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Farmers' knowledge and perception of enset Xanthomonas wilt in southern Ethiopia

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Abstract

Background: Enset Xanthomonas wilt (EXW) was first reported in 1939 and continues to threaten the sustainability of farming systems in south and southwestern parts of Ethiopia. The present study was conducted in the central zones of southern Ethiopia to assess farmers' knowledge and perception about EXW, its etiology and mode of transmission, and its implications for the management of EXW.

Methods: A survey was conducted in 240 households across Hadiya, Kembata-Tembaro and Wolaita zones of southern Ethiopia using focus group discussions and a structured questionnaire to assess farmers' perceptions of causes and modes of EXW transmission, and their knowledge on symptom identification. In addition, EXW prevalence, incidence and severity were determined for each zone. Data were analyzed through descriptive statistics.

Results: The results showed that a significant number of farmers are aware of EXW, its symptoms, etiology and transmission and spread, but they are not able to readily relate modes of spread to control methods. Since 2002, EXW became prominent in Hadiya, with the highest EXW incidence and severity, followed by Wolaita, and Kembata-Tembaro. Farmers identified EXW as the major cause for declining production and productivity of enset in the region.

Conclusion: EXW has spread widely and rapidly in southern Ethiopia, with significant socioeconomic impacts in smallholders' livelihoods. There is a need for developing knowledge-based strategies and awareness-raising campaign for EXW management.

Keywords: Enset, Farmer's knowledge, Southern Ethiopia, Xanthomonas wilt

Background

Enset (*Ensete ventricosum* (Welw.) Cheesman) is a perennial, herbaceous and monocarpic crop belonging to the family Musaceae. Its appearance resembles that of banana, but enset is taller and fatter, with no edible fruits, and is thus named 'false banana.' It is propagated vegetatively from suckers emerging from an underground rhizome (also called the corm). Over time, a sucker develops into a new fruit-bearing plant. It has traditionally ranked as the first in importance as cultivated staple food crop in the highlands of central, south and southwestern Ethiopia, and is also considered as a food security and cash crop. About 302, 143 ha of land is covered by enset crop [1], and more than 20% of Ethiopia's population depends upon enset for human food, animal forage, fiber, construction materials and medicines [2].

The main food product, known locally as 'kocho,' is obtained by fermenting a mixture of the scraped pulp from the pseudostem, pulverized corm and the stalk of the inflorescence. The corm can be harvested at almost any stage of the crop; it can be cooked and consumed in the same way as other root and tuber crops, relieving hunger during periods of critical food shortages. *Kocho* can be stored for a long time without being spoiled [3]. The crop is grown in mixed farming systems, often in association with coffee, multi-purpose trees, and annual food and fodder crops [4].

Despite enset's importance, production and productivity are constrained by several biotic and abiotic factors.

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Bacterial wilt, caused by *Xanthomnas campestris* pv. *musacearum* is an economically important disease of enset, putting the sustainability of enset farming systems in jeopardy [5–7]. Up to 80% of enset farms in Ethiopia are currently infected with enset Xanthomonas wilt (EXW) [8]. The disease has forced farmers to abandon enset production, resulting in critical food shortage in the densely populated areas of southern Ethiopia [9, 10]. This disease directly affects the livelihood of more than 20% of farmers in the country.

In Ethiopia, EXW was first described in 1939 [11]. Subsequently, the causal agent was described as *Xanthomonas campestris* pv. *musacearum* (Xcm) [5]. EXW is now recognized as a national problem, as it spread quickly to neighboring regions of SNNPR and Oromia and on bananas since its initial discovery on enset. Forty years after its initial discovery in Ethiopia, Xcm was reported in central Uganda in 2001 [12], and thereafter the disease rapidly spread and developed into a full-blown epidemic on banana, spreading to neighboring countries, including Tanzania [13], the Democratic Republic of Congo [14], Rwanda [15], Burundi [16] and Kenya [17], where it reportedly caused 80–100% crop loss, especially in beer bananas (ABB genome). Such losses drastically affected poor and vulnerable farmers who depended on the consumption of the crop and where there are already high or medium levels of food insecurity [18].

