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Determining the technical and economic feasibility of combining pest control techniques in open field and netting house chilli cultivation systems

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Abstract: As one of the most widely cultivated vegetable crops worldwide, chillies (*Capsicum annuum* L.) face serious pest-related problems when grown in either open or protected cultivation systems. However, studies aimed at understanding the implementation of various integrated pest management (IPM) techniques on chilli production in both cultivation systems are scarce. The study aimed to evaluate the impact of implementing an integrated approach that combines the use of a sweet corn barrier, thiamethoxam, control threshold, silver plastic mulch, pest traps, and fungicides on chilli pests and diseases in open and protected farming systems. Those techniques were applied simultaneously to overcome major chilli pests and diseases that commonly co-occur in the field. The experiment conducted in West Java, Indonesia from May to November 2021 revealed that control techniques could maintain chilli pest population below their control threshold and prevented disease outbreak in both cultivation systems. The average yields of chilli cultivated in the netting house were higher than those cultivated in the open field, i.e. 20.92 t/ha and 9.77 t/ha, respectively. Furthermore, the profitability of chilli cultivation using IPM technologies has been demonstrated in both open and protected fields, with the profit generated in the protected system being 3.9 times higher than that of the open field.

Keywords: barrier crops; control threshold; mulch; R/C; traps

Chilli production technologies should be continually improved to increase productivity and effectively manage major chilli pests and diseases that could cause 25–100% crop losses (Setiawati et al. 2013). The implementation of integrated pest management (IPM) techniques in open field chilli cultivation systems has been widely reported (Moreira et al. 2021). Protected farming or modifying crop environment

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by employing agricultural production techniques, such as soil or plant covers, is also considered an advanced approach to overcoming pests and disease problems as well as the impact of climate change on crop production (Nordey et al. 2017). Unfortunately, the adoption of the protected farming technique is limited due to the high initial cost required for its infrastructure establishment (Moekasan & Prabaningrum 2017).

Limited studies have been conducted to comprehensively evaluate the combined use of IPM techniques in both open field and protected chilli cultivation systems. The study aimed to determine the technical and economic feasibility of the combinations of various pest control techniques in open field and netting house chilli cultivation systems. The control techniques applied in this study included the application of sweet corn barrier (Ramazeame et al. 2015), thiamethoxam (Mason et al. 2000), silver plastic mulch (Razzak & Seal 2017), light traps (Singh et al. 2014), fruit fly traps (Mulyadi et al. 2021), yellow sticky traps (Hossain et al. 2020), control threshold and fungicides application strategy (Moekasan & Prabaningrum 2017).

MATERIAL AND METHODS

Field experiments were conducted in Lembang, West Java, Indonesia from May to November 2021. The Hot Beauty chilli variety was grown in two cultivation treatments and four replicated plots per treatment, each measuring 88 m^2. The seedlings were transplanted in a double-row system to obtain a population of 256 plants per plot. In the first treatment, crops were cultivated in open field system; pests and diseases were controlled using a combination of pest control techniques. In the nursery, a 25 mL solution of 0.1 g/L Thiamethoxam was applied to each seedling at two and four weeks after chilli sowing. In addition, each chilli crop was treated with a 200 mL solution of 0.5 g/L Thiamethoxam at two and four weeks after transplanting. A crop barrier made up of three beds of sweet corn that were planted one month before and two months after chilli transplanting was also utilized.

The soil beds were covered with silver plastic prior to chilli transplanting. Pest control thresholds used in the study were 15% of crop damage for thrips (*Thrips parvispinus* Karny, Thysanoptera: Thripidae) and 12.5% of crop damage for armyworm (*Spodoptera litura* Fabricius, Lepidoptera: Noctuidae). The implementation of fungicide application strategy to prevent fungicide resistance included the use of azoxystrobin + difenoconazole (1 mL/L) during 1–4 weeks after transplanting (WAT), acibenzolar–*S*–methyl + mancozeb (1 g/L) during 5–12 WAT, tricyclazole + azoxystrobin (1 mL/L) during 13–16 WAT, chlorotalonil (2 g/L) during 17–20 WAT, and mancozeb (6 g/L) during 21–24 WAT.

In this study, 30 light traps, 30 yellow sticky traps, and 30 fruit fly traps were installed per hectare, with one of each type installed in each plot. Solar panel-based light traps were installed one week after transplanting and remained in place until harvest, with the lamp positioned above the canopy. Observations and water changes in the light traps were carried out once a week. Meanwhile, a 20 × 15 cm yellow sticky traps were installed in a tube-like shape encircling a PVC pipe. The yellow sticky traps were set in the field one week after transplanting until harvest, with the height adjusted to the height of the plant canopy. The traps were observed and replaced every two weeks. Fruit fly traps containing methyl eugenol (Ferkop 90 BB; Agritek Tani Indonesia, Indonesia) were installed when the plants started to flower and were left in place until the end of the harvest. One trap was placed 1 m from the outer edge of each plot border to prevent fruit flies (*Bactrocera* sp., Diptera: Tephritidae) from entering the cropland. The traps were observed and replaced once a week to monitor fruit fly populations.

