Determination of control threshold of *Spodoptera litura* on hot pepper

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Abstract. Implementation of control threshold (CT) is one of efforts to suppress insecticides application. The control threshold that has been set for armyworm, *Spodoptera litura* in hot pepper was based on the intensity of plant damage by 12.5%. The implementation of control threshold to control pests needs an adequate skill, so it is still difficult to do at the farmers level. This study aimed to determine the control threshold of *S. litura* based on the catch of moths using sex pheromone traps. The experiment was conducted at Margahayu experimental garden, the Indonesian Vegetable Research Institute (1,250 masl) in Lembang, from February to August 2017. The treatments tested were: (A) CT: 10 moths of *S. litura* caught 5 traps^{-1} week^{-1}, (B) CT: 15 moths of *S. litura* caught 5 traps^{-1} week^{-1}, (C) CT: 25 moths of *S. litura* caught 5 traps^{-1} week^{-1}, (D) CT: plant damage by 12.5%, (E) Routinely spraying of insecticides once a week, and (F) without insecticides were arranged using a randomized block design with four replications. The results showed that: (1) the number of moths caught at sex pheromone trap was positively correlated with the population of *S. litura* larvae in the field (r = 0.59-0.95) and with the plant damage (r = 0.79-0.97), (2) the control threshold based on 25 moths of *S. litura* caught 5 traps^{-1} week^{-1} gave the highest efficiency of insecticide application by 60%, and (3) the control threshold based on 25 moth of *S. litura* caught 5 traps^{-1} week^{-1} could replace the control threshold based on plant damage of 12.5%.

Key Words: *Capsicum annuum* L., armyworm, sex pheromone trap, moth, insecticide application.

Introduction. Pest infestation is one of the problems in the cultivation of hot pepper and one of the main pests is armyworm (*Spodoptera litura*) (Shivaramu & Kulkarni 2008; Bugti et al 2014). The larvae of *S. litura* feed on leaves and fruits resulting in a loss of yield (Calumpang 2013). Yield loss of hot pepper due to *S. litura* and sucking insects was more than 75% (Sarkar et al 2015), whereas in bell pepper was 25.8-100% (Nagal et al 2016). In general, farmers still rely on the use of insecticides to control it. However, Kasymir (2011) reported that pesticide applications that exceeded the recommended level would decrease the yield. The cost of pesticide used in chili cultivation in West Java, Indonesia reached 22.2-25.6% (Adiyoga et al 1999) and in Kediri (East Java) about 21.8% (Utami 2015) of total production costs. As a result hot pepper cultivation becomes less efficient.

One of the actions to reduce the excessive use of pesticides is to apply the control threshold. Control threshold is the level of population or intensity of pest attacks at which control measures should be implemented in order not to cause economic losses. The control threshold indicates the level of pest that can be tolerated or not. With the ability of plants to tolerate the presence of pests, the control needs can be reduced (Higley & Pedigo 1993). The application of control threshold is intended to delay spraying, thus allowing natural enemies to develop. With less spraying, the production costs can be saved (Cameron et al 2001; Ahmed et al 2002; Naranjo et al 2002).

The control threshold that has been determined for *S. litura* on hot pepper was based on plant damage intensity of 12.5% (Moekasan et al 2004; Prabaningrum & Moekasan 2014; Moekasan et al 2015). To implement the control threshold it is required an adequate skills, so it is still difficult to do at the farmers level. Therefore, it is needed an alternative control threshold that is easier to be adopted by the farmers.

Female insects secrete sex pheromones during the mating period to attract the male insects (Eliyahu et al 2003) and male insects find their partners through their sense of smell (Sun et al 2013; Zhang et al 2015). Pheromones are chemicals derived from endocrine glands and used by living creature to recognize the others in the reproductive process (Haryati & Nurawan 2009). Such behavior inspires the making of sex pheromone trap as a tool for catching adult flying insects (Prasannakumar et al 2009; Sun et al 2013). How it works as a trap with a high pheromone content will cover the planting area so that male insects failed to find partners that produce pheromones with a small quantity. Thus marriage can be prevented (Islam 2012).

