity and (535% day) mean AUDPC were recorded from the sole planting control plots in 2012. The integration of intercropping with compost application reduced the final disease severity index by 27.9% and AUDPC by 27% in 2012 and by 43.73% and 35.7%, respectively, in 2013 cropping season. When applied singly, compost application and intercropping reduced, the final mean disease severity by 4.4 % and 22.3% respectively in 2012 and by 13.5% and 36.6% respectively, in 2013 cropping season. The treatments reduced the value of AUDPC by 5.9-27% (mean 13.7%) in 2012 and by 10.5-35.7% (mean 18.8%) in 2013 cropping season. Integration of intercropping with compost application as ecofriendly disease management option was the appropriate management option of common bean anthracnose. 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*

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Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the important grain legume crop eastern Ethiopia (Fininsa and Tefera, 2002; Fininsa, 2003; Tana., *et al*. 2007; Hailu., *et al.* 2016). It is used as the vital 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 (Ensminger., *et al.*

1994), good source of iron and zinc (Buruchara., *et al.* 2011), have a low glycemic index and high fibers, contributing to the health conditions of human beings (Martin-Cabrejas, 1997; Bindera, 2009). It also used in intensifying crop production in space and species mixture (intercropping) and soil fertility management (Tana., *et al*. 2007; Hailu., *et al.* 2015). This ecologically and economically important legume is extensively cultivated in low and mid altitude areas (1200 to 2000 masl) of eastern Ethiopia (Fininsa and Yuen, 2001; Tana., *et al*. 2007; Katungi., *et al*. 2009). Optimum temperature for common bean production is about 24°C. Common bean is grown on about 366,876.94 ha in Ethiopia from which about 463,008.5 tons are produced in the year 2012/2013, with an average national yield of 1.26 tons per hectare (CSA, 2013). Based on area and legume production, this crop ranked second next to faba bean at national level.

Common bean cultivation during main cropping season with high humidly and low temperature predisposes the crop to attack by various fungal and bacterial pathogens (Yesuf and Sangcho, 2005; Sharma., *et al.* 2008: Lemessa., *et al*. 2011; Mohammed., *et al*. 2013; Mohammed., *et al.* 2014). Among common bean diseases, bean anthracnose caused by *Colletotrichum lindemuthianum* (Sacc. and Magnus) is one of the most destructive diseases in the tropical and sub-tropical regions especially under cool and humid climates (Pastor-Corrales and Tu, 1989; Kumar., *et al*. 1999; Khalequzzaman KM. 2015). The crop is vulnerable to the attack of the pathogen from seedling to maturity depending on the prevalence of favourable environmental conditions that are essential for initiation and further development of the disease (Yesuf and Sangcho, 2005; Sharma., *et al.* 2008: Katungi., *et al*. 2009; Lemessa., *et al.* 2011; Mohammed, 2013).

In Ethiopian highlands, common bean anthracnose is of common recurrence with wide pathogenic variability (Katungi., *et al*. 2009; Mohammed, 2013; Mohammed., *et al*. 2014) and local cultivars are susceptible to one or the other race of the pathogen (Kumar., *et al*. 1997; Pathania., *et al*. 2006; Katungi., *et al.* 2009). The pathogen causes losses both in terms of yield and quality (Pastor-Corrales and Tu, 1989) and yield losses as high as 95 percent has been reported in susceptible varieties (Sharma., *et al.* 2008). Though different management aspects of bean anthracnose have been studied in detail yet little information is available in literature on integrated field based strategies of crop disease management such as resistant varieties, intercropping and compost application.

Understanding the effect integrated field based strategies of crop disease management practices through compost application (Sullivan, 2004; Luske, 2010), soil water conservation (Aydinalp and Cresser, 2008; Toulmin, 2011), and species mixture combinations (Fininsa, 2003) on disease intensities will assist identification of the most important variables and focus efforts in developing integrated management packages. The epidemic of bean anthracnose needs to be assessed under sole and integrated field based management practices such as resistant variety, intercropping and compost application. The objective of this study was, therefore, to assess the effects of the intercropping, compost application and their integration on anthracnose epidemiology of common bean in eastern Ethiopia.

