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ORGANIC MANAGEMENT OF CUCURBIT MOSAIC DISEASE IN CUCUMBER (*CUCUMIS SATIVUS* L.)

Ratna Chanu Konjengbam[1], Ranima Mishra[1*], Nirmali Borah[2], Budha Bora[1], Nirmal Mazumder[1] and Nayanmoni Buragohain[3]

[1]Department of Plant Pathology, Biswanath College of Agriculture, Assam Agricultural University, Biswanath Chariali-784176, Assam, India.
[2]Department of Entomology, Biswanath College of Agriculture, Assam Agricultural University, Biswanath Chariali-784176, Assam, India.
[3]Department of Horticulture, College of Agriculture, Assam Agricultural University, Jorhat-785013, Assam, India.
*Corresponding author E-mail: ranima.mishra@aau.ac.in
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ABSTRACT

One of the most serious threats to cucurbit growers worldwide is Cucurbit mosaic disease, which severely affects crop health and yield. Organic agriculture, being one of the most focused areas in the present-day context; this research aims to develop sustainable solutions to manage cucurbit mosaic disease by exploring organic management strategies, identifying symptoms and assessing incidence and thereby enhancing productivity for growers. Field experiment was conducted at the PG research experimental plot of Biswanath College of Agriculture (BNCA), Assam Agricultural University (AAU). Additionally, laboratory analyses were carried out at the Department of Plant Pathology, BNCA, AAU and College of Agriculture, AAU, Jorhat. Symptoms of cucurbit mosaic disease observed in the experimental plot ranged from mosaic patterns on leaf and leaf mottling to severe chlorosis and leaf deformities. Aphids (*Aphis gossypii* and *Myzus persicae*) were identified as the primary vectors responsible for the virus transmission. Leaf samples collected from the experimental field confirmed the presence of Cucumber mosaic virus (CMV) through DAS-ELISA. Field experiment evaluating cucurbit mosaic disease management through organic methods, including botanicals and biopesticides, showed that treatment T_3 (spraying of garlic extract @ 0.5% at 15, 30, 45, and 60 DAT) was the most effective, with the lowest disease incidence of 9.27% with low aphid populations and achieving the highest cucumber yield (41.40 t/ha). This was followed by treatment T_1 (spraying of neem oil @ 0.5% applied at 15, 30, 45, and 60 DAT), which resulted in a disease incidence of 10.94% and a yield of 36.00 t/ha.
***Keywords*: Cucumber mosaic virus, DAS-ELISA, Garlic extract, Neem oil, Organic management.**

Introduction

Cucumber (*Cucumis sativus* L.) is a widely cultivated creeping vine plant and a significant vegetable crop belonging to the Cucurbitaceae family. It is primarily grown as an annual crop. Native to South Asia, particularly the warm and humid Himalayan region of Northwest India**,** cucumbers may also have origins in northern Africa. Comprising nearly 95% water**,** cucumbers are rich in folic acid, potassium, carotenoids, and vitamins A and C. With a history of over 3,000 years of cultivation, cucumbers trace their origins to India, where a diverse range of varieties has been documented. Despite their significant economic value, cucumbers are highly susceptible to different disease stresses, *viz.;* viral, bacterial, and fungal diseases leading to significant economic losses in their production. Among these, Cucurbit mosaic disease is one of the most severe challenges affecting cucurbit crops worldwide. This disease is caused by several viruses, including cucumber mosaic virus (CMV), watermelon mosaic virus (WMV), zucchini yellow mosaic virus (ZYMV), pumpkin yellow vein mosaic virus (PYVMV), and papaya ringspot virus-watermelon strain (PRSV-W) (Biswas and Ghosh, 2018; Kumar *et al.,* 2008). Among these viruses, CMV alone can result in crop losses of up to 100% (Khan *et al.,* 2015). Cucumber mosaic disease, caused by the Cucumber mosaic virus (CMV), is widely regarded as the most significant and destructive factor in cucurbit production (Myti *et al.,* 2014). CMV is the type member of the Cucumovirus genus, which belongs to the Bromoviridae family. One of the distinguishing characteristics of CMV is its broad host range, as it can infect over 1000 host species from 85 different plant families (Roossinck, 2001). Cucurbit mosaic diseases are prevalent globally, holding a significance due to its widespread pandemic nature, normally causing 10- 20 per cent loss in production and possess the capability for 100 per cent yield losses in cucurbits.

Symptoms associated with this virus encompass leaf mosaic or mottling, yellowing, ringspots, stunting, and distortion of leaves, flowers, and fruits. Infected plants also frequently exhibit necrosis, lower yields, and discoloration (Petrov, 2015). Specifically, regarding cucumbers, CMV infection may cause them to become pale and develop bumps. The leaves of such plants display mosaic patterns, often undergoing changes in texture that result in wrinkling and distortion. Moreover, the growth of these plants is frequently stunted, resulting in fewer flowers. Cucumber fruits may also exhibit irregular shapes, a greyish appearance, and a bitter taste, hence earning them the moniker "white pickles".

CMV is primarily transmitted mechanically, although it can also be transferred in a non-persistent manner by over 75 species of aphids (Palukaitis *et al.,* 1992). The most efficient vector for CMV transmission is *Aphis gossypii*, a species belonging to the Aphididae family and Hemiptera order.

