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Occurrence and Severity of Angular Leaf Spot of Common Bean in Kenya as Influenced by Geographical Location, Altitude and Agroecological Zones

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Abstract: A survey to determine the prevalence, incidence and severity of angular leaf spot of common bean was conducted in Embu, Kakamega, Kiambu, Machakos and Taita Taveta districts of Kenya. The districts were selected based on the intensity of bean production, spatial and ecological location. Angular leaf spot was prevalent in all the districts and was recorded in 89% of the farms visited. The disease was present in all the farms surveyed in Embu, Kakamega and Machakos districts. In Taita Taveta and Kiambu districts, disease prevalence was 80 and 65%, respectively. The disease was prevalent across the lower midland, lower highland and upper midland agroecological zones and altitude ranges of 963-2322 m above sea level (m.a.s.l.). Disease incidence and severity were high (mean values of 49.6 and 21.4%, respectively) and varied significantly ($p \leq 0.05$) among districts, farms, agroecological zones and different altitudes. Kakamega and Taita Taveta districts recorded the highest disease incidence and severity, respectively, whereas Embu district had the lowest incidence and severity. Bean fields in the altitude ranges of below 1200 m and 1600-2000 m.a.s.l. had the highest disease severity (33.8%) and incidence (52.9%), respectively, whereas areas above 2000 m recorded lower disease levels. Agroecological zone LM2 and UM4 had the highest levels of disease incidence and severity whereas zones LH1 and UM3 had the lowest levels, respectively. These results indicate that angular leaf spot is severe and highly prevalent in Kenya. The disease spans across all the agroecological zones and altitude ranges where beans are grown. Efforts should, therefore, be geared towards an integrated approach to manage the disease.

Key words: Bean field, disease, district, incidence, prevalence, *Phaeoisariopsis griseola*

INTRODUCTION

Amongst the legumes grown in Kenya, common bean (*Phaseolus vulgaris* L.) is ranked as the most popular in both production and utilisation. Beans form a significant part of many diets and play a critical role in human nutrition, providing as much as 45% or more of the total proteins consumed in some areas (Allen *et al*., 1996; Mwaniki, 2002; Wachenje, 2002). It is an important food for people of all income categories and especially for the poor as a source of dietary protein. In addition, the crop is increasingly becoming a significant source of income for smallholder farmers (Wortmann *et al*., 1998). Thus, beans play an essential role in the sustainable livelihoods of smallholder farmers, providing both food security and income. Bean production is, however, constrained by several biotic and abiotic factors, most important of which are diseases, insect pests, low soil fertility and periodic water stress (Songa *et al*., 1995; Mwaniki, 2002; Wachenje, 2002).

Angular Leaf Spot (ALS), caused by the imperfect fungus *Phaeoisariopsis griseola* (Sacc.) Ferraris is one of the most widely distributed and damaging diseases of common bean, causing yield losses as high as 80% (Schwartz *et al*., 1981). In the recent past, ALS incidence and severity have increased in many areas where beans are cultivated (Jarvie, 2002; Stenglein *et al*., 2003). In Africa, particularly in Kenya, Malawi, Ethiopia, Uganda, Tanzania and the Great Lakes Region, ALS is considered the number one constraint to bean production (Pastor-Corrales *et al*., 1998), with annual losses estimated at 374,800 tonnes (Wortmann *et al*., 1998). When weather conditions are favourable for its development, ALS can be very destructive with crop losses resulting mainly from

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premature defoliation (Mwang'ombe *et al*., 1994). The disease affects foliage and pods throughout the growing season and is particularly destructive in areas where warm, moist conditions are accompanied by abundant inoculum from infected plant residues and contaminated seed (Saettler, 1991).

Infected seeds, plant debris, volunteer plants and off-season crops have been identified as important sources of *P. griseola* inoculum (Stenglein *et al*., 2003). In the absence of the living host, the pathogen has been reported to survive for up to 19 months on host plant debris (Sindhan and Bose, 1979). Formation of a stroma after the destruction of host cells permits the pathogen to remain dormant in infected plant tissues until favourable conditions prevail (Monda *et al*., 2001). The fungus has been reported to survive on seed for up to 12 months (Sindhan and Bose, 1979). In addition to seed, water and air currents play an important role in dissemination of *P. griseola* (Liebenberg and Pretorius, 1997). In Kenya, farmers use their own seeds from the previous season or supplement their seed requirements with purchases from informal markets (Wakahiu, 2000; Mwaniki, 2002; Wachenje, 2002). This practice coupled with continuous cropping and poor field sanitation leads to inoculum build-up and hence, higher ALS levels.

