Assessment of Sesame Bacterial Blight (*Xanthomonas Campestris Pv. Sesami*) on Sesame (*Sesamum indicum L.*) in North Gondar, Ethiopia

Asfaw Azanaw[1*], Chemeda Fininsa[2], Samuel Sahile[3], Geremew Terefe[4]

[1]Plant Pathologist, Gondar Agricultural Research Center, P.O.Box 1337 Gondar, **ETHIOPIA**
[2]Plant Pathologist and University President, Haramaya University, P.O.Box 138 Dire Dawa, **ETHIOPIA**
[3]Plant Pathologist, University of Gondar, P.O. Box 309, Gondar, **ETHIOPIA**
[4]Plant Pathologist, Sesame Bussiness Network Programme Coordinator, P.O.Box 1337 Gondar, **ETHIOPIA**

*Corresponding Contact:
Email: asfaw.azanaw@yahoo.com

ABSTRACT

Sesame is one of the important oil crops in Ethiopia for the international market while its production has challenged by lack of appropriate agronomic practices, weather uncertainties, weeds, insects and diseases outbreaks. Bacterial leaf blight caused by Xanthomonas campestris PV. sesami is the most common and inflicts heavy qualitative and quantitative losses. The objectives of the present study were to assess bacterial blight incidence, severity and its association with agronomic practices in north Gondar Ethiopia. A Field survey was conducted in Metema and Mirab Armachiho in 2014 cropping season at flowering and fruiting growth stages. A total of 80 fields were assessed for the disease assessment from both large and small-scale farmers. Data on prevalence, incidence, severity and, management practices have been recorded. All surveyed fields were infected both at flowering and fruiting stage of the crop. Mean incidence over the two districts varied from 78% at Metema to 96.5% at Mirab Armachiho. The minimum mean severity (6.1%) has been recorded in Metema district and, the highest mean severity (76.9%) has been recorded at Mirab Armachiho. The association of independent variables with bacterial blight incidence and severity were varied. The district, variety, growth stage, altitude, slope, crop density, previous crop, soil type, and weed density variables have significantly associated with bacterial blight incidence. Variables producer and sowing date were non-significant as a single predictor in the logistic regression model. Similarly, all the variables were significantly associated with bacterial blight severity.

Keywords: Sesame, Bacterial blight, Severity, Variable, and Association

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INTRODUCTION

Sesame is an annual plant that belongs to the Pedaliaceae family. It is a short-day plant and is self-pollinated although it has cross-pollination ranging from 5 to over 50% occurs (Pathirana, 1994). It is an erect, herbaceous annual plant that has two growth characteristics: indeterminate and determinate, with heights of up to two meters. Similarly most varieties show an indeterminate growth habit, which is also shown as a continuous production of new leaves, flowers, and capsules as long as the environment remains suitable for growth (Carlsson *et al.*, 2008). The growth period ranges from 70 to 150 days, depending on the variety and the conditions of cultivation (Ashri, 1998).

Sesame is grown in areas with annual rainfall of 625-1100 mm and temperature of greater than 27 ºC. The crop is tolerant to drought, but not to water logging and excessive rainfall. Sesame is well adapted to a wide range of soils but requires deep, well-drained, fertile sandy loams. In Ethiopia, sesame grows well in the semiarid areas of Amhara, Tigray, Benshangul Gumuz, and Somali regions. Lowlands of Oromiya and Southern Nations Nationalities and Peoples Regions also grow a significant amount (Geremew *et al*., 2012).

In Ethiopia, sesame is the first among oil crops in area coverage and total production. It covers nearly 299,724.41ha of land with annual production of about 220,216 metric tons with an average productivity of 735 kg ha^{-1}. The Amhara region account for 138,848.29 ha with 100,590.6 metric tons and North Gondar covers 103,629.43ha (74.64%) of sesame land of the Amhara region (CSA, 2014). The Amhara region accounts for 138,848.29 ha with 100,590.6 metric tons, and North Gondar covers 103,629.43ha (74.64%) of sesame land of the Amhara region (CSA, 2014). There is a wide gap between the national yield average of sesame under rain fed conditions (400-900 kg ha^{-1}) and under irrigated conditions (1,000-1,800 kg ha^{-1}) (EARO, 2004).

Sesame is known to be a susceptible crop for some diseases. In Ethiopia, the widest diseases include bacterial blight, phyllody, powdery mildew, wilt, leaf curl and viral (Geremew and Asfaw, 1992; Getinet *et al*., 1997). In Pakistan, it has been reported to be the host of many diseases that include bacterial blight (*Xanthomonas campestris* (Pammel) Dawsonpv. *sesami*), bacterial leaf spot (*Pseudomonas syringae*), Alternaria leaf spot (*Alternaria sesami*) (Ojiambo *et al*., 2003), and damping-off or root rot (*Macrophomina phaseolina*). Virus and virus-like organisms, causing diseases such as mosaic, leaf curl, and phyllody have also been reported.

