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Association Between Angular Leaf Spot (*Phaeoisariopsis griseola* (Sacc.) Ferraris) and Common Bean (*Phaseolus vulgaris* L.) Yield Loss at Jimma, Southwestern Ethiopia

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Abstract: Common bean (*Phaseolus vulgaris*) production in the tropics is usually limited by damage due to Angular Leaf Spot (ALS) caused by *Phaeoisariopsis grisola*. Field experiments were conducted in 2005, 2006 and 2007 at Jimma, Ethiopia, to determine the amount of yield loss due to ALS and to investigate the relationship between ALS and bean yield. Different levels of disease severity were created on two common bean varieties (GLPX-92 and ICA15541) using natural epidemics by spraying the fungicide benomyl at 7-14- 21 and 28-day intervals and by seed dressing. Generally, all fungicide sprays significantly reduced ALS severity and increased yield and seed weight but seed dressing did not affect significantly. The relative yield and seed weight losses to ALS ranged from 2 to 47 and 15 to 33%, respectively. Single-point regression models predicted that for each per cent increase in ALS severity, there was a seed yield loss of 18 to 124.5 kg ha^{-1} in GLPX and 12.9 to 103.9 kg ha^{-1} for ICA15541 and 100-seed weight loss per sample of 100 seeds of 10 to 13 g for GLPX-92 and 13 to 22 mg for ICA15541. The study suggests that fungicide sprays affect ALS epidemics and influence the amount of loss in yield attributable to ALS permitting the crop to reach physiological maturity without being under severe infection. Thus fungicide sprays can be used as a means to reduce ALS severity and increase common bean yield.

Key words: Disease severity, fungicide, grain yield, seed weight, single point model

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important crop in the daily diet of more than 300 million of the world's people (Hadi *et al*., 2006). Nutritionists characterize the common bean as a nearly perfect food because of its high protein content and generous amount of fiber, complex carbohydrates and other dietary necessities (Anonymous, 2001; Akond *et al*., 2011).

Common bean is grown as both food and cash crop in monoculture and various cropping systems in East Africa (Wortmann and Allen, 1994). In 2004 summer cropping season, the crop was grown on 245,597 hectares and about 211,347 Mg (8.6 Mg ha^{-1}) was produced in Ethiopia (CSA, 2005). It forms an essential part of the daily diet of most Ethiopians (Simane *et al*., 1998) and generates significant foreign earnings.

Despite its high economic importance, the average bean yield obtained by farmers in Ethiopia under low input conditions is very low ranging from 775 to 925 kg ha^{-1} (CACC, 2001). Bean production is constrained by several biotic and abiotic factors; most important ones include diseases, insect pests, low soil fertility and periodic water stress in the lowlands (Mwaniki, 2002; Mwang`ombe *et al*., 2007). Bean angular leaf spot caused by *Phaeoisariopsis griseola* (Sacc.) Ferraris, bean rust caused by *Uromyces appendiculatus* (Pers. Pers) Unger, common bacterial blight caused by *Xanthomonas campestris* pv. *phaseoloi* (Erw. Smith), Dowson and anthracnose caused by *Colletotrichum lidemuthianum* (Sacc. and Magn.) Briosi and Cav., are the major diseases of common bean in tropical regions including Ethiopia (Habtu *et al*., 1996; Fininsa and Tefera, 2002; Fininsa and Yuen, 2002; Lemessa and Tesfaye, 2005). These diseases are widely distributed in Africa and are a menace to boost common bean production (Habtu *et al*., 1996; Fininsa and Yuen, 2001; Fininsa, 2003). Of these major diseases, Angular Leaf Spot (ALS) is the most important constraint to bean production in Africa (Pastor-Corrales *et al*., 1998) with an annual loss estimated at 374, 800 Mg (Wortmann *et al*., 1998). ALS is of

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particular importance in southwestern Ethiopia where the disease is severe and widely occurs with abundant inoculum throughout the cropping season (Lemessa and Tesfaye, 2005).

ALS causes lesions on leaves, pods, branches and petioles that result in severe pre-mature defoliation. It is particularly destructive in warm, humid areas with abundant inoculum from infected plant debris, volunteer plants, off-season crops and contaminated seed (Stenglein *et al*., 2003; Mwang`ombe *et al*., 2007). In the absence of adequate control, it is one of the chief agronomic constraints of bean in Africa (Pastor-Corrales *et al*., 1998). It also causes a yield loss of 70% in Brazil (De Jesus Junior *et al*., 2001). In Ethiopia, yield loss due to bean ALS has not been quantified and the relationship between ALS and yield loss is not determined. However, optimal combinations of sustainable controls cannot be determined without knowledge of the severity of the disease and empirical yield loss estimates (Madden and Nutter, 1995). Loss estimates provide information for disease forecasting and for making management decisions (Campbell and Madden, 1990). Therefore, this study was conducted with the objectives of (1) quantifying the amount of yield loss due to ALS and (2) assessing the relationship between ALS and yield loss of common bean.