At this time the sex pheromones have been synthesized and used as a monitoring tool for pest populations in the field and for mass catching of male insects (Dangi et al 2013; Kumar et al 2013; Sun et al 2013; Murua et al 2014). However, the selection of sex pheromones is important because there are indications of differences in insect responses to sex pheromones used in an area or region. As reported by Permana & Rostaman (2006), the sex pheromone for *Ettiella zinckenella* produced in Egypt was ineffective for catching male moths of the same species from East Asia and Southeast Asia including Indonesia.

Suckling et al (2012) stated that sex pheromones have been developed and commercialized as a control tactic in integrated pest management (IPM). Punithavalli et al (2014) reported that the insects caught using the pheromone trap could be used as an indicator of the population of egg masses and larvae of *S. litura.* Therefore, the sex pheromone trap can be used as a reference in implementation of control threshold, because it indicates when the crops have to be sprayed to get an effective control (Zada & Saljogi 2015). Moekasan et al (2013) stated that sex pheromone traps had been used as a reference of insecticide spraying for controlling *S. exigua* on shallot, and it could reduce insecticide use by 35.71%.

Gajendran et al (2006) and Putra et al (2013) evaluated the technology components IPM to control *Helicoverpa armigera* and *S. litura*. One component tested was the use of sex pheromone. The results showed that the treatment with the sex pheromone was able to produce higher yield and higher profits than conventional technology (farmers). The results of Bento et al (2016) indicated that the control threshold based on catch of moth may reduce insecticide volume by up to 50%. In Indonesia, the sex pheromone trap has been made by the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development, Agency for Agricultural Research and Development. However, its use as a reference in controlling *S. litura* on hot pepper has not been widely reported.

This study aimed to determine the control threshold of *S. litura* on hot pepper crop based on moth caught using sex pheromone traps. The hypothesis proposed was the moth caught by the sex pheromone trap could be used as a reference when insecticide spraying could be done for controlling *S. litura* on hot pepper.

Material and Method. The experiment was conducted at the Margahayu experimental garden (1,250 masl), the Indonesian Vegetable Research Institute in Lembang from February to August 2017. The study was prepared using a randomized block design with six treatments and four replications. The treatments tested were:

A. 10 moths of *S. litura* 5 traps^{-1} week^{-1}
B. 15 moths of *S. litura* 5 traps^{-1} week^{-1}
C. 25 moths of *S. litura* 5 traps^{-1} week^{-1}
D. Plant damage by 12.5%
E. Spraying insecticides regularly 1x week^{-1}
F. Check (Without insecticide)

Five sex pheromone capsules in the experimental plot were placed diagonally using water traps (Figure 1). Replacement of sex pheromone capsules was done every 2.5 months. Installation of sex pheromone traps was done when the hot pepper transplanted to the field.

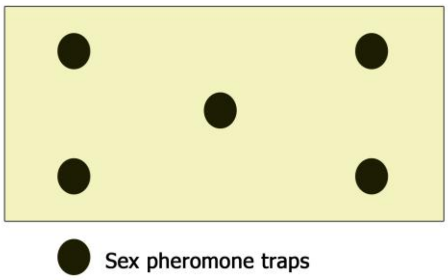

Figure 1. Layout of sex pheromone traps in hot pepper field (left) and the water trap with sex pheromone capsule.

The variety of hot pepper used in the experiment was cv. Pilar, a hybrid variety of hot pepper. Each treatment plot was 10 x 5 m = 50 m^2. The hot pepper plants were planted in a double row system with a planting distance of 50 x 60 cm. Each plot consisted of 160 plants. Prior to planting, manure (horse manure or chicken manure or a mix of horse manure and chicken manure) was applied at a rate of 20 tons ha^{-1} in each bed by broadcasting it. As basic fertilizer, Nitrogen, Phosphorus and Potassium fertilizers were applied at the rate of 110 kg N ha^{-1}, 110 kg P_2O_5 ha^{-1}, and 180 kg K_2O ha^{-1}, respectively.

