J. Trop. Plant Pests Dis.
Vol. 23, No. 2, September 2023
Pages: 49–57

ISSN: 1411-7525
E-ISSN: 2461-0399
DOI : 10.23960/j.hptt.23249-57

RESEARCH PAPER

Effects of holy basil (*Ocimum sanctum*) on viral disease of chili (*Capsicum annum* L.) under mixed crop cultivation

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Manuscript received: 12 April 2022. Revision accepted: 9 February 2023. Available online: 25 July 2023.

ABSTRACT

Chili is one of the important commodities in Indonesia. Chili cultivation faces many obstacles, leading to a decrease in production, such as virus infections. Yellow leaf curl and curly top viruses are groups of viruses that are often found in chili fields. This research was conducted to investigate the effect of intercropping (basil-chili) in suppressing viral diseases, especially yellow leaf curl and curly top viruses. A Randomized block design was used for this research, including intercropping and monoculture. The parameters observed in this study included disease incidence and intensity, the number and weight of chilies. Symptoms of virus infection include leaf curl, yellowing, and stunting. The disease has been reported to be transmitted by insect vectors, such as *Aphis gossypii* and *Bemisia tabaci*. The results showed that the incidence and intensity of yellow leaf curl and curly top virus diseases in chili pepper and basil plants were not significantly different in each treatment. The number of healthy chilies and their weight were also not significantly different. Damaged chilies are fruits that have been attacked by fruit flies. Basil intercropped with chilies attracts fruit flies, which affects the quantity and weight of the harvested chilies. The population of *B. tabaci* was significantly different in each treatment, while *A. gossypii* did not show significant differences among the treatments. Intercropping basil and chili increased the population of *A. gossypii*, while the population of *B. tabaci* decreased in this treatment. These two insect pests are vectors for yellow leaf curl and curly top viruses.

Key words: *Aphis gossypii, Bemisia tabaci,* curly virus and yellow curly virus

INTRODUCTION

Red chili (*Capsicum annuum* L.) has a high economic value (Purwaningsih et al., 2019; Suminah et al., 2021). The community favors chili as an ingredient in cooking (Affandi et al., 2017). Chilli is a native plant of America and has spread to European and Asian continents, including Indonesia (Rondhi et al., 2018; Scaldaferro et al., 2018). Red chilies are found throughout Indonesia, such as in Kalimantan, Java, Sulawesi, and Sumatera (Sativa et al., 2017; Susanawati et al., 2021; Wardhono et al., 2020). In Sumatera, red chilies are widely cultivated in Lampung, Jambi, Bengkulu, West Sumatera, North Sumatera, Aceh, and South Sumatera. Consequently, numerous researchers are studying red chili (Iskandar & Ayu, 2021; Jasmin et al., 2020; Jhon et al., 2018; Nasution et al., 2021; Pakpahan & Nababan, 2018). South Sumatera chili is extensively grown in both highlands and lowlands (Annissa & Impron, 2017; Ganefianti et al., 2017). The high demand for chili, which continues to increase every year, presents a good opportunity for chili cultivation and can support efforts to improve farmers' economy (Ganefianti et al., 2017; Rondhi et al., 2018).

Chili cultivation faces various obstacles that can hinder chili production. One of the pathogens that poses a significant threat to chilies is the yellow curl virus (Windarningsih, 2019). Chilies infected with this virus exhibit several symptoms, including chlorosis, where the leaf edges roll up like a cup, curl, and develop into small flowers (Windarningsih, 2019). Such infections can greatly reduce chili production and lead to crop failure. Other viral pathogens that infect red chilies include the *Tobacco mosaic virus* (TMV), which causes mosaic symptoms, and the *Pepper yellow leaf curl virus* (PepYLCV), which leads to yellowing symptoms (Kim et al., 2011; Nisar et al., 2022).

Virus spread occurs through vegetative

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propagation, seeds, and by insects vectors (Tálaga-Taquinas et al., 2020). These viruses also have a wide host range, infecting both monocots and dicots (Ghosh & Ghanim, 2021). Resistant varieties can be utilized to control the viruses; however, no reports have been made regarding resistant varieties (Chauhan et al., 2019). An intercropping system can be employed to control virus diseases in chili (Mwani et al., 2021). This system has shown better effectiveness in suppressing vector populations, reducing virus disease incidence, and increasing yields compared to monocropping (Cheriere et al., 2020; Straub et al., 2020; Wang et al., 2021). One advantage of the intercropping system is that farmers can obtain multiple types of harvests (Straub et al., 2020). Intercropping also proves beneficial if one of the intercrops fails (Liu et al., 2020; Wang et al., 2021).

