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Assessment of the Distribution of Enset Bacterial Wilt Disease (Xanthomonas Campestris Pv.Musacearum) in South Omo zone, Southern Ethiopia

Kedir Bamud[1]*, Elfinesh Shikur[2] and Fikre Handoro[3]

[1]Southern Agricultural Research Institute, Worabe Agricultural Research Center, Crop Research Directorate, Worabe, Ethiopia
[2]Hawassa University, College of Agriculture, School of Plant and Horticultural sciences, Hawassa, Ethiopia
[3]Southern Agricultural Research Institute, Hawasa Agricultural Research Center, Crop Research Directorate, Hawassa, Ethiopia

Abstract

Enset bacterial wilt (EBW) caused by Xanthomonas campestris pv.Musacearum is one of the most serious diseases in enset growing areas of Ethiopia. There were no documented reports on the distribution of enset bacterial wilt in South Omo zone. Therefore, the objectives were to determine the prevalence and incidence of EBW. The study was carried out during 2017/2018. South Ari and North Ari districts were purposely selected based on enset production. Nine and six representative kebeles in South Ari and North Ari districts respectively were selected. Ten enset fields from each kebele were randomly assessed. In each enset field, the plants were grouped into three cycles (Cycle 1, 2 and 3) based on the crop growth stages. Disease assessment in fields was performed in "X" fashion for cycle 3 and 2, respectively and for cycle 1, ten suckers were randomly selected from each of mass grown suckers. The survey result revealed that the disease was detected in both districts and all kebeles but in varying extent. At district level, the higher disease prevalence (65%) and incidence (6.85%) were recorded in North Ari, while the lower prevalence (40%) and incidence (2.73%) were observed in South Ari district. At kebele level, the prevalence varied from 10% to 90%, while incidence 1.21% to 15.46% in Komer and Kalet kebeles, respectively.

Keywords*:* Bacterial wilt; Prevalence; Incidence; Disease; Assessment

Introduction

Enset (Ensete ventricosum (Welw.)Cheesman) is perennial crop and it is one of the indigenous crops widely cultivated for its food and fiber values [1]. It is widely cultivated in the mid to highlands of South and Oromia regions [2].

It has been existed for several hundreds of years as sustainable form of agriculture in Ethiopia [3]. More than 20% of Ethiopia's population depends upon enset for food, fiber, animal feed, construction materials and medicines [4]. The crop is drought tolerant and multi-purpose crop by which its leaf, leaf sheath, petiole, corm and roots are utilized for different purposes. It is mainly produced for food (kocho, bulla and amicho).

However, its production is affected by a number of biotic and abiotic factors. Among the constraints, enset bacterial wilt (EBW) caused by Xanthomonas campestris pv.Musacearum (Xcm) is the most important disease affecting the production and yield of enset [5, 6]. The disease first reported by [7] in Ethiopia and currently it is widely distributed in most enset growing areas of Ethiopia. It also attacks *Musa* spp. [8] and causing a maximum yield loss. Up to 80% of enset farms in Ethiopia infected with enset *Xanthomonas* wilt [9]. The disease mainly spreads through infected farming equipments, diseased suckers, insects and animals [5].

Cultural practices such as use of healthy suckers, crop rotation, controlling movement of diseased plants and disinfecting of working equipment which are contaminated with disease are the most principal control measures for EBW [10]. The status of enset bacterial wilt is studied in most of enset growing areas of SNNPR, Ethiopia. South Omo zone is one of enset producing areas of SNNPR. Even though the presence of bacterial wilt is evident, there is no documented information on distribution of enset bacterial wilt. Thus, this study was initiated to determine the prevalence and incidence of enset bacterial wilt disease in South Omo zone.

