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Farmers' Management Practices of Potato Bacterial Wilt and Its Implications in Disease Prevalence in Kenya

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Abstract

The widespread occurrence of potato bacterial wilt significantly contributes to the reduced potato yields in Kenya. Implementing effective management strategies for this disease usually necessitates understanding the knowledge and practices of farmers regarding potato bacterial wilt. To gain insights into farmers' knowledge and practices in managing bacterial wilt and to outline feasible intervention strategies, a survey was conducted involving 136 randomly selected farmers from four key potato-growing counties in Kenya between April and June 2019. The results indicate that farmers mainly identified potato bacterial wilt through visual indicators like plant wilting (53.7%) and tuber rot (30.9%), which is a general symptom of many plant diseases. Most farmers (59.6%) believed the disease to be seed-borne, while 31.6 % reported that infested soils caused it. The most preferred potato variety was Shangi, and the majority of farmers (60.3%) used seeds saved from their farms, while only 5.9% used certified seeds. The results of this survey suggest a gap in farmers' understanding of the link between *infection and disease control. Potato breeders should consider marketability traits alongside pest and disease resistance when developing new varieties. Potato farmers' education on diagnosis, epidemiology, and management of bacterial wilt is also needed.*

Introduction

The potato (Solanum Tuberosum L.) ranks as the fourth most crucial food crop globally, following maize, wheat, and rice in terms of human consumption/use (FAO, 2019; FAO, 2022). Worldwide potato production totals 376 million tonnes, with China contributing 94 million tonnes and India 54 million tonnes (FAOSTAT, 2021). The crop's global popularity can be linked to its short growth cycle, typically 90 days or less, which makes it a suitable bridging crop, providing food and income before other crops mature (Devaux et al., 2020). This short growth cycle also gives the potato a significant potential to reduce malnutrition and alleviate hardship in developing countries (Devaux et al., 2020).

In Kenya, the potato is the second most essential staple crop after maize, playing a vital role in enhancing food security, eradicating poverty, and providing employment for smallholder farmers (Devaux et al., 2021). Despite its economic significance, potato yields in Kenya are low, averaging 8.7 t/ha compared to the global average of 21 t/ha (FAOSTAT, 2022). The low yields could be attributed to various biotic and abiotic factors prevalent in the country, with bacterial wilt disease caused/brought about by Ralstonia solanacearum being a major biotic factor (Sharma et al., 2022). This disease affects over 70% of potato farms, resulting in yield losses ranging from 50% to 100% in critical potato-growing regions in Kenya (Mwaniki et al., 2019).

Bacterial wilt poses a severe challenge for potato cultivation because the likely pathogen can persist in soil for long periods, especially in deeper layers, and it can spread over large distances and act as an alternative host in many common weeds (Liyama et al., 2022; Wang *et al*., 2023). R. solanacearum can survive as an endophyte and persist by colonizing the rhizosphere of non-host plants (Akiko et al., 2019).

Controlling bacterial wilt in potatoes presents a significant challenge, as no single treatment has proven entirely effective (Bereika *et al.,* 2020; Wang *et al.,* 2023). An integrated management approach incorporating cultural practices, phytosanitation, chemical control, and biological control has been recommended (Karlson *et al*., 2020). Since R.- solanacearum- is both a seed and soil-borne pathogen, the primary methods to prevent the disease include using disease-free planting materials and planting in the best soils that are health-sound (Hayes et al*.,* 2022). Additionally, biological controls such as Trichoderma asperellum and Bacillus subtilis, the cultivation of resistant varieties, and the use of clean seeds are suggested techniques for managing the disease in the field (Adnani et al., 2024; Karacic et al*.,* 2024; Yao et al., 2023; Liu et al., 2022;). However, these methods are not always efficient, cost-effective, or practical (Wang et al*.,* 2023).

The effective management of potato bacterial wilt (Ralstonia solanacearum) by farmers relies on their comprehensive understanding of the disease, including its life cycles, visible known and unknown symptoms on infested potato plants and tubers, and how it spreads from one area or plant to another (Tessema et al*.,* 2023; Gobena, 2020). To develop a practical, community-based disease management strategy that aligns with potato production systems, it is essential first to comprehend the role of farmers' knowledge in their practices (Gobena, 2020). Therefore, control strategies should be tailored to the local environment of the farmers, considering their knowledge level about bacterial wilt disease (Assefa, 2020; Ocimati et al., 2021).