Management of CMV disease is a challenge due to its exceptionally broad natural host range. Typically, CMV disease is managed by using various insecticides to control its vector. However, excessive reliance on chemical control methods leads to environmental hazards, insecticide resistance, and increased production costs (Ginting, 2006). Considering these factors, there is a growing interest in exploring the potential of ecofriendly approaches like use of plant extracts and biocontrol agents against vectors to minimize virus disease incidences. As chemical pesticides are not environmentally safe as well as these are toxic to non-target organisms and destroy natural ecosystem, therefore, eco-friendly management strategies comprising use of plant extracts, biopesticides etc., can be considered as potential options for management of plant viral diseases.

This study provided insights into the organic management of cucurbit mosaic disease in cucumbers through an eco-friendly approach. The organic management module demonstrated sustainable strategies that effectively reduced yield losses. It also enhanced understanding of virus-vector-host interactions, promoting disease control with minimal environmental impact while reducing disease severity and crop damage.

Materials and Methods

The components used during the field experiment for organic management of cucurbit mosaic disease included garlic extract @ 0.5%, neem oil @ 0.5% (Purineem 1000 ppm; manufactured by Purity Agritech Pvt. Ltd.), and Bio Green L @ 2% (UmComb; developed by the School of Crop Protection, CPGS, Central Agricultural University, Umiam, Meghalaya). Bio Green L comprised a combination of beneficial microorganisms, including *Trichoderma harzianum, Beauveria bassiana, Metarhizium anisopliae, Verticillium lecanii,* and *Pseudomonas fluorescens.* While neem oil and Bio Green L were procured, the garlic extract was freshly prepared at the required concentration *in-vitro*. Bulbs of *Allium sativum* were collected and washed thoroughly with sterile distilled water. 100 grams of the washed bulbs were ground in a pre-chilled mortar and pestle along with 100 ml of sterilized water, maintaining a 1:1 w/v ratio. The resulting crude solution was obtained by filtering the extract through muslin cloth and then centrifuging it at 10,000 rpm for 20 minutes at room temperature using a RemiC24 centrifuge. The supernatant was used as a 100percent stock solution, following the method described by Shekhawat and Prasad (1971), with some modifications. The extract was further filtered under aseptic conditions using a bacterial membrane filter (RanDisc, PVDF 0.22 µm).

Evaluation of bioefficacy of botanicals and biopesticide on aphid mortality *in-vitro*

Prior to field experiment, the botanicals (neem oil and garlic extract) and the biopesticide (BioGreen L) were assessed for their bioefficacy against aphids though mortality test *in vitro*. Healthy cucumber leaves were collected from the experimental plot and thoroughly washed with tap water and dried in laboratory condition. Once cleaned, they were cut into discs (2.5 cm in diameter) and treated with garlic extract @ 0.5%, neem oil @ 0.5%, and BioGreen L@ 2%. These treated discs were then placed on top of filter paper (110 mm) on Petri dishes (9 cm in diameter). A total of nine Petri dishes arranged in three replications, with three Petri dishes per replication for each of the three treatments were prepared for the study. Petri dishes containing adult aphids were maintained at 26°C, and aphid mortality was observed and recorded at 24 hours, 48 hours, and 72 hours post treatment application (Sonowal *et al.,* 2024). Aphid mortality was confirmed by gently touching the insects with a fine brush those that showed no movement were considered dead [Fig 1 (a-c)].

The percent mortality was calculated as per the following formula-

$$\text{Mortality (\%)} = \left(\frac{\text{Number of dead individuals}}{\text{Total number of individuals}}\right) \times 100$$

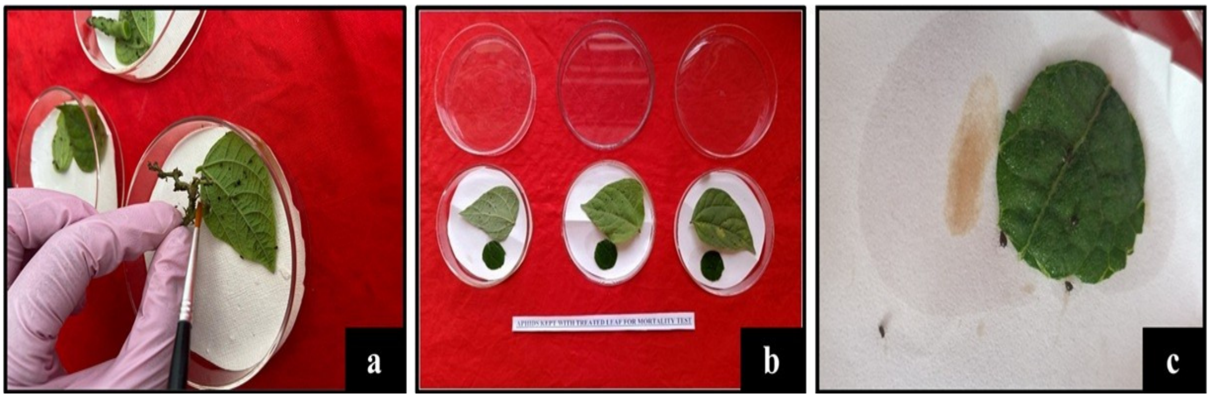

Fig. 1 : *In-vitro* evaluation of bioefficacy of garlic extract, neem oil and BioGreen L on aphid mortality (a) collection of aphids (b) release of aphids on petri dish containing treated leaf disc (c) mortality of aphids observed after placement with treated leaf disc.