Materials and Methods

Experimental Sites

Field experiments were conducted at Haramaya University experimental field station at Haramaya in 2012 and 2013, eastern Ethiopia, during main cropping seasons (June to November). Haramaya is located at 09° 26´ N and 42° 3´ E. The altitude of the area is 1980 meters above sea level with average annual rainfall of 786.8 mm, with mean minimum temperature of 10.4°C and means maximum temperature of 23.4°C. The location has varied soil types (from luvisol to vertisol) with pH range of 5.0-8.0.

The weather variables of the location for 2012 and 2013 growing seasons are indicated on [Figure 1]. 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 [5]. Similarly, in sole planting of common bean 40 cm inter-row and 10 cm inter-plant spacing with 9 rows per plot were used. Spacing between blocks was 1.2m and between plots was 1m. (on a plot size of 3m x 4m ($12m^2$) with the net harvested plot size of $9.6m^2$ for intercropping and $8.4m^2$ for sole common bean.

Experimental Procedures

Compost was applied two weeks before sowing at a rate of 8 tons per hectare, about half the rate recommended for cereals (EARO, 2004) for both plants. Sorghum seeds were sown on 20 June 2012 and 02 July 2013 by hand drilling seeds at the rate of 5 kg ha^{-1}, and the plants were thinned to one plant per hill of 25 cm intra-row spacing after emergence. Common bean seeds were sown on 07 July 2012 and 09 July 2013. After emergency and establishment of seedlings, the rows were thinned to one plant per hill. Recommended agronomic practices were used for sole common bean planting. Fertilizer application and artificial inoculation were not applied for common bean. Plants were hand weeded three times at and cultivated once during the growth periods at both cropping seasons. The treatment combinations for a susceptible variety are listed in Table 1 and the treatments were repeated for resistant variety constituting eight treatments.

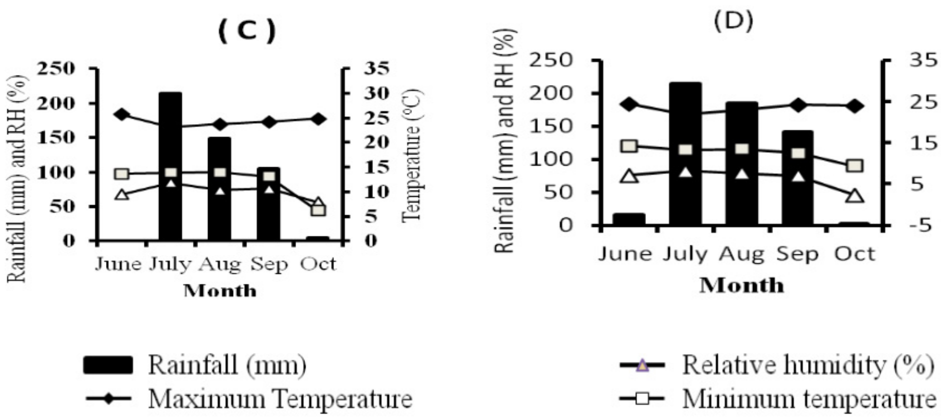

Figure 1: *The weather variables (mean maximum and mean minimum temperature (°C), mean relative humidity (%) and total monthly rainfall (mm) at Haramaya in 2012 (C) and in 2013 (D).*

Treatments and Experimental Design

Two field based management practices, their integration and a control were used as treatments. The management practices are crop diversification (row intercropping) and soil nutrient management (composting). The treatments were common bean-sorghum row intercropping, compost application, their combination and sole planting. The treatments were applied separately and in integration using Gofta (G 2816) and Mexican 142 (G 11239) common bean varieties. Gofta is moderately resistant while Mexican 142 is susceptible to CBB. The varieties were obtained from Melkasaa Agricultural Research Center, Ethiopia. Sorghum variety, Teshale (3442-2 OP) was used. Eight treatment combinations were arranged in a randomized complete block design in three replications on a plot size of 3.4 m x 3.6 m (12.24 m^2). Compost was applied two weeks before sowing at a rate of 8 tons per hectare, about half the rate recommended for cereals for both crops.

