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RESEARCH PAPER

Integrated pest management strategies for controlling *Etiella zinckenella* in peanut cultivation: field evaluation of sustainable approaches

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ABSTRACT

Etiella zinckenella is a significant pest of peanuts in Indonesia, causing pod yield losses of up to 100% in infested fields. This study aims to identify an appropriate strategy for the sustainable management of *E. zinckenella* by validating the effectiveness of various integrated pest management approaches through field trials. The experiment was conducted in two locations, Natar (Lampung) and Muneng (East Java), using 11 treatment combinations with three replications. The peanut variety planted was Gajah (GH 51). The treatments included a range of pest control technologies, such as seed treatment with thiamethoxam, application of carbofuran, neem seed powder (NSP), release of *Trichogrammatoidea bactrae-bactrae*, application of *Spodoptera litura Nuclear Polyhedrosis Virus* (SlNPV), trap crops (Crotalaria, soybean, maize, mung bean), organic fertilizer, and lambda-cyhalothrin. The findings revealed that the population density of pod borers and the extent of pod and seed damage were higher in Natar than in Muneng. In Natar, pod damage ranged from 43.7% to 76.3%, with the highest levels recorded in untreated plots and those treated with lambda-cyhalothrin. Similarly, the highest pest population densities in Natar were observed in untreated plots and those treated with lambda-cyhalothrin. In contrast, Muneng exhibited significantly lower pod damage, ranging from 0.2% to 2.6%, with the highest recorded damage at 2.64%. The most effective pest management strategy in both locations was a combination of thiamethoxam seed treatment, carbofuran, NSP, *T. bactrae-bactrae*, SlNPV, and *Crotalaria* trap crops, which reduced pod damage to 43.7% in Natar and 0.2% in Muneng. These results suggest that an integrated pest management approach effectively mitigates *E. zinckenella* infestations in endemic areas. This method not only minimizes pest damage but also helps maintain populations of natural enemies, including Formicidae, *Coccinella* sp., *Paederus* sp., and *Oxyopes* sp., thereby supporting ecological balance. Furthermore, trap crops such as maize, soybean, and mung bean, when planted around peanut fields, demonstrated considerable efficacy in reducing pest attacks compared relative to chemical insecticides, highlighting their potential for a sustainable pest management strategy.

Key words: Biopesticide, chemical pesticide, *E. zinckenella*, pod borer, peanut

INTRODUCTION

The peanut pod borer (*Etiella* spp.) has become a major threat to peanut production in Indonesia, with infestations increasing since the early 2000s (Baliadi et al., 2008; Prayogo & Bayu, 2020). This pest is a primary cause of yield losses in peanut cultivation, as uncontrolled infestations can lead to up to 100% yield loss (Baliadi et al., 2010). Symptoms of pod borer infestation include empty pods without kernels, kernel decay due to larval feeding, and the presence of *Aspergillus flavus*, a fungal pathogen responsible for aflatoxin contamination. The consumption of aflatoxin-contaminated peanuts poses significant health risks, including carcinogenic effects and acute hepatitis in humans (Smith et al., 1995; Reddy & Raghavender, 2007; Setiarto, 2011; Rajarajan et al., 2013).

The peanut pod borer has caused outbreaks in several peanut production centers across Java and other regions of Indonesia, resulting in significant crop damage. Apriyanto et al. (2009) identified *E. zinckenella* Treitschke as the species responsible for peanut infestations in Bengkulu. However, other studies have reported *E. behrii* as the peanut pod borer species in some cases. Morphologically, these two species are highly similar, making them difficult to distinguish. Kalshoven (1981) observed pod borer species and concluded that *E. zinckenella* was the predominant species affecting peanuts in Indonesia. In contrast, *E. behrii* has been documented as a peanut

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pest in Australia.

Managing the peanut pod borer remains a significant challenge due to the subterranean growth of peanut pods, which limits the effectiveness of conventional treatments. The use of resistant peanut varieties and chemical insecticides has shown limited success in controlling this pest (Yadav et al., 2000). Moreover, the intensive application of chemical insecticides has led to an increase in both pod borer populations and the extent of crop damage. Consequently, implementing an integrated pest management strategy that combines multiple control technologies is essential for effectively suppressing *E. zinckenella* infestations in the field (Tengkano et al., 1995). This study aims to assess and validate the effectiveness of integrated management approaches for controlling *E. zinckenella* in peanut cultivation through field trials, ultimately contributing to the development of a sustainable pest management strategy.

