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The current status, farmers' management practices, knowledge, and perceptions of common bean anthracnose in Tanzania

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Abstract

Effective disease management requires farmers' awareness of its cause, transmission mechanisms, and appropriate management methods. This study assessed the current status, farmers' management knowledge, practices, and perceptions of common bean anthracnose in Tanzania. Field surveys were conducted during the February-June 2020 growing season in ten Districts, namely Misenye, Karagwe, Hanang, Mbulu, Hai, Kilindi, Arusha DC, Mbozi, Njombe, Mufindi, and Mukalama. Ten farms from each District were surveyed for the disease prevalence and incidences using a Z-survey technique. Structured questionnaires were also administered to 280 farmers to elicit their knowledge, management practices, and perceptions of bean anthracnose. The results indicate that the disease is prevalent in all the surveyed Districts and disease incidence varied significantly across districts (p<0.001). Disease incidence was higher in Mufindi (68%) and least in Hai (5%), whereas prevalence was higher in Karagwe (100%) and least in Hai (40%). Most of the farmers (94.3%) had noticed the disease in their farms and could identify symptoms. Only 26.4% associated bean anthracnose with a particular cause, and only 21.4% know how it is transmitted. Similarly, the majority of the farmers had limited knowledge of appropriate management methods, although they perceived bean anthracnose a serious disease, causing significant losses. Very few farmers used fungicides, cultural practices, and botanicals to manage the disease, and the majority did nothing after noting symptoms in their farms. Our findings provide an alert for anthracnose disease levels in Tanzania and suggest the need for capacity building among farmers on the disease's cause, transmission, and management.

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Introduction

Bean anthracnose is a fungal disease caused by *Colletotrichum lindemuthianum* and is one of the most destructive diseases of common bean worldwide (Padder *et al.*, 2017). Significant yield losses due to anthracnose have been reported in common beans, especially when susceptible cultivars are grown (Mohammed, 2013). Seeds infected by *C. lindemuthianum* are the primary source of inoculum disease transmission; however, plant to plant transmission is also possible through conidial spread by rain splashes and infected plant residues (Padder *et al.*, 2017). Symptoms of bean anthracnose are always apparent on the plant's above-ground parts, particularly on leaves and pods. These symptoms include small, brick-red or black lesions on the leaf veins and circular brown sunken lesions on the pods (Mwesigwa, 2009). These symptoms can be visible in any part of the plant in susceptible varieties. The first symptoms appear on first or cotyledonary leaves and are dark brown to small black lesions. Severely infected cotyledons senesce prematurely, leading to stunted plant growth (Buruchara *et al.*, 2010). Under favourable conditions, small, pink masses of spores are produced in the lesions, and there is a possibility of spreading the spores to the leaves (Buruchara *et al.*, 2010).

Bean anthracnose has been reported in many parts of the world, including Tanzania (Ansari *et al.*, 2004). In Tanzania, anthracnose is the second most important disease of common beans after angular leaf spot (Hillocks *et al.*, 2006). Annual losses from bean anthracnose of up to eighty per cent, estimated to be equivalent to USD dollars 304 million, are expected in Tanzania (Mohammed, 2013). Although the information on the current status of bean anthracnose in Tanzania is limited, ancient studies reported the possibility of total crop loss (100%) in susceptible cultivars (Shao and Terri, 1985).

Various methods are used to manage anthracnose in different regions around the globe. The most common methods include applying synthetic fungicides (Mohammed, 2013b), cultural practices, and the use of resistant varieties (LeClair *et al.*, 2015; Mohammed, 2013b). In recent years, however, much attention has been on using biological control and plant-based fungicides to reduce the adverse effects of synthetic fungicides on the ecosystem and users (Mwabulambo *et al.*, 2018). To effectively manage diseases using any of these technologies and their adoption, farmers' knowledge of the pathogen, the disease, management practices, and perceptions need to be considered (Chitere & Omolo, 1993; Moses *et al.*, 2018).

From literature, information is available regarding the pathogen, transmission, and appropriate methods for managing bean anthracnose. However, such information may not be available to farmers, especially in rural areas, as reported in other crops where farmers could identify the disease symptoms but unaware of the cause, transmission mechanisms, and appropriate control options (Islam *et al.*, 2020; Tafesse *et al.*, 2018). A similar observation was reported by a recent study in Tanzania whereby most farmers were not aware of appropriate control methods for insect pests and weeds but perceived them as one of the major production constraints (Laizer *et al.*, 2019). This lack of knowledge on the cause, transmission, and management of a given disease is among the main factors leading to increased losses in various crops, particularly in low-income countries (Islam *et al.*, 2020).

Therefore, it has been hypothesized that to manage any crop disease effectively, farmers need to have adequate knowledge of the pathogen, the disease spread mechanisms, and effective management methods (Moses *et al.*, 2018). Bean anthracnose is not an exception; thus, this study was undertaken to assess the current status, farmers' perceptions, management knowledge, and practices of bean anthracnose in Tanzania.

