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Field Evaluation of Local and Improved Cassava Varieties for Cassava Mosaic Begomoviruses in Lower Eastern Kenya Region

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ABSTRACT

Cassava is a drought-tolerant crop that can help ensure long-term food security in Kenya. However, various diseases and climatic variations pose significant challenges to its production. One of the most detrimental diseases affecting cassava is cassava mosaic disease (CMD), primarily caused in East Africa by two viral species: East Africa Cassava Mosaic Virus (EACMV) and African Cassava Mosaic Virus (ACMV). This study focused on agronomically screening different cassava varieties for diseases and examining their prevalence across Makueni, Machakos, and Kitui Counties in Kenya, using an experimental design. The aim was to determine the cause of abnormal morphological changes observed in some cassava varieties in the field. The investigation revealed that all cassava varieties grown in Kitui, Makueni, and Machakos counties were affected by CMD, except for the bitter cassava variety grown in Kitui County. Morphological confirmation of CMD was conducted by carefully examining the disease characteristics in the field, supported by literature on cassava leaf diseases. Statistical analysis showed no significant difference in the prevalence of ACMV and EACMV among the locations ($p = 0.3141 > 0.05$) and ($p = 0.1394 > 0.05$) or between the cultivars ($p = 0.3141 > 0.05$) and ($p = 0.1394 > 0.05$), respectively. Additionally, molecular analysis performed on randomly selected leaves confirmed the presence of ACMV and EACMV in the three counties. For improved management of cassava, further research should focus on bitter cassava to better understand the genetic traits that make it less susceptible to CMD and to inform future breeding programs.

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1 Introduction

Cassava (*Manihot esculenta*) is one of the most important tropical root crops, primarily recognized for its high carbohydrate production. It ranks globally as the sixth most valuable root crop, playing a vital role in food security, livestock feed, and various industrial applications (Fei et al. 2023). In Africa, cassava is the third-largest source of carbohydrates, surpassing maize and rice (Scaria et al. 2024). According to Adebayo (2023), it is also among the tropical crops with the highest calorie output, delivering approximately 250,000 calories per hectare per day, which exceeds that of sorghum, wheat, maize, and rice. In tropical regions of Africa, 'sweet' cassava cultivars are consumed as boiled vegetables (Scaria et al. 2024). In the semi-arid areas of Eastern Kenya, cassava has been a traditional staple food cultivated for centuries (Nyawira et al. 2023).

Beyond serving as a staple food, cassava is processed into a wide variety of products, including alcohol, animal feed, flour, starches for textiles, paper sizing, natural sweeteners, and biodegradable films (Alabi et al. 2023; Lilavanichakul and Yoksan 2023; Matheus et al. 2023). Cassava is also considered a climate-smart crop (Borku 2025) because it can tolerate high temperatures of up to 34°C, provided there is adequate moisture (Phanthanong et al. 2025). According to Mohidin et al. (2023), cassava is mainly cultivated between latitudes 30° N and 30° S as a rain-fed crop. Various biotic constraints, particularly pathogenic diseases, significantly influence the growth and yield of cassava (Ntui et al. 2024). One serious concern is cassava mosaic disease, caused by cassava mosaic Begomoviruses (CMBs) from the Geminiviridae family. This disease was first reported in East Africa in 1894 (Seethapathy et al. 2025) and is transmitted by the whitefly vector (*Bemisia tabaci*), severely diminishing cassava production in Kenya (Orek et al. 2023). Cassava Mosaic Geminiviruses (CMGs) cause cassava mosaic disease (CMD) in both Asia and Africa (Hareesh et al. 2023). In East Africa, CMD is primarily associated with the East African Cassava Mosaic Virus (EACMV) and the African Cassava Mosaic Virus (ACMV) (Saffa et al. 2025). Symptoms of CMD include leaf mosaic patterns, characterized by a mix of green, yellow, and white areas, stunted growth, weak stems unsuitable for cuttings, and deformed leaf blades that are usually smaller (Hareesh et al. 2023; Vannatim et al. 2025). CMD poses a significant threat to food security in sub-Saharan Africa, with estimated annual economic losses exceeding $1 billion (Torkpo and Amponsah 2023). Various cassava varieties have been agronomically screened on experimental farms in Makueni, Machakos, and Kitui Counties in Kenya. However, some cassava varieties exhibited morphological abnormalities of unknown cause. These abnormalities raised concerns about the potential presence of CMD, highlighting the need for experimental data to confirm these observations. Early detection of cassava leaf diseases in the field is a crucial first step in managing their detection and spread (Sambasivam et al. 2025). Therefore, this study aims to identify and evaluate any possible microbes that may have caused the observed abnormalities in the cassava varieties within the experimental fields.

