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

Amelia Seftiarini[1], Tri Mujoko[1,✉], Wiwin Windriyanti[1]

[1] Master of Agrotechnology Study Program, Faculty of Agriculture, UPN "Veteran" Jawa Timur, Surabaya, INDONESIA.

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Corresponding Author:
✉ trimujoko.agri@upnjatim.ac.id
(Tri Mujoko)

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 ≤ 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.

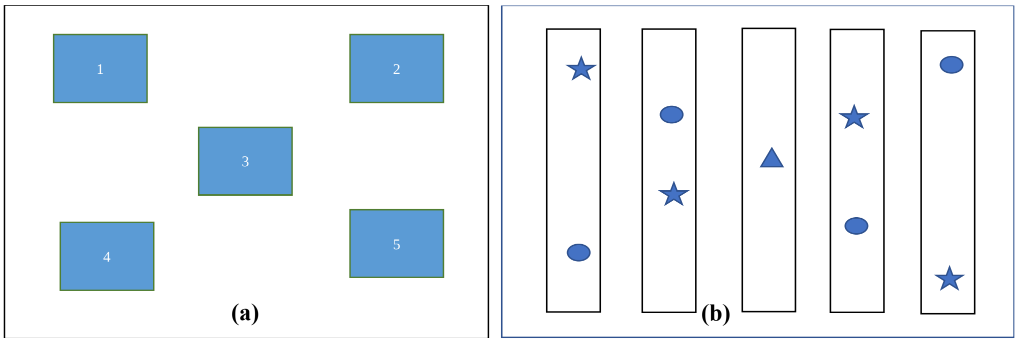

Figure 1. (a) Lay out of observation plots for shallot planting study, and (b) arrangement of insect traps in each plot. [(▲) light trap, (⬬) pitfall trap, (★) yellow sticky trap]

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 ±60 cm from the ground.

2.5.2. Pitfall Trap

The pitfall trap was made from a clear water bottle of ±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 ± 20 cm x 25 cm which has been coated with insect adhesive glue. Traps were installed using wood at a height of ±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):

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

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: $0 < E \leq 0.5$ is low uniformity stressed community; $0.5 < E \leq 0.75$ is medium uniformity unstable community; and $0.75 < E \leq 1$ 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: $0 < D \leq 0.5$ mean no dominant species, and $0.5 < D \leq 1$ 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.