Field experiment for organic management of cucurbit mosaic disease in cucumber

The field experiment consisting of eight treatments, including a control, with three replications was carried out at PG experimental plot of Biswanath College of Agriculture AAU, Biswanath Chariali to develop a strategy for management of cucurbit mosaic disease through organic approach. Geographically, Biswanath is situated at a latitude of 26º 73' N and a longitude of 93º 15' E, with an elevation ranging from 48 to 849 meters above sea level. This region belongs to the North Bank Plain Zone and is characterized by a humid subtropical climate with dry winters. The annual average temperature is 26.02°C, which is 0.05% higher than the national average. The study utilized the F1 hybrid cucumber variety "Miraz", which has crop duration of 60-120 days and a potential yield of 50-60 q/ha. For the nursery treatment (TA), seeds were germinated and seedlings were raised in within a 40-mesh insect-proof net house before being transplanted at the 2-3 leaf stage in the main field.

The field experiment included the following treatment combinations:

T_1 = Spraying of neem oil @ 0.5% at 15, 30, 45 and 60 DAT

T_2 = Spraying of Bio Green L @ 2% at 15, 30, 45 and 60 DAT

T_3 = Spraying of Garlic extract @0.5% at 15, 30, 45 and 60 DAT

$T_4 = T_1 + T_2$

$T_5 = T_1 + T_3$

$T_6 = T_2 + T_3$

$T_7 = T_1 + T_2 + T_3$

T_8 = Control

Field data; *viz.,* symptoms, disease incidence and vector population count; were recorded three days after each treatments, beginning from the first sprays with one initial record taken before the first treatment application.

To record the disease incidence, leaves and twigs were examined for CMV symptoms, and disease incidence was recorded for each plot in the experimental area. All plants in each plot were assessed for symptoms and categorized as severe (more than 75% infected), moderate (more than 50% infected), or mild (less than 50% infected) (Dey *et al.,* 2025).

Per cent disease incidence of cucurbit mosaic disease was calculated as follows-

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Aphid population was counted on the top, middle, and bottom sections of randomly selected cucumber plants in each plot (Nzanza and Mashela 2012; Borah *et al.,* 2025). The average from five plants per plot was calculated, and vector populations were classified as low (less than 10 aphids per leaf), medium (more than 10 aphids per leaf), and high (more than 20 aphids per leaf).

Leaf samples were collected from crops from experimental plot as well as surveyed areas at different growth stages; *viz.,* vegetative, flowering, and maturity and screened using Double Antibody Sandwich-Enzyme Linked Immuno sorbent Assay (DAS-ELISA) to detect cucurbitmosaic disease infection in individual samples and assess CMV incidence treatment wise and in the surveyed areas in the Plant Virology Laboratory, Department of Plant Pathology, AAU, Jorhat according to the protocol established by Clark and Adams (1977).

Statistical analysis

RBD analysis was performed to determine the significance of differences and critical difference (CD) among treatments for disease incidence and vector population. The treatments were further compared using Duncan's Multiple Range Test (DMRT). Also, correlation analysis between Cucumber mosaic virus disease (CMVD) incidence, aphid population, and various meteorological parameters was conducted. The formula used for the correlation analysis is as follows:

$$R = \frac{\sum xy}{\sqrt{(\sum x)^2 (\sum y)^2}}$$

The correlation coefficient (R) was calculated to analyse the relationship between disease incidence, aphid population, and various meteorological parameters. These parameters included maximum and minimum temperature, day and night temperature, total number of rainy days, relative humidity (morning and evening), wind speed, sunshine hours, and total rainfall.

The impact of various factors, including aphid population and meteorological parameters, on CMV incidence was assessed through multiple linear regression analysis. Based on the results obtained, a disease prediction model was developed. The multiple linear regression equationused for the analysis is as follows:

$$Y= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

Where, Y= Disease incidence (%),

X_1= Aphid population,

X_2= Temperature (maximum)

X_3=Temperature (minimum)

X_4= Relative humidity (morning),

X_5= Relative humidity (evening),

X_6= Sunshine hours

βi= Regression coefficients

Results and Discussion

Bioefficacy of botanicals and biopesticide on aphid mortality *in-vitro*

The in vitro assay showed the effectiveness of Neem oil, Garlic extract, and BioGreen L at 24, 48, and 72 hours on aphid mortality (Table 1 and Fig 2). Neem oil showed the fastest initial impact, with 30% mortality at 24 hours, 60% at 48 hours, and 100% at 72 hours. Garlic extract followed, causing 20% mortality at 24 hours, 53.33% at 48 hours, and 100% at 72 hours. BioGreen L had the slowest initial effect, with 16.66% mortality at 24 hours, 40% at 48 hours, and 100% at 72 hours. The findings suggest that all three treatments effectively eliminate aphids within 72 hours, with Neem oil acting the fastest, Garlic extract at a moderate pace, and BioGreen L taking the longest.

Table 1 : Effect of different treatments on mortality of Aphids *in vitro*

Treatments	Mortality %		
	24HAT	48HAT	72HAT
Neem oil @0.5%	30.00	60.00	100.00
Garlic extract @ 0.5%	20.00	53.33	100.00
BioGreen L @2%	16.66	40.00	100.00

