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# Farmers' Knowledge, Perceptions and Management of Moroccan Watermelon Mosaic Virus Disease Infecting Cucurbits in Selected Counties in Kenya

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**Abstract**

Cucurbits are important food crops worldwide due to their nutritional benefits and contribution to the national economies. In Kenya, cucurbits are mainly produced by small scale farmers for their leaves, immature or mature fruits and seeds. However, their production in the country is constrained by viral disease infections including Moroccan watermelon mosaic virus (MWMV), a potyvirus in the family potyviridae. The virus is transmitted mainly by several species of aphids in a non-persistent manner, with early infection resulting in complete yield loss. This study assessed farmers' knowledge, perceptions and management practices of MWMV in three major growing cucurbits counties and seven sub-counties in Kenya namely, Machakos County (sub-counties Matungulu and Kangundo), Kirinyaga county (sub-counties Mwea East, Kirinyaga East and Kirinyaga West), Embu county (sub-counties Mbeere North and Embu West). A total of 229 smallholder farmers were randomly identified and a semi-structured questionnaire administered through face-to-face interviews was used to collect the data. The collected data was cleaned and subjected to analysis of variance (ANOVA) and Chi square test using SPSS software. The findings indicate that the respondents were aware of MWMV disease symptoms presence in their farms ranging from leaf distortion, dark green blisters and mosaic on the leaves. Majority of the respondents (49.5%) perceived the symptoms to be caused by weather changes while (16.1%) associated the symptoms with pests' infestation while (11.1%) did not know the cause of the symptoms.

Therefore, the Strategies to tackle plant viral diseases must include farm-level training to improve farmers' knowledge and disease management.

**Keywords:** Cucurbit, Farmers' Knowledge, Viral Disease, Constraints, Control Strategies

## Introduction

Cucurbit are important crops in Kenya cultivated for both domestic and export markets (HCDA, 2020) [14]. The crops produces fruits that serve as a source of food that can be consumed fresh, cooked, baked, dried, or processed into various products including pumpkin flour, melon juice, cucumber juice and squash soup (Ahmad & Khan, 2019) [2]. The leaves of pumpkin is also an important vegetable in some communities in Kenya (HCDA, 2020) [14]. Medicinally, the crops are rich in antioxidants that are good for the skin and phytonutrients used to reduce the risk of certain types of cancer (Ahmad & Khan, 2019) [2]. The crops are also rich in minerals such as magnesium, potassium, copper, calcium and vitamins A, B, C, E, and K (Elinge *et al*. 2012 [7]; Khan, 2019).Therefore, cucurbit crops are a good source of nutrients and income to the farmers (HCDA, 2020) [14].

Cucurbits production in the country however, is challenged with abiotic constraints such as drought, nutrient deficiency, temperature stress and biotic constraints such as pest, downy mildew, powdery mildew, anthracnose, and viral infections plays a significant role (Mumo *et al*. 2021; HCDA, 2020 [14]; Kidanemariam *et al*. 2019 [13]).

Moroccan watermelon mosaic virus is one of the most destructive viral disease affecting cucurbits production in Africa and the Mediterranean region (Ibaba *et al*. 2016; Lecoq *et al*. 2001; Yakoubi *et al*. 2008; Fischer and Lockhart, 1974) [15, 16, 25, 9].The virus belong to the genus potyvirus in the family potyviridae. The virus affects cucurbit crops at all stages of growth, ultimately resulting in yield loss of up to 100% (Davis *et al*. 2020) [6]. The infected plants portray the following symptoms; mosaic, mottling, blistering, yellowing and deformation of leaves, fruit deformation, and stunted growth (Lecoq *et al*. 2001; Mumo *et al*. 2020) [16, 20].

Some of these symptoms closely resemble those caused by other biotic and abiotic factors such as nutrient deficiency, and

drought (Schreinemachers *et al*. 2015) [23]. A key component of developing integrated disease management strategies in agriculture is understanding farmers' perspectives and knowledge of the disease and how these influences the management techniques (Schreinemachers *et al*. 2015) [23]. The farmers knowledge, perceptions and practices can be used in developing an integrated disease control package and capacity building on improving their capacity to manage pests and diseases effectively (Midega *et al*. 2016; Mendesil *et al*. 2016) [19, 18].

Therefore, this study was conducted to determine farmer's knowledge, perceptions and management practices of Moroccan watermelon mosaic virus disease effecting cucurbit crops production.

## Materials and Methods

### Study areas

The study was conducted in selected counties in Kenya, focusing on three major cucurbit production counties. The counties included Machakos, Kirinyaga and Embu. Within the counties, the leading sub-counties in cucurbits production were selected for the study (HCDA, 2020) [14]. The sub-counties included Matungulu and Kangundo in Machakos county, Mwea East, Kirinyaga East, and Kirinyaga West in Kirinyaga county and Mbeere North and Embu West in Embu county. The surveyed sites were mapped using a global positioning system (GPS; Magellen GPS315, San Dimas, CA).

### Sampling procedure and data collection

Stratified random sampling, purposive and snow-ball sampling techniques were used to sample cucurbits farmers in the selected sub-counties. Data was collected using a semi-structured questionnaire administered through face-to-face interviews.

