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Research Article

Foliar Diseases Status of Common Bean (*Phaseolus vulgaries* L.) in Borana, Southern Ethiopia

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Abstract

The common bean cultivation and usage is most widely practiced in the study areas, where it is mostly used for home consumption. However, its production and productivity is constrained by several factors. Among the factors, foliar diseases are the major biotic factor that affects bean productivity in the region. Hence, to provide a valuable input which contributes in solving this production constraint, the present study was conducted with the objectives of studying the relative importance of major foliar diseases of common bean. The assessment was done in Yabello, Teltelle, and Elwaye districts. Four kebeles were selected per district and the assessment was done at 4-7km intervals. A simple random sampling method was used to collect disease samples which were performed at 5 points in a W-shaped fashion per field with 1m^2 quadrat. The survey result revealed angular leaf spot (ALS), common bacterial blight, anthracnose, common bean mosaic virus, and leaf rust were the major common bean diseases in Borana. Of which ALS was the most distributed disease over the study areas. With, the prevalence of ALS was 96.77%. Of these fields 91.67% had a disease severity index of more than 50%. For such a high intensity and distribution of ALS, weed infestation, low tillage frequency, and crop density were found to be the most associated agronomic factors. Moreover, the present study indicated that there is high potential to combat the disease in the area using resistant varieties and some agronomic measures such as proper weeding, tillage, plant spacing and crop rotations.

Keywords

Angular Leaf Spot, Common Bean, Disease, *Phaeoisariopsis griseola*

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is an important legume crop grown around the world and shares about 85% of world bean production and it feeds more than 300 million people linked to agricultural economy [15]. It is the most widely cultivated legume crop in the world for direct human consumption and a staple food that does not require industrial processing [31]. Among the legume crops cultivated common bean is an essential crop that is consumed directly by human's worldwide [4]. It is consumed as a grain and vegetable, also it can be prepared in different types of recipes such as nifro, sambosa, shiro, and kik. Further, it can be mixed with different cereals or vegetables to prepare soup, and other consumption methods [40].

In Ethiopia common bean cultivation is increasing throughout the year. This may be due to its fast-maturing characteristics that enable households to get cash income and other

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household needs when other crops have not yet matured and it is mostly preferred over the other crops [3]. Common bean is among the major crops grown in southern Ethiopia where the majority of the farmers are Agro-pastoralist and produce the crop mainly for home consumption [12]. It is the most favourable crop and helps to change the livelihood of smallholder farmers [27]. But, the yield of common bean is still below the yielding potential of the crops. Its yielding potential could be ranged from 2.5-3 tonnes per hectare under research, while 1.74 tonnes per hectare under farmers field [9]. Likewise, in the same production year yield obtained from common bean farms around Borana was 1.65 tonnes per hectare [9]. This shows that the productivity of common beans in Borana is very low compared to the national average yield and far from the yield obtained under research conditions with a yield gap of 0.85- 1.35 tonnes per hectare. This yield gap could be due to biotic and/or abiotic factors and these conditions become challenging factors of common bean production in the area. Among the biotic factors, common bean diseases are considered as one of the major production threats.

Diseases in common beans are mostly known to reduce the quality of harvested seed, germination ability, and market value of the seed. In addition, depending on incidence and severity, production system and management practice applied, environmental condition, cultivars used and affected crop stage, average yield loss ranged between 20% and 100% [20]. The most important disease of common beans that causes significant yield losses on common beans includes angular leaf spot, anthracnose, rust, bacterial blight, mosaic, halo blight, and Ascochyta blight [10]. Among these angular leaf spot causes great economic losses to common bean production and it is a difficult disease, yet it grows and produces spores on artificial culture media [28]. It causes a necrotic lesion on the aerial parts of the plant and reduces the productivity and quality of common bean seeds [38].

Moreover, there is scant of information on diseases that have a significant role in the yield reduction of common beans in Borana lowlands. Besides, there is a limited study that has been conducted on testing for epidemics of diseases on common beans and no adequate documentation made in the area. So, a detailed understanding of the type, occurrence, and distribution of major pathogens that cause foliar diseases in common beans are a precondition activity to formulate sustainable disease management practices around the study area. This understanding would also fill knowledge gaps related to effective and durable management of the diseases. Therefore, the study was initiated with the objective of determining the occurrence and importance of major foliar diseases of common bean in Borana zone.

2. Materials and Methods

2.1. Description of the Study Area

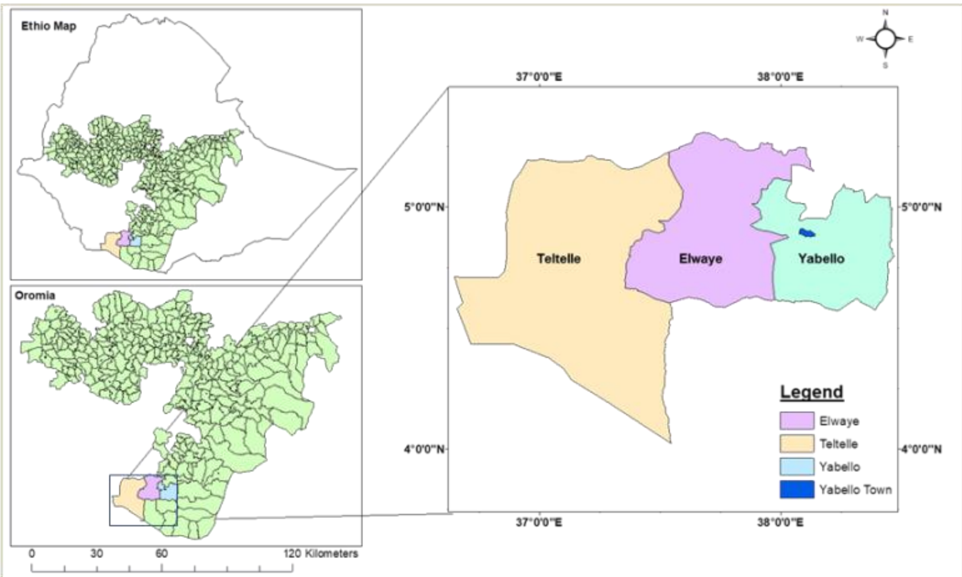

Figure 1. Map of the study area.