**HAT = Hours after treatment*

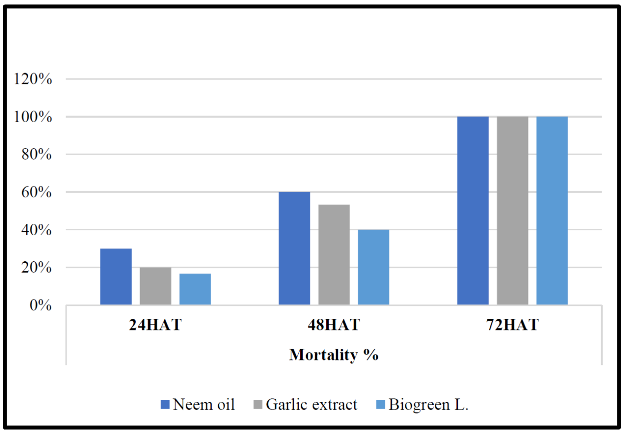

Fig. 2 : Effect of treatments on aphid mortality

Organic management of cucurbit mosaic disease in cucumber

Symptom severity of cucurbit mosaic disease

In the experimental plot characteristic symptoms observed were leaf roughness, severe mottling and yellowing, mosaic patterns, puckering, upward curling, vein clearing, small crinkled leaves, and deformed fruits [Fig 3 (a-h)]. Table 2 observations highlight the diverse symptom expression of cucurbit mosaic disease under different condition. The symptoms on infected plants ranged from mild to severe. Treatment T_3 (spraying of garlic extract @ 0.5% at 15, 30, 45, and 60 DAT), T_1 (spraying of neem oil @ 0.5%at 15, 30, 45, and 60 DAT) and T_2 (spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT) showed mild disease symptoms with the low vector population; while all other treatments showed moderate symptoms with medium vector population. Treatment T_8 (control) had the most severe symptoms with high vector population.

Effect of different treatments on cucurbit mosaic disease incidence

Disease incidence was observed at regular intervals based on symptom appearance in the experimental plot. As shown in Table 3 and Fig 4, the lowest disease incidence (0- 9.27%) was recorded in T_3 (spraying of garlic extract @ 0.5%at 15, 30, 45, and 60 DAT), followed by T_1 (spraying of neem oil @ 0.5%at 15, 30, 45, and 60 DAT) with 0- 10.94% and T_2 (spraying of BioGreen L @ 2% at 15, 30, 45, and 60 DAT) with 0- 11.94%. These treatments showed a significantly lower disease incidence than the others.

Effect of different treatments on vector population

The vector population was evaluated by counting the number of aphids per leaf on plants in the experimental plots at regular intervals during the cropping period. As shown in Table 4 and Fig. 5, the lowest aphid population was recorded throughout the cropping period in treatment T_3 (spraying of garlic extract @ 0.5%at 15, 30, 45, and 60 DAT). This was followed by a low vector population in T_1 (spraying of neem oil spray @ 0.5%at 15, 30, 45, and 60 DAT) and T_2 (spraying of BioGreen L @ 2% at 15, 30, 45, and 60 DAT). The aphid population across all treatments ranged from 0 to 17.00 aphids per leaf, with the highest population (17.00 aphids per leaf) observed in the control plot (T_8). The lowest aphid population (0-4.67 aphids per leaf) was found in T_3 (garlic extract spray), followed by T_1 (neem oil spray) with 0-9.00 aphids per leaf, and T_2 (BioGreen L spray) with 0-10.67 aphids per leaf throughout the cropping period.

Serological assay

Presence of CMV was confirmed in the representative samples collected from experimental plot through serological assay using the Double Antibody Sandwich ELISA (DAS-ELISA) technique. Detection of CMV from experimental plot through DAS-ELISA showed that the mean ELISA value for all positive samples was found lowest (0.149) in the treatment T_3 (spraying of garlic extract @ 0.5% applied at 15, 30, 45, and 60 DAT) followed by 0.159 in the treatmentT_1 (spraying of neem oil @ 0.5% at 15, 30, 45 and 60 DAT) and 0.172 in the treatment T_2 (spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT) (Table 5).

