

# Simultaneous Mitigation of Cucumber Mosaic Virus and Yellow Virus in Local Chili Pepper (*Capsicum frutescens* L.) Plants Using Natural Cultivation Systems in Minahasa, Indonesia

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## ABSTRACT

Attacks by cucumber mosaic virus (VMM) and yellow virus (VK) can kill chili peppers. One control solution is to plant chili peppers among vegetation in a multi-year fallow garden. The objectives of this study were to identify plant species in the fallow garden, then calculate diversity and uniformity, calculate population densities of *Myzus persicae* and *Bemisia tabaci*, and calculate the incidence and severity of cucumber mosaic virus and yellow virus diseases. The experimental gardens were located in Ranowangko Dua Village, Kombi District, Minahasa Regency, North Sulawesi Province, Indonesia. Plots for chili planting were surrounded by vegetation of 2.5 m wide. Chili peppers were planted in two rows, with a spacing of 1.5 meters. The spacing between rows was also 1.5 meters. The distance between planting holes and vegetation was 50 cm. Each planting hole was planted with three chili pepper seedlings. Monoculture chili cultivation was carried out in gardens approximately 200 m from natural gardens. Samples for calculating the incidence and severity of VMM and VK, and the population densities of *B. tabaci* and *M. persicae* were 20% of the total number of plants per garden. Vegetation sampling for diversity and

uniformity calculations was conducted in 1 m x 1 m observation plots located along Z-shaped intersecting lines at 10 m intervals. The plant diversity level was moderate, plant species were evenly distributed, and *Nezara viridula* was present in the natural chili garden, while *B. tabaci* was absent. The natural chili garden was protected from VMM and VK invasion, while in monoculture, the incidence of these viral diseases was 80.55 and 85.46%.

**Keywords:** Cucumber mosaic virus, yellow virus, *Bemisia tabaci*, *Myzus persicae*, natural cropping pattern

## INTRODUCTION

North Sulawesi has not achieved chili self-sufficiency for decades (Rondonuwu, 2021). The main problem behind North Sulawesi's failure to achieve chili self-sufficiency is the infestation of plant pests (OPT). Many farmers in North Sulawesi are reluctant to plant chilies again because they are no longer profitable. According to farmers, after only about seven harvests, the crop fails (pers. comm. 2024). The most important pests contributing to chili crop failure are cucumber mosaic virus and yellow leaf spot virus (Montong, 2022). A solution to controlling these viruses simultaneously can be achieved by planting

cayenne peppers naturally (Rondonuwu, 2021). Natural planting patterns represent a new paradigm in plant cultivation, emulating nature rather than subjugating or ignoring it. Natural planting patterns are implemented in open-field gardens for at least three years, as these gardens already harbor several hundred species of macro and micro-organisms that can create a balance within the garden. Nutrient cycles for plants and soil conditioners are also established (Rondonuwu, 2021). Therefore, this study aims to identify plant species in fallow gardens, then calculate diversity and evenness, calculate population density of *Myzus persicae* and *Bemisia tabaci*, and calculate the incidence and severity of cucumber mosaic virus and yellow virus diseases.

## **MATERIALS & METHODS**

### **Cultivation of Chili Peppers in Natural Farming Systems**

The natural and monoculture seeding and planting of local varieties of cayenne pepper were carried out in a garden in the administrative area of Ranowanko II Village, Kombi District, Minahasa Regency (1012'53.92''N, 125001', 51.42''E, and an elevation of approximately 106 m above sea level). This research took approximately six months to complete.

Local chili pepper cultivation practices mimic natural patterns in land preparation and seed preparation, as follows:

#### **a. Land preparation**

The garden used for the natural farming system is a coconut plantation, but several trees have died, allowing for ample space. The vegetation under the coconut trees is only pruned (no other crops are planted, except in some areas where there are banana groves).

#### **b. Seed Preparation for Local Chili Pepper Varieties, Nursery, and Planting**

The procedures for chili pepper seed preparation are as follows: (1) Exploration of local chili pepper varieties in Southeast Minahasa Regency, Minahasa Regency, North Minahasa Regency, and Tomohon

City; (2) Selecting 1.2 kg of ripe (red), fresh, perfectly shaped, unblemished, and disease-free chilies, soaking them for six days, and then separating the seeds from the pods; (3) Spreading the chili seeds on newspaper and air-drying them for two days. The stages of seed sowing are: (1) Determining the seeding location, namely in the middle of the research garden so that it is difficult for pests and pathogens to find; (2) Clearing vegetation in the seeding plot, then the chili seeds that have been mixed with four sacks of ash from the copra drying place are spread evenly; (3) Placing split coconuts on the sides of the seeding plot (on each side of the plot, four split coconuts are placed with a distance of one meter). Planting is carried out from morning to evening in the rainy season. Dead plants or plants that are not growing well are replanted after 1 - 1.5 months of planting. Plant maintenance includes weeding wild grass that grows around the plant stem, then other grass is cut with a lawn mower.