The study was carried out during the main cropping season of 2023, (from mid-March to early June) at three districts *viz.* Yabello, Elwaye and Teltelle of the Borana zone. The assessed districts were selected purposively based on common bean production potential. Throughout the assessment of major common bean foliar diseases, seventy-five common bean fields were assessed. The districts are characterized by the following variables; Yabello district is found at 570km from capital city Addis Ababa, to the southern part of the country with an altitude range of 1490-1800masl and 04^{0}51'.1789"N, 038^{0}06'223"E latitude and longitude respectively. Its soil feature is mostly known as sandy and has an annual maximum and minimum temperature of 26.3°C and 14.5°C respectively, with maximum and minimum annual rain fall of 700mm and 400mm. Teltelle district is located 670km from Addis Ababa and it is located at an altitude range of 1356-1560masl, 037^{0}22'528"E, and 05^{0}3'505"N longitude and latitude respectively. Its soil is vertisoil and has an annual maximum and minimum temperature of 28.3°C and 16.7°C respectively. Elwaye district is found at about 606km from Addis Ababa to southern; it is located at an altitude range 1405-1570masl, 037^{0}54'499"E longitude and 04^{0}57'662"N latitude. Its soil is characterized as sandy texture and has an annual average maximum and minimum temperature of 27.33 and 14.63°C.

2.2. Sampling Methods and Sample Size

The fields were assessed within 4-7km distance interval based on the availability of common bean fields within kebele's. From each district four kebeles were purposively selected for the assessment of major foliar diseases of common bean. Based on this, twenty six, twenty two and twenty seven farmers' fields from Yabello, Elwaye and Teltelle districts were assessed respectively. The fields were randomly selected from each kebele's and the variation in the number of fields assessed between each district was because of the presence/absence of common bean fields within a specified distance interval. In each fields, the assessment was made at five points in a 'W' shape fashion by using a 1m^{2} size quadrat, to represent five replications per field. [41] also used 'W' shape assessment fashion to sample the diseased plant parts per field and to evaluate the severity of the diseases and incidences per field.

The quadrat was pointed with the assumption of 10m apart within a field to assess the foliar disease of common bean in each field. To categorize the infected and uninfected plants per field, common bean plants in each quadrat were counted and recorded. Subsequently, the number of healthy and infected leaves of plants within the quadrat was recorded. Then the samples of infected common bean tissues were collected across the study area with simple random sampling methods. During sample collection infected common bean plants were selected, among the plants found in a quadrat and the infected plant parts were cut from the mother plant by scissors. In general, the samples were collected from early infected common bean plant parts packed in paper bags and labeled with codes such as district and kebele name, field, and quadrat number. The collected samples were brought to the Jimma University College of Agriculture and Veterinary Medicine, plant pathology laboratory, and the disease diagnosis under laboratory conditions was done. GPS was used for geographical data such as elevation, latitude and longitude, and distance measurement.

2.3. Measurement of Disease Variables

The fundamental disease measurement variables include disease incidence, severity, percent disease severity index, and disease prevalence over the assessed field. As indicators of incidence, the percentage of infected plants per field or the percentage of diseased leaves per plant can also be calculated. By evaluating the disease condition of plant units in one or more sample units, disease incidence is calculated [23]. Hence, for each disease symptom in the quadrat the disease incidence per farm was determined with the help of the following formula:

$$\text{Disease Incidence (DI)} = \frac{\text{Number of diseased plants in quadrat} \times 100}{\text{Total number of plants in quadrat}}$$

Disease Severity

Disease severity was rated on five randomly selected plants per quadrat in each field using a 1- 9 scoring scale of [7]. [1-Plants with no visible disease symptoms, 3-Plants with 1-15% of the leaf area with lesions, 5-Plants with 16-40% of the leaf area with lesions, 7-Plants with 41-70% of the leaf area with lesions and 9-Lesions of leaves with 71-100%, associated with early loss of the leaves and plant death]. Then, the severity grades obtained were converted into percent severity index (PSI) for analysis based on [43] following formula:

$$\text{Percent Severity Index (\%)} = \frac{\text{Sum of numerical ratings} \times 100}{\text{Number of plants scored x maximum score in the scale}}$$

The disease prevalence (DP) shows how much the disease is spread over the production area. It is used to describe the number of fields with particular disease in the assessed fields and expressed as percentage. Therefore, the prevalence of common bean diseases across the study area was calculated using the formula suggested by [8].

$$\text{Disease Prevalence (DP)} = \frac{\text{Number of Infected Fields} \times 100}{\text{Total Number of Fields Assessed}}$$

2.4. Assessment of Agronomic and Cultural Practices

Agricultural practices are essential strategies that must be applied to agricultural fields/processes to attain better agricultural products. In addition to disease data, crop growth stages, cropping systems, weeding practices/frequency and infestation levels, land preparation frequency, common bean cultivars grown, seed sources, and previous crops grown, practices of using inputs such as fertilizers and pesticides, availability of the crop rotation were observed for each field. Then, for all these variables the farmers were interviewed and the obtained information's were scored. Also, the crop growth stage was recorded as flowering, and pod forming. The study area farmers were operating common bean weeding operations from one hand weeding practice up to three times hand weeding.