In this context, an investigation was carried out across four counties known for potato cultivation in Nyandarua, Nakuru, Bomet, and Bungoma to assess farmers' understanding of bacterial wilt disease management and examine how this knowledge affects their practices for preventing and controlling the disease. The results from this study are crucial for shaping a community-oriented strategy to improve the management of potato bacterial wilt among smallholder farmers in Kenya.

Methodology

A multi-stage sampling technique starting with the deliberate selection of four counties: Nyandarua, Nakuru, Bomet, and Bungoma, from two major agroecological zones (AEZ) in Kenya (Table 1). The two AEZs included the upper highlands (U.H.) (Nyandarua and Nakuru) and the upper midlands (U.M.) (Bomet and Bungoma), both prominent potato-growing regions in the country. These counties were selected based on expected variations in farmers' practices regarding potato bacterial wilt disease management, attributed to differences in local conditions such as weather, agricultural production systems, and access to potato technologies. Each county identified one sub-county, in consultation with county agriculture officers, based on county potato production levels and crop production profiles.

The selected sub-counties from the two AEZs were Olkalau in Nyandarua County, Molo in Nakuru County, Bomet Central in Bomet County, and Mt Elgon in Bungoma County. Two wards were then purposely chosen from each selected sub-county based on their potato production levels and significance in potato cultivation. The wards included in the study were Mirangine and Kanjuire Ridge in Olkalau, Elburgon and Molo in Molo, Singorwet and Chesoen in Bomet Central, and Elgon and Kaptama in Mt. Elgon (Table 1). In the second stage, 136 farmers were randomly sampled from the two AEZs. The sample size for this study was determined using Cochran's method (1963).

A total of 136 farmers were interviewed: 68 from the upper highlands AEZ and 68 from the upper midlands AEZ (Table 1).

Interviews were conducted in Kiswahili or the local language prevalent in the study areas, which helped farmers express their opinions more comfortably.

Table 1: Areas involved in bacterial wilt disease study in the two potato-growing agroecological zones in Kenya

Agroecological zones	County	Sub-county	Wards	Sample size
Upper Highland	Nyandarua	Olkalau	Mirangine	15
			Kanjuire Ridge	19
	Nakuru	Molo	Molo	17
			Elburgon	17
Upper Midland	Bomet	Bomet central	Singorwet	18
			Chesoen	16
	Bungoma	Mt. Elgon	Kaptama	20
			Elgon	14
Total No. of households surveyed				136

Assessment of Farmers' Knowledge of Potato Bacterial Wilt Disease

The farmers' understanding of potato bacterial wilt was evaluated by presenting them with infested plants in the field and asking them to identify the symptoms of the disease. This was supplemented by colour photographs depicting symptoms of bacterial wilt on the potato leaves, the stems, and the tubers, as outlined by Tafesse et al. (2018).

Evaluation of Farmers' Potato Bacterial Wilt Management Practices

To assess the criteria farmers use in selecting potato varieties, they were asked to list the characteristics necessary for a potato variety to be extensively embraced in their region. These were then ranked these criteria based on their need analysis.

Estimation of Bacterial Wilt Disease Incidence and Severity in the Field

Potato farms belonging to randomly selected farmers, each with a minimum area of 0.1 ha, were used to estimate the incidence as well as the severity of potato bacterial wilt disease. This size is significant as it ensures that the produce may be used for both home consumption and sale, providing a larger area for crop assessment. Indicators of bacterial wilt, such as wilting and the presence of milky white bacterial ooze, were used for quick field diagnosis of the disease caused by *R. solanacearum* (Khairy et al., 2021). Sampling was performed on each farm at three distinct stages: the start, middle, and end of the growing season. The process involved using quadrants of roughly 10 plants by 10 plants (4.5m x 4.5m), leading to a total sample size of approximately 100 plants. The incidence of bacterial wilt was determined using the specified formula:

$$\text{Bacterial wilt disease incidence (\%)} = \frac{\text{Number of infected plants per plot}}{\text{Total plants per plot}} \times 100$$

……………….Equation 2

Severity Scoring of Bacterial Wilt Disease

The severity of bacterial wilt disease was assessed using the Horita and Tsuchiya (2001) severity scale. This scale categorizes severity as follows: The severity of potato bacterial wilt was evaluated using a scale where 1 indicated no wilted leaves, 2 represented 25% wilted leaves, 3 corresponded to 50% wilted leaves, 4 denoted 75% wilted leaves, and 5 reflected complete wilt (100%). The average proportion of wilted leaves observed in each field was utilized to determine the relative intensity of the disease.