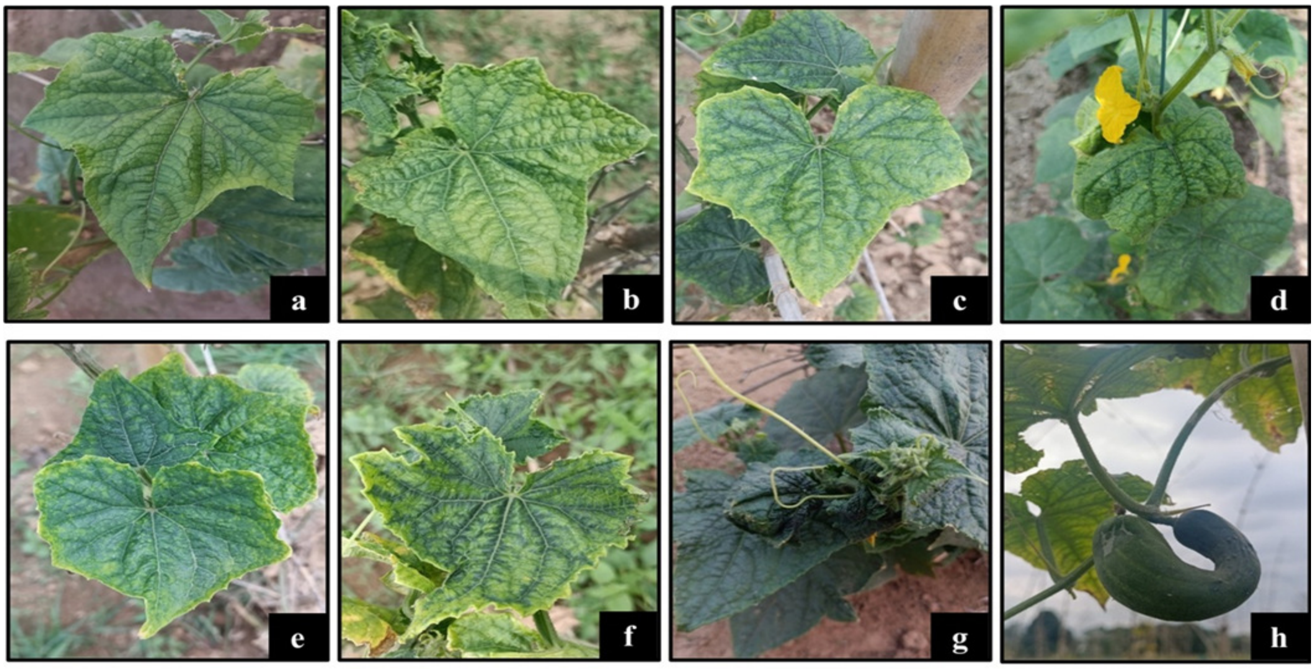

Fig. 3 Different symptoms of cucumber mosaic virus observed in the experimental research plot. (a) leaf roughness (b) severe mottling and yellowing (c) mosaic pattern on leaf (d) puckering of leaves (e) upward curling (f) vein clearing (g) small crinkled leaves (h) deformed fruit.

Table 2 : Severity of cucurbit mosaic disease symptoms and vector population in experimental plot

Treatment	Symptoms severity	Vector population
T_1 = Spraying of neem oil @ 0.5% at 15, 30, 45 and 60 DAT	+	*
T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT	+	*
T_3= Spraying of Garlic extract @ 0.5% at 15, 30, 45 and 60 DAT	+	*
$T_4 = T_1 + T_2$	++	**
$T_5 = T_1 + T_3$	++	**
$T_6 = T_2 + T_3$	++	**
$T_7= T_1 +T_2 +T_3$	++	**
T_8= Control	+++	***

(*) = Low (< 10), (**) = Medium (>10), (***) = High (> 20)
(+) = Mild (< 50%), (++) = Moderate (50-75%), (+++) = Severe (75% and more)

Table 3 : Effect of different treatments on CMV disease incidence (%) under field condition

Treatment	18 DAT	33 DAT	48 DAT	63 DAT
T_1 = Spraying of neem oil @ 0.5%at 15, 30, 45 and 60 DAT	-	10.27^{ab} (0.65)	15.83^{ab} (0.82)	10.94^{ab} (0.67)
T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT	-	11.11^{b} (0.68)	16.66^{b} (0.84)	11.94^{b} (0.71)
T_3= Spraying of Garlic extract @0.5%at 15, 30, 45 and 60 DAT	-	8.27^{a} (0.58)	12.94^{a} (0.74)	9.27^{a} (0.62)
$T_4 = T_1 + T_2$	-	14.94^{bc} (0.79)	19.66^{bc} (0.92)	12.94^{bc} (0.74)
$T_5 = T_1 + T_3$	-	15.94^{c} (0.82)	21.83^{c} (0.97)	14.94^{c} (0.79)
$T_6 = T_2 + T_3$	-	24.05^{c} (1.03)	25.94^{c} (1.07)	15.93^{c} (0.82)
$T_7= T_1 +T_2 +T_3$	-	12.94^{b} (0.74)	18.66^{b} (0.89)	12.83^{b} (0.73)
T_8= Control	-	25.94^{c} (1.07)	29.61^{c} (1.95)	29.61^{c} (1.08)
SEd	**NA**	**0.061**	**0.055**	**0.057**
CD (p=0.05)	**NA**	**0.91**	**0.82**	**0.85**

**There was no disease development up to 15 days after transplanting. Records were taken 3 days after every treatment*
T_1= Spraying of neem oil @0.5%at 15, 30, 45 and 60 DAT, T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT, T_3= Spraying of Garlic extract @0.5%at 15, 30, 45 and 60 DAT, $T_4 = T_1+ T_2$ (Neem oil + BioGreen L), $T_5 = T_1+ T_3$ (Neem oil + Garlic extract), $T_6 = T_2 + T_3$ (BioGreen L + Garlic extract), $T_7= T_1 +T_2 +T_3$ (Neem oil + BioGreen L + Garlic extract), T_8 = Control

Table 4 : Effect of different treatments on aphid population (number per leaf) under field condition

Treatment	18 DAT	33 DAT	48 DAT	63 DAT
T_1 = Spraying of neem oil @ 0.5% at 15, 30, 45 and 60 DAT	5.00^{ab} (2.35)	9.00^{ab} (3.08)	7.33^{ab} (2.80)	5.33^{ab} (2.42)
T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT	5.33^{b} (2.42)	10.67^{b} (3.34)	7.00^{b} (2.74)	6.00^{b} (2.55)
T_3= Spraying of Garlic extract @ 0.5 % at 15, 30, 45 and 60 DAT	4.67^{a} (2.27)	5.33^{a} (2.42)	6.33^{a} (2.61)	5.33^{a} (2.42)
$T_4 = T_1 + T_2$	11.67^{bc} (3.49)	13.33^{bc} (3.72)	7.00^{bc} (2.74)	6.00^{bc} (2.55)
$T_5 = T_1 + T_3$	12.67^{c} (3.63)	14.00^{c} (3.81)	9.00^{c} (3.08)	7.00^{c} (2.74)