Materials and methods

The study area

This study was conducted in the following Districts: Misenye and Karagwe (the Lake or Western Zone),

Hanang, Mbulu, Hai, Kilindi and Arusha DC (Northern zone), Mbozi, Njombe and Mufindi (Southern Highlands) and Mukalama. Field surveys were conducted during the February-June, 2020 growing season. The altitudes and locations of each sampled site were recorded using GPS, and the map representing the sampled sites is presented in Figure 1.

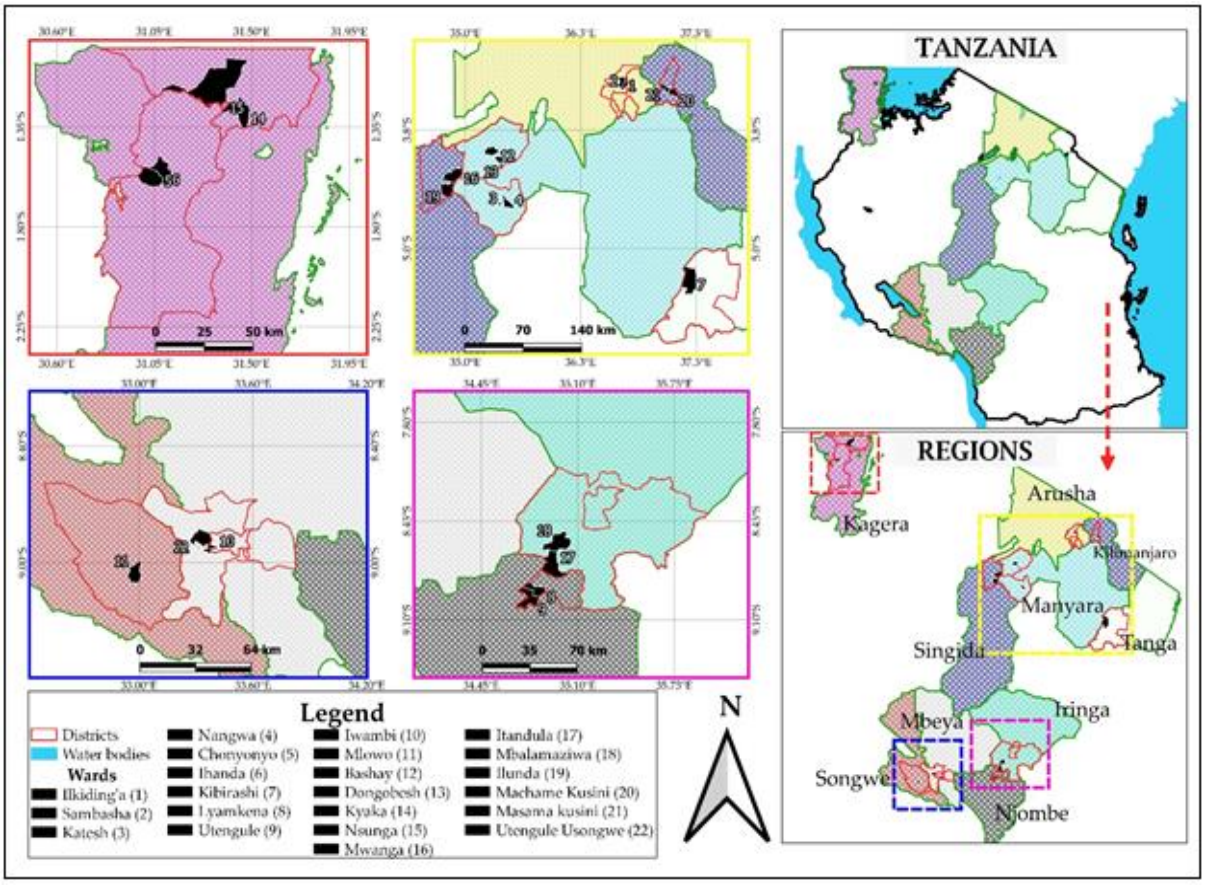

Fig. 1. Map of Tanzania showing the sampled Districts for the study.

Field sampling procedure

Field surveys were conducted in selected Districts from all agro-ecological zones of the country (Figure 1). The selection of the Districts was purposively based on the bean production records. In each District, at least one ward was selected for data collection depending on the size of the ward and availability of fields with pods, a suitable stage of sampling. At least ten farms from each District were randomly selected using a list provided by the ward extension officers.

Determination of disease prevalence and incidence

The disease prevalence was determined according to a method proposed by Strindberg & Buckland (2004) with minor modifications. A 'Z' walk along the sampled fields/farms was done. Plants with green pods were sampled along Z-route, and close observation of the presence or absence of the typical symptoms of bean anthracnose was visually done. The typical circular and brown-black lesions on pods and leaf veins were considered typical symptoms of bean anthracnose.