2 Materials and Methods

2.1 Experimental site

The experiment was conducted in three counties within the South Eastern Kenya region: Makueni (Lukenya University), Kitui (South Eastern Kenya University), and Machakos (Scott Christian University). Makueni County is situated between longitudes 37°10' and 38°30'E and latitudes 1°35' and 3°00'S. The county experiences high temperatures, with a mean ranging from 23°C to 27°C (Ondiko et al. 2024). Annual rainfall in Makueni ranges from 250 mm to 400 mm. Kitui County is located between latitudes 0°10'S and 3°10'S and longitudes 37040'E and 39010'E (Kagimbi et al. 2024). It experiences semi-arid conditions with erratic rainfall between 201 mm and 500 mm per year (Amboka et al., 2025). The temperature in Kitui ranges from a maximum of 26°C to 34°C and a minimum of 14°C to 22°C (Mutunga et al. 2024). Machakos County is located at approximately 1°29′59″S latitude and 39°14′60″E longitude, at an elevation of 1,138 meters above sea level (Nzioki et al. 2024). Both Machakos and Makueni counties, along with Kitui, experience semi-arid climatic conditions. Furthermore, Machakos and Makueni are situated in the eastern low midlands agroecological zones (AEZs).

2.2 Planting materials

The cassava varieties used in this research included Kasukari, Makueni mixed, Machakos mixed, Kitwa, Makueni kituaa, Bitter cassava, Mzungu, Katsuhanzala, and Makueni local. These varieties were selected because they are commonly cultivated in the designated region. Notably, Kasukari is a drought-resistant variety developed by the Kenya Agricultural and Livestock Research Organization (KALRO). The need for improvement of local cassava varieties at the KALRO Katumani center arose due to challenges such as low yield, late maturity, and diseases, which pose a threat to food security. Various new varieties have been developed based on specific characteristics, including yield, earliness, and starch content. Among these, Kasukari and Katsuhanzala stand out as drought-resistant varieties with enhanced starch content. Orek (2022) also recognizes these as improved varieties. The Katumani center is situated near Machakos town, within a semi-arid region of eastern Kenya.

2.3 Experimental design and crop management in the field

The experiment was conducted from 2020 to 2023 using a randomized block design (RBD) under field conditions. Different cassava varieties were planted at each location and tested across the blocks. Each location consisted of three replications, and each variety was replicated three times within those blocks. The experimental units were organized into blocks to account for variations within each location. The number of blocks varied by location, with Kitui featuring eighteen blocks and both Machakos and Makueni having twelve blocks each, resulting in a total of forty-two blocks across the three locations. The blocks in Makueni and Machakos measured 10 meters by 10 meters, while those in Kitui measured 10 meters by 20 meters. Three-meter-wide paths separated the blocks. Within all experimental units, cassava was planted in 18 rows, with a spacing of 1 meter between plants. Weeding was uniformly performed across the three experimental locations as necessary.

2.4 Inspection and disease detection of CMD

Field observations were conducted to identify viral disease infestations. The detection and inspection of Cassava Mosaic Disease (CMD) involved examining infected cassava plants for specific foliar symptoms, such as narrowing and distortion of the leaflets, curling of the leaflets, and the presence of yellow or green mosaic patterns (Vannatim et al. 2025; Igwe 2023).