EXW invades the vascular system of enset, causing permanent wilting and eventual death of the plant. Primarily, EXW is transmitted via insects, contaminated tools and infected planting materials [19]. Symptomless enset and/or banana bunches and leaves used to wrap bunches for transport to markets are another important source of Xcm inoculum that may be responsible for its long distance spread [20]. The main symptoms of EXW are wilting and necrosis of leaves and vascular discoloration. Internally, yellowing and/or brown discoloration of vascular bundles can be seen throughout the plant when the plant is sectioned, but this discoloration is often much more apparent in the central tissues of the pseudostem than in the outer leaf sheaths. A cream or yellow-colored ooze exudes within a few minutes of cutting tissue (Fig. 1). Initial symptoms on affected plants vary depending on the point of infection. When Xcm transmission occurs via contaminated garden tools, infected plants display a progressive yellowing of leaves from the leaf tip toward the petioles. Most infected suckers die prematurely [7, 19].

Control of EXW is challenging, as there are no resistant cultivars or effective chemical or biological measures. Sanitation and reducing Xcm transmission are the main measures to manage this disease. Management practices recommended for EXW and BXW include uprooting and discarding infected plants, planting healthy, disease-free plants from less susceptible varieties, disinfecting farm tools after every use, crop rotation, avoiding overflow of water from infected to uninfected fields, removing alternate hosts around plants, and controlling leafhoppers, aphids and mole rats that may transmit Xcm [10, 21]. However, the most labor-intensive practices may not always be adopted by farmers, and recommendations like burying or burning of infected enset stems have been abandoned by farmers in some enset- and banana-producing areas. [22, 23].

Effective disease management intervention requires a good understanding of disease epidemiology and the pathogen's transmission dynamics in time and space [24–26]. Knowledge of the specifics that surround disease development is crucial for identifying risk factors, designing efficient surveillance methods and identifying control strategies [26]. Local farmers can provide substantial information about local diseases and practices to manage the disease as farmers' traditional knowledge is often impressively broad and comprehensive [27]. Farmers' knowledge of diseases is well documented on many crops such as cotton [28], rice [29], beans [30] and vegetables [31]. Similar documentation for enset is scant and not up-to-date. A few studies have documented farmers' perceptions and ethnobotanical knowledge of the enset crop; however, there is no systematic information that explicitly describes indigenous knowledge about EXW in Ethiopia and the impact of farmers' practices on the spread of EXW in Ethiopia. It is therefore important to understand farmer's knowledge about EXW and their perceptions about crop loss. This information could help to guide EXW management practices in a sustainable manner.

The purpose of this study was to investigate farmers' knowledge and perceptions of the cause and spread of EXW, and their indigenous practices in managing EXW. The specific objectives were to (1) identify enset production constraints based on farmers' perception of their importance, (2) assess farmers' awareness of EXW incidence and severity and (3) document farmers' knowledge about EXW, their damage and indigenous management practices.

Methods

The study area

The SNNPR is located in the south and southwestern parts of Ethiopia, 4.43°–8. 58°N latitude and 34.88°–39.14°E, bordering Kenya to the south and South Sudan to the west and southwest, and the Oromia region of Ethiopia to the north and east (Fig. 2). It has a total area of ~ 111,000 km^2, lying within elevations of 378–4207 m above sea level. The annual mean temperature is less

Fig. 1 **a** Enset plantation in Hadiya zone, **b** Healthy enset plants with strong pseudostem, **c** Xanthomonas wilt infected enset plant, and **d** yellow ooze from cut pseudostem

than 10 °C in the extreme highlands and over 27 °C in the lowlands. The region is subdivided into zones, which are organized into woredas/districts. Within woredas, kebeles are the smallest administrative units. This study was conducted in the three zones of SNNPR, namely Hadiya, Kembata-Tembaro and Wolaita, a hot spot for EXW disease [8]. Two woredas per zone were selected (Table 1). In each woreda, two kebeles were selected. Selection of the woredas and kebeles were done in consultation with the zone, woreda and kebele agricultural officers and extension experts based on the enset production records. Twenty households per kebele were selected, which brought the total number of households to 240. The areas selected for the study were those with the highest enset production. Farmers were selected based on their involvement in enset cultivation for at least one cycle (4–6 years) and their willingness to participate in this study.

