

Seed Transmission and Epidemics of *Colletotrichum lindemuthianum* in the Major Common Bean Growing Areas of Ethiopia

Mohammed Yesuf¹ and Somsiri Sangchote²

ABSTRACT

The seed-borne nature, mechanism of transmission and disease development of *Colletotrichum lindemuthianum* in the field was studied in three major common bean growing areas including Arssinegelle, Ambo and Bako in Ethiopia. The relationship between level of seed infection by *Colletotrichum lindemuthianum*, and its transmission to the seedlings in the field and greenhouse was studied. Multiple regression analysis showed positive and linear relationship with high coefficient of determination ($R^2=0.98, 0.91, 0.86$) between seed infection and early seedling infection at Bako, Ambo and Arssinegelle respectively. During germination of the infected seeds, the pathogen was transferred from seed coat, by colonizing the cotyledons, radicle and plumule of the emerging seeds. Pre- and post-emergence seedling mortalities were very common both in the field and greenhouse. Sporulation of *C. lindemuthianum* from acervuli was observed on the cotyledons of un-germinated seed. Moreover, sporulation of *C. lindemuthianum* on the growing seedling was common at Bako and Ambo where there was frequent rainfall during the crop season. Anthracnose inoculum in the field transferred to the young pods, consequently enabled the pathogen to grow through the entire pod surface, showing sunken anthracnose lesions, and infected the seed coats of the newly formed seed. Seedling infection and disease epidemic in the field varied between different bean growing locations. Seed infection by *C. lindemuthianum* played the major role as the main source of primary inoculum of bean anthracnose and further disease epidemic in the field.

Key words: anthracnose, *Colletotrichum lindemuthianum*, seedborne, epidemics, common bean

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a very important source of protein and natural fiber in eastern, central and southern Africa and tropical America (Pachico, 1993). In sub-Saharan Africa and Latin America, where 70% of world beans are produced, diseases are considered as the major threat to common bean production. The area under common bean production in Ethiopia is estimated

about 200,000 hectare annually (CSA, 2000). Bean anthracnose caused by *C. lindemuthianum* (Sacc. & Magnus) Scribner is one of the most widespread and economically important diseases, mainly in the tropical and sub-tropical bean growing regions of the world including Ethiopia (Tu 1983, Habtu *et al.*, 1996). Yield losses due to bean anthracnose can reach 90-100% when susceptible genotypes are grown in conditions favorable for the pathogen during the growing season (Pastor-Corrales and

¹ Melkassa Agricultural Research Center P. O. Box 436, Nazareth, Ethiopia.

² Department of Plant Pathology, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.

Tu, 1989). The average yield loss incurred due to bean anthracnose in Ethiopia is estimated about 63% (Tesfaye, 1997). Bean anthracnose is known to be widely distributed wherever common beans are grown throughout the world (Sicard *et al.* 1997; Balardin *et al.*, 1997; Bigirimana *et al.*, 2000). The pathogen can over-season infect plant residues but diseased seeds are the main source of primary infection in the field (Tu, 1983; Pastor-Corrales and Tu, 1989; Tu, 1992a). Contamination of seed dressing equipment used during the cleaning of infected bean seeds is postulated as the way by which the delta race of *C. lindemuthianum* was transferred to commercial *Phaseolus* bean seed samples, the possible sources of the anthracnose epidemic in Canada in 1976 (Tu, 1992b). The most important strategy for effective control of bean anthracnose is to clearly understand its seed-borne nature, and produce disease free seeds with strict seed certification programs. According to Tu (1983), *C. lindemuthianum* can survive for five years in infected dry seeds or pods stored at 4 °C. However, alternating dry-wet conditions heavily affected *C. lindemuthianum* longevity (Siddiqui *et al.*, 1983, Dillard and Cobb, 1993). Considering the seed transmitted nature of *C. lindemuthianum*, detailed knowledge on its seed-borne nature, i.e. infection sites in the seed and transmission mechanisms are prerequisite for effective and sustainable management of anthracnose disease of common beans. Agarwal and Sinclair (1997) noted that the location of *C. lindemuthianum* on cowpea seed was on the seed coat and embryo. No detailed investigation was made on seed infection site of this pathogen on common bean seed. Tu (1983) established a positive and linear relationship between seed infection severity and percent seedling infection in his greenhouse study. However, it was not yet investigated the role and relationship between seed infection, transmission and disease epidemics under field condition. Therefore, this experiment was conducted to study

the infection sites of anthracnose inoculum in the seed, mechanism of transmission to the seedlings, relationship between level of seed infection and disease development in the field and further colonization of the pathogen to subsequent generation of seeds under natural epiphytotic condition in the major common bean growing areas of Ethiopia.