Disease Data

All disease data were collected from central four rows. Disease severity (leaf area showing characteristic anthracnose symptom) was assessed four times at an interval of seven days during the experimental periods beginning from 55-57 days after planting (DAP). Disease severity rating was performed on 10 randomly pre-tagged plants per treatment plot during both cropping seasons. Severity was rated using standard scales of 1-9 (Madden, 2006; CIAT, 1987). Where 1 = no visible symptom and 9 = disease covering more than 25% of the foliar tissue and the severity grades were converted into percentage severity index (PSI) for analysis using:

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

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 Vander Plank, (1963) and Madden (2006).

$$AUDPC = \sum_{i=1}^{n-1} 0.5(xi + 1 - xi)(ti + 1 - ti)$$

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

Data Analysis

Disease severity at different DAP and AUDPC were subjected to analysis of variance using the PROC GLM procedure of Statistical Analysis System or SAS version 9.2 (SAS Institute. 2003) to determine the treatment effects. Homogeneity of variances was tested using F-test as described by [19] and the F-test was significant. Thus, separated analysis of the two-year data was performed. Differences among treatment means were compared using the Fisher's least significant difference (LSD) test at 5% level of significance.

Results

Disease Severity

The epidemics of anthracnose was appeared on both varieties during both cropping seasons varied between management practices significantly. Disease severity was consistently less on the integrated plots than sole planted plots. Disease severity in the two cropping seasons was significantly different ($P < 0.01$) between management practices and between varieties. During both cropping seasons, the disease severity was significantly different ($P < 0.01$) between management practices 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.

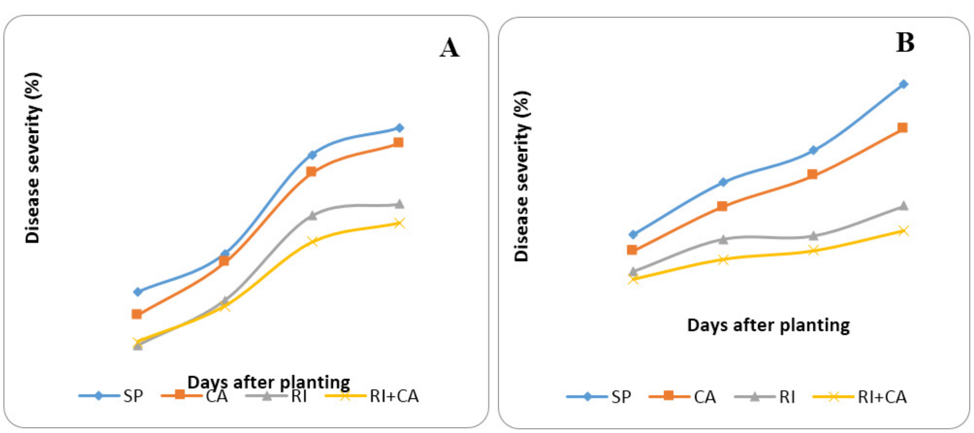

Figure 2: *The mean disease progress curve of common bean anthracnose Gofta and Mexican 142 varities (A) in 2012 and (B) in 2013. RI + CA row intercropping + compost application; RI , row intercropping ; CA, compost application; SP, sole planting.*

In 2012, the highest mean initial disease severity (17.13%) at 55 days after planting (DAP) was recorded from sole planted plots, while the lowest (11.94%) was recorded in row intercropping plots of [Figure 2A]. Similarly, the highest mean final disease severity (30.04%) at 76 DAP was recorded from sole planning whereas the lowest mean final disease severity (23.8%) was recorded from row intercropping followed by row intercropping (25.7%). During the 2013 cropping season, the highest mean final disease severity (30.58%) was obtained from sole planting followed by compost application while the lowest mean final disease severity (17.2%) was obtained from row intercropping + compost application [Figure 2B].