MATERIALS AND METHODS

Research Site. The experiment was conducted from January to April 2021 at two locations: the Natar Experimental Station, Lampung Assessment Institute for Agriculture Technology (AIAT Lampung), Lampung Province (10 meters above sea level [m asl]), and the Muneng Experimental Station, Indonesian Legume and Tuber Crop Research Institute (ILETRI), East Java, Indonesia (600 m asl).

Experimental Design. The experiment followed a randomized block design with three replications. The peanut variety used in the study was Gajah (GH 51). The treatments consisted of 11 combinations of control technologies, including seed treatment, chemical pesticides (carbofuran and lambda-cyhalothrin), botanical pesticides (neem seed powder, NSP), trap crops, biological control agents (*T. bactrae-bactrae* and *Spodoptera litura* Nuclear Polyhedrosis Virus (SlNPV) collected from the laboratory), and organic fertilizer. The organic fertilizer used was goat manure with the following nutrient composition: N= 1.36%, P= 0.27%, K= 0.44%, Ca= 0.57%, and Mg= 0.11% (Table 1).

Planting. A basal fertilizer consisting of 50 kg Urea, 100 kg SP36, and 50 kg KCl per ha was applied along the planting rows immediately after sowing (BP2TP, 2024). The peanut variety GH 51 was planted at a spacing of 40 cm × 10 cm, with one seed per planting hole. Manual weeding was performed manually at 21 and 45 days after planting (DAP). Seed treatment

Table 1. Component of control technology against peanut pod borer

Treatment	Combination of pest control technology							
	Seed treatment	Carbofuran	NSP	*T. bactrae-bactrae*	SlNPV	Trap crop	Organic fertilizer	Lambda cyhalothrin
T0	-	-	-	-	-	-	-	-
T1	+	+	+	+	+	*Crotalaria*	-	-
T2	-	+	+	+	+	Soybean	+	+
T3	-	-	+	+	+	Soybean	+	+
T4	-	-	-	+	+	Maize Soybean Mungbean	+	+
T5	-	-	-	-	+	Maize	+	+
T6	-	-	-	-	-	Soybean Maize Mungbean	+	+
T7	-	-	-	-	-	Maize, Mungbean	+	+
T8	-	-	-	-	-	Mungbean	+	+
T9	-	-	-	-	-	-	+	+
T10	-	-	-	-	-	-	-	+

Seed treatment= thiamethoxam, application before planting; Carbofuran= aplication at planting date; NSP= neem seed powder with application at 35–75 DAP/week; *T. bactrae-bactrae*= application at 35 DAP; SlNPV= *Spodoptera litura* Nuclear Polyhedrosis Virus, application at 35–75 DAP/week; Trap crop= soybean, maize, and mungbean were planted at the same time with peanut; Organic fertilizer= aplication at planting date, Lambda-cyhalothrin= application at 35–75 DAP.

was carried out using thiamethoxam, while carbofuran was applied directly into each planting hole at sowing to protect the crop from bean fly infestations. Neem extract was applied weekly between 35 and 75 DAP (50 g/L of water, spray volume of 500 L/ha). The neem used in this study was derived from dried *Azadirachta indica* seeds, which were ground into a fine powder before application.

Parasitoid. The parasitoid *T. bactrae-bactrae* was initially obtained from the Entomology Laboratory at ILETRI, East Java. It was reared on the eggs of the storage pest *Corcyra cephalonica*, which were attached to *pias* paper measuring 3 cm × 6 cm. A total of 15,000 *T. bactrae-bactrae* individuals per ha were released onto peanut plants at 35 DAP. The parasitoid application involved securing *pias* paper containing *C. cephalonica* eggs parasitized by *T. bactrae-bactrae* to peanut stems for field deployment.

***Spodoptera litura* Nuclear Polyhedrosis Virus (SlNPV)**. *Spodoptera litura* Nuclear Polyhedrosis Virus (SlNPV) was initially obtained from the Virology Laboratory at ILETRI, East Java. To augment the virus, it was first sprayed onto soybean leaves, which were then used as a food source for *S. litura* larvae. Upon consuming the infected leaves, the larvae became infected with the virus and subsequently died. The infected larvae were then homogenized using a mortar, and water was added to create a viral suspension. This suspension, containing entomopathogenic viral particles, was quantified using a hemocytometer to achieve a polyhedral particle density of approximately 15,000/mL. The SlNPV inoculum was applied to peanut plants weekly from 35 to 75 DAP. The spray volume varied according to plant age, with approximately 300 L/ha applied at 35 DAP and 500 L/ha at 75 DAP. The application was conducted twice per week, with a virus density of 10^{10} PIB/mL.