2.5 Sampling and Molecular Diagnostics

Leaf samples were collected from all three experimental locations in September 2022. The freshly picked samples were placed in 50 mL Falcon tubes and preserved with silica gel for transportation to the University of Nairobi laboratory for DNA extraction. A total of 70 samples, five from each variety at each location, were screened for the presence of African Cassava Mosaic Virus (ACMV) and East African Cassava Mosaic Virus (EACMV). Data was recorded based on the presence or absence of each viral species. Molecular diagnostics were conducted following the procedure outlined by Musa et al. (2023), which involved extracting genomic DNA and assessing its integrity. Polymerase Chain Reaction (PCR) was then used to detect Cassava Mosaic Begomoviruses (CMBs). Specific primers were employed for amplification: ACMV-ARo/Ra and AL1/Fa for ACMV and EACMV-391C+EACMV for EACMV. The PCR products were visualized, and gel images were captured using a gel documentation system.

2.6 Root rot severity of Kasukari and bitter cassava plants

A total of fifteen cassava plants were sampled. In each plot, five plants were randomly uprooted from the ends and the center, and morphological data were recorded. As a control, asymptomatic, bitter cassava roots were included in the study. The uprooted roots were examined for signs of root necrosis by making longitudinal and transverse cuts. The procedure outlined by Mkamilo et al. (2024) was followed to score the severity of root rot necrosis on a scale of 1 to 5, where: 1 = no clear symptoms, 2 = less than 5% of the root necrotic, 3 = 5–25% of the root necrotic, 4 = 25–50% of the root necrotic, with mild root constriction, and 5 = more than 50% of the root necrotic.

2.7 Data analysis

Microsoft Excel was used to summarize the data. The R-GUI software (version 4.2.2.0) was employed to perform analysis of variance (ANOVA) for calculating disease prevalence. This software also helped determine the percentage of cassava mosaic disease (CMD) occurrence across the three counties. A t-test was conducted to compare the means, and the Least Significant Difference (LSD) method was applied to separate the means. All statistical tests were performed at a significance level of $p < 0.05$.

3 Results and Discussion

In Kenya, cassava is primarily grown in the western and lower eastern regions of the country. However, cassava production is significantly impacted by diseases, particularly cassava mosaic disease (CMD). Conducting field surveys in arid and semi-arid lands (ASALs) in Kenya is crucial. These studies help identify the occurrence of diseases in locally grown cultivars, assess potential yield losses that farmers may face, and provide insights into the quality of future planting materials and produce if the disease is not managed effectively. This study presents findings on the occurrence of CMD in both locally grown and improved cassava cultivars (Kasukari and Katsuhanzala) in the lower eastern regions of Kenya, specifically in Makueni, Kitui, and Machakos counties. It also highlights the specific virus responsible for the disease and the presence of root necrosis. Field observations revealed symptoms similar to those associated with cassava mosaic virus (CMV) infestation on cassava leaves. All varieties grown in the three counties exhibited symptoms of CMD, except for the bitter cassava cultivated in Kitui at the time of data collection. Symptomatic cassava displayed distorted leaf blades along with patches of varying colors, including white and yellow, across all three counties (Figure 1). These symptoms were primarily observed in young foliage leaves and matched the characteristics of cassava mosaic disease described by Vannatim et al. (2025).

There were no distinct phenotypic traits for ACMV and EACMV (Figure 1B and C). However, mixed infections (ACMV + EACMV) revealed more severe symptoms that might have resulted from synergistic effects (Figure 1A). This result concurs with previous findings where mixed infections of EACMV-UG and ACMV resulted in severe symptoms (Orek et al. 2023).