Twenty (20) plants were picked randomly along the Z-route and examined for the typical disease symptoms (circular and brown-black sunken lesions on pods and brown leaf veins). Disease symptoms identification was achieved using the bean diseases and pest identification guide (Buruchara *et al.*, 2010). Disease incidence was then computed as a percentage of the infected plants over the total number of plants sampled (20) (Forrest *et al.*, 1991), as per the formula below:

$DI = \frac{\sum n}{\sum N} x\ 100$, whereby:

DI = disease incidence

$\sum n$ = number of infected plants

$\sum N$ = total number of sampled plants

The disease prevalence was, on the other hand, calculated as the percentage of the farms showing disease symptoms against the total number of the fields surveyed in each district as proposed by Forrest *et al.* (1991) in the formula below:

$$Prevalence = \frac{Fields\ with\ disease\ symptoms}{Total\ number\ of\ fields\ surveyed} x\ 100$$

The sampled pods showing typical anthracnose symptoms were used for isolation of the pathogen, and pathogen identification was done using the procedures described by Mathur and Kongsdal (2003) and Junaid *et al.* (2014) (data not presented).

Farmers' management knowledge, practices and perceptions of bean anthracnose

Structured questionnaires were administered to farmers from selected bean growing districts to elicit information on their perceptions, knowledge and management practices of common bean anthracnose. These representative districts included Hai, Hanang, Karagwe, Misenye, Arusha DC, Kilindi and Mufindi. Wards within each district were identified with the aid of District Agricultural Officers, and at least two villages were randomly selected from each ward using a method described by Midega *et al.* (2012). In the selected villages, farmers who grow common beans were identified based on the list provided by the Ward Agricultural Officer. Forty (40) farmers were randomly selected from each district.

Before questionnaires were administered, respondents were introduced to the purpose of the study and were assured of anonymity and confidentiality of the information they provided. Contact information of the enumerators was also provided to farmers, and they were requested for their consent to participate in the survey voluntarily. The questionnaire was pre-tested on ten (10) farmers who were later excluded from the study, and corrections were made accordingly before they were administered to the respondents. Questions were in English but were later translated into Swahili and included both open and close-ended questions. Data collected included respondents' characteristics, common bean production characteristics, farmers' knowledge, perceptions and management practices of bean anthracnose. Coloured photos of diseased plants and seeds were provided to respondents for easy identification of the disease symptoms.

Data analysis

The mean percentages of incidence and prevalence of bean anthracnose were computed for each district and then subjected to a One-Way Analysis of Variance (ANOVA). Tukey's HSD Post hoc test was performed to separate the means between Districts. Correlation analysis was also done to determine the relationship between disease incidence, prevalence and altitude. All these analyses were performed using *jamovi* software (version 1.1.9). Descriptive statistics for the farmers' knowledge and perceptions were computed using the Statistical Package for Social Sciences (SPSS), and the Chi-square test was used to test association among respondents across the surveyed districts.

Results

Incidence of bean anthracnose

The one-way analysis of variance (ANOVA) showed that there was a significant difference between means of disease incidence (DI) among the districts, $F(9, 58) = 9.688$, $p<0.0001$. A Tukey Post-hoc test revealed differences between means among the districts. The highest disease incidence was recorded in Mufindi, Mukalama and Karagwe, whereas Hai, Mbulu and Arusha DC recorded the least incidence in that order (Figure 2).

Disease prevalence

Bean anthracnose symptoms were observed in all the districts sampled, though with varying extents. The disease was highly prevalent in Karagwe, Mufindi and Misenye, whereas Hai and Mbulu had the least prevalence (Figure 4). No disease symptoms were observed for some farms in some districts, but in

Karagwe, all the surveyed farms had disease symptoms (Figure 3).

Correlation between disease incidence and altitude

The correlation analysis revealed a weak positive relationship between disease incidence and altitude (r = 0.267), which was not statistically significant (p=0.244). Similarly, a weak positive correlation was observed between disease prevalence and altitude (r = 0.126, p = 0.373). However, disease incidence and prevalence had strong positive correlation (r = 0.681, p = 0.022) (Figure 4).

Table 1. Characteristics of the sample of common bean farmers in selected districts in Tanzania.

Variables	Districts								
	KRG	MIS	HAN	ARS-DC	KLD	HAI	MFD	overall	Chi-Square
	%	%	%	%	%	%	%	%	
Gender Males	65	60	65	52.5	65	70	55	61.8	x^2 = 3.693
Females	35	40	35	47.5	35	30	45	38.2	p = 0.682
Level of Education									
Non-formal	0	0	0	0	0	7.5	7.5	2.2	x^2 = 63.695
Primary	77.5	60	77.5	90	80	77.5	40	71.8	p = <0.001
Secondary	22.5	32.5	12.5	10	12.5	7.5	52.5	21.4	
College	0	7.5	10	0	7.5	7.5	0	4.6	

**KRG = Karagwe, MIS = Misenye, HAN = Hanang, ARS-DC = Arusha DC, KLD = Kilindi, and MFD = Mufindi.*

Characteristics of respondents

The sample consisted of 61.8% males and 38.2% females. A large proportion of the sample (71.8%) had primary education, 21.4% had secondary education, 4.6% had a college education, whereas only 2.2% had non-formal education (Table 1).