Observations were made from two weeks after transplanting with a one-week interval. A total of 10 plant samples at each treatment were randomly assigned systematically. The variables observed in the plant sample were:

(1) Population of *S. litura* larvae

(2) Intensity of plant damage due to *S. litura* was assessed by estimating the value (score) of damage in each sample plant, then the intensity was calculated using the following formula (Prabaningrum & Moekasan 2014):

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

Where :

P - Intensity of plant damage (%)

v - The value (score) of damage based on area of leaves attacked on each plant, namely:

0 - No damage at all

1 - Plant damage area > 0 -≤ 20%

3 - Plant damage area > 20 - ≤ 40%

5 - Plant damage area > 40 - ≤ 60%

7 - Plant damage area > 60 - ≤ 80%

9 - Plant damage area > 80%

n - Number of plants having the same v (plant damage) value.

Z - The highest score (v = 5).

N - Number of plants observed.

(3) Intensity of fruit damage due to *S. litura* at harvest time was assessed by counting the amount of fruits infected by *S. litura* marked with hollow fruit due to caterpillar bite and number of healthy fruits per treatment plot; then the intensity was calculated using the following formula (Prabaningrum & Moekasan 2014):

$$P = \frac{a}{a + b} \times 100$$

Where:

P - fruit damage intensity (%)
a - number of healthy fruits per plot
b - number of fruits attacked per plot

(4) The number of insecticide application at each treatment.
(5) The observation of *S. litura* moths caught in the sex pheromone traps was done once a week at the same time as the soap water change. It was done so that the scent of sex pheromone was not disturbed by the smell of carcasses from trapped moths.

If the threshold value of each treatment was achieved, the crops were sprayed with insecticide Emamectin benzoate (0.1 g L^{-1}). The observed data was analyzed by analysis of variance (Anova) and calculated using PKBTStat-01 software. If there was any difference between the treatments, the continue test was conducted by using LSD test at 5% level.

Results and Discussion

The moth caught on the sex pheromone trap. The moth caught on the sex pheromone trap is shown in Figure 2. From the figure it is showed that the first *S. litura* moths caught at 36 days after transplanting and the population increased along with the growth of the plants.

Control threshold of 10 moths 5 $traps^{-1}$ $week^{-1}$ was always reached, therefore the hot pepper plants of this treatment were always sprayed with insecticide every week. Thus until the end of the study, the treatment had been sprayed as many as 15 times, which was similar to the routinely spraying treatment once a week. The application of insecticide at the control threshold treatment of 15 moths 5 $traps^{-1}$ $week^{-1}$ was delayed up to 78 days after transplanting and continued to be sprayed until the end of the observation as many as 9 times. Control threshold of 25 moths 5 $traps^{-1}$ $week^{-1}$ was first achieved at 85 days after transplanting, and then re-achieved at 106 days after transplanting until the end of the observation. Thus the treatment was sprayed as many as 6 times.

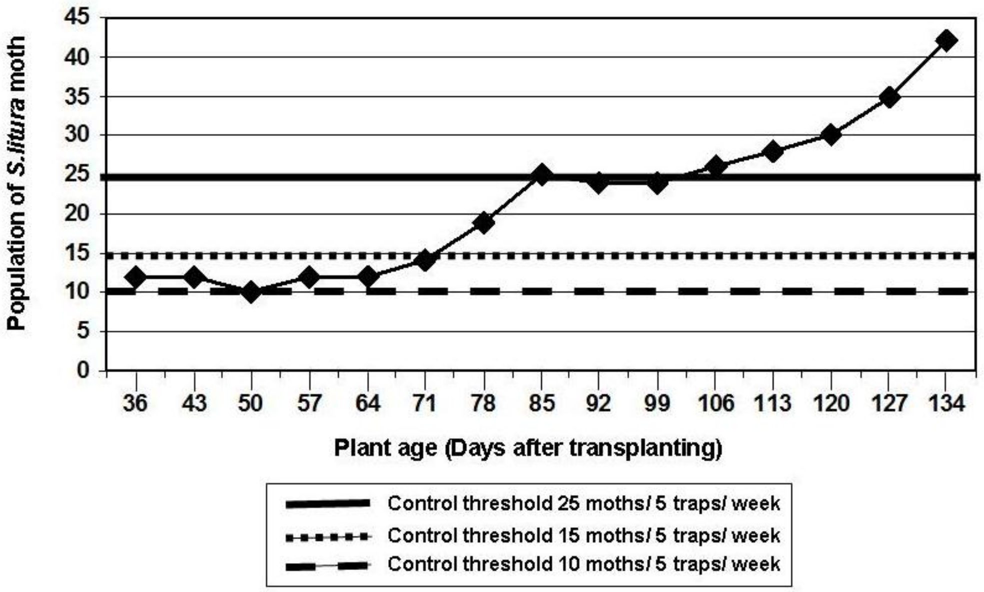

Figure 2. *Spodoptera litura* moths caught on 5 sex pheromone traps.