Among these diseases bacterial leaf blight caused by *Xanthomonas campestris* (Pammel) Dawson PV. s*esami* is the most common and could inflict heavy losses on production (Girma, 2010). The disease has been reported to be endemic in much high rainfalls and humid areas of the country (Geremew and Asfaw, 1992; Geremew *et al*., 2009). Typically it is manifested by dark brown water-soaked spots, which later coalesce and form foliage blight and lead to defoliation (Bashir *et al*., 2007). Major sources of initial inoculums are infected seeds and plant debris in the soil (Kolte, 1986). The secondary cycle of the disease starts the foci of primary infection mainly by rain splash, as the bacteria emerge from diseased tissue into the surface water, providing a source of inoculums for as long as the rain lasts.

Even though North Gondar like Metema and Mirab Armachiho are a potential area for sesame production, in recent years, information on the importance of sesame bacterial blight under varying production systems (small and large scale) has not been assessed so far and there is no detailed quantitative information of the sesame bacterial blight level and its association with agronomic practices for designing an effective integrated sesame bacterial blight management. Therefore, the present study is designed to assess the importance of bacterial blight disease on sesame and determine the relationship of the disease intensity with crop management practices.

MATERIALS AND METHODS

Survey districts

Survey of bacterial blight of sesame has been conducted in Metema and Mirab Armachiho district in north Gondar Zone during 2014 main cropping season. The area represents the lowlands of major sesame production area of Amhara region. The altitude of Metema district ranges from 550 to 1608 masl and located 12^0 47′N latitudes to $38^0$27′ longitude (IPMS, 2005). The altitude of Mirab Armachiho district ranges from 620 to 850 masl and located13^{0}59′N latitude to $38^0$27′ longitude. In both districts, the mean minimum and maximum annual temperature are 20^0C and 35°C during the rainy season, respectively. Daily temperature becomes very high during March to May, where it may get as high as 42°C. According to the available digital data, the mean annual rainfall for the Metema ranges from 850 to around 1100 mm. The soils in the area are predominantly veritisol and nitosol types mostly with clay and sandy loam texture.

A Mixed farming system is the main occupation of the farm house holds. The Districts are known for its high potential for sesame, sorghum and cotton production. Besides, it is rich in small ruminant animals, incense and gum resources. According to offices of agriculture of the zone report, every year area covered by sesame, cotton, and sorghum farms in the districts were above 90%, and these crops are the most important marketable commodities.

Table 1**:** Climatic features of districts surveyed for sesame bacterial blight in North Gondar zone 2014

Month	Metema				Mirab Armachiho			
	Temperature (ºC)		RF (mm)	RH (%)	Temperature (ºC)		RF (mm)	RH (%)
	Max	Min			Max	Min		
May	38.4	21.9	86.4	47.5	36.4	27.1	110.8	56.8
June	34.6	20.9	89.3	55.2	32.2	25.5	112.4	58.3
July	30.8	20.5	198.7	71.4	27.5	24.1	397.4	69.9
August	30.2	19.8	223.2	77.9	25.9	22.2	332.4	74.8
September	31.7	19.3	324	77.2	N/A	N/A		72.5
October	34.4	19.2	127.9	78.5	N/A	N/A		

Source: Bahirdar Meteorology Agency

Max = Average maximum monthly temperature, Min = Average minimum monthly temperature, RF = Average monthly rainfall, RH = Average relative humidity, N/A = Not Available

Disease assessment

A total of 80 fields were randomly assessed for sesame bacterial blight incidence and severity assessment purposely both from large and small-scale farmers. The survey was done once at flowering and fruiting growth stages. Fields were sampled randomly at intervals of 5–10 km along accessible roads starting from Gende wuha town. Data were taken at 15 meters interval once at three points along the diagonal of the field using 1 x 1m quadrate randomly. A number of healthy and infected leaves of 5 plants within the quadrate have been recorded. Bacterial blight incidence has been rated as a mean percentage of infected leaves of 5 plants showing a typical symptom of the disease per total leaves of plant units assessed. Severity was recorded on five plants using Rayner's graphic representation. Disease prevalence has been taken as the proportion of the field's sesame bacterial blight was occurred.

