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# Insect Diversity Study on Shallot Plants: Comparison of Ecological Engineering and Conventional Cultivation Systems

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#### **ABSTRACT**

This study examines the cultivation of shallots using an ecological engineering approach to enhance insect diversity and natural pest control. The applied methods include compost application, refugia planting, and the use of biological agents to reduce synthetic pesticide dependence. The study compares two management systems: ecological engineering farmland (EF) and conventional farmland (CF), with insect data collected using various trapping methods. The results show that EF had a higher insect population (23,428 individuals) compared to CF (14,880 individuals). A total of 181 morphospecies from 10 orders, 85 families, and 170 genera were identified, with Coleoptera being the dominant order and predatory insects prevailing in both farmlands. The diversity index was higher in EF (3.079) than in CF (2.725). The evenness index was also higher in EF (0.608-0.624) than in CF (0.561-0.603), indicating a more stable ecosystem. The dominance index was low in both farmlands (0.003–0.188), showing no single species significantly dominated. The community similarity index was relatively high at 0.666 (vegetative), 0.651 (generative), and 0.712 (one growing season). Although the t-test showed no significant differences, EF tends supports more sustainable shallot farming by enhancing biodiversity and ecosystem stability. Further research is needed to evaluate long-term impacts and the implementation of polyculture systems to strengthen agricultural ecosystems.

## 1. INTRODUCTION

Shallots (*Allium ascalonicum* L.) have an important role in agriculture, both as a source of income for farmers and because of their bioactive content which is beneficial for health (Badan Litbang Pertanian, 2006). According to data from the Center for Agricultural Data and Information Systems (2023), East Java is the second largest center for shallot production in Indonesia, reaching 24.86%. Nganjuk Regency is the main producer producing more than 1,800 tons in 2023 (Badan Pusat Statistik, 2024).

One of the main challenges in shallot cultivation is pest attacks, such as onion caterpillars (*Spodoptera exigua*), thrips (*Thrips tabaci*), leaf miners (*Liriomyza phaseoli*), armyworms (*Spodoptera litura*), and aphids (*Aphis* sp.), which attack hundreds of hectares of land in East Java (UPT Proteksi Tanaman Pangan dan Hortikultura, 2024). Excessive use of synthetic chemical pesticides can have negative impacts on the environment and human health, including excessive residues in soil and tubers (Fatkhurrahman *et al.*, 2020; Nelly *et al.*, 2015).

Ecological engineering is a sustainable solution in managing shallot pests by implementing Healthy Plant Management or *Manajemen Tanaman Sehat* (MTS). This approach includes biological control through the use of natural enemies and modification of the microenvironment, such as soil conservation with organic matter, planting refugia, and using biological agents. By increasing biodiversity, this approach is expected to balance the agro-ecosystem, reduce

dependence on synthetic pesticides, and support sustainable cultivation and farmer welfare. This study aims to determine the effect of cultivation with different approaches on shallots on insect diversity.

#### 2. RESEARCH MATERIALS AND METHODS

#### 2.1. Time and Location of the Research

This research began with the collection of insects in two shallot fields under ecological engineering farmland (EF) and conventional farmland (CF) methods, both in Sukorejo Village, Rejoso District, Nganjuk Regency which was carried out in June – August 2024. Nganjuk Regency is one of the national centers for shallot production. Rejoso District was chosen as the research location because it is the largest shallot producer in Nganjuk Regency. The process of sorting and identifying insects was carried out at the Laboratory of the UPT Food Crop Pests and Horticulture Protection of East Java Province.

#### 2.2. Tools and Materials

The tools used in this study included light traps, pit fall traps, yellow traps, camera, microscope, collection bottles, magnifying glasses, insect collection equipment, stationery, and laptop. The materials used in this study included soapy water and 4% formalin.

## 2.3. Addition of Soil Organic Material

Land preparation was carried out before planting shallots by spreading compost containing *Trichoderma* sp. and *Metarhizium* sp. (10-20 tons/ha) on the ridges 25 days before planting to increase biodiversity and soil fertility. If the soil pH is  $\leq$  4.5, dolomite (2-3 tons/ha) was applied 15 days before planting. Macro fertilizers are given three days before planting, namely SP36 and Phonska, each 100 kg/ha. After planting, NPK fertilizers (100 kg/ha) and urea (50 kg/ha) were applied at 15 DAP, and NPK (100 kg/ha) and KCl (50 kg/ha) at 35 DAP. Shallots were planted with a distance of 15x15 cm.

### 2.4. Refugia Planting

For ecological engineering farmland (EF), several refugia seeds were sown 45 days before planting so that they are ready to become a habitat for natural enemies before the shallots grow or pests arrive. The types of refugia used included cosmos plant (*Cosmos sulphureus*), bougainvillea (*Zinnia elegans*), sunflowers (*Helianthus annus*), tomatoes (*Solanum lycopersicum*), and basil (*Ocimum basilicum*). Refugia were planted in rows in the middle of the planting to attract beneficial insects and create a more stable ecosystem.