Baseline survey

A detailed baseline survey was carried out in 240 households in 2015. The questionnaire was pretested among the farming community living near to Areka Agricultural Research Center at Wolaita in December 2014, and found to capture the intended data (see additional file 1). Surveys were conducted by experienced Areka Agricultural Research teams and well-trained agricultural extension officers from woredas in collaboration with international institutes such as the International Livestock Research Institute, and International Potato Center. The data collection was conducted mainly through: (1) individual interviews and direct on-farm participatory monitoring

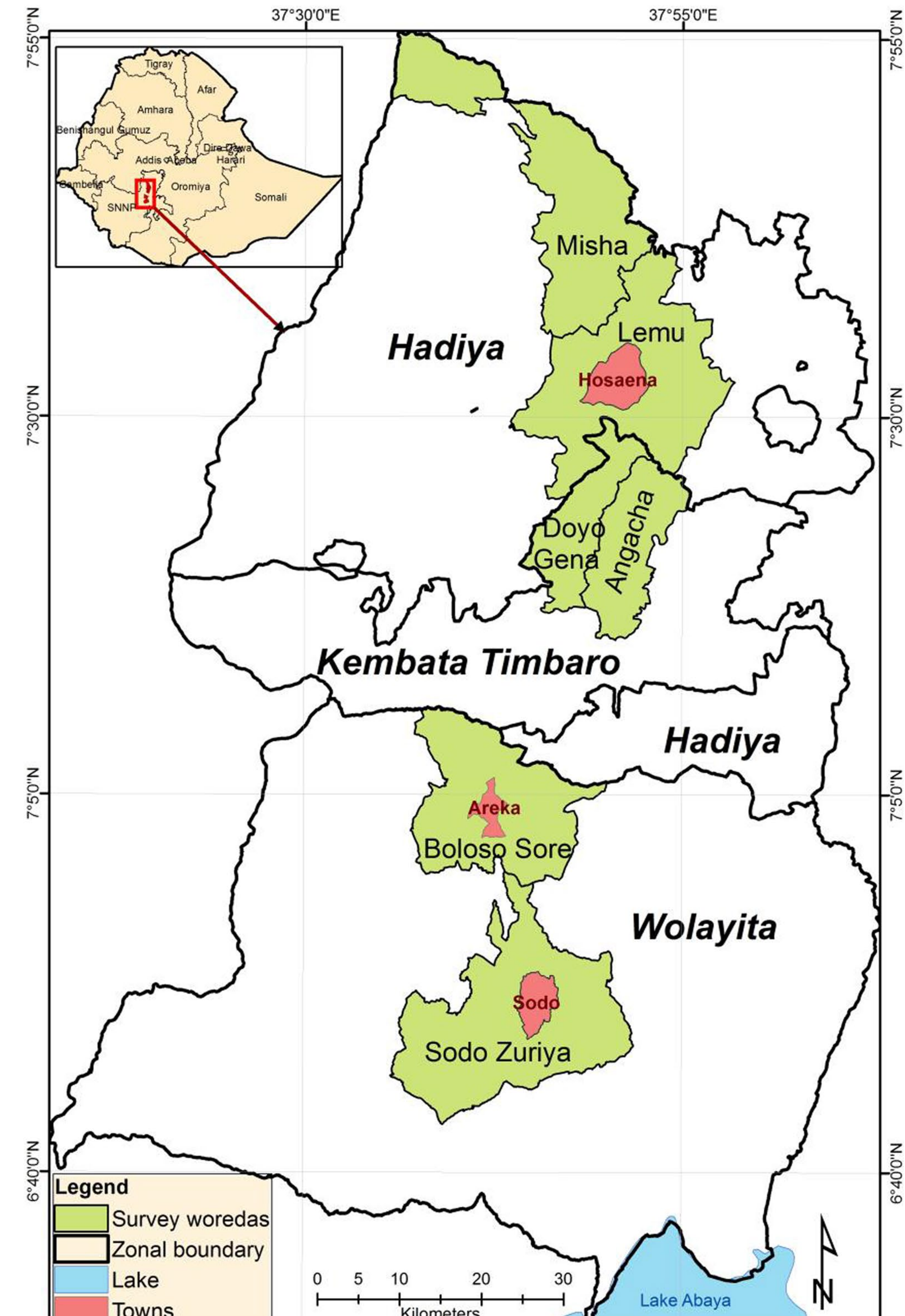

Fig. 2 Geographical location of SNNP region of Ethiopia where the enset Xanthomonas wilt surveys were conducted in 2015

Table 1 Description of surveyed woredas and their agro-ecological characterization

Zone	Woreda	Altitude range (masl)	Temp. (°C) range	Annual rainfall range (mm/year)
Hadya	Lemu	1780–2780	15–21	1000–1200
	Misha	1400–2980	21–27	800–1150
Kembata-Tembaro	Angacha	1700–3028	15– 24	900–1750
	Doyogena	1900–2800	15–20	1000–1800
Wolaita	Boloso Sore	1800–2900	14 – 25	1100–1500
	Sodo Zuria	1500–2300	14 – 25	1100–1800

and observation; (2) key informant and focus group discussion; and (3) secondary data and literature reviews.

