J. Trop. Plant Pests Dis.
Vol. 24, No. 1, March 2024
Pages: 120–127

ISSN: 1411-7525
E-ISSN: 2461-0399
DOI : 10.23960/j.hptt.124120-127

RESEARCH PAPER

The effect of tobacco leaf extract dosage on the development of virus disease in curly chili

Haryuni Haryuni & Sapto Priyadi

Manuscript received: 4 July 2023. Revision accepted: 16 December 2023. Available online: 15 March 2024.

ABSTRACT

Curly chili is a horticultural product with high nutritional value, greatly demanded as a distinctive complement or flavoring for dishes due to its unique taste and aroma. Despite the increasing demand for chilies, production has not followed suit, mainly due to disruption caused by viruses transmitted by *Bemisia tabaci* and *Thrips* sp. This study aimed to investigate the effect of tobacco extract on the growth and development of viral diseases in curly chili. Conducted at Kwangsang Village, Jumapolo District, Karanganyar Regency, from September to December 2021, the research was designed using a completely randomized block design, with treatment doses of tobacco extract at 0 mL/L, 1 mL/L, 2 mL/L, 3 mL/L, and 4 mL/L, labeled J0, J1, J2, J3, and J4, respectively. The results indicated that the variabels, i.e. plant height, number of leaves, number of fruits, and fruit weight per plant, were significantly affected by the tobacco extract. Similarly, the disease incidence and severity of viral infection were significantly influenced by the tobacco extract application. The yield decrease in curly chili was attributed to virus infection by *Bemisia tabaci* and *Thrips* sp., which caused chlorosis and mosaic symptoms on the leaves. Although the affected plants did not die, they experienced a yield reduction. The application of tobacco extract significantly reduced the percentage of incidence and severityof virus infection on curly chili. The highest disease incidence was 35.42% (J0) and disease severity was 70.92% (J0), while the lowest disease incidence was 14.58% (J4) and disease severity was 20.58% (J4).

Key words: disease incidence, disease severity, disease symptom, tobacco leaf extract, virus vector

INTRODUCTION

Chili (*Capsicum annuum* L.), a member of the *Solanaceae* family, originates from America and was introduced to Indonesia by the Portuguese. It is classified into three types: big chili, curly chili, and cayenne pepper. Curly chilies, characterized by their (Herison et al., 2018), are significant for their suitability for cultivation in Indonesia (Nurjati, 2021). As a strategic commodity with high economic value, chili is used in cooking, the food industry, medicine, and herbal remedies, containing vitamins A, C, B6, and potassium (Kumar et al., 2020). The consumption of spicy foods has been found to increase brain activity (Zhou et al., 2019) due to chili's spicy flavor, which comes from biochemical compounds such as capsaicin and the antioxidant α-glucosidase inhibitor, beneficial in managing diabetes mellitus (Lu et al., 2020).

According to BPS-Statistics Indonesia (2022a) the harvested area of curly chili in Indonesia increased from 82,804 ha in 2021 to 95,564 ha in 2022. Additionally, BPS-Statistics Indonesia (2022b) reports that production rose from 8.60 million tons in 2021 to 10.17 million tons in 2022. Despite this increase, the production has not yet met the domestic needs for chili. The Center for Agricultural Data and Information (2020) has projected that national chili consumption will rise from 1.297 million tons in 2022 to 1.340 million tons in 2023. Moreover, Indonesian chili imports from countries like India, China, Malaysia, Spain, and Australia reached 27,800.02 tons in 2021 (Putri, 2021).

Currently, the increasing demand for chilies in Indonesia has not been met, partly because the plants are suffering from pathogenic disorders caused by viruses. This infection is characterized by leaves turning pale, followed by the leaf blade turning yellow while the veins remain green, and eventually, the leaves roll and spread to healthy ones. Viral infections are transmitted by *Bemisia tabaci* and *Thrips* sp., necessitating the control of these intermediary pests (Rodríguez-Verástegui et al., 2022). Control of this virus vector has been reported using various techniques, including the use of plant extracts. The efficacy of tobacco extracts has been tested for reducing pest populations, including the coffee berry borer (*Hypothenemus hampei*) (Haryuni et al., 2019),

Corresponding author:
Haryuni (haryuni@lecture.utp.ac.id)

Faculty of Agriculture, University of Tunas Pembangunan, Surakarta, Central Java, Indonesia 57139

the rice weevil (*Sitophilus oryzae*) (Kanmani et al., 2021), and the apple pest (*Grapholita molesta*) (Sarker & Lim, 2018).

