Occurrence of Clubroot Disease and Farmers' Knowledge on its Management in Cabbage Growing Areas of Morogoro, Tanzania

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Abstract

Clubroot disease caused by Plasmodiophora brassicae (Woronin) is recently one of the most economically important diseases of Brassica vegetable crops. It causes more than 10 -15% yield losses of cabbage in the world. A survey was conducted in August, 2018 to investigate farmers' awareness of cabbage clubroot disease and assess its occurrence in cabbage fields at Mgeta Ward in Mvomero District, Morogoro, Tanzania. Mgeta Ward was purposely selected based on its intensive cabbage production and farmers concern on occurrences of clubroot disease. About 23 cabbage fields were surveyed for assessment of cabbage clubroot disease and 120 farmers were interviewed on indigenous knowledge on clubroot disease management and other pests of cabbage. Results showed that the level of education among the respondents was low as majority (95.5%) of farmers had primary education. Based on colored photograph of clubroot infested cabbage plant, a total of 88.3% of farmers interviewed reported the presence of the disease in their fields. Some farmers have been using several clubroot management options. Clubroot disease management options mentioned by farmers were such as crop rotation (33.7%), application of sulphate of ammonia fertilizer (5.0%), a combination of crop rotation and ashes during transplanting (3.7%), early maturing varieties (3.4%), a combination of crop rotation and using early maturing varieties (3.3%), early maturing varieties and crop rotation (0.9%), transplanting cabbage seedlings after adding ashes and later irrigate the fields until they are water logged (0.3%). However, 49.7% of the interviewed farmers had not used any means of controlling clubroot disease in their fields. Generally, the average disease incidence in all surveyed cabbage fields was 31.7%. Cultural practices are the only reliable management option since there is no currently fungicides recommended for clubroot management.

Keywords: *Plasmodiophora brassicae,* survey, pests, disease control

Introduction

Cabbage (*Brassica oleracea* var. *capitata*) is the third important crop in Tanzania after tomato and onion in horticulture (Massomo *et al.,* 2005). Cultivation of cabbage in Tanzania started in the early seventies. Cultivation is mainly as a mono-crop or otherwise as an intercrop with banana and coffee (Massomo *et al.,* 2005). Production takes place throughout the year with a peak period from July to February (De Putter *et al.,* 2007). The total area under cabbage production in Tanzania was 3,580 ha of which 3,565 ha (99.6%) was in Mainland and 15 ha (0.4%) in Zanzibar. Among regions in Mainland, Morogoro had the largest planted area estimated at 1,168 ha (32.8%), followed by Arusha (592 ha; 16.6%) and Mwanza (344 ha; 9.6%) (URT, 2016/2017). Cabbage production is constrained by a number of factors mostly insect pests and diseases (Kiptoo *et al.,* 2015), partly being aggravated by sub-optimal application of fertilizers due to the high cost of chemical fertilizers (Tsegaye and Beshir, 2018) and lack of knowledge on good agronomic practices such as intercropping (Ünlü *et al.,* 2010).

Clubroot is caused by *Plasmodiophora brassicae* (Woronin) which recently is one of the most economically important diseases

of canola/rapeseed and other Brassica vegetable crops in the world (Diederichsen *et al.,* 2009). *Plasmodiophora brassicae* belongs to the Kingdom Protista and phylum Plasmodiophoromycota; which is classified as a protist, an organism with plant, animal, and fungal characteristics. Members of this phylum are necrotrophic endoparasites of vascular plants (Alexopoulous *et al.,* 1996). They cause an abnormal enlargement (hypertrophy or hyperplasia) of host cells, and in vascular plants, disruption of vascular elements. *P. brassicae* is widespread and it causes clubroot or finger-and-toe disease of cabbage and related crucifers, both cultivated and wild (Alexopoulous *et al.,* 1996). The life cycle of *P. brassicae* is shown in Fig. 1 (Heinrich *et al.,* 2016).

The pathogen survives in the soil as long-lived resting spores. If a host plant is not present, these spores remain dormant. Secretions from the growing roots of host plants (root exudates) stimulate the resting spores to germinate and produce short-lived zoospores. The zoospores have tails that allow them to swim toward the plant, and then infect a root through root hairs or wounds.