Trap Crops. Trap crops, including soybean, maize, and mung bean, were planted in a single row surrounding the experimental plots simultaneously with peanut planting. Additionally, 2.5 t/ha of organic fertilizer was applied during soil tillage (Armanda et al., 2021). Lambda-cyhalothrin was applied to the peanut crop at the recommended dosage weekly from 35 to 75 DAP. The population of pod borers was recorded after harvest, while populations of other insects, including natural enemies, were monitored from 35 to 75 DAP. Pod damage levels and dry pod weight (yield) were assessed after harvest. The level of pod borer infestation was determined based on the percentage of pods exhibiting external feeding symptoms, such as burrs on the pod surface. To confirm damage, affected pods were peeled to examine the kernels. Pod damage was quantified at harvest by counting the total number of harvested pods, identifying damaged pods, and calculating the percentage of damage

Observation Variables. Observations of insect pests were conducted directly on all parts of the plant. Assessments were carried out weekly for three months, spanning from the vegetative phase at planting to the generative phase at harvest. Data collection included the population of *E. zinckenella* larvae on pods, pest populations on leaves, pod and kernel damage, symptoms of *E. zinckenella* infestation, dry pod weight, and the population of predators and other insect pests. All observed insect species were identified and recorded systematically.

Data Analysis. Data analysis was conducted using SPSS software version 22. Analysis of Variance (ANOVA) was performed to assess differences among treatments, followed by Tukey's test at a 95% confidence level to determine specific treatment effects.

RESULTS AND DISCUSSION

Population of *E. zinckenella* in Peanut. The treatment without any control application (T0) exhibited a high population of peanut pod borers, predominantly consisting of third- and fourth-instar larvae, reaching up to 5.5 individuals per two plants in Natar. This was not significantly different from the plot treated with weekly applications of lambda-cyhalothrin (T10), which recorded 5 individuals per two plants. However, in Muneng, the pod borer population was considerably lower, with only 1.5 individuals per plant in T0 and 1 individual per two plants in T10 (Figure 1).

In Natar, the use of soybeans, maize, and mung bean as trap crops combined with organic fertilizers and lambda-cyhalothrin (T6) still resulted in a relatively high larval population, with an average of 3 individuals per two plants. However, in Muneng, no larvae were found in the T6 treatment. *E. zinckenella* larvae were also observed in treatments T4, T5, T7, T8, and T9 In Natar. In both locations, no larvae were detected in treatments T1, T2, and T3. In Muneng, fourth-instar *E. zinckenella* larvae were found only in T0, T7, and T10, with an average population of 1 to 1.5 individuals per two plants.

In both locations, there was no significant difference in the population of pod borers between the untreated control plot (T0) and the plot treated with weekly applications of lambda-cyhalothrin (T10). This outcome suggests that a single application of lambda-cyhalothrin from 35 to 75 DAP had limited effectiveness against the target pest. This inefficacy was likely due to the larvae residing inside the pods beneath the soil, while the insecticide primarily remained on the soil surface and pod shell. Although lambda-cyhalothrin is systemic and toxic, its limited penetration into the pod reduced its efficacy. Conversely, treatments T1, T2, and T3 were found to be effective in suppressing *E. zinckenella* development, as no larvae were detected inside the pods at either location. This was particularly notable in Natar, which is known as an endemic area for this pest.

In Muneng, the combination of control technology components could not be conclusively deemed effective in suppressing the pod borer population inside the pods. This was likely due to the naturally low population of *E. zinckenella* in the experimental field during the study, resulting in no significant effect of the applied control strategies. Fourth-instar larvae of *E. zinckenella* were only observed in T0, T7, and T10, with an average of 1 to 1.5 individuals per two plants. The low *E. zinckenella* population in Muneng was associated with the abundance of alternative host plants such as soybean, mungbean, and maize surrounding the experimental site. It is presumed that pod borers preferentially infested these alternative hosts rather than groundnut. Hattori & Sato (1983) reported that soybean is a preferred host for *E. zinckenella* development. When primary host plants are readily available in the field, *E. zinckenella* shows a decreased preference for groundnut, even though groundnut remains a potential host.

The control technology components in T1 effectively reduced pod damage caused by *E. zinckenella* by up to 33%. Infestation by *E. zinckenella* resulted in characteristic symptoms, including black spots on the pods, perforated pod surfaces, and damaged kernels (Figure 2). No larvae were found inside the pods, as late-instar larvae typically create small exit holes before moving into the soil to undergo pupation.