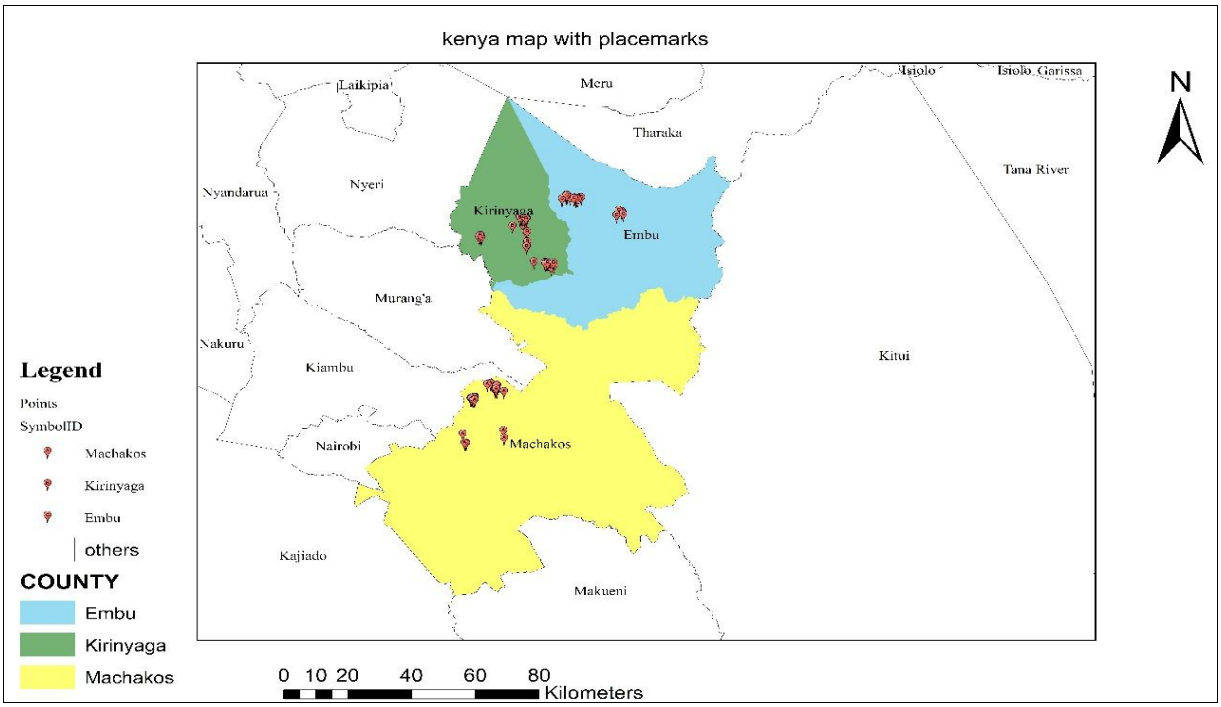


**Fig 1:** A section of a map of Kenya showing three counties where the survey was conducted

The questionnaire was pre-tested with ten (10) farmers before conducting the study. Data collected included socioeconomic characteristics of the farmers, cucurbits production, farmers' knowledge, perception and management practices of the MWMV disease. To test farmers knowledge of the disease, an A4-sized photographs of cucurbit plants infected by Moroccan watermelon mosaic virus disease was used (Asudi *et al*. 2015; Khan *et al*. 2014) [3, 11]. The photos had no text to ensure the identification was based on visual cues by correlating the symptoms in the fields with those in the picture. Where necessary, the disease symptoms were described. Farmer's knowledge of the disease was assessed by asking if they knew the symptoms in the photos and if the cucurbits in the farms displayed those symptoms. The responses to the knowledge questions were recorded in a series of binary responses (1 for yes and 2 for no). The perception of the disease and the rate of spread was captured as a categorical variable using a 4-point Likert scale rating (Khan *et al*. 2014; Asudi *et al*. 2015) [11, 3]. The farmers were asked to rate the disease problem on a scale of 0 to 3, where 0 = no problem, 1 = moderate problem, 2 = severe problem, 3 = very severe problem. The current rate of the disease spread was scored on a scale of 0 to 3 where 0 = no spread, 1 = slow spread, 2 = fast spread, 3 = very fast spread. Information such as the purpose for cucurbits production, the cropping system they use, seasonal prevalence of the symptoms on cucurbit crops, the cause of the symptoms and the control measures was also captured.

### Data Analysis

Data collected was cleaned then subjected to analysis using Statistical package for the Social Sciences (SPSS) sofrware version 21. Frequency analysis was used to describe the distribution of key categorical variables, providing insights into the count and percentage of responses across different categories. To assess the differences in means between multiple groups of more than two, an analysis of variance (ANOVA) was conducted. Cross-tabulation and Chi-square test were employed to explore associations betweeen two categorical variables. Statistical siginficance was determined

at 0.05 level. Correlation analysis was also done to determine the associations between farmers' knowledge, perception and management of MWMV

## Results

### Socio-demographic characteristics of cucurbit farmers interviewed during the survey

A total of 229 farmers were interviewed with 72, 26, 39, 12, 11, 55 and 14 farmers from Matungulu, Kangundo, Mwea East, Kirinyaga West, Kirinyaga East, Embu West, and Mbeere North sub-counties respectively (Table 1). About 59% of the respondents were females and 41% were males. The age of the respondent ranged between 18 to more than 66 years. There was no significant difference observed between the age group ($\chi2 = 40.9$; P = 0.08 Table 1). About 63.3% of the respondents had obtained primary education (8 years of basic education). The production purpose of cucurbits varied significantly across sub- counties ($\chi2 = 47.5$, P < 0.001; Table 1) with 68.1% of the respondents producing cucurbits for home consumption and selling the surpuls (Table 1). The land size owned by respondents varied across sub-counties, 2.83 acres in Kangundo, 2.27 acres in Matungulu, 2.16 acres in Kirinyaga East, 1.98 acres in Mbeere North, 1.88 acres in Mwea East, 1.66 acres in Embu West and 1.43 acres in Kirinyaga West (Table 1).The average land size in acres that was under cucurbit crops production varied across sub-counties with Matungulu, Mbeere North, Kangundo, Mwea East, Kirinyaga West, Kirinyaga East and Embu West 1.10, 0.84, 0.655, 0.50, 0.41, 0.40 and 0.33 respectively. There was a significant difference across the sub-counties in regards to current land size under cucurbits production ($\chi2 = 4.58$, df = 6, P = <0.001 Table 1).