### **Chili Cultivation Using Monoculture Farming System**

Chili pepper cultivation activities using a monoculture system include soil preparation, bed preparation, seed preparation, and planting. These activities are carried out similarly to those carried out by farmers.

### **Observation, Sampling, Parameters, and Data Analysis**

#### **a. Vegetation Analysis**

Analysis is used to record and interpret vegetation in a habitat. The scope of vegetation analysis includes sampling, diversity, and uniformity of plant species, as well as identification, following the methods used by Andrade et al. (2019) and Christine et al. (2020).

#### **b. Density and Incidence of *M. persicae* and *B. tabaci***

The sampling pattern in natural farming systems to calculate the population density of these two pests uses a zigzag or z-shaped pattern due to the trapezoidal shape of the

garden (Zehnder, 2015). The sampling frequency is weekly for four months. The number of samples taken is 20% of the chili plant population.

### c. Calculation of Cucumber Mosaic Virus and Yellow Virus Incidence

The calculation of CMV and YV incidence in natural and monoculture chili cropping patterns is carried out using the following formula:

$$IP = \frac{n}{N} \times 100 \%$$

Description:

IP: Disease incidence

n: Number of infected plants

N: Number of plants observed

Pest incidence data in monoculture (control) and natural chili farming systems were analyzed using descriptive analysis.

## RESULT AND DISCUSSION

### Identification, Diversity, and Uniformity of Vegetation

The plant species found in the natural farming system garden are: cempaka (*Magnolia champaca* L.), nyatoh (*Palaquium* sp, Blanco), Kenanga (*Canaga odorata* (Lam.) Hook, f. & Thomson), betel wood (*Piper aduncum* L.), egg wood (*Alstonia scholaris* L.), *Gliricidia sepium* (Jacq.) Kunth ex, Walp., vanilla (*Vanilla planifolia* Andrews), Tagalolo (*Ficus septica* Jacks, ex Andrews), cassava (*Manihot utilissima* L.), tembelekan (*Lantana camara* L.), durian (*Durio zibethinus* L.), coconut (*Cocos nucifera* L.), Langsat (*Lansium domesticum* (Corrêa) Pellegrin (1911)), banana (*Musa paradisiaca* L.), vegetable fern (*Athyrium* sp, Roth), deer fern (*Platynerium nidus* Desv.), suplir (*Adiantum cuneatum* Langsd, et Frisch), *Echinocloa colonum* (L.) Link, *Eleusine indica* (L.) Gaertn., mansiang (*Scirpus grossus* Linn, f.), Krinyuh (*Chromolaena odorata* (L.) King & H.E, Robins), sintrong (*Crassocephalum crepidioides* (Benth.) S, Moore), sosoro (*Dendrognide* sp, L.), wood grass (*Oplismenus setarius* (Lam, ) Roem, & Schult.), *Portulaca oleraceae* L., pearl grass

(*Hedyotis corymbosa* L.), sidagori (*Sida rhombifolia* L.), meniran (*Phyllanthus urinaria* L.), *Nephrolepis* sp., and *Cyrtococcum* sp., *Cyrtococcum* sp, and *Oplismenus* sp, were the dominant weed species in the experimental garden. *Gliricidia sepium*, *Palaquium* sp, *Canaga odorata*, and *Piper aduncum* were the dominant tree species.

Vegetation analysis in the chili garden with a natural cultivation pattern was conducted by estimating the diversity and uniformity of plant species. The total number of plant species sampled in the chili garden with a hidden cultivation pattern was 29, and the total number of individuals of all plant species was 268. The Shannon-Wiener Plant Diversity Index (H') in this chili garden was 2.30, indicating that plant diversity in this chili garden is classified as moderate. The plant species diversity (E) was 2.30, indicating that each plant species was evenly distributed.

The level of plant diversity in natural chili gardens is classified as moderate, and plant species grow evenly distributed in the garden. Chili plants planted among vegetation grow normally and only a few trees are attacked by *M. persicae* (but the attack is only temporary), and do not carry CMV, while *B. tabaci* was not found. This phenomenon is in accordance with the results of research by several researchers (Mitchell et al, 2002; Altieri et al, 2006; Maynes, 2010). They suggest that the higher the plant diversity in a garden, the lower the pest and pathogen attacks.

### Density of *M. persicae* and *B. tabaci*, Incidence of Cucumber Mosaic Virus (CMV) and Yellow Virus in Natural and Monoculture Chili Gardens

The presence of *M. persicae* on chili plants in natural chili gardens was apparent in September, but by October, the aphid population was no longer present (Table 1), while *B. tabaci* was not found. In monoculture chili gardens, *M. persicae* and *B. tabaci* infestations continued to increase until the final month of observation. The

incidence of CMV and yellow virus in natural chili gardens was 0%, while in untreated chili gardens, the incidence was directly proportional to the observation period.

