Effectiveness of nylon exclusion net for preventing chili fruit damage by the oriental fruit fly, *Bactrocera dorsalis* Hendel (Diptera: Tephritidae)

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**Abstract.** Oriental fruit fly (*Bactrocera dorsalis* Hendel) is one of the most damaging insect pests of chili plants causing yield loss up to 90% in Indonesia. Chili growers apply insecticides so heavily that the pest has been reported resistant to insecticides in many places. Safer but more effective alternative control measures must be sought and developed. Therefore, the purpose of this study was to determine the effectiveness of nylon net cage in protecting chili plants from the fruit fly attack. The study was conducted at the Experimental Farm of the Faculty of Agriculture, Hasanuddin University, Makassar, from January to June 2018. This experiment consisted of three treatments: plants caged with nylon net, plants sprayed weekly with insecticide, and unsprayed and uncaged plants (control plants). Treatments were arranged in a complete randomized block design with three replications and each replication consisted of four chili plants. The results showed that the use of nylon net cage provided a total protection, 0% fruit damaged by the fruit fly. In contrast, the plants sprayed with insecticide and control plants suffered fruit damage of 29.1 and 37.5%, respectively. Therefore, nylon net was effective but weekly insecticide spray was not effective in protecting the plants from the fruit fly attack.

1. **Introduction**

Fruit flies are main pests of chili plants which often cause problems for chili producers because they damage the fruits so they are not suitable for consumption. Female adult of fruit flies lays eggs by puncturing their ovipositors into the fruit. After the eggs hatched, the larvae consume the contents of the fruit from inside. The last instar (third instar) of the larvae comes out of the fruit then drops to the surface of the soil and then enters the soil (4-8 cm deep) to pupate [1]. A female fruit fly *B. dorsalis* is capable of producing 1,200 to 1,500 eggs during its lifetime, depending on the size of its host [2]. The damages can result in a 40-60% loss of yield from various plants [3]. Potential damage to chilies by fruit flies can reach 90% [4].

To control the fruit flies, the farmers are mostly dependent on the use of synthetic insecticides. The farmers apply synthetic insecticides in chili plants with a high frequency of up to 3 times a week [5]. Deltamethrin with 1 mL/liter, fipronil with 0.5 mL/liter, and 2.5 mL/liter of abamectin are the recommended rates in China to control the pest [6]. The cultivation practice raises concerns about the potential negative impacts on farmers, consumers, other non-target organisms, and the environment. For this reason, effective and safe control methods for fruit flies are needed, including mechanical control.
One way to control fruit flies mechanically is the use of nylon cages. Using mosquito nets can effectively control the diamondback moth, *Plutella xylostella*, and reduce the damage it causes to cabbage plants [7]. Similarly, *Lipaphis erysimi* populations on cabbage plants were effectively suppressed by using mosquito nets made of nylon [7]. Therefore, this study was conducted to determine the effect of plant confinement in suppressing the intensity of fruit fly attacks on chili plants in comparison to insecticide use.

2. Methodology
The field research was conducted at the Experimental Farm (Exfarm), Faculty of Agriculture, Hasanuddin University, Tamalanrea District, Makassar City, South Sulawesi, Indonesia, from January to June 2018.

2.1. Design and implementation of the experiment
The experiment was arranged in a complete randomized block design with three treatments: nylon cage treatment, confining the plants in a nylon cage; insecticide treatment with the active ingredient of deltamethrin, applied once per 7 days; and control, without the application of insecticide and confinement. Each treatment was replicated three times and each replication consisted of four chili plants cv. Bhaskara Hybrid F1 planted in separate polybags (30 x 40 cm). Three weeks old chili seedlings were transferred to the polybags placed 70 cm apart between rows and 70 cm between plants in a row, so that there were two rows of plants per repetition and each row consists of two plants.

For nylon cage treatment, the cage frame was made of PVC pipe (3/4 inch) with a size of 1.2m x 1m x 1m (length x width x height) and the nylon material used is fine woven nylon with a mesh size of 1.6 mm x 1.6 mm. Plants in the confinement treatment were caged when flowers began to form. The number of plants in a cage is four plants, according to the number of plants per replication in other treatments.