Common bean production characteristics of respondents

Most of the farmers (71.1%) had been growing common beans for more than five years, and most of them (56.4%) owned the land of between 1 to 4 acres where they grew common beans. Majority of the sample (93.9%) had grown common bean in the season before, and 76.8% of the sample intercropped common bean with maize. The study also revealed that most farmers (59.3%) depended on seeds saved from the previous season, whereas the rest either bought seeds from agro-shops, local markets or borrowed from neighbours. Further, most farmers (76.8%) who participated in the study grew common beans for food and cash, but the rest grew the crop for either food or cash. The chi-square test revealed a significant association between districts and production characteristics (p<0.001) (Table 2).

Farmers' perceptions and knowledge about bean anthracnose

Of all farmers who responded, 93.7% had seen and could identify the disease symptoms. A large proportion of the farmers (57.1%) had experienced disease symptoms in their farms for more than four years. Very few farmers (26.4%) said that they knew the cause of the disease, though only 15.4% of them perceived it as a fungal disease.

The rest of the farmers perceived bean anthracnose as being caused by either bacteria, weather, insects or insufficient nutrients. Similarly, a few farmers (21.4%) had an idea of how the disease is transmitted but only 13.2% associated it with previously infected seeds. When asked to estimate yield loss due to the disease, the majority (35.4%) pointed out that half of the yield is lost. All these opinions and knowledge varied significantly across districts (p<0.001) across districts (Table 3).

Table 2. Characteristics of common bean production in the surveyed districts in Tanzania.

Variables	Districts								
	KRG	MIS	HAN	ARS-DC	KLD	HAI	MFD	Overall	Chi-Square
	%	%	%	%	%	%	%	%	
Length of growing Common beans	2.5	10	10	30	10	32.5	5	14.3	$x^2 = 58.322$
1-3 years									
4-5 years	17.5	0	2.5	22.5	27.5	25	7.5	14.6	$p = <0.001$
More than 5	80	90	87.5	47.5	62.5	42.5	87.5	71.1	
Size of the farm									
Less than one acre	5	15	10	72.5	0	27.5	22.5	21.8	$x^2 = 224.155$
2-4 acres	80	80	55	25	10	67.5	77.5	56.4	$p = <0.001$
5-9 acres	15	5	25	2.5	50	2.5	0	14.3	
More than 9 acres	0	0	10	0	40	2.5	0	7.5	
Whether grew beans									
in the previous season									
Yes	90	95	95	80	100	100	97.5	93.9	$x^2 = 20.917$
No	10	5	5	20	0	0	2.5	6.1	$p = 0.002$
Other crops grown									
with common bean									
Only common beans	0	20	12.5	10	32.5	7.5	10	13.2	$x^2 = 97.944$
Maize	72.5	50	87.5	87.5	65	92.5	82.5	76.8	$p <0.001$
Maize and banana	10	17.5	0	0	2.5	0	0	4.3	
Coffee	17.5	12.5	0	0	0	0	0	4.3	
Other crops	0	0	0	2.5	0	0	7.5	1.4	
Source of seeds									
Local markets	35	22.5	0	80	20	0	47.5	29.3	$x^2 = 146.016$
Agro shops	7.5	7.5	17.5	0	2.5	5	30	10	$p <0.001$
Saved seeds	57.5	70	82.5	20	77.5	85	22.5	59.3	
Borrowed from neighbors	0	0	0	0	0	10	0	1.4	
Purpose of growing beans									
Food only	0	12.5	5	37.5	0	47.5	17.5	17.2	$x^2 = 142.168$
Cash only	0	5	0	0	40	0	0	6.4	$p <0.001$
Food and cash	100	82.5	95	62.5	60	52.5	82.5	76.4	
Number of seasons per year									
One	0	17.5	100	87.5	100	90	10	57.9	$x^2 = 208.843$
Two	100	82.5	0	12.5	0	10	90	42.1	$p <0.001$

**KRG = Karagwe, MIS = Misenye, HAN = Hanang, ARS-DC = Arusha DC, KLD = Kilindi, and MFD = Mufindi.*

Farmers' knowledge of bean anthracnose and management practices

Although most respondents were aware of and had noted the disease symptoms in their farms, 60.4% of them did nothing to manage it, whereas 20% used synthetic fungicides.

The rest either used cultural practices, botanical fungicides or reported to extension officers. Of the farmers who responded, 32.9% could not use synthetic fungicides to manage anthracnose because they are expensive, and 31.1% had no knowledge of appropriate fungicides. Only 27.1% of respondents had an idea of the names of fungicides for anthracnose management. Most farmers (77.1%) were not aware of the cultural practices that could reduce disease incidences in their farms.