Several disease control strategies have commonly been advocated in attempts to reduce losses caused by angular leaf spot. These include use of resistant varieties, planting disease-free seeds, field sanitation, crop rotation, use of cultivar mixtures and fungicides (Stenglein *et al*., 2003). However, effectiveness of these methods is limited by the high pathogenic variability occurring in *P. griseola* (Wagara *et al*., 2005), land unavailability to practise crop rotation, ability of the pathogen to survive in plant debris for a long period of time (Liebenberg and Pretorius, 1997) and unavailability and high cost of certified seed. In addition, use of fungicides is hardly a disease control option for the smallholder farmer due to high cost, lack of expertise and the health hazards involved. Therefore, the strategy most likely to be effective in the management of ALS is integrated disease management, with a strong component of resistant varieties.

Development and implementation of integrated disease management systems require precise and accurate information on the disease and factors that influence its development. Knowledge of spatial and temporal disease relations and fungal population biology have an impact on ALS control (Stenglein *et al*., 2003). It is important to understand the distribution of the disease and the factors that affect its occurrence and severity. In Kenya, beans are widely grown across the country over a wide range of altitudes and agroecological zones but the distribution and severity of ALS in the different bean growing areas is not known. In addition, the influence of altitude, agroecological zones and geographical location on the occurrence and severity of ALS has not been determined. Such information is important in the management of the disease. It would be useful in identification of bean growing areas with low or no occurrence of ALS where bean cultivation can be intensified, especially for seed production. The information would also help in identification of ALS hotspots, which can be used as germplasm screening sites for bean breeding programs. The objective of this study was, therefore, to determine the prevalence, incidence and severity of angular leaf spot in different agroecological zones, altitudes and geographical locations in Kenya.

MATERIALS AND METHODS

Survey sites in selected districts of Kenya: An observation method survey to determine the prevalence, incidence and severity of angular leaf spot of beans was conducted in Kakamega, Kiambu, Embu, Machakos and Taita Taveta districts, representing the diverse conditions under which beans are produced in Kenya. The districts were selected based on the intensity of bean production, spatial and ecological location. Kiambu and Embu districts represented the high altitude areas (1400-2300 m.a.s.l.), Kakamega district the medium altitude areas (1300-1900 m.a.s.l.) whereas Machakos and Taita Taveta districts represented the low altitude areas (700-2100 m.a.s.l.) (Jaetzold and Schmidt, 1983). In each district, four agroecological zones were selected (Table 1), within which twenty bean fields at least 5 km apart were selected. A combination of both purposive and simple random sampling methods was used to select the bean fields and sampling sites. The survey was conducted at the mid-podding stage during the short rains of the year 2000 and the long rains of 2001.

Data collection and analysis: Three sampling sites were randomly selected per farm and bean plants were assessed for disease incidence and severity. One hundred plants were evaluated per site and disease incidence was recorded as the number of plants infected expressed as a percentage of the total number of plants observed. Ten infected bean plants were randomly selected in each site and disease severity was estimated as the percent leaf area diseased. Disease prevalence was determined as the percentage of the number of bean fields in which the disease was observed in a given Altitude Range, Agroecological Zone (AEZ) and district.

Table 1: Agroecological zones of the angular leaf spot survey sites in five districts of Kenya

Districts	Divisions	Agroecological zone
Embu	Runyenjes	Upper midland, sub-humid zone (UM2)
	Central	Upper midland, transitional (UM4)
	Gachoka	Lower midland, semi-humid zone (LM3)
	Gachoka (Kiritiri)	Lower midland, semi-arid zone (LM5)
Kakamega	Lurambi, Ikolomani	Lower midland, humid (LM1)
	Kabras (Malava)	Lower midland, subhumid (LM2)
	Shinyalu, Sabatia, Municipality	Upper midland, humid (UM1)
	Lugari	Upper midland, transitional (UM4)
Kiambu	Githunguri	Upper midland, humid (UM1)
	Kikuyu	Upper midland, semi-humid (UM3)
	Limuru, Tigoni, Lari	Lower highland, humid (LH1)
	Kabete	Lower highland, semi-humid (LH3)
Machakos	Kathiani	Upper midland, sub-humid zone (UM2)
	Athi-River, Central	Upper midland, semi-arid zone (UM5)
	Mwala	Lower midland, semi-humid zone (LM3)
	Yathui	Lower midland, semi-arid zone (LM5)
Taita Taveta	Wundanyi (Weruga)	Upper midland, semi-humid zone (UM3)
	Wundanyi (Wesu)	Lower highland, subhumid zone (LH2)
	Mwatate (Kidayangerenyi)	Upper midland, transitional zone (UM4)
	Mwatate	Lower midland, semi-arid zone (LM5)

Data on percent disease incidence and severity for the different districts, agroecological zones and altitude ranges were transformed using arc sine transformation (Gomez and Gomez, 1984) and analysed by Analysis of Variance (ANOVA) using GenStat Release 6.1 (GenStat Procedure Library Release PL14). Separation of means was done using Least Significant Difference (LSD) at $p\leq 0.05$. The correlation coefficient between disease prevalence, incidence and severity was determined.