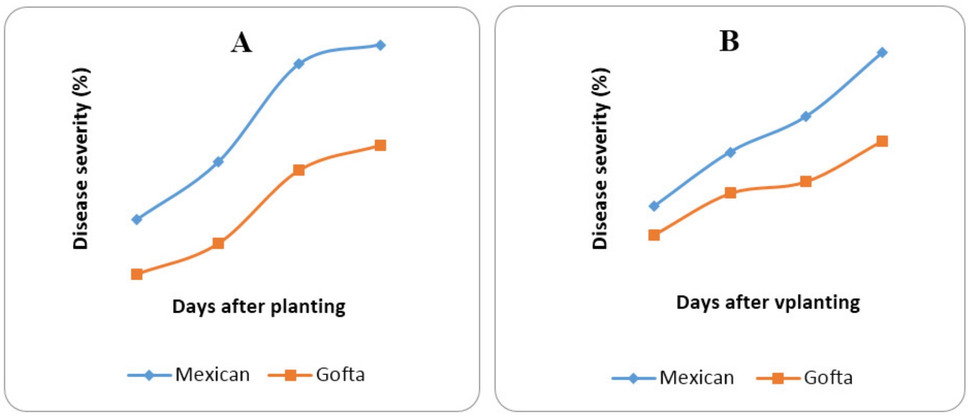

Figure 3: *The mean disease progress curve of common bean anthracnose Gofta and Mexican 142 varities (A) in 2012 and (B) in 2013, obtained from four management practices.*

With respect to mean initial and final disease severity of two varieties during both cropping seasons, higher mean initial disease severity was obtained from variety Mexican 142 and lower mean initial disease severity was obtained from variety Gofta throughout the whole disease recording periods of time [Figure 3].

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 2A] and from 29-35.7% (mean 18.8%) during 2013 (Figure 2B). Similarly, using resistant variety Gofta reduced the mean final disease severity by 28.8% in 2012 cropping season and by 23.69% in 2013 when compared to susceptible variety Mexican 142 [Figure 3].

Variety	**Days after planting (2012)**				**Days after planting (2013)**			
	55	62	69	76	57	64	71	78
Mexican	16.67a	22.13a	31.51a	33.34a	15.56a	19.44a	21.99a	26.55a
Gofta	11.47b	14.36b	21.34b	23.71b	13.56b	16.52b	17.36b	20.26b
LSD	2.36	2.15	2.63	3.13	1.37	1.78	1.96	2.52
Treat	Days after planting				Days after planting			
	55	62	69	76	57	64	71	78
SP	17.13a	20.86a	30.48a	33.04a	16.79a	21.58a	24.49a	30.58a
CA	14.91ab	20.02a	28.70a	31.57a	15.29ab	19.36a	22.17a	26.46b
RI	11.94b	16.32b	24.56b	25.66b	13.45bc	16.41b	16.70b	19.40c
RI+CA	12.31b	15.77b	21.97b	23.82b	12.71c	14.56b	15.34b	17.20c
LSD	3.34	3.04	3.72	4.43	1.93	2.52	2.78	3.56

		Days after planting (2012)				Days after planting (2013)			
Source	DF	55	62	69	76	57	64	71	78
Variety	1	162.3**	362.4***	620.8***	556.4***	24.1**	51.3**	25.5**	237.3***
Rep	2	0.205ns	6.7ns	30.3ns	22.1ns	8.0ns	30.4**	7.3**	40.8*
Treat	3	35.4*	39.7**	90.0**	120.1**	20.4**	58.1***	22.6***	230.5***
Variety*Treat	3	2.92ns	0.98ns	3.6ns	8.5ns	2.8ns	5.6ns	5.4*	35.2*
Error	14	7.25	6.04	9.01	12.79	2.43	4.13	5.03	8.27
CV (%)		19.14	13.48	11.36	12.54	10.71	11.30	11.40	12.29

Area under Disease Progress Curve

There were significant ($P < 0.001$) differences among the management practices in both seasons in mean AUDPC [Figure 4]. The mean (550.5%-days) AUDPC value was higher on the variety Mexican 142 than on the Gofta (373.02%-days) in 2012 cropping season and mean AUDPC value (437.4%-days) higher on the variety Mexican 142 than on the variety Gofta (355.5%-days) in 2013. The overall mean (461.8%-days) AUDPC value in the 2012 cropping season was higher than in 2013 (396.5%-days).