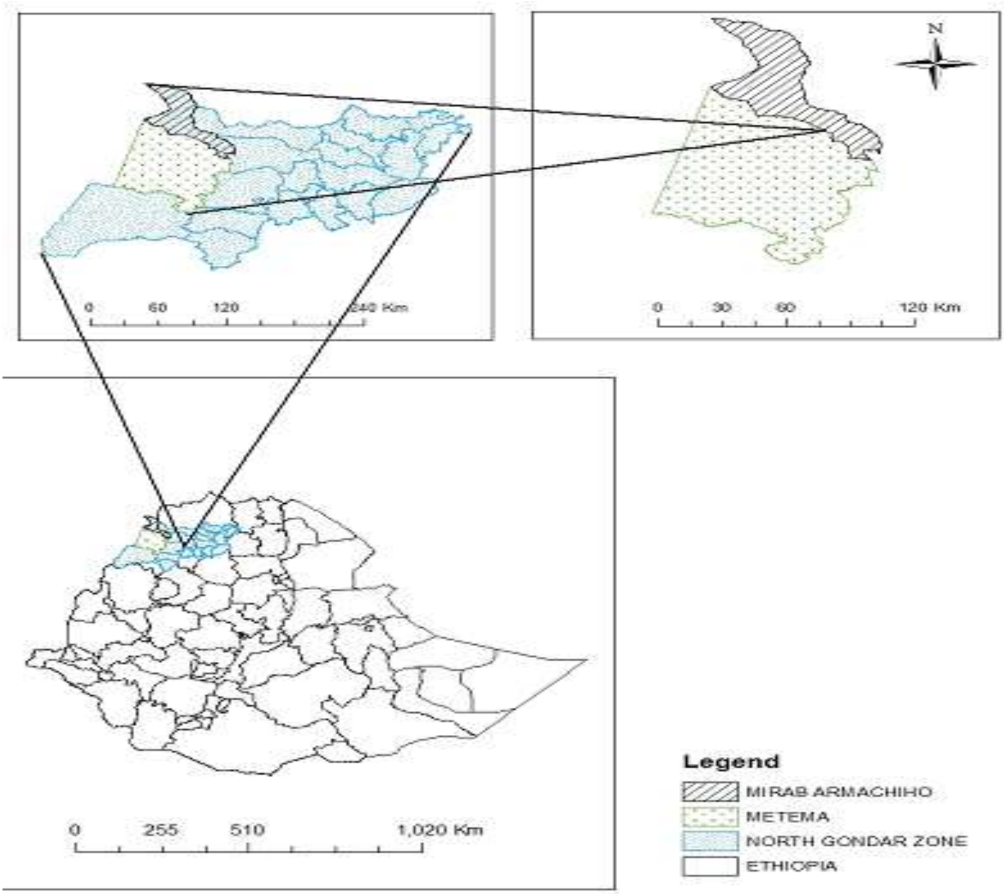

Figure 1: Map of sesame bacterial blight surveyed areas in 2014 cropping season at North Gondar zone, Ethiopia

To do an association of sesame bacterial blight besides the disease intensity data, agronomic practices were also recorded on each field. The variety grew whether local or improved, previous crop (sesame, sorghum, and cotton), planting date (June or July), were collected through interview and assessment. The average of three quadrate ($1m^2$) of sesame and weed stand count (≤ 25 /m^2, 25-40/m^2 and >40/m^2) were taken to determine the crop and weed density, respectively. Altitude ($\leq$700 and >700masl) and slope ($\leq$8 and >8%) of each field were measured using GPS and Clinometers, respectively. Soil type (black or brown), and growth stage (flowering and fruiting) have been also recorded in each field.

The disease intensity was classified in two whether or not the levels of infestation exceed 25% severity and 95% incidence. It is on the base that as to experienced researchers said sesame below 25% severity is categorized under tolerant group. Based on this, the disease intensity was categorized into two main groups to generate binary dependant variable. A contingency table of disease intensity by independent variables was built to represent the bivariate distribution of fields (Table 2).