After the initial infection, the zoospore forms an amoeba-like cell. This abnormal cell multiplies and joins with other cells to form a plasmodium (a naked mass of protoplasm with many nuclei). The plasmodium divides to form many secondary zoospores (a second generation of zoospores), which are released into the soil. The second-generation zoospores infect the roots of the initial host or nearby plants and invade the root cortex. Once in the cortex, the amoeba-like cells multiply or join with others to form a secondary plasmodium. As this plasmodium develops, plant hormones are altered, causing the infected cortical cells to swell. Clusters of these enlarged cells form clubs or galls, which are typically visible 4 to 6 weeks after planting. After secondary plasmodia mature, they divide into millions of long-lived resting spores. These spores are released into the soil as the clubs decompose, completing the disease cycle.

Clubroot disease was recorded in Japan in 1890s (Diederichsen *et al.,* 2009) and now it is known to occur in Brassica crops in more than 60 countries. Yield losses of 10–15% were reported

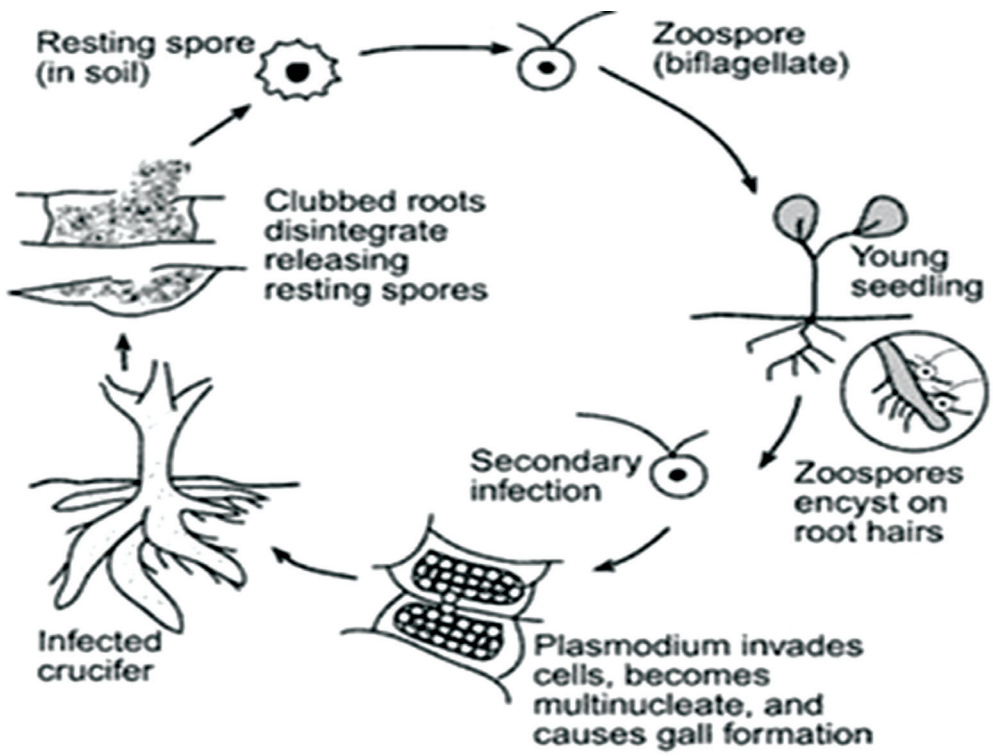

Figure 1: Life cycle of *Plasmodiophora brassicae* (*Source:* Heinrich *et al.,* 2016)

due to clubroot disease in Brassica crops around the world (Diederichsen *et al.,* 2009). Some clubroot infested cabbage roots were observed in small scale farmer's field in Mgeta area in 2015/2016 cropping season. The causal agent was identified to be *P. brassicae*. Clubroot disease distribution was not immediately established during that particular season. So, this study aimed at establishing clubroot incidence as a first report on this disease in Tanzania. Further, farmers' knowledge about this disease was established and the management options practiced was documented.

Materials and Methods

Study sites: The study was carried out in Mvomero district in Morogoro region in Tanzania (Fig. 2). The area is composed of cool areas which are conducive for the cultivation of cabbage and other Brassicaceae family crops. Mvomero district is located at 6°49'15'' S and 37°39'40''E with an altitude of around 440 - 1720 m above sea level. The location is dominated by various topography and ecological zones with different soil characteristics. It is also characterized by a bi-modal rainfall pattern with long rains between Marchs to May while the short rains are between November to January (Hashim *et al.,* 2018a). Average rainfall is 800 - 1600 mm with a mean temperature ranging from 18°C in June to 26°C in October (Hashim *et al.,* 2018a).