# 2.5. Utilization of Biological Agents

For ecological engineering farmland (EF), biological agents were also applied before planting by mixing *Trichoderma* sp. and *Metarhizium* sp. into the compost. Three weeks before planting, PGPR (Plant Growth-Promoting Rhizobacteria) (15 L), *Trichoderma* sp. (15 L), and local microorganisms (50 L) were sprayed to increase soil biodiversity. *Pseudomonas fluorescens* was also sprayed (300 L/ha) two days before planting to reduce weed germination, increase biodiversity, and suppress the risk of disease. After planting, PGPR, liquid organic fertilizer, and biological control agents were sprayed twice a week since 4 DAP (day after planting), 4 L each, to increase biodiversity and provide nutrients. Spraying was done in the afternoon to maintain the continuity of microorganisms.

#### 2.6. Conventional Cultivation of Shallots

For comparison, shallot cultivation under conventional farmland (CF) system was also observed in Sukorejo Village, Rejoso District, Nganjuk Regency, adjacent to the ecological engineering land (EF). In general, the methods of soil preparation, fertilization, irrigation, and pest control were similar to that of ecological engineering farmland (EF), but without the application of organic materials such as compost. Fertilization used NPK (300 kg/ha), Urea (100 kg/ha), ZA (100 kg/ha), SP36 (100 kg/ha), and KCl (50 kg/ha). Control for plant disturbing organisms or OPT (*Organisme* 

*Pengganggu Tanaman*) was carried out routinely with synthetic chemical pesticides such as Cimegra, Arjuna, Rhizotin, Biozep, Antracol, Metindi, Rhemazol, and Besmor, as well as pre- and post-emergence herbicides as much as 2–16 bottles for about 0.20 ha per planting season.

## 2.3. Insect Collection Process

In both shallot planting methods, land agroecosystem engineering (EF) and conventional land (CF), 5 study plots were selected with an area of about 0.1 ha. Each study plot was equipped with one unit of light trap, four units of pitfall trap, and four units of yellow sticky trap arranged diagonally. The placement of the traps is shown in Figure 1. The caught insects were collected every 5 days.

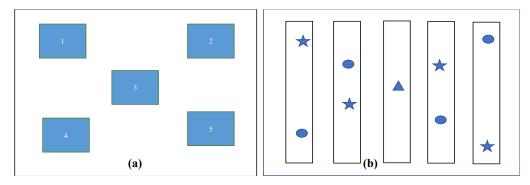


Figure 1. (a) Lay out of observation plots for shallot planting study, and (b) arrangement of insect traps in each plot. [ ( light trap, ( ) pitfall trap, ( ) yellow sticky trap]

#### 2.5.1. Light Trap

Light trap was installed in each plot at the center. The light was powered by a solar panel. The caught insects were fallen into a bucket or basin under the solar cell that has been filled with soapy water and formalin. The trap was installed using wood frame at a height of  $\pm 60$  cm from the ground.

#### 2.5.2. Pitfall Trap

The pitfall trap was made from a clear water bottle of  $\pm 1500$  ml. The bottle was cut to almost a third then filled with soapy water and formalin and inserted into the ground. Four traps were installed in each area and provided with shade to protect the traps from rain water.

## 2.5.3. Yellow Sticky Trap

This trap is made of yellow paper measuring  $\pm 20$  cm x 25 cm which has been coated with insect adhesive glue. Traps were installed using wood at a height of  $\pm 50$  cm from the ground.

## 2.4. Morphological Identification and Data Analysis

The insects collected were then identified to the family level using an insect identification book (Borror *et al.*, 1992) and the website https://bugguide.net (Yunus *et al.*, 2022).

# 2.6.1. Diversity Index

The diversity of insect pests and natural enemies in shallots was measured using the Shannon-Wienner diversity index (H'). To calculate the Shannon-Wienner index (H'), the formula used (Hill et al., 2005 in Wijayanto et al., 2022):

$$H' = -\sum_{i=1}^{S} p_i \cdot \ln(p_i) \tag{1}$$

where H' is diversity index,  $p_i$  is number of individuals of each species, and S is total number of all individuals or species. The criteria for the diversity index (H') were as follows: H' > 3 (high diversity); 1 < H' < 3 (medium diversity), and H' < 1 (low diversity).

## 2.6.2. Uniformity Index

The uniformity of insect pests and natural enemies on shallots is measured using the uniformity index (*E*). The Uniformity index was calculated using the following formula (Krebs, 1989 in Reksiana *et al.*, 2023):

$$E = \frac{H'}{\ln S} \tag{2}$$

According to Krebs (1985), the uniformity index value ranges from 0 (zero) to 1 (one). The uniformity index value is categorized as follows:  $0 < E \le 0.5$  is low uniformity stressed community;  $0.5 < E \le 0.75$  is medium uniformity unstable community; and  $0.75 < E \le 1$  is high uniformity stable community

#### 2.6.3. Dominance Index

The dominance of insect pests and natural enemies in shallots was measured using the Simpson Dominance Index (*D*). This index was calculated using the following equation (Krebs, 1989; Reksiana *et al.*, 2023):

$$D = \sum_{i=1}^{S} p_i^2 \tag{3}$$

where  $p_i$  is proportion of individual of species  $i^{th}$  over the total number of individuals.