**Table 1:** Characteristic of cucurbit farmers in the seven sub-counties in Kenya

| | Embu County | | Machakos County | | Kirinyaga County | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub-counties | | Sub-counties | | Sub-counties | | | | | | |
| | Embu West | Mbeere North | Kangundo | Matungulu | Kirinyaga East | Kirinyaga West | Mwe East | Total | Mean | $\chi2$ | P-value |
| Number of farms surveyed | 55 | 14 | 26 | 72 | 11 | 12 | 39 | 229 | | | |
| **Gender of respondents (%)** | | | | | | | | | | | |
| Male | 43.6 | 42.9 | 53.8 | 33.3 | 36.4 | 16.7 | 54 | | 41 | $7.8^{ns}$ | 0.16 |
| Female | 56.3 | 57.1 | 46.2 | 66.7 | 63.6 | 83.3 | 46 | | 59 | | |
| **Age (years) of respondent (%)** | | | | | | | | | | | |
| 18-24 | - | 7.1 | - | 5.6 | - | - | 7.7 | | 3 | $40.9^{ns}$ | 0.08 |
| 25-34 | 12.7 | 28.6 | 11.5 | 8.3 | 18.2 | - | 13 | | 13 | | |
| 35-44 | 16.4 | 21.4 | 15.4 | 20.8 | 9.1 | 8.3 | 18 | | 16 | | |
| 45-54 | 25.5 | 35.7 | 7.7 | 31.9 | 27.3 | 41.7 | 18 | | 27 | | |
| 55-65 | 30.9 | 7.1 | 61.5 | 25.0 | 18.2 | 41.7 | 31 | | 30 | | |
| Above 66 | 14.5 | - | 3.8 | 8.3 | 27.3 | 8.3 | 13 | | 11 | | |
| **Educational level of Respondents (%)** | | | | | | | | | | | |
| Primary School | 45.5 | 50 | 34.6 | 94.4 | 60.0 | 83.3 | 51 | | 60 | $93.3^{**}$ | <0.001 |
| Drop out secondary | 12.7 | 28.6 | 7.7 | - | 10.0 | - | 15 | | 10.5 | | |
| Secondary school completed | 30.9 | 21.4 | 42.3 | 28 | 30.0 | - | 26 | | 22 | | |
| Technical training | 9.1 | - | 15.4 | - | - | - | - | | 3.5 | | |
| Undergraduate | - | - | - | 1.4 | - | 8.3 | 7.7 | | 2.4 | | |
| Post graduate | 1.8 | - | - | 1.4 | - | 8.3 | - | | 1.6 | | |
| **Reason for cucurbits Production (%)** | | | | | | | | | | | |
| Subsistence | 47.3 | 50 | 7.7 | 19.4 | 54.5 | 33.3 | 17 | | 28.8 | $47.5^{**}$ | <0.001 |
| Subsistence and Market | 52.7 | 28.6 | 88.5 | 79.2 | 88.5 | 66.7 | 77 | | 68.1 | | |
| Market | - | 21.4 | 3.8 | 1.4 | - | - | 5.1 | | 3.1 | | |
| **Average land owned by respondents (Acres)** | 1.66 | 1.98 | 2.83 | 2.27 | 2.16 | 1.43 | 1.88 | | 2.05 | $4.00^{ns}$ | 0.06 |
| **Land under cucurbits production (Acres)** | 0.33 | 0.84 | 0.65 | 1.10 | 0.40 | 0.41 | 0.50 | | 0.68 | 4.58** | 0.001 |

Chi- square test, and P < 0.05) at *P < 0.05, **P < 0.001; shows significant difference; ns means not significant, - mean no case present

### Cucurbits farming experience and production constraints

The farming system differed across the sub-counties with majority of the farmers adopting intercropping system (94.1%), Mono cropping (5.1%), crop rotation (0.4%), and shifting cultivation (0.4%).The farming system differed significantly across sub-counties ($\chi2 = 45$, P < 0.001; Table 2).The years of cucurbits production varied significantly across the sub- counties ($\chi2 = 56.4$; df = 18; P = <0.001). Most of the farmers had more than two years of experience (89.1%) in cucurbit farming (Table 2).Cucurbit species grown varied significantly across the seven sub-counties ($\chi2 = 18.8$; df = 8; P = 0.015), with majority of the respondents (97.3%), growing pumpkin, followed by watermelon (5.9%), butter nut (5.7%), and zucchini (0.37%). There were no reported cucumber cultivation during time of the survey in the sub-counties. Production constraints in cucurbits reported in the surveyed areas included pest infection such as melon fly, aphids, whiteflies, and beetles. The major disease reported to infect cucurbits were mainly fungal including anthracnose, powdery and Downey mildew, and blights. Disease encounter during the survey as per respondents varied significantly across the sub-counties ranging from anthracnose with a significant difference of ($\chi2 = 2.55$; df = 6; P = <0.001), followed by powdery mildew ($\chi2 = 26.1$; df = 6; P = < 0.001), downy mildew ($\chi2 = 39.0$; df = 6; P = 0.001) and blight ($\chi2 = 45.98$; df = 25; P = 0.006), the pest (melon fly) also varied significantly across the sub-counties with a significant difference of ($\chi2 = 53.9$; df = 24; P = 0.004 Table 2).