Materials and Method

Description of study area

The survey was conducted in South Omo zone of SNNPR, Ethiopia which is located at 750 km and 520 km from Addis Ababa and Hawassa cities, respectively. It is situated between 380 to 3,300 m.a.s.l and 34^0 57 ' -37^0 49 'East longitude and 4° 27 ' - 6° 26 ' North latitude. The average temperature ranges from 10.1 to 35.5^{0}C and the average annual rainfall ranges from 400 to 1600 mm. The zone possesses highland (dega), midland (woina dega), lowland (kolla) and pastoral rangelands (bereha) agro-ecological zones. The two districts (South Ari and North Ari) where survey was conducted are potential enset growing areas in South Omo zone (Figure 1).

Data collection

Sampling techniques

Among the eight districts of South Omo zone, two districts/ woredas/namely North Ari and South Ari were covered in this study. Both districts were selected purposively because they are the only

***Corresponding author:** Kedir Bamud, Southern Agricultural Research Institute, Worabe Agricultural Research Center, Crop Research Directorate, Worabe, Ethiopia, E-mail: kedirbamud@gmail.com

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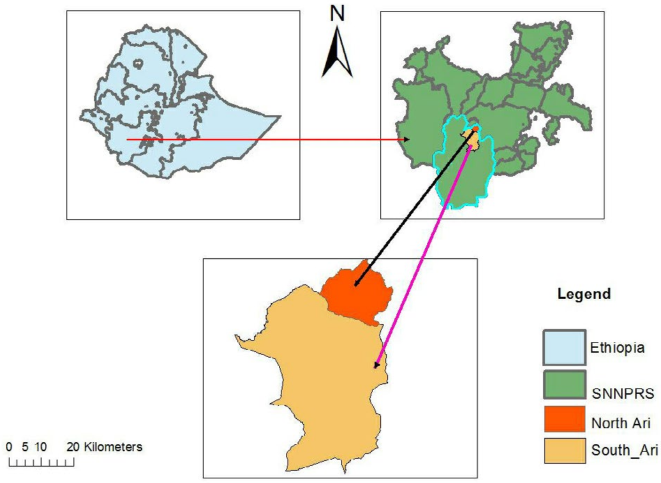

Figure 1: Map of Ethiopia showing locations of SNNPR and surveyed areas for EBW disease.

enset producing areas in the zone and EBW disease is most important farming communities issue in the areas. For the ease of this research work, ago-ecologies were categorized into three altitudinal ranges (groups), namely lowland (Kolla) with below 1,830 m.a.s.l, midland (Woinadega) with 1,830- 2,440 and highland (Dega) with above 2,440 m.a.s.l. Nine and six representative kebeles in South Ari and North Ari districts respectively were selected based on number of kebeles in each district. The kebeles were selected purposively by consulting district experts based on road accessibility, agro-ecologies (Kolla, Woinadega and Dega) and enset production status. Ten enset fields were randomly selected and disease data were collected from each kebele at a distance of 1-2km based on enset availability. Accordingly, a total of 150 enset fields were assessed in the course of survey. Disease assessment in farms was performed with a simple random sampling technique by two diagonal walking (in "X" fashion) in a sampling area of 200m^2 (20m*10m) and 50m^2(10m*5m) for cycle 3 and 2, respectively. The number of samples from each farm observed were three to five for cycle 3 and one to three for cycle 2 depending on the size of the farm. For cycle 1, ten suckers were randomly selected from each of mass grown suckers propagated from corm.

Primary and secondary data were used during survey. Primary data collection was done through direct field observation and interview with farmers and key informants. Secondary data were obtained from zone and districts Agriculture Offices.

Assessment of bacterial wilt of enset

In each field, the enset plants were grouped into three cycles based on growth stages. Based on this, Cycle 1 was the sucker stage, which was produced from a single corm; cycle 2 was two years old which was transplanted from cycle one, cycle 3 was three years to harvesting (maturity) stage. In each cycle, the total number of plants and the number of plants showing typical bacterial wilt symptoms was recorded through direct field observations. Disease incidence and disease prevalence were calculated using the following formula.

$$\textbf{Disease incidence}\ (\%) = \frac{\text{Number of diseased plants}}{\text{Total No of plants examined}} \text{x}100 \qquad (1)$$