MATERIALS AND METHODS

Location of seedborne infection

Seeds of two commercial common bean variety (Mexican 142 and Awash-1) susceptible to bean anthracnose were collected during the 2002 and 2003 crop seasons. All samples were stored at +5 °C before testing in the laboratory. Based on the severity of seed infection, seeds were categorized into four groups: A) seeds with brown spot, B) seeds with brown streak but no acervuli, C) seeds with brown lesions with few acervuli, D) seeds with sunken lesions with numerous acervuli.

One hundred seeds from each category were tested by the component plating technique as described by Maden *et al.* (1975). The sampled seeds were surface sterilized for 5 minutes using freshly prepared 1% sodium hypochlorite solution (NaOCl) and washed with sterile water. Seed samples were separately soaked in sterile water for 24 hours at room temperature (20-23 °C), and again washed using distilled or sterile water.

Each seed was dissected aseptically into different seed components (seed coat, cotyledon and embryo axis). Each component was plated separately on 4 layers of moistened blotter paper in 9-cm diameter glass petri-dishes. The dishes were incubated at 24 ± 1 °C under 12 hour alternating cycles of near ultraviolet (NUV) light and darkness. All the components were examined on the 7th day after incubation under stereomicroscope, and compound microscope was also used for further confirmation of the pathogen.

Transmission of *C. lindemuthianum* from seeds to the seedlings in the field

Common bean seeds of two commercial varieties (Mexican 142 and Awash 1) were multiplied during the off season/dry season under irrigation in bean anthracnose free areas to obtain anthracnose free seeds. Seeds of the same variety were also planted in a hot spot area for bean anthracnose. Severely infected common bean pods of the same variety were selected and seeds with typical anthracnose sunken lesions of equal size were collected to check the presence of the pathogen. The disease-free seeds were also examined to confirm that they were free from anthracnose infection.

Infected and disease-free seeds were mixed to obtain a proportion of different infection levels of infected seed sample at 0, 5, 10, 15, and 20 percents. The five seed infection levels were re-tested using ISTA rules (1993) and confirmed for their seed-borne infection prior to sowing. The field experiments were conducted at three different locations (Ambo 37 96⁰ E, 8 64⁰ N; Bako 37 23⁰ E, 9 11⁰ N and Arssinegelle 38 79⁰ E, 7 41⁰ N) in the experimental fields of the Ethiopian Agricultural Research Organization during the 2003 crop season. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in factorial arrangement containing two factors, i.e. two commercial white seeded common bean varieties and five seed infection levels. Each plot was 9.6 m² (4 meter × 2.4 meter), and contained a total of 6 rows. Spacing between each plot was 2 meter and between blocks 2.5 meter. The experimental fields were isolated by 40 meters from other common bean fields to avoid the splash of *C. lindemuthianum* conidia from other sources. All the experimental fields had not been planted by common beans for the last two consecutive years from the execution of this experiment. All data were collected from the middle 4 rows. The experiment was started in June, the beginning of normal main crop season. Seeds

were sown by hand in 10 cm spacing between plants and 40 cm between rows. Two rows of tall wheat variety were planted between each plot and block. Moreover, three rows of dense noug (*Guizotia abyssinica* L.) plant were also planted in the surrounding of the experimental field as a natural barrier.

The total number of emerged and infected seedling was counted 10 days after planting. Seedlings with typical anthracnose lesions on the cotyledon were labelled and collected from each plot for laboratory examination. Each of the cotyledonary leaf was examined under stereomicroscope. Seedlings with characteristic anthracnose lesion and sporulation were considered as infected samples, whereas, seedlings with lesion but no sporulation were surface-rinsed with tap water and then, disinfected using 1% sodium hypochlorite for 1 minute followed by washing with sterile distilled water. The leaves were then incubated in petri dishes for 6-7 days on moist 4 layers of blotter paper. The plates were examined under microscope. Transmission efficiency (TE) of *C. lindemuthianum* was calculated using the formula developed by Carmona *et al.* (1999).

$$TE = \frac{C}{S} \times 100$$

Where, C is percentage of infected seedlings, while S is the percentage of seed infection. Infected seedlings were counted starting from full germination till pre-flowering stage. Disease severity in the field was assessed in terms of percent plant/foliage damage starting from early vegetative stage to full pod filling stage (Pastor-Corrales and Schoonhoven (1987). The Area Under the Disease Progress Curve (AUDPC) was calculated according to Shaner and Finney (1977) at different growth stages of the crop in all locations. Weather variables like rainfall, rainy days and temperature were also recorded for the whole crop season.