In the second treatment, the crops were grown in a netting house system, and similar control techniques as in open field were used to control crop pests and diseases, except for crops barrier and light traps. The experiment site was located in a vegetable production area, where various vegetables, including chillies, cabbage and shallots, were widely cultivated.

Chilli growth was observed 30, 90, and 180 days after transplanting (DAT). Weekly observations were made on the pest populations and crop damages of 10 randomly selected sample plants per plot, starting from 14 DAT. The intensities of crop damage caused by thrips, armyworm, fruit fly, bacterial wilt (*Ralstonia solanacearum*), and gemini virus (pepper yellow leaf curl virus) infections were then determined (Moekasan & Prabaningrum 2017). The number of moths trapped in the light trap was counted weekly, and the intensity of crop damage due to pest infestation was then determined using the following Equation 1 (Moekasan & Prabaningrum 2017).

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$$P = \frac{\Sigma(n \times v)}{N \times Z} \times 100\% \quad (1)$$

where: P – the percentage of damage level; v – the value of the damage category, n – the number of plants that have the same v value; Z – the highest value of the damage category (which is 9); N – the number of observed plants. The value of v is based on the percentage of leaf area damage, with 0 indicating no damage, 1 indicating 0 ≤ 20% damage, 3 indicating 20 ≤ 40% damage, 5 indicating 40 ≤ 60% damage, 7 indicating 60 ≤ 80% damage, and 9 indicating 80 ≤ 100% damage.

The intensity of plant damage due to fungal disease was determined using Equation 2 (Moekasan & Prabaningrum 2017), as follows:

$$P = \frac{\Sigma(n \times v)}{N \times Z} \times 100\% \quad (2)$$

The category of plant damage value (v) was determined based on the percentage of leaf damage. Specifically, 0 was assigned if there was no damage to the leaf area, 1 was assigned if there was 0 ≤ 10% leaf area damage, 2 was assigned if there was 10 ≤ 20% leaf area damage, 3 was assigned if there was 20 ≤ 40% leaf area damage, 4 was assigned if there was 40 ≤ 60% leaf area damage and 5 was assigned if there was 60 ≤ 100% leaf area damage.

The intensity of plant damage due to bacterial and viral diseases was determined using the following Equation 3 (Moekasan & Prabaningrum 2017).

$$\text{Plant damage intensity (\%)} = \frac{\text{number of infected plants per plot}}{\text{total number of plants per plot}} \times 100\% \quad (3)$$

The number of *S. litura* moths caught in the light traps was also counted weekly. On the day of harvest, the number and weight of marketable fruits, as well as the number and weight of damaged fruits, were recorded. The intensity of damaged fruits caused by anthracnose (*Colletotrichum* sp.), bacterial wilt, fruit fly, and armyworm was determined using Equation 4 (Moekasan & Prabaningrum 2017).

$$\text{Fruit damage intensity (\%)} = \frac{\text{number of infected fruits per plot}}{\text{total number of fruits per plot}} \times 100\% \quad (4)$$

The different effects between treatments were analysed using t-test at 5% significance level. All the expenses and revenues in both cultivation systems were recorded, and the economic feasibilities of the control methods were calculated using benefit-cost ratio analysis (Khan et al. 2017).

RESULTS AND DISCUSSION

The performance of chilli plants grown in the netting house was better than in open field. Similar studies have found that chilli produces higher plant biomass and fruit yield when cultivated in 30% shade, due to the relatively high leaf chlorophyll and photosynthetic activity under the shade (Zhu et al. 2012). Crops cultivated in both systems were attacked by numerous pest species, including thrips, armyworms, and fruit flies. The intensities of crop damage due to thrips attacks during the study tended to increase in line with crop growth (Figure 1). The intensity of crop damage due to this pest is

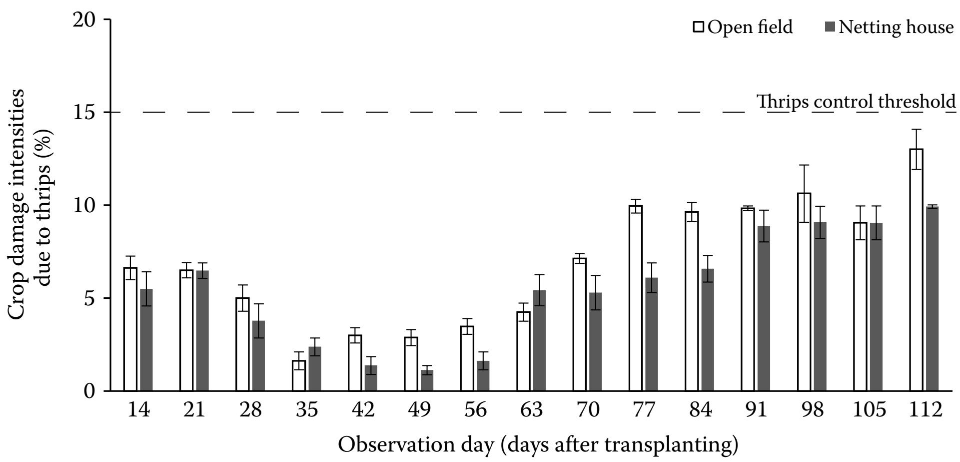

Figure 1. Crop damage intensities due to thrips infestation in open field and netting house

