Evaluation of integrated crop management against disease in chili (*Capsicum* sp.) planting in Pulau Beringin District, South OKU Regency, South Sumatera

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Abstract. One of the vegetable commodities that is needed by almost everyone from various circles of society is chili (Capsicum annuum L.). Important diseases that generally attack chili plants are anthracnose fruit rot, leaf spot disease caused and fungus yellow virus disease (Pepper yellow leaf curl virus). The purpose of this study was to determine the integrated crop management on the incidence and intensity of chili plant disease attack in Pulau Beringin District, South OKU Regency. This research was conducted by collecting primary data obtained through direct surveys in the field using questionnaires to farmers as respondents and disease observations using purposive sampling method. Parameters of this study include disease incidence, disease intensity and ICM. Based on the percentage results, different values are obtained in each village. The highest order with a percentage value of 98% is Kemu Village, in Tanjung Bulan Village with a percentage value of 96% and Pulau Beringin Village with a value of 92%. In Pulau Beringin sub-district, the incidence of severity and intensity of C. capsici leaf spot disease attack had the highest percentage value among the three villages.

1. Introduction

Horticultural crops are one of the agricultural sub-sectors that play a vital role in supporting food security, increasing farmers' incomes, and driving economic growth in various tropical countries, including Indonesia. One horticultural commodity of strategic importance is the chilli (*Capsicum annuum* L.), as it serves as a staple food, a source of vitamins and antioxidants, and possesses high economic value. The demand for chillies, which continues to rise every year, makes this commodity one of the main sources of income for farmers [1]. However, chilli productivity in Indonesia remains volatile due to various factors, both biotic and abiotic, necessitating more effective and sustainable cultivation management practices [2]. Recent research indicates that increased humidity resulting from high rainfall contributes to a rise in the intensity of disease outbreaks in chilli plants, thereby reducing both yield and product quality [3]. Consequently, changing environmental conditions represent one of the key challenges in chilli cultivation, necessitating adaptive management strategies. Some of the major diseases that frequently affect chilli plants include anthracnose, caused by the fungus Colletotrichum spp., leaf spot disease caused by Cercospora capsici, and yellow virus disease [4], [5]. These three diseases are the main causes of reduced chilli productivity in various major production areas. Anthracnose attacks the fruit at various stages of ripeness, resulting in significant crop losses. Meanwhile, leaf spot disease reduces the surface area of leaves capable of active photosynthesis, whilst yellow virus disease attacks almost all parts of the plant, thereby inhibiting growth and fruit set [6]–[8]. Several recent studies have also reported that climate change and high humidity levels promote the development of these pathogens, thereby increasing the risk of yield loss [9].

In agricultural practice, disease control generally still relies on the use of synthetic pesticides. Although pesticides are capable of rapidly suppressing the growth of pathogens, their excessive use has led to various negative impacts, such as increased pathogen resistance to the active ingredients in pesticides, soil and water pollution, a decline in the diversity of non-target organisms, and increased risks to human health. Consequently, more environmentally friendly and sustainable farming systems have become a key focus in the development of modern agriculture. One approach that has been widely developed in recent years is Integrated Crop Management (ICM) [9]–[11]. ICM is a cultivation approach that integrates various technological components, such as the use of high-yielding varieties, high-quality seeds, the utilisation of organic matter, crop population management, balanced fertilisation based on crop requirements, integrated pest management (IPM), and soil preparation tailored to environmental conditions. Various studies published over the last five years have shown that the implementation of PTT can increase crop productivity, reduce reliance on chemical pesticides, improve soil quality, and enhance the sustainability of agricultural systems. However, the effectiveness of PTT implementation is greatly influenced by agroecosystem

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conditions, environmental characteristics, and the types of pests present in each region [12].

Although numerous studies on Integrated Crop Management (ICM) have been conducted, the majority still focus on increasing crop yields or the effectiveness of individual technological components in isolation. Research examining the comprehensive application of ICM by linking disease incidence, arthropod diversity and chilli plant productivity within local agroecosystem conditions—particularly in Pulau Beringin Sub-district—remains very limited. However, environmental characteristics and cultivation practices in each region can influence the success of IPM implementation.