Average wilt incidence for the field was obtained by summing up the percentage wilt incidence for each cycle divided by two or three (based on the number of cycles used).

$$\textbf{Disease Prevalence}\ (\%) = \frac{\text{Number of fields affected}}{\text{Total number of fields assessed}} \text{x}100 \qquad (2)$$

Data analysis

The incidence and prevalence of EBW data which is obtained from field surveys were analyzed by using the simple descriptive statistics after being entered in SPSS computer program version 23.0 for windows. Summary of wilt incidence and prevalence were presented for each independent variable and variable classes in tables and graphs. The association of EBW incidence and incidence at cycle 3 with independent variables was analyzed using logistic regression with SAS Software. The wilt incidence and wilt incidence at cycle 3 were classified into distinct groups of binomial qualitative data. Thus, ≤5 and >5% were chosen for wilt incidence yielding a binary dependant variable. Class boundaries of ≤10 and >10% were chosen for incidence at cycle 3.

Result and Discussion

General features of the surveyed fields

Enset clones have different vernacular names in study areas. Farmers differentiate one clone from the other by morphological characters (midrib colour, petiole colour, and leaf colour), growth attributes (vigor, maturity), disease resistance and use value food (kocho yield and quality, bulla quality, amicho use), fiber quality and medicinal value. According to the survey, there were more than 108 enset clones with different vernacular names (Table 1) in the South Omo zone. In the surveyed areas, farmers grew mixtures of enset clones in their farm. The clone numbers per farm ranging from 2 to 15. About 35.3% of the surveyed fields contained less than or equal to five clones and 64.7% of the fields contained greater than five clones. The average number of enset clones in the surveyed area were 7.65 and 6.82 in North Ari and South Ari districs, respectively. The number of clones per farm also varied across altitude groups with an average number of clones 5.10, 7.07 and 9.85 in an altitudinal range of <1830, 1830-2440 and >2440 masl, respectively. This shows that diversity of enset was higher in higher altitude than mid and lower altitudes. Enset clones such as Maza, Karta, Chelaka, Genna, Golla, Babsul, Aleka, Shufa, Chisi, and Kechak were the dominant clones grown by the farmers in the surveyed areas.

Enset is multipurpose perennial crop which is mainly produced for food (kocho, bulla and amicho). According to the survey data, the majority (58.33%) of the sampled enset plant was grown for the consumption of amicho, 25% was for both kocho and amicho and the rest 16.67% for kocho. The local name of kocho, amicho and bulla in sudy area known as washe, mossa and mukti, respectively. Farmers in both districts have no a knowledge on how to process bulla. They use their enset plants for consumption of only kocho and amicho. In the survey area, farmers harvested 24 to 96 ensets per year with an average of 45.12 ensets per year. About 38% of the household harvested ≤40 enset per year, 56% of the household harvested 41-60 ensets and 6% of households harvested greater than 60 enset plants per year. About 76.7% of farmers in the surveyed areas grew enset as a primary crop for their food and 18.7% and 4.7% as secondary and tertiary crop, respectively.

Out of enset farms surveyed, 51.3% of the surveyed farms were characterized by monocropping and 48.7% of enset fields were mixed cropped (Table 2). Mixed cropping was more practicable in low altitude than high and mid altitudes. The most mixed cropping plants in surveyed areas included maize, coffee, avocado, banana, cabbage, cardamom, taro, faba bean and field bean. Cabbage, faba bean, potato

Table 1: Enset clones with their vernacular names in South omo zone.