Population of S. litura larvae. The population of *S. litura* larvae observed in the field at 36 days after transplanting is indicated in Table 1. The increasing number of moths caught was followed by the increasing population of *S. litura* larvae in hot pepper plants. The results showed a significant positive correlation between the number of moths caught with the larval population (r = 0.56-0.95). This condition was in accordance with the results of several researches by Punithavalli et al (2014), Ponnusamy et al (2014) and Babu et al (2017).

The larval population at all treatments tended to increase, despite spraying with emamectin benzoate. However, when compared with the treatment without insecticide, the larval population at other treatments was lower. This indicated that the insecticide was quite effective in suppressing the population of *S. litura* larvae.

From the data in Table 1 it was found that in the control threshold of 15 moths 5 traps^{-1} week^{-1}, 25 moths 5 traps^{-1} week^{-1} and the control threshold based on 12.5% damage, the total larval population was not significantly different. It indicated that the pheromone trap could be used as a monitoring tool for the moth populations for decision making.

Table 1

Population of *Spodoptera litura* larvae

Treatments	*Population of S. litura larvae according to plant age (DAT)*								
	36	*43*	*50*	*57*	*64*	*71*	*78*	*85*	*92*
10 moths of *S. litura* 5 traps^{-1} week^{-1}	0.73^{a}	0.15^{d}	0.33^{ab}	0.60^{ab}	0.48^{bc}	0.50^{b}	1.15^{bc}	1.05^{b}	0.75^{b}
15 moths of *S. litura* 5 traps^{-1} week^{-1}	0.70^{a}	0.63^{ab}	0.65^{ab}	0.73^{ab}	0.58^{ab}	0.75^{ab}	0.98^{bc}	1.30^{b}	0.93^{b}
25 moths of *S. litura* 5 traps^{-1} week^{-1}	0.38^{a}	0.63^{ab}	0.48^{ab}	0.57^{ab}	0.50^{bc}	0.68^{ab}	1.15^{bc}	1.08^{b}	0.98^{b}
Plant damage of 12.5%	0.28^{a}	0.40^{bc}	0.93^{a}	0.85^{a}	0.57^{ab}	0.80^{a}	1.18^{b}	1.13^{b}	0.93^{b}
Routinely spraying insecticide once a week	0.33^{a}	0.20^{cd}	0.25^{b}	0.35^{b}	0.30^{c}	0.55^{b}	0.85^{c}	0.93^{b}	0.68^{b}
Without insecticide	0.48^{a}	0.77^{a}	0.70^{ab}	0.75^{ab}	0.78^{a}	0.80^{a}	2.13^{a}	2.35^{a}	2.68^{a}
LSD 5%	0.84	0.24	0.62	0.47	0.24	0.25	0.31	0.42	0.46
CV (%)	11.98	6.20	8.61	6.43	7.15	8.44	6.58	7.30	6.72

Treatments	*Population of S. litura larvae according to plant age (DAT)*						*Total population of S. litura larvae*	*Correlation with moths caught (r)*
	99	106	113	120	127	134		
10 moths of *S. litura* 5 traps^{-1} week^{-1}	1.38^{b}	1.88^{d}	0.83^{d}	0.88^{d}	0.95^{d}	0.88^{d}	11.50^{c}	0.59
15 moths of *S. litura* 5 traps^{-1} week^{-1}	1.2^{b}	1.55b^{c}	1.35^{bc}	1.50^{bc}	1.53^{bcd}	1.63^{bc}	15.97^{b}	0.94
25 moths of *S. litura* 5 traps^{-1} week^{-1}	1.3^{b}	1.63^{b}	1.70^{b}	1.85^{b}	1.80^{bc}	1.85^{bc}	16.60^{b}	0.93
Plant damage of 12.5%	1.18 ^{b}	1.13^{cd}	1.23^{bcd}	1.38^{bcd}	2.13^{b}	2.03^{b}	16.10^{b}	0.89
Routinely spraying insecticide once a week	1.13^{b}	1.10c^{d}	0.98^{cd}	1.13^{cd}	1.27^{cd}	1.33^{cd}	11.35^{c}	0.93
Without insecticide	3.15^{a}	3.78^{a}	3.88^{a}	4.15^{a}	4.25^{a}	4.30^{a}	34.92^{a}	0.95
LSD 5%	0.42	0.48	0.52	0.58	0.64	0.58	3.42	-
CV (%)	7.67	8.24	9.86	8.74	8.38	9.24	9.79	-