Given these circumstances, this study aims to evaluate the implementation of Integrated Pest Management (IPM) in chilli cultivation in Pulau Beringin Sub-district through observations of plant disease incidence, arthropod diversity, and chilli plant productivity. It is hoped that the results of this study will provide scientific information on the effectiveness of IPM as an environmentally friendly and sustainable cultivation strategy capable of increasing chilli productivity in accordance with local agroecosystem conditions.

2. Research Method

Place and time

This research was conducted in chili fields in June 2024 until completion in Pulau Beringin District, South OKU Regency, South Sumatra. Furthermore, pathogen identification activities were carried out at the Phytopathology Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Sriwijaya University.

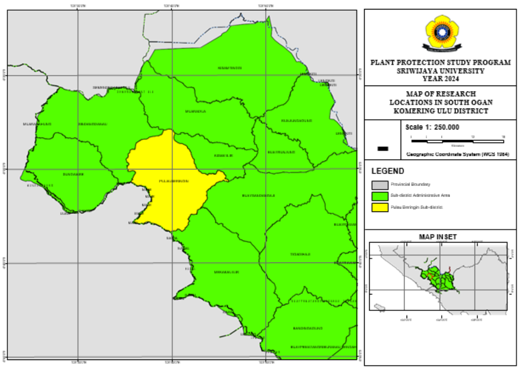

Fig. 1. Map of the research location of chili plants in Pulau Beringin District.

Tools and materials

The tools used in this study are: 1) Stationery, 2) Bunsen, 3) Coverglass, 4) Hand sprayer, 5) Syringe, 6) Camera, 7) Matches, 8) Microscope, 9) Tape, 10) Preparations, and 11) Tissue. The materials used in this thesis research are: 1) Aquadest and 2) Samples of chili leaf spot disease.

Research methods

This study was conducted by collecting primary data obtained through a direct field survey using a questionnaire administered to 30 farmers as respondents, whilst disease observation was carried out using a purposive sampling method. This disease observation method involved selecting five plots on each plot of land and taking 10 chilli plants from each plot as observation samples. The number of chilli plants observed on each plot was 50, bringing the total number of chilli plants observed across the 30 plots to 1,500. Sampling was carried out by calculating the incidence and intensity of disease attack on each chilli plant. Subsequently, the data obtained from the observations were recorded and documented, and samples of diseased plants were collected for identification in the laboratory. The diseases were identified at the Plant Pathology Laboratory of the Department of Plant Pests and Diseases, Faculty of Agriculture, University of Sriwijaya. The diseased chilli plants were collected, placed in plastic containers and covered with tissue moistened with water. The diseases were identified under a microscope.

Interviews were conducted directly to determine the level of implementation of Integrated Crop Management on farms which were analyzed descriptively. Calculating the level of application of Integrated Crop Management components can be categorized into three categories, namely, low, medium and high and calculated using a formula referenced from (Romdon et al., 2012) as follows:

TPT= (Total Value)/ (Total Weight) ×100%
Description:

TPT : Percentage of technology application rate
Total Value : Sum of the component answer values from each respondent
Total Weight : Expected value of the respondent component

The scale of application of the level of adoption of Integrated Crop Management Technology using the Likert's Summated Ratings (LRS) method can be categorized as follows:

Table 1. Criteria for ICM implementation level.

N0	Score Value	Category of ICM Implementation Level
1	0,0 - 33,3 %	Low adoption rate
2	33,4 - 66,7 %	Medium adoption rate
3	66,8 - 100 %	High adoption rate

Table 2. Components of Integrated Crop Management (ICM).