S.N	Enset clone name	Purpose	Farmers' perception on reaction	S.N	Enset clone name	Purpose	Farmers' perception on reaction
1	Achebukma	Amicho type	Susceptible	**55**	Gurgim	Amicho type	Susceptible
2	Aflar	Amicho type	Susceptible	**56**	Intati	Amicho type	Susceptible
3	Aleka	Amicho type	Susceptible	**57**	Jinka	both type	Susceptible
4	Aletta	Amicho type	Susceptible	**58**	Jolak	Amicho type	Susceptible
5	Ancha	Amicho type	Susceptible	**59**	Kakissa	Amicho type	Susceptible
6	Angimaz	Kocho type	Susceptible	**60**	Karta	Kocho type	Relatively resistant
7	Ani	Amicho type	Susceptible	**61**	Kayssidak	Both type	Susceptible
8	Ankima	Amicho type	Susceptible	**62**	Kechak	Both type	Susceptible
9	Ankmar	Both type	Susceptible	**63**	Ketsima	Amicho type	Susceptible
10	Arezemech	Both type	Susceptible	**64**	Kewzer	Both type	Susceptible
11	Arfa	Amicho type	Susceptible	**65**	Kuchi	Both type	Susceptible
12	Atmamos	Amicho type	Susceptible	**66**	Kuldirkush	Kocho type	Susceptible
13	Atrakay	Amicho type	Susceptible	**67**	Kumcha	Amicho type	Susceptible
14	Babsul	Amicho type	Susceptible	**68**	Kunka	Kocho type	Susceptible
15	Bahaka	Both type	Susceptible	**69**	Lefi	Amicho type	Susceptible
16	Berga	Amicho type	Susceptible	**70**	Lichar	Amicho type	Susceptible
17	Beytsematocha	Amicho type	Susceptible	**71**	Lular	Amicho type	Susceptible
18	Borgoda	Both type	Susceptible	**72**	Makai	Amicho type	Susceptible
19	Bosar	Both type	Susceptible	**73**	Malai	Amicho type	Susceptible
20	Bubna(bubni)	Both type	Susceptible	**74**	Maza	Kocho type	Relatively resistant
21	Bukma	Amicho type	Susceptible	**75**	Mona	Amicho type	Susceptible
22	Buta	Kocho type	Susceptible	**76**	Monet	Amicho type	Susceptible
23	Butamoss	Amicho type	Susceptible	**77**	Moset	Amicho type	Susceptible
24	Chelaka	Kocho type	Relatively resistant	**78**	Moyleba	Amicho type	Susceptible
25	Chishi	Amicho type	Susceptible	**79**	Noifusle	Amicho type	Susceptible
26	Chulaki	Amicho type	Susceptible	**80**	Notikucha	Amicho type	Susceptible
27	Dakay	Amicho type	Susceptible	**81**	Ombula	Kocho type	Susceptible
28	Delai	Both type	Susceptible	**82**	Osat	Amicho type	Susceptible
29	Dema	Both type	Susceptible	**83**	Ousak	Amicho type	Susceptible
30	Demet	Both type	Susceptible	**84**	Puseka	Kocho type	Susceptible
31	Dempar	Kocho type	Susceptible	**85**	Selta	Both type	Susceptible
32	Dima	Both type	Susceptible	**86**	Sesa	Amicho type	Susceptible
33	Dunna	Amicho type	Susceptible	**87**	Shufa	Both type	Susceptible
34	Dusa	Amicho type	Susceptible	**88**	Shufera	Amicho type	Susceptible
35	Ebla	Amicho type	Susceptible	**89**	Shufrak	Amicho type	Susceptible
36	Elar	Amicho type	Susceptible	**90**	Shukra	Amicho type	Susceptible
37	Elsinda	Amicho type	Susceptible	**91**	Sikar	Amicho type	Susceptible
38	Enteda	Amicho	Susceptible	**92**	Sikma	Amicho type	Susceptible
39	Ershint	Both type	Susceptible	**93**	Siknida	Amicho & ornamental	Susceptible
40	Eserkiman	Amicho type	Susceptible	**94**	Silferi	Amicho type	Susceptible
41	Ferenje	Amicho type	Susceptible	**95**	Soka	Amicho & medicinal	Susceptible
42	Garacha	Amicho type	Susceptible	**96**	Sula	Amicho type	Susceptible
43	Gecha	Amicho type	Susceptible	**97**	Tibla	Amicho type	Susceptible
44	Genna	Kocho type	Relatively resistant	**98**	Tsafrak	Both type	Susceptible
45	Gesachewl	Both type	Susceptible	**99**	Tselak	Kocho type	Susceptible
46	Geya	Amicho type	Susceptible	**100**	Washingan	Kocho type	Susceptible
47	Godera	Kocho type	Susceptible	**101**	Werezemech	Amicho type	Susceptible
48	Gofa	Kocho type	Susceptible	**102**	Wesra	Both type	Susceptible
49	Golai	Kocho type	Relatively resistant	**103**	Wobajolak	Both type	Susceptible
50	Golet	Kocho type	Susceptible	**104**	Zergina	Amicho type	Susceptible
51	Gomi	Both type	Susceptible	**105**	Zigola	Amicho type	Susceptible
52	Gudincha	Both type	Susceptible	**106**	Zinka	Amicho type	Susceptible
53	Gufak	Both type	Susceptible	**107**	Zokima	Both type	Susceptible
54	Gufera	Amicho type	Susceptible	**108**	Zokmar	Both type	Susceptible