Similar responses were noted for the application of medicinal plants to manage anthracnose, as 93.9% of them were unaware. There was a significant association *($p<0.001$)* between the surveyed districts with the farmers' knowledge of disease management practices (Table 4).

Table 3. Farmers' perceptions and knowledge about bean anthracnose.

Variables	Districts								
	KRG	MIS	HAN	ARS-DC	KLD	HAI	MFD	Overall	Chi-Square
%		%	%	%	%	%	%	%	
Whether has experienced Anthracnose symptoms In the farm Yes	82.5	95	90	97.5	95	100	100	94.3	x^2 = 17.367
No	17.5	5	10	2.5	5	0	0	5.7	p= 0.08
Whether knows the cause									
Yes	7.5	0	32.5	35	10	60	40	26.4	x^2=56.536
No	92.5	100	67.5	65	90	40	60	73.6	p <0.001
Seasons a farmer has been experiencing symptoms									
One season	5	0	5	0	5	5	0	2.9	x^2 = 120.335
2-4 seasons	55	12.5	32.5	40	37.5	90	2.5	38.6	p <0.001
More than 4 seasons	40	87.5	57.5	60	57.5	5	97.5	57.1	
Never seen symptoms	0	0	10	0	0	0	0	1.4	
Whether knows how the disease is transmitted									
Yes	12.5	12.5	12.5	7.5	2.5	62.5	40	21.4	x^2 = 67.073
No	87.5	87.5	87.5	92.5	97.5	37.5	60	78.6	p <0.001
Ways of transmission									
Air	2.5	7.5	10	5	0	2.5	0	3.9	x^2 = 143.652
Soil	5	0	0	0	0	0	0	0.7	p <0.001
Infected seeds	0	0	2.5	0	0	50	40	13.2	
No idea	87.5	87.5	87.5	92.5	97.5	35	60	78.2	
Rainfall	5	2.5	2.5	0	2.5	12.5	0	3.2	
Insects	0	2.5	2.5	2.5	0	0	0	0.7	
Estimated yield loss									
Negligible	0	0	7.5	0	50	17.5	0	10.7	x^2 = 252.573
Quarter to one-third	52.5	32.5	30	15	27.5	45	20	31.8	p <0.001
About half of yield	37.5	27.5	32.5	17.5	15	37.5	80	35.4	
More than half	2.5	0	10	52.5	2.5	0	0	9.6	
No idea	7.5	40	20	15	5	0	0	12.5	

*KRG = Karagwe, MIS = Misenye, HAN = Hanang, ARS-DC = Arusha DC, KLD = Kilindi, and MFD = Mufindi.

Discussion

This study aimed at assessing the current status of bean anthracnose in selected bean growing Districts in Tanzania.

Our findings indicate that bean anthracnose is prevalent in all the districts surveyed in the country, though at varying extents. Disease incidences also varied across the surveyed districts, with some of them recording higher incidence relative to others. These results provide baseline information on the current status of bean anthracnose in Tanzania. Therefore, such information should be an alert to implement sustainable management strategies for managing bean anthracnose.

These results agree with the previous studies on the possibility of total crop loss in the absence of appropriate control measures if susceptible varieties are grown (Shao & Teri, 1985).

Table 4. Farmers' knowledge of bean anthracnose management practices.

VARIABLES	DISTRICTS								
	KRG	MIS	HAN	ARS-DC	KLD	HAI	MFD	overall	Chi-Square
	%	%	%	%	%	%	%	%	
Reaction after noting symptoms Do nothing	82.5	62.5	32.5	52.5	65	45	82.5	60.4	x^2 = 100.32
Use fungicides	5	5	40	27.5	15	30	17.5	20	p <0.001
Use cultural practices	7.5	12.5	12.5	0	0	10	0	6.1	
Use botanicals	0	0	15	20	20	7.5	0	8.9	
Report to extensionist	5	20	0	0	0	7.5	0	4.6	
Reasons for not using fungicides									
Are expensive	5	50	20	0	32.5	50	72.5	32.9	x^2 = 297
Not available	10	12.5	0	0	2.5	0	10	5	p <0.001
Not safe	5	0	0	0	0	10	0	2.1	
No knowledge	72.5	7.5	20	70	42.5	5	0	31.1	
No idea	7.5	30	47.5	30	17.5	0	0	18.9	
Not applicable	0	0	12.5	0	5	35	17.5	10	
Whether know cultural practices for control									
Yes	7.5	30	32.5	17.5	0	70	2.5	22.9	x^2 = 80.937
No	92.5	70	67.5	82.5	100	30	97.5	77.1	p <0.001
Whether has knowledge of botanicals									
Yes	7.5	5	7.5	0	0	17.5	5	6.1	x^2 = 14.480
No	92.5	95	92.5	100	100	82.5	95	93.9	p = 0.022
Whether knows names of fungicides to use									
Yes	5	5	45	15	7.5	50	62.5	27.1	x^2 = 72.926
No	95	95	55	85	92.5	50	37.5	72.9	p <0.001
Whether has knowledge of resistant varieties									
Yes	0	0	0	5	17.5	2.5	45	10	x^2 =73.889
No	100	100	100	95	82.5	97.5	55	90	p <0.001

*KRG = Karagwe, MIS = Misenye, HAN = Hanang, ARS-DC = Arusha DC, KLD = Kilindi, and MFD = Mufindi.

