Intercropping Shallots with Aromatic Plants

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Abstract. Spodoptera exigua is the main pest on shallot plants. The attack rate can reach 40% which results in a decrease in onion production. One way of controlling the environment that is environmentally friendly and reduces pest resistance is by intercropping using aromatic plants. This study aims to control the pest attack Spodoptera exigua. The research method used a randomized block design with 4 treatments, namely: monoculture (P1), onion and celery intercropping (P2), onion and mint intercropping (P3), onion and rosemary intercropping (P4). Each treatment was repeated 6 times so that there were 24 experimental units. In each experiment, the calculation of farming analysis was carried out. Observations of pests were carried out on colonization, attack area, attack level, and intensity of attack of Spodoptera exigua. This intercropping research with aromatic plants aims to determine the effect of several types of aromatic plants on attack. Selection of the right aromatic plants can affect the attack of Spodoptera exigua. Rosemary plants were most affected by Spodoptera exigua attacks compared to mint and celery plants.

Keywords: Intensity of attack · Growth · Production and business analysis of shallot

1 Introduction

Shallots (*Allium ascalonicum* L) is one of the important horticultural crop commodities for the people of Indonesia and is widely used as a basic ingredient for cooking spices. Indonesia has the potential in developing shallot farming due to the suitability of its natural conditions as indicated by the increase in shallot production every year [1]. From 2012 to 2017 in East Java, the production of shallot bulbs increased. But in 2018 the production of shallot bulbs decreased by 16.5% [2]. The decline in shallot production can be caused by cultivation techniques that are not optimal by climate change, facilities and infrastructure are still limited and the most important is the high attack of plant pest organisms (OPT). *Spodoptera exigua* H. (Army caterpillar) is one of the main pests that cause a decrease in production yields in shallot cultivation. The decrease in crop yields caused by armyworm attacks can reach 62.98% and even crop failure can occur [3]. Attacks of Spodoptera exigua H. in the vegetative growth phase can result in yield losses reaching 57–100% and a decrease in the quality of onion yields such as small bulbs [4].

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At this time farmers are still controlling armyworm pests manually and spraying chemical pesticides. The use of pesticides that are too intensive can cause pest resistance to pesticides. Resistance can give rise to new pest strains. Therefore, it is necessary to control the armyworm in an environmentally friendly way, including technical cultures, such as intercropping with aromatic plants. Certain aromatic plants have repellent properties against the pest Spodoptera exigua H. [5].

The intercropping pattern can suppress pest attacks and improve the performance of natural enemies [1]. One of the plants that have chemical compounds that *Spodoptera exigua* H. does not like include rosemary, celery and mint. Compounds in rosemary that have insect repellent properties include cineol, camphor, camphene, linalool, limeon, borneon, mircene, terpineol and caryophyllene [6]. Celery (Apium graveolens) contains flavonoids, saponins and tannins. Flavonoids have a way of inhibiting the larvae's eating power (antifedant), as a stomach poison. The content of saponins can reduce the activity of digestive enzymes and absorption of food [7]. Mint (Mentha arvensis) has several active ingredients such as eugenol, thymol, and cinerol which have properties as insect repellent [8] The aromatic plants of rosemary, celery and mint were chosen to be repellent plants because they contain chemical compounds that are not liked by insects. The reduced population of pests is due to the role of volatile chemical compounds released by plants that are repellent so that pests found in the main plant avoid [9]. Therefore, the control of Spodoptera exigua H. with an intercropping pattern needs to be investigated. This intercropping research with aromatic plants aims to determine the effect of several types of aromatic plants on attack.

2 Research Methods

ThE research was carried out on agricultural land in Pecalukan Village, Prigen District, Pasuruan Regency. The study lasted for 2 months from February to April 2021. The onion variety used in this study was the Bauji variety. Observations were made 7 DAP with an observation interval of 4 days.

This study used an experimental method with a Randomized Block Design (RBD), namely P1: shallots were grown in monoculture as a control treatment with a spacing of 20 cm × 20 cm, P2: intercropping shallots with celery planted in empty gaps between shallot plants with a spacing of 25 cm × 25 cm, P3: Intercropping shallots with mint planted in empty gaps between shallot plants with a spacing of 25 cm × 25 cm, P4: Intercropping shallots with rosemary planted in empty gaps between shallot plants with a spacing of 25 cm × 25 cm. There were 4 treatments in total and repeated 6 times so that there were 24 experimental units.