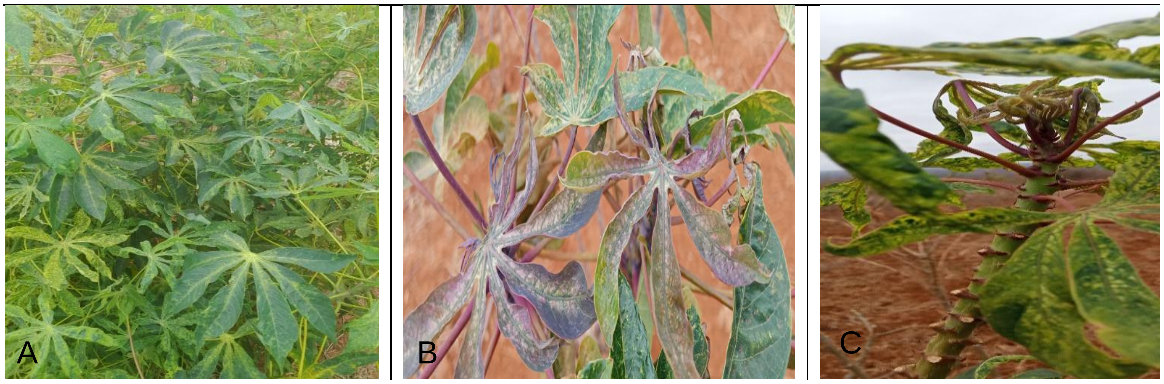

Figure 1 Plant samples showing CMD symptoms in the experimental farm: (A) Kitwa variety (ACMV+EACMV symptom), (B) Kasukari variety (EACMV symptom), and (C) Makueni kituaa variety (ACMV symptom).