The application of tobacco extract is expected to affect the activity of *Bemisia tabaci* and *Thrips* sp. which interfere with chili plants. Tobacco extract contains bioactive compounds with antioxidant, anti-inflammatory, and antifungal properties (Banožić et al., 2020). Numerous researchers have reported various groups of substances in tobacco, including alkaloids (including nicotine) (Li et al., 2015), fatty alcohols, phytosterols (Liu et al., 2010), limonene, indole, pyridine (Gozan et al., 2014), aroma and bioactive compounds (Popova et al., 2015), polyphenols, terpenoids and essential oils (Zou et al., 2021). The content of these compounds acts as a poison for virus-mediating pests that infect chili plants. The purpose of this study was to determine the effect of tobacco extract on the growth and development of virus disease in curly chili.

MATERIALS AND METHODS

Research Site. The research was conducted in Kwangsang village, Jumapolo, Karanganyar, Central Java, 7°41'43.4"S 110°58'25.5"E from December 2022 to February 2023. The soil type is Latosol, with an altitude of 511 m above sea level.

Research Design. This study was designed using a completely randomized design (CRD) with 5 treatments of tobacco leaves extract doses (0 mL/L, 1 mL/L, 2 mL/L, 3 mL/L, 4 mL/L) referred to as J0, J1, J2, J3, and J4, and each treatment having 3 replications. Disease symptom transmission was not initiated in this study; these symptoms typically manifest when the land is planted with chili plants.

Preparation of Tobacco Leaf Extract. Tobacco leaves were extracted using the Extended Heat Reflux Extraction (EHRE) method (Sentosa et al., 2019). The extraction was carried out by the research group of the University of Indonesia and PT Zekindo, located in Bekasi Recency, East Java Province, Indonesia with a production capacity of 1.5–2.0 kg per day.

Preparation of Planting. The curly chili seeds used in this study were hybrid curly chili Lado F1 (PT East West Seed Indonesia). Land preparation was carried out two weeks before planting, involving two stages of processing. The first stage included turning the land, while the second stage involved plowing and leveling the land. The distance between the beds was set at 60 cm, with each bed measuring 0.5 m in length, a month before planting. The planting space for chilies was designated as (60 × 50) cm. Once the land was prepared, it received 20 tons/ha of cow manure (Masriyana et al., 2020) and was left for 7 days. After this period, basic fertilizer comprising Urea 60 g, TSP 60 g, and KCl 30 g was applied, and the land was left undisturbed for another 7 days. Seedlings were then transferred to the field 21 days after sowing, following the method described by Hardiansyah et al. (2017) and Soedjarwo & Tjokrosumarto (2017).

Application of Tobacco Leaf Extract. This tobacco leaf extract is sprayed onto chili plants according to the treatment. Spraying is carried out 8 times when the plants are 2 weeks old, with the frequency of application being once every 2 weeks.

Incidence and Severity of Virus Disease. Disease incidence was calculated six weeks after transplanting using the formula provided by Mohamed et al. (1999).

$$P = \frac{n}{v} \times 100\%$$

P = Disease incidence (%);
n = Number of affected plants;
v = Number of observed plants each plot.

Disease severity which indicates the number of plants affected by pest attacks based on category, description, and visual symptoms, was calculated using the formula from Wongpia & Lomthaisong (2010).

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

DS = Disease severity (%);
n = Number of chillies infected by virus;
v = Disease category scale;
Z = Scale value of the highest disease category;
N = Total number of chillies observed.