The Simpson Dominance Index ranges from 0 to 1, which means that if the index value is close to 0, it means that there is no dominant species in the ecosystem, so it can be said that the ecosystem is stable. On the other hand, if it is close to 1, it means that there are dominant species in the ecosystem, so that the ecosystem is unstable and there is even stress or pressure in the ecosystem. According to Odum (1996), the criteria for Dominance Index is as follows:  $0 < D \le 0.5$  mean no dominant species, and  $0.5 < D \le 1$  indicate there is a dominant species

## 2.6.4. Community Similarity Index

The similarity of insect pests and natural enemies in shallots was measured using community similarity from Bray Curtis or Bray Curtis Index (*IBC*), calculated using the following formula (Krebs, 1989; Reksiana *et al.*, 2023):

$$IBC = 1 - \frac{\sum |x_i - y_i|}{\sum (x_i + y_i)} \tag{4}$$

where  $x_i$  is number of individuals of species  $i^{th}$  at the first location,  $y_i$  is number of individuals of species  $i^{th}$  at the second location,  $\sum |x_i - y_i|$  is sum of absolute values of differences in individuals between species at two locations, and  $\sum (x_i + y_i)$  is total number of individuals of all species at both locations

The Bray-Curtis index criterion for community similarity is a value that ranges between 0 and 1. A value of 0 indicates perfect community similarity, while a value of 1 indicates perfect community difference.

## 2.6.5. Comparative Population Analysis

The *t*-test was then used to compare insect populations between conventional land (CF) and land with ecological engineering (EF). Data analysis was carried out using R studio.

## 3. RESULTS AND DISCUSSION

## 3.1. Insect Diversity in Shallot farmlands

Shallot plants have 2 growth phases, namely the vegetative and generative phases. The vegetative phase in shallot plants begins at the age of 11-35 days after planting, while the generative phase begins at the age of 36 days after planting until harvest, which is around 56 days after planting. In this phase, there is also a phase of bulb formation and bulb maturation (Hirsyad, 2019).

## 3.1.1. Insect Composition in Both Types of farmlands

In land with ecological engineering (EF), there were 10 types of insect orders were found, including insects from the orders *Coleoptera*, *Dermaptera*, *Diptera*, *Embioptera*, *Hemiptera*, *Hymenoptera*, *Lepidoptera*, *Odonata*, *Orthoptera*, and *Thysanoptera*. Meanwhile, on land conventional (CF), 8 types of insect orders were found, including insects from the orders *Coleoptera*, *Dermaptera*, *Diptera*, *Hemiptera*, *Hymenoptera*, *Lepidoptera*, *Orthoptera*, and *Thysanoptera*. Figure 2 details the population and composition of each insect family.

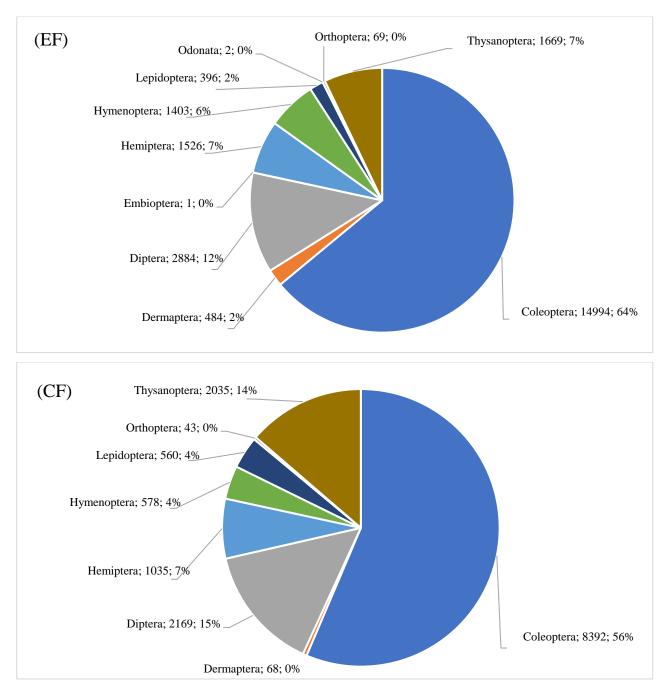


Figure 2. Insect population and composition (family) found in two different shallot lands: (a) Ecological engineering farmland (EF), (b) Convectional farmland (CF)

It can be seen that the largest order obtained, in land A is insects from the Coleoptera order, namely 14,994 or around 64.00% of the total number of insects collected, namely 23,428. Likewise in farmland B, insects from the Coleoptera order were the most obtained, amounting to 8,392 or around 56% of the total number of insects observed. The Coleoptera order dominates in both lands even though the population number in farmland A is quite different compared to farmland B. In a study conducted by Rahayu *et al.* (2017), insects from the Coleoptera order, for example Carabidae, can be found in early succession or open land. Coleoptera can also thrive in environments with closed canopies. In addition, Coleoptera has an important role in the ecosystem as a plant eater (herbivore), predator, scavenger, and decomposer. So it is not surprising if in a land or ecosystem it is dominated by Coleoptera.

#### 3.2. Status and Role of Insects in the Shallot Ecosystem

Insects play an important role in the ecosystem, including as herbivores, predators, parasitoids, pollinators, Decomposers, and neutral insects. Herbivorous insects eat plants and can become pests if they are economically detrimental (Arifan *et al.*, 2021). In the shallot ecosystem, 7 orders, 26 families, and 49 morphospecies of Herbivorous insects were found, with *Thrips tabaci* (Thysanoptera: Thripidae) as the most numerous species.