No	Component	Parameters	Score
1	Use of high-yielding varieties	Always done	3
		Sometimes	2
		Never done	1
		Always done	3
2	Use of quality and healthy seeds	Sometimes	2
		Never done	1
		Always done	3
3	Site-specific fertilization	Sometimes	2
		Never done	1
		Always done	3
4	IPM according to pest	Sometimes	2
		Never done	1
		Always done	3
5	Crop management	Sometimes	2
		Never done	1
		Always done	3
6	Young seedlings 15-20 HSS	Sometimes	2
		Never done	1
		Always done	3
7	Use of organic materials	Sometimes	2
		Never done	1
		Always done	3
8	Intermittent Irrigation	Sometimes	2
		Never done	1
		Always done	3
9	Micro fertilizer	Sometimes	2
		Never done	1
		Always done	3
10	Weed control	Sometimes	2
		Never done	1
		Always done	3
11	harvest and post-harvest handling	Sometimes	2
		Never done	1
		Always done	3
12	Tillage	Sometimes	2
		Never done	1

Data analysis

Data obtained from observation were analyzed statistically and accurately using the Microsoft Excel program and presented in the form of tables, figures and graphs. The parameters of this study include disease incidence, disease intensity and ICM. The incidence of disease-stricken plants was calculated using the incidence calculation formula referring to the research of (Tricahyati et al., 2022) as follows:

$$P = n/N \times 100\%$$

Description:

P : Percentage of plant disease incidence (%)
n : Number of disease-affected plants
N : Number of plants observed

While the observation of the intensity of disease attack on chili plants is calculated using a scale category with the following calculation formula:

$$Is = (\sum(n \times v))/(Z \times N) \times 100\%$$

Description:

Is : Intensity of disease attack (%)
n : Number of plants per symptom category
v : Scale value of each category
Z : Scale value of the highest category
N : Number of plants observed

Table 3. Scale criteria for plant disease damage.

Scale	Description	Attack Criteria
0	Healthy Leaves	Healthy
1	≤ 10% of the leaflets are diseased	Very light
2	> 10% - ≤ 25% of the leaflet is diseased	Lightweight
3	> 25% - ≤ 50% of the leaf is diseased	Medium
4	> 50% of the leaf is diseased	Weight

3.Result and discussion

Based on the results of research in Pulau Beringin District, the results of interviews with farmers about the cultivation of chili plants show little difference. These differences can be seen from the land area, planting age, fertilizer used, planting varieties used, planting distance and surrounding varieties. All chili farmers use the same planting distance of 60 cm.

In the cultivation of chili plants in Pulau Beringin District, different chili varieties are used, namely Laba F1, Kastilo F1, ORI 212 and Tangguh F1. The Laba F1 variety has the advantage of being resistant to bacterial wilt disease and can be planted in various seasons. The Kastilo F1 variety has the advantage of being resistant to stem rot and plants grow upright and flower continuously. The Tangguh F1 variety gets a faster harvest while the ORI 212 variety is a cayenne pepper variety that has the advantage of being resistant to diseases and pests and is already adapted to the lowlands. Farmers use NPK and Mutiara fertilizers for more optimal plant growth and development, TSP is used for improvement in plant root development and helps the plant's photosynthesis process, kendang fertilizer is used as a nutrient provider and improves soil structure for optimal plant growth and ZPT is used to accelerate chili growth.

Identification of Anthracnose Disease (*Colletotrichum capsic*)

The characteristic of chili fruit attacked by anthracnose disease caused by the fungus C. capsici shows symptoms of brownish black spots and develops into soft rot until the fruit becomes completely dry with a black spot in the middle of the spot. From the results of the identification of C. capsici carried out microscopically, it has been found that the conidia are cylindrical and have blunt ends and bend like a crescent with hyphae insulated with transparent conidia.

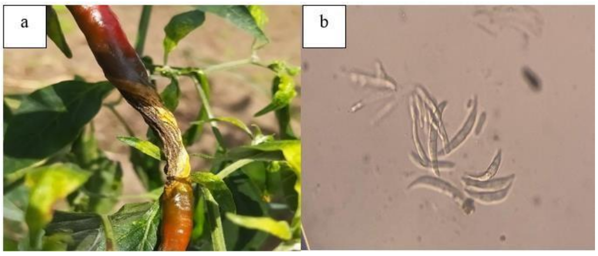

Fig. 2. Anthracnose disease symptoms observed in the field (a) and conidia of *Colletotrichum capsici* (b).