The symptoms caused by a *Bemisia* vector and a *Thrips* vector cannot be differentiated because they both occur in the same location. To estimate the diseases on chilli fruit, a 0–5 scale was followed as proposed by Reang et al. (2018) and Steel & Torrie (1980) based on the following symptoms. The disease score was determined based on visual symptoms in plants from Selangga & Wiyono (2021), as shown in Table 1. This scoring observation was carried out to determine the severity and presence of symptoms of viral diseases in chili plants, as depicted in Figure 1.

Growth Observation. The growth variables include plant height, number of leaves, number of fruits, and weight of fruits per plant. The plant height and the number of leaves were observed from 2 weeks after planting up to 70 days after planting, at 2-week intervals. The number of chilies and their weight were recorded starting from the first harvest, which occurred 70 days after planting, followed by 8 subsequent harvests, at one-week intervals.

Statistical Analysis. The data were analyzed using analysis of variance (ANOVA) followed by the Duncan Multiple Range Test (DMRT) at the 5% level (Gomez & Gomez, 1995).

RESULTS AND DISCUSSION

Incidence and Severity of Virus Disease. Treatments of tobacco leaf extracts at 1 mL/L, 2 mL/L and 3 mL/L did not show significant differences, but significant differences were observed in treatments of tobacco extracts at 0 mL/L and 4 mL/L (Table 2). As the extract dose increased, disease incidence and virus infection (as shown in Figure 3) decreased. Plants not treated with tobacco leaf extract (0 mL/L) experienced the highest attack, significantly different from plants with tobacco

Table 1. Disease severity scale

Category	Description	Visual symptom
0	No symptom	Symptomless
1	Symptoms of disease 0–24%	Part yellow of leaves
2	Symptoms of disease 25–49%	Yellow and curly on the leaves
3	Symptoms of disease 50–74%	Yellow and cupped with curved leaf edges up or down, it looks curly

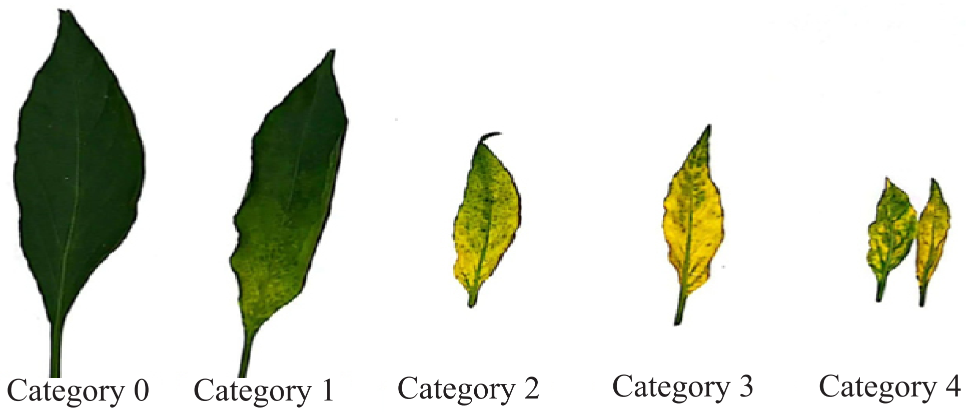

Figure 1. Differences in symptoms in plants based on category, description and visual symptoms.

Table 2. The effect of tobacco extract on disease incidence and severity of virus disease

Treatment	Virus disease of chili	
	Disease incidence (%)	Disease intensity (%)
J0	35.42 a	70.92 a
J1	22.92 b	63.58 a
J2	20.83 b	36.92 b
J3	18.75 bc	28.57 c
J4	14.58 c	20.58 d

The number followed by different etters in the same column are significantly different according to the Duncan test at the 5% level. J0= Tobacco leaf extract at 0 mL/L; J1= Tobacco leaf extract at 1 mL/L; J2= Tobacco leaf extract at 2 mL/L; J3= Tobacco leaf extract at 3 mL/L; J4= tobacco leaf extract at 4 mL/L.

leaf extracts at 1 mL/L, 2 mL/L, 3 mL/L and 4 mL/L. In treatment 0 mL/L, all plants were infected with the virus, while 4 mL/L.

This is due to the presence of nicotine and alkaloids in tobacco extract, which function to repel insects (Prommaban et al., 2022), including *Bemisia tabaci* and *Thrips* sp. which have potential as virus vectors. Tobacco has also contain chlorogenic acid, a phenolic compound with antioxidant properties and insect-fighting abilities (Prommaban et al., 2022).

