Assessment of *Fusarium* wilt (*Fusariumoxysporum*f.sp.*sesami)* Disease Incidence in Sesame (*Sesamum indicum* L.) in Western Tigray, Northern Ethiopia

Abstract

Fusarium wilt disease is one of the most serious diseases threatening sesame production in Tigray, northern Ethiopia. The aim of the present study was to assess Fusarium wilt disease incidence and its association with agronomic practices and environmental factors. Field survey was conducted in Kafta-Humera, Welkayt and Tsegedie districts in 2018 cropping season. A total of 92 farmers' fields were assessed for the prevalence and incidence of the disease. Results indicated that 67% of farmers' fields were infected by Fusarium wilt disease from the total assessed fields. Fusarium wilt disease incidence was varied from 0.22% to 80%. Itwas ranged from 0-72% in Kafta-Humera, 0-56% in Welkayt and 0-80% in Tsegedie.The mean disease incidence was 11.89% at Kafta-Humera, 11.14% at Welkayt and 10.69% at Tsegedie. According to the single predictor in the logistic regression model Fusarium wilt disease incidence was most affected significantly (p < 0.05) with the previous crop and altitude. Higher levels of disease incidence were recorded when the previous crop was sesame, lower altitudes and in clay loam soil texture. Overall results of the present study indicated that Fusarium wilt disease is the major challenge to sesame production in study areas. Therefore, efforts should be put in place to manage the disease via integration of appropriate strategies.

Key words: - Disease Incidences; *Fusarium* wilt disease;independent variable; Sesame; Survey

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest and most important crops cultivated by man, mainly for its high oil content and nutritive value. Sesame seed contains about 48-60% oil, 18-23.5% protein and 13.5% carbohydrate [1]. Moreover, the crop has good medicinal value, because sesame oil contains antioxidants such as sesamoline, sesamin and sesamol[2]. Sesame oil is used in cuisine for salad dressings and the manufacturing of margarine. It is also an ingredient in industry for making paints, varnishes, soaps, perfumes and pharmaceuticals [3].

Sesame is widely cultivated in tropical and sub-tropical parts of the world. It is a short-day plant, predominantly a self-pollinated plant species; with varying degrees of natural crossing ranging from 2% to 48% [4, 5]. The growth period may range from 70 days to 150 days, depending on the variety and the conditions of cultivation [6].Sesame requires adequate moisture for germination and early growth, and a precipitation of 300 mm to 800 mm per season is necessary for reasonable yields [7]. However, optimum yields are obtained in areas with 500 mm to 650 mm rainfall per annum well distributed over the 3 to 4 months growing period [8]. Sesame needs adequate amount of water during the seedling, flowering, and grain filling stages. It is well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams [7].

Ethiopia is among the leading sesame growing countries in the world. Total sesame production in the country was 2.56 million tons harvested from about 0.37 million hectares (ha) of land [9]. Sesame is predominantly cultivated in Tigray, Amhara, Oromia and BenishangulGumuz regions[9].In Ethiopia, sesame is a high value cash crop for both smallholder and commercial growers, and it is the second largest source of foreign exchange earnings after coffee [10]. However, yield per unit area remains low (0.7 tonnes/ha) in Ethiopia. This low productivity is attributed to various biotic and abiotic stresses. Plant diseases are the most important biotic factors causing huge economic losses [11, 12].Sesame is known to be affected by a number of plant diseases. The most wide spread diseases include bacterial blight (*Xanthomonasesesame*), *Fusarium* wilt (*Fusarium oxysporum* f. sp.*sesame*), phyllody (Phytoplasma/Mycoplasma), *Alternaria* leaf spot (*Alternariasesame*), *Cercospora* leaf spot (*Cercosporasesame*) and viral diseases [11, 12].Among the sesame diseases *Fusarium* wilt disease caused by *Fusariumoxysporum*f.sp.*sesame*is economically the most important and emerging disease that causes sudden death of plants and limiting sesame production [12]. However, little is known regarding the incidences, distribution and yield loss levels due to this fungal disease of sesame under varying production or farming system. Similarly, very little is known about the disease and its association with agronomic practices as well as in relation with the prevailing environmental condition and sesame cultivars in the major sesame growing areas of Tigray (Kafta-Humera, Welkayt and Tsegedie districts). In view of this, the present study was undertaken: 1) to assess the incidence and prevalence of *Fusarium* wilt disease in the major sesame growing areas of Tigray, northern Ethiopia; 2) to investigate the influence of agronomic practices and environmental factors on *Fusarium*wilts disease development in sesame.