Predatory insects act as natural enemies of pests and help reduce the use of synthetic pesticides (Idris *et al.*, 2023). 7 orders, 25 families, and 74 morphospecies were found, with *Atheta* sp. (Coleoptera: Staphylinidae) as the most numerous species. Parasitoid insects obtain food by parasitizing the bodies of other insects (Dumalang *et al.*, 2024). In the shallot ecosystem, 2 orders, 15 families, and 23 morphospecies were found, with *Scelio* sp. (Hymenoptera: Scelionidae) dominant in ecologically engineered land and *Argyrophylax* sp. (Diptera: Tachinidae) in conventional land. Pollinator insects help plant pollination (Budianto & Sukendah, 2023), with 3 orders, 6 families, and 7 morphospecies, and *Amata huebneri* (Lepidoptera: Eribidae) as the most abundant species. Decomposer insects accelerate the decomposition of organic matter (Riawan, 2023), with 3 orders, 19 families, and 26 morphospecies, and *Chironomus* sp. (Diptera: Chironomidae) as the dominant species.

Neutral insects do not have a direct impact on agriculture but support ecosystem balance (Melhanah *et al.*, 2018; Kurniawati, 2015). Found 1 order, 2 families, and 2 morphospecies, with *Culex* sp. (*Diptera*: *Culicidae*) as the most abundant species. The composition of the total insect status caught in shallot EF and CF fields can be seen in the Annex 1 with visual images is provided in **Supplementary file S1**.

Table 1 provides a summary of the comparison on the insect status found in the ecological engineering (A) and conventional (B) shallot farmlands. Both fields are dominated by predatory insects from the Carabidae, Coccinellidae, or Staphylinidae families. Meanwhile, Herbivore insects, which are pest insects, are more commonly found in field B than in field A. This is in accordance with the statement of Westerkamp & Gottsberger (2000), that ecosystems are generally dominated by insect species that are beneficial to humans.

Insect Status	Ecological Engineering Farmland (EF)	Percentage	Conventional Farmland (CF)	Percentage
Herbivore	3114	13.29	3774	25.36
Predator	16985	72.50	8753	58.82
Parasitoid	120	0.51	29	0.19
Pollinator	19	0.08	10	0.07
Decomposer	2032	8.67	862	5.79
Neutral	1158	4.94	1452	9.76
Grand Total	23428	100.0	14880	100.0

Table 1. Comparison of insect status (role) in ecological engineering (EF) and conventional (CF) shallot farmlands

## 3.3. Diversity Index, Uniformity, Dominance, and Community Similarity

## 3.3.1. Diversity Index

The diversity index (H') is measured from the number of species and the population balance of each species observed in a community. The greater the number of species found, the higher the diversity value in the shallot field. The diversity index in both fields (Table 2) showed a moderate category since the vegetative phase, with a higher value in the

ecologically engineered field (EF) of 2.998 compared to the conventional field (CF) of 2.607. Higher diversity reflects a more diverse community without the dominance of certain species, creating a stable ecosystem (Indriyanto, 2012).

Table 2. Comparison of diversity index of insect population in shallot fields (ecological engineering vs. conventional farmland) based on growth stages.

Farmland	Vege	etative	Gen	erative	One planting season		
Farmand	Value	Category	Value	Category	Value	Category	
Ecological engineering farmland (EF)	2.998	Medium	2.929	Medium	3.079	High	
Conventional farmland (CF)	2.607	Medium	2.342	Medium	2.725	Medium	

In the generative phase, a similar trend occurred with a moderate index, namely 2.929 in field A and 2.342 in CF field. However, a significant difference was seen in the calculation of one planting season, EF field reached the high category (3.079), while CF field remained in the moderate category (2.725). These results indicate that ecological engineering, such as the use of refugia, can increase biodiversity compared to conventional methods. Previous studies Wijayanto *et al.* (2020); Lu *et al.* (2015), also support these findings, showing that ecological engineering in agroecosystems can increase the population of beneficial insects, including predators and parasitoids, and play a role in biodiversity recovery (Pilianto *et al.*, 2021).

#### 3.3.2. Evenness Index

The evenness index (E) describes the level of evenness of the distribution of the number of individuals of each species (Dimara et al., 2020), where the greater the E value, the higher the evenness, indicating a more stable community (Odum, 1996). The level of insect uniformity in the two shallot fields showed a clear difference in the vegetative phase. The ecologically engineered land (EF) had a high level of uniformity (0.608), indicating a stable community. In contrast, the conventional land (CF) had a moderate level of uniformity (0.597), indicating a fairly even distribution of individuals but still with more dominant species, indicating a less stable ecosystem.

In the generative phase, EF land still had high uniformity (0.624), indicating a stable ecosystem as in the vegetative phase. Meanwhile, CF land was still in the moderate category with a value of 0.561, indicating a more unstable ecosystem and vulnerable to environmental disturbances.

During one planting season, both lands reached a high uniformity category, with EF land at 0.601 and land B slightly higher at 0.603. Higher uniformity indicates a more even species population without the dominance of certain species, creating a more stable ecosystem. This condition allows natural enemies to control insect pest populations more effectively. This finding is in line with research by Windriyanti *et al.* (2023), which states that high uniformity can be influenced by cultivation practices such as refugia planting and proper pesticide use.

Table 4. Comparison of uniformity index of insect population in shallot fields (ecological engineering vs. conventional farmland) based on growth stages.