Data Analysis

Percentages were calculated for sex, age of the farmer, years of experience in potato cultivation and level of education. Chi-square tests were employed to explore relationships between farmers' knowledge of potato bacterial wilt and these sociodemographic factors, assessed whether farmers' preferences for certain potato varieties were related to their agroecological zone (AEZ) and whether these traits were found in the varieties they preferred, and bacterial wilt disease incidence and severity at a 95% significance level.

Results and Discussions

Sources of Infection and Main Symptoms

The majority of farmers (59.6%) attributed the cause of the disease to the use of infected potato seeds during planting, 31.6% believed that contaminated soil was responsible, while 5.1% suspected that infected farm tools might be the source (Table 2). Although 31.6% of the farmers believe that contaminated soil is the source of infection, Garcia et al., 2019 reported that bacterial wilt is mainly soil-borne.

Most respondents relied primarily on general visual symptoms for diagnosing bacterial wilt, such as plant wilting (53.7%) and tuber rot (30.9%). These general symptoms, which are expected in many plant diseases, may lead to misdiagnosis and inadequate control measures. Previous research by Buja et al. (2021) emphasized that accurate and prompt identification of plant pathogens is crucial for effective disease management and crop production. Misidentification can result in ineffective control measures, leading to further plant losses (Zhang et al., 2022; Buja et al., 2021). Thus, there is a need to train farmers in quick, accurate, and cost-effective identification and diagnosis of potato bacterial wilt.

Management Practices to Control Potato Bacterial Wilt

Only 12.5% of farmers implemented methods such as rouging, applying ash, and burying infected plants. In contrast, about 43% did not employ any control measures against the disease (Table 3). The absence of effective control strategies may contribute to the high incidence and severity of the disease (Figures 3a and 4a), particularly in Bungoma County, where 76.5% of farmers did not apply any control measures. Additionally, approximately 35.3% of farmers left infested, rotten potato tubers in the field after harvest.

Farmers' Preferred Potato Varieties

In the four potato-growing counties surveyed, the Shangi variety was the most favoured, with at least 75 % preference in Nyandarua, Nakuru, and Bungoma counties. In Kenya, several registered potato varieties exhibit varying levels of disease resistance (NPCK 2021). Despite this, the Shangi variety, known for its susceptibility to bacterial wilt and other fungal diseases, was the most preferred in the surveyed regions. This preference suggests that disease resistance is not a primary consideration for farmers when selecting potato varieties. Similar findings were reported by Kwambai et al. (2024), where the majority of farmers in Northwestern Kenya were reported to mainly prefer the potato variety Shangi. The preference for Shangi may be due to its early maturity, quick harvesting period (75 days), short dormancy, market appeal, and versatility (NPCK 2021). Potato plant breeders should focus on market-preferred traits alongside disease resistance to facilitate the adoption of new varieties.Dutch Robjin variety was preferred by 97.1% of farmers in Bomet County (Table 4). The Dutch Robijn variety is valued for its flavour and suitability for producing crisps, which aligns with the region's focus on value addition (Korir et al., 2020). This preference highlights the need for varieties that meet both market demands and disease resistance. Improving seed quality has been denoted as a significant challenge to most potato farmers in developing countries (Atieno et al., 2023).

Farmers prioritized characteristics such as marketability, high yield, early maturity, seed availability at planting time, and resistance to pests and diseases in that order of importance. For instance, the preference for the Shangi variety in Nyandarua, Nakuru, and Bungoma and the Dutch Robjin variety in Bomet was mainly based on marketability and high yield. The favoured traits of potato varieties were not significantly associated with the AEZ where the farmers resided ($\chi^2 = 9.14$).