Isolation and Identification of the Pathogens

The samples collected from the farmer's field were cultured and isolation of the pathogen was done at Jimma University College of Agriculture and Veterinary Medicine, Plant Pathology Laboratory. To facilitate the sample culturing, collected leaves were cut into small pieces (1cm x 1cm) along the lesion border by sterilized scissors and disinfected with 1% sodium hypochlorite solution and sterilized distilled water (SDW). Subsequently, the disinfected plant tissues were incubated on prepared Potato dextrose agar (PDA) media. The media was boiled and sterilized with pressurized steam heat sterilizer autoclave to sterilize at 121°C temperature. After sterilized, it was poured evenly to the Petri dishes prepared for culturing the samples in the safety cabinet. The disinfected plant tissues were cultured with the help of forceps on poured media and then the petridish were sealed with parafilm tape and labeled with necessary information kept at room temperature.

The identification of the pathogen was done by taking fungal conidia from a matured (aged) colony. From each Petri dish incubated with fungus, the conidia were taken with an inoculation loop and placed on a microscopic slide. Then, it was covered with a cover slide and observed under compound microscope at a 40x magnification point. Then, the conidial morphology such as shape, presence or absence of septation, size, and spore formation was observed. In addition to microscopic characterization the colony growth, elevation and pigmentations were recorded from the cultured isolates.

2.5. Data Collection

Field survey for common bean foliar disease was carried out in the main rainy season of the study area. Common bean foliar diseases prevalence, incidence and severity were scored from the assessed field using quadrats per field and the plants per quadrats were counted and classified in to healthy and infected plants. The cultural and environmental factors that contribute in disease development such as weeding frequency, tillage frequency (as two or three times plough), altitude ranges, crop cultivars, crop rotation with maize, tef, on fallow land and without rotation, crop stages as flowering and pod filling, and seed sources (purchased or saved) were separately recorded from the assessed fields.

2.6. Data Analysis

Descriptive statistics was used to describe the data obtained from survey (distribution and relative importance of foliar diseases common bean severity across the surveyed areas). A summary of the incidence and severity of recorded diseases were presented for each independent variable and variable class. Disease severity was classified into distinct groups of binomial qualitative data as described by [6]. Contingency tables of the disease severity and independent variables were built to represent the bivariate distribution of the fields according to data classifications. Thus, the binary variable classes <50 and ≥50% were set for disease severity. The associations of mean disease severity with cultural practices and environmental factors were analyzed using a logistic regression model [45]. The logistic regression model allows the evaluation of the importance of multiple independent variables that affect the response variable. The significance of each independent variable was tested in two different ways. In the first, the independent variable alone association with disease severity was tested in a single variable model. It consisted of a testing of the deviance reduction attributed to a variable when it first enters into model. In the second, the association of the independent variable with disease severity was evaluated when enter last in to the model with all independent variables. The deviance and likelihood ratio statistics analysis were used to compare the single and multiple variable models. To determine whether the frequency distributions of two variables were independent or associated, Chi-square (X^2) tests were used [26]. All collected data was entered into the computer and managed by using Excel and the collected data was analyzed using SAS software version 9.3.

3. Results and Discussion

3.1. Field Survey Results

All the assessed fields of common bean were cultivated in a sole cropping system and planted in broadcast. The common bean foliar diseases infected 82.67% of the total assessed fields and the maximum overall foliar disease prevalence was scored from the Elwaye (86.36%) district, while the minimum diseases prevalence (77.78%) was scored from the Teltelle district. The differences in disease prevalence among the districts, as well as farmer's fields may be a result of the varied cultural practices applied to the crop farm by the producers. Most farmers of the study area prepare their farms for common bean cultivation through two different cultivation frequencies viz., twice (26.67%) or three (73.33%) times plough. However, in some areas about four times tillage during land preparation before planting practiced and helps to reduces common bean diseases intensity such as angular leaf spot [16]. The other farming practices that affect the disease distribution is crop rotation and in the study area, the common bean is mostly cultivated in rotation with different crops, such as Maize, tef, and on fallow land. However, some farmers cultivate common beans without rotation (repeat the common bean on the same farms). The survey result indicated that most farmers rotate their fields with cereal crops (tef (45.33%) and Maize (12%)) and fallow (37.33%), while few of them do not follow crop rotation practices (5.33%). The overall disease predominance was high in fields with no crop rotation. In most of the assessed fields, the plant densities observed were highly condensed and it was seen as a major factor for foliar disease development and epidemics. The fields with highly dense plants were more infected with foliar diseases than the fields with low plant density. [2] reported that crop density had a strong association with disease incidence and the incidence mean is higher in highly dense common beans than in sparsely populated common beans. A dense population could increase relative humidity and competition for similar resources, which could make host plants weak and susceptible to the pathogen to enhance the development of high disease incidence. A low plant population is supposed to decrease the canopy enclosure and may increase the free circulation of air under the crop canopy.

Among the assessed fields, the maximum numbers of common bean fields were found at flowering (58.67%) and the fields found at the podding crop growth stage were 41.33%. The maximum mean disease incidence and severity were recorded in fields where the common bean was at the podding stage. Nearly all surveyed fields had similar sowing periods and the similarity is due to the nature of the study areas' rainy periods. Moreover, the main cropping season (starting from sowing to harvesting of the crops) in the study area ranges from mid-March to early June [29]. As a result, common bean growers in the study area followed constant sowing from mid-March to the end of March.

The study area farmers practiced different hand-weeding frequencies, and as the scored field survey data indicated about 49.3% of fields were weeded with once-hand weeding, 28% of fields were weeded twice with hand weeding, and 22% of fields were three-hand weeded. The highest weed infestations occurred on the fields with a once hand-weeded field (low weeding frequency) and the low infestation of weeds occurred on three times hand-weeded fields (high weeding frequency). The fields infested with high weeds were highly exposed to disease compared to fields with low weed infestation (Table 1). The mean foliar disease of common bean incidence was higher in highly infested fields with weeds than in weed-free fields of common bean. The result is in parallel with the finding of [2] who reported high weed infestation could reduce crop vigour and promote disease development through competition for available resources that render crops susceptible to both foliar and soil-borne pathogens. Similarly, [41] reported that common bean diseases are associated with weeding levels and the diseases were mostly infecting the fields with weedy (no weeded) than moderate weed levels (once weeded) and light weeds (twice weeded). It is also reported, that weed modifies the microclimate and increases canopy humidity which would assist in epidemic development [17].