and field bean were commonly mixed cropping plants with lower cycles in high lands. On the other hand, avocado, banana, coffee, taro and cardamom were commonly mixed cropping plants with cycle three in low and mid land altitudes.

Enset production in South Omo zone had three cycles with two transplantations. Cycle 1 is the sucker stage, which is developed from a single corm and it takes at least one year to be transplanted to next stage called cycle 2. Cycle 2 is transplanting stage which is transplanted from Cycle1 and allowed to grow for one or more years depending on management, soil fertility status and vigorous of the sucker. In this zone, farmers practiced planting of 5 to 10 suckers together per hole in cycle 2 and transplant the vigorous suckers into Cycle 3 in the next season. Cycle 3 is the final stage which is planted at permanent farm as long as maturity or ready to harvesting. In this zone farmers not practiced the planting of enset plants by using rows and recommended plant spacing. Planting of enset plants over crowdedly was more common during survey.

The survey results indicated that bacterial wilt of enset was widely distributed and a very serious problem in all the surveyed areas. However, it varies across agro ecologies, locations and farming system. The farmers were asked if the disease was occurred in their field previously (Table 2) and from interviewed farmers, 60.7% of them responded that the disease existed in their fields previously. The farmers were also asked if they knew any resistant enset clone and about 96.7% of them answered that no resistant clone exists while 3.3% of them knew the presence of some relatively resistant clones (Table 2). At the time of survey farmers were interviewed about alternative hosts of bacterial wilt other than enset and banana. They responded that taro crop is an alternative host for the disease.

Assessment of prevalence and incidence of enset bacterial wilt

The distribution of the bacterial wilt varied within assessed kebeles. 50% of enset fields were affected by the disease. It was most prevalent in North Ari district with 65% prevalence (Table 3). The disease was found in all surveyed kebeles with disease prevalence ranging from 10 to 90%. The highest (90%) EBW prevalence was recorded in Kalet kebele followed by Aymatol kebele with 70% disease prevalence. Whereas, the lowest EBW prevalence (10%) was recorded in Komer kebele.

Table 2: General features of the surveyed Enset fields.

No.	Variable	Variable class	No. of fields	Percent
1	Total enset farm (ha)	≤0.25	79	52.7
		>0.25	71	47.3
2	Total Enset Harvest	≤40	57	38.0
		41-60	84	56.0
		>60	9	6.0
3	Priority of Enset by the farmer	1st	115	76.7
		2nd	28	18.7
		3rd	7	4.7
4	No. of clones in sample	≤5	53	35.3
		>5	97	64.7
5	Cropping system	Mono cropping	77	51.3
		Mixed cropping	73	48.7
6	Occurrence of EBW before	Yes	91	60.7
		No	59	39.3
7	Occur. of EBW now	Yes	75	50.0
		No	75	50.0
8	Resistant clone	Yes	5	3.3
		No	145	96.7

Table 3: The mean incidence and prevalence of Ebw for different locations in South ari and North ari woredas of South omo zone.