Transmission of *C. lindemuthianum* from seeds to the seedlings in the greenhouse

In order to establish the relationship between level of seed infection and seed transmission under controlled condition, proportions of infected and healthy seed were prepared as it was done in the field experiment. Two hundred seeds of each infection level were sown in 3 replications using 10-cm diameter pots. The pots were filled with an autoclaved soil mixture consisting of sand, peat, and sandy loam with a ratio of 2:1:1, respectively. After emergence, the seedlings were misted with water and covered using polyethylene bags. Symptom development was recorded 10 days after planting. This experiment was repeated two times in the greenhouse and laboratory growth chamber. The seedlings were examined by following the same procedure described on the field transmission study.

Statistical analysis

All data were analysed by analysis of variance (ANOVA) procedure. Mean separation tests were performed using Student's Newman Keuls test (SNK) using SAS version 6.12, SAS Institute Inc. Statistical graphics and regression lines were plotted using Sigma Plot 2000 Science,

version 6.0.

RESULTS AND DISCUSSION

Location of seed-borne infection

Component plating revealed that the infection of *C. lindemuthianum* in the seeds of common bean was mainly located internally in the seed coat and rarely in the cotyledon and embryo axis. The infection of *C. lindemuthianum* in common bean seed components, the seed coat, cotyledon and embryo axis were 74.4, 21.3 and 4.3%, respectively (Table 1). Embryo infection was recovered only from seed samples collected from Bako and Ambo where early and very severe field infection of anthracnose was observed. Embryo infection was always associated with seed coat infection. This indicated that infection of common bean seeds by *C. lindemuthianum* was through the seed coat by direct penetration but not systemically through the funiculus. Neergaard (1977) also noted that *C. lindemuthianum* of beans was a pathogen with embryo infection that might lead to non-systemic seed transmission and the pathogen could be carried as hyphae in the embryo and seed coat.

Table 1 Sites of infection of *C. lindemuthianum* in different components of infected common bean seed with different infection severities using the standard blotter method, after incubating at 25°C for 7 days.

Seed infection category ¹⁾	Sites of seed infection (%)			
	Seed coat	Cotyledon	Embryo axis	Total
A	3.6 d ²⁾	1.8 dc	0 c	5.4
B	6.4 c	2.6 c	0 c	9.0
C	16.0 b	5.3 b	1.5 b	22.8
D	48.4 a	11.6 a	2.8 a	62.8
Total	74.4	21.3	4.3	100

¹⁾ Seed infection category: A = seeds with brown spot, B = seeds with brown lesion but no acervuli, C = seeds with brown lesions with few acervuli, D = seeds with sunken lesions and numerous acervuli.

²⁾ Means followed by different letters in each column were significantly different using Student's Newman Keuls test ($P < 0.05$).

Transmission of *C. lindemuthianum* from seeds to seedlings in the field

This study showed that the primary inoculum source of *C. lindemuthianum* of common beans was the infected seeds. Typical bean anthracnose symptoms on the cotyledon and first true leaves were becoming visible within a few days after emergence thereby indicating an important role of seedborne infection as primary source of inoculum. Pre- and post-emergence mortalities of seed and seedling were also commonly observed due to severe seed infection by *C. lindemuthianum*. After few days of emergence, the typical anthracnose lesions became visible on the cotyledonary and first true leaves. Plots planted with anthracnose free seeds did not show any anthracnose symptom at the early seedling stage. However, anthracnose symptoms became visible on these plots at the latter stage of crop development after third trifoliate leaf opened and the buds on the lower nodes produced branches. This indicated *C. lindemuthianum* conidia might splash from initially infected seedlings to the neighbouring plants by wind or rain splashes.