**Table 2:** Farmer knowledge in cucurbit production and constraints

| | Embu county | | Machakos county | | Kirinyaga county | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub- Counties | | Sub-counties | | Sub-counties | | | | | | |
| | Embu West (N = 55) | Mbeere North (N = 14) | Kangundo (N = 26) | Matungulu (N = 72) | Kirinyaga East (N = 11) | Kirinyaya West (N = 12) | Mwea East (N = 39) | Total 229 | Mean | $\chi 2$ | P-value |
| **Farming System (%)** Crop rotation | - | - | - | - | 3.8 | 1.4 | - | | 0.4 | 49.9* | 0.005 |
| Mixed cropping | 94.5 | 91.7 | 100 | 90.9 | 96.2 | 98.6 | 87.2 | | 94.1 | | |
| Mono cropping | 5.5 | 16.7 | - | 9.1 | 3.8 | - | 10.3 | | 5.1 | | |
| Shifting cultivation | - | 8.3 | - | - | - | - | - | | 0.4 | | |
| **Years of experience in cucurbit production (%)** | | | | | | | | | | | |
| <1 year | - | 21.4 | - | - | - | 8.3 | 5.1 | | 4.9 | 56.4** | <0.001 |
| 1 year | 1.8 | 7.1 | - | - | - | - | - | | 1.3 | | |
| 2 year | 1.8 | 21.4 | 3.8 | - | - | - | 5.1 | | 4.5 | | |
| More than 2 years | 96.4 | 50 | 96.2 | 100 | 100 | 91.7 | 89.7 | | 89.3 | | |
| **Cucurbit species grown by the respondents (%)** | | | | | | | | | | | |
| Cucumber | - | - | - | - | - | - | - | | - | | |
| Watermelon | - | 14.3 | - | 1.4 | - | 8.3 | 17.9 | | 5.9 | | |
| Butter nut | - | 14.3 | 19.2 | 4.2 | - | 16.7 | 5.1 | | 5.7 | 18.8** | 0.01 |
| Pumpkin | 100 | 85.7 | 100 | 98.6 | 100 | 100 | 97.4 | | 97.3 | | |
| Zucchini | - | - | - | - | - | - | 2.6 | | 0.37 | | |
| **Cucurbits production constraint (%)** | | | | | | | | | | | |
| Anthracnose | - | - | - | 14.1 | - | - | - | | 2.01 | 2.55** | <0.001 |
| Powdery mildew | 89.1 | 100 | 91.7 | 63.4 | 100 | 66.7 | 87.2 | | 85.4 | 26.1** | <0.001 |
| Downy mildew | 50 | 85.7 | 91.7 | 31 | 72.7 | 50 | 66.7 | | 64.9 | 39.0** | <0.001 |
| Blight | 85.7 | - | 100 | 68.2 | 25 | - | 50 | | 46.9 | 45.9* | 0.006 |
| Melon fly | 70 | 100 | 28.6 | 76.3 | 81.8 | 97.1 | 80 | | 76.2 | 52.9* | 0.004 |

Chi- square test, and $P < 0.05$) at *$P < 0.05$, **$P < 0.001$; shows significant difference; ns means not significant, - mean no case present

**Farmer's knowledge of the disease, its cause and symptoms observed in the field**

MWMV disease symptoms were found in the seven sub-counties namely mosaic, severe filiform, chlorosis, dark green blister, and deformation on the leaves. The highest disease symptoms reported was leaf distortion (72.5%), followed by dark blister on leaf (64.5%), followed by chlorosis on leaf (64.4%), mosaic (64.1%), and severe leaf filiform (24.1%) respectively (Table 3). The presence of the disease symptoms across the seven sub-counties ranged from 100% in Kirinyaga East and Kirinyaga West, 90.3% in Matungulu, 92% in Kangundo, 85.7% in Mbeere North, 74.4% in Mwea East and 68.8% in Embu West (Table 3). All the respondents in the survey field were able to recognize the presence of MWMV symptoms with in their farms using an A4 –sized photographs of cucurbit plants infected by (MWMV (Table 3).

The cause of the disease varied significantly within the sub-counties ($\chi 2 = 13.6$; df = 4, P = 0.009). Majority of the sampled respondents (49.5%), associated the cause of the disease to be due to weather changes and 16% believed the symptoms were due to pest's infestation. About 12.9% linked the symptoms with disease infestations, 6.2% thought the symptoms were due to nutrient deficiency. However a significant number of the sampled respondents (11.1%) did not know the cause of the disease (Table 3).