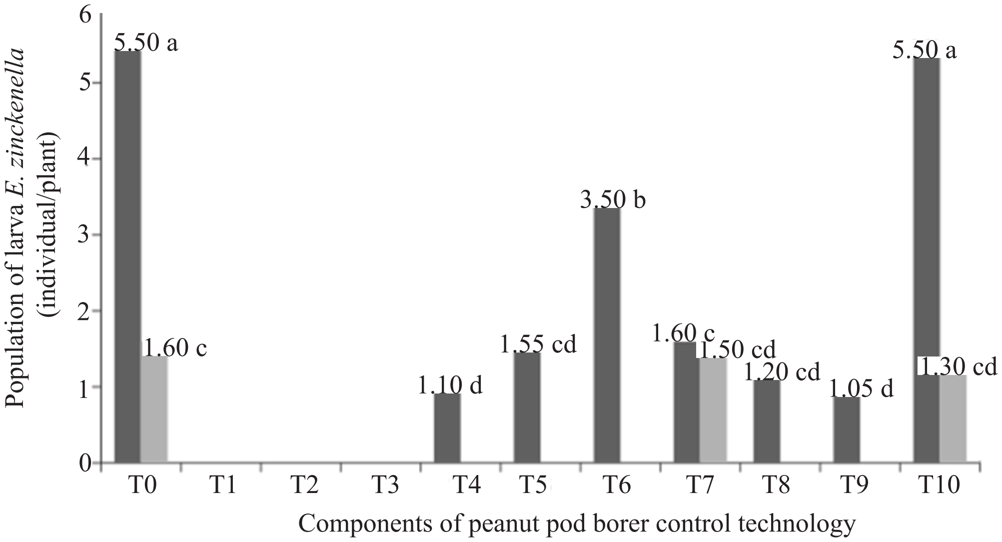

Figure 1. The population of *E. zinckenella* larvae on the pod at physiological maturity stage in Natar (Lampung) and Muneng (Probolinggo).

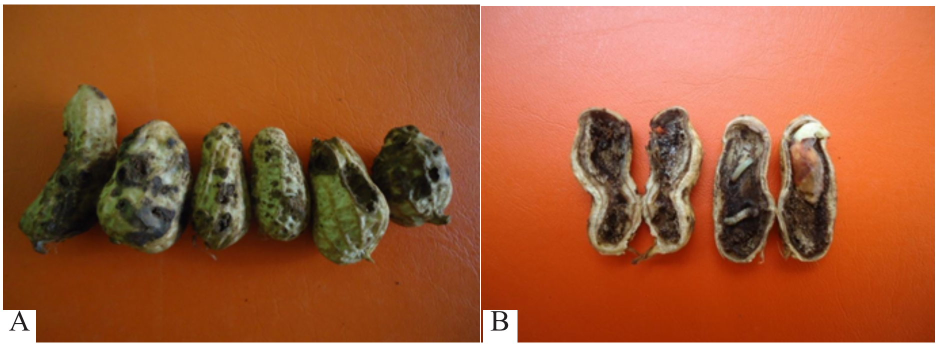

Figure 2. Black spot on the pod caused by *E. zinckenella*. A. Damaged pod and seed peanut; B. Natar, Lampung.

Soybean and mung bean pods growing around the experimental plots may have been more attractive to adult female *E. zinckenella* for oviposition and served as a preferred food source for larvae compared to peanut pods, which develop underground. According to Tengkano et al. (1997) dan Tengkano et al. (2000), the soybean cultivar MLG 3023 was highly preferred by adult females for egg-laying and effectively supported larval development. Additionally, Tohamy & El-Hafes (2005) reported that mung bean, maize, and sunflower were more effective as trap crops for *E. zinckenella* than other plant species. Abdallah (2012) further emphasized that planting trap crops early in the season can significantly reduce *E. zinckenella* infestations.

Pests Population on Peanut Leaves. The observation of pest populations on peanut leaves was conducted three times during the reproductive stage at 42, 49, and 56 DAP. The results identified six pest species present in the peanut field namely *Spodoptera litura, Helicoverpa armigera, Bemisia tabaci, Aphis craccivora, Tetranychus urticae,* and *Frankliniella occidentalis* (Table 2). Among these, *S. litura* primarily damaged peanut leaves, while *H. armigera* attacked peanut flowers and pods.