Individual interviews, direct on-farm participatory monitoring and observation

Semi-structured interviews were designed, and data were collected with the head of the household or the person responsible for maintenance of the enset plantation. Two hundred and forty farmers were interviewed, and data were collected on a farmer's indigenous knowledge about EXW, their perceptions of causes and modes of EXW transmission, means of disease management, and each farmer's knowledge about symptom identification. In addition, information about the study area, landholdings, crops commonly grown and specific information on challenges of enset production were also collected.

Key informant interviews and focus group discussion

To assess the farmers' indigenous knowledge in each zone, key informants were interviewed, including up to five individuals per kebele, community leaders, local administrations and Ministry of Agriculture (MoA) officials, and other members in each zone. One focus group discussion was conducted in each of the studied kebele. Each of these 12 focus group discussions consisted of 15–20 people, including enset farmers, model enset farmers, kebele leaders and development agents.

Secondary data and literature survey

Data sources included the National Enset Research Program and McKnight project progress report [8] as secondary data and personal communication and discussion with elderly people and senior experts in line with knowledge of farmers on EXW. Literature on EXW management was reviewed from published and unpublished sources and reports.

Data analysis

Data were analyzed through descriptive statistics (frequencies, percentages, cross-tabulation and means) to generate summaries and tables at zone level using SPSS ver. 20 software (see additional file 2). Chi-square tests were conducted to test for significant differences between zones for variables: (1) frequencies of households who observed EXW for the first time in their farm, (2) perceptions on causes and modes of EXW transmission, and (3) knowledge on symptom identification was calculated. We calculated EXW incidence (number of households with at least one EXW-infected plant) and EXW severity (proportion of EXW-infected plants per household with EXW-infected fields) in 2015 for each zone. Throughout this paper, the term 'household' will be used to refer to a group of persons who normally live and eat their meals together in the same dwelling.

Results and discussion

Characteristics of interviewed households

Most (80%) of the interviewed heads of households were men, while the rest (20%) were female household heads who are widows or divorced (Table 2). Household resource leaders are mostly males as is the case in other enset-growing regions [8, 32, 33] and other African countries [34–36]. In all zones, the ages of interviewed heads of households ranged from 24 to 92 years, about 62% of respondent households were within the range of working age (24–65 years old), whereas 38% of them were older (> 65 years old).

On average, the level of education of the households was found to be high; 56% had completed one form of formal education or the other, while the remaining 44% had no formal education at all. This indicates that more than half of the farmers had a primary-level education to understand basic farming practices that can positively affect the adoption of agricultural technologies. Furthermore, farmers' education could be extended through reading materials such as pamphlets, leaflets and other aids [34, 37]. Another study on adoption of modern beehive technologies by smallholder farmers confirmed that there was a positive correlation between education level and adoption of technologies [38].

Mean family size of households in Wolaita and Kembata-Tembaro zones were similar (7), while that of

Table 2 Household characteristics of interviewed farmers from four zones of SNNP region, Ethiopia, in January–February of 2015

Characteristics	Zones		
	Hadiya	Wolaita	Kembata-Tembaro
Head of household			
Male	68[a]	66	60
Female	12	14	20
Age (years)	28–70	24–70	32–92
Education (grade)			
0	0	3	0
1–4	52	59	74
5–8	28	14	6
9–10	0	4	0
Household size (persons)	4–7	5–8	5–8
Plantation age (years)	2–19	3–21	2–26
Enset farming experience (years)	4–61	6–33	3–34
Total farm size (ha)	0.25–3.50	0.30–4	0.15–3.50
Area under enset (ha)	0.01–0.38	0.01–0.25	0.02–0.63

[a] Household surveyed per zone is 80, see materials and method section for detailed information

Hadiya was 8 family member (Table 2). As pointed out by previous studies [8, 32, 33], higher family size of household is a common characteristic in enset-growing regions. As family labor increases, it is expected that agricultural activities can also be accomplished on time. On the other hand, large household size may not guarantee increased labor efficiency as school age children are always in school during working periods [39]. Area under enset cultivation was mostly very small, although plantation ages, and years of enset farming experience varied widely among the interviewed households of Hadiya, Wolaita and Kembata-Tembaro zones. Enset farming experience of households ranged from 12 to 70 years, and total land size occupied by a household ranged from 0.15 to 4 ha (Table 2), of which enset farm size occupied by enset ranged from 0.01 to 0.4 ha (Table 2). This suggests that smallholder farmers have allocated their land for different crops to maintain or improve their household food security.