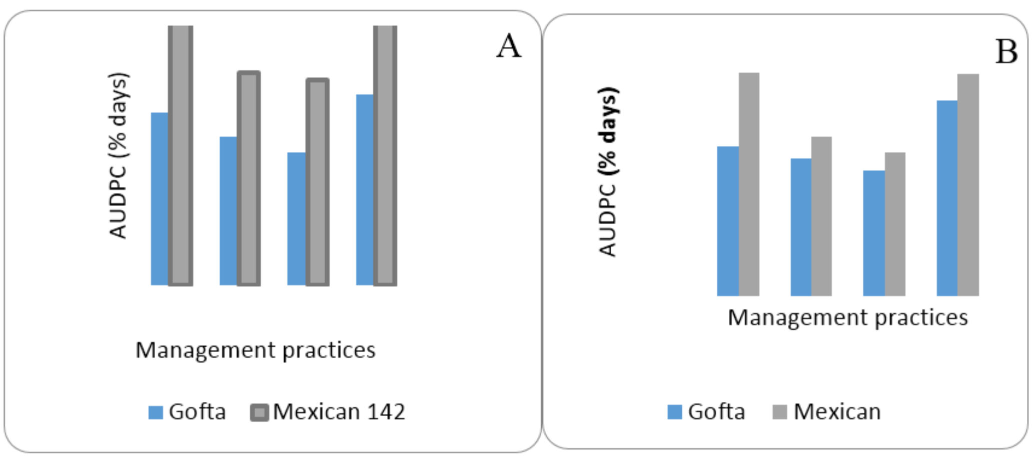

Figure 4: *AUDPC Values of bean anthracnose against management practices on Gofta and Mexican 142 varieties of common beans in 2012 (A) and 2013 (B) at Haramaya.*

The lowest AUDPC value was computed from row intercropping + compost application on both Gofta and Mexican 142, in 2012 (Figure 4A). The row intercropping + compost application reduced the AUDPC value by 30.3% on the variety Gofta and by 24.7% on the variety Mexican 142. The management practices reduced AUDPC values by 9.5-30.25% (mean 20.6%) on variety Gofta and by 3.3-24.7% (mean 16.6%) on variety Mexican 142 than the sole planting at in 2013 cropping season (Figure 4A). In 2013 cropping season, maximum AUDPC value (519.2%-days) was computed on variety Mexican 142 from the sole planting, whereas the minimum AUDPC value (334.9%-days) was from row intercropping + compost application plots, followed by row intercropping (372.7%-days). The management practices reduced AUDPC values by 20.5-33.5% (mean 21.7%) on variety Gofta and by 16.9-46.8% (mean 34.8%) on variety Mexican 142 than the sole planting at in 2013 cropping season (Figure 4B).

Source	DF	2012	2013
		Mean Square	AUDPC
Variety	1	189075.96***	4.02E+05
Rep	2	5386.1619	12586.29*
Treat	3	28254.91**	38656.2***9
Variety*Treat	3	1056.17ns	5506.6*
CV		9.65	9.90
Average UDPC		461.7813	396.4674
Variety	AUDPC 2012	AUDPC 2012	
Mexican	550.54a	437.4a	
Gofta	373.02b	355.5b	
LSD	39.03	34.374	
	AUDPC 2012	AUDPC 2012	
SP	535.03a	488.27a	
CA	503.73a	436.84b	
RI	417.76b	346.75c	
RI+CA	390.61b	314.01c	
LSD	55.196	48.612	

Disease Progress Rate

Comparisons of disease progress rates management practices were made based on the Logistic model by fitting severity data with dates of assessment. The rates of disease progress were significantly different among treatments and between seasons. During 2012 cropping season, the highest disease progress rate (0.067-logit day^{-1}) was on Mexican 142 variety and (0.051 logit day^{-1}) on Gofta variety from compost application while the lowest epidemic rate (0.014 logit day^{-1}) was on Gofta variety during 2013 cropping season from row intercropping + compost application. The disease progress rates calculated for varieties, management practices, and years were different and presented in Table 1 for 2012 and 2013 seasons. The reduction of disease progress rate by management practices did not completely have similar trend to the disease severity and area under disease progress curve in varieties and cropping seasons.