Woreda	Kebele	NIF	Prevalence (%)	Max. (%)	Min. (%)	Mean (%)	SD.	SEM.
North Ari	Aymatol	7	70	11.20	0.00	4.96	4.43	1.40
	Aykiselmi	6	60	22.20	0.00	4.83	7.03	2.22
	Ambi	5	50	12.05	0.00	4.02	4.69	1.48
	Kalet	9	90	28.00	0.00	15.46	8.22	2.60
	Gomera	5	50	15.20	0.00	5.80	6.49	2.05
	Melorasha	7	70	15.00	0.00	6.07	6.04	1.90
	Total	39	65	28.00	0.00	6.85	7.19	0.93
South Ari	Del	6	60	13.90	0.00	4.57	4.65	1.47
	Weset	5	50	10.00	0.00	2.93	3.58	1.13
	Dordora	6	60	10.80	0.00	3.72	4.31	1.36
	Pelpa	6	60	10.50	0.00	4.09	4.19	1.32
	Gomir	4	40	11.00	0.00	2.67	3.92	1.24
	Shishir	4	40	8.41	0.00	2.58	3.50	1.11
	Metser	2	20	7.73	0.00	1.41	3.00	0.95
	Komer	1	10	12.10	0.00	1.21	3.83	1.21
	Muti	2	20	7.20	0.00	1.35	2.85	0.90
	Total	36	40	13.90	0.00	2.73	3.81	0.40
	GT	75	50	28.00	0.00	4.38	5.76	0.47

SD: Standard Deviation, SEM: Error mean square, NIF: Number of infected fields, Max: maximum incidence, Min: minimum incidence, Mean: Mean incidence, GT: Grand total

The incidence and prevalence of bacterial wilt varied for different variables and variable classes (Table 3). The overall mean incidence of the disease was 4.38%. About 6.85% and 2.73% mean EBW incidence were recorded in North Ari and South Ari woreda districts, respectively. Among surveyed kebeles, the least affected kebele was Komer with mean incidence of 1.21%. Likewise, the highest mean incidence (15.46%) was recorded in Kalet kebele. Enset fields showed various level of EBW infection with crop losses ranging from 0-100% on some sampled enset fields in West Shewa, Ethiopia.

The distribution of the diseases varied across altitudes. High disease prevalence (60%) was recorded at altitude range of 1830-2440 masl followed by >2440 and <1830 masl, which had EBW prevalence of 57.5% and 32%, respectively (Table 4). The finding of the present research is in agreement with the report of [6]who registered highest prevalence (50%) at altitude of 2000-2500 masl, lowest (16.67%) in altitude of <2000 masl. Similarly, recorded the highest EBW prevalence at elevation of 2300 to 2500 m. a.s. l. Study by also indicated that the disease is severe at midland in banana plant. Maximum mean incidence (6.05%) was recorded in the altitude of 1830-2440 masl, while minimum mean incidence of 2.53% was recorded in an altitude of less than 1830 masl. EBW mean incidence in high altitude (>2440 masl) was 4.18%.

When comparisons were made across environmental conditions, farmers responded that the disease can occur in all kinds of weather conditions whether there is excess rainfall, drought, high or low temperature. According to farmers' response, even if the disease is seen throughout the year in the field it becomes more severe at the time of high rainfall. *Xcm* cells persist longer in high moisture conditions than in low moisture soil conditions. This indicates the pathogen may require high moisture.

The survey result revealed that *Xcm* attacked enset plant at all growth stages. The minimum disease prevalence (3.4%) occurred in cycle 1 while the maximum disease prevalence (50%) was recorded in cycle 3 followed by cycle 2 which had disease prevalence of 21.1%. This indicated the disease was more destructive in cycle 3 and it is agreed