Intercropping chili with basil can be used to control curly top virus in chili. Basil contains essential oils with aromatic properties, giving it a pungent smell that can act as a pest repellent (Manikome, 2021). Basil has been reported to effectively suppress pest populations. This research aimed to investigate the effect of intercropping (basil-chili) in suppressing virus diseases, particularly yellow leaf curl and curly top viruses.

MATERIALS AND METHODS

Research Site. This research was conducted at the Phytopathology Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya.

Preparation of Seeds and Research Land. Red chili seeds were obtained from agricultural stores, while basil seeds were obtained from farmers in the Indralaya district. The chili seeds were soaked for 15 min to break the dormancy period (Abbas et al., 2020) and then they were sown in a seedling tray filled with soil. After two weeks, the seedlings were transferred to 10 × 15 cm polybags. Similarly, basil seedlings were also planted in polybags of the same size. During the chili seedling period, watering was performed twice daily in the morning and afternoon to maintain soil moisture. Both basil and chili seedlings were then transplanted to an 8 × 19 m land area that had been prepared by forming mounds measuring 1.5 × 3 m. The seedlings were alternately planted between chili and basil, with a spacing of 50 × 50 cm (Figure 1). Each treatment consisted of 8 plants in one mound. Planting was carried out at 4:00 pm, and watering was done twice daily at 7:00 am and in the afternoon at 5:00 pm.

Research Land Sanitation. Each treatment plot, measuring 1 × 2 m, was given 5 kg of chicken manure one week before planting. Fertilization was carried out two weeks after planting using NPK in a ratio of 1: 1: 1. Weeding was performed around the mounds. Observations of yellow leaf virus, curly top virus disease, and vector populations were conducted one month after planting. The observation of virus vectors involved counting the pest population using a hand tally counter. Disease incidence was determined by counting the number of healthy plants and plants with damage, following the formula (Asmaliyah & Rostiwati, 2015):

$$P = \frac{n}{N} \times 100$$

P = Incidence of disease;
n = Number of diseased plants;
N= Number of plants observed.

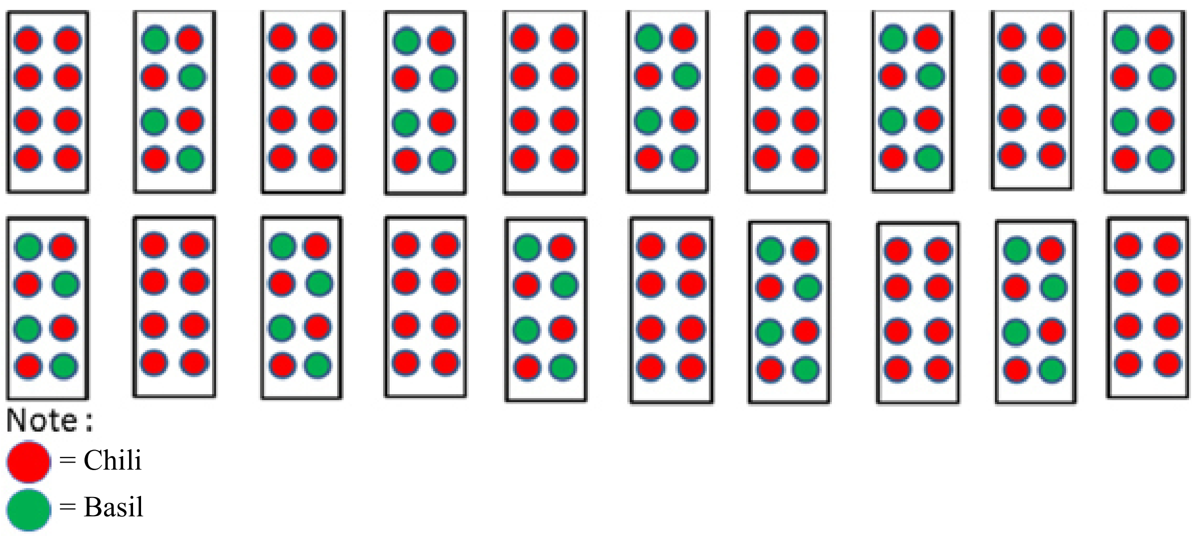

Figure 1. Lay out of research on chili and basil

Diseases intensity was observed by scoring the damage of the plant and then calculating following the formula (Asmaliyah & Rostiwati, 2015):

$$I = \frac{\sum (n \times v)}{N \times Z} \times 100$$

I = Disease intensity;
N = Number of plants observed;
Z = Highest score;
n = Number of diseased plants;
v = Observed score value.