- The data were transformed to $\sqrt{(x + 0.5)}$
- DAT = Days after transplanting
- The average numbers at the same column followed by the same letters were not significantly different at 5% level according to LSD (Least Significant Difference) test.

Intensity of plant damage due to S. litura. The number of moths caught correlated with the population of larvae in plants, also correlated with the intensity of plant damage. The data in Table 2 shows that the intensity of hot pepper damage increased with the increasing number of moths caught in the sex pheromone traps with r values ranging from 0.79 to 0.97. This condition was in accordance with the results reported by Prasannakumar et al (2009), i.e. there was a significant positive correlation (r = 0.82) between moths caught with the percentage of plant damage.

Table 2

Plant damage due to *Spodoptera litura*

Treatments	*Percentage of plant damage due to S. litura according to plant age (DAT)*							
	36	*43*	*50*	*57*	*64*	*71*	*78*	*85*
10 moths of *S. litura* 5 traps^{-1} week^{-1}	4.45^{a}	3.33^{b}	5.83^{b}	8.06^{b}	6.67^{b}	8.34^{b}	11.11^{bc}	13.33^{b}
15 moths of *S. litura* 5 traps^{-1} week^{-1}	5.28^{a}	6.11^{a}	9.45^{ab}	10.00^{abc}	8.34^{b}	9.17^{b}	11.94^{bc}	14.45^{b}
25 moths of *S. litura* 5 traps^{-1} week^{-1}	2.50^{a}	6.95^{b}	7.50^{b}	11.11^{abc}	8.89^{b}	10.56^{b}	13.34^{bc}	15.56^{b}
Plant damage of 12.5%	2.50^{a}	6.67^{b}	13.89^{a*}	12.78^{ab*}	11.11^{ab}	12.78^{ab*}	15.28^{b*}	17.78^{b*}
Routinely spraying insecticide once a week	4.44^{a}	3.61^{b}	6.94^{b}	7.22^{c}	6.11^{b}	7.50^{b}	10.00^{c}	13.33^{b}
Without insecticide	3.89^{a}	13.05^{a}	14.45^{a}	15.00^{a}	15.28^{a}	16.39^{a}	21.67^{a}	25.00^{a}
LSD 5%	5.26	4.16	5.11	5.15	5.52	5.44	4.93	4.99
CV (%)	9.20	6.70	5.06	9.60	9.70	9.43	5.73	9.80

Treatments	*Percentage of plant damage due to S. litura according to plant age (DAT)*							*Correlation with moths caught (r)*
	92	*99*	*106*	*113*	*120*	*127*	*134*	
10 moths of *S. litura* 5 traps^{-1} week^{-1}	10.28^{b}	12.22^{b}	13.89^{bc}	11.67^{bc}	17.23^{bc}	23.89^{cd}	22.78^{bc}	0.94
15 moths of *S. litura* 5 traps^{-1} week^{-1}	10.84^{b}	12.50^{b}	14.17^{b}	12.22^{bc}	18.89^{bc}	26.11^{bc}	25.00^{bc}	0.91
25 moths of *S. litura* 5 traps^{-1} week^{-1}	10.56^{b}	12.50^{b}	13.34^{bc}	14.17^{b}	21.11^{b}	28.34^{b}	26.11^{b}	0.89
Plant damage of 12.5%	11.9^{b}	13.61^{b*}	11.94^{bc}	13.34^{b*}	19.45^{b*}	25.55^{bc*}	24.44^{bc*}	0.79
Routinely spraying insecticide once a week	8.61^{b}	10.00^{b}	9.45^{c}	8.89^{c}	15.28^{c}	21.11^{d}	20.56^{c}	0.90
Without insecticide	27.2^{a}	30.00 ^{a}	31.67^{a}	34.45 ^{a}	42.78^{a}	52.22^{a}	57.23^{a}	0.97
LSD 5%	4.75	4.53	4.53	4.30	3.91	3.78	4.55	-
CV (%)	8.10	9.86	9.08	8.05	8.56	8.50	10.28	-