Table 2: Categorization of variables used for logistic regression analysis of bacterial blight in sesame fields (n = 80) during the 2014 cropping season, North Gondar, North West Ethiopia

Independent variable	Variable classes	Number of fields with Bacterial Blight			
		Incidence (%)		Severity (%)	
		≤95	>95	≤25	>25
Districts	Metema	23	17	17	23
	Mirab Armachiho	3	37	7	33
Growth stage	Flowering	8	16	6	18
	Fruiting	18	38	18	38
Variety	Local	18	46	14	52
	Improved	8	6	10	4
Crop density	≤25 /m^2	0	1	1	0
	25-40/m^2	2	2	1	3
	>40/m^2	24	51	20	55
Sowing date	June	18	32	20	30
	July	8	22	4	26
Previous crop	Sorghum	16	15	18	13
	Cotton	2	4	3	3
	Sesame	8	35	3	40
Producer	Small scale	14	25	17	22
	Large scale	12	29	7	34
Soil	Brown	19	27	17	29
	Black	7	27	7	27
Weed density	≤25 /m^2	5	2	6	1
	25-40/m^2	12	15	11	16
	>40/m^2	9	37	7	39
Altitude	≤700	0	29	4	25
	>700	26	25	20	31
Slope	≤8%	14	39	11	42
	>8%	12	15	13	14

DATA ANALYSIS

Disease incidence and severity were described using the SAS software system (SAS, 2002). The association of bacterial blight disease incidence and severity with independent variables was analyzed using logistic regression as described by McCullagh and Nelder, 1989; Fininsa and Yuen, 2001; Woldeab *et al.*, 2006; Sahile *et al.*, 2008; Girma, 2010 with the SAS procedure GENMOND. The logistic regression model assesses the importance of multiple independent variables that affect the response variable. It calculates the probability of a given binary out come as a function of the independent variables. The binary outcome was the probability that bacterial blight severity exceeds 25% and incidence exceeds 95% in a given sesame field. The SAS procedures GENMOND and logistic were used to estimate the parameter estimates. Exponentiation the parameter estimates of each variable class results in the odds ratio, which is interpreted as relative risk.

The importance of the independent variables (risk factors) have been evaluated in two ways; first, the association of an independent variable alone with bacterial leaf blight incidence or severity was examined. In the other method, independent variables with a high association to bacterial leaf blight incidence or severity were added to reduce multiple variable model. Deviance reduction was calculated for each variable as it was added to the reduced model and likelihood ratio test was used to examine the importance of the variable and was tested against χ^2- value (McCullagh and Nelder, 1989). To predict the severity of sesame bacterial blight effect the relationship of the disease severity with weed and crop density per square meter were modeled using a simple linear regression model.

RESULTS AND DISCUSSION

Prevalence

Out of the total 80 fields assessed all sesame fields were 100% affected with the bacterial blight at flowering and fruiting stages of the crop in both districts. Similar reports have been made by Malaguti (1971) indicating that the disease affecting plants of all ages and causing a severe blight on leaves, petioles, flowers, and stem, resulting in defoliation, and sterility.

Incidence

Bacterial blight of sesame has been observed in all surveyed fields of the two districts in both large and small-scale producers. Mean incidence over the two districts varied from 78% at Metema to 96.5% at Mierab Armachiho. A minimum incidence of 22.7% and 33.6% was recorded for Metema and Mirab Armachiho, respectively while the maximum mean incidence of 100% was recorded for both districts. The overall disease incidence of 63% was recorded at flowering and fruiting stages of the crop. Geremew *et al.* (2009) reported that sesame blight incidence varied from 25 to 99% in Ethiopia. It is also in a full agreement with the survey result of Girma (2010) done at Assosa zone where overall disease incidence was 99.1%.

Sesame that was sown by large-scale producers on sesame residue late on July using a local variety with crop density above 40 plants per meter square, at the stage of flowering noted highest mean incidence of bacterial blight. Also, sesame that was sown on black soils with a slope less than 8% and high weed density had relatively highest bacterial blight mean incidence. However, sesame sown by small-scale producers on sorghum residue early on June using an improved variety with less plant population and weed per meter square and on relatively sloppy field noted relatively had lowest bacterial blight on the districts (Table 3).

Geremew *et al.* (2012) reported, in Ethiopia, sesame bacterial blight intensity varies depending on topography, altitude, and weather conditions. Disease incidence reaches up to 100% in areas such as Wellega, Pawe, and Gambella where high humidity persists for a longer time, while it is about 10-50% in semi-arid areas like Werer and Humera. Water logging encourages the spread of the disease.

Severity

Among the sesame fields surveyed, the minimum mean severity (6.1%) was recorded in Metema district, and the highest mean severity (76.9%) was recorded at Mierab Armachiho during the cropping season. The least mean bacterial blight severity (6.1%) was noted on sesame sown on cotton residue, and the highest (76.9%) was obtained on sesame residue fields. Sesame fields cultivated by large-scale producers with local varieties at an altitude below 700m, with high crop and weeds population and at fruiting stage had the highest severity as compared to their respective variable classes in the two districts on the cropping season (Table 3). The assessment done at Assosa zone by Girma (2010) on the bases of localities showed that the mean highest severities were recorded at Assosa (52%), Banbasi (40%) and lowest in Sherkole (19%) and Kurmuk (22%). The disease has been reported to be more damaging under conditions where there is high rainfall and humidity persisted for a long period (Habish and Hamad, 1970).