Scoring the observation of viral disease symptoms in chili:
0 = Asympotomatic;
1 = Symptoms of disease attack 1–25%;
2 = Symptoms of disease attack 26–50%;
3 = Symptoms of disease attack 51–75%;
4 = Symptoms of disease attack above 75%.

These scoring observations were conducted to assess the severity and presence of viral disease symptoms in chili plants. Moreover, the healthy and damaged red chili paper caused by fruit flies was collected and counted for each weight.

Data Analysis. The experiment was arranged using a Randomized block design consisting of two treatments and ten replications. The treatments included monoculture of chili plants and intercropping of basil and chili. Data on the incidence and intensity of viral disease, weight of infected chilies, and populations of vector insects were analyzed using analysis of variance (ANOVA) in R-Studio. Post-hoc comparisons were performed using the 5% LSD Test.

RESULTS AND DISCUSSION

The results revealed that the symptoms of a viral attack began with a change in leaf color, accompanied by leaf curling. Further infection led to stunted growth (Figure 2). The initial symptom of yellow leaf curl virus infection in plants was the appearance of yellow spots on young leaves. Over time, the symptoms spread to the leaf veins, resulting in yellowing, leaf cupping, and a mild mosaic color (Fadhila et al., 2020; Windarningsih, 2019). According to Choi et al. (2020), the symptoms of yellow leaf curl virus infection in chili can vary depending on the cultivar and environmental conditions. The intercropping treatment exhibited the lowest disease incidence, which was 72.50%, while the monoculture treatment had the highest disease incidence at 75.00%.

The incidence of curly top virus disease was observed nine weeks after planting and showed an increasing trend. However, the severity of symptoms was not as pronounced as those caused by the yellow leaf curl virus. The results indicated that the disease incidence of curly top virus in each treatment did not show significant differences from the first observation to the eighth observation. This suggests that intercropping was not effective in controlling the virus vector. Environmental factors appeared to play a role in promoting the development of the virus vector. The highest incidence of curly top virus disease was observed in the monoculture planting, while the lowest incidence was found in chilies that were intercropped

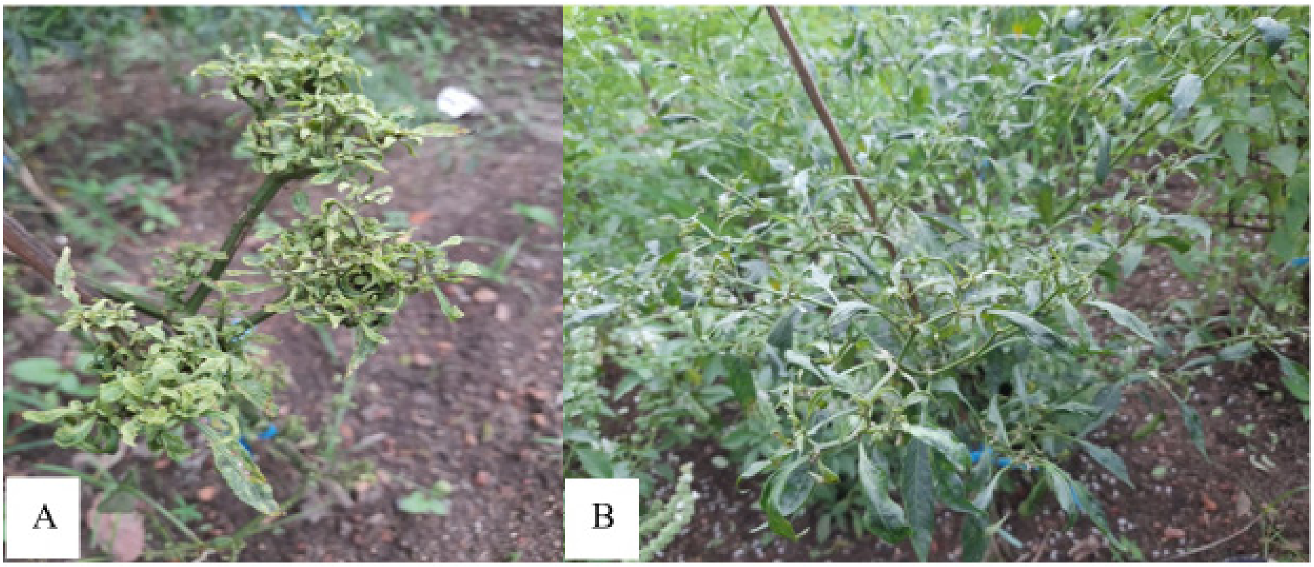

Figure 2. Symptoms of virus infection on chili. A. Symptoms of yellow leaf curl virus infection; B. Symptoms of curly top virus infection.

with basil (Table 1).