In Natar, the population of these six species was high, especially in T0, where 9 larvae of *S. litura*, 7 larvae of *H. armigera*, 21 adults of *B. tabaci,* 8 individuals of *A. craccivora*, 11 adults of *T. urticae,* and 6 individuals of *F. occidentalis* were found. The population of *S. litura* and *H. armigera* was low in treatment that used SlNPV, neem, trap crop, and lambda-cyhalothrin (1-3 larvae per plant). Moreover, *H. armigera* was not found in P1, P2, P3, P4, and P5.

The population of *B. tabaci* in Natar was higher than that of others pest. The highest population was found on T10 (22 adults/plant), followed by T0 and T9 (21 adults/plant) and T8 (19 adults/plant). However, the population of *B. tabaci* in T1, T2, and T3 was low, with only 4 adults/plant. In T4, T5, T6, and T7, the population ranged from 9 to 11 adults/plant. In Muneng, the peanut pest population was dominated by *B. tabaci*, with 97-199 individuals per clump (Table 3). Apart of *B. tabaci*, the population of *T. urticae* in Muneng was also high in each treatment. The highest population was found in T0, with 99 individuals per clump (Table 3). However, the lowest population were found in T1 and T4, with was 34 individuals per clump. Population of *S. litura* in Muneng was low. Moreover, *H. armigera* larvae and *A. craccivora* nymphs were not found.

The high population of *B. tabaci* in T8 and T9 was likely due to the use of mung bean as the only trap crop. Mung bean is not a major host plant for *B. tabaci* and was not an effective barrier because its height was similar to that of peanuts. However, the use of maize as trap crop in P1-P7 resulted in a low *B. tabaci* population. According to Inayati & Marwoto (2017), four rows of maize planted around soybean fields effectively prevented *B. tabaci* tinfestations. The high *B. tabaci* population in Muneng was likely due to the dry season and low humidity during the experiment. During the dry season, wind dispersal enhances *B. tabaci* mobility, even in the presence of plant barriers.

This study indicated that SlNPV, neem, trap crop, and lambda-cyhalothrin can suppress the growth and development of these two lepidopteran pests. SlNPV and chemical insecticide were effective in controlling insect pests from the ordo Lepidoptera. In addition, neem

Table 2. Pest population at 42-56 DAP on 11 combination of peanut pod borer control technologies in Natar, Lampung

Treatment	Pest population (individual/plant)					
	S. litura	*H. armigera*	*A. craccivora*	*T. urticae*	*F. occidentalis*	*B. tabaci*
T0	9	7	8	11	6	21
T1	2	0	0	3	1	4
T2	2	0	0	5	1	4
T3	2	0	0	5	2	4
T4	2	0	0	3	1	11
T5	3	0	0	3	4	10
T6	3	2	0	7	3	9
T7	3	2	1	7	3	9
T8	3	2	1	3	5	19
T9	3	2	1	9	4	21
T10	1	2	1	12	4	22

acted as a repellent, preventing adults from attacking the plant, discouraging egg-laying, and reducing the larval consumption rate. According to Marwoto (2007), rokaglamida is a type of repellent produced by the leaf extract of *Aglaia odorata*. Pests are less likely to attack plants treated with this repellent. The leaf extract of *A. odorata* can suppress yield loss caused by Lepidoptera of up to 46%. Neem also produces azadirachtin, a compound that acts as both a repellent and a toxin for insect pest. This botanical insecticide has been shown to suppress the development of *E. zinckenella* (Byrappa et al., 2012).

The pest composition in Muneng was lower, but the population was higher compared to Natar. This phenomenon occurred due to the monoculture system in Muneng, which was limited to soybeans, mung beans, and peanuts. In contrast, in Natar, the variety of cultivated plants was greater, leading to an abundance of both pests and natural enemies. Natural enemies can effectively suppress pest populations. Apart from *B. tabaci*, population of *T. urticae* in Muneng was also high accross all treatment. Based on the population levels of *T. urticae* and *B. tabaci*, it can be assumed that the pest control technology was less effective in suppressing these species. This may be due to the unsuitability of the technology for controlling leaf pests.

In Muneng, the population of *S. litura* was low. Furthermore, no of *H. armigera* larvae or *A. craccivora* nymphs were found. The low pest population in Muneng was attributed to the intensive use of insecticide. Additionally, intensive monitoring and mechanical control, such as the manual removal of *S. litura* and *H. armigera* larvae and eggs, prevented pest establishment. This condition was observed because most of the area in Muneng was used for seed production, necessitating intensive pest control to protect the seeds from pest and disease infestations.