**Farmer's perceptions on MWMV disease rate of spread and cause of spread**

Famer's perception of the disease problem differed significantly with the sub-counties (($\chi 2 = 40.8$; df = 12; P = 0.001 Table 4). Majority (52.8%) of the respondents perceived it as a minor problem, and 31.6% perceiving it as a severe problem. The spread of the virus disease on cucurbit farms across the seven sub-counties varied significantly ($\chi 2 = 19.6$; df = 6; P = 0.003 Table 4) with the respondents from Kirinyaga East and Mbeere North sub-counties reporting the highest spread of 100%, 95.5% of the farmers in Kangundo and Matungulu, 90.6%, in Mwea East, 91.7% in Kirinyaga West, and 73.3% in Embu West sub-counties reported its spread. There is a significant difference amongst factors responsible for the disease spread across sub-counties ($\chi 2 = 30.3$, df = 18, P = 0.003 Table 4). About 64.7% of the respondents did not know what was causing the spread of the disease. 25.2% associated the disease spread with weather, 9.2% thought the disease was spread by pest while 1.1% associated the viruses to be spreading the disease (Table 4). The disease spread across the seven sub-counties was rated as slow by 56.5%, fast by 42.9%, and very fast by 0.6%. There is significant difference across sub-counties in regards to the seasonal prevalence of the disease ($\chi 2 = 54$; df = 24; P = 0.001 Table 4).

**Table 3:** Farmer's awareness of MWMV presence in their farm and cause of the disease in your farms

| | Embu county | | Machakos County | | Kirinyaga county | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub- counties | | Sub-counties | | Sub-counties | | | | | | |
| | Embu West (N = 55) | Mbeere North (N = 14) | Kangundo (N = 26) | Matungulu (N = 72) | Kirinyaga East (N = 11) | Kirinyag West (N = 12) | Mwea East (N=3) | Total (N=229) | Mean | $\chi 2$ | P- Value |
| Farmers' awareness of MWMV disease Symptoms presence in their farm (%) Yes | 64.8 | 85.7 | 92 | 90.3 | 100 | 100 | 74.4 | | 82.4 | 22.9** | 0.001 |
| Farmers' awareness of Mosaic symptoms in their farm Yes | 64.6 | 50 | 80 | 52.1 | 81.8 | 66.7 | 53.8 | | 64.1 | $10.1^{ns}$ | 0.12 |
| Farmers' awareness of Severe leaf filiform symptoms in their farm Yes | 6.3 | 35.7 | 33.3 | 25.4 | - | 45.5 | 23.1 | | 4.5 | 17.4* | 0.008 |
| Farmers' awareness of chlorosis leaf symptoms in their farm Yes | 58.3 | 64.3 | 68 | 57.1 | 63.6 | 83.3 | 56.4 | | 64.4 | $4.0^{ns}$ | 0.67 |
| Farmers' awareness of dark green blisters on leaf in their farm Yes | 50 | 64.3 | 44 | 69 | 81.8 | 91.7 | 51.3 | | 64.5 | 15.7** | 0.01 |
| Farmers' awareness leaf distortion in their farm Yes What is the cause of the problem | 56.3 | 78.6 | 68 | 60.6 | 100 | 83.3 | 61 | | 72.5 | $11.3^{ns}$ | 0.78 |
| Pest Yes | 21.4 | 25 | 38.5 | 13.6 | - | - | 13.8 | | 16.1 | $10.1^{ns}$ | 0.122 |
| Disease Yes | - | - | 7.7 | 29.5 | 9.1 | 20 | 24.1 | | 12.9 | $9.3^{ns}$ | 0.157 |
| Weather Yes | 61.5 | 100 | 38.5 | 44.2 | 18.2 | 50 | 34.5 | | 49.5 | $11.1^{ns}$ | 0.86 |
| Nutrient deficiency Yes | - | - | 9.1 | 5.7 | 9.1 | 20 | - | | 6.2 | $6.8^{ns}$ | 0.34 |
| Not aware | - | - | 60 | 18.2 | - | - | - | | 11.1 | 13.6* | 0.009 |

Chi- square test, and P < 0.05) at *P < 0.05, **P < 0.001; shows significant difference; ns means not significant, - mean no case present

**Table 4:** Farmer's awareness and perception of MWMV of MWMV disease rate of spread and prevalence

| | Embu County | | Machakos County | | Kirinyaga County | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub-counties | | Sub-counties | | Sub-counties | | | | | | |
| | Embu West (N = 55) | Mbeere North (N = 14) | Kangundo (N = 26) | Matungulu (N = 72) | Kirinyaga East (N = 11) | Kirinyaga West (N = 12) | Mwea East (N =39) | Total 229 | Mean | $\chi 2$ | P-Value |
| **Is the disease problem spreading in your farm Yes** | 73 | 100 | 95 | 95.5 | 100 | 91.7 | 90.6 | | 90 | 19.6* | 0.003 |
| **What is causing the spread of the problem** | | | | | | | | | | | |
| Pest | 15.2 | 8.3 | 4.8 | 7.7 | - | - | 16.1 | | 9.2 | | |
| Virus | - | - | - | 3.1 | - | - | - | | 1.1 | 30.3* | 0.003 |
| Weather | 9.1 | - | 23.8 | 23.1 | 45.5 | 63.6 | 35.5 | | 25.2 | | |
| Not aware | 75.8 | 91.7 | 71.4 | 66.2 | 54.5 | 36.4 | 48.4 | | 64.7 | | |
| **How do you rate the disease problem in your farm** | | | | | | | | | | | |
| No problem | 33.3 | - | 9.5 | 5.9 | 9.1 | 8.3 | 21.6 | | 15.6 | | |
| Low/ minor problem | 58.8 | 58.3 | 76.2 | 45.6 | 45.5 | 50 | 45.9 | | 52.8 | 40.8** | <0.001 |
| Severe | 7.8 | 41.7 | 14.3 | 48.5 | 45.5 | 41.7 | 32.4 | | 31.6 | | |
| **The rate of the disease spread** | | | | | | | | | | | |
| Slow | 63.6 | 54.5 | 30 | 66.1 | 63.6 | 72.7 | 37.9 | | 56.5 | | |
| Fast | 36.4 | 45.5 | 70 | 32.3 | 36.4 | 27.3 | 62.1 | | 42.9 | $16.6^{ns}$ | 0.16 |
| Very fast | - | - | - | 1.6 | - | - | - | | 0.6 | | |