Farmland	Vege	etative	Gen	erative	One planting season		
raimiand	Value	Category	Value	Category	Value	Category	
Ecological engineering farmland (EF)	0.608	High	0.624	High	0.601	High	
Conventional farmland (CF)	0.597	Medium	0.561	Medium	0.603	High	

# 3.3.3. Dominance Index

The dominance index (C) is calculated to determine the extent to which a species in a shallot field dominates other species. The higher the dominance value, the higher the indication that the ecosystem is experiencing instability or stress. The insect dominance category in both shallot fields during the vegetative phase is relatively low, indicating that no species significantly dominates. However, as can observed in Table 3, the ecologically engineered field (EF) has a higher dominance value (0.100) during vegetative phase as compared to the conventional field (CF) (0.003). This indicates that the species population in EF field is less evenly distributed compared to CF field. Conversely, the very low dominance in CF field could be caused by two possibilities: the species population is evenly distributed or the total number of insect

individuals is smaller. This is evident from the total number of insects found in EF field (19,119) which is much greater than in CF field (10,171).

Table 5. Comparison of Dominance Index of insect population in shallot fields (ecological engineering vs. conventional farmland) based on growth stages.

Farmland	Vege	etative	Gen	erative	One planting season		
Farmand	Value	Category	Value	Category	Value	Category	
Ecological engineering farmland (EF)	0.100	Low	0.106	Low	0.094	Low	
Conventional farmland (CF)	0.003	Low	0.188	Low	0.022	Low	

In the generative phase, dominance remains relatively low in both fields, but there is a difference in pattern compared to the vegetative phase. The EF field has a dominance value of 0.106, while CF field is higher, namely 0.188. Although still in the low category, the lower dominance in EF land indicates that the distribution of species in this land is more even compared to CF land.

The difference in dominance patterns can be seen from the vegetative phase to the generative phase. If in the vegetative phase CF land has a lower dominance value than EF land, then in the generative phase this pattern is reversed, with the dominance of CF land being higher than EF land. This indicates that although both are low, the distribution of species in EF land is more even throughout the season compared to CF land.

Overall in one planting season, both lands still show a low dominance category, which means that no species truly dominates. However, the dominance value of EF land is higher (0.094) than CF land (0.022). This difference is most likely due to the greater number of insect individuals found in EF land (23,428) compared to CF land (14,880), which is only around 65% of the total individuals in EF land.

According to Nuraina *et al.* (2018), the smaller the dominance value (C), the more widespread the insect species dominance pattern is. This shows that in both ecologically engineered and conventional lands, the distribution of species is quite even. The diversity of species found in both lands is quite diverse, so that no species dominates significantly. In addition, insect communities in agricultural lands with low dominance values indicate that various insect species have a better chance of surviving and maintaining ecosystem balance. In conditions like this, the presence of pests and natural enemies is expected to be more stable, thus supporting natural pest control (Sanjaya & Dibiyantoro, 2012).

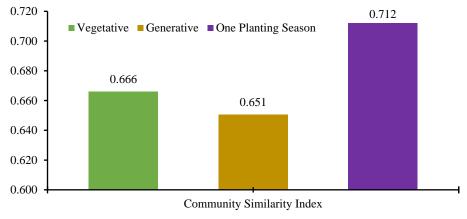


Figure 3. Community similarity index of insect population communities in shallot fields

#### 3.3.4. Community Similarity Index

The level of community similarity uses the Bray Curtis (BC) index calculation which will test the extent of the similarity of the insect community in the shallot field using the ecological engineering approach (EF) and conventional methods (CF). From the analysis results, the similarity of communities in both shallot fields with ecological engineering (EF) and conventional methods (CF), both in the vegetative, generative phases, and during one planting season is

relatively high with values of 0.666; 0.651; and 0.712, respectively. In the vegetative and generative phases, it shows a fairly high level of similarity with values of 66% and 65%, but throughout one planting season the level of community similarity is relatively high with a value of 71% compared to the previous two values, meaning that the two communities being compared have more species in common or a more similar composition.

## 3.3.5. Comparative Population Analysis Between the Two Shallot Fields

Although the diversity, uniformity, dominance, and community similarity indices show differences between the two fields, these differences are not statistically strong enough in the *t*-test. One possible cause is the large variability of the data, so that even though there are differences in index values, the data distribution still shows a similar pattern. Another factor contributing to this result is that ecological engineering on the shallot land was only implemented in this planting season. Previously, EF land used the same cultivation method as CF land, so the biodiversity in both lands has not shown a statistically significant difference. In addition, relatively similar environmental factors between the two lands can also affect the results of this test. The two adjacent lands are likely to have almost the same abiotic conditions, such as temperature, humidity, light intensity, and rainfall, which can cause biodiversity patterns that are not much different (Astari *et al.*, 2019).

## 3.4. Effect of Ecological Engineering on Insect Diversity

Ecological engineering includes the design, construction, and management of ecosystems through the addition of organic matter, planting of refugia, and the use of biological agents (Windriyanti *et al.*, 2023). One of the main factors that distinguishes these two methods is the addition of organic matter. In ecologically engineered land (EF), the use of compost, PGPR, and liquid organic fertilizers helps fertilize the soil and supports the development of insects, especially soil insects (Petrovic *et al.*, 2019). In contrast, conventional land (CF) only uses synthetic fertilizers such as NPK, which in the long term can reduce soil fertility, increase acidity, and reduce insect diversity. As stated by Heddy (1994) in Farah (2017), soil pH that is too acidic or alkaline can inhibit the development of soil organisms, including insects.