Enset production trends, constraint and source of planting material

Enset production trends in the last 15 years varied among three zones according to the information collected from sample respondent (Table 3). About 86, 81 and 27.5% of respondents from Hadiya, Kembata-Tembaro and Wolaita zones, respectively, reported decreasing enset production. At the same time in Wolaita zone, 40% of respondents reported increasing enset production, whereas 31% mentioned no change in production ($\chi^2 = 75.42$, $P < 0.00016$). Farmers also identified various enset production constraints in their locality. The majority of the respondents from Hadiya (88%) and Wolaita (50%) zones believe pests and diseases, especially EXW, to be a major cause for declining production

Table 3 Farmers perception on the enset production trend, reasons for decreasing production and sources of planting materials among Hadiya, Wolaita and Kembata-Tembaro zones of SNNP region of Ethiopia

Variables	Zones[a]			Chi-square test	Chi-square *P* value
	Hadiya (%)	Wolaita (%)	Kembata-Tembaro (%)		
Enset production trend since the last 15 years					
Increasing	10	40	8.8	75.42	1.62E−15
Decreasing	86.2	27.5	81.2		
No change	3.8	32.5	10		
Reasons for the decreasing production					
Pest and diseases (EXW%)	88.4 (75)	50 (16.5)	12.3 (27.5)	80.79	3.38E−14
Climate change	11.6	42.3	61.5		
Minimal use of good agricultural practices	0	7.7	21.5		
Shortage of clean suckers	0	0	3.1		
Poor value chain	0	0	1.5		
Sources of enset planting material					
Research center	0	0	29	2.89	1.56E−59
Relatives	12.5	100	0		
Neighbor	87.5	0	42		
Local market	0	0	29		

[a] % of respondents, total number of surveyed households were 80 per zone

and productivity of enset in the region, while 61.1% of farmers in Kembata-Tembaro zones believe that climate change is the major constraint ($\chi^2 = 80.79$, $P < 0.00034$). Among others, minimal use of good agricultural practices was also cited the most times as an important constraint in Kembata-Tembaro zone, followed by shortage of clean suckers and poor enset value chain. For many years, enset was the dominant crop in the SNNPR, while teff, cassava, sweet potatoes and maize were considered as minor crops [40]. In the past, people who consumed maize, cassava, sweet potato, potato and taro were considered poor. With the recent outbreak of EXW in the SNNPR, farmers have expanded maize, potato and cassava production, and about 67% of the farmers in the region reduced their consumption of enset due to EXW [8]. Moreover, the area under maize, potato, sweet potato and taro in the SNNPR has increased significantly in recent years [40]. The same trend was observed in Uganda [41, 42] and Tanzania [26].

EXW prevalence, incidence and severity

The interviewed farmers observed EXW for the first time in different years on their farms (Fig. 3a), but interventions in terms of EXW control have not been implemented. There are some years where the number of households observing EXW for the first time in their farms was high and vice versa. EXW was observed in four of the interviewed farmers' fields for the first time in 1952 at Hadiya, in one in 1980 at Kembata-Tembaro and in 1981 at Wolaita zone (Fig. 3b), indicating that the farmers from these zones observed EXW much later than the initial discovery of EXW [11] published in 1939. The number of farmers with EXW was very low until 1980, increasing to eight in 1981, ten in 1982, twelve in 1985, and thirteen in 1987 and 1990. During 1991–2001, the number of farmers reporting EXW ranged from one to six: only once at Kembata-Tembaro, three at Hadiya and seven at Wolaita. All farmers considered 2009 to be the year with the highest EXW prevalence in their area. Since 2002, EXW has become prominent in Hadiya with the highest EXW incidence and severity (incidence = 69, severity = 11.4%), followed by Wolaita (incidence = 18, severity = 8.6%), and Kembata-Tembaro (incidence = 6, severity = 4.5%) in 2015 (incidence $\chi^2 = 117.86$, df = 3, $P < 0.00025$, and severity $\chi^2 = 128.6$, df = 3, $P < 0.00013$) (Fig. 4). The results from this study corroborated previous findings that EXW was most prevalent in Hadiya zone [43, 44]. A previous study [22] also confirmed that EXW was the most important constraint in West Shewa zone. A more comprehensive study [8] in the southern region revealed that on average 28.7% of enset stands were lost due to EXW disease. These levels are high and