Table 3: Mean incidence and severity of sesame bacterial blight for different independent variables in 2014 cropping season, north Gondar zone

Independent variable	No. fields	Incidence (%)				Severity (%)			
		Min	Max	Mean	SD	Min	Max	Mean	SD
District									
Metema	40	22.7	100.0	78	26.1	6.1	67.5	29	15.3
Mirab Armachiho	40	33.6	100.0	96.5	13.0	18.3	76.9	41	14.5
Growth stage									
Flowering	24	31.9	100.0	90.2	18.3	8.7	67.5	31.3	12.5
Fruiting	56	22.7	100.0	86.1	24.1	6.1	76.9	36.8	17.2
Variety									
Local	66	31.9	100.0	91	18.9	14.8	76.9	37.5	14.9
Improved	14	22.7	100.0	72.5	31.5	6.1	67.5	24.1	17.3
Crop density									
≤25 /m^2	1	100.0	100.0	100	-	8.7	8.7	8.7	-
25-40/m^2	4	36.7	100.0	79.2	29.3	10.7	67.5	28.1	26.5
>40/m^2	75	22.7	100.0	87.6	22.3	6.1	76.9	35.8	15.3
Sowing date									
June	50	22.7	100.0	86.0	23.1	6.1	76.9	32.9	17.2
July	30	28.7	100.0	89.5	21.6	17.1	68.9	38.8	13.1
Previous crop									
Sorghum	31	28.7	100.0	77.7	26.8	8.7	67.5	26.9	14.6
Cotton	6	22.7	100.0	79.0	33.8	6.1	48.7	27.9	15.1
Sesame	43	35.4	100.0	95.5	12.3	18.5	76.9	42.1	14.0
Producer									
Small scale	39	28.7	100.0	85.2	23.9	8.7	68.9	31.6	16.5
Large scale	41	22.7	100.0	89.4	21.1	6.1	76.9	38.5	15.2
Soil									
Brown	46	30.8	100.0	83.9	23.2	8.7	68.9	32.5	15.4
Black	34	22.7	100.0	92.1	20.9	6.1	76.9	38.7	16.4
Weed density									
≤25 /m^2	7	22.7	100.0	67.9	31.0	6.1	29.6	17.0	7.6
25-40/m^2	27	28.7	100.0	83.2	25.5	8.7	55.4	29.6	12.2
>40/m^2	46	33.6	100.0	92.8	16.7	14.3	76.9	41.1	15.9
Altitude									
≤700	29	100	100.0	100.0	0.0	18.3	76.9	42.5	14.1
>700	51	22.7	100.0	80.2	25.5	6.1	68.9	30.9	15.6
Slope									
≤8%	53	30.8	100.0	91.0	18.7	9	68.9	36.9	15.0
>8%	27	22.7	100.0	80.1	27.4	6.1	76.9	31.6	17.6

SD = Standard deviation, m = meter, Min = Minimum, Max = Maximum

Association of independent variables with the disease intensity

The association of independent variables with bacterial blight incidence and severity was presented in Table 4. Variables such as district, variety, growth stage, altitude, slope, crop density, previous crop, soil type, and weed density were significantly associated with bacterial blight incidence. However, variables such as producer, and sowing date were non-significant as a single predictor in the logistic regression model. Similarly, all the variables were significantly associated with bacterial blight severity when entered the variables into the logistic regression model (Table 4).

Table 4: Independent variables used in logistic regression modeling of sesame bacterial blight incidence and severity and likelihood ratio test (LRT) for 11 variables as single predictor of disease outcome

Independent variable	df	Bacterial blight incidence LRT>95%		Bacterial blight severity LRT>25%	
		DR	$Pr>\chi^2$	DR	$Pr>\chi^2$
District	1	2512.4	<0.0001	788.5	<0.0001
Producer	1	2510.9	0.2214	776.4	0.0005
Altitude	1	2084.2	<0.0001	771.6	0.0291
Soil	1	2007.9	<0.0001	760.3	0.0007
Sowing date	1	2007.7	0.6408	750.1	0.0014
Variety	1	1753.2	<0.0001	708.0	<0.0001
Growth stage	1	1638.1	<0.0001	673.7	<0.0001
Slope	1	1565.2	<0.0001	661.5	0.0005
Previous crop	2	1153.0	<0.0001	558.1	<0.0001
Weed density	2	1100.3	<0.0001	430.5	<0.0001
Crop density	2	989.2	<0.0001	415.0	<0.0001

df = degree of freedom, DR = deviance reduction, Pr = Probability of $\chi2$ value exceeding the deviance reduction, SE = standard error, LRT = likelihood ratio test