The symptoms appear because the virus moves from one cell to another through plasmodesmata, and when it reaches the phloem vascular tissue, the virus rapidly spreads and affects the leaves (Selangga & Listihani, 2021). The symptoms of an infection caused by the curly top virus in chilies include noticeable mosaic or light green patterns on the leaves, curling of leaf shoots, and the formation of narrow strands. The incidence of chili infection with the main diseases has been increasing each week. However, the incidence of yellow leaf curl virus disease in chilies did not show significant differences. The highest incidence of the yellow leaf curl virus was observed in chilies grown in monoculture, while chilies grown using an intercropping system with basil had a lower incidence.

The results indicated that yellow leaf curl and curly top virus infections in chilies exhibit symptoms similar to those caused by Geminivirus. The primary symptom observed in the field is leaf yellowing and curling. The incidence of the main disease varies in each treatment, including chilies grown in monoculture and those grown in intercropping with basil.

The disease incidence during each observation, starting from nine weeks after planting, was initially low. However, in subsequent observations, the disease incidence continued to increase. Chilies infected with the yellow leaf curl and curly top viruses exhibited symptoms in both the monoculture and intercropping systems with basil (Table 2).

The disease intensity of the yellow leaf curl virus in the monoculture planting system was the highest, with an average of 28.28% throughout the observation period. On the other hand, the intercropping system with basil had the lowest intensity, with an average of 3.04% over nine observations. Regarding the curly top virus, the infection intensity was higher in chili plants under the monoculture system, averaging about 19.01% over eight observations. Conversely, chili plants in the intercropping system had a lower intensity, averaging 15.45% over eight observations.

The high and low intensity of viral disease infection is influenced by several factors. One important factor that contributes to disease development is environmental conditions. Implementing an intercropping system is a control method that can be utilized to manage pests and diseases in plants.

At the first observation, the intensity of viral disease infection in chili plants was relatively low in each treatment. However, the intensity of yellow leaf curl virus disease increased in subsequent observations. Notably, the intercropping treatment with basil

Table 1. Incidence and Intensity of virus disease in chilies grown with monoculture and intercropping system

Treatment	Incidence ± SE (%)		Intensity ± SE (%)	
	Yellow curly virus	Curly virus	Yellow curly virus	Curly virus
Monoculture	61.25–75.00 ± 7.90	18.75–27.50 ± 7.25	3.04–28.28 ± 4.00	3.23–19.01 ± 5.41
Intercropping	60.00–72.50 ± 8.25	22.50–25.00 ± 8.66	2.73–26.55 ± 6.04	3.23–15.45 ± 5.26
ANOVA F-value	0.01 ns	0.85 ns	0.15 ns	0.86 ns
F Table (5%)	5.12	5.12	5.12	5.12
LSD test 5%	-	-	-	-

Note: the numbers followed by the same letter were not significantly different at the test level $p< 0.05$; *= Significantly different; ns= not significantly different. Original data in arscin transformation before statistical analysis.

Table 2. Number and weight of chilies infected with the virus with monoculture and intercropping patterns

Treatment	Number of chilies (fruit) ± SE		Weight of chilies (g)	
	Healthy	Diseased	Healthy	Diseased
Monoculture	3.81 ± 1.03	7.15 ± 0.94	4.59 ± 1.30	8.43 ± 3.21
Intercropping	2.73 ± 1.35	3.83 ± 1.09	3.62 ± 1.76	4.43 ± 1.65
ANOVA F-value	0.10 ns	0.14 ns	0.07 ns	0.14 ns
F Table (5%)	5.12	5.12	5.12	5.12
LSD test 5%	-	-	-	-

Note: the numbers followed by the same letter were not significantly different at the test level $p <0.05$; *= Significantly different; ns= not significantly different. Original data in arscin transformation before statistical analysis.

consistently exhibited the lowest disease intensity or severity during multiple observation periods.