In addition, the presence of refugia plants on EF land contributes to increasing biodiversity. Refugia plants not only increase the diversity of flora but also support fauna that play a role in biological control (Sabirin, 2010). According to Altieri (1999), habitat manipulation with refugia can reduce disturbances from Herbivore organisms. This more diverse environment supports predators and parasitoids that help control pests naturally, thereby reducing dependence on synthetic pesticides.

The application of biological agents is also a differentiating factor between the two fields. Ecologically engineered (EF) field uses *Metarhizium* sp., *Bacillus thuringiensis*, *Pseudomonas fluorescent*, and *Serratia marcescens* to reduce the need for synthetic pesticides. In contrast, CF field still relies on synthetic pesticides and herbicides that are applied on a schedule. The use of synthetic pesticides can reduce insect populations, including non-target insects. For example, Yang *et al.* (2008), found that even low doses of pesticides can interfere with the behavior of bees in foraging. In addition, herbicides can damage soil insects and inhibit the growth of mycorrhizal fungi that are important for nutrient absorption (Aktar *et al.*, 2011). Overall, ecological engineering supports ecosystem balance by increasing biodiversity, reducing dependence on synthetic chemicals, and creating a more sustainable environment for shallot cultivation.

## 4. CONCLUSION

The conclusion of this study is that land with ecological engineering has a higher level of diversity compared to conventional land, especially in one planting season. Individual uniformity is more even, and species dominance is low in both lands, indicating a stable ecosystem. A fairly high community similarity index indicates that even though the management systems are different, the species composition is still not too different. The implementation of ecological engineering in shallot cultivation has been proven to be able to increase biodiversity and support ecosystem stability. This finding proves that ecological engineering can have a sustainable positive impact, especially if given a longer implementation time of two planting seasons or more. Another approach in the form of integrating more complex planting patterns, for example polyculture with additional plants other than refugia, also has the potential to increase the resilience of agricultural ecosystems.

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Annex 1. Insect composition on ecologically engineered (EF) and conventional (CF) farmlands