Identification of Leaf Spot Disease (*Cercospora capsici*)

The results of the identification of *C. capsici* leaf spot disease in the field found symptoms of attack of small round spots on the surface of the leaves then developed into irregular spots with a pale center and darker edges. From the results of microscopic identification of *C. capsici*, conidiophores of *C. capsici* were found. Conidiophores found have a dark color, unbranched hyphae and have 3 or more partitions.

Fig. 3. Symptoms of Cercospora capsici leaf spot disease in the observations field (a) and conidiophores of Cercospora capsici (b).

The results of the identification of yellow virus disease in the field found that the characteristic symptoms of this disease are that the leaves of chilies become striking yellow and the stems of chilies become stunted and have no fruit on the affected plants. Signs of chili plants infected by this virus are yellowing leaves starting from the top of the plant or on young leaves. This disease can be easily recognized in the field because of its yellow characteristics and stunted growth, causing plants attacked by this virus to be different from other chili plants.

Fig. 4. Symptoms of yellow virus attack on chili plants, dwarfed (a), all over (b). leaf yellowing (b).

Adoption rate of integrated crop management technology on chili (Capsicum sp.) in Pulau Beringin District

In observing the application of integrated crop management technology, all farmers in Pulau Beringin District have applied this technology in cultivating chili plants on their land. This can be seen in (Table 4) the percentage value of the application of integrated crop management technology is relatively high. The highest order of the three observation locations is Kemu Village at 98% and the second highest order in Tanjung Bulan Village 96% then Pulau Beringin Village at 92% (Table 4).

Table 4. Percentage of Integrated Crop Management Technology Implementation.

	Village	Percentage (%)	Scale
1.	Kemu	98	High
2.	Banyan Island	92	High
3.	Cape Moon	96	High

Anthracnose disease incidence (*Colletotrichum capsici)*

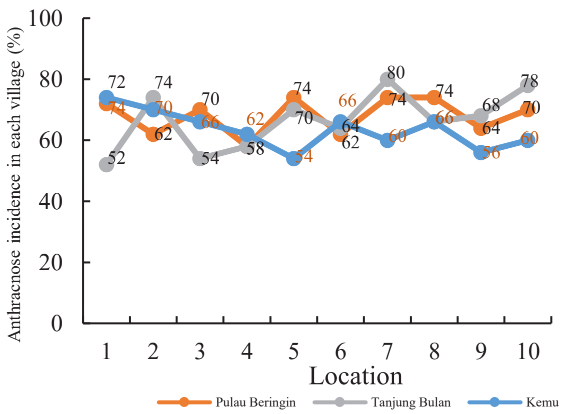

Fig. 5. Incidence of Anthracnose Disease Colletotrichum capsici in Pulau Beringin District.

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It can be seen that the incidence of anthracnose disease by *C. capsici* in the three observation areas has different values and is erratic. The highest anthracnose disease incidence observation was in Tanjung Bulan Village with a percentage reaching 80% (Figure 5.) and the lowest disease incidence was also in Tanjung Bulan Village with an observed incidence percentage of 52% (Figure 5.).

Leaf spot disease incidence (*Cercospora capsici)*

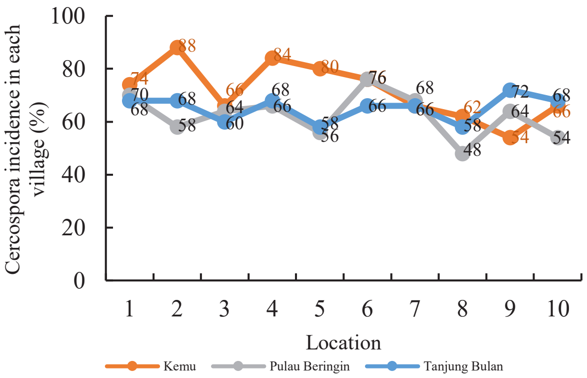

Fig. 6. Incidence of Leaf spot disease incidence *Cercospora capsici* in Pulau Beringin District.