Transmission of *C. lindemuthianum* from infected seeds of two common bean varieties to the subsequent seedlings was measured using regression analysis for all locations, and found positive and highly significant ($R^2 = 0.98, 0.91$ and 0.86 at Bako, Ambo and Arssinegelle, $P < 0.01$ respectively (Figure 1. A, B, and C). Seed infection by *C. lindemuthianum* showed a negative effect on seed germination and vigour of common beans. At all locations, plots planted with disease free seeds gave high seed germination percentage (Table 2). Environmental conditions such as high rainfall, humidity and number of rainy days (Figure 2) favored the establishment and increased severity of the disease in the field. Some of the young seedlings with anthracnose symptom on the cotyledon died after reaching three leaf stages. Planting of 20% infected seeds gave different transmission efficiency of *C. lindemuthianum*, 82%

at Bako followed by 60.5% at Ambo and 28% at Arssinegelle. Seedling infection also varied at different bean growing areas of the experimental location. High seedling infection and consequently severe pod infection was recorded from Bako followed by Ambo and Arssinegelle (Table 3). The first two locations were characterized with high and frequent rainfall during the main crop season.

During this study, sporulation of *C. lindemuthianum* was clearly observed on the ungerminated seeds by colonizing the cotyledon with several sporulations on its surface, young leaves, and growing seedlings both in the field and greenhouse. No root infection by *C. lindemuthianum* was observed both in the field and green house. This might be due to the epigeal type of germination of the common bean seedling. Unlike other bean crops such as pea and faba bean, the cotyledon of common bean grew upwards and brought an infected seed component above the soil level. This type of growth favored pathogens to attack above ground plant parts (Maude, 1996). Recurrence of anthracnose in the field was mainly through reintroduction of diseased seeds and prevalence of high and frequent rainfall during the growth of the bean crop (Kumar *et al.*, 1999). Epidemics of bean anthracnose initiating from introduced primary inoculum provided by infected seeds largely depend on the subsequent rain pattern (Araya Fernandez *et al.*, 1987). *C. lindemuthianum* free bean seeds planted in the field previously infected by bean anthracnose do not show any anthracnose symptom (Anon, 1993, unpublished), due to easily degradation of the inoculum present in the soil. Tu (1983) also established alternate dry and wet cycles during the off-season to show the adverse affect on survival of the pathogen on diseased debris in soil. He also found common beans planted in the fields with heavily infected crop from the previous years failed to develop anthracnose disease. Dillard and Cobb (1993) reported that anthracnose inoculum could survive