MATERIALS AND METHODS

Experimental site: The ALS and bean yield loss relationship was studied in the 2005, 2006 and 2007 cropping seasons in Ethiopia. The study was conducted at the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) experimental station, southwestern Ethiopia. The experimental site is located at 7°, 33' N and 36°, 57' E at an elevation of 1722 m above sea level and is characterized by warm and humid weather conditions that is conducive for the epidemic development of bean ALS.

Treatments, experimental design and management: For the experiments, two common cultivars currently under production and differing in their resistance level to ALS obtained from the Ethiopian Institute of Agricultural Research were used. The cultivars were GLPX-92 and ICA 15541 which are moderately susceptible and resistant to angular leaf spot, respectively and are resistant to other bean diseases known to occur in the study area. Based on CIAT's classification, the growth habit of both cultivars is bushy and determinate type.

Different severity levels of ALS were created by spraying the systemic fungicide benomyl 50WP at a rate of 0.5g L and intervals of 7, 14, 21 and 28 days. Furthermore, seed was dressed by benomyl at a rate of 0.5 g per 100 g of seed as another treatment. Unsprayed plots were left as a control to allow maximum ALS development on each variety. Fungicide spray for the 7 day spray interval was started at the time of appearance of disease symptom. For the spray intervals 14, 21 and 28 days, fungicide spray started two, three and four weeks after disease appearance, respectively and seed dressing was made on the day of planting the seed.

The experiment was laid down with randomized complete block design in factorial arrangements and with four replications. Nine rowed plots of 3.2×3.6 m and 0.1 m intra row and 0.4 m inter row spacing were used. Each plot was 0.8 m apart and bordered on each side by two rows of wheat (*Triticum* spp.) to reduce inter-plot interference such as fungicide drift. As the study area, southwestern Ethiopia is a hot spot for the disease (Lemessa and Tesfaye, 2005). ALS was allowed to develop naturally on each cultivar without any artificial inoculation. Plots were sown manually in rows and weeds were removed manually three times a year.

Disease assessment: ALS disease severity was assessed at flowering, pod formation, grain filling and physiological maturity stages using the standard scales of 1-9 scale (Van Schoonhoven and Pastor-Corrales, 1987), where 1 = no visible symptom and 9 = disease covering more than 25% of the foliar tissue. Twelve randomly selected and tagged plants in the middle five rows (excluding two border rows on each side) were used for the angular leaf spot assessment. The severity grades were converted into percentage severity index (PSI) for analysis using:

$$PSI = \frac{S_{nr}}{N_{pr} \times M_{sc}} \times 100$$

where, S_{nr} is the sum of numerical ratings, N_{pr} is the number of plants rated and M_{sc} is the maximum score on the scale. Means of the severity from each plot were used in data analyses.

Yield assessment: Data for yield was recorded for each plot from the harvest in the middle five rows excluding two border rows on both sides to minimize border effects. Bean seed yield at 10% seed moisture content and 100-seed weight were recorded. Relative percent bean yield loss (L) from each plot was calculated as:

$$L(\%) = \frac{(Y_{bt} - Y_{lt})}{Y_{bt}} \times 100$$

where, Y_{bt} is the yield of base treatment (spray at 7-day intervals) and Y_{lt} is the yield of lower treatments (sprays at 14, 21 and 28-day intervals, seed dress and unsprayed control). The relative 100-seed weight losses were similarly calculated.

Statistical analysis: Mean ALS disease and yield data from each cultivar and spray treatment were examined and used for data analysis. Data of ALS disease severity at different bean growth stages, grain yield and 100-seed weight were subjected to analysis of variance using SAS version 8 (SAS Institute, 1999) by the PROC GLM procedure to determine treatment effects. Whenever significant interactions were observed between factors, the level of one factor was compared at each level of the other factor. Comparison of means was using Fisher's Least Significance Difference (LSD) test. Correlation (r) analysis was carried out using the PROC CORR procedure of SAS to determine the relationship between ALS disease severity at different growth stages and grain yield and seed weight. Furthermore, regression analysis was performed using the PROC REG procedure in SAS. For each year and variety, a linear regression model to predict yield loss was fitted as a function of severity at different growth stages. The significance of the model, the intercept (b_0) and the regression coefficient (b_1) were tested using the F-statistic. Coefficient of determination (R^2) estimated the proportion of the variation explained.