All variables have been tested in a reduced multiple variable models with bacterial blight severity as the dependent variable. For added variables analysis of deviance, parameter estimates, standard errors resulting from the reduced regression model are given in Table 5. Lower bacterial blight severity (≤25%) had shown that a high probability of association with district Metema, small-scale producers, altitude (>700 masl), brown soil, improved varieties, sown June, flowering growth stage, fields with slope (>8%), previously cotton planted fields, weed population (≤25 m^2) and crop density (≤25 m^2) while their compared variable classes had higher probability of association to bacterial blight severity (>25%) (Table 5).

As the odds ratio indicates in the severity, there was a high association of the disease on the reference group variable classes than their comparable variable classes and a probability of 38-73% on reducing bacterial blight severity below 25% was observed the variable classes than their reference group (100%) (Table 5).

Except for producer and sowing date, all variables have been tested in a reduced multiple variable models with bacterial blight incidence as the dependent variable. Analysis of deviance, parameter estimates, and a standard error resulting from the reduced regression model for added variables is given in Table 6. High bacterial blight incidence (>95%) had a high probability of association to district Mirab Armachiho, black soil, local varieties, fruiting growth stage, fields with slope (≤8%), previously sesame planted fields and weed population (>40 m^2) while their compared variable classes had a lower probability of association to bacterial blight incidence (>95%) (Table 6).

The probability of reducing bacterial blight incidence below 95% was 54, 50, 75, 77, 50, 38, 71,64,80,86, and 19% of the variable classes than their reference group (100%). As the odds ratio indicate, there were 0.85, 0.33, 0.31, 0.4, 0.56, 0.25, and 0.17 times less probabilities that of bacterial blight incidence exceed 95% at Metema, brown soil, improved varieties, flowering growth stage, fields with slope (>8%), previously sorghum and cotton planted fields as compared with their reference group variable respectively (Table 6).

Bacterial blight intensities had a direct correlation with rain fall and relative humidity (Habish and Hamad, 1970, and Girma, 2010) as meteorological data indicate there was high rainfall distribution in Mirab Armachiho (Table 2) this favors for high development of disease intensity in the area as to the rain splash is secondary source to the pathogen. A similar result was reported by Geremew and Asfaw (1992) as the disease is damaging under conditions of high rainfall and where high humidity persists for long periods and less damaging when sesame is grown in more arid areas under furrow irrigation. Ahmed (2004) further verified that during highly humid weather conditions, the disease is more damaging sesame yields in Pakistan.

High blight severity (76.9%) was recorded on fields sown by large-scale producers than small-scale producers and this could be due to a lack of crop rotation in large-scale production system. Mostly the large-scale producer's sow sesame after sesame in each year while small-scale producers sow sesame on a residue of sorghum and cotton but the infected seed they use become the main source of inoculum. Report of Agrios (2005) indicates that bacteria overwinter on infected or healthy parts, especially buds of perennial plants, on or in seeds, on infected plant debris, on contaminated containers or tools, and on or in the soil. Similarly, the topography of the land (slope) also contributes to their difference in the disease intensity. As observed most of the large-scale producers cultivate sesame on flat fields that retain moisture creating favorable condition for the disease development. A similar result was reported by Girma (2010) where vertisol soils types had high disease intensity of bacterial blight due to their water holding capacity. Samuel *et al.* (2008) similarly reported high intensity of chocolate spot was observed on flat fields (≤8%) and large fields on faba-bean.

Improved varieties had less severity (24.1%) of the disease this might be due to the inherited characteristics. Thomas and Orellana (1962) reported that different levels of resistance to different races of *X. campestris* PV. *sesami* were shown by the sesame varieties Margo, Venezuela 51 and early Russian during experiments conducted in the field and laboratory in Venezuela. The varieties Venezuela 51 and Delco were more susceptible to the disease, whereas Early Russian was a resistant variety. Planting sesame varieties early (June) has less intensity than those sown on July in the cropping season and this might be due to the availability of moisture and relative humidity on the microclimate. The result also agrees with Akpa *et al*. (1988) in which the sowing date may affect bacterial blight development. In India, it was tested in pots and field trials for the incidence and severity of bacterial blight during the rainy season (June-September). Compared with early sowings, late sowing resulted in low yield and poor plant development without significantly affecting disease incidence and severity. Moreover, a frequency of premature leaf drop has increased in the plants arising from the late sowing. Symptom expression occurred earlier and secondary spread of the disease was more rapidly happened than in early sown crops.