2. Materials and methods

2.1.Description of study area

The survey for the prevalence and distribution of *Fusarium* wilt disease of sesame was conducted in three districts of western Tigray (Kafta-Humera, Welkayt and Tsegedie), northern Ethiopia (Figure 1), during the 2018 cropping season. The study area has a common boundary with Eritrea in north, TahtayAdyabo district in the east, Amhara Regional State in the south, and Sudan in the west [13]. The study area has altitude of 500 – 1600 meters above sea level (masl). These areas have mean annual temperature ranging from 21to 28^{o}C and with 300-800mm mean annual rainfall[7]. The average climatic data (temperature and rainfall) in the study districts during 2018 is presented in Table (1). The soils in the area are predominantly chronic vertisol types mostly with clay and clay loam texture [14]

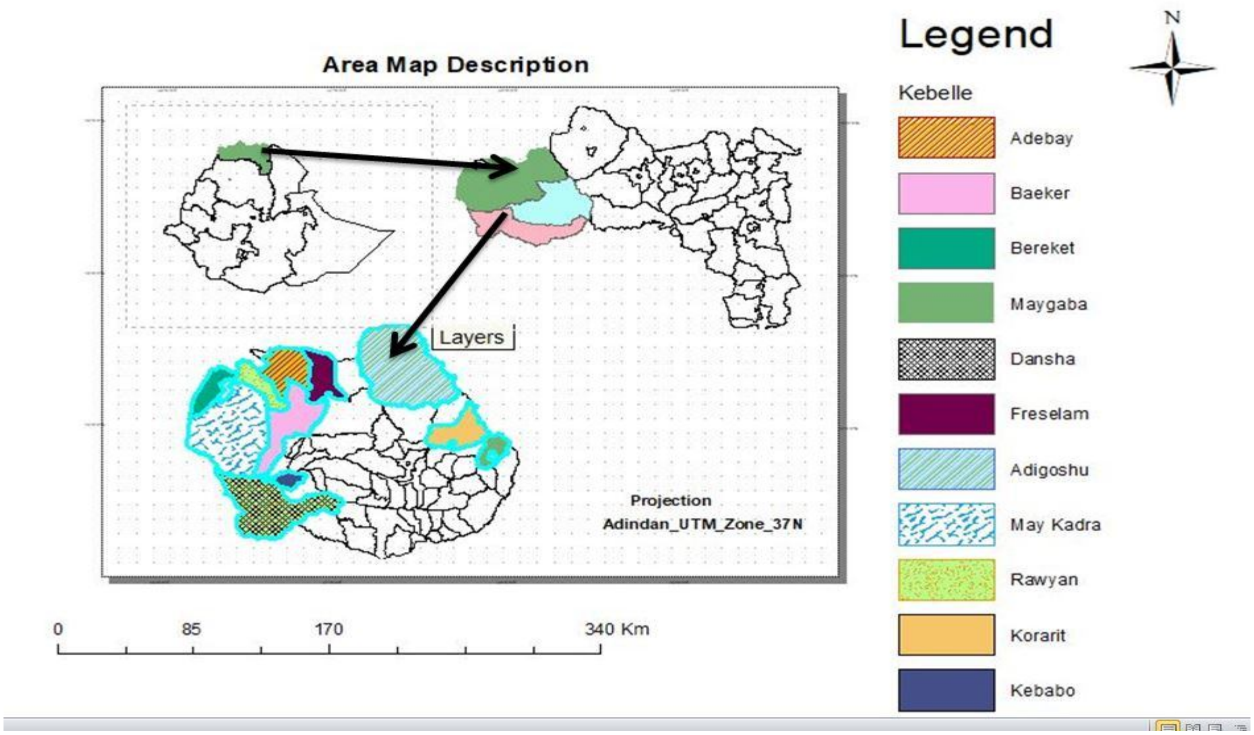

Figure1. Maps of Ethiopia and western Tigray where the sesame *Fusarium* wilt disease incidence and distribution survey study was performed.

Mixed farming system is the main occupation of the farm households. Sesame and sorghum are the major annual crops grown in the area. Both smallholder and commercial farmers grow sesame in the area. Over 400 large- scale investors are cultivating sesame on an average of 600 hectares of land each, while local farmers cultivate up to 12 hectares of land per head. In the area, investors cultivate 58% of the cultivated land while local farmers use the remaining 42%. Besides, the area is rich in small ruminant animals (cattle, sheep and goat), incense and gum resources [15]. These districts are lowlands and they are the major sesame production areas in Tigray, northern Ethiopia.

Table1. Climatic data of the study districts/ Woredas surveyed for the prevalence of sesame *Fusarium* wiltdisease, during 2018.

Kafta-Humera			Welkayt			Tsegedie (Dansha)		
Temperature (^oC)		RF (mm)	Temperature (^oC)		RF (mm)	Temperature (^oC)		RF (mm)
Max	Min		Max	Min		Max	Min	
36.07	21.84	736.5	34.94	20.98	661.3	36.56	20.18	769.2

RF: Rain fall; Max: Maximum;Min: Minimum; mm: Millimeter

2.2.Disease assessment and sampling technique

To determine the prevalence and incidence of sesame *Fusarium* wilt disease a total of 92 fields were randomly assessed in the three districts. A total of eleven Kebelles (the lowest administrative unit) were assessed: seven from Kafta-Humera district (Rawuyan, Bereket, Bahker, Adebay, May-kadra, Freselam and Adigoshu), two from Welkayt district (Korarit and Maygaba) and another two from Tsegedie district (Danshazurya and Kebabo). Districts were varied in agroecological conditions such as altitude, annual rainfall and temperature. The representative kebelles were selected based on the area coverage under sesame production and number of farmers cultivating the crop.