The assessed fields were found in a range of 1300masl-1693masl altitudes and grouped into two classes i.e., the fields found at an altitude range of 1501-1693masl and 1300-1500masl. Among the assessed fields about 48% of fields were found under 1300-1500masl, and 52% of the fields were found at an altitude range of 1501-1693masl. The highest 1693masl and lowest 1300masl elevations were found at Yabello and Teltelle districts respectively. The common bean foliar diseases prevalence was high (83.33%) in altitudes ranged 1300-1500masl compared to the 1501-1693masl altitude range (Table 1).

The common bean cultivars used by farmers in the study area were mostly local cultivar (known with the name of *Aca*) (81.33%), while a few farmers used different unknown varieties (18.67%) for their production. The seeds of common beans were obtained from savings (40%) and bought from a local market (60%). Among the common bean cultivars used, fields sown with unknown cultivars were 100% infected and 78% of fields sown with local cultivars were infected by different diseases. In the study area, as the information identified from the interviewed farmers stated, none of the farmers applied any pest management practices to common bean fields to manage the disease and other pests. Also, [2] reported that none of the common bean growers used pesticides to manage the common bean disease, and then more than 40% of growers applied cultural practices such as rouging of diseased plants to management of the disease. Similarly, land tillage frequency influences the prevalence of the disease and it was highly epidemic on fields with less than two tillage/ploughed frequencies (95%) and fewer epidemics on fields ploughed three times (75%).

Table 1. *Assessed independent variables and variable class frequency with overall foliar disease prevalence.*

Variable	Variable class	Assessed fields	Disease prevalence per variable class	Variable	Variable class	Assessed fields	Disease prevalence per variable class
District	Elwaye	22	86.36	Weeding frequency	Low	17	23.53
	Teltelle	27	77.78		Medium	21	100.00
	Yabello	26	84.62		High	37	100.00
Previous crop	Common bean	4	100.00	Altitude category	1501-1693masl	39	82.05
	Fallow	28	75.00		1300-1500masl	36	83.33

Variable	Variable class	Assessed fields	Disease prevalence per variable class	Variable	Variable class	Assessed fields	Disease prevalence per variable class
	Maize	9	88.89	Tillage frequency	Two times	20	95.00
	tef	34	85.29		Three times	55	75
Crop growth stage	Pod forming	31	93.55	Cultivar name	cultivar (Aca)	61	78.69
	Flowering	44	75.00		Unknown	14	100.00
Soil type	Vertisoil	24	87.50	Seed source	Farmer saved	30	90.00
	Sandy	51	80.39				
Plant population	High	55	90.00		Purchased	45	77.78
	Low	20	80.00				

In the study area, several common bean foliar diseases were identified. However, the recorded diseases were concurrent on some fields, i.e., there was a case in which more than one disease type was scored from the same fields as well as the same quadrats during the same cropping season. [25] also, reported that in many common bean production of the world it is very common to see 2-3 diseases on common bean simultaneously. Thus, the identified diseases have different intensities and prevalence from location to location and also among the disease types. The overall foliar disease's prevalence in the districts was, 86.36%, 84.62%, and 77.78% at Elwaye, Yabello, and Teltelle respectively. In the majority of assessed fields, angular leaf spot (ALS) and common bacterial blight (CBB) were the most prevalent diseases of the common bean and they were highly devastated throughout the study areas. Following this, ALS, CBB, and anthracnose were the major foliar diseases of the common bean among the identified diseases from the study area.

Among the infected fields by different diseases (82.67%), ALS was observed on 96.77% of infected fields, CBB was observed on 88.71% of infected fields and anthracnose was on 72.58%, common bean mosaic virus on 24.2% and common bean rust 16.12% fields. The variation might be due to the availability of necessary growth factors for each disease causal agent. Thus, among the major factors, temperatures and humidity conditions of the study area are more favorable for ALS and CBB compared to the other diseases observed. ALS is mostly epidemic in areas with humid and warm, as well as in dry-wet weather conditions [37]. The distribution of ALS in all areas might be due to environmental conditions that favor the development of the disease and due to the presence of diversified causative pathogens across different common bean-growing areas [2].

Moreover, the prevalence of each disease from the total of seventy-five assessed fields were 80%, 73.33%, 60%, 20%, and 13.33%, for ALS, CBB, Anthracnose, common bean mosaic virus, and common bean leaf rust respectively.

Table 2. *Major common bean diseases distribution in Borana zone during 2023 main cropping season.*

Districts	Infected fields by each disease			Disease prevalence of each disease		
	Angular leaf spot	Common bacterial blight	Anthracnose	Angular leaf spot	Common bacterial blight	Anthracnose
Elwaye	19	17	13	86.36	77.27	59.09
Teltelle	19	19	14	70.37	70.37	51.85
Yabello	22	19	18	84.62	73.08	69.23
Total	60	55	45	80	73.33	60

The overall identified foliar diseases mean incidence and severity score from the three assessed districts expresses, that the highest disease intensity was scored from Yabello followed by Elwaye (Figure 2). The highest foliar diseases severity percentage (62.47%) was scored in Yabello, while the lowest disease severity percentage (55.14%) was scored from Elwaye district (Figure 2). Then, it was highly prevalent and severely damaged the crop in Yabello compared to other assessed districts.