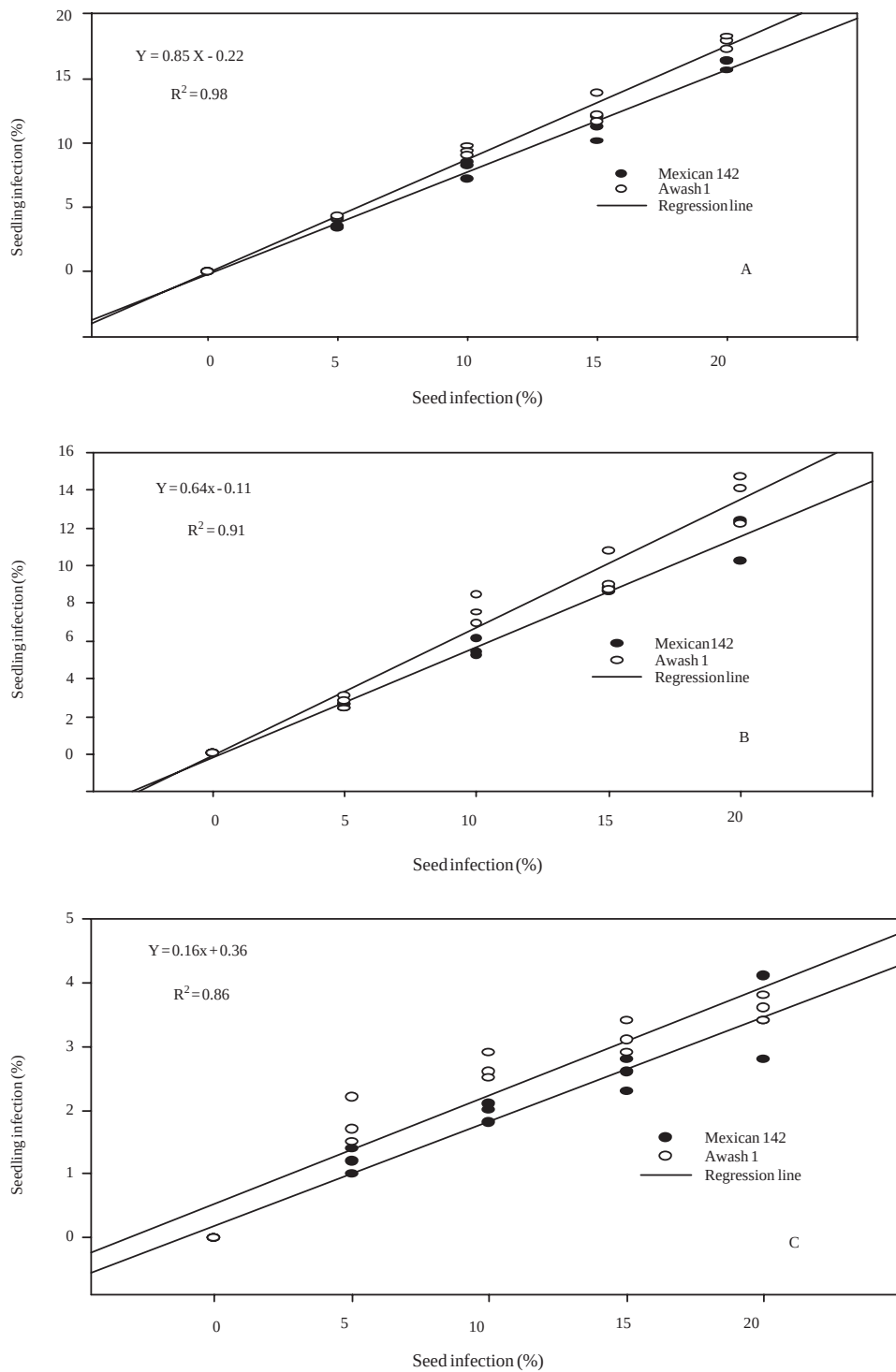


Figure 1 Effects of different level of seed infection by *C. lindemuthianum* on seedling infection 10 days after planting in the field at different locations (A-Bako, B-Ambo, C- Arssinegelle).

at different depths of soil for about 4 months during winter. Nichol森 and Moraes (1980) demonstrated that removal of the mucilaginous matrix of conidia by water before storage could significantly reduce the conidial viability of *C. graminicola* in a storage period as short as 24 hr.

The Area under the Disease Progress Curve

(AUDPC) at different growth stages of the plant was much higher at Bako followed by Ambo and Arssinegelle (Table 5). Severity of bean anthracnose in the field coincided with heavy and frequent rainfall with moderate temperature regimes ($20\pm2\text{ }^{\circ}\text{C}$) was in confirmation with the findings of Chambers’ (1969) and Tu (1981). Tu

Table 2 Effects of different level of *C. lindemuthianum* infected seed on the germination (%) of two common bean varieties (Mexican-142 and Awash-1) 10 days after planting at three locations (Bako, Ambo and Arssinegelle).

Seed infection (%)	Seed germination (%)					
	Bako		Ambo		Arssinegelle	
	Mex-142	Awash-1	Mex-142	Awash-1	Mex-142	Awash-1
0	93.1 a ^{1/}	93.6 a	94.1 a	93.8 a	95.1 a	94.3 a
5	90.6 b	90.3 b	92.7 a	92.1 ba	93.8 a	93.5 a
10	88.0 c	85.1 c	90.3 b	90.4 cb	91.3 b	90.5 b
15	86.1 dc	85.1 c	89.6 b	89.3 c	89.6 b	90.0 b
20	84.3 d	84.5 c	86.3 c	85.3 d	89.4 b	89.8 b

^{1/} Means followed by different letters in each column were significantly different using Student’s Newman Keuls test ($P < 0.05$).