$T_6 = T_2 + T_3$	13.33^{c} (3.72)	14.00^{c} (3.81)	12.33^{c} (3.58)	8.33^{c} (2.97)
$T_7 = T_1 + T_2 + T_3$	6.00^{b} (2.55)	12.33^{b} (3.58)	9.33^{b} (3.14)	6.33^{b} (2.61)
T_8 = Control	12.00^{c} (3.54)	17.00^{c} (4.18)	12.67^{c} (3.63)	9.67^{c} (3.19)
SEd	**0.278**	**0.178**	**0.180**	**0.141**
CD (p=0.05)	**4.07**	**2.61**	**2.65**	**2.08**

T_1= Spraying of neem oil @0.5%at 15, 30, 45 and 60 DAT, T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT, T_3= Spraying of Garlic extract @ 0.5%at 15, 30, 45 and 60 DAT, $T_4 = T_1 + T_2$ (Neem oil +BioGreen L), $T_5 = T_1 + T_3$ (Neem oil + Garlic extract), $T_6 = T_2 + T_3$ (BioGreen L + Garlic extract), $T_7 = T_1 + T_2 + T_3$ (Neem oil + BioGreen L + Garlic extract), T_8 = Control

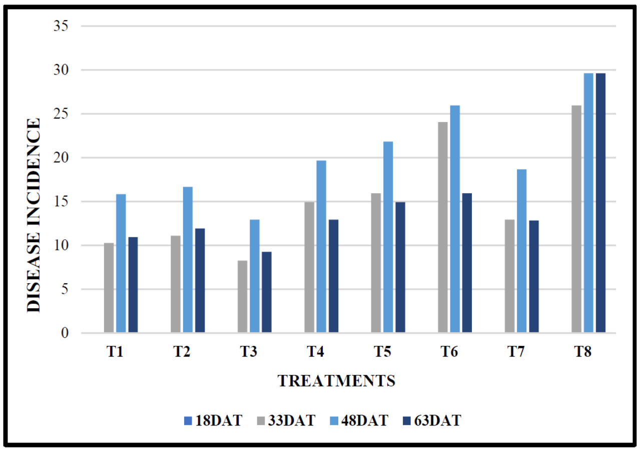

Fig. 4 : Effects of different treatments on development of cucurbit mosaic disease incidence at 18, 33, 48, 63 DAT

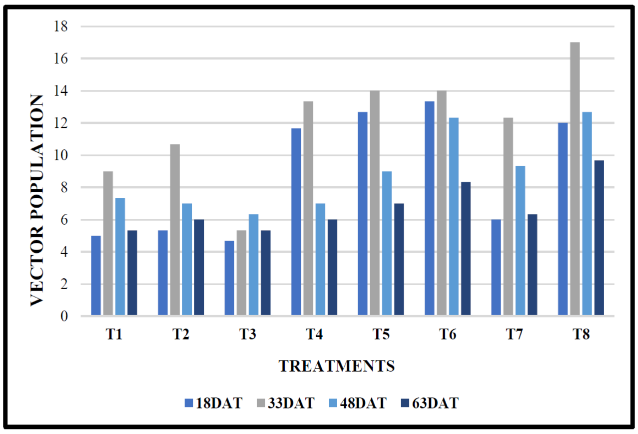

Fig. 5 : Effect of different treatments on development of vector population at 18, 33, 48, 63 DAT

Table 5 : ELISA values for leaf extracts of samples collected from the experimental plot

Treatments	Mean ELISA for all positive samples	Maximum ELISA value	Minimum ELISA value	ELISA value for positive control
T_1 = Spraying of neem oil @ 0.5%at 15, 30, 45 and 60 DAT	0.159	0.193	0.143	0.150
T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT	0.172	0.198	0.145	0.150
T_3= Spraying of Garlic extract @0.5%at 15, 30, 45 and 60 DAT	0.149	0.186	0.126	0.150
$T_4 = T_1 + T_2$	0.184	0.210	0.159	0.150
$T_5 = T_1 + T_3$	0.182	0.238	0.140	0.150
$T_6 = T_2 + T_3$	0.189	0.228	0.150	0.150
$T_7 = T_1 + T_2 + T_3$	0.178	0.193	0.153	0.150
T_8 = Control	0.154	0.215	0.140	0.150

T_1= Spraying of neem oil @0.5%at 15, 30, 45 and 60 DAT, T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT, T_3= Spraying of Garlic extract @0.5%at 15, 30, 45 and 60 DAT, $T_4 = T_1 + T_2$ (Neem oil + BioGreen L), $T_5 = T_1 + T_3$ (Neem oil + Garlic extract), $T_6 = T_2 + T_3$ (BioGreen L + Garlic extract), $T_7 = T_1 + T_2 + T_3$ (Neem oil + BioGreen L + Garlic extract), T_8 = Control

Correlation and Regression analysis

The correlation analysis in Table 6 showed a positive relationship between disease incidence and aphid population, with a correlation coefficient of 0.016. This indicates that for each unit increase in aphid population, disease incidence increases by 0.016 units. Additionally, a negative correlation was found between disease incidence and cucumber yield, with a correlation coefficient of -0.018. This means that for each unit increase in disease incidence, cucumber yield decreases by 0.018 units.

The regression analysis (Fig. 6) indicated a coefficient of 0.144 between the aphid population and CMV incidence. This suggests that for every 1%

increase in aphid population, there is a corresponding 0.144% increase in disease incidence, highlighting a direct relationship between aphid numbers and the severity of CMV.