The majority of farmers (60.3%) used seeds saved from their own farms, while 29.4% obtained potato seeds from neighbors (Figure 1). Only 5.9% of farmers acquired certified seeds from registered seed multipliers outside their counties. Surprisingly, 4.4% of farmers sourced their seeds from local markets, which primarily sell ware potatoes. Despite recommendations for regular seed renewal to prevent disease buildup, including bacterial wilt, 89.7% of farmers did not renew their seeds as advised (Figure 2). The source of potato seeds was not significantly associated with the AEZ ($\chi^2 = 0.55$). Similar results were also reported by Kwambai *et al*., 2024 where it was noted that potato farmers in North Western Kenya recycled their seeds for more than five years seeds. Izuogu et al. (2024) noted that farmers' attitudes to cultivating certified seeds were not favourable, which may be a possible reason why potato farmers do not renew their seeds. There is a need to carry out a study to find out why farmers recycle their potato seeds for several years in the study area. It was also noted that distance from the source, education level, and access to extension services were the factors that influenced farmers' attitudes towards certified seeds Izuogu et al., (2024). In another research, it was noted that education level, access to extension services and farm size had significant positive influences on the adoption of improved cultivars or certified seeds, while age and distance to the market had a negative influence on the same (Njiru *et al*., 2021) Based on the results of the current study, there is a need to Sensitize farmers on the importance of regular potato seed renewal which could help reduce disease inoculum build up and improve potato yields.