Symptoms on chili plants occur due to infection by viruses transmitted by insect vectors. Once inside plant tissue, viruses spread from one cell to another through special pathways called plasmodesmata (Mandadi & Scholthof, 2013). The symptoms indicate a disturbance in cell metabolism. These viruses assemble or engage in inclusion bodies through host cell activityand are only active inside living host cells. When the virus reaches the phloem tissue, it spreads rapidly and invades the leaves.

Symptoms can be recognized by green lines, spotting patterns, changes in the shape of leaves that curl on the shoots, and stunted plant growth, especially in newly formed organs such as narrow strands (Sumbria et al., 2021; Rodríguez-Verástegui et al., 2022). This condition in chili plants leads to degradation of chlorophyll pigments, changes in chloroplast structure, decreased chlorophyll content, changes in electron transport rates, disruption of photosynthetic reactions, and decreased carbon dioxide fixation (Zanini et al., 2021; Zhao et al., 2016). Additionally, it affects carbohydrate and chlorophyll metabolism (Ananthu & Umamaheswaran, 2016), resulting in a decrease in the rate and efficiency of photosynthesis (Lei et al., 2017).

Growth Observation. The dosage of tobacco leaf extract at 4 mL/L resulted in significantly different plant height, number of leaves, number of fruits, and fruit weight compared to 0 mL/L, 1 mL/L, 2 mL/L and 3 mL/L (Table 3). Potassium content in tobacco extract is elastic and hard, rich in oil, and plays a role in increasing cell elongation (Iqbal et al., 2017; Hu et al. 2019). Research conducted by Cheng et al. (2021) showed that increasing nicotine also increases soluble starch, soluble protein, vitamin C, cellulose, free amino acids, total phenolics, choline, total flavonoids, and procyanidin. The increase in these compounds contributes to plant growth (Jassbi et al., 2017; Zou et al., 2021). Additionally, tobacco extract increases the NPK element in plant tissues, thereby

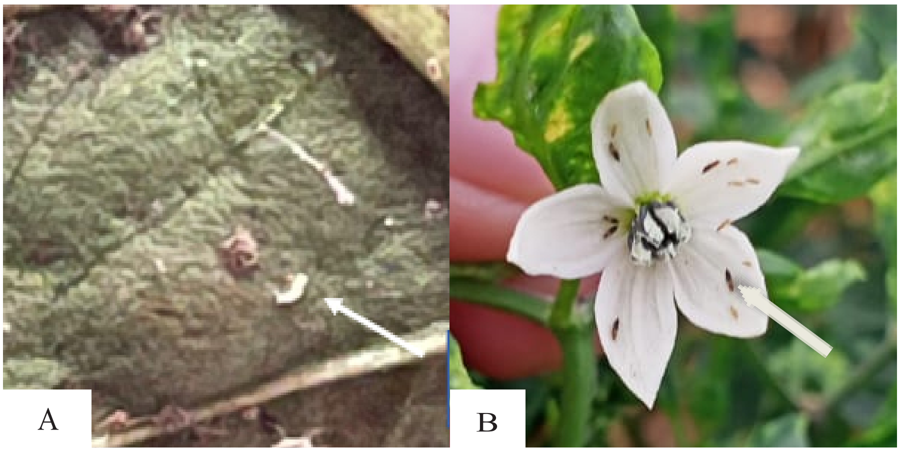

Figure 2. Viral infections are transmitted. A. *Bemisia tabaci*; B. *Thrips* sp.