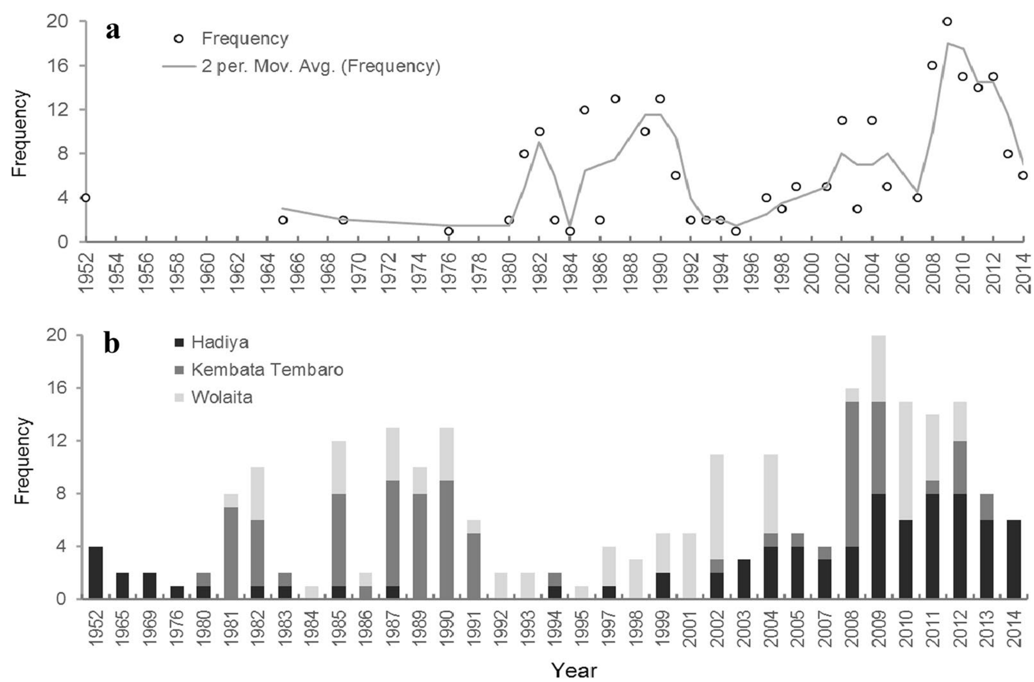

Fig. 3 Number of farmers who observed EXW for the first time in their farm, **a** prevalence of EXW in moving average pattern during 1952–2014, and **b** frequency distribution of interviewed farmers during 1952–2014 when they observed the prevalence of EXW in Hadiya, Kembata-Tembaro and Wolaita zones of SNNPR, Ethiopia

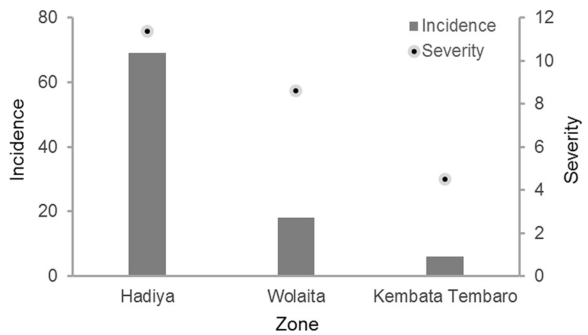

Fig. 4 EXW incidence (number of households with at least one EXW-infected plant) and EXW severity (proportion of EXW-infected plants/household with EXW-infected fields) among surveyed households from Hadiya, Wolaita and Kembata-Tembaro zones in 2014–2015

suggest large potential economic losses if EXW is not controlled. Further studies are required to determine the economic losses due to EXW in Ethiopia.