RESULTS

ALS disease severity: Bean ALS appeared during all the experimental seasons and on both bean cultivars during the study period. At flowering ($p<0.0001$), pod formation ($p = 0.05$) and pod filling ($p = 0.03$) stages of the crop, the three way interactions between year, variety and fungicide were significant. This indicates that the effect of fungicide on ALS severity depends on season and the type of variety used. As a result, the effect of fungicide on ALS severity was presented for each year and variety. However, at physiological maturity stage, there was significant interaction between year and fungicide ($p<0.0001$) whereas no interaction effect between year and variety. This indicates that the effect of fungicide on ALS severity at physiological maturity depended on the season but not on variety.

At flowering stage of the crop, ALS severity was significantly reduced by all fungicide treatments including the seed dressing in both varieties in 2005 cropping season (Table 1). The severity of ALS was reduced by 35 to 42% in GLPX and by 18 to 66% in ICA15541. In 2006, fungicide spray reduced ALS disease severity significantly by all sprays on GLPX while there was no significant difference between fungicide application and control on ICA15541. The fungicide application reduced

Table 1: The effect of year×variety×fungicide application on common bean angular leaf spot severity at flowering stage at Jimma, southwestern Ethiopia

		Severity (%)		
Variety	Spray interval	2005	2006	2007
GLPX	7	12.22ef*	11.11f	13.05def
	14	12.77def	11.39f	11.66ef
	21	11.94ef	11.39f	13.06def
	28	11.39f	11.66ef	12.50def
	Seed dressing	12.78def	11.11f	11.11f
	No spray	19.72c	16.67cd	14.72def
ICA 15541	7	15.83cde	11.94ef	11.94ef
	14	11.94ef	11.11f	11.39f
	21	11.11f	11.11f	11.11f
	28	11.39f	11.11f	11.11f
	Seed dressing	27.22b	12.02ef	11.39f
	No spray	33.06a	15.28def	15.83cde

*Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

Table 2: The effect of year×variety×fungicide application on common bean angular leaf spot severity at pod formation stage at Jimma, southwestern Ethiopia

		Severity (%)		
Variety	Spray interval	2005	2006	2007
GLPX	7	12.22f*	16.39ef	11.11f
	14	11.11f	11.39f	11.11f
	21	11.11f	11.11f	12.78f
	28	11.11f	11.11f	11.11f
	Seed dressing	24.18de	34.44cd	16.39ef
	No spray	47.78ab	44.17b	31.11cd
ICA 15541	7	16.39ef	12.22f	11.94f
	14	11.67f	11.39f	11.39f
	21	11.67 f	11.11f	11.39f
	28	11.11f	11.11f	11.11f
	Seed dressing	46.67ab	38.33bc	21.39ef
	No spray	57.22a	47.78ab	33.33cd

*Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

ALS disease on GLPX by 30 to 33%. In 2007 cropping season, there was no significant difference between fungicide treatments and the control for GLPX while all the fungicide applications have significantly reduced ALS severity in ICA15541, the reduction being ranging from 25 to 30%. When the effect of each fungicide concentration is compared across seasons, consistently, there was no significant difference between the seasons for spray intervals 7 to 28-days on both varieties, whereas that of seed dressing was inconsistent.

In 2005 cropping season, all fungicide treatments significantly reduced ALS severity in both cultivars. However, in 2006 and 2007, the reaction of the fungicides in reducing ALS disease severity was inconsistent. On the other hand, in all the seasons and cultivars, there was no significant difference between the different concentrations of the fungicide across the years.

At pod formation (Table 2) and grain filling (Table 3) stages of the crop, the effect of fungicides treatment on ALS severity showed similar trend across the seasons but not across the varieties. In GLPX all fungicide treatments significantly reduced ALS severity, while in ICA15541 all the fungicide sprays (7 to 28-days) significantly reduced ALS disease severity but there was no significant difference between the seed dressing and the control. The exception being severity at pod formation for the season 2007 where there was significant difference between the control and seed dressing. At pod formation, ALS severity was reduced by 49 to 77, 22 to 75 and 47 to 64% for 2005, 2006 and 2007 cropping seasons, respectively on GLPX and by 18 to 81, 20 to 77 and 36 to 67% for 2005, 2006 and 2007 cropping seasons, respectively on ICA15541 (Table 2). Furthermore, at grain filling stage reduction of disease severity due to fungicide applications were by 27 to 79, 22 to 84 and 46 to 80% for 2005, 2006 and 2007 cropping seasons, respectively for GLPX and by 2 to 84, -9 to 81 and 5 to 75% for 2005, 2006 and 2007 cropping seasons, respectively for ICA15541 (Table 3).