**Table 1. Dynamics of *M. persicae* infestation in natural chili cultivation from September to October 2025**

Plant Number	Population density of <i>M. Persicae</i> (%)	
	September	October
7	11	0
9	51	0
13	10	0
121	19	0
131	21	0
135	17	0
141	17	0
147	15	0
151	21	0
180	135	0
181	108	0
182	52	0
185	35	0
186	75	0

Information from Table 1 is that the number of chili trees attacked by *M. persicae* was only 14 trees out of 80 sample trees or the incidence of aphids was only 11.20%, but in the following month's observation, this aphid population was no longer visible, and the chili trees that were attacked had recovered.

The incidence of VMM disease in natural chili gardens was 0%, while in monoculture gardens it reached 80% at the end of the observation period. The incidence of yellow virus disease in natural and monoculture gardens at the end of the observation period was 0% and 85%, respectively. Data on the incidence of CMV and yellow virus disease are presented in Table 2.

**Table 2. Average Cucumber Mozaic Virus (CMV) and yellow virus disease incidence based on chili cropping pattern.**

Cropping Pattern	Average of Incidence (%)	Average of Incidence (%)
	CMV	CMV
Natural	0	0
Monoculture	0	0

The presence of *M. persicae* populations on several chili pepper trees is only temporary because the orchard contains numerous

natural enemies, especially spiders. The diversity and density of these spider species align with research by Ratschker et al. (2000), which found that fallow cereal gardens increase spider density and diversity. Pluess et al. (2010) also confirmed that abundant non-crop habitats in and around wheat orchards can increase spider density.

Predators found in the natural farming system experimental garden included five spider species, three dragonfly species, four lizard species, three lizard species, two frog species, and two snake species. Natural enemies, such as spiders, are abundant in the natural chili pepper plantations. Of the 80 chili pepper trees observed, 34 were found to harbor several spider species. In addition to being found on chili pepper plants, spiders were also found on vegetation surrounding the plants.

In general, the diet of Tetragnatha spp. consists of arthropods. However, wandering Tetragnatha consume a wider range of taxa than orb-weavers. Both Tetragnatha prey on members of the Homoptera, Lepidoptera, Diptera, and Psocoptera (Binford, 2001). More detailed information on Tetragnatha prey is provided by Luo et al. (2014) who

report that these spiders prey on *Aphis gossypii*, *A. atrata*, *A. medicaginis*, *Bemisia tabaci*, and *Thrips tabaci*.

Jumping spiders (Salticidae) have a wide prey range. The orders they prey on are Homoptera, Coleoptera, Heteroptera, Diptera, Collembola, Lepidoptera, and Hymenoptera (Huseynov et al., 2005). Huseynov (2006) listed the families within an order that are prey for Salticidae, namely Diptera: Bombyliidae and Usiidae, Lepidoptera: Notodontidae and Tortricidae, Hemiptera: Anthocoridae, and Homoptera: Aphidinea and Cicadinea. Li (1996) reported that the prey of the salticid species, *Euophrys* sp., are aphids, brown planthoppers, psyllid flies, and termites. *Chalcotropis* sp. preys on aphids, green leafhoppers, cockroaches, flies, moths, and *Chilo suppressalis* larvae. The diet of *Telamonia* includes aphids, brown planthoppers, green leafhoppers, *Chilo medinalis* larvae, cockroaches, flies, moths, and termites.

Crab spiders (Araneae: Thomisidae) are commonly found on flowering plants and have 2,093 species, with the largest number of species found in tropical regions. These spiders hunt prey, including large insects. *Thomisus* spp. prey on flies, wasps, bees, butterflies, or beetles (Rocha-Filho and Rinaldi, 2011). Another member of Thomisidae, *Systicus loeffleri*, preys on members of the Coleoptera, Hemiptera, Homoptera, Thysanura, Formicidae, and Lepidoptera (Huseynov, 2006).

Araneids, or orbital web-weaving spiders, are sit-and-wait predators that use their webs to capture prey. These spiders efficiently catch insects of the orders Diptera, Ephemeroptera, Neuroptera, Coleoptera, Hemiptera, Orthoptera, Lepidoptera, and Odonata (Prokop, 2006; Solanki & Kumar, 2015).

The presence of Anisoptera and Zygoptera dragonflies in chili gardens is natural due to the presence of irrigation channels and rice fields around the gardens. According to Trueman and Rowe (2009), Odonata require water for the survival of their nymphs

(aquatic nymphs). Dragonflies and damselflies are predators of insect nymphs and adults. Adult Odonata hunt flying insects smaller than their adult bodies. Regarding the role of Odonata as predators of insect pests, Pamungkas and Ridwan (2015) reported that Odonata can suppress insect pest populations.