Pod and Seed Damage in Peanut by *E. zinckenella.* The population of *E. zinckenella* was higher in Natar than in Muneng. Pod damage caused by this pest was observed in T0, with 76% in Natar (Tabel 4). However, a lower percentage of pod damaged was observed in T1, at 43%. CThe technological components in T1 reduced pod damage caused by the pod borer by 33%. However, a single application of chemical insecticide (T10) was not effective, as pod damage in the insecticide-treated plot remained high at 72.28%. The lowest intensity of seed damage in Natar was observed in T1 (6.65%). In contrast, the intensity of pod and seed damage in Muneng was 0.18%, significantly lower than in Natar.

Pod and seed damage intensity in Natar was higher than in Muneng. A possible explanation for this phenomenon is that 80% of the fields surrounding the experimental site in Muneng were planted with soybeans, coinciding with the experiment. The abundance of soybeans in the area likely caused the pod borer to prefer attacking soybean pods over peanut pods. Despite the lower population of pod borers across treatments, the control technology applied in Muneng was not highly effective. In Natar, most of the fields were dominated by cassava, which is not a known host plant for the pod borer. Without its preferred host plant, the pod borer inflicted more damage on peanuts.

Dry Pod Weight Peanuts. In Natar, the highest dry pod weight was observed in T1, reaching 13 g/plant, although this was not significantly different from T6

Table 3. Pest population peanut on 42–56 days after planting in Muneng

Treatment	Population (individual)					
	S. litura	*H. armigera*	*A. craccivora*	*T. urticae*	*F. occidentalis*	*B. tabaci*
T0	2	1	0	99	7	119
T1	0	0	0	34	1	99
T2	0	0	0	65	3	110
T3	0	0	0	58	2	101
T4	0	0	0	34	3	97
T5	0	0	0	57	0	114
T6	0	0	0	71	0	110
T7	1	0	0	70	0	105
T8	1	0	0	39	0	111
T9	1	0	0	49	0	119
T10	1	0	0	62	14	112

(12.68 g/plant). The dry pod weight in T9, T3, and T2 was also relatively high, ranging from 11.18 to 11.69 g/plant, compared to synthetic pesticide application (T10). Conversely, the lowest dry pod weight was recorded in T0 (8.85 g/plant), which was not significantly different from T10, where insecticides were applied. In Muneng, dry pod weight ranged from 23 to 30 g/plant (Figure 3). The highest dry pod weight was recorded in T1 (30 g/plant), while the lowest was observed in T0 (23 g/plant).

The lower dry pod weight in Natar compared to Muneng was attributed to the high intensity of pod damage, characterized by black spots on the pod surface. Severe damage resulted in empty pods, kernel decay, and subsequent colonization by *Aspergillus* sp. These findings suggest that the integrated management approach—including seed treatment with thiamethoxam, soil application of carbofuran, neem application at 35–70 DAP, *T. bactrae-bactrae* at 35 DAP, SlNPV at 35–70 DAP, the use of soybean, maize, and mung beans as trap crops, organic fertilizer application, and lambda-cyhalothrin at 35–70 DAP (as implemented in T1)—resulted in higher pod weight compared to other treatments in both locations.

Predator Population. Predator populations in both locations were dominated by *Coccinella* sp., *Oxyopes* sp., and Formicidae, with higher abundances in

Table 4. Pod and seed peanut damaged by *E. zinckenella* in Natar, Lampung and Muneng

Treatment	Damaged intensity (%)*			
	Natar (Lampung)		Muneng (Probolinggo)	
	Pod	Kernel	Pod	Kernel
T0	76.33 a	21.62 a	2.21 ab	2.43 a
T1	43.71 c	6.65 b	0.19 c	0.18 d
T2	45.42 c	9.67 ab	1.72 ab	1.66 abc
T3	49.42 bc	10.43 ab	1.29 b	1.24 c
T4	53.11 abc	13.64 ab	2.32 ab	1.48 c
T5	59.67 abc	11.39 ab	2.64 a	1.50 bc
T6	60.00 abc	12.42 ab	2.07 ab	1.39 c
T7	64.95 abc	17.20 ab	1.91 ab	1.73 abc
T8	65.16 abc	19.39 a	1.75 ab	1.16 c
T9	68.60 abc	14.09 ab	1.94 ab	1.65 abc
T10	72.28 ab	11.58 ab	2.22 ab	2.27 ab

*Number with the same letters in the same coloumn are not significantly different (LSD test, $p<0.05$).