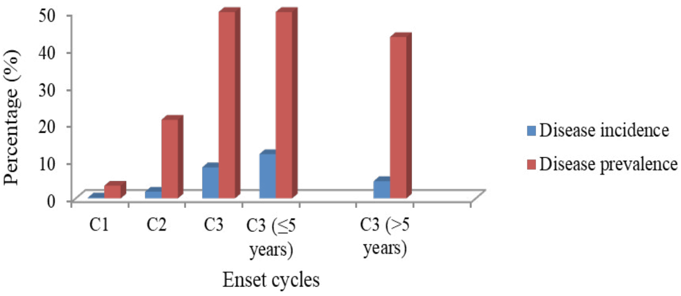

Figure 2: Mean prevalence and incidence at different cycles and ages of enset in South Omo zone C1=Cycle 1; C2= Cycle 2 and C3 = Cycle 3.

with the report of [6]. The minimum mean EBW incidence (0.23%) was recorded in cycle 1, followed by cycle 2 with mean incidence of 1.8%. Maximum mean incidence (8.34%) was registered in cycle 3 (Figure 2). Minimum EBW incidence at lower stage does not indicate the plant is immune to the disease; rather it might be due to less exposure of the plants to disease transmission factors at that stage. On the other hand, the highest wilt incidence at cycle 3 might be due to long exposure time of the host to the pathogen; crop management practices that predispose the host to *Xcm* and frequent cutting of leaves or other parts of the plant by infected farm tools for different purposes.

Disease data for cycle 3 was categorized into two age groups, with age of less than or equal to five years and age greater than five years for analysis. When comparison was made between young and old stage of cycle 3, maximum (50%) disease prevalence was recorded at younger stage of cycle3 (an age of less than or equal to five) and minimum (43.3%) disease prevalence was recorded at older stage of cycle 3 (an age of greater than five years). The maximum mean incidence (11.87%) was also recorded at age of less than or equal to five years and minimum (4.62%) at an age of greater than 5 years. This indicated that wilt incidence was higher at mid stage than at sucker and old stages. Similarly, [3] and [6] reported that EBW was severe at middle age of enset. However, indicated in an experiment involving cutting of plants with contaminated knife that young plants were more vulnerable to infection than older plants.

Higher (54.4%) and lower (48.4%) disease prevalence was recorded on fields with less than or equal to five clones and greater than five enset clones per field, respectively. Similarly, [6] recorded higher disease prevalence on fields with less than or equal to five clones. The higher wilt incidence (5.15%) was also registered from enset fields which possess less than or equal to five clones per enset field, while lower (4 %) incidence was recorded from enset fields having more than five clones.

To analyze disease prevalence and incidence, data on the field size were grouped into two categories (≤0.25 and >0.25 ha) (Table 4). According to the results, 53.9 % and 45.9 % disease prevalence was recorded in ≤0.25 and >0.25 ha, respectively. Incidence of 4.83% was recorded in enset field size of less than or equal to 0.25 ha, whereas 3.88% incidence was noted in enset farm size with greater than 0.25 ha. According to farmers cropping practices, EBW incidence was greater in mono cropping than in mixed cropping with mean incidence of 4.46%and 4.29%, respectively.

Association of enset bacterial wilt incidence with independent variables

Enset bacterial wilt incidence and wilt incidence at cycle 3 were significantly associated (p<0.05) with woreda and altitude in the logistic regression (Table 5). However, EBW incidence and incidence at cycle 3 had no significant association (p<0.05) with cropping system, field size and number of clones. The likelihood ratio test showed that the associations of the woreda and altitude with infection of EBW were the highest as evidenced by higher deviance reductions and x^2 value.

Table 4: The mean incidence and prevalence of Ebw for different variables in South omo zone.

Variables	Variable class	Prevalence (%)	Max. (%)	Min (%)	Mean (%)	SD.	SEM.
Cropping Cycle	Cycle1	3.40	14.30	0.00	0.23	1.64	0.17
	Cycle2	21.10	26.60	0.00	1.80	4.32	0.37
	Cycle3	50	40.20	0.00	8.34	10.90	0.89
Cycle3 (by Age)	≤5 years	50	60.50	0.00	11.87	14.80	1.21
	>5years	43.30	30.00	0.00	4.62	7.23	0.59
Altitude (masl)	<1830	32	15.00	0.00	2.53	4.27	0.60
	1830-2440	60	28.00	0.00	6.05	6.84	0.88
	>2440	57.50	22.20	0.00	4.18	4.96	0.78
Cropping system	Mono	54.50	28.00	0.00	4.81	6.06	0.69
	Mixed	45.20	24.15	0.00	3.92	5.44	0.64
No. of clones	≤5	54.4	22.00	0.00	5.15	6.15	0.77
	>5	48.4	28.00	0.00	4.00	5.53	0.85
Enset farm size (ha)	>0.25	45.9	24.15	0.00	3.88	5.38	0.56
	≤0.25	53.9	28.00	0.00	4.83	6.09	0.69