Several members of the Hymenoptera as general predators of arthropods in natural chili gardens, namely *Vespa* sp., *Oecophylla smaragdina*, *Myrmecia* sp. and *Camponotus* sp. have long been known as predators of caterpillars, larvae, beetles, flies, true lice, and larger insects (Martin, 1995, Raupp et al., 2017). *Oecophylla smaragdina* can control 50 species of insect pests on about 12 different plants in tropical areas, *Myrmecia* sp. prey on caterpillars, earwigs, beetles, wasps, cockroaches, crickets, and flies (Murray, 2024). Ashar (2015) reported that *Camponotus* spp. prey on shell lice (*Cerataphis* sp.), and also the honeydew produced by these lice.

Lizards are predators of several animal species. The five-lined skink (*Eumeces fasciatus*) preys on beetles, butterflies, small invertebrates, and spiders (Hurst, 2017; Howes & Loughheed, 2007). The diet of the golden skink includes members of the orders Hemiptera, Diptera, Lepidoptera, Orthoptera, Coleoptera, Hymenoptera, Isoptera, and Odonata, as well as insect larvae (Chung et al., 2014; Chung et al., 2015). The house lizard, the gecko, preys on members of the orders Homoptera, Heteroptera, Lepidoptera (pre-adults and adults), Coleoptera, Diptera, Isoptera, and Hymenoptera (Ituriaga and Marrerq, 2025; Tkaczenko et al., 2014). Several researchers have suggested that the higher the plant diversity in a garden, the lower the incidence of pests and pathogens (Mitchell et al., 2002; Altieri et al., 2006; Maynes, 2010). In such gardens, plant pests and pathogens persist but never reach a point where chemical poisons must be applied (Fukuoka, 1985). This phenomenon in natural chili cultivation systems can occur due to the following reasons: (1) pests

landing in the wrong place, (2) the concentration of volatile compounds in chili plants is very low or is substituted by volatile compounds from non-host plants, (3) a greater number of natural enemies, (4) the spread of disease-causing agents and pests is inhibited, (5) a conducive microclimate, and (6) continuous soil health.

Most cultivated plants originate from wild plants that are usually invisible to herbivores (plant eaters) in a diverse community (Feeny, 1976). Agriculture supports the concentration of certain plant species, meaning that previously invisible plants become highly visible. High planting densities and weeding contribute significantly to the increased visibility of a plant (Ratnadass, 2012). Further explanation for herbivores not being able to see their hosts is put forward by (Finch & Collier, 2000) that herbivorous insects land indiscriminately on green surfaces but avoid brown surfaces such as soil, so there is a possibility that these insects land on non-host plants. Therefore, the height of plants with other plant species around them needs to be higher so that the opportunity for mistaken landings for pest insects is greater. This principle of observation is similar to the "source concentration" hypothesis, whereby in monocultures, signals from the source (plant) are diluted or mixed with signals from other plant species over time. In natural farming systems, the host's volatile compound composition allows for substitution with compounds from non-host plants and/or other sources, preventing insect pests from detecting their host (Root, 1973). According to Bruce & Pickett (2011), the mixture of volatile compounds from a host plant with volatile compounds from non-host plants prevents herbivores from recognizing their host.

Observations of natural enemies indicate that natural enemies of insect pests are more numerous in hidden chili cultivation systems because, according to Van Emden (1965), wild (natural) habitats provide shelter for the natural enemies of plant

pests. Habitats consisting of annual and perennial vegetation can serve as sources of pollen and nectar for parasitoid insects (Bianchi et al., 2006). Parasitoid lifespan and fecundity significantly increase when nectar is available (Baggen & Gurr, 1998). High plant species diversity in a garden also tends to prevent viral infections in plants - 89% of viruses are transmitted by herbivorous insects. Greater plant species diversity reduces the abundance of insect virus vectors (Power & Flecker, 2008). *M. persicae*, which attacks some native chili plants, does not carry pathogenic viruses because these pests spread from other nearby plant species that do not harbor the viruses. The diverse plant species in a chili garden hinders the spread of insect pests and pathogens (disease-causing insects) to other chili plants, and they can encounter natural enemies such as spiders, which are abundant on chili plants and surrounding plants.

## CONCLUSION

1. The level of plant diversity in natural chili gardens is moderate, and plant species grow evenly within the garden.
2. In gardens with natural cropping patterns, the *N. viridula* population is only temporary, and the *B. tabaci* population is absent. Meanwhile, in monoculture chili gardens, the populations of both pests continue to increase.
3. Natural chili gardens are free from CMV and yellow virus invasions, while in monoculture chili gardens, the incidence of yellow virus disease is 80.55% and 85.46%, respectively.

### *Declaration by Authors*

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