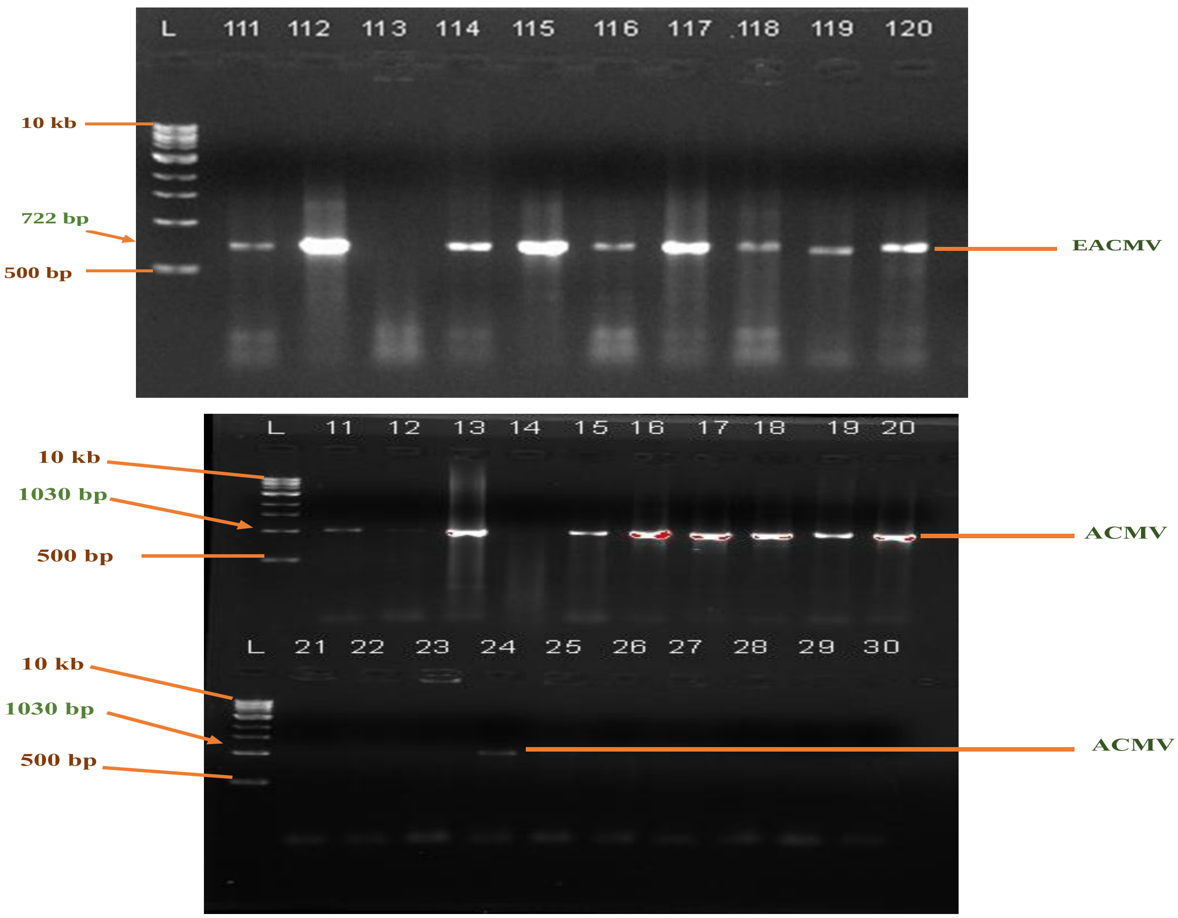

Figure 2 PCR shows the amplification of EACMV (722 bp) and ACMV (1030 bp) from cassava using specific primers EACMV-391C+EACMV 24695 and ACMV-ARo/Ra + ACMV AL1/Fa, respectively. L indicates the molecular weight ladder (1 kb Promega ladder-NEB), with the numbers representing cassava PCR products.

3.1 PCR amplification of ACMV and EACMV using specific primers

Polymerase Chain Reaction (PCR) was performed to detect East African Cassava Mosaic Virus (EACMV) using specific primers EACMV-391C and EACMV-24695. For the African Cassava Mosaic Virus (ACMV), primers ACMV-ARo/Ra and AL1/Fa were utilized. The PCR results confirmed the presence of both ACMV and EACMV in the samples (Figure 2). The analysis of the specific primers showed that 55.7% of the tested samples were positive for

Table 1 Percentage Incidence of Cassava Mosaic Geminiviruses in the Lower Eastern Kenya Region

County/ Region	Cassava variety	Number of samples	Cassava Mosaic Geminiviruses		
			ACMV (%)	EACMV (%)	ACMV+EACMV (%)
Makueni County	Mzungu	5	5 (12.8)	4 (7.5)	4 (11.8)
	Kasukari	5	5 (12.8)	5 (9.4)	5 (14.7)
	Makueni local	5	5 (12.8)	5 (9.4)	5 (14.7)
	Kitwa	5	5 (12.8)	5 (9.4)	5 (14.7)
Machakos County	Katsuhanzala	5	2 (5.1)	5 (9.4)	2 (5.9)
	Kasukari	5	0 (0.0)	3 (5.7)	0 (0.0)
	Mzungu	5	0 (0.0)	3 (5.7)	0 (0.0)
	Kitwa	5	0 (0.0)	4 (7.5)	0 (0.0)
Kitui County	Kasukari	5	0 (0.0)	5 (9.4)	0 (0.0)
	Kitwa	5	5 (12.8)	5 (9.4)	5 (14.7)
	Machakos mixed	5	5 (12.8)	5 (9.4)	5 (14.7)
	Makueni mixed	5	3 (7.7)	4 (7.5)	3 (8.8)
	Makueni kituaa	5	4 (10.3)	0 (0.0)	0 (0.0)
	Bitter cassava	5	0 (0.0)	0 (0.0)	0 (0.0)
	Total (%)	70 (100)	39 (55.7)	53 (75.7)	34 (48.6)

single infections of ACMV, while 75.7% tested positive for single infections of EACMV (Table 1). The findings of this research highlighted the co-occurrence of EACMV and ACMV in Makueni, Kitui, and Machakos counties in Kenya (Table 1). Notably, the Kasukari variety from Kitui County was positive only for EACMV, while the Makueni Kituaa from the same location was negative for EACMV but positive for ACMV. Similarly, the Kasukari variety from Machakos County was negative for ACMV but positive for EACMV. Alarmingly, the Kasukari from Makueni County tested positive for both ACMV and EACMV. However, statistical analysis indicated that there was no significant difference in the prevalence of ACMV and EACMV among the different locations ($p = 0.3141 > 0.05$ for ACMV), and ($p = 0.1394 > 0.05$ for EACMV), nor between the cultivars ($p = 0.3141 > 0.05$ for ACMV), and ($p = 0.1394 > 0.05$ for EACMV).