In Table 7 correlation analysis of weather data with disease incidence showed varied relationships between weather factors and disease incidence. In T6 (BioGreen L + Garlic extract), wind speed had a strong positive correlation (0.748), suggesting it promotes disease spread. Lower temperatures were generally linked to reduced disease incidence, while rainfall had mixed effects, being positive in T1 (Neem oil) and T7 (Neem oil + BioGreen L + Garlic extract) but negative in T2 (BioGreen L.). Evaporation and sunshine hours had weak to moderate effects, with T7 showing the strongest link to BSSH (0.487). Higher humidity mostly negatively correlated, indicating it may help suppress the disease in some cases.

The correlation analysis of weather data with aphid population Table 8 revealed differences in the impact of weather factors on aphid populations across treatments. In T8 (control), relative humidity (RH-E) had a strong positive correlation (0.690 at 0.01 level), and RH (M) (0.600 at 0.05 level), indicating that higher humidity promotes aphid populations in untreated plots. In T3 (garlic extract), maximum temperature (-0.740) and RH (M) (-0.676) showed significant negative correlations, suggesting that lower temperatures and reduced humidity are linked to fewer aphids. Other treatments had weaker or inconsistent correlations, but wind speed (WS) had a moderate positive correlation in T7 (0.602) and T6 (0.558), suggesting wind aids aphid dispersal. Overall, the data show that wind speed (WS) in T6 positively correlates with disease spread, while RH-E in T8 promotes aphid growth. In contrast, garlic extract (T3) significantly reduces aphid populations, particularly under higher temperatures and lower humidity.

Table 6 : Estimation of correlation

Variables	Coefficients	Correlation
Disease incidence and Aphid population	0.016	Positively correlated
Aphid population and yield	-0.022	Negatively correlated
Disease incidence and yield	-0.018	Negatively correlated

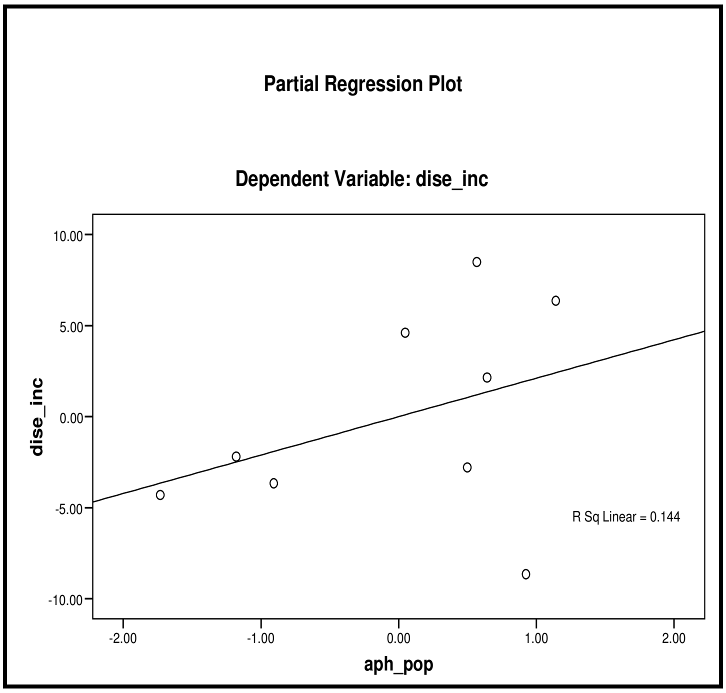

Fig. 6 : Normal probability plot showing disease incidence and aphid population

Table 7 : Correlation estimates of weather parameters with disease incidence (%) of various treatments

Treatments	Min. Temp	Max. Temp	Rainfall	Evap.	WS	BSSH	RH(M)	RH(E)
T_1 =Spraying of neem oil @0.5% at 15, 30, 45 and 60 DAT	-0.385	-0.125	0.424	0.207	0.653	0.437	-0.035	0.109
T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT	-0.059	-0.440	-0.393	-0.305	-0.050	-0.376	-0.468	-0.529
T_3= Spraying of Garlic extract @0.5% at 15, 30, 45 and 60 DAT	-0.501	-0.556	0.197	-0.501	0.087	-0.202	-0.32	0.316
$T_4 = T_1 + T_2$	-0.214	-0.458	-0.313	0.385	0.117	0.332	-0.217	0.001
$T_5 = T_1 + T_3$	-0.396	-0.606	0.119	-0.320	0.266	0.036	-0.390	-0.044
$T_6 = T_2 + T_3$	-0.515	-0.579	0.186	0.008	0.748*	0.077	-0.617	-0.361
$T_7= T_1 +T_2 +T_3$	-0.195	0.05	0.453	0.293	0.381	0.487	0.008	0.197
T_8 = Control	-0.535	-0.665	0.166	-0.400	0.261	-0.227	-0.579	0.047

***Correlation is significant at the 0.01 level (2-tailed).*
**Correlation is significant at the 0.05 level (2-tailed).*
T_1= Spraying of neem oil @ 0.5% at 15, 30, 45 and 60 DAT, T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT, T_3= Spraying of Garlic extract @ 0.5% at 15, 30, 45 and 60 DAT, $T_4 = T_1+ T_2$ (Neem oil + BioGreen L), $T_5 = T_1+ T_3$(Neem oil + Garlic extract), $T_6 = T_2 + T_3$ (BioGreen L + Garlic extract), $T_7= T_1 +T_2 +T_3$ (Neem oil + BioGreen L + Garlic extract), T_8 = Control

Table 8 : Correlation estimates of weather parameters with aphid population in various treatments