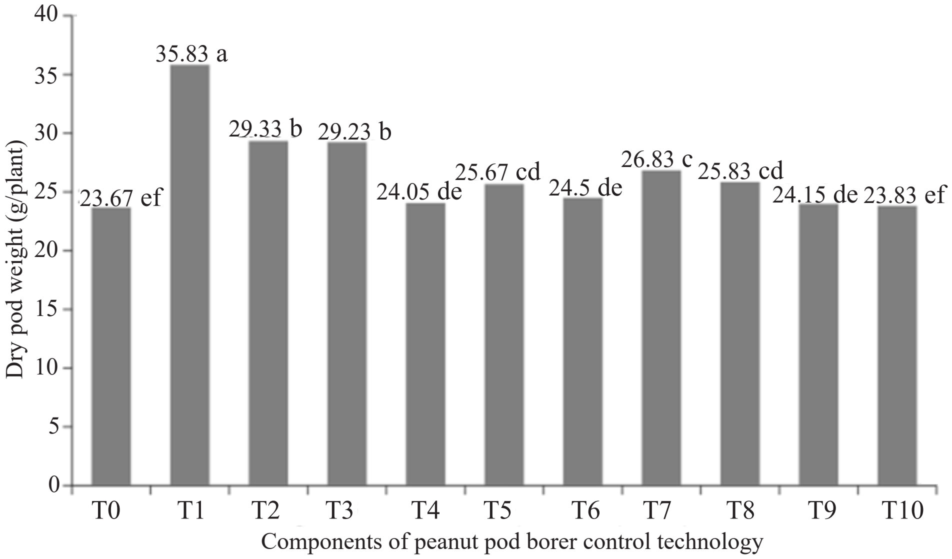

Figure 3. Dry pod weight attacked by *E. zinckenella* larvae (Muneng, Probolinggo).

Muneng than in Natar (Table 5–10). Predator numbers peaked between 49 and 63 DAP, corresponding to increased prey availability, while the lowest populations were recorded at 35 DAP. Among these predators, Formicidae were the most abundant, particularly in Muneng, where their population reached 15 individuals per plant in P0 and 12 individuals per plant in P1. However, the application of chemical insecticides (T10) led to a decline in predator populations, whereas biological control methods facilitated predator survival and effectively reduced peanut pod borer infestations.

The high abundance of Formicidae in Muneng was likely due to the prevalence of *Bemisia tabaci* and *Empoasca* sp., which serve as primary prey. Previous studies have shown a positive correlation between predator and prey populations (Hubert, 1993; Sakata, 1995), with Formicidae exhibiting strong predation on Hemipteran pests (Coppler et al., 2007; Masuko, 2009) and being particularly effective in aphid management (Hubert, 1993).

In contrast, *Coccinella* sp. and *Oxyopes* sp. populations were relatively low across both locations and were absent in T0, likely due to prey preferences (Riaz et al., 2014; Greenstone et al., 2014). *Oxyopes javanus* has been reported to prefer *S. litura* larvae and *Riptortus linearis* nymphs, with predation rates reaching 12 individuals/day (Tengkano et al., 2007). However, in this study, the populations of *S. litura* and *R. linearis* were lower than those of *Empoasca* sp. and *B. tabac*i, potentially explaining the limited presence of *Oxyopes* sp.

The lower abundance of *Coccinella* sp. and *Oxyopes* sp. was also attributed to their susceptibility to chemical insecticides, particularly thiamethoxam (Swaran, 1999; Meena & Dadhich, 2002; Solangi et al., 2007). The reliance on insecticides for pest control negatively impacts natural enemy populations, potentially leading to pest outbreaks, pesticide residues, and environmental pollution (Satpute et al., 2002; Agarwal et al., 2010).

This study highlights the effectiveness of integrated crop management in reducing peanut pod borer infestations while preserving natural enemies, particularly soil- and canopy-dwelling predators. A combination of control methods—including seed treatment with thiamethoxam, carbofuran application, *T. bactrae-bactrae,* SlNPV, trap crops (corn, soybean, mung bean), organic fertilizers, and lambda-cyhalothrin —proved more effective in suppressing *E. zinckenella* in endemic areas while maintaining natural enemy populations, including Formicidae, *Coccinella* sp., *Paederus* sp., and *Oxyopes* sp. (Larsen et al., 2001). Furthermore, trap crops demonstrated superior pest suppression compared to chemical insecticides, underscoring their role in sustainable pest management.