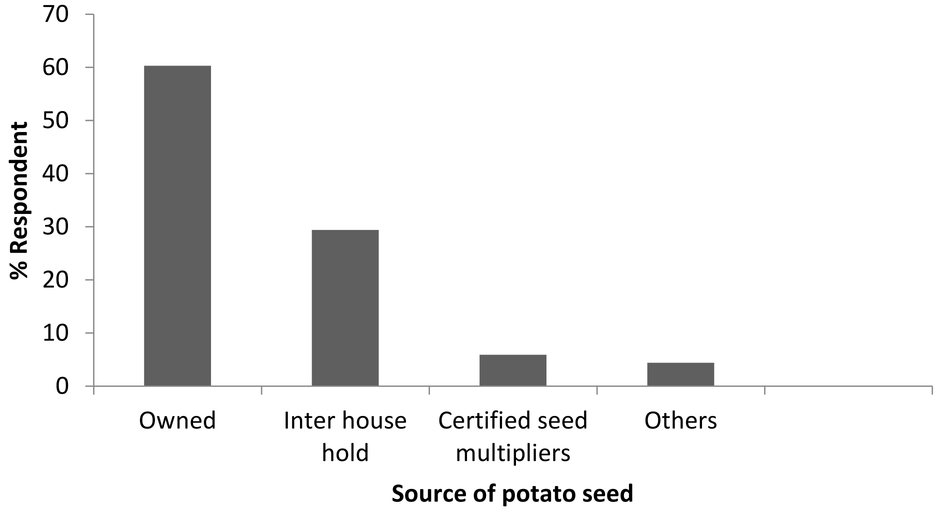


Figure 1: Sources of potato planting material

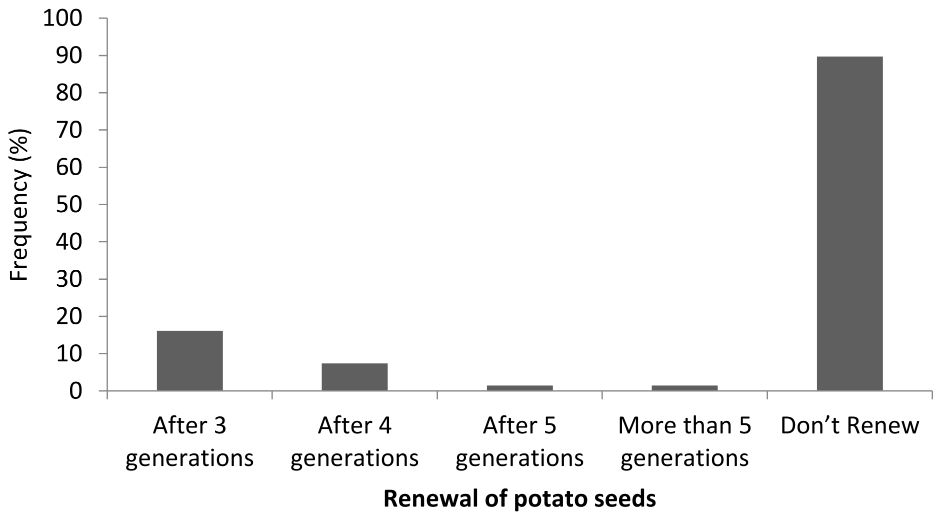


Figure 2: Renewal of potato seeds by farmers

Table 2: Bacterial wilt disease source of infection, main symptoms and control

	Nyandarua	Nakuru	Bomet	Bungoma	Mean	df	χ2	*p-value*
Source of infection								
Infected tuber/seed	55.9	67.6	76.5	38.2	59.6			
Infected tools	2.9	2.9	5.9	8.8	5.1	9	11.92	0.22
Infested soils	38.2	26.5	14.7	47.1	31.6			
Others	2.9	2.9	2.9	2.9	2.9			
Main symptom								
Wilting of plant	52.9	44.1	85.3	32.4	53.7			
Tuber rot	32.4	38.2	5.9	47.1	30.9	9	23.03	< .01
Oozing of pus in tuber eyes	8.8	5.9	5.9	8.8	7.4			
White milky slime flow from cut stem/tuber	5.9	11.8	2.9	11.8	8.1			

df = degrees of freedom, χ2 –Chi square test, *P ≤ 0.05.

Table 3: Farmer's management practices to control potato bacterial wilt on infected farms

	Nyandarua	**Nakuru**	**Bomet**	**Bungoma**	**Mean**	**df**	**χ2**	***p-value***
Disposal of wilting plants								
Burry	44.1	41.2	58.8	23.5	41.9	3	14.80	< .01
Do not burry	55.9	58.8	41.2	76.5	58.1			
Disposal of rotten tubers								
Leave in the field	35.3	32.4	11.8	61.8	35.3			
Throw in a hole and burry	17.6	41.2	52.9	20.6	33.1	6	26.04	< .01
Throw away	47.1	26.5	35.3	17.6	31.6			
Control								
Rogue/uprooting	38.2	55.9	64.7	20.6	44.9			
Rogue &apply ash/lime 8.8	11.8	26.5	2.9	12.5		6	36.81	< .01
Do nothing	52.9	32.4	8.8	76.5	42.6			

df = degrees of freedom, χ2 –Chi square test, *P ≤ 0.05

Table 4: Preferred potato varieties by farmers in selected potato-growing counties in Kenya

Agroecological zone	County	Preferred varieties
Upper highland	Nyandarua	***Shangi,
	Nakuru	***Shangi, *Markies *Sherekea
Upper midland	Bomet	***Dutch robjin, **Shangi
	Bungoma	***Shangi,**Asante, *Kenya Karibu

*** selected by at least 75% of the farmers surveyed, ** selected by at least 50%, and * selected by at least 25% of the farmers.

Incidence and Severity of Potato Bacterial Wilt

The analysis of bacterial wilt occurrence across different counties indicated that Bungoma County had the highest rate of incidence at 13.75%, with Bomet following at 11.87%, Nakuru at 9.39%, and Nyandarua at 8.45% (see Figure 3a). Among the two agroecological zones (AEZs) surveyed, the upper midland AEZ had a higher disease incidence of 12.81%, while the upper highland AEZ had a lower incidence of 8.92% (see Figure 3b). Chi-square tests indicated that the variations in potato bacterial wilt incidence were more significant by AEZ than by the specific potato-growing counties. Regarding disease severity, Bungoma recorded the highest severity score of 4.29, followed by Bomet with a score of 4.08, Nakuru at 3.33, and Nyandarua at 3.14 (see Figure 4a). The upper midland AEZ had the highest disease severity, whereas the upper highland AEZ showed the lowest severity (Figure 4b). Chi-square tests demonstrated that differences in disease severity were more bits significant by AEZ than/versus by the selected counties.