RESULTS

Disease prevalence: Angular leaf spot occurred in all the five districts surveyed and was recorded in 89% of the farms visited. The disease was present in all the bean fields surveyed in Embu, Kakamega and Machakos districts (Table 2). In Taita Taveta and Kiambu districts, the disease prevalence was 80 and 65%, respectively. The disease occurred in all the agroecological zones covered (Table 3). It was highly prevalent (100%) in agroecological zones UM1, UM2, UM4, UM5, LM1, LM2, LM4 and LH3. Agroecological zone UM3 had the lowest disease prevalence (58%) whereas LM5, LH1 and LH2 had 63, 67 and 69% disease prevalence, respectively. The disease was not observed in the lower midland semi-arid zone (LM5) of Taita Taveta district, which covers Maktau and Godoma areas of Mwatate division. Likewise, the disease was not recorded in Saghasa area of Wundanyi division, which lies in lower highland subhumid zone (LH2) of Taita Taveta district. In Kiambu district, three farms in Limuru and four farms in Ndeiya divisions were free of the disease. These areas are in agroecological zones LH1 and UM3, respectively.

ALS was observed from 963 to 2322 m above sea level (m.a.s.l). Disease prevalence differed significantly ($p\leq 0.05$) among the different altitudes (Table 4). The disease was more prevalent (97.7%) in areas below 1600 m.a.s.l and less prevalent (66.3%) in areas above 2001 m.a.s.l. The highest disease prevalence (98.4%) was recorded in the altitude range of 1201-1600 m.a.s.l.

Table 2: Prevalence, incidence and severity of angular leaf spot in Kakamega, Kiambu, Embu, Machakos and Taita Taveta districts

Districts	Prevalence (%)	Incidence (%) Mean	Incidence (%) Range	Severity (%) Mean	Severity (%) Range
Embu	100	31.0	5-75	11.0	1-65
Kakamega	100	71.0	20-95	21.0	1-75
Kiambu	65	33.0	0-75	19.0	1-80
Machakos	100	47.0	3-96	21.0	1-90
Taita Taveta	80	66.0	0-100	35.0	1-95
$LSD_{(p=0.05)}$		4.2		2.6	
CV (%)		23.6		33.7	
SE		11.7		7.2	

Table 3: Prevalence, incidence and severity of angular leaf spot in various agroecological zones in Kenya

Agroecological zone	Prevalence (%)	Incidence (%)	Severity (%)
LH1	67	27.3	12.7
LH2	69	40.8	18.3
LH3	100	32.3	21.9
LM1	100	71.0	22.2
LM2	100	77.8	26.9
LM3	100	40.8	23.9
LM4	100	31.1	17.4
LM5	63	40.0	13.3
UM1	100	63.1	24.0
UM2	100	40.3	13.9
UM3	58	37.2	12.3
UM4	100	62.2	34.8
UM5	100	61.3	24.0
Mean	89	49.6	21.4
$LSD_{(p=0.05)}$		13.5	10.7
SE		19.0	17.4
CV (%)		36.4	29.2

Disease incidence: Disease incidence varied significantly ($p\leq 0.05$) among the districts and also among the farms (Table 2). Even farms in the same location had

Table 4: Prevalence, incidence and severity of angular leaf spot at varying altitudes

Altitude (m.a.s.l)	Prevalence	Incidence (%)	Severity
0-1200	97.0	48.7	33.8
1201-1600	98.4	49.7	17.8
1601-2000	94.3	52.9	24.6
2001-2400	66.3	34.5	17.4
Mean	89.0	49.6	23.4
$LSD_{(p=0.05)}$		8.3	5.3
SE		22.6	14.3
CV (%)		50.8	57.5

significantly different angular leaf spot incidences. Fifty two percent of the farms had a disease incidence of more than 50%. Disease incidence was highest (71%) in Kakamega district, whereas Embu district had the lowest incidence (31%). Ninety percent of the farms in Kakamega had a disease incidence of more than 60% with 15% of the farms recording 100% incidence. In Embu district, 80% of the farms had disease incidence of less than 50%. Lurambi division of Kakamega district had the highest mean disease incidence (83%) whereas Mwatate division of Taita Taveta district had the lowest incidence of 7%.