Assessment for sesame *Fusarium* wilt disease prevalence and incidence were conducted on farmer's field/ farm. Survey was conducted once per growing season at flowering and capsuling growth stage of the crop. Prevalence in this case reference to the occurrence of *Fusarium* wilt disease across the assessed areas (districts, kebelles and farmers' fields). Sampling sites within each Kebelle were separated by at least 1 km and at most 5 km apart from each other. In each field, sampling (data) was taken at 15 meters interval at 5 points along the diagonal of the selected field/ farm using 1 m x 1 m quadrat by randomly throwing in the field. Number of healthy and infected plants within the quadrat was counted and recorded. Then *Fusarium* wilt incidence was computed as mean percentage of infected plants showing typical symptom of the sesame *Fusarium* wilt disease divided by the total number of plants assessed in the quadrats.

2.3.Isolation and identification of the pathogen

The identification of the disease was primarily achieved using signs and symptoms [16] to support the field identification, diseased sesame plant samples were taken to the laboratory in Mekelle University for identification of the disease causative agent using culture characteristics and morphological features according to *Fusarium* laboratory manuals [17]. Sample plants were cut into small pieces, surface sterilized using 70% alcohol for 1 min followed by soaking in 1% sodium hypochlorite (NaOCl) solution for 2 mints and washed three times in sterile distilled water. After dried briefly in sterile paper towels under fume hood (biosafety cabinet) and samples were transferred to Petri-dishes containing Potato Dextrose Agar (PDA), and incubated for 7 days at 25 °C in the dark. Then colonies of *Fusarium* were transferred to SpeziellerNärstoffarmer Agar (SNA) and the identity of *Fusarium* species were confirmed by growing at 22±2 °C under alternating near UV/white fluorescent light (12 h) and dark (12 h) according to the procedures indicated in the *Fusarium*laboratory manual [17]. The identification of *Fusarium* isolates to species level was achieved using morphological features and cultural characters as described by [17].