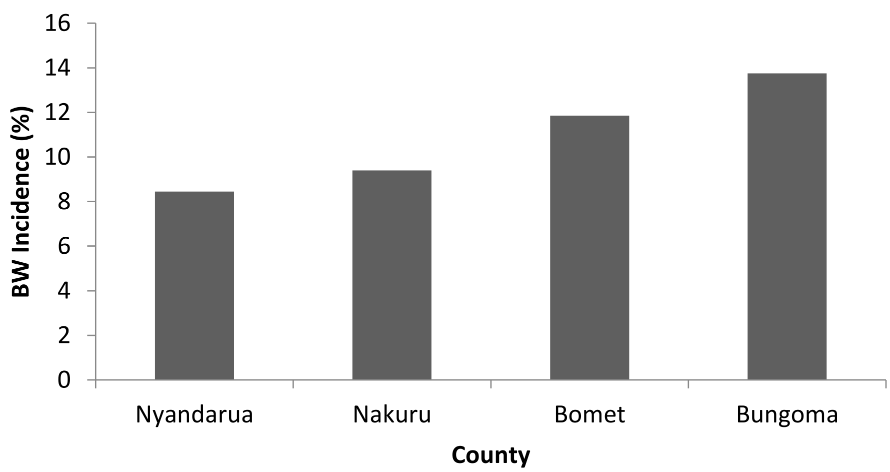
Additionally, a negative correlation was observed between altitude and both disease incidence (r = -0.091) and severity (r = -0.2138) (Table 5). The study found that as altitude increased, both the incidence and severity of bacterial wilt decreased. The lower incidence and severity in the upper highland AEZ, compared to the upper midland AEZ, may be due to cooler temperatures at higher altitudes, which inhibit the growth and spread of Ralstonia solanacearum (Wang et al., 2023). Similar findings were reported by Singh *et al*., 2023 where higher altitudes correlated with lower impacts on pathogens due to cooler temperatures. Anoumaa *et al.* (2022) also noted a decrease in bacterial wilt incidence with rising elevation. The elevated bacterial wilt incidence observed in the upper midland AEZ could be linked to the widespread cultivation of the Shangi variety, which is known to be susceptible to this disease (NPCK 2021). The use of uncertified seed sources, as noted in the study, could also contribute to higher disease incidence. Kapalasa et al. (2022) similarly reported high bacterial wilt incidence in Malawi due to the widespread use of uncertified seed suppliers. The study underscores the need for improved disease diagnosis, better seed management practices, and consideration of disease resistance in potato variety selection to manage bacterial wilt effectively.

Table 5: Relationships between bacterial wilt disease incidence, severity and altitude.

Variable	Altitude	BWI	Severity
Altitude	-	-0.091ns	-0.2138
BWI	-0.091ns	-	-0.5181*
Severity	-0.2138ns	0.5181*	-

* P ≤ 0.05. BWI=Bacterial wilt incidence

(a)



(b)