There was a significant ($p \leq 0.05$) difference in disease incidence among the various agroecological zones (Table 3). On the average, zone LM2 (lower mid-land, sub-humid zone) had the highest disease incidence (77.8%) whereas LH1 (lower highland, humid zone) had the lowest incidence (27.3%). Disease incidence also varied among the different altitude ranges but only areas above 2000 m had a significantly ($p \leq 0.05$) lower disease incidence (Table 4). Areas in the altitude range of 1601-2000 m.a.s.l had the highest disease incidence (52.9%).

Disease severity: Angular leaf spot severity was high and varied significantly ($p \leq 0.05$) among the five districts surveyed (Table 2). The mean disease severity was highest (35%) in Taita Taveta district with a range of 1-95% as compared to Embu district which had the lowest mean severity (11%). High disease severity levels were often accompanied by heavy defoliation. Disease severity also varied significantly among the different agroecological zones (Table 3). Zone UM4 had the highest average disease severity (34.8%) as compared to zone UM3 which recorded the lowest severity of 12.3%. Disease severity was significantly ($p \leq 0.05$) different among the various altitude ranges (Table 4). Higher disease severity (33.8%) was observed at altitudes below 1200 m.a.s.l and was lowest at 2001-2400 m.a.s.l. There was a significant positive correlation (r = 0.638) between disease incidence and severity.

DISCUSSION

Angular leaf spot was prevalent in all the five districts surveyed and was widespread across the diverse agroecological zones and altitude ranges where beans are produced. The disease was recorded in 89% of the farms visited. These results are in agreement with those of Mwang'ombe *et al.* (1994) who reported the occurrence of angular leaf spot in all the bean growing areas in Kenya. The disease was present in all the bean fields visited in Embu, Kakamega and Machakos districts. It was, however, not recorded in four farms in the lower semi-arid zone of Mwatate division of Taita Taveta district. This could be attributed to the high temperatures and dry conditions prevailing in these areas (Jaetzold and Schmidt, 1983). Seven farms in Kiambu district were also free of the disease. The low occurrence of the disease in Kiambu district as compared to the other districts was probably due to the dry and hot conditions that prevailed in the district during the year 2000 when the survey was conducted. A general agreement exists among authors that adequate moisture (95-100% relative humidity) and favourable temperatures (20-25°C) are critical requirements for the successful infection of the host and sporulation of the pathogen (Liebenberg and Pretorius, 1997). Variations in these parameters among the different bean growing areas may account for the differences observed in prevalence, incidence and severity of the disease.

Angular leaf spot occurred in all the agroecological zones and altitude ranges covered in the present study. The disease was present across 963-2322 m.a.s.l. but the prevalence differed significantly among the altitude ranges. The disease was more prevalent (97.7%) in areas below 1600 m.a.s.l. and less prevalent (66.3%) in areas above 2000 m.a.s.l. The cool temperatures in the high altitude areas may inhibit ALS development. Inglis and Hagedorn (1986), reported that cool temperatures of 16°C delay disease development and areas with moderate temperatures and high humidity generally record high levels of ALS. This may explain the absence of the disease in most farms in Limuru division of Kiambu district, which is relatively cold (Jaetzold and Schmidt, 1983). A similar relationship between disease incidence, severity and prevalence and agroecological zones and altitude ranges has been reported in *Fusarium* wilt of pigeon pea in Kenya (Kiprop, 2001). ALS was highly prevalent in the lower midland zones (LM1, LM2, LM3 and LM4), upper midlands (UM1, UM2 and UM4) as well as the lower highland semi-humid zone (LH3). This could be attributed to the favourable humid conditions prevailing in these areas (Jaetzold and Schmidt, 1983).

Contrary to expectations, the upper midland semi-arid zones (UM5) of Machakos and Embu districts recorded high ALS occurrence probably due to the heavy rains that were experienced in the year 2001 when the survey was conducted in these areas. This conclusion is supported by observation by Makini (1994), who reported that yield loss, incidence and severity of angular leaf spot vary considerably from one season to another across locations depending on weather conditions.