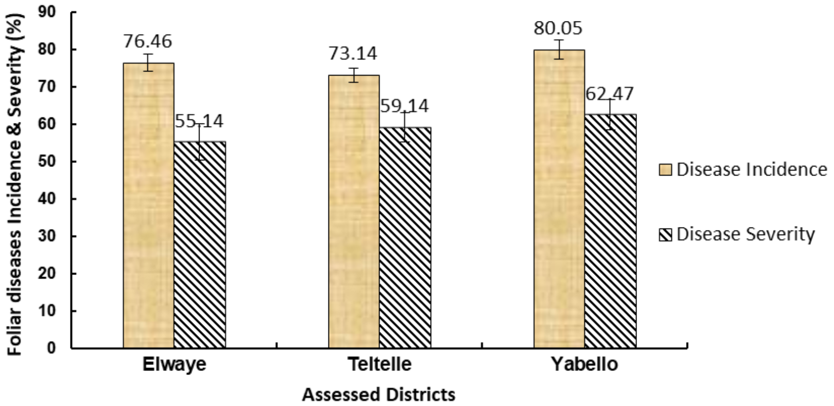

Figure 2. Assessed districts with scored common bean foliar diseases mean incidence and severity percentage.

Among the identified foliar diseases, ALS was the most prevalent, compare to the other identified foliar diseases. Angular leaf spot mean disease incidence and severity score range is presented in Table 3. The CBB prevalence was also high at Elwaye, followed by Yabello and low at Teltelle with 77.27%, 73.08%, and 70.37% respectively. The mean prevalence of the CBB of the common bean in the surveyed area was 73.33%. The CBB means incidence score was in the range of 24.11 to 98.71% in all surveyed areas. Both the minimum and maximum common bacterial blight incidence percentage was recorded in Teltelle. The mean disease severity of CBB at Teltelle ranges from 41.11-98.89%. The maximum and minimum severity was observed in Teltelle (Table 3). Also, [34] reported ALS occurrence on common beans in the range of 26.7 to 90%, CBB occurrence in a range of 48.3 to 86.7% and anthracnose 0 to 15% disease severity index.

Among the major diseases identified CBB was a disease with a wide range of weather conditions that infects the crop and is distributed throughout the field. Its development could be favored by a temperature that is optimum for pathogen development and below the optimum for growth of the host plant [19], and each pathogen has an optimum temperature for growth. Correspondingly, differences between agroecological zones affect infection and the development of disease due to variable environmental factors such as soil types [32]. The soil varies in its structure, moisture content, pH and fertility, while disease heaviness varies due to the suitability of the pathogen to these variations. The resistance levels of the common bean genotypes may be improved when temperatures rise and soil moisture content decreases because of the utilization of resources into the host drought resistance mechanisms such as reduced stomata size [18].

In the study area, common bean anthracnose was the third common bean disease detected, next to angular leaf spot and common bacterial blight in terms of intensity and distribution. Its prevalence was high at Yabello, followed by Elwaye and Teltelle with prevalence percentages of 69.23%, 59.09%, and 51.85% respectively. The overall mean prevalence of common bean anthracnose disease distribution over the surveyed area was 60.05%. The common bean anthracnose's mean disease incidence recorded was in the range of 24.11-98.71% in all surveyed areas. Both the minimum and maximum incidence percentage of anthracnose was recorded in the Teltelle district. Also, the mean anthracnose disease severity ranges from 45.56-98.89% (Table 3).

Table 3. Major common bean diseases incidence, percent severity index mean and its range in Borana during 2023 main cropping season.

Disease	Variables	Elwaye		Yabello		Teltelle	
		Range	Mean	Range	Mean	Range	Mean
Angular leaf spot	Incidence	54.77 - 94.67	79.79	61.33 - 92.29	82.39	61.33 - 99.43	76.25
	Severity Index%	45.56 - 83.33	59.92	43.33 - 98.89	69.82	45.56 - 94.44	70.29
Common bacterial	Incidence	51.46 - 79.67	66.05	40.27 - 84.43	61.36	24.11 - 98.71	65.05

Disease	Variables	Elwaye		Yabello		Teltelle	
		Range	Mean	Range	Mean	Range	Mean
blight	Severity Index%	43.33 - 74.44	56.86	41.11 - 94.67	59.39	41.11 - 98.89	63.19
Anthracnose	Incidence	42.58 - 73.00	59.52	43.0 - 79.6	62.21	24.11 - 98.71	67.82
	Severity Index%	50.00 - 78.89	61.48	45.56 - 94.44	65.75	45.56 - 98.89	64.9

The priority of common bean foliar diseases varies based on the level of their distribution, including disease severity, incidence, and prevalence in specific locations. Consequently, ALS was found to have a wider distribution and higher epidemics, being recorded in all assessed districts and kebeles and having high disease intensity over the other scored diseases. ALS is epidemic and extensively scattered in all common bean growing areas studied regardless of agro ecology, altitude, sowing date, cropping system, growth stage, weed and crop density [2].

3.2. Distribution and Relative Importance of Angular Leaf Spot (ALS)

The incidence and severity of the common bean ALS was very highly significant (P<0.001) among the assessed fields. ALS incidence was varied from 0 to 100% among the assessed fields. The incidence of 100% indicates that the disease infects every plant that exists in the sampled area/quadrat. Correspondingly, [42] reported that the highest common bean ALS incidence score of 96.3% followed by 86.8% happened in Mandura. The scored mean incidence of angular leaf spot in each districts ranged from 54.77%-99.43%. Following this, the maximum mean of angular leaf spot incidence was scored from Teltelle (61.33-99.43%). The result is supported by [1] findings that the mean final ALS incidence ranged from 21.33% to 92.33%. The ALS severity scores per quadrat was ranged from 1 to 9, a severity scale score. The maximum mean disease percent severity index range was recorded from Yabello (43.33-98.89%), followed by Teltelle (45.56-94.44%) areas, while the lowest (45.56-83.33%) range of mean disease severity index was obtained from Elwaye district (Table 5). Also, [1] reported that the mean final ALS severity on a common bean ranged from 15% to 61.7%.