The population of weeds influenced the intensity of the disease; sesame field with more weed population had relatively high severity (41.1%) of the disease whereas, less population of weed had less severity (17%). This could be due to an increase of relative humidity on the crop microclimate which favors for the pathogen and their completion for nutrients. This result agrees with Sahile *et al.* (2008) high weed density resulted in high level of a chocolate spot of faba bean and Girma (2010) good field management showed lesser bacterial blight intensity (27%) as compared to poorly managed sesame fields.

Table 5: Analysis of deviance, natural logarithms of odds ratio, odds ratio and standard error of added variables in a reduced model predicting bacterial blight severity less than 25%

Added variable	df	LRT		Variable class	Estimate $Log_e^{(OR)}$	SE	Odds ratio	Prob. <25%
		DR	$Pr>\chi^2$					
Intercept					0.2838	0.0753	1.33	
District	1	788.5	<0.0001	Metema	-0.1189	0.0716	0.89	0.53
				M.Armachiho	0.0000a	0.0000a	1.00	
Producer	1	776.4	0.0005	Small scale	-0.1071	0.0809	0.90	0.53
				Large scale	0.0000a	0.0000a	1.00	
Altitude	1	771.6	0.0291	>700	-0.0741	0.0785	0.93	0.52
				≤700	0.0000a	0.0000a	1.00	
Soil	1	760.3	0.0007	Brown	-0.0362	0.0519	0.96	0.51
				Black	0.0000a	0.0000a	1.00	
Sowing date	1	750.1	0.0014	June	-0.3682	0.0629	0.69	0.59
				July	0.0000a	0.0000a	1.00	
Variety	1	708.0	<0.0001	Improved	-0.1847	0.0795	0.83	0.55
				Local	0.0000a	0.0000a	1.00	
Growth stage	1	673.7	<0.0001	Flowering	-0.4589	0.0673	0.63	0.61
				Fruiting	0.0000a	0.0000a	1.00	
Slope	1	661.5	0.0005	≤8%	0.1542	0.0612	1.17	0.46
				>8%	0.0000a	0.0000a	1.00	
Previous crop	2	558.1	<0.0001	Sorghum	-0.3724	0.0855	0.69	0.59
				Cotton	-0.4914	0.1258	0.61	0.62
				Sesame	0.0000a	0.0000a	1.00	
Weed density	2	430.5	<0.0001	≤25 /m^2	-0.9990	0.1130	0.37	0.73
				25-40/m^2	-0.6624	0.0637	0.52	0.66
				>40/m^2	0.0000a	0.0000a	1.00	
Crop density	2	415.0	<0.0001	≤25 /m^2	-0.2517	0.3768	0.78	0.56
				25-40/m^2	0.5046	0.1330	1.66	0.38
				>40/m^2	0.0000a	0.0000a	1.00	

a = reference group, df = degree of freedom, DR = deviance reduction, Pr = Probability of $\chi 2$ value exceeding the deviance reduction, SE = standard error, LRT = likelihood ratio test, E = Exponent

Linear regression of weed density per m^2 with severity (%) was done for predicting the severity level of bacterial blight of sesame as shown in Figure 2 for one unit increase in weed density there were 0.566 units of severity increments of the disease on sesame.

Table 6: Analysis of deviance, natural logarithms of odds ratio, odds ratio and standard error of added variables in a reduced model predicting bacterial blight incidence less than 95%

Added variable	df	LRT		Variable class	Estimate $Log_e^{(OR)}$	SE	Odds ratio	Prob. <25%
		DR	Pr>χ^2					
Intercept					27.4821	0.1896	8.6E+11	
District	1	2512.4	<0.0001	Metema	-0.1611	0.1257	0.85	0.54
				M.Armachiho	0.0000a	0.0000a	1.00	
Altitude	1	2115.8	<0.0001	>700	-23.8689	0.0000	1.00	0.50
				≤700	0.0000a	0.0000a	1.00	
Soil	1	2068.9	<0.0001	Brown	-1.0992	0.1012	0.33	0.75
				Black	0.0000a	0.0000a	1.00	
Variety	1	1934.7	<0.0001	Improved	-1.1715	0.1128	0.31	0.77
				Local	0.0000a	0.0000a	1.00	
Growth stage	1	1870.8	<0.0001	Flowering	-0.0004	0.1072	1.00	0.50
				Fruiting	0.0000a	0.0000a	1.00	
Slope	1	1834.9	<0.0001	≤8%	0.5051	0.0955	1.66	0.38
				>8%	0.0000a	0.0000a	1.00	
Previous crop	2	1750.9	<0.0001	Sorghum	-0.9193	0.1112	0.40	0.71
				Cotton	-0.5855	0.1797	0.56	0.64
				Sesame	0.0000a	0.0000a	1.00	
Weed density	2	1498.8	<0.0001	≤25 /m^2	-1.4007	0.1127	0.25	0.80
				25-40/m^2	-1.7523	0.1120	0.17	0.86
				>40/m^2	0.0000a	0.0000a	1.00	
Crop density	2	1254.1	<0.0001	≤25 /m^2	27.3991	42260	7.9E+11	0.00
				25-40/m^2	1.4291	0.1591	4.18	0.19
				>40/m^2	0.0000a	0.0000a	1.00	