Allen and Lenné (1998) estimated that an increase of one percent of the incidence of bean anthracnose results in seed yield reduction of 9 kg/ha. Based on this fact, the observed incidences may imply that farmers, particularly those in areas with high incidences, as revealed in the field survey, experience substantial yield reduction due to bean anthracnose. Therefore, if the disease is adequately managed by using appropriate and affordable methods, such incidences could be minimized, thereby improving yield.

The study revealed significant disease prevalence and incidence variation among the surveyed districts. Districts in higher altitudes recorded higher incidences and prevalence than those in lower altitudes. The surveyed districts represent different agro-ecological zones where farmers apply different

practices. These practices include cropping seasons, cropping systems, disease management, and using various seeds sources, as revealed in this study from farmers' responses.

All these practices might have partly contributed to the observed variation in disease prevalence and incidences. Similar observation was also made by earlier scholars (Fernández *et al.*, 2000; Padder *et al.*, 2007; Mogita *et al.*, 2013; Devi & Narayanaswamy, 2017). Although there was a weak positive correlation between disease incidence, prevalence, and altitude, the districts with high disease prevalence and incidence were found in higher altitudes. Similarly, the district, which recorded the least disease incidence and prevalence, was at lower altitudes.

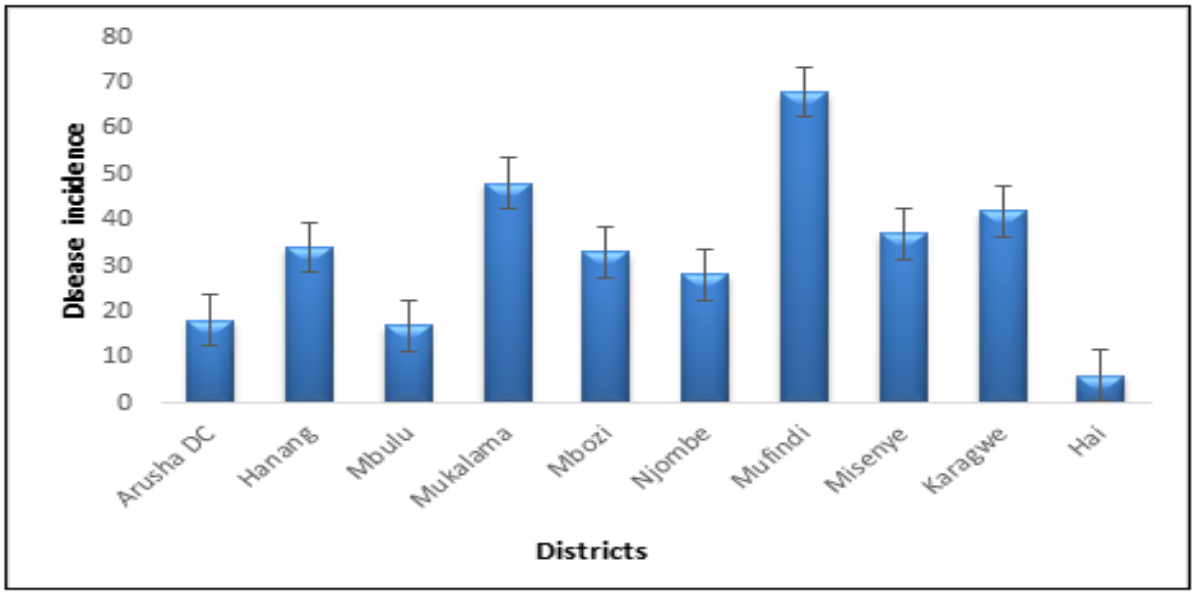

Fig. 2. The incidence of bean anthracnose in Tanzania (%).

This observation conforms with the findings of Mwesigwa (2009), who reported that the disease is associated with elevated altitudes in Uganda. Also, Yesuf and Sangchote (2007) reported a similar observation that bean anthracnose is more prevalent in higher altitudes with a moderate temperature ranging between 18-24°C, frequent rains, and high humidity. Interestingly, the study revealed a strong positive correlation between disease incidence and prevalence. This correlation may imply that farmers in given areas apply similar farming practices over seasons, resulting in inoculum build-up in the fields. Therefore, in absence of appropriate control measures as revealed in the farmers' responses, it may be difficult to break a diseases cycle in farms already infested with anthracnose. This observation conforms with a well-established scenario from several previous studies that disease prevalence is one of the main determinants of incidence as revealed by Ericson *et al.* (2001) in the rust fungus epidemics. Further, Paparu *et al.* (2018) reported a similar pattern in root rot diseases of common beans in Uganda.