In the study area, as the analyzed data indicated, the overall mean incidence of ALS was 79.48% across the surveyed districts. However, spatial distribution and relative importance of ALS was varied across assessed districts. Among the fields scored with ALS, only ten (16.67%) fields had less than 75% disease incidence and the rest of fifty (83.33%) fields had more than 75% disease incidence. This revealed that the common bean ALS is highly devastated throughout the fields. The result is supported by the findings of [21] that the incidence of ALS varied from 75 to 100% among the sampled fields, with over 98% of the assessed fields having more than 75% ALS incidence. Based on disease severity recorded, only five (8.33) fields had less than 50% severity and the other 55 (91.67%) fields had more than 50% disease severity.

An angular leaf spot (ALS) epidemic was varied between each independent variable and their class categories. The assessed districts were tested as specific independent variables and grouped into three class variables. The highest number of fields infected per district was observed in Yabello and the lowest field infected with ALS was observed in Teltelle district. Among the common bean fields surveyed in three districts, the least mean incidence (76.25%) was recorded in Teltelle district and the highest mean disease incidence (82.39%) was observed in the Yabello district. The least ALS mean disease severity index (59.92%) was recorded in Elwaye district and the highest mean severity index (70.29%) was recorded in Teltelle (Table 4). The findings of the current disease assessment showed that common bean ALS was observed across the three surveyed districts, with varying degrees of incidence and severity. The variations in disease epidemics across the locations are due to ranges of altitude and other associated weather conditions [14].

Table 4. Prevalence, incidence and severity (mean ± SE) of common bean angular leaf spot for different independent variables.

Variable	Variable class	Prevalence%	Incidence (%)	PSI (%)
Districts	Yabello	84.62	82.39±1.44	69.82±4.40
	Elwaye	86.36	79.40±2.78	59.92±3.71
	Teltelle	70.37	76.65±3.38	70.29±3.94

Variable	Variable class	Prevalence%	Incidence (%)	PSI (%)
Previous crop	Common bean	100	75.59±5.61	65.00±6.44
	Fallow	75	80.19±1.93	56.53±1.93
	Maize	88.89	74.62±7.86	56.13±7.00
	tef	79.41	80.91±1.73	51.07±3.35
Crop growth stage	Flowering	75	76.27±1.99	48.24±2.91
	Pod forming	93.55	83.59±2.28	62.75±3.33
Soil type	Vertisoil	79.17	76.35±3.92	54.66±4.13
	Sandy	80.39	80.87±1.37	54.46±2.92
Weeding frequency	Low	100	80.67±2.62	64.2±2.69
	Medium	90.47	79.21±3.29	52.95±3.32
	High	23.53	73.55±2.12	36.95±4.18
Altitude	1300-1500masl	88.89	77.04±2.61	57.91±2.98
	1501-1693masl	71.79	82.18±1.39	50.65±3.74
Tillage frequency	Two times	95.00	81.48±1.69	68.67±3.35
	Three times	74.55	82.30±1.15	66.71±2.13
Cultivar used	Local (Aca)	75.41	81.42±1.15	67.42±1.86
	Unknown	100	84.05±1.85	69.24±4.90
Plant population	High	80.00	82.63±2.623	63.47±2.06
	Low	80.00	81.90±1.00	63.19±4.14
Seed source	Farmer saved	86.67	75.91±3.00	52.99±3.59
	Purchased	75.55	82.14±1.39	55.69±3.19

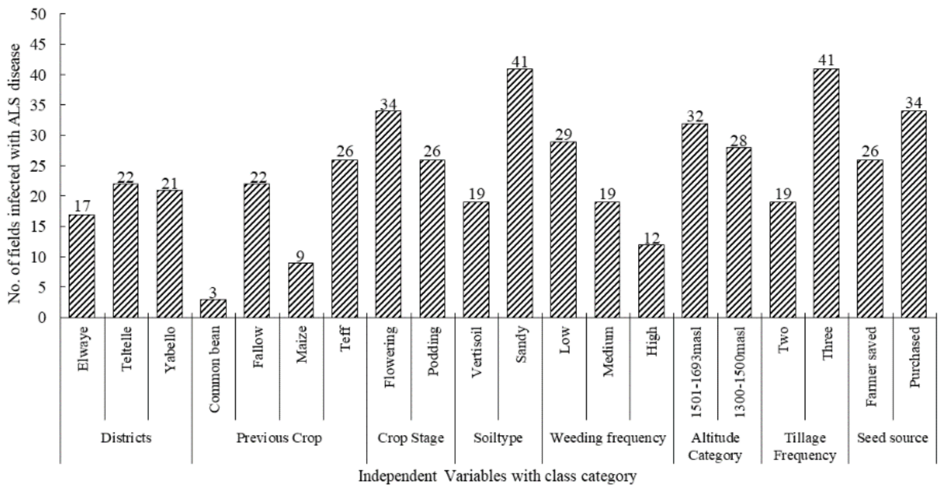

Figure 3. *Number of fields infected with ALS per independent variables with class category.*

Among the fields infected by angular leaf spot (ALS), about 53.33% were found at an altitude of 1501-1693masl, while 46.67% were found under an altitude range of 1300-1500masl. The highest ALS severity mean (57.91%) was scored from an altitude ranging from 1501-1693masl and the mean angular leaf spot disease severity of common bean fields found at an altitude of 1300-1500masl was 50.65%. As the assessed data revealed, the common bean ALS was highly prevalent at an altitude range between 1501 and 1693masl. Among the fields infected with ALS, large numbers of fields were found at an altitude of 1501-1693masl. [32] stated that the common bean ALS is more prevalent in areas with an altitude range of below 1600masl and less prevalent in areas above 2000masl. Moreover, the highest ALS could occur in an altitude range of 1201-1600masl.