a = reference group, df = degree of freedom, DR = deviance reduction, Pr = Probability of χ2 value exceeding the deviance reduction; SE = standard error, LRT = likelihood ratio test, E = Exponent

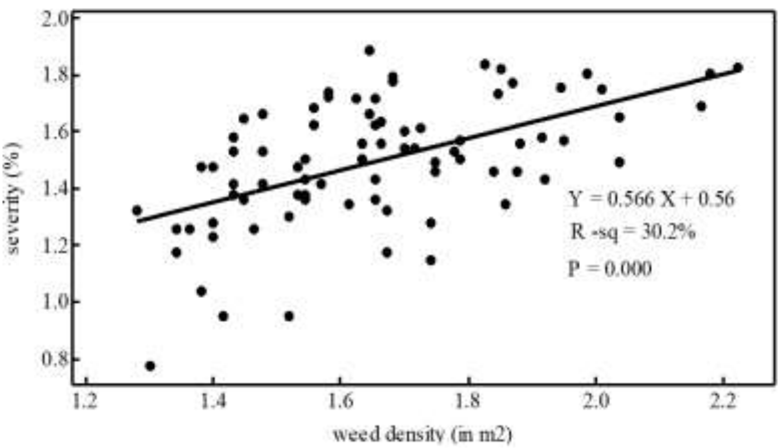

Figure 2: Linear regression of sesame bacterial blight severity (%) and weed density (m^2) at North Gondar during 2014 main cropping season

Similarly, a linear regression of crop density per m^2 with severity (%) was done for predicting the severity level of bacterial blight of sesame (Figure 3). For one unit increase in crop density, there were 0.192 units of severity increments of the disease on sesame.

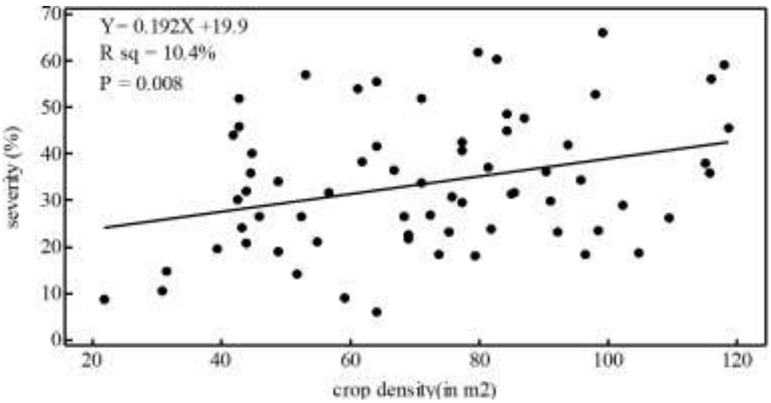

Figure 3: Linear regression of sesame bacterial blight severity (%) and crop density (m^2) at North Gondar during 2014 main cropping season

CONCLUSION

Despite the increasing demand and price of sesame in the world market, its production and productivity are declining in Ethiopia. The major reasons are lack of technologies, weeds infestation, weather uncertainties insect and diseases outbreaks. Thus generating information on improved agronomic practices, weed and pest management will undoubtedly increase sesame production and productivity. Survey for bacterial blight of sesame revealed that all field were infected during flowering and fruiting stage of the crop. Mean incidence over the two districts varied from 78% at Metema to 96.5% at Mierab Armachiho. The minimum mean severity (6.1%) has been registered in Metema district, and the highest mean severity (76.9%) has been recorded at Mierab Armachiho. The association of independent variables with bacterial blight incidence and severity was varied. Variables district, variety, growth stage, altitude, slope, crop density, previous crop, soil type, and weed density were significantly associate with bacterial blight incidence. However, variables, producer and sowing date were non-significant as a single predictor in the logistic regression model. Similarly, all assessed variables were significantly associated with bacterial blight severity.

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