Parameters observed included observations of Spodoptera exigua: colonization, attack area, attack level and intensity of the attack, plant growth observations: plant height (cm), number of leaves (strands). Observation of crop yields: number of tubers, fresh weight of tubers and dry weight of tubers consumed (g), and farming business analysis. Observations of pests and shallot plant growth were carried out from 7 DAP to 43 DAP with observation intervals of 4 days. Observation of the results was carried out after harvest.

2.1 The Colonialization of Spodoptera Exigua H.

The colonialization of Spodoptera exigua H. was calculated using the Eq. 1:

$$P = \frac{n}{N} \times 100\% \quad (1)$$

Description:

P = Colony population
n = Number of Spodoptera exigua found in sample plants
N = Number of samples observed.

2.2 The Area of the Attack

The area of the attack is calculated by the Eq. 2:

$$L = \frac{a}{b} \times 100\% \quad (2)$$

Description:

L = Area of attack.
a = Number of affected plants.
b = Number of plants observed.

After the percentage of affected plants is known, it will be entered into the attack criteria table (Table 1) to determine the extent of the Spodoptera exigua attack.

2.3 The Level of Attack

The level of attack is carried out by finding the percentage (%) of the affected plants using the Eq. 3:

$$T = \frac{a}{a+b} \times 100\% \quad (3)$$

Description:

Table 1. Determination of the scale value of each attack category

Attack Category	Percentage	Scale Score
0	-	Normal
1	>0–25%	Mild
2	>25–50%	Medium
3	>50–75%	Weight
4	>75–100%	Very Heavy

Source: Wali and Soamole [10].

Table 2. The attack rate of Spodoptera exigua on Shallots

Scale	Attack Percentage	Attack Category
0	0%	Healthy
1	$>0–\leq 10\%$	Very Low
2	$>10–\leq 20\%$	Low
3	$>20–\leq 40\%$	Medium
4	$>40–\leq 60\%$	High
5	$>60–\leq 100\%$	Very High

Source: Moekansan et al. [11].

T = Percentage of affected leaves
a = number of affected leaves
b = Number of leaves not affected.

After the percentage of affected plants is known, it will be entered into the attack criteria table (Table 2) to determine the level of attack.

2.4 The Intensity of the Attack

The intensity of the attack is calculated by the Eq. 4 (Table 3):

$$I = \frac{\sum (\text{ni} \times \text{vi}) \times 100\%}{\text{N} \times \text{Z}} \tag{4}$$

Description:

I: attack intensity (damage) (%)
ni: the number of plants observed in each category
vi: Large scale attack
Z: attack category with the highest numerical value
N: the total number of plants observed.

2.5 Farming Business Analysis

Farming business analysis is calculated by the Eqs. 5–9:

2.5.1 Total Cost of Production

$$\text{TC} = \text{TFC} + \text{TVC} \tag{5}$$

Description:

TC = Total cost (Rp)
TFC = Total fixed costs (Rp)
TVC = Total variable cost (Rp).

Table 3. Attack intensity scale

Scale	Damage Percentage
0	No Leaf Damage was Observed
1	Damage 1%–25% on Observed Leaves
2	Damage 26%–50% on Observed Leaves
3	Damage 51%–75% on Observed Leaves
4	Damage 76%–100% on Observed Leaves

2.5.2 Total Farm Revenue

$$\mathrm{TR} = \mathrm{P} \times \mathrm{Q} \tag{6}$$

Description:

TR = Total revenue
P = Product price (Rp)
Q = Total sales (Rp).

2.5.3 Farming Income

$$\pi = \mathrm{TR} - \mathrm{TC} \tag{7}$$

Description:

π = Income (Rp)
TR = Total revenue (Rp)
TC = Total cost (Rp).

2.5.4 R/C Ratio

$$R/C\ Ratio = \frac{TR}{TC} \tag{8}$$

Description:

TR = Total Revenue
TC = Total Cost.

With criteria:

- R/C Ratio > 1 = Farming is said to be efficient and profitable and feasible to be developed.
- R/C Ratio < 1 = Farming is said to be inefficient.
- R/C Ratio = 1 = Farming is said to be in a break-even state or experiencing BEP (no profit and no loss).

2.5.5 B/C Ratio

$$B/C\ Ratio = \frac{\pi}{TC} \quad (9)$$

Description:

B/C = Benefit/Cost Ratio
FI = Total Revenue (Rp)
TC = Total Cost (Rp).