For insecticide treatment, one active ingredient, deltamethrin, was used once a week. The insecticide was used following the recommended dosage of 1 mL/liter of water and was applied in the afternoon at 17.00 using a knapsack sprayer. Spraying was done by spraying the upper and lower surfaces of the leaf, and on the surface of the fruits.

2.2. Observation
Observation of the damage of the fruit flies started when the chili plants begin to form fruits. Observations were made every seven days after the appearance of the first fruit (30 days after transplanting). All plants were observed eight times during the season, by observing all the plants in each replication. The number of fruits damaged by the fruit fly and the total number of fruits in each plant were recorded in each observation. Damaged fruits by fruit flies were indicated by the presence of unique brown-black spots on the surface of the fruit. The spots are the marks of the ovipositor from the fruit flies. In each observation, all damaged fruits were removed from the plants and only healthy fruits were allowed to remain on the plants. In the last observation, the number and weight of the healthy fruits were determined.

The percentage of fruit damaged by the fruit fly was determined using the following equation:

\[
\text{Percentage of damaged fruits} = \frac{\text{Total fruits damaged by fruit flies}}{\text{Total number of fruits}} \times 100\%
\]

The percentage of fruit damage data and the weight of healthy fruit data were analysed using ANOVA and if a significant difference was detected among the treatments, means were separated by Tukey’s test (P ≤ 0.05).
3. Results

3.1. Damaged fruit
The percentage of fruit damaged by fruit flies can be seen in table 1.

**Table 1.** Average percentage of chili fruits damaged *B. dorsalis* for eight observation during the season

| Observation | Nylon Cage | Insecticide | Control |
|-------------|------------|-------------|----------|
| 1           | 0<sup>a</sup> | 4<sup>a</sup> | 39<sup>b</sup> |
| 2           | 0<sup>a</sup> | 28<sup>b</sup> | 50<sup>c</sup> |
| 3           | 0<sup>a</sup> | 32<sup>b</sup> | 50<sup>c</sup> |
| 4           | 0<sup>a</sup> | 25<sup>b</sup> | 32<sup>b</sup> |
| 5           | 0<sup>a</sup> | 45<sup>b</sup> | 35<sup>c</sup> |
| 6           | 0<sup>a</sup> | 32<sup>b</sup> | 37<sup>b</sup> |
| 7           | 0<sup>a</sup> | 34<sup>b</sup> | 27<sup>b</sup> |
| 8           | 0<sup>a</sup> | 33<sup>b</sup> | 30<sup>b</sup> |
| Total       | 0          | 233         | 300      |
| Average     | 0.0<sup>a</sup> | 29.1<sup>b</sup> | 37.5<sup>b</sup> |

Numbers followed by different letters in the same row are significantly different according to the BNJ Test level of 5%

There was a significant difference in the percentage of fruits damaged by the fruit fly amongst treatments (table 1). For the nylon cage treatment, from the first observation to the last observation, no fruits were attacked by fruit flies. During the first three observations more damaged fruits were found on the control plants than on the plants sprayed with insecticide. However, starting from the fourth observation until the end of the season, there was no significant differences between insecticide treatment and control. When the damage data were average across all observations, the insecticide and control treatments showed an average of damaged fruits was 29.1% and 37.5%, respectively; but they were not significantly different.

3.2. Average number of fruit per plant
The number of healthy fruits and damaged fruits from each treatment in the last observation can be seen in table 2.