Four villages from Mgeta Ward (Nyandira, Ndugutu, Tchenzema and Mwalazi) were selected for this study. These villages were selected due to their long history of producing cabbage and other Brassicaceae related crops over the years. In each village 30 farmers were purposely selected making a total of 120 respondents for the ward.

A structured questionnaire was administered to a total of 120 farmers (Chacha and Mamiro, 2019). Generic questions included personal information (gender, sex, age and level of education) and farm details (geographical location, duration of cabbage production, farm size, yield per unit area and varieties produced). Additionally, respondents were requested to explain on their awareness on insect pests, diseases and weeds constraining cabbage production. To assess farmers' understanding of clubroot disease photographs of cabbages infected with clubroot disease (Fig. 3a, b and c) were shown to farmers to avoid confusion with nematodes (Schreinemachers *et al.,* 2015). Farmers were further questioned on the clubroot disease management strategies/techniques.

A transect walk was made across 23 cabbage

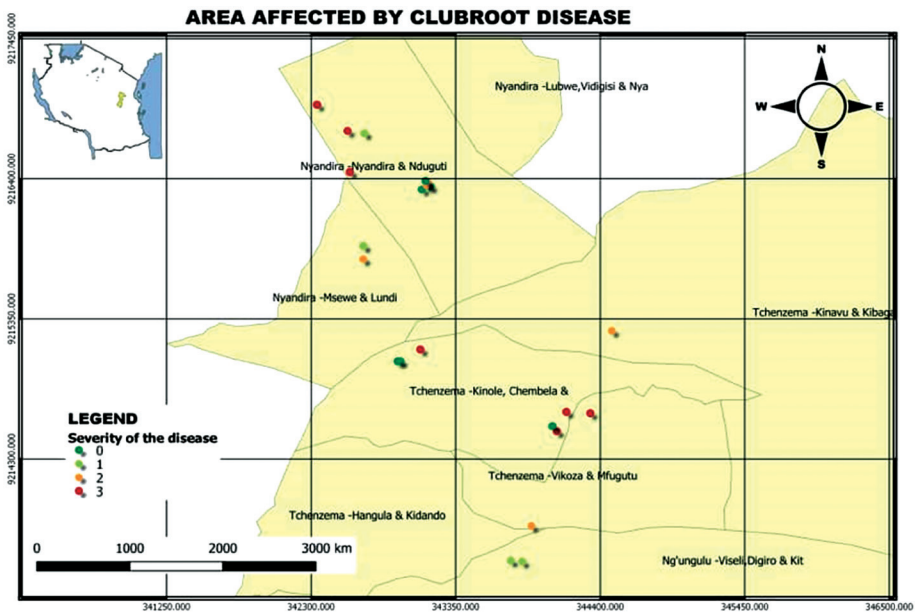

Figure 2: Map of part of Morogoro showing villages where the study was conducted

fields from three villages, vis a vis Ndugutu, Nyandira and Tchenzema to assess the incidence of clubroot disease. Clubroot disease incidence was assessed according to Aloyce and Mamiro (2017). In those 23 cabbage fields sampled, one

Figure 3a: Healthy cabbage roots

Figure 3b: Clubroot disease symptoms

Figure 3c: Clubroot disease severe roots distortion

village contributed between 6-9 cabbage fields depending on availability of fields grown with cabbage. Destructive sampling was applied whereby a 5 m^2 plot was randomly selected per field. Ten plants per plot were uprooted for clubroot disease symptoms observation. To distinguish the nematode galls versus clubroot without laboratory work, roots with clubroot were heavily clubbed and sometimes appeared spindle shaped while nematodes infestation caused galls or swellings on the roots but without club or spindle shapes.

The data were analyzed by using the Statistical Package for Social Sciences (IBM SPSS version 20). The analysis involved computations of mean, frequency, Cross-tabulation tables and descriptive statistics were calculated to summarize the questionnaire. To make statistical inferences, contingency chi-square tests were computed at $p \leq 0.05$ levels of significance to analyze relationships between variables. This allowed empirical analyses and description of associations between the collected parameters across the four study villages.