2.4.Data collectionand calculation

2.4.1. **Prevalence:**

Proportion or percentage of sesame growing areas/ fields infected by *Fusarium* wilt disease to the total assessed areas/fields. Disease prevalence tells us the geographic or spatial distribution of the diseases.The percent diseases prevalence was calculated as follows using the following formula;

$$Disease\ prevalence\ (\%) = \left(\frac{number\ of\ cases\ infected}{total\ number\ of\ areas\ or\ fields\ assseed}\right) * 100$$

2.4.2. **Incidence:**

Disease incidenceis the proportion or percentage ofinfected plants showing typical symptom of sesame *Fusarium* wilt disease in field to the total plant units investigated. The percent of disease incidence was calculated using the following formula:

$$Disease\ incidence\ (\%) = \left(\frac{numberof\ plants\ infected\ with\ Fusarium\ wilt\ disease}{total\ number\ of\ plants\ assseed}\right) * 100$$

2.5.**Agronomic and edaphic data:**

In each surveyed area additional detailed information such as cultivar type (released varieties and local cultivars), planting date (late June and early July), previous crop (sesame and sorghum)and soil texture (clay, clay loam and sandy loam) was collected. Altitude, longitude and latitude of each assessed field were recorded using GPS.

2.6.**Climatic data:**

Mean annual temperature and rainfall of each district was obtained from Welkayt sugar corporation project, Hiwot agricultural mechanization Privet Limited share Company and Humera Agricultural Research Center (HuARC).

2.7.Data analysis

The mean *Fusarium* wilt disease incidence and prevalence in the different sesame growing districts, Kebelles and farmers' fields were analyzed using the SPSS version 20 (IBM SPSS statistics 20, Armonk, New York) software. Ordinal logistic regression model (often just called 'ordinal regression') was used to analyze analysis deviance, odds ratio and assesses the association of multiple independent variables on the response variable (*Fusarium* wilt disease incidence).

3. Results and discussion

3.1.Distribution and incidence of *Fusarium* wilt (*Fusariumoxysporum***f.sp.** *sesame)* disease:-

Fusarium oxysporum and its various *formaespecialies* have been characterized as causing the following symptoms: vascular wilt, yellows, damping-off and wilting of the leaves and stem (Figure 2). *Fusarium* wilt disease was prevalent across all sesame districts and Kebelles (Tabials) included in this survey. Assessment was conducted on ninety two fields at three districts. Out of the assessed fields, 67.4% were affected by *Fusarium* wilt disease. Disease prevalence varied greatly among fields, in which some of the fields were free of the disease whereas in some other fields 80% of the sesame plants were infected by *Fusarium* wilt disease. In *Fusarium* wilt affected fields disease incidence varied from 0.22% to 80%. On average, 17.23% of the sesame plants were affected with *Fusarium* wilt disease in the fields assessed. In Kafta-Humera district, the mean *Fusarium* wilt disease incidence in the surveyed Kebelles ranged from 3.4% to 23.8% with overall average disease incidence of 11.89%. The lowest mean disease incidence of 3.4% was recorded at Bereket; while the highest mean disease incidence (23.8%) were recorded at Adigoshu followed by May-kadra (21.56%). The highest *Fusarium* wilt disease incidence recorded was 72%, which was recorded in one of the fields at May-kadra (Table 2).