Treatments	Min. Temp	Max. Temp	Rainfall	Evap.	WS	BSSH	RH(M)	RH(E)
T_1	-0.020	0.124	0.004	0.138	0.549	-0.292	-0.237	0.044
T_2	0.086	0.454	0.111	0.117	0.296	-0.217	0.135	0.451
T_3	-0.401	- 0.740*	-0.264	-0.537	0.140	-0.549	-0.676*	-0.37
T_4	-0.199	-0.488	-0.303	-0.276	0.266	-0.391	-0.44	-0.443
T_5	-0.076	-0.271	-0.293	-0.012	0.17	-0.437	-0.56	-0.615
T_6	-0.445	-0.426	0.283	-0.111	0.558	0.211	-0.149	0.089
T_7	-0.338	0.121	0.329	0.197	0.602	0.13	0.197	0.275
T_8	-0.055	0.55	0.327	0.146	0.451	-0.051	0.600*	0.690**

***Correlation is significant at the 0.01 level (2-tailed).*
**Correlation is significant at the 0.05 level (2-tailed).*
T_1= Spraying of neem oil @ 0.5% at 15, 30, 45 and 60 DAT, T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT, T_3= Spraying of Garlic extract @ 0.5% at 15, 30, 45 and 60 DAT, $T_4 = T_1+ T_2$ (Neem oil + BioGreen L), $T_5 = T_1+ T_3$ (Neem oil + Garlic extract), $T_6 = T_2 + T_3$ (BioGreen L + Garlic extract), $T_7= T_1 +T_2 +T_3$ (Neem oil + BioGreen L + Garlic extract), T_8 = Control

In Table 9, the regression analysis highlights the significant influence of environmental factors including temperature, humidity, sunshine hours, and aphid population on disease incidence. Bright sunshine hours (BSSH) and evening relative humidity (RH-E) had the strongest positive impact, indicating their role in increasing disease occurrence. Conversely, maximum temperature (Max T) and morning relative humidity (RH-M) showed a negative correlation, suggesting their potential to reduce disease incidence.

Table 9 : Regression analysis influence of independent variables on the disease incidence

Particulars	Coefficients
Aphid population	0.376
Max T	-0.470
Min T	0.095
BSSH	1.008
RH-M	-0.885
RH-E	1.009
R Square	0.781

Effect of different treatments on yield

Table 10 presents the cucumber yield under field conditions across different treatment plots. The data revealed a significant increase in yield due to reduced disease incidence and aphid populations in treatment T_3 (spraying of garlic extract @ 0.5% at 15, 30, 45, and 60 DAT), which resulted in the highest yield of 39.60 q/ha. This was followed by T_1 (spraying of neem oil @ 0.5% at 15, 30, 45, and 60 DAT) with a yield of 36.00 q/ha, and T_2 (spraying of BioGreen L @ 2% at 15, 30, 45, and 60 DAT) with 34.20 q/ha. The lowest yield, 25.25 q/ha, was recorded in the control treatment (T_8).

Table 10 : Effect of different treatments on yield of cucumber

Treatments	No. of cucumber per plant	Weight of cucumbers (g) per plant	Yield (q/ha)
T_1 = Spraying of neem oil @0.5% at 15, 30, 45 and 60 DAT	9	200	36.00
T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT	8	190	34.20
T_3= Spraying of Garlic extract @0.5% at 15, 30, 45 and 60 DAT	14	230	41.40
$T_4 = T_1 + T_2$	6	174	31.32
$T_5 = T_1 + T_3$	5	170	30.60
$T_6 = T_2 + T_3$	4	165	29.70
$T_7 = T_1 + T_2 + T_3$	7	180	32.40
T_8 = Control	2	110	19.80
SEd			**0.74**
CD(P=0.05)			**1.59**
CV			**17.055**

T_1= Spraying of neem oil @0.5% at 15, 30, 45 and 60 DAT, T_2= Spraying of BioGreen L @ 2% at 15, 30, 45 and 60 DAT, T_3= Spraying of Garlic extract @0.5% at 15, 30, 45 and 60 DAT, $T_4 = T_1 + T_2$ (Neem oil + BioGreen L), $T_5 = T_1 + T_3$ (Neem oil + Garlic extract), $T_6 = T_2 + T_3$ (BioGreen L + Garlic extract), $T_7 = T_1 + T_2 + T_3$ (Neem oil + BioGreen L + Garlic extract), T_8 = Control

Conclusion

The results suggested some effective treatments for managing cucurbit mosaic disease. Garlic extract, in particular, demonstrated efficient results with low disease incidence and vector populations, along with minimal environmental impact, making it a safer alternative to chemical pesticides. When combined with early detection and routine field inspections, these strategies become crucial for successful disease management. Additionally, the use of botanicals and biopesticides showed promising outcomes, suggesting that these eco-friendly methods are effective and sustainable strategies for controlling cucurbit mosaic disease.

CMV disease is commonly managed with insecticides targeting its aphid vectors, however; heavy reliance on chemical methods has led to significant challenges, including environmental degradation, insecticide resistance, and higher production costs. These issues have increased interest in sustainable and eco-friendly alternatives, such as plant extracts and biocontrol agents, to reduce viral disease incidence and control vectors. While chemical pesticides can be effective in the short term, they pose risks to non-target organisms and harm natural ecosystems, exacerbating environmental concerns. Therefore, integrating eco-friendly strategies, like plant-based solutions, biopesticides, and natural predators, offers a sustainable approach to managing CMV while safeguarding both productivity and the environment. This study focuses on organic management of cucurbit mosaic disease in cucumber from Assam, exploring eco-friendly approaches such as plant extracts and biopesticides to provide sustainable solutions for managing CMV in the region.

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