Cabbage clubroot disease incidence was calculated using the formula:

$$Disease\ Incidence = \frac{Number\ of\ Diseased\ Plants}{Total\ number\ of\ Plants} \times 100$$

Results

The demographic characteristics of the respondents are presented in Table 1. A total of 120 farmers (30 farmers per village) were interviewed. Among the farmers interviewed about 62.7% were males whilst 37.2% were female. There was no significant difference ($p \leq 0.05$) on the sex of respondents ($p \leq 0.05$). Respondent farmer's age from all four villages ranged between 20 and 69 years. There was significant difference ($p \leq 0.05$) in level of education among farmers. Most (95.5%) of the respondents completed primary education as their highest education level. Only 2.5% of the respondents had either an ordinary level of secondary education or higher education levels. However, 2% of respondent farmers had no formal education. There was no significant difference ($p \leq 0.05$) on farm size among farmers from all the four villages. Plot sizes for cabbage production ranged between quarter to two acres. Majority (38.8%) of cabbage farmers had plot size of quarter an acre and only 7% had up to 2 acres. It was further found that there was

Table 1: Demographic characteristics of farmers from four cabbage-growing villages used in this study

Characteristics	Cabbage producers (%)							
	Nyandira (n=30)	Ndugutu (n=30)	Tchenzema (n=30)	Mwalazi (n=30)	Mean	df	χ^2	*p*-value
Age of respondents								
Youth 1 (20-29)	4.6	0	12.5	0	4.3	9	7.099	0.627
Youth 2 (30-39)	27.6	20	12.5	6.7	16.7			
Adult 1 (40-49)	66.7	80	75	93.3	78.6			
Adult 2 (50-59)	0	0	0	0	0			
Old (60-69)	1.1	0	0	0	0.3			
Sex of respondents								
Male	70.1	70	37.5	73.3	62.7	3	3.829	0.281
Female	29.9	30	62.5	26.5	37.2			
Level of education								
None	8	0	0	0	2	6	13.794	0.032
Primary	92	90	100	100	95.5			
Secondary	0	0	0	0	0			
Technical/ college/ certificate/ diploma	0	10	0	0	2.5			
Size of the cabbage farm								
Quarter acre	33.3	50	25	46.7	38.8	12	14.814	0.252
Half acre	41.4	10	50	20	30.4			
One acre	18.4	40	12.5	20	22.7			
One and a half acres	4.6	0	0	0	1.1			
Two acres	2.3	0	12.5	13.3	7			
Experience in cabbage production (years)								
1 to 3	13.8	10	12.5	20	14.1	12	21.084	0.012
4 to 7	42.5	0	87.5	53.3	45.8			
8 to 11	29.9	50	0	26.7	26.7			
More than 11	13.8	40	0	0	13.4			
Cabbage varieties cultivated (F1)								
Gloria	77	40	62.5	60	59.9	9	18.31	0.032
Victoria	4.6	0	0	20	6.2			
Gloria and Victoria	2.3	0	0	0	0.6			
Gloria, Victoria, Mapema and Fanaka	16.1	60	37.5	20	37.8			

Where df = degrees of freedom, χ^2 = Chi-Square test, $p \leq 0$.

significant difference ($p \leq 0.05$) in cabbage production experience among farmers in the four villages where 13.4% had an experience of more than 11 years. About 14.1% had 1 - 3 year experience in cabbage production activities. Majority (45.8%) of the interviewed cabbage producers had an experience of up to 7 years. There was significant difference ($p \leq 0.05$) in the range of cabbage varieties grown by farmers. Among the respondent farmers 37.8% were growing up to 4 different varieties namely Gloria, Victoria, Mapema and Fanaka. Cabbage variety Gloria was most (≈60%) popular (Table 1).

Although there were no significant difference ($p \leq 0.05$), among respondents on the most destructive pests of cabbage, 32.2% of respondents reported clubroot as one of the most destructive disease. Only 25.4% of farmers reported other cabbage diseases (downy mildew, soft rot, bacterial diseases) to be destructive. Majority (42.4%) of respondent farmers ranked insect pests (ants, diamond back moth, aphids, snails) as the most destructive arthropod pests (Table 2). Significant differences ($p=0.001$) were observed among farmers with respect to occurrence of clubroot disease in their fields (Table 2). Results showed that farmers observed the occurrence of clubroot disease in their fields at different times. Majority of respondents (45.8%) observed the disease over the past 4-7 years, 26.7% over the past 8-11 years while 13.5% observed the disease over 11 years ago. Results further revealed that some (14%) respondent farmers observed the disease recently, 1-3 years ago (Table 2).