With criteria:

- B/C > 1, farming is feasible
- B/C < 1, farming is not feasible
- B/C = 1, the farm is said to break even

Data from pest attack observations were analyzed using descriptive analysis, growth observations were analyzed using analysis of variance (ANOVA) with a significance level of 5% and DMRT 5%.

3 Results and Discussion

3.1 Colonization of Spodoptera Exigua

Observation of Spodoptera exigua colonization was carried out at the age of 7 DAP to 47 DAP with an observation interval of 4 days. The results of the descriptive analysis showed different results between treatments. Pest Spodoptera exigua H. was not found in every observation. Colonization of Spodoptera exigua showed interactions occurred at 15 DAP, 19 DAP and 31 DAP.

Figure 1 shows that at the age of 15 DAP Spodoptera colonization was found in the intercropping treatment of shallots with aromatic mint plants. At the age of 31 DAP Spodoptera colonization was found in the intercropping treatment of shallots with monoculture aromatic plants and celery. In the intercropping treatment of shallots with rosemary plants, no Spodoptera colonization was found in each observation. The intercropping treatment of shallots with rosemary plants was the best treatment among other

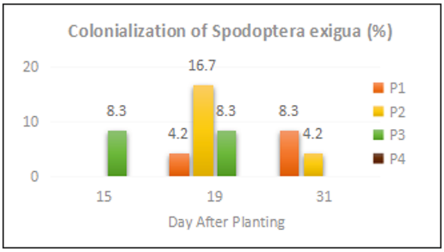

Fig. 1. Graph of average colonization of Spodoptera exigua on Shallots with various types of aromatic plants.

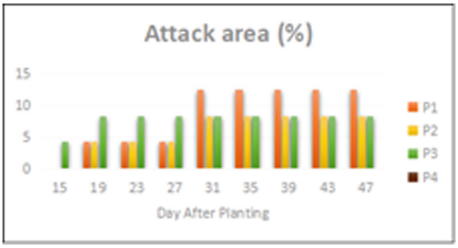

Fig. 2. Graph of the average area of Spodoptera exigua H. attack on Shallots with various types of aromatic plants.

treatments with 0% Spodoptera exigua H. colonization. This is presumably because rosemary plants secrete compounds that are repellent to Spodoptera exigua H. Aromatic companion plants can affect the performance of pests on their hosts, this is because aromatic companion plants release volatile organic compounds and their effectiveness does not only depend on the type of plant but regulation in the cultivation system [12].

3.2 Spodoptera Exigua Attack Area

Observation of the attack area of Spodoptera Exigua was carried out at the age of 7 DAP to 47 DAP with an observation interval of 4 days. The results of the descriptive analysis showed different results between treatments. Pests Spodoptera exigua H. were found at the ages of 15, 19, 23, 27, 31, 35, 39, 43, 47 DAP. The average area of attack by armyworm (Spodoptera exigua) on shallot plants with various treatments of aromatic plant species can be seen in the following figure.

Figure 2 shows that the intercropping treatment of shallots with rosemary plants is the best treatment among other treatments with 0% attack area. The rosemary plant contains linalool, burneol and camphor compounds and its essential oil content is often used as an insect repellent [12]. Ecosystem diversity is able to suppress the presence of major pests in shallot plantations [13].

3.3 Spodoptera Exigua Attack Rate

Observation of the attack rate of Spodoptera Exigua was carried out at the age of 7 DAP to 47 DAP with an observation interval of 4 days. The results of the descriptive analysis showed different results between treatments. Pests Spodoptera exigua H. were found at the ages of 15, 19, 23, 27, 31, 35, 39, 43, 47 DAP. The average attack rate of armyworm (Spodoptera exigua) on shallot plants with various treatments of aromatic plant species can be seen in the following figure.

Figure 3 shows that in the intercropping treatment of shallots with rosemary plants, no spodoptera colonization was found in each observation. The intercropping treatment of shallots with rosemary plants was the best treatment among other treatments with an attack rate of 0%. Figure 4 shows that the intercropping treatment of shallots with rosemary plants was the best treatment among other treatments with an attack intensity of 0%. In the intercropping treatment of shallots with rosemary plants, no damage to

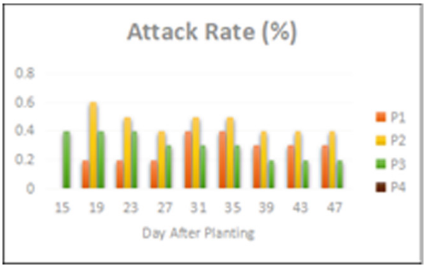

Fig. 3. Graph of average attack levels of Spodoptera exigua on Shallots with various types of aromatic plants.