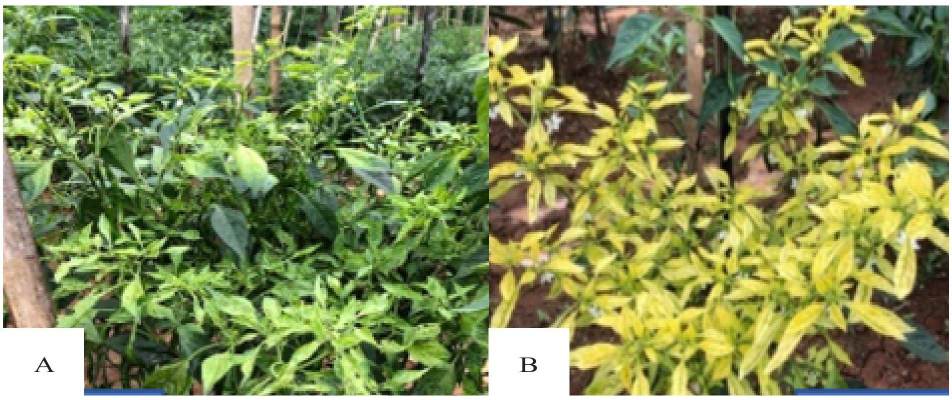

Figure 3. Symptoms of yellow leaf curl disease on *Curly red chili*. A. Mottle; B. Yellowing.

Table 3. Effect of tobacco extract on plant height, number of laves, number of fruits, weight of fruits per plant

Treatment	Growth observation			
	Plant height (cm)	Number of leaves	Number of fruits	Weight of fruits per plant (g)
J0	32.67 e	97.00 d	21.12 e	371.24 e
J1	44.67 d	109.92 c	32.75 d	489.22 d
J2	54.67 c	126.75 b	36.67 c	559.36 c
J3	63.50 d	136.25 a	47.33 b	575.22 b
J4	71.67 a	140.12 a	50.83 a	599.85 a

The number followed by different letters in the same column indicate significant differences based on the Duncan test at the 5% level. J0= Tobacco leaf extract at 0 mL/L; J1= Tobacco leaf extract at 1 mL/L; J2= Tobacco leaf extract at 2 mL/L; J3= Tobacco leaf extract at 3 mL/L; J4= Tobacco leaf extract at 4 mL/L.

enhancing the resistance and health of vanilla (Haryuni et al., 2020).

The results of this research revealed that tobacco extract can be used to control the spread of *Bemissia* and *Thrips*, thereby reducing plant virus infection. This finding provide valuable information on controlling viral disease in red-chilli pepper.

CONCLUSIONS

The decrease in the yield of curly chili was caused by a virus transmitted through infection with *Bemisia tabaci* and *Thrips* sp., resulting in chlorosis and mosaic symptoms on the leaves. Affected plants do not die but experience a decrease in yield. The application of tobacco extract significantly reduced the percentage of incidence and severity of virus attacks on curly chili. The highest disease incidence was 35.42% (0 mL/L), and disease severity was 70.92% (0 mL/L), while the lowest disease incidence was 14.58% (4 mL/L) and disease severity was 20.58% (4 mL/L). Future research needs to observe chlorophyll levels and the number of vectors causing symptoms of viral disease in curly chilies.

ACKNOWLEDGMENTS

Thank you to Tunas Pembangunan University, Faculty of Agricultural, research team, who have facilitated and collaborated in the implementation of this research.

FUNDING

This research was funded by a research grant from Tunas Pembangunan University Surakarta research, Grant No.014/PK-P/LPPM-UTP/I/2023.

AUTHORS' CONTRIBUTIONS

HH conceptualized and planned the experiment. HH and SP collected data on the area of plant damage caused by *Bemisia tabaci* and *Thrips* sp. SP performed the analysis and interpretation of the plant damage data. HH prepared the manuscript. The authors provided feedback and comments on the research flow, data analysis and interpretation, and the structure of the manuscript. All authors have read and approved the final manuscript.

COMPETING INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Ananthu N & Umamaheswaran K. 2019. Effect of viral infection on carbohydrate and chlorophyll contents in ginger (*Zingiber officinale* Rosc.). *Int. J. Curr. Microbiol. App. Sci*. 8(6): 862–867. https://doi.org/10.20546/ijcmas.2019.806.104

Banožić M, Babić J, & Jokić S. 2020. Recent advances in extraction of bioactive compounds from tobacco industrial waste-a review. *Ind. Crops Prod*. 144: 112009. https://doi.org/10.1016/j.indcrop.2019.112009

Badan Pusat Statistik (BPS-Statistics Indonesia). 2022a. *Produksi Tanaman Sayuran 2022*. [Vegetable Crops Production 2022]. https://www.bps.go.id/id/statistics-table/2/NjEjMg==/produksi-tanaman-sayuran.html. Accessed 6 July 2023.