The intensity of yellow leaf curl virus infection progressively increased each week. Although the intensity of the virus was not significantly different between the two treatments, it was higher in the monoculture system compared to the intercropping system with basil.

Virus infection had a negative impact on chili production as infected plants were unable to yield red chili peppers. In the monoculture system, chili yields were lower compared to the intercropping system, although the difference in weight was not significant. The intercropping system resulted in a higher number of healthy chili yields compared to the monoculture system (Table 2).

In the intercropping system, the presence of fruit flies is higher compared to monoculture, resulting in increased chili damage. Additionally, the intercropping system attracts more pollinating insects, leading to competition among fruit flies, virus vectors (e.g., *Bemisia tabaci* and *Aphis gossypii*), and pollinating insects. This competition results in a lower number of virus attacks in the intercropping system.

Based on the general nature of viral infections, the virus cannot directly penetrate host cells to initiate disease development. Therefore, the transmission of the virus is facilitated by insect vectors (Mwani et al., 2021). According to Semangun (2008), the yellow leaf curl virus is transmitted by *B. tabaci* in a persistent manner, while other viruses are transmitted by *A. gossypii*. Inside the host, the virus spreads and forms genes that can damage tissues (Figure 3).

The most commonly found vector insects in the field were *A. gossypii* and *B. tabaci*. Chilies grown using an intercropping system with basil exhibited a lower aphid population compared to chilies grown in monoculture. This can be attributed to the role of basil in suppressing the aphid population, as aphids are known vectors of viruses in chili plants.

Whiteflies were predominantly found on the underside of chili leaves, and their presence was more common in monoculture-grown chili plants compared to those in the intercropping system. According to Table 3, the whitefly population differed significantly between the treatments. The average population of whitefly pests was higher in monoculture-grown chilies than in those intercropped with basil (Figure 4).

Intercropping chili with basil demonstrated the ability to reduce the population of aphids, likely due to the repellent properties of basil against aphids. Although the population of aphids found in each treatment did not differ significantly, chili plants grown in monoculture had a higher aphid population compared to those

Figure 3. Insects as vectors of virus transmission in chili. A. *Aphis gossypii*; B. *Bemisia tabaci*.

Table 3. *Bemisia tabaci* and *Aphis gossypii* as virus vectors in chili

Treatment	Population ± SE (Tail)	
	B. tabaci	*A. gossypii*
Monoculture	42.10–60.00 ± 2.42 b	34.00–371.80 ± 6.00
Intercropping	0.60–6.00 ± 0.37 a	162.40–24.90 ± 7.00
ANOVA F-value	6.87*	0.79 ns
F Table (5%)	5.12	5.12
LSD test 5 %	0.21	-

Note: the numbers followed by the same letter were not significantly different at the test level p< 0.05. *) Significantly different. ns) not significantly different. Original data in arscin transformation before statistical analysis.

intercropped with basil (Figure 5).

Basil is an aromatic plant that contains various compounds, including essential oils. Basil essential oil is known to contain compounds such as methyl eugenol, cineol, camphor, methyl cinnamate, and others (Zahra & Iskandar, 2017). These essential oils exhibit biological activities against insects, acting as repellents, attractants, toxins (contact poisons), fumigants (respiratory poisons), antifeedants (appetite suppressants), ovulation deterrents (inhibiting egg laying), growth inhibitors, fertility reducers, and even affecting insect vectors.

Basil, when intercropped with chili, acts as a repellent against insects such as aphids, which are known vectors for the curly top virus in chili. This repelling effect is attributed to the strong scent of basil. It is evident from the lower number of aphids found in chilies grown in intercropping with basil compared to those grown in monoculture.

The results indicate that both monoculture and intercropping systems have an impact on chili production. There are variations in the number of fruits and their weights among different chili treatments. Intercropping has the added benefits of reducing soil and airborne diseases, suppressing weed and pest populations, and ultimately increasing primary productivity.

Chili grown in monoculture yields more compared to chili grown in intercropping. This difference in yield is primarily due to the higher population of fruit flies in the intercropping system. Basil, which acts as an attractant, attracts fruit fly pests, leading to the infestation of young chilies. Infected chili fruits, as a result of fruit fly pests, become rotten and drop to the ground before reaching harvest. Fruit flies are particularly attracted to methyl eugenol, a compound primarily produced by basil (Hikmawanti et al., 2016). The presence of basil not only attracts fruit flies to the intercropping plots but also to monoculture chili plots due to the fruit fly imago's fly activity.