Ordo* / Family	Genus	Species	EF	CF	Status	Ordo* / Family	Genus	Species	EF	CF	Status
*Coleoptera						Scatopsidae	Psectrosciara	Psectrosciara sp.	1	0	Decomposer
Anthicidae	Anthicus	Anthicus sp.	27	24	Predator	Sciaridae	Bradysia	B. ocellaris	4	0	Herbivore
Carabidae	Acupalpus	Acupalpus sp.	30	0	Predator	Sciomyzidae	Sepedon	Sepedon sp.	15	0	Parasitoid
	Bradycellus	Bradycellus sp.	3	3	Predator		Tetanocerini	Tetanocerini sp.	1	0	Predator
	Clivina	Clivina sp.	4	0	Predator	Syrphidae	Chalcosyrphus	Chalcosyrphus sp.	1	0	Pollinator
	Harpalus	Harpalus sp.	7	0	Predator	Tabanidae	Tabanus	Tabanus sp.	2	0	Pollinator
	Ophionea	Ophionea sp.	7	7	Predator	Tachinidae	Argyrophylax	Argyrophylax sp.	23	27	Parasitoid
	Perigona	P. nigriceps	2	0	Predator		Besseria	Besseria sp.	1	0	Parasitoid
	Pheropsophus	P. occipitalis	46	22	Predator	*Embioptera		<u> </u>			
	Stenolophus	S.quinquepustulatus	521	320	Predator	Oligotomidae	Oligotoma	Oligotoma sp.	1	0	Decomposer
		Stenolophus sp01	708	483	Predator	*Hemiptera	B	- 110 a 111 a 111			
		Stenolophus sp02	802	610	Predator	Alydidae	Leptocorisa	L. acuta	1	0	Herbivore
	Tachys	Tachys sp01	44	33	Predator	Aphididae	Aphis	A. gossypii	0	1	Herbivore
	Tachys	Tachys sp01 Tachys sp02	311	293	Predator	Anthocoridae	Orius	O. laevigatus	4	0	Predator
	Тоовулино		105			Cicadellidae		U		82	Herbivore
Cl 1: 1	Tachyura	Tachyura sp.	0	111	Predator	Cicadellidae	Balclutha	Balclutha sp.	68		
Chrysomelidae	Longitarsus	L. linnaei		3	Herbivore		Cicadella	C. viridis	13	0	Herbivore
	Phyllotreta	Phyllotreta sp.	8	10	Herbivore		Cicadulina	C. bipunctata	85	122	Herbivore
	Psyliodes	Psyliodes sp.	0	1	Herbivore		Cofana	C. spectra	19	37	Herbivore
a	Altica	Altica sp.	0	5	Herbivore		Dalbulus	Dalbulus sp.	106	78	Herbivore
Cicindelidae	Myriochila	M. specularis	1	0	Predator		Deltocephalus	Deltocephalus sp.	46	4	Herbivore
Coccinellidae	Coccinella	C. transversalis	1	0	Predator		Empoasca	Empoasca sp.	59	74	Herbivore
	Harmonia	H. octomaculata	2	0	Predator		Idiocerus	I. niveosparsus	0	1	Herbivore
	Menochilus	M. sexmaculatus	9	3	predator		Idioscopus	Idioscopus sp.	9	0	Herbivore
	Micraspis	M. discolor	3	0	Predator		Macrosteles	Macrosteles sp.	0	1	Herbivore
	Scymnus	Scymnus sp.	49	13	Predator		Maiestas	M. dorsalis	67	94	Herbivore
	Stethorus	Stethorus sp.	10	10	Predator		Nephotettix	Nephotettix sp.	5	62	Herbivore
	Verania	V. lineata	12	10	Predator	Coreidae	Gonocerus	Gonocerus sp.	1	0	Herbivore
Curculionidae	Baris	Baris sp.	0	1	Herbivore	Corixidae	Hesperocorixa	Hesperocorixa sp.	142	0	Predator
	Sitophilus	S. oryzae	1	1	Herbivore	Cydnidae	Geotomus	Geotomus sp.	2	8	Herbivore
	Xyleborus	Xyleborus sp.	3	0	Decomposer	Delphacidae	Nilaparvata	N. lugens	70	126	Herbivore
Dytiscidae	Agabus	Agabus sp.	266	1	Predator		Peregrinus	P. maidis	3	2	Herbivore
•	Hydroglyphus	H. geminus	9	1	Predator		Sogatella	S. furcifera	7	1	Herbivore
		Hydroglyphus sp01	2	0	Predator		Tagosodes	Tagosodes sp.	0	2	Herbivore
	Hydroporus	Hydroporus sp.	2	0	Predator	Dictyopharidae	Dictyophara	Dictyophara sp.	1	0	Herbivore
	Hydrovatus	H. subtilis	1	0	Predator	Enicocephalidae	Systelloderes	Systelloderes sp.	62	0	Predator
	Laccophilus	Laccophilus sp.	4	10	Predator	Geocoridae	Geocoris	Geocoris sp.	1	0	Predator
	Neobidessus	Neobidessus sp.	1	0	Predator	Lygaeidae	Nysius	N. raphanus	0	2	Herbivore
Elateridae	Conoderus	Conoderus sp01	9	29	Herbivore	Mesoveliidae	Mesovelia	Mesovelia sp.	17	14	Predator
	Conoderus	Conoderus sp02	0	2	Herbivore	Micronectidae	Micronecta	Micronecta sp.	286	1	Decomposer
Endomychidae	Indalmus	I. hirsutus	1	0	Decomposer	Miridae	Cyrtorhinus	C. lividipennis	80	41	Predator
Heteroceridae	Heterocerus	Heterocerus sp.	144	104	Decomposer	Pentatomidae	Scotinophara	Scotinophara sp.	51	85	Herbivore
Hydrophilidae	Berosus	Berosus sp01	99	26	Predator	Rhyparochomidae	Horridipamera	H. nietneri	298	197	Herbivore
11, Gropiiii dae	Dolosus	Berosus sp01 Berosus sp02	306	174	Predator	Veliidae	Microvelia	Microvelia sp.	23	0	Predator
	Enochrus	Enochrus sp.	5	8	Predator	*Hymenoptera		листочени вр.	ديد	U	1100001
	Helobata	Helobata sp.	5 16	8 7	Predator Predator	Bethylidae	Cephalonomia	Cephalonomia sp.	1	0	Parasitoid
	Laccobius	1	16 56	/ 19		•	1	, ,	2	0	Parasitoid Parasitoid
		L. bipunctatus		0	Decomposer	Braconidae	Apanteles	Apanteles sp.	7		
rutudta	Paracymus	Paracymus sp.	1		Predator		Cotesia	Cotesia sp.		0	Parasitoid
Leiodidae	Agathidium	Agathidium sp.	2	0	Decomposer		Fopius	F. arisanus	2	2	Parasitoid
Melyridae	Attalus	Attalus sp.	1	0	Predator		Macrosentrus	Macrosentrus sp.	3	0	Parasitoid