- * Spraying of insecticide
- The data were transformed to arc.sin $\sqrt{x}$
- DAT = Days after transplanting
- The average numbers at the same column followed by the same letters were not significantly different at 5% level according to LSD (Least Significant Difference) test.

Data at the end of the observation showed that the plant damage in control threshold treatment of 15 moths 5 traps^{-1} week^{-1} and 25 moths 5 traps^{-1} week^{-1} were equivalent to damage in control threshold treatment based on plant damage of 12.5%. Thus the sex pheromone trap can be used as a monitoring tool for moth populations to determine when the application of insecticides has to be implemented.

Efficiency of insecticide spraying and yield. Insecticide spraying in control threshold control treatment of 10 moths 5 traps^{-1} week^{-1} was done from the beginning to the end of the observation because the threshold value was always reached. The number of applications in the treatment was similar to the routinely spraying once a week, which was 15 times. It meant no efficiency of spraying at the treatment. Despite the larval population and the percentage of plant damage at control threshold treatment of 15 moths 5 traps^{-1} week^{-1}, 25 moths 5 traps^{-1} week^{-1} and plant damage of 12.5% were equivalent, but the spraying efficiency was different and the highest efficiency was it at the control threshold of 25 moths 5 traps^{-1} week^{-1}, that was 60%.

Table 3

Number of insecticide applications and yield

Treatments	*Insecticide spraying*		*Yield*	
	Number of applications	*The spraying efficiency compared with routinely spraying (%)*	*Per plot (kg 50 m^{-2})*	*ton ha^{-1}*
10 moths of *S. litura* 5 traps^{-1} week^{-1}	15	0	63.50 a	12.70
15 moths of *S. litura* 5 traps^{-1} week^{-1}	9	40.00	66.20 a	13.24
25 moths of *S. litura* 5 traps^{-1} week^{-1}	6	60.00	62.00 a	12.40
Plant damage of 12.5%	10	33.33	63.33 a	12.67
Routinely spraying insecticide once a week	15	0	61.43 a	12.28
Without insecticide	0	100.00	35.03 b	7.01
LSD 5%	-	-	4.87	-
CV (%)	-	-	8.26	-

- The average numbers at the same column followed by the same letters were not significantly different at 5% level according to LSD (Least Significant Difference) test.

Hot pepper yields at all control thresholds were not significantly different from the results in routinely spraying once a week, and only significantly differed from those without insecticides. This condition it is suggested that the application of control threshold based on moth caught using sex pheromone traps could keep the yield still high.

Some of the advantages of using the sex pheromone trap for monitoring and controlling had been reported by some researchers, that it did not cause pollution, the product did not contain insecticide residues, it was sensitive to detect low populations, it could reduce insecticide use and insecticide costs significantly, and saved labor (Yang et al 2009; Ponnusamy et al 2014; Bento et al 2016; Sarwar 2017). The use of sex pheromone traps as a monitoring tool to determine the insecticide application was also supported by Cruz et al (2012) who had implemented it to control *Spodoptera frugiperda* on corn crops.

Conclusions. Based on the results of research it were concluded that:

1. The number of moths caught in the sex pheromone trap was positively correlated with the population of *S. litura* larvae in the field (r = 0.59 to 0.95) and with hot pepper plant damage (r = 0.79 to 0.97).
2. Implementation of control threshold based on the catch of 25 moths 5 traps^{-1} week^{-1} resulted in the highest insecticide application efficiency of 60%.

3. Control threshold based on the catch of 25 moths 5 traps^{-1} week^{-1} could replace the control threshold based on plant damage of 12.5%.

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