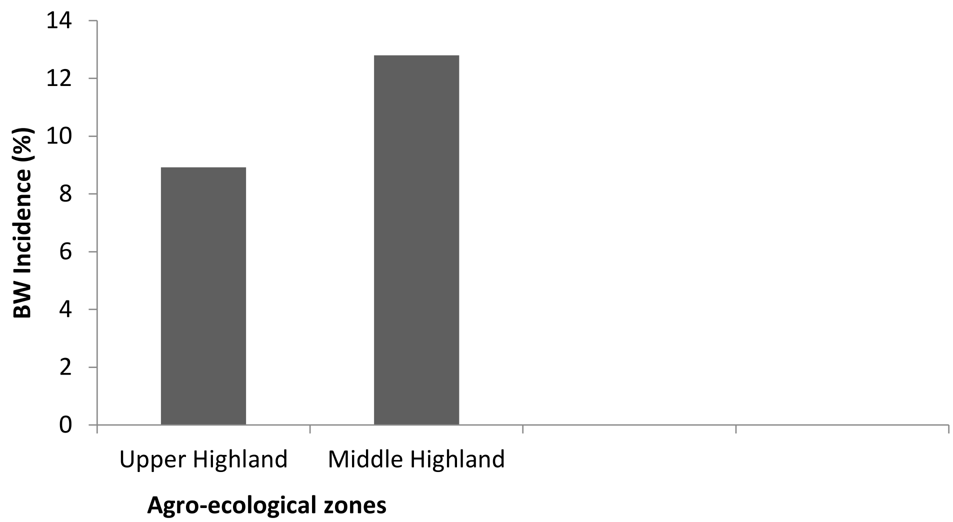
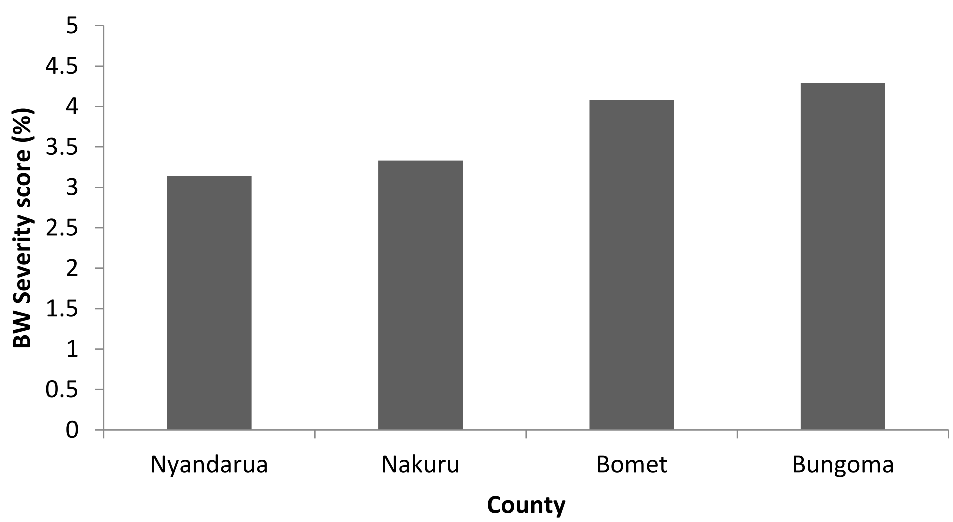


Figure 3. Bacterial wilt disease incidence (a) Counties (b) Agroecological zones

(a)



(b)

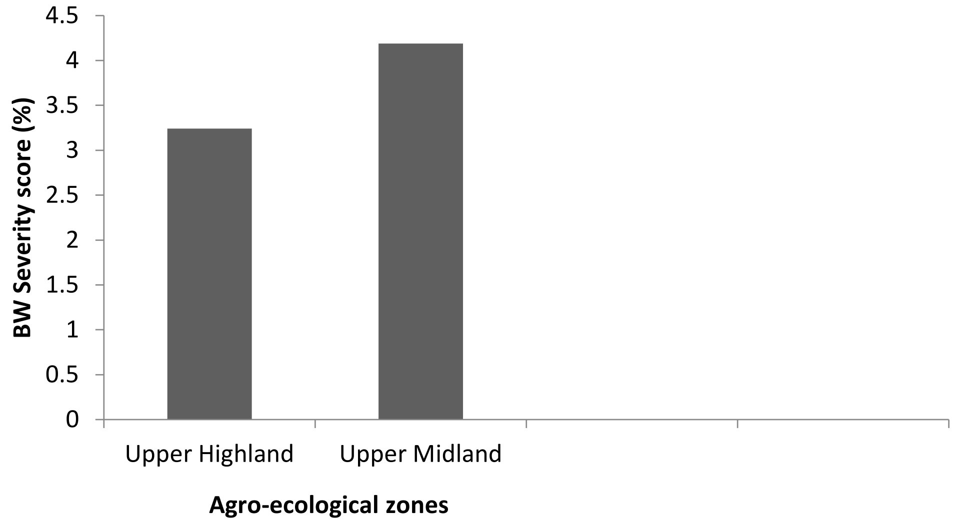


Figure 4. Bacterial wilt disease severity (a) Counties (b) Agroecological zones

Conclusion and Recommendations

Training potato farmers on the specific symptoms and diagnosis of bacterial wilt, along with effective management strategies, is crucial for reducing the disease's impact and improving potato yields. Enhanced awareness and accurate disease identification will enable farmers to implement appropriate control measures. Additionally, plant breeders should integrate marketability attributes into their breeding programs, alongside disease resistance, to ensure that new potato varieties meet both economic and agronomic needs.

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