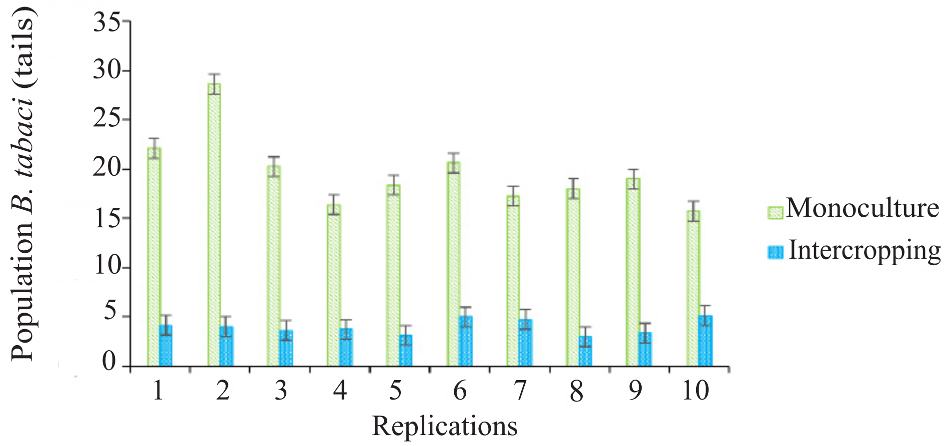

Figure 4. Population of *B. tabaci* on chili grown in monoculture and intercropping.

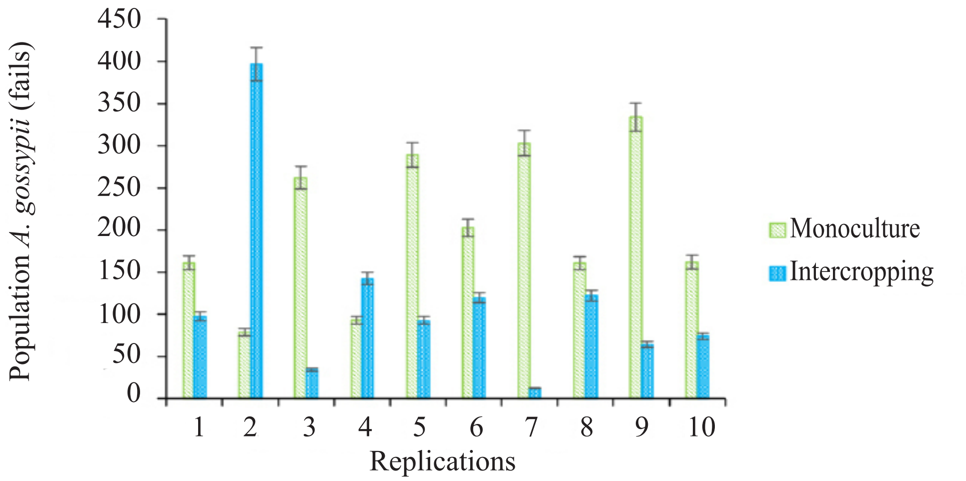

Figure 5. Population of *A. gossypii* on chili grown in monoculture and intercropping.

CONCLUSION

Diseases caused by viruses, specifically yellow leaf curl and curly top virus diseases, were found in both monoculture and intercropping systems of chili cultivation. The intercropping of chili and basil did not have a significant effect on the incidence of yellow leaf curl and curly top diseases in chilies, which are caused by viruses and transmitted by vector insects. It was observed that the incidence and intensity of yellow leaf curl disease, transmitted by whiteflies, were higher compared to the incidence and intensity of curly top virus, transmitted by aphids, indicating differences in the activity of the two vectors. Interestingly, chili plants grown in the intercropping treatment with basil were found to be more susceptible to fruit flies.

ACKNOWLEDGMENTS

Plant Protection Study Program, Faculty of Agriculture, Universitas Sriwijaya and the research team so that this research can be completed properly.

FUNDING

This research was independently.

AUTHORS' CONTRIBUTIONS

AR and LR are those who carry out research. observation and data analysis. SP, HH, RP, and BG guide in the presentation of data and writing. SW, YP, AU, and CI guided the identification of pests and diseases as well as writing. All authors read and approved final manuscrip.

COMPETING INTERESTS

The author has no interest in competing in our publication.

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