In Welkayt district *Fusarium* wilt disease assessment was performed in two major sesame growing kebelles, namely Korarit and Maygaba. The mean disease incidence at Korarit was 7.29%, whereas the mean disease incidence at Maygaba was 15%. The individual farm level disease incidence in this district ranged from nil to 56%, with the highest disease incidence recorded in one of the fields at Maygaba (Table 2).

In Tsegedie district fields in the major sesame growing areas of Danshazurya and Kebabokebelles were assessed for the disease. The lowest 0.33% means disease incidence was observed in Danshazurya, whereas the highest mean disease incidence (19.57%) was recorded at Kebabo. Individual farm level data indicated that disease incidence ranged from nil to 80%, with the maximum disease incidence recorded in KebaboKebelle (Table 2).

Figure 2. *Fusarium* wilt disease affected sesame plants in the areas surveyed.

Results of the present study indicated that *Fusarium* wilt disease is the major constraints and challenge to sesame production in western Tigray, northern Ethiopian.The disease was widely distributed in most sesame producing areas. High mean percent *Fusarium* wilt disease incidence was observed across all the districts included in this study indicating a substantial sesame loss, as the disease kills infected plants which directly translated into yield losses. Results also showed that there was great variation ($p<0.05$) in *Fusarium* wilt disease incidence among sesame growing fields (0-80%) and among kebelles (0.33% to 23.8%), and to some extent among sesame growing districts. This could be partly due to variation in climatic condition such as temperature and moisture/rainfall as well as edaphic factors including soil texture differences among sesame growing districts and kebelles. [18]Indicated that the influence of climatic conditions on the prevalence of *Fusarium* spp. may be due to a direct effect on the growth, production and dispersal of inoculum, but also indirectly by the effect on soil and vegetation type, which may influence saprophytic survival. It is known that *Fusarium oxysporum* is a common soil pathogen and saprophyte that feeds on dead and decaying organic matter; it survives in the soil debris and pathogen spreads short distances by water splash, and long distances by wind and infected seeds [19, 17]. In addition to climatic and edaphic factors, agricultural practices such as previous crop and choice of crop cultivar/variety applied by different sesame growing farmers, may have great impact on the amount of inoculum and incidence of sesame *Fusarium* wilt disease. Results of the present study are in agreement with the survey result of [20] in India that reported the incidence of *Fusarium* wilt could vary depending on the growing condition.

Table 2. Distribution and incidence of *Fusarium* wilt disease in the major sesame growing district and kebelle of western Tigray, northern Ethiopia, during the 2018 cropping season.

			Disease Incidence (%)			
District	Kebelle	Sample farm	Maximum	Minimum	Mean	Standard error
Kafta- Humera	Rawuyan	9	12	0	3.67	1.344
	Bereket	5	12	0	3.40	2.358
	Bahker	8	22	0	6.75	2.827
	May-kadra	18	72	0	21.56	5.276
	Freselam	9	30	0	5.67	3.180
	Adebay	11	35	0	10.09	3.290
	Adigoshu	5	70	0	23.80	12.924
	Total	65	72	0	11.89	2.104
Welkayt	Korarit	7	24	0	7.29	3.797
	Maygaba	7	56	0	15.00	7.290
	total	14	56	0	11.14	4.091
Tsegedie	Danshazurya	6	2	0	.33	.333
	kebabo	7	80	0	19.57	11.781
	total	13	80	0	10.69	6.712
Assessed field	Free	30	0	0	0	0
	Infected	62	80	0.22	17.23	2.44