Dual infections of EACMV and ACMV were identified in 48.6% of the samples examined (Table 1). Our study revealed a lower incidence of mixed infections compared to single infections of either ACMV or EACMV, with a percentage incidence of 48.6%. This finding aligns with previous research indicating no increase in viral DNA titers in cases of dual infections involving ACMV and EACMV (Annang et al. 2024). It also corresponds with studies from Togo, which found mixed infections in cassava plants (Allado et al. 2023). The slightly lower percentage of mixed infections may be attributed to farmers' tendency to avoid severely infected plants when selecting planting materials. However, these results contrast with those reported in Nigeria, where ACMV infections were more prevalent than EACMV infections (Musa et al. 2023).

The presence of mixed infections may stem from the use of infected planting materials. Farmers in Makueni County might be using infected cuttings for planting, which could have led to dual infections in all the cultivars sourced from local farms. Additionally, the occurrence of dual infections in Makueni, followed by Kitui County, could be linked to climatic conditions. The warmer temperatures in these areas may promote a higher abundance of whiteflies (*Bemisia tabaci*) by creating favorable conditions for their survival and reproduction compared to Machakos, thus facilitating the spread of the disease. The high incidence of EACMV in the Makueni region also identifies it as a hotspot for the virus. A study conducted in Ghana describes this phenomenon as the introduction of an infected stem cutting initially planted in one area, which, over time, is cultivated by other farmers. This is common practice, as farmers often share and exchange cuttings of their preferred varieties (Annang et al. 2024). The use of infected cuttings facilitates the widespread proliferation of the CMD virus in a particular area, the presence of the vector (*B. tabaci*), and the cultivation of regional traditional varieties that are susceptible to the virus. Wosula et al. (2024) confirm that both infected cuttings and whitefly transmission are essential routes for disease spread, as populations of hyper-abundant *B. tabaci* contribute to the increased incidence of CMD. It is worth noting that the Kasukari cultivar appears to be more susceptible to CMD than the Mzungu cultivar (Table 1). These two varieties are commonly found across all three counties.

3.2 Severity of root damage

Both the severity and incidence results indicate that bitter cassava is resistant to cassava mosaic disease (CMD) at the time of data collection. This resistance is evidenced both morphologically (Figure 3a) and through PCR results (Table 1). The potential adaptive properties of bitter cassava contribute to its protection against disease infestation. Bitter cassava contains a higher level of cyanide compared to sweet cassava varieties. According to Ospina et al. (2024), bitter varieties typically have more than 100 mg of hydrogen cyanide (HCN) per kilogram of fresh weight, while sweet varieties contain less than 100 mg HCN per kilogram of fresh weight. This higher concentration of HCN may enhance its resistance to CMD by deterring pests and pathogens (Boter and Diaz 2023). Furthermore, epigenetic mechanisms, such as histone modifications and inherited DNA methylation, may influence how bitter cassava responds to environmental stress. These epigenetic changes can regulate gene expression in response to environmental factors, facilitating rapid defence responses. Additionally, plants appear to release enzymes based on their various epigenetic memories of environmental factors, which are passed down to subsequent generations of cassava (Wang and Bart 2025).

Most Kasukari roots exhibited a severity score of 2 or 3, indicating that a significant portion of the root tissue had clearly defined areas of infection and signs of degradation, respectively. However, some roots were found to be rotten and emitted a foul smell, with perforations resulting from the decay of the tissue (Figures 3b, c, and d). No Kasukari roots were completely healthy; each had some traces of root necrosis. In contrast, the asymptomatic bitter cassava exhibited healthy roots, as evidenced by the white appearance of the tissue (Figure 3a). The observed severity of damage to the Kasukari roots suggests a potential reduction in food supply. Additionally, processors typically reject roots with a necrosis score of 3 or higher, as these are considered unfit for processing. Roots with a necrosis score of 2 or lower, however, are deemed fit and marketable (Mkamilo et al. 2024). It is also noteworthy that the Kasukari variety produces large roots, which is a favorable agronomic trait. However, the presence of disease has compromised the quality of these roots. This suggests that the Kasukari variety could be beneficial for enhancing food security in arid and semi-arid regions of Kenya, provided that the disease is effectively managed or eradicated. Furthermore, 10% of the roots received a score of 5, indicating they were rotten and had a foul odor. Robson et al. (2024) demonstrate a positive correlation between a decrease in storage roots and the severity of symptoms. Farmers in the lower eastern region of Kenya may incur significant losses due to the high prevalence of cassava mosaic disease (CMD) if proper management is not implemented. Since Kasukari is a