3.3. Association of Common Bean Angular Leaf Spot with Cultural Practices

The analysis of common bean ALS associations with different independent variables recorded during disease assessment is presented in Table 5. Thus, the independent variables showed varied association responses to ALS incidence and severity. [46] reported that understanding the association of disease intensity with independent variables such as cropping systems, crop combinations and management practices helps to identify the most important variables and sustainable management options. Among the independent variables observed from the field survey, districts, previous crops, crop growth stages, weeding frequency, land preparation, and crop cultivar were highly significant ($p<0.001$) and associated with angular leaf spot mean severity. However, seed source and altitude category showed a non-significant association with ALS mean percent severity index when entered first into the regression model. When all variables entered last into the regression model, independent variables were very highly ($P<0.001$) significant in association with ALS of common bean mean severity, except seed source, which showed a highly significant association. This finding is also in line with the finding reported by [41] who stated that frequency of weeding is significantly associated with the occurrence of ALS, bean anthracnose, halo blight, floury leaf spot, bean mosaic virus, Cercospora leaf spot, and Ascochyta blight.

Table 5. Logistic Regression Model for bean Angular leaf spot (ALS) severity (%) and Likelihood Ratio Test on independent variables in Borana 2023 main cropping season.

Independent variable	Degree freedom	ALS Severity, Likelihood ratio test			
		Variable first entered in the model		Variable last entered in the model	
		Deviance reduction	$Pr>X^2$	Deviance reduction	$Pr>X^2$
District	2	495.15	<.0001	617.89	<.0001
Previous crop	3	1081.38	<.0001	474.51	<.0001
Crop growth stage	1	263.18	<.0001	161.16	<.0001
Altitude	1	112.02	0.888	252.98	<.0001
Land preparation	1	406.41	<.0001	620.33	<.0001
Seed source	1	86.27	0.6732	9.32	0.2000
Crop cultivar	1	878.50	<.0001	202.19	<.0001
Weed frequency	2	983.04	<.0001	5485.74	<.0001
Soil type	1	604.53	<.0001	162.81	<.0001

Pr=Probability of an X^2 value exceeding the deviance reduction, X^2=Chi-square

Seed source was continued as an insignificant variable in both the first and last entered regression models and altitude was insignificant in first entering. Among the evaluated independent variables previous crop (X^2=1081.38, df=3), nature of the disease occurrence (X^2=1093.1, df=1), weed frequency (X^2=983.04, df=2), soil type (X^2=604.53, df=1) and districts (X^2=495.15, df=2) were the most important variables in association with disease severity, while seed source (X^2=86.27) and altitude (X^2=112.02) associations were slight with disease severity when entered first and last into the model. The logistic regression model used in the analysis of the survey data confirmed that districts, previous crops, altitude ranges, land preparation, bean cultivars, crop growth stages, and weed infestation levels were highly associated with angular leaf spot (Table 5). These variables had significant contributions to the development of epidemics with varying levels alone or in combination.

Crop Growth Stage and Angular Leaf Spot (ALS)

The crop growth stage was observed during the assessment and the maximum number of infected fields with angular leaf spot disease from the flowering stage (Figure 3). The crop growth stage is one of the independent factors that affect the prevalence of ALS on common beans. Among the sixty common bean fields infected with ALS 28% (17 fields) of the fields were at the pod forming stage, while 72% (43 fields) were at the flowering stage. The crop found at pod-forming growth stages was highly significantly ($p<0.001$) associated with ALS severity and incidence in the multiple variable model. The mean severity value of angular leaf spot disease at the flowering and pod-forming stages was 48.25% and 62.75% respectively. The mean incidence value of ALS at the flowering and pod-forming stages was 76.27% and 83.59% respectively. This shows that the common bean ALS severity and incidence were higher when the crop reached pod pod-filling stage than at the flowering stage. [2] also reported that ALS incidence and severity are doubled at pod filling stages compared to the flowering stage. This could imply that at this crop growth stage, the plant is highly exposed (susceptible) to the disease, and when it coincides with favorable weather variables; the disease would be highly devastating. The highest ALS prevalence was recorded in common bean fields found at pod pod-forming stage. The ALS causing pathogen can colonize intercellular spaces of the common bean leaf and other aerial plant parts palisade cells, resulting in angular lesions [30]. Generally, the disease prevalence was high on the fields with the crops at flowering and pod setting stages. This result is supported by findings of [35] the maximum disease development by *Phaeoisariopsis griseola* occurs between flowering and pod setting. In common bean production flowering and pod setting is a period characterized by an increase in the photosynthetic rate. The occurrence of ALS at these stages of plant development reduces the net assimilation rate through a sink effect in which the causal pathogen diverts carbon fluxes from the growing seed for its own growth [13]. As a result, seeds borne by infected plants are few, shrivelled and often discoloured. Since the seed yield of common bean is influenced by the number of pods per plant, number of seeds per pod and average seed weight, reducing any of these yield components will lead to lower yields with an additional negative effect on seed quality [39].

Cropping history and Angular Leaf Spot (ALS)

The cropping history affects the ALS of common bean development and severity. It was highly severing the field with no crop rotation (Table 4). In the fields without crop rotation, the assessed common bean fields were entirely infected by the disease. The result is in line with [24] report that continuous cropping of the same plant without crop rotation can lead to disease persistence in the area. However, among the assessed fields, the land previously covered by tef had a large percentage and the land previously covered by the common bean field is the minimum. The prior cultivated crop tef occupies 43.33%, fallow 36.67%, maize 15%, and common bean 5%. Accordingly, 96% of fields covered by tef in the previous cropping season had a greater than 50% severity index, while only about 4% of tef fields were severed with less than 50%. Similarly, about 92% of prior tef fields had greater than 75% ALS incidence percentage and 8% had less than 75% ALS incidence percentage. Crop management is one of the major factors of disease development on the crop in the field and it includes, cropping system, weeding, application of fertilizers and pesticides, tillage frequency, and system [36].