Badan Pusat Statistik (BPS-Statistics Indonesia). 2022b. *Luas Panen Tanaman Sayuran dan Buah–Buahan Semusim Menurut Jenis Tanaman 2022* [Harvested Area of Vegetable and Seasonal Fruits by Crop Type 2022]. https://www.bps.go.id/id/statistics-table/3/VTNWM01VdGhTelZTTTNSS1NFSkVZazkzWjJKcWR6MDkjMw==/luas-panen-tanaman-sayuran-dan-buahbuahan-semusim-menurut-jenis-tanaman--2022.html?year=2022. Accessed 6 July 2023.

Center for Agricultural Data and Information. 2020. *Statistics of Food Consumption*. https://satudata.pertanian.go.id/assets/docs/publikasi/Statistik_Konsumsi_Pangan_Tahun_2020.pdf. Accessed 6 July 2023.

Cheng YD, Bai YX, Jia M, Chen Y, Wang D, Wu T, Wang G, & Yang HW. 2021. Potential risks of nicotine on the germination, growth, and nutritional properties of broad bean. *Ecotoxicol. Environ. Saf.* 209: 111797. https://doi.org/10.1016/j.ecoenv.2020.111797

Gomez KA & Gomez AA. 1995. *Prosedur Statistik untuk Penelitian Pertanian* [*Statistical Procedures for Agricultural Research*]. Translator: Sjamsuddin E & Baharsjah JS. UI-Press. Jakarta.

Gozan M, Yasman, Wulan PPDK, & Dawitri E. 2014. Tobacco leaves pyrolysis for repellent active compound production. *Int. J. Appl. Eng. Res.* 9(21): 9739–9750.

Hardiansyah AN, Sulistyaningsih E, & Putra ETS. 2017. Effects of pyraclostrobin on growth and yield of curly red chili (*Capsicum annum* L.). *Ilmu Pertanian* (*Agricultural Science*). 2(1): 9–14. https://doi.org/10.22146/ipas.12841

Haryuni H, Dewi TSK, Suprapti E, Rahman SF, & Gozan M. 2019. The effect of *Beauveria bassiana* on the effectiveness of *Nicotiana tabacum* extract as biopesticide against *Hypothenemus hampei* to robusta coffee. *IJTech*. 10(1): 159–166. https://doi.org/10.14716/ijtech.v10i1.2215

Haryuni H, Harahap AFP, Supartini, Priyatmojo A, & Gozan M. 2020. The effects of biopesticide and *Fusarium oxysporum* f.sp. *vanillae* on the nutrient content of binucleate *Rhizoctonia* -induced vanilla plant. *International Journal of Agronomy.* 2020: 5092893. https://doi.org/10.1155/2020/5092893

Herison C, Surmaini E, Rustikawati R, & Yulian Y. 2018. Morphological characterization of 10 hot pepper genotipes in low altitude location. *Akta Agrosia.* 21(2): 47–54.

Hu W, Di Q, Wang Z, Zhang Y, Zhang J, Liu J, & Shi X. 2019. Grafting alleviates potassium stress and improves growth in tobacco. *BMC Plant Biol*. 19: 130. https://doi.org/10.1186/s12870-019-1706-1

Iqbal N, Khan NA, Ferrante A, Trivellini A, Francini A, & Khan MIR. 2017. Ethylene role in plant growth, development and senescence: interaction with other phytohormones. *Front. Plant Sci*. 8: 475. https://doi.org/10.3389/fpls.2017.00475

Jassbi AR, Zare S, Asadollahi M, & Schuman MC. 2017. Ecological roles and biological activities of specialized metabolites from the genus *Nicotiana*. *Chem. Rev*. 117(19): 12227–12280. https://doi.org/10.1021/acs.chemrev.7b00001