Management Practices	2012				2013			
	Gofta		Mexican		Gofta		Mexican	
	Rate (r)	R^2	Rate (r)	R^2	Rate (r)	R^2	Rate (r)	R^2
SP	0.045	82.6	0.07	78.1	0.033	68.6	0.056	82.3
CA	0.051	83.1	0.067	80.5	0.02	36	0.052	84.3
RI	0.045	86	0.054	79.2	0.018	42.7	0.019	36.6
RI + CA	0.035	59.7	0.047	77.2	0.014	28.4	0.015	27.7

Application of row intercropping + compost application reduced disease progress rate by 22% and 33% on Gofta and Mexican 142 respectively compared to sole planting in 2012 cropping season. Row intercropping + compost application also reduced disease progress rate by 57.6% and 73% on Gofta and Mexican 142 respectively compared to sole planting in 2013 cropping season.

Discussion

Common bean anthracnose epidemics were significantly varied among the management practices, between common bean varieties and cropping seasons. The variety Mexican 142 had higher disease severity and higher area under disease progress curve (AUDPC) than the variety Gofta, which might be due to the higher resistance level of the variety Gofta than the variety Mexican 142 not only common bean anthracnose but also other major common diseases like common bacterial blight in the study area. The result of this study is in agreement with the findings of Fininsa and Tefera (2006) who described the variety Gofta as a moderately resistant variety to Common bean anthracnose, common bacterial blight and halo blight while the variety Mexican 142 was considered as a susceptible variety. Higher disease epidemic was recorded in 2012 cropping season than in 2013 cropping season. This was because of higher relative humidity and relatively lower maximum temperature [Figure 1] were recorded in August and September in 2012 cropping season, which could have created an environment.

The applied management practices had lowered final disease severity (21.9-35.9%) and AUDPC values by 3.3-46.8% compared to the values for sole planting on both varieties of common bean in both cropping seasons. The variation of final disease 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. Row intercropping whether applied single in combination significantly reduced the final disease severity by 19.4-43.8% compared to sole planted plots in both seasons. Similarly, Fininsa (2003) reported reduction of common bacterial blight severity 17-40% in bean-maize intercropping than sole cropping. Ihejirika., *et al*. (2010) also observed a 24% and 36% reduction in early leaf spot of groundnut with maize and melon intercrops, respectively, 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.

Microclimate change, such as reduction in temperature and wind velocity, may disfavor the pathogen and cause reduction in disease. The microclimate 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 Matusso., *et al.* (2014) who reported the principal reasons for intercropping are soil conservation and improvement of soil fertility, diseases control and balanced nutrition.

Compost application reduced the final common bacterial blight disease severity by 4.0-13.5% when applied singly and reduced disease severity by 19.4-43.8% when integrated with row intercropping in both cropping seasons. The result of this experiment is in agreement with the findings of Vallad., *et al.* (2003) and Abbasi., *et al*. (2002) who reported similar results on foliar plant diseases. Vallad., *et al.* (2003) found that compost showed 34-65% disease symptom reduction in bacterial speck *Pseudomonas syringae* pv. *tomato* of Arabidopsis thaliana compared with non-amended soil. Similarly, Abbasi., *et al.* (2002) found that application of compost reduced bacterial spot incidence by 28-33% on tomato fruit compared with non-amended soil. Hassan., *et al.* (2013) reported that compost application resulted in the highest reduction (44.4%) in anthracnose of chili over the control. Hassan., *et al*. (2013) also reported that disease management with compost has been attributed to successful competition for nutrients, antibiotic production by beneficial microorganisms and activation of disease-resistant genes in common beans. This result is in agreement with the findings of Barker and Bryson (2006) who reported that using compost could supply plant nutrients and 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 (Barker and Bryson, 2006).

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 Gofta in both seasons.

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. Some experimental studies have shown that the rates of disease increase were considerably influenced by the number of initial inoculum (Jeger., *et al*. 2004). In an experiment with southern blight of carrot, the rate of disease severity generally increased as the number of initial foci increased (Smith., *et al*. 1988).

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 eastern 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 eastern Ethiopia and in areas with similar agro-ecological conditions.