SD: Standard Deviation, SEM: Error mean square, Max: maximum incidence, Min: minimum incidence, Mean: Mean incidence

Table 5: Independent variables used in logistic regression modelling of Ebw incidence and incidence at cycle 3 and likelihood ratio test for 5 variables.

Independent Variables	DF	Incidence LRT >5%		Incidence at Cycle 3 LRT >10%	
		Deviance	Pr> x2	Deviance	Pr> x2
Woreda	1	4.2546	0.0391	4.3548	0.0369
Number of clones	1	2.1042	0.1469	0.0001	0.9935
Cropping system	1	0.4283	0.5128	2.1029	0.1471
Field size	1	0.0727	0.7875	0.5668	0.4515
Altitude	2	12.0164	0.0025	9.9485	0.0069

DF, degrees of freedom; Pr, Probability of a x^2-value exceeding the deviance; LRT, likelihood ratio test

Low wilt incidence (≤5%) and incidence (≤10%) at cycle 3 had a high probability of association to South Ari woreda and lower altitude (<1830 masl). On the other hand, wilt incidence (>5%) and incidence at cycle 3 (>10%) had a high probability of association to North Ari and mid altitude (1830-2440 masl) (Table 6).

Conclusion and Recommendation

Enset is the major perennial crop in study area which is mainly grown for food, animal feed, medicine, fiber and income generation. The production and yield of enset is affected by both biotic and abiotic constraints. EBW caused by *X.campestris* pv.*musacearum* is one of the major biotic constraints of enset production. It is widely distributed in all enset producing areas and can result up to 100% yield loss in fields where no management measures were taken. This study was conducted to assess the distribution of EBW disease in North Ari and South Ari districts of South Omo zone.

The result of the survey in South Omo zone showed that 50% of enset farms were infected with the disease with mean incidence of 4.38%. EBW prevalence and incidence was highest at North Ari district with 65% and 6.85%, respectively, while it was the lowest in the South Ari district with prevalence of 40% and incidence of 2.73%. The disease was most destructive in Kalet kebele with prevalence of 90%

Table 6: Analysis of deviance, natural logarithms of odds ratio, parameter estimate and standard error of added variables in logistic regression model analyzing Ebw incidence and incidence at cycle 3.

			Incidence			Incidence at Cycle 3		
Independent Variables	DF	Variable class	parameter estimate*	Standard error	odds ratios	parameter estimate*	Standard error	odds ratios
Woreda	1	South Ari	-0.43	0.21	0.42	-0.42	0.20	0.43
		North Ari	0.00[a]	0.00[a]	1	0.00[a]	0.00[a]	1
Altitude	2	<1830	-0.04	0.35	2.20	0.25	0.34	3.28
		1830-2440	0.87	0.26	5.48	0.70	0.25	5.15
		>2440	0.00[a]	0.00[a]	1	0.00[a]	0.00[a]	1

Reference group; DF, degrees of freedom; Pr, Probability of a x^2-value exceeding the deviance; SE, standard error.

and incidence of 15.46% and least destructive in Komer kebele with prevalence of 10% and incidence of 1.21%.

The current survey results showed that the disease is widely distributed in surveyed areas. Different studies recommended use of cultural management practices such as disease-free suckers, destruction of diseased plants, resistant clones, disinfection of farm tools and rotation of crops to control EBW. Therefore, continuous awareness creation on these cultural practices is highly recommended.

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