It was observed that; mean *Fusarium* wilt disease incidence was higher on sesame fields with cropping history of sesame after sesame (14.61%) thanthaton thefieldwithsesame rotated with sorghum (6.94%) (Figure 3). Mon-croppingof sesame with season year to year may lead to increased inoculum of the pathogen in the soil, and subsequently higher disease incidence in next generation of plants. *Fusarium* wilt is a monocyclic disease and the initial inoculum level is very important for determining the incidence of the disease. However, management of *Fusarium* wilt disease using crop rotation is not simple, as the inoculum can survive in the soil for long time, by forming thick-walled structures, known as chlamydospores and as mycelia in infected plant debris, saprophytically[17]. According to several authors [21, 22] the use of crop rotation helps to reduce inoculum of *F. oxysporum* and it can be used for management of *Fusarium* wilt disease in combination with other control strategies such as host plant resistance. [23]Stated that the use of resistant cultivars is the most effective measure to manage diseases caused by *Fusarium oxysporum*. In addition, [24] indicated that planting resistant varieties, using clean seeds, cleaning of infected crop residue and removing infected plant tissue to prevent overwintering of the pathogen, could help to reduce the prevalence of the disease.

Highest mean *Fusarium* wilt disease incidence was recorded on fields of clay loam textured soil (16.5%) and lowest on fields of sandy loam soil texture 4.91% (Figure 3). The observed highest *Fusarium* wilt disease incidence on sesame plants grown on clay loam soil could be due to its high moisture retaining capacity, which is important for germination of spores and growth of the pathogen. The fungus possesses a high competitive saprophytic ability and spreads in the soil, mainly by conidia carried by water movements. However, well-drained and aerated soil may reduce *Fusarium* wilt disease intensity by improving root development and liming microbial activity [25]. In contrast, soils with high levels of compaction and lower aeration may favor the disease.In addition, [26] reported that soils with high bulk density are more conducive for *Fusarum* wilt disease. The disease is more severe when the soil and air temperature are high during the growing season [16]. This was clearly observed during the survey in the sesame growing areas and meteorological data in these areas. According to [27], the optimum temperature for growth of pathogen is between 25-30 °C, and the optimum soil temperature for root infection is 30 °C or above and warm moist soils.

The highest mean Fusarium wilt was recorded on less than 700 mill-meters above sea level. It could be due to amount temperature increase when altitude of sesame cultivated areas decrease this leads to favorable condition for the pathogen. Similarly, studies by [18, 28] revealed lower altitudes recorded high incidence of wilt and thus higher temperatures encourage the development of *Fusarium* wilt.