Chi- square test, and P < 0.05) at *P < 0.05, **P < 0.001; shows significant difference; ns means not significant, - mean no case present

**Famer's perception on the disease prevalent and management practices**

There is significant difference across the sub-counties in regards to the seasonal prevalence of the disease ($\chi 2$ = 54, df = 24, P = 0.001 Table 5). About 56% of the respondents perceived the symptoms of the disease to be more prevalent during the cold season and 33.1% during the hot season (Table 5). The infection of new cucurbit crops by the disease after planting varied significantly across the sub-counties ($\chi 2$ = 69.8, df = 24, P = 0.001). Majority of the respondents (41.5%) across the sub-counties were not aware of when their newly planted cucurbit crops get infected with the disease, whereas 24.4%, 16.6% and 0.5% reported noting the symptoms more than three months, three months, two months, and one month after planting respectively. The management practices of the disease varied across sub-counties with majority of the respondents sprayed chemicals, with 100%, 90%, 89.7%, 81.8%, 94.1%, 72.1% in Mbeere North, Kirinyaga West, Mwea East, Kirinyaga East, Kangundo, Matungulu and Embu West respectively. Use of cultural practices such traps and ashes in the management of the disease was also reported by 40% in Kirinyaga West, 26.2% in Matungulu, 23.5% in Kangundo, 22.2% Embu West, 10.3% Mwea East, and 9.1% Kirinyaga East. Meanwhile, 23.8% respondents in Embu West, 14.3% in Kangundo, 18.2% in Kirinyaga East, 6.6% in Matungulu, and 3.6% in Mwea East did not apply any control measure (Table 5).

**Table 5:** Farmer's perception and management practices of MWMV

| | Embu County | | Machakos County | | Kirinyaga County | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub- counties | | Sub- counties | | Sub-counties | | | | | | |
| | Embu West (N = 55) | Mbeere North (N = 14) | Kangundo (N = 26) | Matungulu (N = 72) | Kirinyaga East (N = 11) | Kirinyaga West (N = 12) | Mwea East (N = 39) | Total 229 | Mean | $\chi 2$ | P-Value |
| **Seasonal prevalent of the disease** | | | | | | | | | | | |
| Cold season | 45.7 | 91.7 | 21.7 | 62.3 | 81.8 | 50 | 58.1 | | 56 | | |
| Hot season | 54.3 | - | 73.9 | 18.8 | 18.2 | 33.3 | 29 | | 33.1 | | |
| Rainy season | - | - | - | 4.3 | - | - | - | | 1.6 | 54.0** | <0.001 |
| Always | - | - | - | - | - | - | 3.2 | | 0.5 | | |
| Don't know | - | - | 4.3 | 14.5 | - | 16.7 | 9.7 | | 8.8 | | |
| **When are new plants affected** | | | | | | | | | | | |
| One month | 2.9 | - | - | - | - | - | - | | 0.5 | | |
| Two months | 5.7 | 41.7 | - | 13 | 27.3 | - | 32.3 | | 15 | | |
| Three months | 20 | 25 | 4.3 | 15.9 | 9.1 | 25 | 19.4 | | 16.6 | 69.8** | 0.001 |
| More three months | 25.7 | 8.3 | 4.3 | 46.4 | 18.2 | 8.3 | 16.1 | | 26.4 | | |
| Not aware | 45.7 | 25 | 91.3 | 24.6 | 45.5 | 66.7 | 32.3 | | 41.5 | | |
| **Control measure** | | | | | | | | | | | |
| Chemical (%) | 71.4 | 100 | 94.1 | 72.1 | 81.8 | 90 | 89.7 | | 85.5 | $10.8^{ns}$ | 0.09 |
| Cultural (%) | 22.2 | - | 23.5 | 26.2 | 9.1 | 40 | 10.3 | | 18.7 | $9.27^{ns}$ | 0.15 |
| No control | 23.8 | - | 14.3 | 6.4 | 18..2 | - | 3.6 | | 9.2 | $35.5^{ns}$ | 0.22 |

Chi- square test, and $P < 0.05$) at *$P < 0.05$, **$P < 0.001$; shows significant difference; ns means not significant, - mean no case present

**Correlation analysis for cucurbits farmer practices and MWMV management**

There is no correlation between farmer educational level and MWMV management, this indicate that education level did not play a significant role in determining disease control. Therefore, there are other underlying factors that influence farmer's disease management (See Table 6).A strong positive and statistically significant correlation ($r = 0.896$, $p < 0.01$) exists between years of farming experience and years of growing cucurbits, suggesting that those with more general farming experience also tend to have more specific experience with cucurbits. There is also a moderate positive correlation between chemical control use and efforts to manage the disease ($r = 0.605$, $p < 0.01$), indicating that respondents who attempted to manage the problem were more likely to use chemical methods. Interestingly, cultural control shows a statistically significant but negative correlation with chemical control ($r = -0.357$, $p < 0.01$), which may imply that respondents tend to prefer one control method over the other rather than using both simultaneously. Additionally, the perception that weather causes the problem negatively correlates with the belief that disease is the cause ($r = -0.207$, $p < 0.05$) and with nutrient deficiency ($r = -0.192$, $p < 0.05$), suggesting different root cause of the problem among farmers. Overall, while most correlations are weak, a few statistically significant patterns offer insight into farmers' perceptions, experiences, and management strategies related to cucurbit production challenges (Table 6).