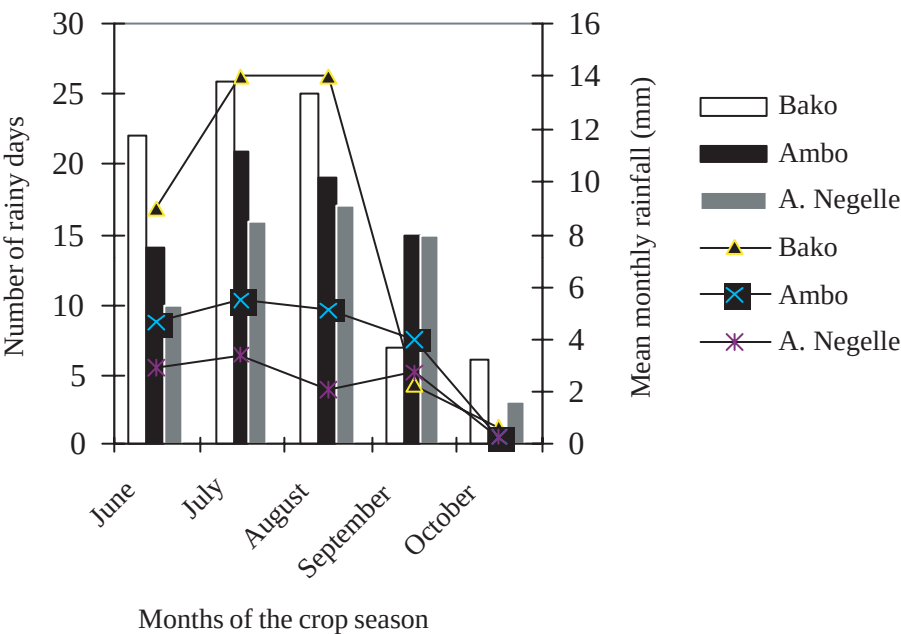


Figure 2 Numbers of rainy day (bars) and mean monthly rainfall (lines) at different common bean growing locations during the 2003 crop season.

(1983) also demonstrated that severity levels of seed infection by *C. lindemuthianum* were positively correlated with seedling infection. Higher plot yield was obtained from Arssinegelle and Ambo, while plot yield at Bako was lower by almost three folds as compared to other locations (Table 4). Laboratory seed analysis after harvest was also revealed that high percentage of seed infection was recorded from Bako and Ambo. The lower seed infection was obtained from Arssinegelle (Table 6).

Field transmission and disease development

study showed that seed infection of common beans by *C. lindemuthianum* played major role for the initiation of primary inoculum and cause epidemics of bean anthracnose in the field. Special attention should also be paid to the weather variables especially during the latter crop developmental stages. If the pod filling stage of beans coincides with frequent rainfall and moderate temperature in areas like Bako and Ambo, the risk of severe pod and seed infection must be anticipated.

Transmission of *C. lindemuthianum* from seeds

Table 3 Effects of different level of *C. lindemuthianum* infected seed on pod infection (%) during physiological maturities of two common bean variety (Mexican-142 and Awash-1) grown at three different locations (Bako, Ambo and Arssinegelle) during 2003 crop season.

Seed infection (%)	Pod infection (%)					
	Bako		Ambo		Arssinegelle	
	Mex-142	Awash-1	Mex-142	Awash-1	Mex-142	Awash-1
0	74.3 c ^{1/}	76.0 c	19.6 e	23.7 d	4.0 d	6.2 c
5	78.5 c	81.1 c	27.7 d	31.1 c	6.2 cd	8.0 cb
10	81.9 bc	82.4 bc	35.4 c	39.1 b	7.4 cb	9.2 cb
15	88.0 ba	88.3 ba	42.8 b	42.5 b	9.3 ba	11.4 ab
20	91.1 a	90.9 a	51.5 a	53.5 a	10.8 a	14.9 a

^{1/} Means followed by different letters in each column are significantly different using Student's Newman Keuls test ($P < 0.05$).

Table 4 Effect of different levels of *C. lindemuthianum* seed infection on seed yields of two common bean varieties (Mexican-142 and Awash-1) grown at three different locations (Bako, Ambo and Arssinegelle) during 2003 crop season.

Seed infection (%)	Seed yield (grams/plot)					
	Bako		Ambo		Arssinegelle	
	Mex-142	Awash-1	Mex-142	Awash-1	Mex-142	Awash-1
0	534.8 a ^{1/}	421.9 a	1500.7 a	1572.5 a	1527.6 a	1616.2 a
5	515.9 ba	417.3 a	1383.5 b	1319.3 b	1470.8 b	1576.2 b
10	497.8 ba	408.9 a	1299.4 c	1268.1 cb	1462.0 b	1568.8cb
15	482.4 b	390.0 ba	1137.8 d	1200.4 c	1456.0 cb	1565.6cb
20	474.8 b	371.7 b	1058.7 e	1032.1 d	1444.1 c	1560.3 c

^{1/} Means followed by different letters in each column were significantly different using Student's Newman Keuls test ($P < 0.05$).