**Table 2.** The number of healthy fruits, damaged fruits by *B. dorsalis*, and the total number of fruits per plant for the last observation.

| Treatment  | Healthy Fruits | Damaged Fruits | Total |
|------------|----------------|----------------|-------|
| Nylon Cage | 28.7<sup>a</sup> | 0.0<sup>a</sup> | 28.7<sup>a</sup> |
| Insecticide| 19.7<sup>b</sup> | 10.1<sup>b</sup> | 29.8<sup>a</sup> |
| Control    | 21.7<sup>b</sup> | 9.5<sup>b</sup> | 31.2<sup>a</sup> |

Numbers followed by different letters in the same row are significantly different according to the BNJ Test level of 5%

For the last observation, the average number of healthy fruits per plant were 28.7, 19.7, and 21.7 for nylon net, insecticide, and control treatments, respectively. Significantly more healthy fruits were found on the confined plants than the other treatments. While the average numbers of damaged fruits per plant were 0.0, 10.1, and 9.5% for nylon net, insecticide, and control treatments, respectively. There was no
significant difference in the number of healthy fruits or damaged fruits between plants sprayed with insecticide and the control plants. However, the total numbers of fruits produced in all treatments were not significantly different.

For the last observation, the average weight of the healthy fruits per plant can be seen in figure 1. The average weights of healthy fruits per plant were 22.2 g, 15.8 g, and 17.9 g for nylon net, insecticide, and control treatments, respectively. Confined plants produced significantly heavier healthy fruits than the other treatments. The weights of healthy fruits found on plants sprayed with insecticide and control were not significantly different.

![Bar chart showing average weight of healthy fruits per chili plant from the last observation](chart)

**Figure 1.** Average weight (g) of healthy fruit per chili plant from the last observation

4. Discussion

In this experiment, nylon cage used to prevent the entry of fruit flies into the cage so that the fruit can be protected from the pest. The use of the nylon net cage reduced the percentage of damaged fruits by the fruit fly and increased the percentage and weight of healthy fruits. The results are in agreement with the previous report that the use of confinement in chili plants is very useful to avoid and prevent attacks from fruit flies (*Bactrocera cucurbitae*) [8]. In addition, previous reports showed that the use of nylon net could reduce the number of whiteflies and transmission of the tomato yellow leaf curl virus. The net used in our experiment provided total protection to the chili crop [9]. In this experiment, the net was set up when the plants started blooming as suggested by Kalie [10] that confinement should be installed before or after the plants start flowering and before fruiting, because fruit flies attack fruit when the chili fruits are young.

Deltamethrin could only reduce the percentage of fruit fly damage by 8.4% in comparison to the control. The best suppression of the percentage of fruit fly damaged by deltamethrin was 19% [11], which is still far below the net confinement did in this experiment (100%). In general, the use of synthetic pesticides in fruit fly control is not very effective because the insecticide could not reach the larvae that live and develop inside the fruit [12].

During this research, the caged chili plants were not attacked and produced 100% healthy fruits, but the insecticide and control treatments were only able to produce 67% and 70% of healthy fruits, respectively. Thus, the results of this study indicated that the use of the deltamethrin to control fruit fly attacks is ineffective. This encourages farmers to increase the spray rate and spray frequency in order to get satisfactory control. On the other hand, the use of these insecticides in excessive amounts could have an impact on the environment, predators, parasitoids, livestock, and human health. Deltamethrin is a
neurotoxin, which attacks an animal’s nervous system. Skin contact can cause tingling or redness in the applied area. If contact is in the eye or mouth, a common symptom is facial paresthesia, which can feel like many different abnormal sensations, including burning, partial numbness, and needling [13]. Other methods of controlling fruit flies include the use of methyl eugenol is one of the effective and inexpensive ways to reduce fruit fly attacks around 39-59% of fruit yields [14], while our study indicated that the use of confinement is a much more effective way to suppress fruit fly attacks on the fruit yields.

5. Conclusion
The nylon net prevented fruit fly attacks (0% of fruit damage during this experiment), while the plants sprayed with insecticide and the control had 29.1 and 37.5% fruits damaged by the fruit fly, respectively. Plants confined in the nylon net produced more and heavier healthy fruits than the other treatments. Our results suggested that the use of insecticide did not provide sufficient protection that the percent damaged fruit and fruit weight was not significantly different from the control. Before the nylon net is recommended for commercial use, further studies need to be conducted, including its economic feasibility.

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