Table 2: Cabbage pests and the history of clubroot disease in the study area

Pests and cabbage disease history	Percentage of respondents							
	Nyandira (n=30)	Ndugutu (n=30)	Tchenzema (n=30)	Mwalazi (n=30)	Mean	df	χ^2	*p*-value
Most destructive pests								
Clubroot	37.9	20.0	37.5	33.3	32.2	6	6.719	0.348
Insect pests	26.4	60.0	50.0	33.3	42.4			
Other cabbage diseases	35.6	20.0	12.5	33.3	25.4			
Most destructive weeds								
Grasses	13.8	0	0	20	8.5	9	26.483	0.002
Grasses and blackjack	43.7	0	0	13.3	14.3			
None	37.9	100	100	60	74.5			
Blackjack	4.6	0	0	6.7	2.9			
Clubroot occurrence in farmers' fields								
Observed	93.1	60	100	100	88.3	3	15.453	0.001
Not observed	6.9	40	0	0	11.7			
First time observed clubroot in the field								
1-3 years	13.8	10	12.5	20	14	9	21.084	0.012
4-7 years	42.5	0	87.5	53.3	45.8			
8-11 years	29.9	50	0	26.7	26.7			
More than 11 years	13.8	40	0	0	13.5			

df = degree of freedom, χ^2 = Chi-Square test, $p \leq 0.05$

The disease incidences from the three villages were 43.3, 36.7 and 15% for Tchenzema, Ndugutu and Nyandira, respectively (Table 3). Mwalazi was one among four villages where questionnaires were administered, but was not involved in disease assessment because farmers had already abandoned the cabbage crop due to high crop loss due to clubroot disease infestation. The overall disease incidence in all assessed villages was 31.7%.

There was a significant difference (p=0.0001) in cabbage clubroot disease management practices used by farmers in the four villages at (χ^2=50.814; p=0.0001). Farmers reported the use of different management practices in an attempt to control clubroot disease in their fields, such as: crop rotation (33.7%), the use of sulphate of ammonia fertilizer (5.0%), a combination of crop rotation and application of ashes during transplanting (3.7%), the use of early maturing varieties (3.4%), a combination of crop rotation and using early maturing varieties (3.3%), the use of early maturing varieties and crop rotation (0.9%), transplanting cabbage seedlings after adding ashes and later on water logging their fields (0.3%) (Table 4). However, most (49.7%) of the farmers had not applied any means of controlling clubroot in their cabbage fields (Table 4).

Table 3: Disease incidence for the three villages where the study was conducted

Village	Total no. of uprooted cabbages	Number of diseased plants	Disease Incidence (%)
Tchenzema	90	39	43.3
Ndugutu	60	22	36.7
Nyandira	80	12	15

Discussion

The study found that cabbage is being produced by age groups (youths and adults), males and females in all four villages (Nyandira, Ndugutu, Tchenzema and Mwalazi). The majority (more than 90%) of cabbage farmers had primary education, the knowledge enough to recognize cabbage pests and apply management technologies. The cabbage farm size ranged between quarters an acre to 2 acres with production experience of up to 11 years. The most preferred cabbage variety was Gloria F1 followed by Victoria F1, Mapema and finally Fanaka. However, all varieties were susceptible to the clubroot disease. The use of improved varieties, for example, Gloria F1 and Victoria F1 as a means of disease management was found not effective and the reasons could be that these varieties produce high yield but were not resistant against clubroot disease. Vegetable farmers in Nyandira were sourcing information on cabbage agronomic and pests' management practices from the Ward Agriculture Extension Officers (WAEO).