Etiology and means of EXW spread

Most of the interviewed farmers (71%) could identify EXW wilt symptoms. Despite no significant difference in diagnostic capacity, about 59% of households knew leaves yellowing, 40% households knew leaves wilting, and 2% knew the appearance of a pale to yellow ooze from cut pseudostem as a symptom of EXW (data not shown). Most of the respondents (77%) said that contaminated tools, diseased plant debris, animals, animal dung and wind are the etiology of EXW, while nearly 23% said they did not know (Table 4).

Farmers in the study areas have their own ways of understanding for the means of EXW transmission and spread (Table 4). Most respondents (70–80%) identified contaminated tools, diseased plant debris, insects and animals as principal means, while a minority of the respondents mentioned that animal dung and wind are the major source of EXW transmission and mentioned spread from an external source to the farmers' fields, and from infected to healthy enset plants. Many farmers know that contaminated farm tools contribute to the rapid spread of Xcm, but recommendations such as the use of disinfectants, use of sterile tools, removal of infected suckers, mat and corms are not practiced in SNNPR, although they are used in Uganda [23]. Moreover, enset and banana traders who move among farms and harvest with nonsterile tools also contribute significantly to EXW spread. Thus, traders must also be trained to use safe harvesting practices.

Table 4 Awareness of farmers of EXW etiology, transmission and spread

Variables	Hadiya (%)	Kembata-Tembaro (%)	Wolaita (%)	Chi-square test	Chi-square *P* value
EXW etiology					
Contaminated farm tools	47.8	33.3	20	70.8	2.26867E−10
Animal and insect	11	6.4	10		
Infected leaf left in enset farm	1.2	12.8	27.5		
Wind	0	24.4	13.7		
Environmental shock	2.5	3.8	11.2		
Animal dung	0	2.6	3.8		
No idea	37.5	16.7	13.8		
Means of EBW transmission from external source					
Contaminated materials	41	36.25	42.5	30.51	0.002
Animal and Insect	20	17.5	28.75		
Animal dung	20	11.25	6.25		
Air	5	5	3.75		
Farm tools	5	10	5		
Runoff	8.75	10	7.5		
No idea	0	10	6.25		
Means of EBW transmission from internal source					
Contaminated materials	70	47.5	53.75	17.3	0.068
Animal and insect	8.75	8.75	5		
Contact between infected and healthy plants	5	15	12.5		
Air	9	20	18		
Farm tools	3.75	2.5	8.75		
No idea	3.75	6.25	2.5		

The different actions taken by farmers in response to infected plants have their own impacts on EXW dissemination. Most farmers uproot the infected enset plant and either throw it away or feed it to their livestock. The difference in type of action taken by farmers for infected plant is statistically significant ($\chi^2 = 28.01$, $P < 0.014$) (Table 5). The destruction of infected plants is labor intensive, and lack of labor was cited by farmers as a major reason for not carrying out Xanthomonas wilt control practices in Ethiopia and other African countries [45]. In addition, they also believe that droppings from animals that consumed infected plants are the source of inoculum to the healthy ones. It seems farmers are not able to readily relate modes of spread, for example via infected plant, to methods of control. These observations demonstrate the need to develop knowledge-based strategies and an awareness creation campaign for EXW management.

Interviewed farmers' perceptions also varied significantly in identifying the progress of EXW symptoms in their farm ($\chi^2 = 26.89$, $P < 0.00021$) (Table 6). Most of the farmers believe that Xcm severely attacks enset at all stages of the plant growth. Even though there is little difference in response, nevertheless the majority of farmers believe that the first symptom of EXW is shown in the leaf and it spreads to other parts of the plant, while some farmers from Kembata-Tembaro and Wolaita zones believe the first symptom of EXW appears on shoot tip and moves downwards. This is in line with the previous findings that Xcm can infect enset at any stage of plant

Table 5 Farmers perceptions on the mode of EXW transmission and their actions on the infected plant

Perception	Hadiya (%)	Kembata-Tembaro (%)	Wolaita (%)	Total (%)	Chi-square test	Chi-square *P* value
Infected enset plant can be cured						
Yes	16.2	5	17.5	12.9	6.74	0.34
No	85.8	95	82.5	87.1		
Use diseased enset for livestock feed						
Yes	55.8	14.3	50	36.2	27.57	1.03E−06
No	44.2	85.7	50	63.8		
Infected enset plant can infect others						
Yes	65	9	7	28	48.31	3.2304E−11
No	35	91	93	72		