Disease incidence and severity were generally high and varied significantly among the districts, agroecological zones and altitude ranges. The disease levels varied from one farm to the other even in the same agroecological zone, altitude and location. This maybe attributed to factors such as amount of inoculum present in each farm, level of field sanitation and type of cropping system. Infected seeds, plant debris and volunteer plants are some of the important sources of *P. griseola* inoculum that influence development of ALS in the field (Stenglein *et al*., 2003). There was a significant positive correlation (r = 0.638) between disease incidence and severity and areas with high disease severity also generally had higher disease incidence. Areas with high disease prevalence, however, did not necessarily record high levels of incidence or severity. Embu district, for example, had 100% disease prevalence but recorded the lowest levels of disease incidence and severity whereas Taita Taveta district had 80% prevalence but recorded the highest level of disease severity. The low disease incidence and severity recorded in Embu district could probably be attributed to the wide range of bean cultivars grown in the district, where farmers were found to be growing up to eight cultivars on the same farm. Farmers plant many bean cultivars on the same farm to fulfil various needs and ensure yield stability (Mwaniki, 2002; Wachenje, 2002). The selection of cultivars to be grown depends on yielding ability, market value, suitability for inter-cropping, taste and cooking properties, availability of seeds and resistance to diseases and pests. Some cultivars are preferred for home consumption while others fetch better prices in the market. Pyndji and Trutmann (1992) demonstrated that using bean mixtures significantly lowers angular leaf spot severity because the cultivars may contain varying levels of resistance to different races of *P. griseola*. Cultivation of many bean varieties on the same farm, even though not necessarily as mixtures, may have a similar effect. Further studies should be done to confirm the effect of this cropping practice on ALS severity, with an aim of recommending it to farmers as a disease management strategy.

Angular leaf spot severity varied significantly among the different agroecological zones and even farms in the same zone had different levels of disease severity. Disease severity was highest (34.8%) in agroecological zone UM4 and lowest (12.3%) in zone UM3. Similarly, different altitude ranges recorded significant differences in ALS severity. Higher severity levels were recorded at altitudes below 1200 m.a.s.l. whereas altitude ranges of 2001-2400 m.a.s.l. had the lowest disease severity. Altitude ranges 1601-2000 had moderate severity of 24.6%. Different AEZs and altitudes have varying soil types, rainfall and temperature regimes (Jaetzold and Schmidt, 1983). These factors, especially rainfall and temperature, affect infection and development of ALS. The disease is reported to develop well in moderate temperature ranges and high relative humidity of above 95% (Stenglein *et al*., 2003). The disease decreases systematically as temperature increases, with the smallest lesions forming at a temperature of 30°C (Verma and Sharma, 1984). Variation in climatic conditions from one season to another also influences the occurrence and severity of the disease (Jarvie, 2002). It has been observed that disease symptoms that develop during cool months (18-22°C) are more severe as compared to those that develop during warmer months (28-32°C) (Verma and Sharma, 1984).

The high prevalence, incidence and severity of angular leaf spot occurring in Kenya may, to a certain extent, be attributed to the farming practices adopted by smallholder farmers who are the main producers of common bean in the country. Due to an increase in pressure on land, consequent to an ever-increasing human population, farmers till their land throughout the year without any fallow or crop rotation. In addition, farmers use their own seeds from the previous season or supplement their seed requirements with purchases from informal markets (Wakahiu, 2000; Mwaniki, 2002; Wachenje, 2002). This results in inoculum build-up, which contributes significantly to the development of disease epidemics. Barros *et al*. (1958) reported that ALS increased dramatically in Colombia when four bean crops were planted per year in Cauca valley. Even when planted twice yearly, the disease was especially serious where beans were planted in or near fields cultivated with beans during the previous one or more seasons. Continuous cropping with little or no farm inputs like fertilizers or manure also results in a poorly established crop that is more prone to extensive disease damage. Similarly, as farmers try to maximize on their small pieces of land, there is close-cropping which leads to increased disease severity as a result of prolonged humidity retention (Barros *et al*., 1958). Therefore, although ALS development and severity are influenced by weather, altitude, agroecological zones and geographical location, other factors such as farming practices and seasons may also influence disease levels. Further studies should, therefore, be undertaken to determine the effect of different farming practices and cropping seasons on occurrence and severity of ALS.

This study revealed that angular leaf spot of common bean is severe and highly prevalent in Kenya. The disease spans across all agroecological zones and altitude ranges where beans are grown. Thus, there is need to develop a viable, cost-effective Integrated Disease Management (IDM) strategy, especially for the smallholder farmers. Components of IDM should include resistant varieties, disease-free seeds, varietal mixtures, crop rotation and proper field sanitation, among others. The upper and lower midland zones of Taita Taveta and Kakamega districts had the highest ALS incidence and severity and can, therefore, be used as disease hotspots for bean germplasm screening. Embu district on the other hand had the lowest ALS levels and can probably be used for bean seed production. Further studies should, however, be done to confirm these results, taking into consideration the probable influence of bean genotype diversity and cropping practices on angular leaf spot development and severity.

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