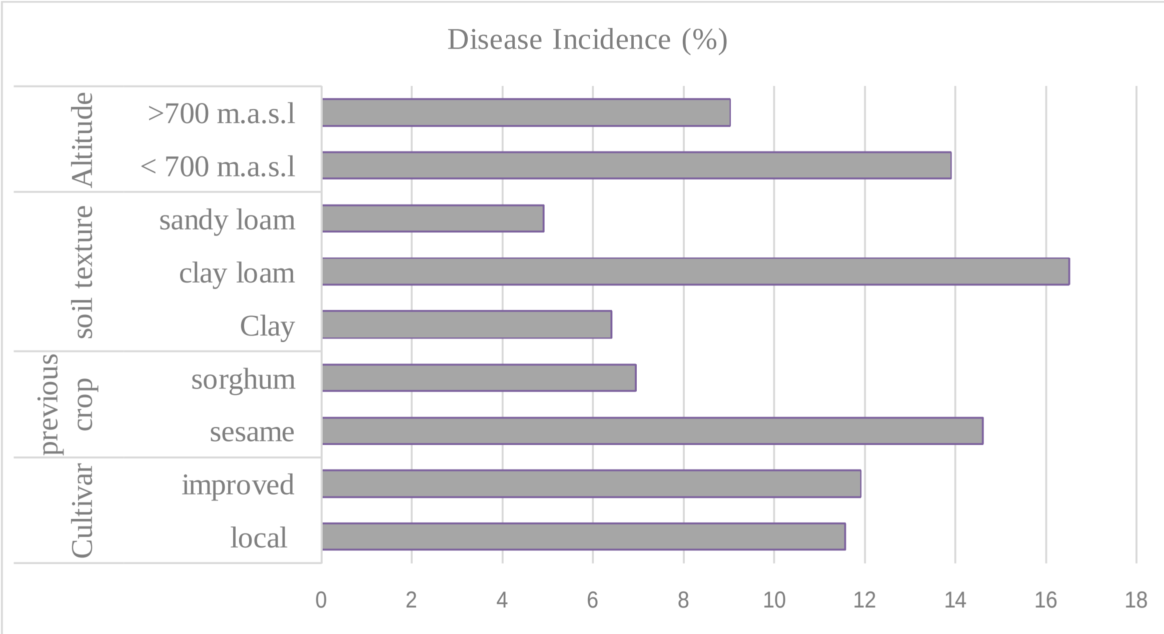

Figure 3. Influence of different agronomic practices and environmental factors on *Fusarium* wilt disease incidence, in western Tigray, northern Ethiopia, during the 2018 cropping season.

3.2.Association of climatic, edaphic and agronomic variables with*Fusarium* wilt disease incidence

The associations of different climatic factors, edaphic and agronomic variables with the incidence of *Fusarium* wilt disease werepresented in table 3. According to the single predictor in the logistic regression model, *Fusarium* wilt disease incidence was significantly affected by the previous crop and altitude. This shows that inoculum density and temperature (both soil and air temperature) are important in *Fusarium* wilt disease development on sesame plants[27, 16]. Therefore, management strategies that are able to reduce the amount of inoculum in the field may help for managing the disease. However, other variables such as district, kebelle, cultivars and sowing date were not significantly associated with the disease incidence. This was because there was not much climatic difference among the investigated districts and Kebelles. Besides, it indicates that there is no difference among the local sesame cultivars andimprovedcultivarsdominantly grown in the area for resistance to *Fusarium* wilt disease.

As the results of odds ratio indicates, there was low association between *Fusarium* wilt disease incidence and the variable class altitude > 700 meter above sea level. However, higher sesame *Fusarium* wilt incidence was observed on the variable classes; Kafta-Humera, local cultivar, Mono-cropping sesame, altitude (<= 700 meter above sea level) and at capsule growth stage (Table 3).

Table 3. Analysis of deviance, parameter estimate, odds ratio and standard error of added variables in a reduced model predicting *Fusarium* wilt incidence.

Group variables	DF	LRT		Variable class	Parameter estimate	Std. Error	Odds ratio	Pro<5%
		DR	Pr>χ2					
District	2	54.85	0.66	K. Humera	0.352	0.772	1.422	0.648
				Welkayt	0.401	1.074	1.493	0.709
				Tsegedie	000[a]	000[a]	1	
Cultivar	1	27.39	0.6	Local	0.051	0.645	1.053	0.937
				Improved	000[a]	000[a]	1	
Previous crop	1	41.05	0.049	Sesame	0.618	0.44	1.855	0.16
				Sorghum	000[a]	000[a]	1	
Soil texture	2	56.03	0.62	Clay	0.45	0.88	1.569	0.609
				Clay loam	1.817	0.817	6.152	0.026
				Sandy loam	000[a]	000[a]	1	
Altitude	1	41.47	0.06	>700masl	-0.844	0.537	0.43	0.116
				<=700masl	000[a]	000[a]	1	

DF: Degree of freedom, DR: Deviance reduction, K. Humera: Kafta-Humera, LRT: Livelihood ratio test, Pr: Probability of χ2 value exceeding the deviance reduction, Std. Error: Standard error, a: Reference group variable.

4. Conclusion

Overall results of the present study indicated that *Fusarium* wilt disease is the major challenge to sesame production in western Tigray, northern Ethiopian. Therefore, efforts should be put in place to manage the disease via integration of appropriate strategies. *Fusarium* wilt disease incidence was more prevalent in Kafta-Humera, but varied from field to field, and future field trials should be placed on these hot-spot areas. Survey result revealed that high disease incidence was associated with some biophysical factors such as previous crop, soil texture and to some extent choice of cultivar. Therefore, further studies on the impact of agricultural practices, environmental and edaphic factors on sesame *Fusarium* wilt disease development should be conducted across several years for better understanding.

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