At physiological maturity stage, only two-way interactions between season and fungicide spray interval, were significant ($p<0.0001$) indicating that the effect of fungicide is season dependent (Table 4). However, there was no interaction between fungicide effect and variety in affecting disease severity which is an indication that fungicide affects ALS disease severity irrespective of a variety used. At physiological maturity stage, all the spray treatments (7 to 28-days) significantly ($p<0.0001$) reduced ALS disease severity, whereas there was no significant difference between seed dressing and the control on severity of ALS. When each spray interval was compared across the cropping season, there was no significant difference between the years for spray intervals 7 to 28 and the seed dressing in 98% of the incidents. The study indicated that all fungicide sprays significantly reduced ALS severity, however, seed dressing has no effect.

Table 3: The effect of year×variety×fungicide spray interval interaction on common bean angular leaf spot severity at grain filling stage at Jimma, southwestern Ethiopia

		Severity (%)		
Variety	Spray interval	2005	2006	2007
GLPX	7	11.50m*	26.67fghij	27.22fghi
	14	11.39m	23.06ghijkl	25.27ghijk
	21	11.11m	13.33lm	11.66m
	28	11.11m	11.11m	11.66m
	Seed dressing	38.89e	55.00cd	32.22efg
	No spray	53.61d	70.28a	59.44bcd
ICA 15541	7	16.67klm	33.33ef	31.66efgh
	14	19.17ijklm	27.22fghi	28.33fghi
	21	17.22jklm	15.28lm	22.22hijkl
	28	11.11m	11.11m	17.22jklm
	Seed dressing	69.44a	63.33abcd	64.16abc
	No spray	70.83a	58.33bcd	67.77ab

*Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

Table 4: The effect of year×fungicide interaction on common bean angular leaf spot severity at physiological maturity stage at Jimma, southwestern Ethiopia

	Severity (%)		
Fungicide spray intervals	2005	2006	2007
7 days	23.89cd*	23.33cd	40.41c
14 days	27.36cd	17.64d	41.39c
21 days	25.83cd	14.44d	25.45cd
28 days	11.80d	11.11d	15.00d
Seed dress	81.38ab	82.50ab	84.63ab
No spray	72.35b	96.53a	89.30ab

*Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

Grain yield: Actual bean seed yield (kg ha^{-1}) harvested varied between years ($p<0.0001$) and fungicide applications ($p<0.0001$) but there was no significant difference between the varieties used. The interaction between year and variety was significant ($p = 0.0015$) indicating that the yield of varieties varied depending on season (Table 5). Furthermore, there was two way interaction between year and fungicide ($p<0.0001$; Table 6). This indicated that the effect of fungicide spray on yield is dependent on year. As a result, the effect of fungicide spray on yield was presented for every year separately. Generally significantly higher yield was obtained in 2005 for both varieties. However, there was no significant yield difference between the varieties during 2006 and 2007 cropping seasons and between the seasons for each variety (Table 5).

The interaction between cropping season and spray interval is shown in Table 6. During the three cropping seasons the different spray intervals gave significantly higher yield than the check. However, there was no significant yield difference between the seed dressed plots and the check. When the cropping seasons were compared for each spray intervals, significantly higher yield was found in 2005 cropping season than the 2006 and 2007 cropping seasons and there was no significant difference between 2006 and 2007 (Table 6). Relative yield loss in the control when compared with the best sprayed plots (7-days interval) was higher in 2005 (47%) compared with 2006 (+3.3%) and 2007 (+3%). Similarly, when the yield loss in the check was compared with the best disease controlled plot which is 28-d interval in this

Table 5: The effect of year×variety on common bean yield at Jimma, southwestern Ethiopia

	Yield (kg ha^{-1})		
Variety	2005	2006	2007
GLPX-92	8939b*	5190c	4905c
ICA15541	10020a	4824c	4821c

*Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

Table 6: The effect of year×fungicide application on common bean yield at Jimma, southwestern Ethiopia