It can be seen that the observation of the percentage value of leaf spot disease incidence (*C. capsici*) is not too different in each field. The highest percentage value of leaf spot disease (*C. capsici*) incidence was in Kemu village at 88% (Figure 6.) and the lowest percentage value was 48% in Pulau Beringin village (Figure 6.). Pepper yellow leaf curl virus (PepYLCV) disease incidence.

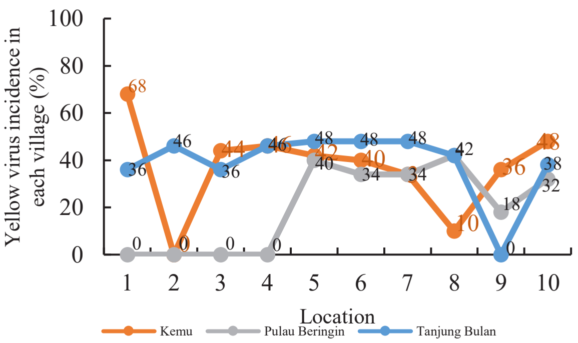

Fig. 7. Incidence of yellow virus in Pulau Beringin District.

The incidence of PepYLCV in chili plants in Beringin Island Sub-district has different levels of attack in each field location. In Kemu village the highest yellow virus disease incidence rate was in the first field reaching 68%, in Pulau Beringin village the highest incidence rate reached 42% in the 8th field and in Tanjung Bulan village the highest disease incidence reached 48% in several fields. The lowest incidence rate in each village was 0%.

Intensity of anthracnose disease (*Colletotrichum capsici*)

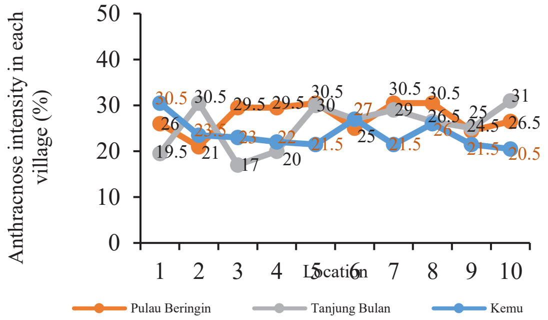

Fig. 8. Intensity of Anthracnose Disease *Colletotrichum capsici* in Pulau Beringin District.

The result showed that the intensity of anthracnose disease by *C. capsica* at each observation in the three villages had different results but not too far (Figure 8.). Tanjung Bulan village is the village that has the highest percentage value with a disease intensity level of 31% and the lowest intensity of 17%.

Intensity of leaf spot disease (*Cercospora capsici)*

The intensity of leaf spot disease by *C. capsici* at each observation in the three villages had different results (Figure 9). Tanjung Bulan village had the highest intensity variation with a disease intensity level of 35% and the lowest intensity of 23.5%.

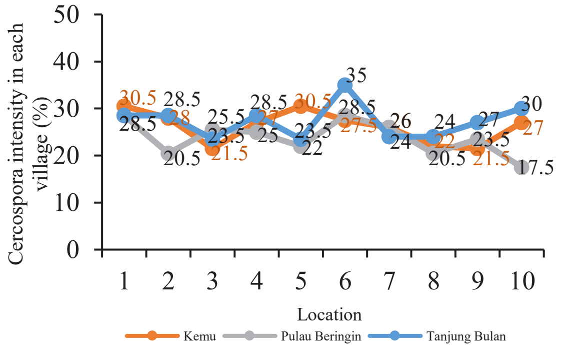

Fig. 9. Intensity of Leaf spot disease incidence *Cercospora capsici* in Pulau Beringin District.

Pepper yellow leaf curl virus (PepYLCV) disease intensity

The results showed that PepYLCV disease intensity at each observation in the three villages had different results (Figure 10). Tanjung Bulan village had the highest diversity of intensity with 14.5% and 0% disease intensity.