In addition, in the study area farmers cultivate tef mostly in the short rainy season of the study area (Mid-September to early November), after they harvest common beans in June during the main cropping season. During this cropping season, the farmers plough only once for sowing of tef. This may create a conducive condition for the pathogens that had over-seasoning features and re-emerge from over seasoning in the soil. [41] reported that some previous crop grown affected the probabilities of occurrences of most common bean diseases except common bean angular leaf spot and anthracnose. Mostly previous crop influences the chance of bacterial blight, halo blight, floury leaf spot, web blight, bean mosaic virus, and Cercospora leaf spot occurrence. The second large number of fields from the assessed disease was recorded on fallow/uncultivated land in the previous season. On the previously fallow land, about 90% of the bean crop was severed highly and had greater than 50%, while only 9% of the fallow land had less than 50% angular leaf spot disease severity score. The incidence level of the disease on the fallow land followed by common bean is also high and about 77% of the assessed farms registered greater than 75% incidence of angular leaf spot and 23% of farms/fields had less than 75% incidence level. In the field with no rotation (Common bean followed by Common bean) disease severity index was higher than the fields with rotation practices and 100% of the fields with no rotation had a severity index of greater than 50% (Table 4).

Angular Leaf Spot association with weeding practices

Common bean fields having good weed management had low ALS incidence and severity, while a field with high weed infestations (low management) had the highest ALS incidence and severity (Table 4). In the study area in all common bean fields weeds and unwanted plants were removed with hand hoeing methods i.e., they didn't practice the herbicides for common bean crops to remove weeds. The disease incidence and percent severity index of the fields infested highly with weed was 80.67% and 64.2% respectively, while the incidence and severity of the disease on the fields with low weed infestation were 73.55% and 36.95% respectively. Fields with highly infested by weeds increase ALS severity by 20.52% on average, compared to low weed fields [44]. Crops highly infested with weeds may have high relative humidity and warmness of the microclimate beneath the crop canopy, and this could favour the onset, infection, and development of ALS [11]. Regarding fertilizer and pesticide applications, the interviewed farm owners responded no fertilizer and pesticides were applied to common beans in the study area. Land preparation is one of the most important factors that influence ALS development and distribution. For soil loosening to common bean production mostly they use two and three times tillage frequencies.

Angular Leaf Spot and tillage practices association

The severity of ALS was high on fields of common beans ploughed less than three times (Table 4). This may occur as a result of not well-decomposed plant debris and disturbing other biotic factors. [22] reported that *Phaeoisariopsis griseola* can survive as spores in infected common bean residue left on the soil surface, although it does not persist for long when the remains of infected common beans are covered up in the soil and decompose. Low tillage frequency, dependency on local seed and continuous sole cropping season after season influence the build-up of primary inoculum from common bean debris and infected seeds, which can cause a primary infection by ALS on common beans [16]. Absence or low tillage practice might result in low degradation of common bean debris and disease severity and incidence rise. *Phaeoisariopsis griseola* is distinguished to survive on infected crop debris over two winters and the stroma that forms in lesions allows the pathogen to remain dormant until environmental conditions are favourable for sporulation [5]. However, land preparation alone is not an independent factor in influencing angular leaf spot establishment, but four times tillage during land preparation before planting reduces angular leaf spot severity by 54.94% compared to twice prepare common bean fields [16]. Though, none of the farmers prepared their farms four times before planting common beans in the study area (Borana). In addition, the study confirmed that farmers were practicing bean-to-bean cropping patterns and depended heavily on uncertified seeds of local varieties obtained from their farm savings and purchased from local markets. The obtained result is supported by [33] reports that the consequences of using their seed and additional germplasm obtained from informal markets are high in angular leaf spot inoculum accumulation and significantly contribute to the development of the disease in the field.

The ALS severity was highly observed in fields sown unknown common bean cultivars (69.24%) and bought from the market (55.69%). The overall F-value of the regression model was 18.94 with <.0001 the corresponding p-value. As the p-value of the regression model shows the independent variables and ALS severity (dependent variable) were statistically significant. The fitness of the model was also satisfactory with the value of R^2=69.63%. That is the variation of the ALS severity index was explained by the independent variables listed. A multiple regression model indicated that independent variables, district, cultivar, nature of disease occurrence, plant population, altitude, crop growth stage, and weed management significantly contributed to the ALS percent severity index. ALS percent severity index (PSI) was generally high (mean =66.67%) and varied significantly among districts (P=0.004), altitude (P=0.002), crop growth stage (p=0.002), cultivar (p=0.020) and weed management (0.024).

4. Conclusions and Recommendations

Common bean is one of the major crops cultivated in sole cropping system in Borana zone. Among the assessed common bean fields about 82.67% were infected by various foliar diseases. The foliar diseases of common beans in the Yabello district was highly damaged the crop compared to other assessed districts. The disease incidence was high in fields highly infested by weeds and this could result in reduce of crop vigor and support disease development through competition for resources. Dependence on the saved seeds and low tillage frequency may serve as a source of inoculum and disease development. Most farmers of the study area used seeds earned from the local market and saved from previous cropping seasons. This implies there is a lack of improved common bean seeds in the study area which leads to the facilitation of disease epidemics and causes high damage to the crop. The major common bean foliar diseases observed from farmer's fields were angular leaf spot, common bacterial blight, anthracnose, common bean mosaic virus, and common bean leaf rust according to their prevalence percentage from larger to lower order. Moreover, ALS prevalence was more than 96.77% of the total infected common bean fields.

Common bean angular leaf spot disease could be managed through practices such as increasing tillage frequency, well removal of unwanted plants, not working in the field during wet time, crop rotation, and using fungicides and resistant varieties. Then, the disease effect on common bean productivity, way its dissemination and management methods should be delivered to the producers. Therefore, all mandatory stakeholders around the study area should pay attention to the disease and work on how to manage the disease and increase crop production. Hence, if this information is properly used, common bean production would be improved in the study area and similar agro-ecologies.

Abbreviations

ALS	Angular Leaf Spot
CBB	Common Bacterial Blight
DI	Disease Incidence
DP	Disease Prevalence
masl	Meter Above Sea Level
PDA	Potato Dextrose Agar
PSI	Percent Severity Index
SDW	Sterilized Distilled Water
SE	Standard Error

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Conflicts of Interest

The authors declare there is no conflicts of interest.

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