Clubroot was the most destructive cabbage pest where by its occurrence in farmers field was reported to be observed by more than 93, 60, 100, and 100% in Nyandira, Ndugutu, Tchenzema and Mwalazi villages respectively. Crop destruction by *P. brassicae* was more than 32%. Majority of the farmers in Nyandira (30%) and Ndugutu (50%) villages respond to have observed clubroot disease of cabbage for the past 8-11 years, with an overall disease incidence in all surveyed villages of 31.7%. However, there are no reports on the occurrence of disease of cabbage caused by *Plasmodiophora brassicae* (Woronin) in Tanzania. Although farmers observed cabbage clubroot disease in their fields for the past 11 years, no research on occurrence, severity, incidence and management technologies have been in place. This is the first research report on cabbage clubroot disease. It seems that the clubroot disease is an emerging threat to cabbage production along the mountainous areas of Morogoro and probably in other cabbage producing areas in Tanzania. Farmers in Mwalazi village have abandoned

Table 4: Farmers response on cabbage clubroot disease management methods (χ^2=50.814; *p*=0.000)

Disease management methos	Nyandira (n=30)	Ndugutu (n=30)	Tchenzema (n=30)	Mwalazi (n=30)	Mean	df	χ^2	*p*-value
Crop rotation	29.9	60.0	25.0	20.0	33.7	21	50.814	0.00
Use of mixture of ashes and poultry manure (various ratios)	3.4	0.0	0.0	0.0	0.9			
Planting early maturing varieties	6.9	0.0	0.0	6.7	3.4			
After application of ashes, the fields were flooded	1.1	0.0	0.0	0.0	0.3			
Application of Sulphate of ammonia	0.0	20.0	0.0	0.0	5.0			
The combination of crop rotation and early maturing varieties	0.0	0.0	0.0	13.3	3.3			
Combination of crop rotation and ashes during transplanting	14.9	0.0	0.0	0.0	3.7			
No means of control	43.7	20.0	75.0	60.0	49.7			

the crop due to high infestation of clubroot disease. More than 49% of farmers did not bother managing the disease because they had no clubroot disease management technologies.

Various control methods were applied by farmers to manage clubroot disease. More than 33% of farmers were practicing crop rotation while others were applying chemical fertilizers like sulphate of ammonia, organic manure, for example poultry manure, ashes, early maturing varieties and flooding. Early maturing varieties are considered to have the same merits as partial resistant varieties because they can escape or avoid infestation of clubroot disease by its ability to mature early. Some partial-resistant varieties in other Brassicaceae or Cruciferae members like Canola were reported to have mild symptoms after infestation with clubroot disease causing pathogens (Wallenhammar *et al.,* 2000). Some farmers were using a single technology while others were combining more than one technology, for example, a mixture of ashes and poultry manure or a combination of crop rotation and early maturing varieties. The majority of farmers in this study area were practicing crop rotation of cabbage with non-host crops such as cereal grains, onions, peas, beans and carrots. The use of crop rotation is one of the most important clubroot disease management practices (Howard *et al.,* 2010).

The method is effective in suppressing the adverse effect of clubroot disease. It reduces field inoculum levels in the season which cabbage was not produced leading to less disease and thus better yield. A long rotation interval of at least 5 years may be effective due to pathogen's ability to persist in the soil with resting spores and to infect many weed species in the mustard family. Since the disease can be transmitted by contaminated tools it is always important to thoroughly clean and sanitize any farming equipment that is used (Heinrich and Stone, 2016).

Some farmers used ashes mixed with manure during transplanting. Farmers reported that the method had a positive impact in managing cabbage clubroot disease. This may be due to the fact that ashes act as liming materials to increase pH of the soil. Cabbage clubroot pathogen is reported to thrive in soils which are acidic in nature (Donald and Porter, 2009; Auer and Ludwig-Müller, 2015). However, the use of ashes method has limitations since continuous application of the same may cause the soils to become too alkaline (Auer and Ludwig-Müller, 2015).

Occurrence of clubroot disease in cabbage fields is high and requires effective management techniques. Farmers are aware of the disease but they lack knowledge on the management. Since there is no research on cabbage club root disease in place, scientists such as breeders, pathologists and other stakeholders should work on technologies on how to manage club root disease in cabbage and other members of Bassicacea family. Based on the nature of cabbage clubroot disease which is largely spread through infested soil and seedlings, it is suggested that farmers should be trained on proper field hygiene and sanitation. It is further recommended that, surveys be conducted in other major cabbage producing regions such as Iringa, Mbeya, Tanga (Lushoto), Kilimanjaro, Mwanza and Arusha to ascertain the distribution of the disease and thus create awareness for the disease management.

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