	2005		2006		2007	
Spray interval	Yield (kg ha^{-1})	Change in yield (%)	Yield (kg ha^{-1})	Change in yield (%)	Yield (kg ha^{-1})	Change in yield (%)
7	11150ab*	0.0	4707fgh	0.0	4285gh	0.0
14	10650b	-4.5	4727efgh	+0.4	5020cdefgh	+17.2
21	10930ab	-2.0	5508cdefg	+17.0	5449cdefg	+27.2
28	12100a	+8.5	6055cd	+28.6	5957cde	+39.0
Seed dress	6175c	-44.6	4184h	-11.1	4055h	-5.4
Check	5885cdef	-47.2	4863defgh	3.3	4414gh	+3.0

* Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

Table 7: The effect of year×variety×fungicide spray interval on hundred seed weight (HSW) of common bean at Jimma, southwestern Ethiopia

		Year					
		2005		2006		2007	
Variety	Spray interval	HSW (g)	Change in HSW (%)	HSW (g)	Change in HSW (%)	HSW (g)	Change in HSW (%)
GLPX-92	7	43.2def*	0.0	51.1ab	0.0	49.8ab	0.0
	14	43.1def	-0.2	41.9efg	-18.0	43.5cdef	-12.7
	21	43.9cdef	+1.6	42.6defg	-16.6	43.4def	-12.9
	28	44.4cde	+2.8	41.8efgh	-18.2	42.5defg	-14.7
	Seed dress	34.4k	-20.4	34.3k	-32.9	34.6k	-30.5
	Control	35.3jk	-18.3	37.2hijk	-27.2	37.2ijk	-25.3
ICA15541	7	51.0ab	0.0	46.8bcd	0.0	46.7bcd	0.0
	14	49.2ab	-3.5	52.0a	+11.1	51.6a	+10.5
	21	50.4ab	-1.2	50.1ab	+7.1	48.1abc	+3.0
	28	51.1ab	+0.2	51.5a	+10.0	51.9a	+11.1
	Seed dress	35.7jk	-30.0	41.1efghi	-12.2	41.4efghi	-11.3
	Control	34.1k	-33.1	38.1ghijk	-18.9	39.5fghij	-15.4

*Means followed by different alphabets within the same column and row differ significantly (p<5%) as established by Fisher's LSD-test

experiment, it was higher in 2005 (51%) compared with the 2006 (20%) and 2007 (26%) (Table 6).

Seed weight: There was three way interaction effect between year, variety and fungicide application for 100-seed weight (p = 0.0003). The seed weight for fungicide application within a season varied significantly and in all seasons and varieties, the 100-seed weight from the sprayed plots were consistently heavier than from unsprayed plots and the seed dressed plots. The 100-seed weights for fungicide sprayed were 41.8 to 51.1 and 46.7 to 52.0 g for GLPX-92 and ICA15541, respectively compared with the lighter check and seed dressed plots weights of 34.3 to 37.2 and 34.1 to 41.4 g for GLPX-92 and ICA15541, respectively (Table 7). Relative 100-seed weight losses in control plots were 18 to 27% for GLPX-92 and 15 to 33% for ICA15541.

Relation of seed yield and 100-seed weight to ALS: The correlation coefficient (r) for the relation between seed yield and seed weight and ALS severity showed inverse relationship (Table 8). Bean yield was significantly (p<0.002) inversely correlated to ALS severity except at flowering stage, while seed weight was significantly (p<0.0001) inversely correlated to ALS severity at all growth stages (Table 8). The highest negative correlation between seed yield and ALS severity was observed at grain filling stage (r = -0.45) and between seed weight and ALS severity was at physiological maturity sstage (r = -0.65). In all cases lower correlation between ALS severity and seed weight and seed weight was at flowering stage of the crop with r = -0.05 for seed yield and ALS severity and r = -0.43 for seed weight and ALS severity.

Table 8: Correlation coefficient (r) values between angular leaf spot severity assessed at different growth stages and bean seed yield (t ha^{-1}) and 100-seed weight

Growth stages	Seed yield (t ha^{-1}) correlation coefficient	p-values	100-seed weight correlation coefficient	p-values
Flowering	-0.05	0.5410	-0.43	<0.0001
Pod formation	-0.26	0.0020	-0.64	<0.0001
Grain filling	-0.45	<0.0001	-0.60	<0.0001
Physiological maturity	-0.41	<0.0001	-0.65	<0.0001

Model relating seed yield and 100-seed weight to ALS: Single-Point (SP) model relating seed yield or 100-seed weight to ALS severity was developed by simple linear regression. Data sources were ALS severity at growth stages at which the severity was most highly inversely correlated to seed yield and to 100-seed weight (Table 8).