Table 5 Area Under the Disease Progress Curve (AUDPC) at different growth stages (vegetative stage and full pod filling stage) of two common bean variety with different seed infection levels grown at three different locations during the 2003 crop season.

Locations	Seed infection (%)	Area Under the Disease Progress Curve (AUDPC)			
		Vegetative stage		Pod filling stage	
		(June - July)		(August - September)	
		Mex. 142	Awash-1	Mex. 142	Awash 1
Bako	0	105 e ^{1/}	160 e	435 e	508 e
	5	332 d	388 d	719 d	801 d
	10	522 c	578 c	1333 c	1436 c
	15	648 b	708 b	1583 b	1676 b
	20	853 a	923 a	1998 a	2092 a
Ambo	0	73 e	88 e	332 e	413 e
	5	227 d	243 d	523 d	627 d
	10	463 c	493 c	1102 c	1218 c
	15	558 b	565 b	1218 b	1298 b
	20	707 a	715 a	1650 a	1650 a
Arssinegelle	0	30 e	45 d	128 d	143 e
	5	60 d	87 c	191 c	217 d
	10	97 c	133 b	238 c	278 c
	15	137 b	157 b	312 b	338 b
	20	188 a	205 a	445 a	433 a

^{1/} Means followed by different letters in each column are significantly different using Student's Newman Keuls test ($P < 0.01$).

Table 6 Effects of different level of seed infection by *C. lindemuthianum* on different varieties grown at various locations on seed infection of the subsequent generations during the 2003 crop season.

Seed infection (%)	Seed infection after harvest (%)					
	Bako		Ambo		Arssingelle	
	Mex-142	Awash-1	Mex-142	Awash-1	Mex-142	Awash-1
0	12.9 d ^{1/}	14.5 e	4.0 d	7.5 d	0.94 d	1.3 c
5	15.1 c	16.5 c	6.8 c	9.4 c	1.5 cd	1.8 c
10	15.9 c	18.2 c	11.1 b	15.3 b	2.1 cb	2.7 b
15	17.9 b	21.2 b	11.4 b	15.4 b	2.9 ab	3.6 a
20	21.3 a	24.6 a	14.0 a	17.6 a	3.3 a	4.3 a

^{1/} Means followed by different letters in each column are significantly different using Student Newman Keuls test ($P < 0.001$)

to seedlings in the greenhouse

The field transmission study was repeated in the greenhouse to investigate the relationship of seed infection and seedling infection under controlled condition. Greenhouse transmission study of *C. lindemuthianum* of common beans showed a positive and significant relationship between seed infection and seedling infection. All the seed infection levels showed highly significant differences ($P < 0.01$) of seedling infection. Pre- and post-emergence seedling mortalities were recorded and further isolation of ungerminated seeds and young seedlings with symptoms yielded sporulation of *C. lindemuthianum* together with acervuli. Unlike the field experiment, pots planted with healthy common bean seeds did not show any anthracnose symptom on the bean seedlings in the greenhouse. This observation suggested that seed infection was the main source of primary infection of *C. lindemuthianum*. Tu (1983) reported recurrence of anthracnose in growers' fields introduced mainly from anthracnose infected seeds and survival of the fungus on debris that remained dry. He also stressed alternate dry and wet conditions heavily affecting the survival of the pathogen on debris in the soil.

CONCLUSION

The primary inoculum source of bean anthracnose in the field was mainly through infected seed materials. Further disease development in the field and subsequent pod and seed infection was highly favored by high and frequent rainfall with moderate temperature during the crop season. Since there is no any government or private institution dealing with the production of disease free seeds, the majority of common bean growers in Ethiopia are using their own seeds saved from their harvest and unaware of seed-borne infection. Bean anthracnose, which is the major production threat of *Phaseolus* beans in the country, is almost entirely seed-borne/seed transmitted pathogen.

Therefore, production of disease free seeds in semi-arid areas, where conditions are not favourable for bean anthracnose infection could play vital role as a component of integrated management of common bean anthracnose.

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