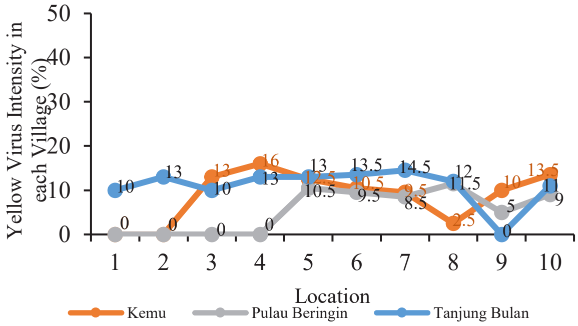

Fig. 10. Intensity of yellow virus in Pulau Beringin District.

Research findings indicate that chilli plants are susceptible to several major diseases that frequently affect them, namely anthracnose caused by the fungus *Colletotrichum capsici*, leaf spot caused by *Cercospora capsici*, and PepYLCV, which is transmitted by whiteflies; these plants are susceptible to several major diseases, namely anthracnose caused by the fungus *Colletotrichum capsici*, leaf spot caused by *Cercospora capsici*, and PepYLCV transmitted by whiteflies (*B. tabaci*) [4], [13]. Anthracnose, caused by the fungus *C. capsici*, is characterised by circular, dark brown to black lesions on the surface of chilli fruits, which subsequently spread across the entire fruit. Severe anthracnose infection can cause the fruit to become shrivelled and dry. This disease affects not only the chilli fruit but can also attack all parts of the plant, such as the stem, twigs, leaves, and branches. It spreads very rapidly and is highly detrimental to production. The fungus *C. capsici* produces long, crescent-shaped conidia with tapered tips. The development of the disease in chilli plants can be influenced by biotic and abiotic factors. Biotic factors affecting the disease in chilli plants include the plant itself, other diseases, and vectors. Susceptible plants can provide a favourable environment for the disease to thrive; furthermore, the age of the plant significantly influences the development and severity of the disease. Susceptible plants provide an ideal environment for diseases to thrive; furthermore, the age of the plant significantly influences the development and severity of disease outbreaks in the field. The virulence of a disease plays a major role in the progression of disease outbreaks in chilli plants. Insect vectors also pose a problem in chilli cultivation, as they can transmit diseases to the plants. Plant diseases can be influenced by abiotic factors such as rainfall. Fungal diseases can thrive on chilli plants in conditions of high humidity. Furthermore, low rainfall can lead to the proliferation of insect vectors, which then transmit viruses to chilli plants.

The progression of the *C. capsici* disease in chilli plants is characterised by the appearance of round spots that begin on the leaves and spread across the entire leaf surface, causing the spots to enlarge and form holes in the leaves. The spread of this disease in chilli plants can be influenced by temperature, humidity and wind. Severe infection can lead to leaf drop. Infected leaves display several brownish spots with dark edges and greyish centres. This disease is also often referred to as 'frog-eye spot' because its characteristic symptoms resemble a frog's eye. The severity of the disease can cause the leaves to turn yellow and eventually fall off. The disease spreads very rapidly among healthy chilli plants, as the fungal spores are carried by the wind and through poor hygiene practices. Affected parts of the plant can be properly disposed of by removing them and burning them. This disease not only attacks the leaves but can also infect other parts such as the stem, petioles and fruit stalks; however, it rarely affects the chilli fruit itself. The conidia of C. capsici are elongated and concentrated. The conidiophores are short and blunt-tipped, whilst the mycelium is a dull white colour [13], [14]. Yellow virus disease, caused by the whitefly vector (*B. tabaci*), is also known as PepYLCV. Symptoms of this disease include bright yellow leaves, stunted plants and curled leaves. The plants turn almost entirely yellow, making them easily recognisable during field observations. Plants affected by this disease experience stunted growth because the photosynthesis process is disrupted, meaning that the flow of nutrients is impaired. Plants infected with the yellow virus do not produce fruit. A crucial factor in the outbreak of this viral disease in yellow chillies is the presence of the insect vector that spreads the virus [4].