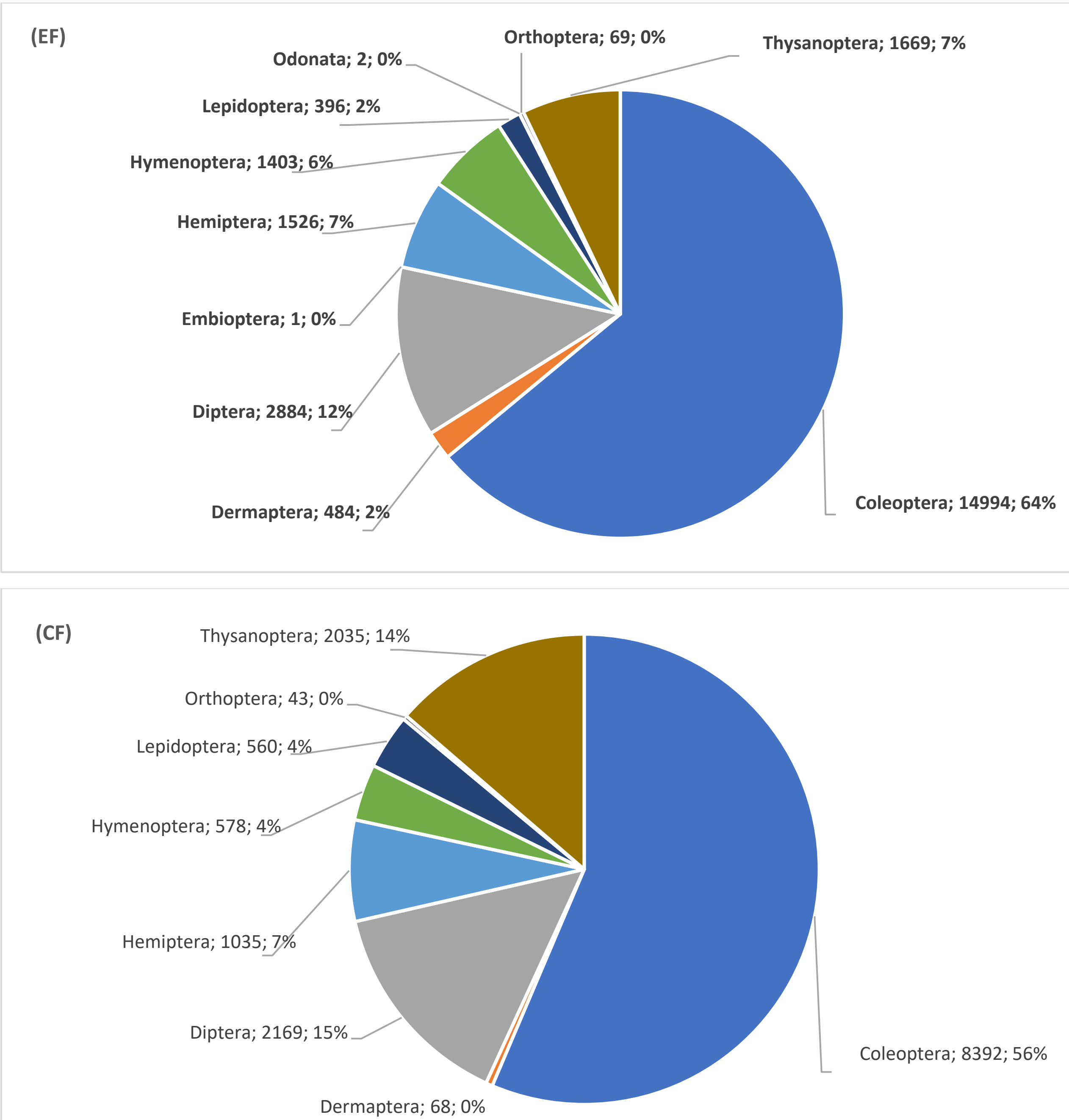

Figure 2. Insect population and composition (family) found in two different shallot lands: (a) Ecological engineering farmland (EF), (b) Convectional farmland (CF)

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.

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

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

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	**Vegetative**		**Generative**		**One planting season**	
	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	**Vegetative**		**Generative**		**One planting season**	
	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).

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

Farmland	**Vegetative**		**Generative**		**One planting season**	
	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).

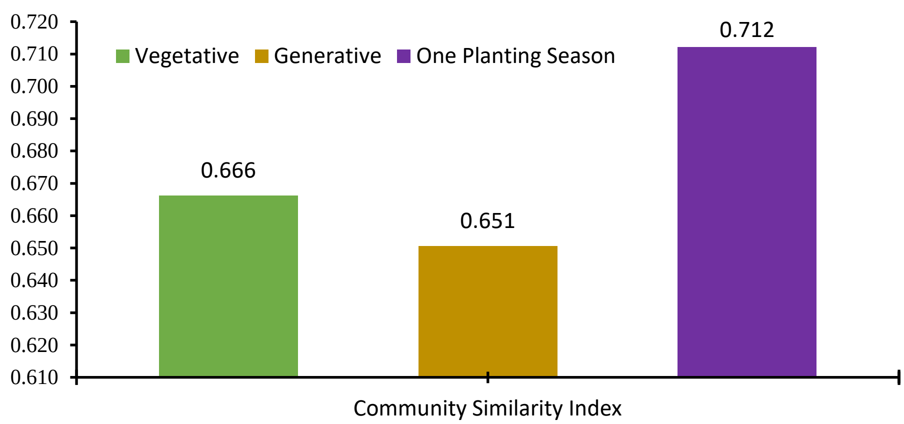

Figure 8. Community similarity index of insect population communities in shallot fields

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

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