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closely related to host availability and pest population development. The population of thrips is commonly higher in the flowering stage of chilli crops, since they are attracted to the colour of flower plants and the liquid contained in the chilli flower (Merta et al. 2017). There was no insecticide applied to control thrips and armyworms in both open field and netting house since plant damages were below its control threshold (Figure 1). Yellow sticky traps have been found to reduce thrips dispersal, while plastic mulch can prevent pests from pupating in the soil (Haerul et al. 2020; Hossain et al. 2020). There was no insecticide applied to control armyworms since the related crop damage was below its control threshold (less than 12.5%) in the open field, and no armyworms were found inside the netting house (Figure 2). The high number of *S. litura* imago caught in the light traps resulted in a reduced pest infestation on the crops. The use of solar cell based-light traps used in this study is a beneficial tool to be used in areas with limited access to electricity.

The low incidence (less than 5%) of bacterial wilt and gemini virus infections in both open field and netting house systems indicates the effectiveness of using a combination of sweet corn border in open field, netting house usage and thiamethoxam application in preventing the infestation of whiteflies (geminivirus vector) (Mason et al. 2000; Ramazeame et al. 2015). Fruits examination revealed a low percentage of anthracnose, bacterial disease, and fruit fly infestation. The application of acibenzolar-*S*-methyl might be attributed to the low infection of anthracnose disease (Jayapala et al. 2020). Additionally, installing methyl eugenol-based traps outside the corn border effectively reduced fruit fly infestation. The average crop productivity in netting house (20.92 t/ha) was significantly higher than that in open field (9.77 t/ha). The higher production in netting house than in open field could be attributed to the favourable conditions provided by the netting house for crop metabolism (Zivanovic et al. 2017).

Implementing a combination of IPM techniques to protect chilli crops against major pests and diseases that commonly occur in the open field or netting house was technically and economically feasible to increase chilli productivity, although the performance and revenue per cost (R/C) of chilli production in the open field were lower than in protected farming. The implementation of pest control techniques was economically feasible (R/C > 1) in either open field or netting house systems. The R/C of netting house production was higher than that in open field, i.e. 1.60 and 1.25, respectively. Chilli productions were profitable, and the profit of chilli production in the netting house was 3.9 times higher than that in the open field. Similarly, Ilić et al. (2017) reported a higher yield of sweet pepper produced in the netting house compared to that in the open field.

CONCLUSION

The implementation of the improved technologies of IPM in both open field and netting house could protect chilli crops against major pests and diseases, including thrips, armyworms, whitefly, fruit fly, anthracnose and other fungal diseases. The application of insecticide is not needed in both systems, while fungicides should be strategically applied to protect crops from disease infestation.

The economic analysis revealed the high feasibility of implementing the improved IPM technolo-

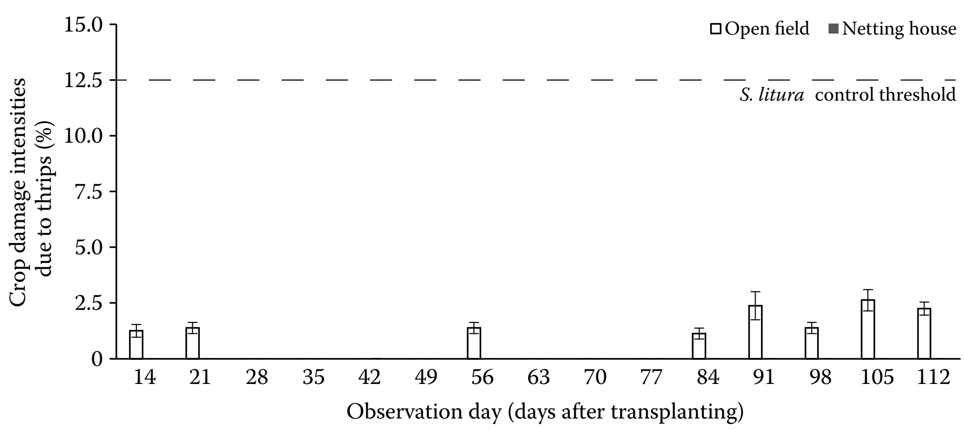

Figure 2. Crop damage intensities due to *Spodoptera litura* infestation in open field and netting house

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gies in open field and netting house systems since the average productivity of chilli grown in both systems was higher than the average national chilli productivity and R/C in both systems was more than 1. This finding is important as chilli is a cash crop and provides a good return to farmers. However, further studies should include further replications to obtain a fruitful conclusion.

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