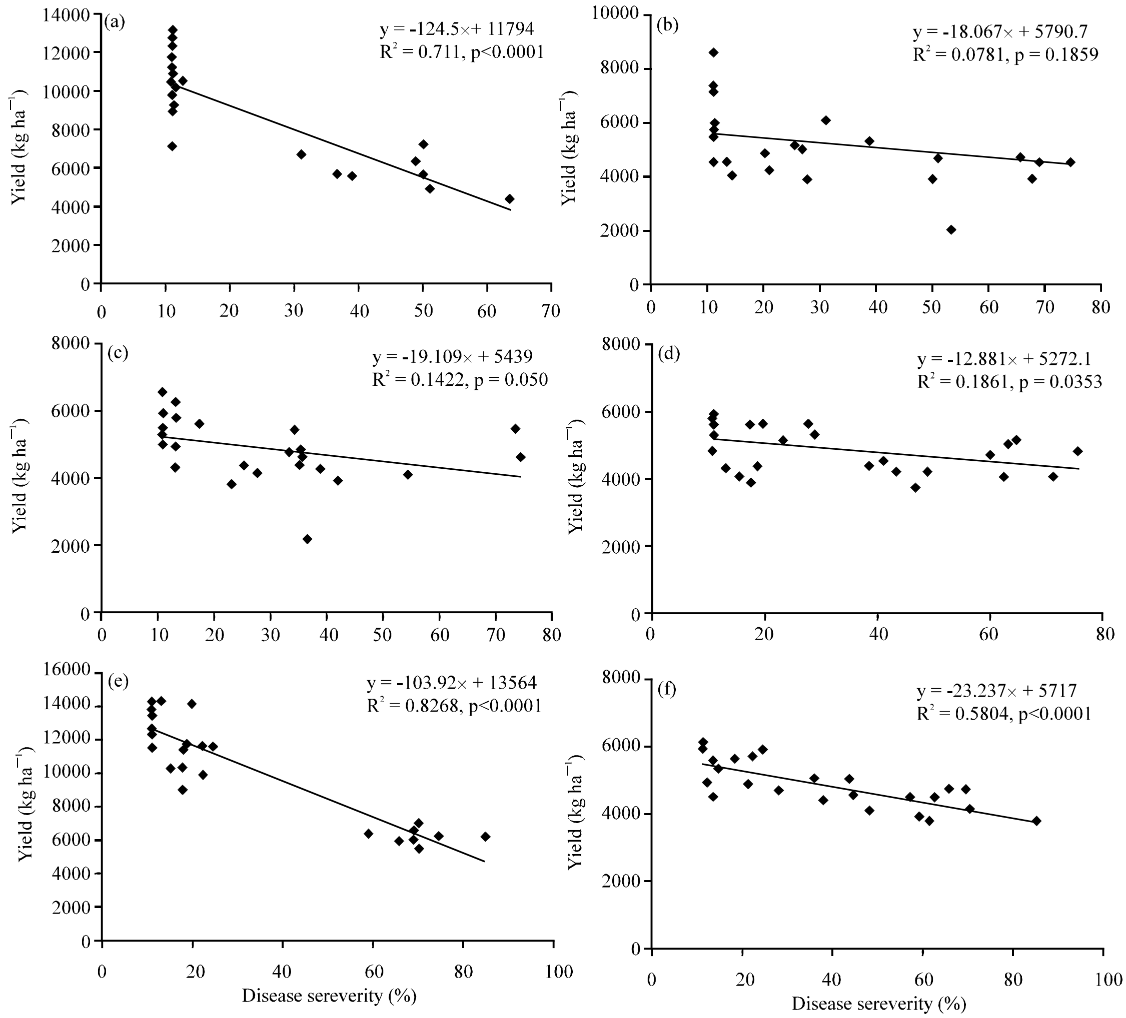

Fig. 1(a-f): Relationship between angular leaf spot severity and grain yield in GLPX (a, b, c) and ICA15541 (d, e, f) in 2005 (a), 2006 (b) and 2007 (c) for GLPX and in 2005 (d), 2006 (e) and 2007 (f) for ICA15541

For this SP model, ALS severity at grain filling stage for seed yield and at physiological maturity stage for 100-seed weight were used in relating to seed yield and 100-seed weight.