Ordo* / Family	Genus	Species	EF	CF	Status	Ordo* / Family	Genus	Species	EF	CF	Status
Mycetophagidae	Pseudotriphyllus	P. colchilus	1	0	Decomposer		Opius	Opius sp.	3	0	Parasitoid
	Typhaea	T. stecorea	1	0	Decomposer	Chrysididae	Stilbum	S. cyanurum	1	0	Parasitoid
Noteridae	Neohydrocoptus	N. subvittulus	21	37	Decomposer	Diapriidae	Entomacis	E. platypes	2	0	Parasitoid
Phalacridae	Stilbus	Stilbus sp.	67	37	Decomposer	Diparidae	Dipara	D. petiolata	3	0	Herbivore
Scarabaeidae	Ataenius	Ataenius sp.	5	0	Decomposer	Eulophidae	Ophelimus	Ophelimus sp.	1	0	Parasitoid
	Holotrichia	Holotrichia sp.	67	82	Herbivore	Formicidae	Camponotus	Camponotus sp.	27	10	Predator
	Onthopagus	Onthopagus sp.	20	0	Decomposer		Crematogaster	Crematogaster sp.	3	0	Predator
	Oryctes	O. rhinoceros	1	0	Herbivore		Dorylus	Dorylus sp.	1	0	Predator
	Xylosandrus	Xylosandrus sp.	2	0	Herbivore		Formica	Formica sp.	13	0	Predator
Staphylinidae	Astenus	Astenus sp.	25	10	Predator		Monomorium	M. pharaonis	9	0	Predator
	Atheta	Atheta sp.	5484	4519	Predator			Monomorium sp01	777	401	Predator
	Lathrobium	Lathrobium sp.	4	0	Predator		Nylanderia	Nylanderia sp.	59	22	Predator
	Oligota	Oligota sp.	2228	0	Predator		Odontoponera	Odontoponera sp.	2	0	Predator
	Paederus	P. fuscipes	2839	1203	Predator		Paratrechina	P. longicornis	57	15	Predator
	Phloeonomus	Phloeonomus sp.	60	27	Decomposer		Pheidole	P. megacephala	10	0	Predator
	Xantholinus	Xantholinus sp.	519	122	Predator		Plagiolepis	P. alluaudi	153	95	Predator
Tenebrionidae	Palosus	P. subdepressus	1	1	Herbivore		Solenopsis	S. geminata	128	12	Predator
	Tribolium	Tribolium sp.	8	10	Herbivore		•	Solenopsis sp01	36	6	Predator
*Dermaptera		•						Solenopsis sp02	40	15	Predator
Anisolabididae	Euborellia	Euborellia sp.	412	66	Predator		Tapinoma	Tapinoma sp.	2	0	Predator
Forficulidae	Forficula	Forficula sp.	72	2	Predator	Halictidae	Lasioglossum	Lasioglossum sp.	2	0	Pollinator
*Diptera		, <u>, , , , , , , , , , , , , , , , , , </u>			·	Heloridae	Helorus	Helorus sp.	2	0	Parasitoid
Agromyzidae	Liriomyza	L. chinensis	1	0	Herbivore	Ichneumonidae	Ophion	Ophion sp.	1	0	Parasitoid
8	Ophiomyia	Ophiomyia sp.	1	0	Herbivore		Xanthocryptus	Xanthocryptus sp.	1	0	Parasitoid
Calliphoridae	Calliphora	Calliphora sp.	4	0	Decomposer	Mymaridae	Anaphes	Anaphes sp.	1	0	Parasitoid
	Lucilia	L. sericata	5	0	Decomposer		Gonatocerus	Gonatocerus sp.	1	0	Parasitoid
Cecidomyiidae	Aphidoletes	A. aphidimyza	1	0	Predator	Pteromalidae	Anisopteromalus	A. calandrae	1	0	Parasitoid
,	Orseolia	Orseolia sp.	0	1	Herbivore	Scelionidae	Scelio	Scelio sp.	30	0	Parasitoid
Ceratopogonidae	Culicoides	Culicoides sp.	2	1	Netral	Beenomade	Telenomus	Telenomus sp.	12	0	Parasitoid
Chironomidae	Chironomus	Chironomus sp.	851	336	Decomposer	Sphecidae	Sceliphron	Sceliphron sp.	2	0	Pollinator
Cinfoliolilidae	Cricotopus	Cricotopus sp.	1	0	Decomposer	Tiphiidae	Tiphia	Tiphia sp.	6	0	Parasitoid
Culicidae	Culex	Cricolopus sp. Culex sp.	1156	1451	Netral	Vespidae	Allorhynchium	A. argentatum	1	0	Pollinator
Dolichopodidae	Amblypsilopus	Amblypsilopus sp.	16	0	Predator	vespidae	Eumenes	Eumenes sp.	1	0	Pollinator
Donenopodidae		** * 1		0		*T 1	Eumenes	Eumenes sp.	1	U	FOIIIIatoi
D	Dolichopus	Dolichopus sp.	3	9	Predator	*Lepidoptera	A 4 -	A 11	10	10	D-11:
Drosophilidae	Drosophila	Drosophila sp.	0		Herbivore	Erebidae	Amata	A. huebneri	10	10	Pollinator
Ephydridae	Hydrellia	Hydrellia sp.	-	36	Herbivore	Noctuidae	Spodoptera	S. exigua	386	550	Herbivore
** 1	Scatella	Scatella sp.	4	0	Decomposer	*Odonata			•		5 1
Hybotidae	Elaphropeza	Elaphropeza sp.	214	5	Decomposer	Coenagrionidae	Agriocnemis	A. pygmaea	2	0	Predator
Muscidae	Atherigona	Atherigona sp.	3	6	Herbivore	*Orthoptera	_			_	
	Fannia	Fannia sp.	7	0	Decomposer	Acrididae	Oxya	O. chinensis	4	0	Herbivore
	Musca	M. domestica	34	6	Decomposer	Gryllidae	Gryllus	Gryllus sp.	23	29	Predator
	Muscina	Muscina sp.	2	0	Decomposer	Gryllidae	Gryllodes	Gryllodes sp.	2	0	Predator
Phoridae	Dohrniphora	Dohrniphora sp.	1	0	Decomposer	Gryllotalpidae	Gryllotalpa	Gryllotalpa sp.	35	13	Herbivore
	Megaselia	Megaselia sp.	508	279	Decomposer	Tridactylidae	Xya	Xya sp.	5	1	Predator
Piophilidae	Unknown	Unknown	18	12	Decomposer	*Thysanoptera					
Pipunculidae	Tomosvarryella	Tomosvarryella sp.	2	0	Parasitoid	Thripidae	Thrips	T. tabaci	1669	2035	Herbivore
Sarcophagidae	Sarcophaga	S. carnaria	2	0	Parasitoid		Grand Total		23428	14880	