Kanmani S, Kumar L, Raveen R, Tennyson S, Arivoli S, & Jayakumar M. 2021. Toxicity of tobacco *Nicotiana tabacum* Linnaeus (Solanaceae) leaf extracts to the rice weevil *Sitophilus oryzae* Linnaeus 1763 (Coleoptera: Curculionidae). *JoBAZ*. 82: 10. https://doi.org/10.1186/s41936-021-00207-0

Kumar V, Kumar A, Singh MK, & Kumar M. 2020. Growth and yield of chilli (*Capsicum annum* L.) as affected by different NADEP compost and chemical fertilizers. *Int. J. Biol. Sci.* 10(1): 57–59. https://doi.org/10.5958/2322-0996.2020.00009.5

Lei R, Jiang H, Hu F, Yan J, & Zhu S. 2017. Chlorophyll fluorescence lifetime imaging provides new insight into the chlorosis induced by plant virus infection. *Plant Cell Rep.* 36(2): 327–341. https://doi.org/10.1007/s00299-016-2083-y

Li Y, Pang T, Shi J, Lu X, Deng J, & Lin Q. 2015. Simultaneous determination of alkaloids and their related tobacco-specific nitrosamines in tobacco leaves using LC–MS-MS. *J. Chromatogr. Sci.* 53(10): 1730–1736. https://doi.org/10.1093/chromsci/bmv082

Liu Y, Yong G, Xu Y, Zhu D, Tong H, & Liu S. 2010. Simultaneous determination of free and esterified fatty alcohols, phytosterols and solanesol in tobacco leaves by GC. *Chromatographia*. 71: 727–732. https://doi.org/10.1365/s10337-010-1507-z

Lu M, Chen C, Lan Y, Xiao J, Li R, Huang J, Huang Q, Cao Y, & Ho CT. 2020. Capsaicin-the major bioactive ingredient of chili peppers: bio-efficacy and delivery systems. *Food & Funct*. 11(4):

2848–2860. https://doi.org/10.1039/d0fo00351d

Mandadi KK & Scholthof KBG. 2013. Plant immune responses against viruses: How does a virus cause disease? *The Plant cell*. 25(5): 1489–1505. https://doi.org/10.1105/tpc.113.111658

Masriyana, Hendarto K, Yusnaini S, & Ginting YC. 2020. Pengaruh aplikasi pupuk hayati dan pupuk kandang (ayam dan sapi) terhadap pertumbuhan dan hasil tanaman semangka (*Citrullus lanatus*). [The effect of application of biological fertilizer and manure (chicken and cattle) on the growth and productiob of watermelon (*Citrullus lanatus*)]. *J. Agrotek Tropika*. 8(3): 511–516. https://doi.org/10.23960/jat.v8i3.4474

Mohamed AA, Mak C, Liew KW, & Ho YW. 1999. Early evaluation of banana plants at nursery stage of Fusarium wilt tolerance. In: Molina, AB, Nik Masdek NH, & Liew KW (Eds.). Banana Fusarium Wilt Management: Towards Sustainable Cultivation. *Proceedings of The International Workshop on Banana Fusarium Wilt Diseases*. pp. 174–185. INIBAP. Malaysia.

Nurjati E. 2021. Price Volatility of Red Chili Peppers in Central Java. *Agrisocionomics: Jurnal Sosial Ekonomi Pertanian*. 5(2): 152–167. https://doi.org/10.14710/agrisocionomics.v5i2.9754

Popova V, Gochev V, Girova T, Iliev I, Ivanova T, & Stoyanova A. 2015. Extraction products from tobacco–Aroma and bioactive compounds and activities. *Curr. Bioact. Compd.* 11(1): 31–37. https://doi.org/10.2174/15734072110115080415 0016

Prommaban A, Kheawfu K, Chittasupho C, Sirilun S, Hemsuwimon K, & Chaiyana W. 2022. Phytochemical, antioxidant, antihyaluronidase, antityrosinase, and antimicrobial properties of *Nicotiana tabacum* L. leaf extracts. *eCAM.* 2022: 5761764. https://doi.org/10.1155/2022/5761764

Putri CA. 2021. *Ternyata RI Masih Impor Cabai, Ini Negara Pemasoknya [It turns out that Indonesia still imports chillies, these are the supplier country]*. https://www.cnbcindonesia.com/news/20210813194116-4-268385/ternyata-ri-masih-impor-cabai-ini-negara-pemasoknya. Accessed 6 June 2023.