Our findings from the survey of 280 farmers show that most farmers in the surveyed districts were aware of the bean anthracnose and had experienced the symptoms for more than four seasons. However, very few farmers were aware of the cause and ways of transmission of the disease. Not all farmers who said they knew transmission methods could associate it with the specific methods; some thought it was transmitted by air, soil, rainfall, or insects.

These results portray a limited knowledge of the bean anthracnose among farmers in Tanzania. Such findings conform with the results of Islam *et al.* (2020), who assessed farmers' knowledge of chilli pepper anthracnose in Bangladesh. Effective crop disease management largely depends on farmers'

knowledge of the respective disease, including the causative agent and its transmission (Tafesse *et al.*, 2018). Therefore, the observed lack of knowledge on the pathogen and disease transmission among farmers may account for the high prevalence and incidences recorded in this study. Thus, farmers need to be acquainted with bean anthracnose symptoms identification in their fields, the cause of the disease, and its transmission. Such knowledge can be disseminated through appropriate channels, including farmer training groups and farmer to farmer training. The training is possible as most farmers in the survey had at least a primary education level, capable of reading and writing. Similar studies have reported this knowledge gap among farmers in Tanzania (Adam *et al.*, 2015) and other developing countries (Islam *et al.*, 2020; Moses *et al.*, 2018; Nsiah *et al.*, 2021).

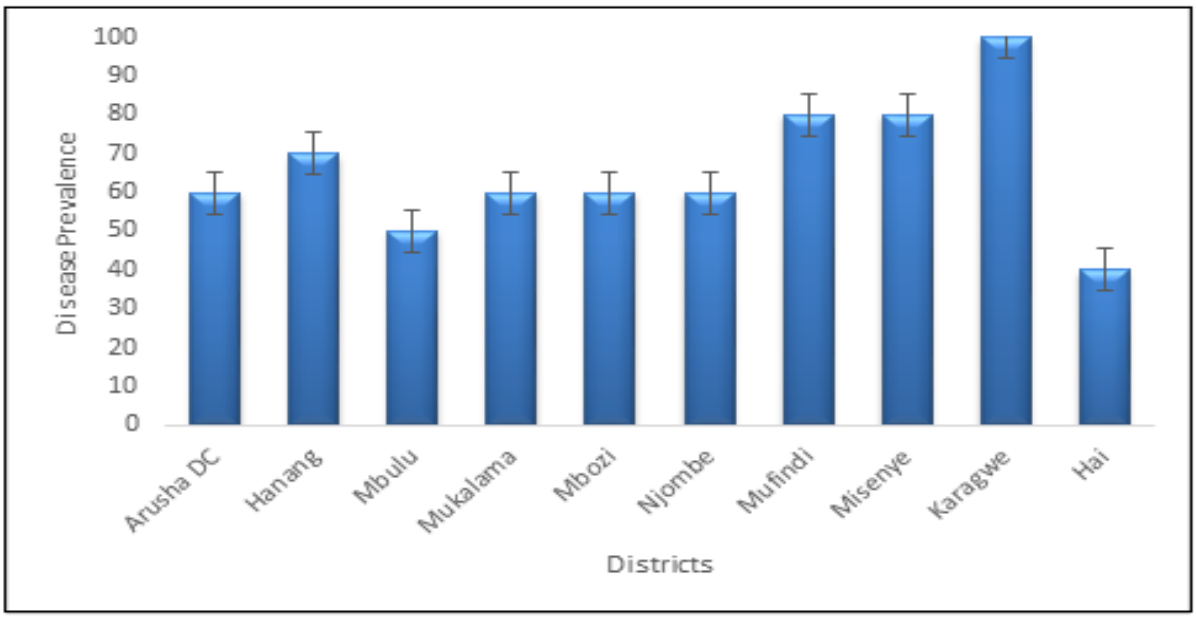

Fig. 3. Prevalence of bean anthracnose in the surveyed Districts in Tanzania.

The survey also revealed that more than half of the respondents used seeds saved from the previous season for sowing and more than a quarter obtained seeds from local markets. Unavailability and cost of certified seeds were the main reasons for their choices. Additionally, almost all respondents had no idea of resistant bean varieties to anthracnose. Because bean anthracnose is primarily transmitted by infected seeds (Yesuf & Sangchote, 2007), seeds saved from infected fields in the previous season and local markets may act as the source of inoculum. If this is done repeatedly, there is a potential for inoculum build-up in the fields and increased disease incidences. Therefore, such knowledge should be provided to farmers through extension services so that even if they use their saved seeds, thorough sorting and treatment is done to minimize the chances of sowing infected seeds. Islam *et al.* (2020) reported a similar observation when assessing farmers' knowledge of chilli anthracnose in Bangladesh. This observation may therefore account for the high disease prevalence and incidences observed in the surveyed districts in Tanzania.