The components of Integrated Crop Management (ICM) used as assessment criteria for chili pepper farmers were observed in Pulau Beringin District in different village locations. Based on the percentage results, different values were obtained in each village. The highest order with a percentage value of 98% is Kemu Village, in Tanjung Bulan Village with a percentage value of 96% and Pulau Beringin Village with a value of 92%. Some farmers believe that technology can save time, reduce the risk of plant diseases and pests, and increase production. Due to the sometimes erratic climate change conditions that can cause various disease attacks, the application of ICM technology is needed in cultivating plants.

The results of the observation of disease severity incidence in Pulau Beringin Sub-district show that the highest and lowest observations are in the observation field of Tanjung Bulan Village with a percentage value reaching 80% and 52%. The incidence of C. capsici leaf spot disease on the highest observation land is in Kemu Village with a percentage value reaching 88% and the lowest incidence percentage value is 48% in Pulau Beringin Village. In the observation of jaundice caused by PepYLCV, the highest incidence percentage value was obtained in Kemu Village, 68% and the lowest value was 0%. From the observation of the incidence of chili plant diseases in Pulau Beringin Sub-district, it was found that the incidence of C. capsici leaf spot disease had the highest percentage incidence value among the three villages.

The results of the percentage of observations of the intensity of anthracnose disease *C. capsici* in Pulau Beringin Sub-district obtained the highest percentage value in Tanjung Bulan Village 31% and the lowest percentage value was in the same village which was 17%. In the intensity of *C. capsici* leaf spot disease, the highest percentage value is 35% in Tanjung Bulan and the lowest intensity percentage value is 20.5% in Pulau Beringin village. The highest percentage value of yellow disease intensity caused by PepYLCV was found in the field in Tanjung Bulan village, which was 14.5% and the lowest percentage value was 0%. From the observation of disease intensity in the three villages in Pulau Beringin Sub-district, it was found that the percentage value of the intensity of C. capsici leaf spot disease was the highest and the highest percentage value in each disease was in Tanjung Bulan Village. The difference in the percentage of incidence and intensity of chili plant diseases on each observation land shows that there are differences in land conditions, land area and also the surrounding environmental vegetation. The growth and development of diseases in chilli plants are greatly influenced by the plants themselves, the diseases and the environment. Susceptible plants are highly conducive to disease development in the field, whilst resistant plants can defend themselves against disease attacks in the field. The severity of a disease outbreak depends on the specific disease in question; this is also linked to a conducive environment [15].

4.Conclusion

Important diseases that attack chili plants include anthracnose caused by the fungus *C. capsici*, leaf spot by *C. capsici*, and *Pepper yellow leaf curl virus* (*PepYLCV*) caused by whitefly (*B. tabaci*). The components of Integrated Crop Management (ICM) evaluated in chili farmers in several villages in Pulau Beringin District showed a high level of technology application. The highest percentage value of intensity in Kemu village is 74% and the lowest is 54%. in Pulau Beringin village the highest percentage value is the same as Kemu village which is 74% and the lowest is 58%. While in Tanjung Bulan village 80% and 52%. on leaf spot disease *C. capsici* the highest percentage value is 88% and the lowest is 54%, in Pulau Beringin village 76% for the highest percentage value and the lowest is 48% and in Tanjung Bulan village the highest percentage is 72% and the lowest is 58%. Then the percentage value of yellow virus disease in Kemu village is the highest at 68% and the lowest at 0%, in Pulau Beringin village the highest percentage value is 42% and 0% for the lowest value while in Tanjung Bulan village has the highest percentage value in this disease which is 48%.

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References

[1] I. R. Murtadho, K. Prasetyowati, U. Tunas, and P. Surakarta, "Marketing chain analysis of big red chilli (Capsicum annum L.) in Kedawung District, Sragen Regency," J. Rural Urban Community Stud., vol. 2, no. 2, pp. 1–6, 2024.