**Table 6:** Correlation analysis for management of MWMV

| | Education | Farming Experience | Years of cucurbit production | Knowledge Pest | Knowledge Disease | Knowledge Weather | knowledge Nutrient deficiency | cause _I don't know | Perception | Chemical Management | Cultural Management |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Education | 1 | | | | | | | | | | |
| Farming Experience | -.054 | 1 | | | | | | | | | |
| Years of cucurbit production | -.056 | .896** | 1 | | | | | | | | |
| Knowledge –Pest | -.116 | .091 | .017 | 1 | | | | | | | |
| Knowledge Disease | -.004 | -.110 | -.096 | -.152 | 1 | | | | | | |
| Knowledge Weather | .017 | .108 | .067 | -.054 | -.207* | 1 | | | | | |
| Knowledge Nutrient deficiency | .077 | -.054 | -.047 | -.106 | -.128 | -.192* | 1 | | | | |
| Causes I don't know | -.016 | -.089 | -.089 | -.130 | -.179 | -.147 | .259 | 1 | | | |
| Perception | -.042 | .024 | .036 | -.183* | .107 | .031 | -.057 | -.236 | 1 | | |
| Chemical Management | .126 | .131 | .117 | .056 | .074 | -.046 | .109 | -.208 | .044 | 1 | |
| Cultural Management | .028 | -.077 | -.096 | .148 | -.018 | .253** | -.109 | -.091 | -.078 | -.357** | 1 |

** shows statistically significant

**Discussion**

Moroccan watermelon mosaic virus cause substantial damage to cucurbits crops globally, posing a serious production risk and early infection ultimately result in complete loss of yield leading to food insecurity (Davis *et al*. 2020) [6]. This study has shown that all the respondents were able to recognize the presence of MWMV disease symptoms in their various farms but were unable to identified the actual cause there by associating the symptoms to be cause by either pest, disease, weather and nutrition deficiency which validate previous report about African farmers lacking precise knowledge about diseases affecting crops (Abang *et al*. 2014; Auwal *et al*. 2015) [1, 4]. The lack of knowledge could be a major hindrance to MWMV management in the county. There is no correlation between farmers' knowledge and management practices of MWMV, in contrast to other study that have found correlation between farmers' knowledge, and management practices (Lwin *et al*. 2012) [17]. Due to the limited knowledge farmers' could relied on their own or other farmers' experience to identify disease symptoms which could be a significant barrier to plant disease management. Therefore, training of farmers' on simple techniques for distinguishing biotic factors from other abiotic factors will improve management (Birithia and Kuria, 2023) [5]. The lack of farmer's knowledge about the disease may have influence

the disease management as 85% of the respondents control the disease by applying chemicals (Khan and Damalas, 2015) [12].

There is significant correlation between years of farming experience and years of growing cucurbits, suggesting that those with more general farming experience tend to have more specific experience with cucurbits. Majority of the respondents 64.7% were not aware about MWMV spread mechanisms there by associating the spreading with viruses and changes in the weather which may influence the disease spread (Strange and Scott, 2005: FAO, 2016) [24, 8]. Majority of the respondents (64.7%) were not ware about the factor responsible for the spread of the disease symptoms in their farms therefore, improper identification of the spread agent could increase the disease level of spread and impede the control mechanism there by causing yield losses (Strange and Scott, 2005; Serge *et al*. 2019) [24, 22].

This study result indicate that majority of the respondents (85.5%) control the disease by spraying of chemical insecticides while (18.7%) used cultural control method. The application of insecticide to control plant diseases is one of the integrated management practices in controlling MWMV since it reduces the aphids' population and distribution there by reducing the level of damage cause (Roy *et al*. 2014) [21]. Meanwhile, the application of chemical insecticides as a management strategy may be ineffective without comprehension of the role of aphids or other vectors in the transmission of the virus responsible for MWMV disease (Kalleshwaraswamy and Kumar, 2008) [10]. Moreover, effective insect control necessitates implementation prior to the manifestation of disease symptoms, which demands farmers' understanding of disease epidemiology

(Schreinemachers *et al*., 2015) [23]. A significant proportion of respondents (41.5%) were unaware of the age at which their plants exhibited symptoms of MWMV disease, as the virus can infect the crop at any growth stage, with early infection potentially resulting in partial or complete yield loss prior to fruit formation (Davis *et al*. 2020) [6]. Majority of the respondents (56%) perceive MWMV symptoms to be more prevalent during the cold season there by attributing the disease to be cause by changes in the weather.

## Conclusion

The strategies to combat plant virus diseases must incorporate farm-level training to enhance farmers' awareness and understanding of plant viruses, encompassing disease identification, epidemiology, and management. The ability to differentiate viral infection symptoms from those of other diseases, along with the understanding that the majority of viruses are disseminated by insect vectors primarily aphids, may motivate farmers to manage insect populations and prevent the surplus application of pesticides that are less effective against viral diseases.