Conclusion and Recommendation

Application of cultural management practices in field experiments enhanced common bean productivity, and reduced common bean anthracnose severity and AUDPC values compared to singly applied management practices and sole planting in common beans across seasons. In addition, row intercropping + compost application, showed promising results in maintaining soil temperature and moisture. Thus, it could be concluded that farmers in eastern Ethiopia should design a strategy to promote common bean production through the application of row intercropping + compost application to improve the physico-chemical properties of soil and sustain enhanced production and productivity of common bean. It is 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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References

1. Abbasi PA., *et al.* “Effect of compost amendments on disease severity and yield of tomato in conventional and organic production systems”. *Plant Disease* 86.2 (2002): 156-161.
2. Aydinalp C and Cresser MS. “The effects of global climate change on agriculture”. *American-Eurasian Journal of Agriculture and Environmental Sciences* 3.5 (2008): 672-676.
3. Barker AV and Bryson GM. “Comparisons of composts with low or high nutrient status for growth of plants in containers”. *Soil Science and Plant Analysis* 37.9 (2006): 1303-1319.

4. Buruchara R., *et al.* "Bean disease and pest identification and management, pp.1-67. In: the handbooks for small-scale seed producers. International Centre for Tropical Agriculture (CIAT). Kampala, Uganda. CIAT (Centro Internacional De Agricultura Tropical). 1987. Standard System for the Evaluation of Bean Germplasm. CIAT, Cali, Colombia.54p.
5. Doll JE and Baranski M. "Climate Change and Agriculture. Fact Sheet Series E3149 on Field Crop Agriculture and Climate change". *Michigan State University, East Lancing, USA* (2011):
6. Mohammed Amin and Fufa Melkamu. "Management of Ascochyta Blight (Ascochyta rabiei) in Chickpea Using a New Fungicide". *Research in Plant Sciences* 2.1 (2014): 27-32.
7. Ensminger AH., *et al.* "Food and Nutrition Encyclopedia. 2nd Eds. CRC Press, Florida". (1994):
8. Fininsa C and Yuen J. "Association of bean rust and common bacterial blight epidemics with cropping systems in Hararghe highlands, eastern Ethiopia". *International Journal of Pest Management* 47.3 (2001): 211-219.
9. Fininsa C and Tefera T. "Inoculum sources of bean anthracnose and their effect on bean epidemics and yield". *Tropical Science* 42.1 (2002): 30-34.
10. Fininsa C. "Relationship between common bacterial blight severity and bean yield loss in pure stand and bean-maize intercropping systems". *International Journal of Pest Management* 49.3 (2003): 177-185.
11. Fininsa C and Tefera T. "Multiple disease resistance in common bean genotypes and their agronomic performance in eastern Ethiopia". *International Journal of Pest Management* 52.4 (2006): 291-296.
12. Gomez KA and Gomez AA. "Statistical Procedures for Agricultural Research. 2nd Edition". John Wiley and Sons, Inc, New York, USA (1984): 680.
13. Hassan MR., *et al.* "Comparative efficacy of compost, compost tea, poultry litter and bavistin in controlling diseases of chili". *Progress in Agriculture* 24.2 (2013): 39-44.
14. Hailu N., *et al.* "Effect of Climate Change Resilience Strategies on Common Bacterial Blight of Common Bean (*Phaseolus vulgaris* L.) in Semi-arid Agro-ecology of Eastern Ethiopia". *African Journal of Agricultural research* 10.15 (2015): 1852-1862.
15. Ihejirika GO., *et al*. "Evaluation of some fungal diseases and yield of groundnut in groundnut-based cropping systems". *Archives of Phytopathology and Plant Protection* 43.11 (2010): 1044-1049.
16. Jeger MJ., *et al*. "The effects of spatial distributions of mycoparasites on biocontrol efficacy: a modelling approach". *Biocontrol Science and Technology* 14.1 (2004): 359-373.
17. Katungi E., *et al*. "Base Line Research Report on Common Bean in Eastern and Southern Africa: a situation and outlook analysis of targeting breeding and delivery efforts to improve the livelihoods of the poor in drought prone areas". *ICRISAT, Kampala, Uganda* (2009): 126.
18. Khalequzzaman KM. "Management of Anthracnose of Hyacinth Bean for Safe Fresh Food Production". *Asian Journal of Applied Science and Engineering* 4.2 (2015): 102-109.
19. Kumar A., *et al.* "Resistance to Colletotrichum lindemuthianum in kidney bean accessions of diverse origin in Himachal Pradesh". *Indian Phytopathology* 50.1 (1997): 59-64.
20. Kumar A., *et al.* "Epidemiology of bean anthracnose under sub-humid mid hills zone of Himachal Pradesh". *Indian Phytopathology* 52.4 (1999): 393-397.
21. Lemessa F., *et al*. "Association between angular leaf spot [(Phaeoisariopsis griseola (Sacco) Ferraris] and common bean (*Phaseolus vulgaris* L.) yield loss at Jimma, Southwestern Ethiopia". *Plant Pathology Journal* 10.2 (2011): 57-65.
22. Luske B. "Reduced greenhouse gas emissions due to compost production and compost use in Egypt comparing two scenarios. Louis Bolk Institute, Amestardem, Netherlands". (2010): 30.
23. Madden LV. "Botanical epidemiology: some key advances and its continuing role in disease management". *European Journal of Plant pathology* 115.1 (2006): 3-23.
24. Martin-cabrejas MA., *et al.* "Changes in physico chemical properties of dry beans (*Phaseolus vulgaris* L.) during long-term storage". *Journal of agricultural and food chemistry* 45.8 (1997): 3223-3227.