[2] D. R. Simbolon, M. Syafi, and M. Syukur, "Anthracnose disease resistance test on IPB hybrid chili (Capsicum annuum L.) Plants in Lowland Karawang," Jurla Agroplasma, vol. 10, no. 1, pp. 97–105, 2023.

[3] N. Prihatiningsih and H. A. Djatmiko, "Epidemic components of chilli anthracnose at Baturraden district Banyumas Regency," J. Agro, vol. 7, no. 2, pp. 203–212, 2020.

[4] A. Arsi et al., "Effects of holy basil (Ocimum sanctum) on viral disease of chili (Capsicum annum L.) under mixed crop cultivation," J. Trop. Plant Pests Dis., vol. 23, no. 2, pp. 49–57, 2023, doi: 10.23960/jhptt.22349-57.

[5] S. Rai, A. Nepal, and R. Rai, "Detection and prevention of fungal pathogens in horticultural and kiwifruit products : a comprehensive review," Agrobiol. Rec., vol. 7182, no. 23, pp. 1–24, 2026.

[6] R. A. Fauzi, M. A. Syaefullah, and M. F. Dwitama, "The effect of various active ingredients of fungicides against anthracnose disease (Colletotrichum gloeosporioides) in chili plants (Capsicum annuum L.)," J. Res. Community Serv., vol. 4, no. 10, pp. 2026–2032, 2026.

[7] A. Y. Perdani, Y. B. Paradisa, and S. Indrayani, "Response of six chili varieties to anthracnose disease caused by Colletotrichum acutatum and C. gloeosporioides," J. HPT Trop., vol. 21, no. 2, pp. 144–150, 2021.

[8] R. Warman, H. Rahma, Darnetty, and R. Noveriza, "Fungal diversity associated with anthracnose in chili peppers of West Sumatra, Indonesia, using conventional and NGS approaches," Biodiversitas, vol. 26, no. 9, pp. 4257–4266, 2025, doi: 10.13057/biodiv/d260901.

[9] X. Wang, M. Xing, J. Li, and B. Li, "The impacts of global climate change and environmental security on fruits and vegetables — A Policy – Technology Nexus Perspective," Food, vol. 4016, no. 14, pp. 1–37, 2025.

[10] A. B. Vermelho, J. Vin, I. T. Akamine, V. S. Cardoso, and F. R. P. Mansoldo, "Agricultural pest management : the role of microorganisms in biopesticides and soil bioremediation," Plants, vol. 2762, no. 13, pp. 1–49, 2024.

[11] J. M. Muñoz-bautista, A. T. Bernal-mercado, O. Martínez-cruz, J. Borboa-flores, J. R. Ramos-enríquez, and C. L. Del-toro-sánchez, "Environmental and health impacts of pesticides and nanotechnology as an alternative in agriculture," Agronomy, vol. 1878, no. 15, pp. 1–30, 2025.

[12] A. Susanti, M. Hoesain, and S. Prastowo, "The impact of synthetic pesticide applications on public health," agaricus Adv. Agric. Sci. Farming, vol. 2, no. 2, 2022.

[13] M. Anwar, D. F. Abdillah, I. Basri, Y. Galahartlambang, and T. Khotiah, "Classification of chili fruit diseases using deep convolutional neural network transfer learning," J. Informatics Dev., vol. 2, no. April, pp. 18–24, 2024.

[14] E. D. Ekawati, T. Wiharti, and A. A. Nugroho, "Identification of pests and diseases in red chili plants (Capsicum annuum L.) in Nangsri, Manisrenggo, Klaten," J. Biol. Trop., vol. 23, no. 4, pp. 507–512, 2023, doi: 10.29303/jbt.v23i4.5650.

[15] R. A. M. Ramadhan, D. N. Amalia, I. Permana, and P. Rahmatullah, "Inventory of chili pests and diseases in Kabandungan Sub-District , Sukabumi Regency," JERAMI Indones. J. Crop Sci., vol. 5, no. 2, 2023.