The single point model accounted for 7.8 to 71% of variance in GLPX-92 and for 18.6 to 82.7% in ICA15541(Fig. 1). More variability was accounted for in 2005 than 2006 and 2007 seasons for GLPX-92 and in 2006 than 2005 and 2007 for ICA15541 with the estimated regression coefficients (slopes) b_1 = -124.5 in GLPX-92 and b_1 = -103.9 in ICA15541. The estimates predict that for every percentage of ALS severity increase, 18.1 to 124.5 and 12.9 to 103.9 kg ha^{-1} seed yield losses occur in GLPX-92 and ICA15541, respectively at grain filling stage (Fig. 1).

In relating 100-seed weight to ALS severity, data at physiological maturity stage were used for the single point models (Fig. 2). The models accounted for 27.3 to 61.4% and 61.4 to 90.9% 100 seed weight variance in GLPX-92 and ICA15541, respectively. In 100-seed weight single point models, more variability was accounted for in 2005 than 2006 and 2007 seasons for both GLPX-92 and ICA15541. The estimated slopes of the regression lines obtained for 2005 season were greater than the 2006 and 2007 seasons with the estimated regression coefficients for 2005 being b_1 = -0.1312 for GLPX-92 and b_1 = -0.2243. Based on estimates, for every percent increase of ALS severity at physiological maturity stage, the seed weight loss per sample of 100 seeds was 0.1 to 0.13 g in GLPX-92 and 0.13 to 0.22 g in ICA15541.