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## References

1. Abang AF, Kouame CM, Abang M, Hanna R, Fotso AK. Assessing vegetable farmer knowledge of diseases and insect pests of vegetable and management practices under tropical conditions. International Journal of Vegetable Science. 2014; 20:240-253.
2. Ahmad G, Khan AA. Pumpkin: Horticultural importance and its roles in various forms: A review. Int. J. Hortic. Agric. 2019; 4(1):1-6.
3. Asudi GO, Van Den Berg J, Midega CAO, Pittchar JA, Khan ZR. Napier grass stunt disease in East Africa: Farmer perspective on disease management. Crop Production. 2015; 71:116-124.
4. Auwal HM, Galadima IB, Madu J, Joseph P. Evaluation of synergistic effect of neem and poultry manure on root knot nematode (Meloidogyne spp.) infecting rice. Open Agriculture Library Journal. 2015; 2:1-4.
5. Birithia RK, Kuria DK. Farmer knowledge, management practices and occurrence of tomato root knot nematodes in Kenya. African Crop Science Journal. 2023; 31(3):337-347.
6. Davis RM, Turini TA, Aegerter BJ, Stapleton JJ. UC Pest Management Guidelines. UC IPM Pest Management Guidelines: Cucurbits UC ANR Publication Accessed. 2020; 3445.
7. Elinge CM, Muhammad A, Atiku FA, Itodo AU, Peni IJ, Sanni OM, *et al*. Proximate, mineral and anti-nutrient composition of pumpkin (Ccucrbita epo L) seed extract. International Journal of plant Research. 2012; 2(5):146-150. Doi: https://doi.org/10.5923/j.plant.20120205.02
8. FAO. Plant Disease Management. Food and Agriculture Organization of the United Nations, 2016.
9. Fischer HU, Lockhart BEL. Serious losses in cucurbits caused by watermelon mosaic virus in Morocco. Plant Disease Reporter. 1974; 58(2):143-146.
10. Kalleshwaraswamy CM, Kumar NKK. Transmission Efficiency of Papaya ringspot virus by Three Aphid Species. Phytopathology. 2008; 98(5):541-546.
11. Khan ZR, Midega CAO, Nyang'au IM, Murage A, Pittchar J, Agutu LO, *et al*. Farmers' Knowledge and perceptions of stunting disease of Napier grass in Western Kenya. Plant pathology. 2014; 63(6):1426-1435.
12. Khan M, Damalas CA. Farmers' knowledge about common pests and pesticide safety in conventional cotton production in Pakistan. Crop Protection. 2015; 77:45-51.
13. Kidanemariam DB, Sukal AC, Abraham AD, Njuguna JN, Stomeo F, Dale JL, *et al*. Molecular characterization of a Putative new polerovirus infecting Pumpkin (cucurbita pepo) in Kenya. Archives of Virology. 2019; (0123456789):0-4. Doi: https/doi.org/10.1007/s00705-019-04219-8
14. HCDA Crop production progress report. Horticultural Crop Development Authority, 2020. www.airc.go.ke
15. Ibaba JD, Laing MD, Gubba A. Genome sequence analysis of two South African isolates of Moroccan watermelon mosaic virus infecting cucurbits. Virus Genes. 2016; 52:896-899.
16. Lecoq H, Dafalla G, Desbiez C, Wipf-Scheibel C, Delécolle B, Lanina T, *et al*. Biological and molecular characterization of Moroccan watermelon mosaic virus and a potyvirus isolate from Eastern Sudan. Plant Disease. 2001; 85:547-552. Doi: https://doiorg/101094/PDIS2001855547
17. Lwin OOM, Yabe M, Khai HV. Farmers' Perception, knowledge and pesticide usage practices: A case study

of tomato production in Inlay Lake. Journal of the Faculty of Agriculture, Kyushu University. 2012; 57:327-331.
18. Mendesil E, Shumeta Z, Anderson P, Ramert B. Smallholder farmers' knowledge, perceptions and management of pea weevil in north and north-western Ethiopia. Crop Protection. 2016; 81:30-37.
19. Midega CAO, Murage AW, Pittchar JO, Khan ZR. Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. Crop Protection. 2016; 90:142-114.
20. Mumo NN, Mamati GE, Ateka EM, Rimberia FK, Asudi GO, Boykin LM, *et al*. Metegenomic Analysis of plant Viruses Associated with Papaya Ringspot Disease in Carica papaya L. in Kenya. Frontiers in Microbiology. 2020; 11:205.
21. Roy SK, Ali MS, Mony FTZ, Islam MS, Matin MA. Chemical control of whitefly and aphid insect pest of French bean (Phaseolus vulgaris L.). Journal of Bioscience and Agriculture Research. 2014; 2(2):69-75.
22. Serge Savary, Laetitia Willocquet, Sarah Jane Pethybridge, Paul Esker, Neil McRoberts, Andy Nelson. The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution. 2019; 3(3):430-439. Doi: https://doi.org/10.1038/s41559-018-0793
23. Schreinemacher P. Balasubramaniam S, Boopathi NM, Ha CV, Kenyon L, Praneetvatakul S, *et al*. Farmers' perceptions and management of plant viruses in vegetables and legumes in tropical and subtropical Asia. Crop Production. 2015; 75:115-123.
24. Strange RN, Scott PR. Plant disease: A threat to global food security. Annual Review of Phytopathology. 2005; 43:83-116.
25. Yakoubi S, Desbiez C, Fakhfakh H, Wipf-Scheibel C, Marrakchi M, Lecoq H. Biological characterization and complete nucleotide sequence of a Tunisian isolate of Moroccan watermelon mosaic virus. Arch. 2008; Virol. 153:117-112.