Furthermore, more than half of the farmers did nothing after noting disease symptoms in their fields, whereas few used synthetic fungicides, cultural practices, and botanicals to manage anthracnose. It was also noted that most of the farmers did not use synthetic fungicides due to high costs, while others did not know the correct fungicides to apply. This observation indicates inadequate knowledge on the appropriate management options of bean anthracnose among farmers in Tanzania. The survey also clearly shows a limited knowledge on the safe application of the fungicides, as even those who used

fungicides could not remember the correct names of such chemicals. Applying inappropriate fungicides not only leads to the wastage of farmers' financial resources but also puts their health at risk. A similar observation was reported by Laizer *et al.* (2019) when assessing farmers' knowledge and perceptions in managing insect pests and weeds in northern Tanzania.

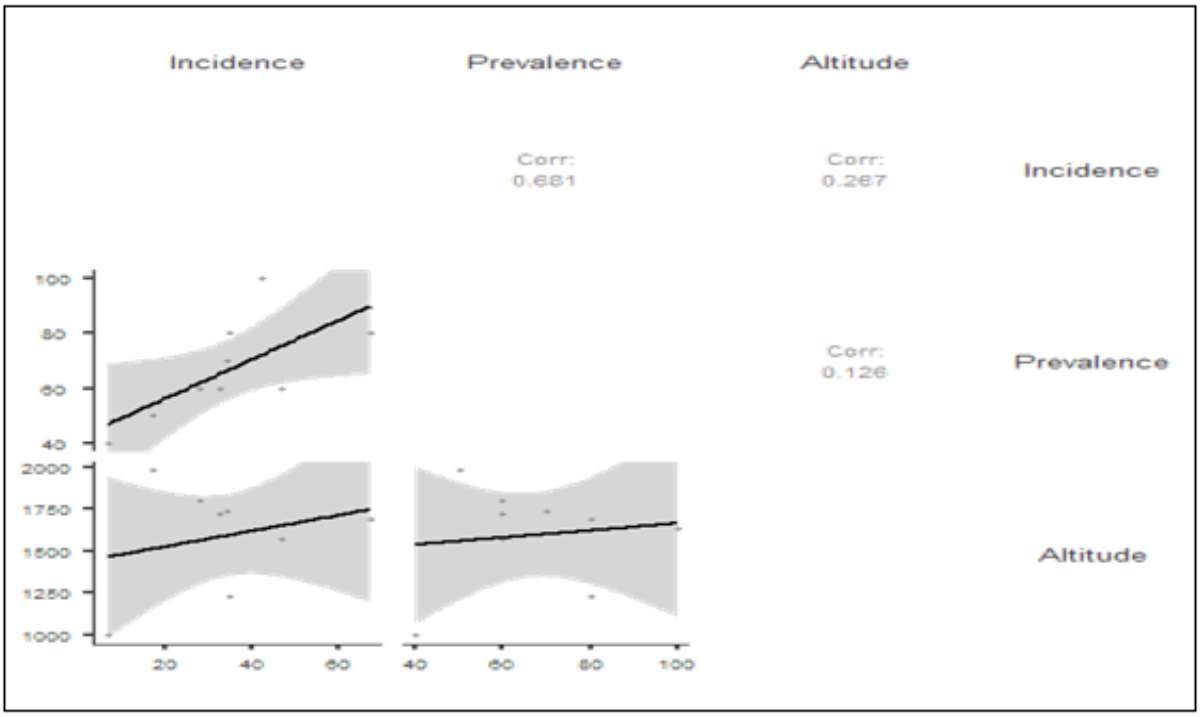

Fig. 4. Correlation between disease prevalence, incidence and altitude.

Additionally, there was a significant association between common bean production characteristics, farmers' knowledge of bean anthracnose, disease management knowledge, and districts. For instance, farmers grow common beans in two seasons annually in some districts, whereas the crop grows once a year in other districts. Sources of seeds, cropping systems and management practices also significantly varied across districts.

This clearly shows that bean growers across different agro-ecological zones in Tanzania apply different practices. Also, farmers' knowledge on managing bean anthracnose differs across the surveyed districts, as revealed in the survey. Mohammed (2013a) stresses that these practices can reduce anthracnose incidence to different extents.

Therefore, such association may account for the variation of disease prevalence and incidences observed during the field survey.

Conclusion

The study confirmed the prevalence of bean anthracnose with varying incidences in all the surveyed areas in Tanzania. The study also revealed that the majority of farmers are aware of the disease symptoms and perceive anthracnose as a bean production constraint. However, the study further indicates limited knowledge among most farmers on the cause and how anthracnose is transmitted. Poor knowledge of appropriate bean anthracnose management methods was also revealed in the study. Therefore, the study provides new insight into the current status and farmers' knowledge of bean anthracnose in Tanzania. The observed knowledge gap among farmers on the disease and its management necessitates capacity building on how bean anthracnose is spread and appropriate and affordable management methods. Farmers' capacity-building could be partly achieved through training, developing knowledge-sharing platforms, and extending extension support services.

Declaration of competing interest

All authors agree that no conflict of interest.

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