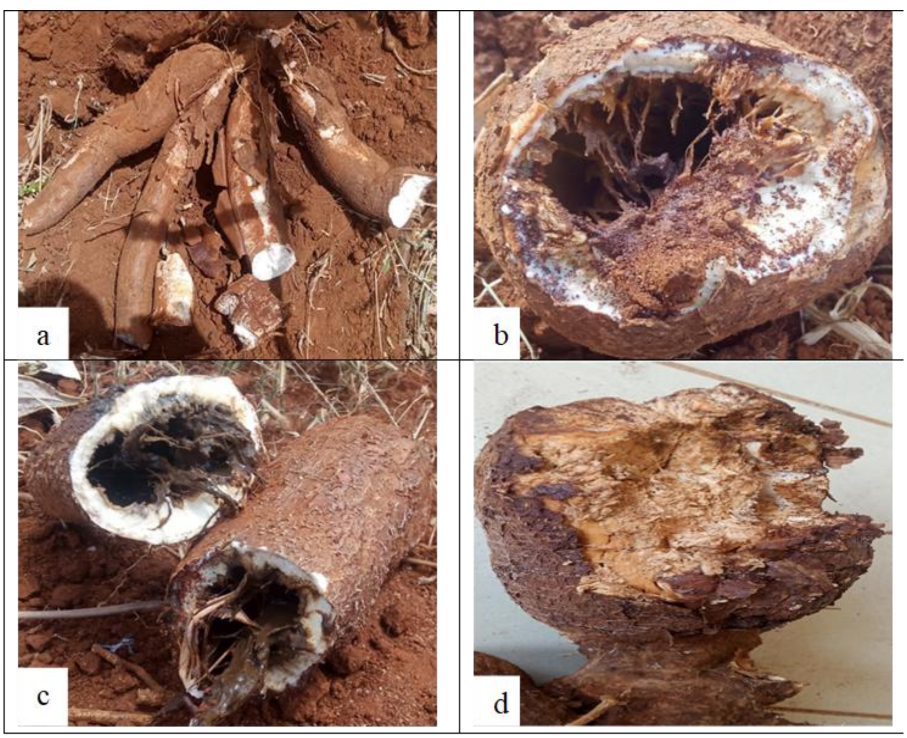

Figure 3 shows harvested cassava roots from the SEKU (Kitui) experimental farm: (a) a sample of asymptomatic bitter cassava tubers; (b, c, and d) infected Kasukari tubers that are severely damaged and unusable.

drought-resistant variety, its cultivation, combined with effective disease control, could enable Arid and Semi-Arid Lands (ASALs) to produce more food and generate revenue as farmers sell the roots for profit while also using them for consumption. The presence of cassava mosaic disease underscores the urgent need to develop superior varieties that are resistant to diseases, have higher yield potential, and are adaptable to varying climatic conditions.

Conclusions

This study found that both EACMV (East African Cassava Mosaic Virus) and ACMV (African Cassava Mosaic Virus) are common in the counties of Makueni, Kitui, and Machakos. Notably, Machakos County had a high incidence of EACMV but a low occurrence of ACMV when compared to Kitui and Makueni counties. Interestingly, bitter cassava varieties appear to be less susceptible to both viruses. In cases of severe infections, cassava mosaic disease (CMD) can damage the roots, making them unsuitable for consumption. To enhance food security, further research is necessary to explore the genetic traits that confer resistance to ACMV and EACMV in bitter cassava varieties. This information could be valuable in breeding programs aimed at developing resilient sweet cassava varieties that appeal to a broader range of consumers. Additionally, it is essential to educate farmers on proper management techniques to minimize the spread of these viruses through infected plant material, such as cuttings.

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Ethical Approval

Not applicable. The study did not use any human or animal samples, nor were any interviews conducted.

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