25. Matusso JMM., *et al*. "Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa". *Research Journal of Agriculture and Environmental Management* 3.3 (2014): 162-174.
26. Mohammed A. "An Overview of Distribution, Biology and the Management of Common Bean Anthracnose". *Journal of Plant Pathology & Microbiology* 4 (2013): 193.
27. Mohammed A., *et al.* "Evaluation of various fungicides and soil solarization practices for the management of common bean anthracnose (*Colletotrichum lindemuthianum*) and seed yield and loss in Hararghe Highlands of Ethiopia". *Journal of Plant breeding and Crop Science* 6.1 (2014): 1-10.
28. Pastor-Corrales M.A and Tu JC. "Bean production problems in the tropics. 2nd ed". (1989): 77-104.
29. Pathania A., *et al*. "Evaluation of resistance sources and inheritance of resistance in kidney bean to Indian virulences of *Colletotrichum lindemuthianum*". *Euphytica* 149.2 (2006): 97-103.
30. SAS (Statistical Analysis System). 2003. SAS/STAT Guide for Personal Computers, Version 9.2 edition. SAS Institute Inc., Cary, NC.
31. Sharma PN., *et al.* "Yield loss assessment in common bean due to anthracnose (*Colletotrichum lindemuthianum*) under sub temperate conditions of North-Western Himalayas". *Indian Phytopathology* 61.3 (2008): 323-330.
32. Smith VL., *et al*. "Effects of host density and number of disease foci on epidemics of southern blight of processing carrot". *Phytopathology* 78.1 (1988): 595-600.
33. Stutz J., *et al.* "Compost in landscaping applications Tellus Institute, Boston, USA". (2003): 16.
34. Sullivan P. "Soil System Guide on Sustainable Management of Soilborne Plant Diseases with Compost and Organic Amendments. Appropriate Technology Transfer for Rural Areas (ATTRA), California, USA". (2004): 16.
35. Tanam T., *et al.* "Agronomic performance and productivity of common bean (*Phaseolus vulgaris* L.) Varieties in double intercropping with maize *(Zea mays* L.) in eastern Ethiopia". *Asian Journal of Plant Sciences* 6.1 (2007): 749-756.
36. Toulmin C. "In: Prospering Despite Climate Change: New Directions for Smallholder Agriculture". Paper presented at the International Fund for Agricultural Development (IFAD) Conference (2011): 1-25
37. Vallad GE., *et al.* "Plant foliar disease suppression mediated by composted forms of paper mill residuals exhibits molecular features of induced resistance". *Physiological and Molecular Plant Pathology* 63.1 (2003): 65-77.
38. Vander Plank JL. "Plant Diseases; epidemics and control. Academic press, London, UK. 206pp".
39. Yesuf M and Sangcho S. "Seed Transmission and Epidemics of Colletotrichum lindemuthianum in the Major Common Bean Growing Areas of Ethiopia". *Kasetsart Journal of Natural Science* 39 (2005): 34-45.