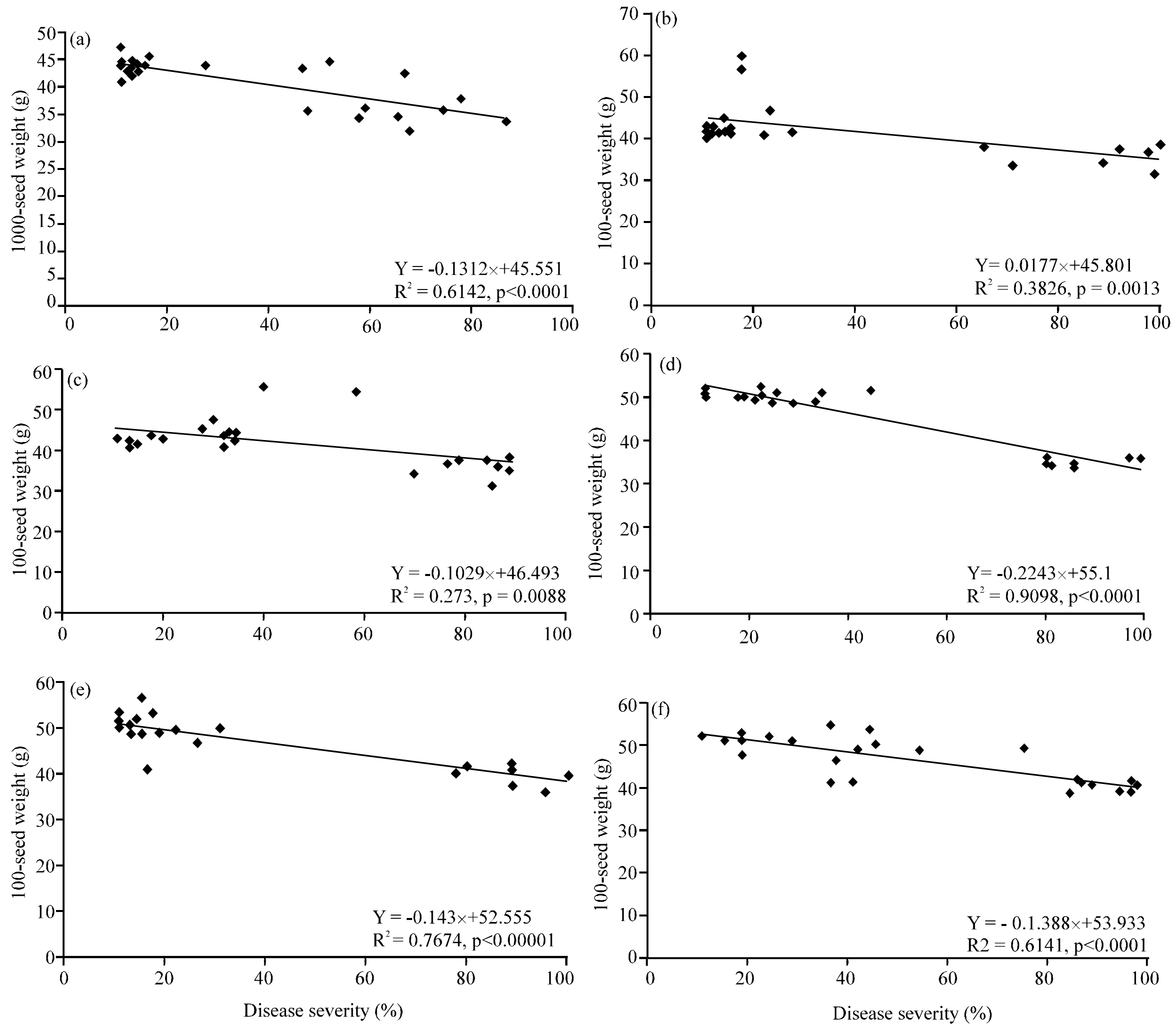

Fig. 2(a-f): Relationship between angular leaf spot severity and 100 seed weight in GLPX (a, b, c) and ICA15541 (d, e, f) in 2005 (a), 2006 (b) and 2007 (c) for GLPX and in 2005 (d), 2006 (e) and 2007 (f) for ICA15541

DISCUSSION

ALS has been reported to be an important common bean disease in Ethiopia particularly, in the southwestern part of the country (Lemessa and Tesfaye, 2005). However, no quantification has been done on the yield loss it causes. Thus this study was conducted to quantify the amounts of yield loss due to the disease and to assess the association between the disease and common bean yield.

ALS severity and bean yield significantly varied between the varieties and among the spray intervals and years. All fungicide sprays reduced ALS severity compared to the unsprayed control plot at all stages except at flowering stage. However, seed dressing tended to reduce ALS severity at early stage but at later growth stages there was no significant difference between seed dressed plots and the unsprayed control plots. This is in contradiction with the result found by Trutmann *et al.* (1992) where bean seed treatment by benomyl reduced the severity of ALS. However, it is in support with a study made on *Fusarium* root rot where fungicide seed treatment did not reduce damage of root rots associated with *Fusarium* root rots (Trutmann *et al*., 1992). This indicated that the effect of benomyl seed dressing on ALS severity is variable depending on growth stage of the crop and cropping season as evidenced in our experiment.

Analyses of ALS seed yield or ALS 100-seed weight regression models revealed some descriptions of relationships. The models demonstrated inverse relationships between ALS severity and both seed yield and 100-seed weight. The regression estimates that for every 1% increase in ALS severity, there was a seed yield loss between 12.9 and 124.5 kg ha^{-1}. Ploper *et al.* (2002) reported average yield loss between 16.8 and 28.1% for a single fungicide applications (35 days after sowing) and 29.0 and 35.7% for double fungicide applications (35 and 50 days after sowing). In our study, the maximum relative yield loss (47%) found was less than the 80% for Colombia 70% for Brazil (De Jesus Junior *et al.*, 2001) and comparable with the 50% for USA (Hagedorn and Wade, 1974). The effect of ALS on yield loss is mainly due to defoliation that leads to a reduction of the total leaf area helpful for photosynthesis (De Jesus Junior *et al.*, 2001).

Present study indicated that, the maximum relative yield loss was obtained in the unsprayed and seed dressing than the fungicide sprays. Of all the 7 to 28 days spray intervals, more percent yield increase was obtained in 21 and 28 days than the sprays every week and fortnightly. Moreover, Celetti and Melzer (2006) recommended two fungicide applications against ALS in Canada. This may be because more frequent fungicide applications can affect the health of the crop through toxicity in addition to affecting the pathogen.

The present field research data obtained provide empirical evidence that fungicide applications and seasonal conditions affect ALS epidemics and influence the amount of loss in yield attributable to ALS. Application of fungicide as spray protected bean from ALS and prevented severe yield loss. However, seed dressing did not help to reduce the severity of ALS and consequently reduction of yield loss. The fungicide spray systems, particularly, permitted the crop to reach physiological maturity without being under severe ALS infection. Because much of the bean yield accumulates during the pod filling growth stage, low levels of ALS in fungicide sprays may have little influence on the rate of either assimilate accumulation or the amount translocated to the seed. In the spray systems there was low ALS severity to have a major influence on yield. Seeds from the fungicide sprays also had heavier weight. However, cost benefit analysis of fungicide use to manage ALS in bean production in southwestern Ethiopia needs to be determined.

The yield loss model predictions developed during this study by relating disease severity at grain filling stage for yield and at physiological maturity stage for 100 seed weight could be used in predicting yield losses from disease surveys and bean production in the Jimma area and areas that have related weather conditions with Jimma area. Furthermore, application of fungicide sprays can be used as a means to reduce ALS severity and increase yield in common bean.

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