CONCLUSION

The integrated pest management strategy for *E zinckenella,* which includes seed treatment with thiamethoxam, carbofuran application, neem seed powder (NSP), release of *T. bactrae-bactrae*, application of *Spodoptera litura* Nuclear Polyhedrosis Virus (SlNPV), trap cropping (corn, soybean, mung bean), organic fertilization, and lambda-cyhalothrin insecticide, effectively suppressed *E. zinckenella* infestations in endemic areas. This approach not only reduced pest damage but also supported the survival

Table 5. Impact of the application of various components of pod borer control technology to the *Coccinella* sp. in Natar

Treatment	Population of *Coccinella* sp. at DAP (Individual/plant)					
	35	42	49	56	63	70
T0	0	0	2	2	1	1
T1	1	1	1	1	2	1
T2	2	0	2	1	1	0
T3	0	0	0	0	2	0
T4	2	1	2	1	0	2
T5	2	0	2	1	2	0
T6	2	1	2	1	1	2
T7	0	1	0	0	1	1
T8	1	0	1	2	1	1
T9	1	0	1	1	1	2
T10	0	0	0	0	0	0

Table 6. Impact of the application of various components of pod borer control technology to the *Coccinella* sp. in Muneng (East Java)

Treatment	Population of *Coccinella* sp. at DAP (Individual/plant)					
	35	42	49	56	63	70
T0	0	1	2	1	2	1
T1	0	1	0	2	2	2
T2	0	0	1	0	2	2
T3	0	0	0	2	0	1
T4	0	0	1	1	1	3
T5	0	1	1	3	2	2
T6	1	2	0	1	1	2
T7	0	1	0	3	2	2
T8	0	1	2	1	2	1
T9	0	2	0	1	3	0
T10	0	0	0	1	0	0

Table 7. Impact of the application of various components of pod borer control technology to the *Formicidae* in Natar (South Sumatra)

Treatment	Population of Formicidae at DAP (Individual/plant)					
	35	42	49	56	63	70
T0	1	0	5	6	4	4
T1	1	1	3	4	2	1
T2	0	0	3	2	1	1
T3	0	0	2	2	2	2
T4	0	0	1	1	1	1
T5	0	0	0	0	0	2
T6	1	1	0	0	2	2
T7	0	0	1	1	1	1
T8	0	0	1	1	0	2
T9	0	0	0	0	0	0
T10	0	0	0	0	0	0

Table 8. Impact of the application of various components of pod borer control technology to the *Formicidae* in Muneng

Treatment	Population of Formicidae at DAP (Individual/plant)					
	35	42	49	56	63	70
T0	0	3	6	8	11	15
T1	0	5	7	6	10	12
T2	0	4	3	4	9	9
T3	0	7	4	7	10	9
T4	0	1	5	8	9	6
T5	1	0	4	4	7	7
T6	0	0	0	3	6	2
T7	0	0	0	2	5	9
T8	0	0	6	3	7	10
T9	2	0	5	7	7	8
T10	0	1	2	2	1	1

Table 9. Impact of the application of various components of pod borer control technology to the abundance of *Oxyopes* sp. (Natar, Lampung)

Treatment	*Oxyopes* sp. population at DAP (individual)					
	35	42	49	56	63	70
T0	1	2	2	1	2	1
T1	0	0	2	2	2	2
T2	0	0	0	2	1	1
T3	0	0	0	1	1	1
T4	0	0	0	1	0	0
T5	0	0	0	0	0	0
T6	0	0	0	0	0	0
T7	0	0	0	1	0	0
T8	0	0	0	0	0	0
T9	0	0	0	0	0	0
T10	0	0	0	0	0	0

Table 10. Impact of the application of various components of pod borer control technology to the abundance of *Oxyopes* sp. (Muneng, Probolinggo)

Treatment	*Oxyopes* sp. population at DAP (individual)					
	35	42	49	56	63	70
T0	0	0	1	1	1	1
T1	0	0	1	0	1	1
T2	0	0	0	0	0	0
T3	0	0	0	1	0	0
T4	0	0	0	0	0	0
T5	0	0	1	0	0	1
T6	0	0	0	0	0	0
T7	0	0	0	0	0	0
T8	0	0	0	0	0	0
T9	0	0	0	0	0	0
T10	0	0	0	0	0	0

of natural enemies such as Formicidae, *Coccinella* sp., *Paederus* sp., and *Oxyopes* sp., thereby promoting ecological balance. Moreover, the use of trap crops around peanut fields significantly reduced pest attacks compared to chemical insecticides, highlighting their potential as a sustainable pest management strategy.

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AUTHORS' CONTRIBUTIONS

YP and SG contributed to the research concept and design, manuscript writing, and final approval of the article. MS and YIB conducted data analysis and interpretation. SWI and YB were responsible for data collection and compilation. DH carried out the morphological identification of insects and critically revised the article. All authors read and approved the final manuscript.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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