Table 6 Farmers perceptions on the susceptibility of enset plant, EXW progression on plants and seasonality of EXW

Variables	Hadiya (%)	Kembata-Tembaro (%)	Wolaita (%)	Total (%)	Chi-square test	Chi-square *P* value
Age of enset						
< 6 months	20.1	22.5	16.2	19.6	24.58	0.017
7–12 months	0	7.5	10	5.8		
1–2 years old	1.2	2.5	8.8	4.2		
2–4 years old	52.5	32.5	37.5	40.8		
Mature	1.2	3.8	2.5	2.5		
Al l stage	7.5	5	1.2	4.6		
No idea	17.5	26.2	23.8	22.5		
First symptom of EXW						
Shoot tip	31.2	58.8	55	48.3	26.89	2.10E−05
Leaf	68.8	33.8	43.8	48.8		
Leaf and corm	0	7.5	1.2	2.9		
Seasonality of EXW						
Yes	48.8	42.5	65	52.1	8.65	0.013
No	51.2	57.5	35	47.9		
Favorable season for EXW						
Wet season	11.2	6.2	14.3	9.2	2.058	0.725
Dry season	37.5	35	35.7	36.2		
Both	51.2	58.8	50	54.6		

growth and EXW symptoms vary also with a plant's phenology and depends on the point of infection [7, 46].

Farmers in the study areas have different beliefs on the seasonality of EXW (Table 6). The majority of farmers (65%) from Wolaita zone believe EXW is seasonal, and about 50% of farmers from Hadiya and Kembata-Tembaro zones do not believe in the seasonality of EXW ($\chi^2 = 8.65$, $P < 0.013$) (Table 6). Most of the respondents think dry season is favorable for occurrence and development of EXW. The results from this study corroborated farmer observations in Uganda and Tanzania that BXW symptoms increased and were more noticeable in dry seasons soon after the wet seasons [7, 26]. The incubation period between Xcm infection and EXW symptom development ranges from 2 weeks up to 3 months [7, 47]. Some studies have shown that moisture on leaves is an important factor in Xcm survival, establishment and spread on plant [45]. Thus, infection likely took place in the rainy season and symptoms appeared in dry season.

Conclusion

In conclusion, EXW has spread widely and rapidly in southern Ethiopia, causing significant socioeconomic impacts in smallholders' livelihoods. Its impacts may include complete crop loss in the field, disease management cost as well as the cost of switching to other crops. Management of EXW should be concentrated toward developing and disseminating control strategies including symptom identification, epidemiology and etiology of EXW, right at the field level. Continued public awareness creation program about the disease is essential. Intensive, harmonized and extended efforts are needed to provide a continuous public awareness toward EXW and developing knowledge-based strategies for its management. Practices, such as leaf removal throughout the year, should be accompanied by tool sterilization. EXW recommendations need to consider what farmers can do, given their resources. Noticeably, all enset-growing farmers must be trained and empowered to decide on a refined practical EXW management recommendations, in particular disinfecting farming and processing tools, keeping fields and surrounding areas free of weeds and volunteer plants (alternative hosts), controlling wild and domestic animals from browsing, use of clean planting materials and strict control of the movement of planting material from one area to other (developing local quarantine). Investment in developing and disseminating control strategies would be profitable.

Additional files

Additional file 1. Questionnaires S1.

Additional file 2. SPSS Data document S1. Datasets.

Abbreviations

AAU: Addis Ababa University; BXW: Banana Xanthomonas wilt; CIP: International Potato Centre; CSA: Central Statistics Authority; EBI: Ethiopian Biodiversity Institute; EXW: Enset Xanthomonas wilt; PED: Pre-extension demonstration; SARI: Southern Agricultural Research Institute; SNNPRS: Southern Nations, Nationalities and Peoples' Regional State.

Authors' contributions

Zerihun Yemataw, Ashenafi Mekonen and Kalpana Sharma conceived and designed the research, collected and analyzed the data and wrote the manuscript. Kassahun Tesfaye, Alemayehu Chala and Kindu Mekonen conceived the study, followed up the field work and reviewed and made editorial comments on the draft of the manuscript. David J. Studholme was involved in proof reading and editorial comments on the draft of the manuscript. All authors read and approved the final manuscript.

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Competing interest

The authors declare that they have no competing interests

Availability of data and materials

The dataset supporting the conclusions of this article is included within the article ("Additional file 1 Datasets").

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