Reang D, Khalko S & Roy A. 2018. To find out the seasonal incidence of diseases in chilli at different locations of Terai zone of West Bengal. *J. Pharmacognosy Phytochem* . 7(5): 2799–2802.

Rodríguez-Verástegui LL, Ramírez-Zavaleta CY, Capilla-Hernández MF, & Gregorio-Jorge J. 2022. Viruses Infecting Trees and Herbs That Produce Edible Fleshy Fruits with a Prominent Value in the Global Market: An Evolutionary Perspective. *Plants*. 11(2): 203. https://doi.org/10.3390/plants11020203

Selangga DGW, Wiyono S, Susila AD, & Hidayat SH. 2021. Distribution and identification of *Pepper yellow leaf curl Indonesia virus* infecting chili pepper in Bali. *Jurnal Fitopatologi Indonesia.* 17(6): 217–224. https://doi.org/10.14692/jfi.17.6.217-224

Sarker S & Lim UT. 2018. Extract of *Nicotiana tabacum* as a potential control agent of *Grapholita molesta* (Lepidoptera: Tortricidae). *PLoS ONE.* 13(8): e0198302. https://doi.org/10.1371/journal.pone.0198302

Sentosa Y, Andjani HN, Yati K, Jufri M, Haryuni H, & Gozan M. 2019. Determination of LC_{50} value of *Nicotiana tabacum* L. extract against *Tenebrio molitor* and *Zophobas morio* larvae. *AIP Conf. Proc.* 2193(1): 030021. https://doi.org/10.1063/1.5139358

Soedjarwo DP, & Tjokrosumarto WA. 2018. Growth and production plant chili pepper (*Capsicum annum*) as a result of the existence pruning leaves. *Proceeding International Joint Conferenceon Science and Technology (IJCST)2017*. 1(1): 439–449. http://ojs.pnb.ac.id/index.php/Proceedings/article/view/937. Accessed 2 June 2023.

Steel RGD & Torrie JH. 1980. *Principles and Procedures of Statistics: A Biometrical Approach*. Edition 2. McGraw-Hill Book Co, New York.

Sumbria D, Berber E, Mathayan M, & Rouse BT. 2021. Virus infections and host metabolism-Can we manage the interactions? *Front. Immunol.* 11: 594963. https://doi.org/10.3389/fimmu.2020.594963

Wongpia A & Lomthaisong K. 2010. Changes in the 2DE protein profiles of chilli pepper (*Capsicum annuum*) leaves in response to *Fusarium oxysporum* infection. *Sci. Asia.* 36: 259–270. https://doi.org/10.2306/scienceasia1513-1874.2010.36.259

Zanini AA, Feo LD, Luna DF, Paccioretti P, Collavino A, & Rodriguez MS. 2021. Cassava common mosaic virus infection causes alterations in chloroplast ultrastructure, function, and carbohydrate metabolism of cassava plants. *Plant Pathol*. 70(1): 195–205. https://doi.org/10.1111/ppa.13272

Zhao J, Zhang X, Hong Y, & Liu Y. 2016. Chloroplast in plant-virus interaction. *Front. Microbiol*. 7: 1565. https://doi.org/10.3389/fmicb.2016.01565

Zhou Y, Gao X, Small DM, & Chen H. 2019. Extreme spicy food cravers displayed increased brain activity in response to pictures of foods containing chili peppers: an fMRI study. *Appetite*. 142: 104379. https://doi.org/10.1016/j.appet.2019.104379

Zou X, BK A, Abu-Izneid T, Aziz A, Devnath P, Rauf A, Mitra S, Emran TB, Mujawah AAH, Lorenzo JM, Mubarak MS, Wilairatana P, Suleria HAR. 2021. Current advances of functional phytochemicals in Nicotiana plant and related potential value of tobacco processing waste: A review. *Biomed Pharmacother*. 143: 112191. https://doi.org/10.1016/j.biopha.2021.112191