the leaves was observed. Insects detect a stimulus which is generally chemical (scent), using a sensor called olfactory. Insects will respond to stimuli by trying to get closer if the stimulus is interesting such as sex pheromones and avoid (away) if the source of the stimulus is considered harmful and disliked by insects. If the insect is too late to escape (away) what happens is that the insect will fall (knock down) which can be temporary (reversible), meaning that the fallen insect can recover after some time and is permanent, meaning that the insect will die [14]. The compounds cineol, camphor, camphene, linalool, limeon, borneon, mircene, terpineol and caryophyllene in rosemary have insect repellent properties [6]. The flavonoid compounds found in celery have a way of inhibiting the feeding power of larvae (antifedant), as a stomach poison and the content of saponins can reduce the activity of digestive enzymes and food absorption [7]. Eugenol, thymol, and cinerol compounds found in Mint (Mentha arvensis) have properties as insect repellants [8].

3.4 Attack Intensity

Observation of attack intensity of Spodoptera Exigua was carried out at the age of 7 DAP to 47 DAP with an observation interval of 4 days. The results of the descriptive analysis showed different results between treatments. Pests Spodoptera exigua H. Interactions were found at the ages of 15, 19, 23, 27, 31, 35, 39, 43, 47 DAP. The average attack rate of armyworm (Spodoptera exigua) on shallot plants with various treatments of aromatic plants can be seen in the following figure.

Figure 4 shows that the intercropping treatment of shallots with rosemary plants is the best treatment among other treatments with an attacking intensity of 0%. In the intercropping treatment of shallots with rosemary plants, no leaf damage was observed. Insects detect a stimulus that is generally chemical (scent), using a sensor called olfactory. Insects will respond to stimuli by trying to approach if the stimulus is interesting such as sex pheromones and avoid (away) if the source of the stimulus is considered harmful and disliked by insects. If the insect is too late to avoid (away) what happens is that the insect will fall (knockdown) which can be temporary (reversible), meaning that the fallen insect can recover after some time and is permanent, meaning that the insect will die [14].

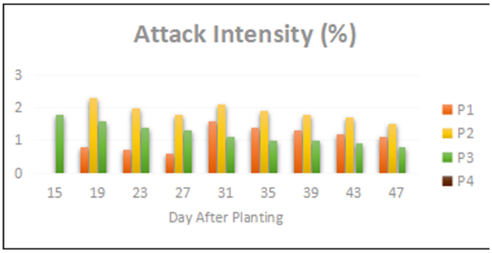

Fig. 4. Graph of the average intensity of Spodoptera exigua Attack on Shallots with various types of aromatic plants.

Table 4. Average plant height of shallots with various control treatments

Treatment	Number of Leaf Shallots (pieces) in age (DAP)																			
	7		11		15		19		23		27		31		35		39		43	
Monoculture	12	a	15	a	18	a	21	a	24	a	28	A	31	a	36	a	39	a	42	a
Celery Intercropping	12	a	16	a	20	a	22	a	25	a	29	A	32	a	35	a	37	a	41	a
Mint Intercropping	12	a	16	a	19	a	21	a	23	a	26	a	29	a	32	a	35	a	38	a
Rosemary Intercropping	11	a	15	a	18	a	21	a	24	a	27	a	30	a	33	a	36	a	40	a

Note: Numbers followed by different letters (notations) in the same column indicate that there is a significant difference with Duncan's test at the 5% level.

3.5 Onion Plant Height

Observation of shallot plant height was carried out at the age of 7 DAP to 43 DAP with an observation interval of 4 days. The results of analysis of variance showed that the intercropping of shallots with aromatic plants had a significant effect on the plant height of shallots. Interactions were found at 11, 39 and 43 DAP. The average height of shallot plants with various control treatments can be seen in Table 4.

Table 4 shows that among the 4 treatments, the best treatment was monoculture treatment. Plant height can be affected by plant spacing, so the closer the spacing, the higher the plant growth, plant growth will occur etiolation [15]. In addition to the effect of light, the application of NPK fertilizer on shallot plants can also help increase the growth of shallot plants. The application of the same fertilizer in all treatments caused the intercropping treatment to have a lower value than monoculture. N, P, and K fertilizers are needed by plants during the vegetative period because the macronutrients N, P, and K can stimulate plant growth during the vegetative period such as roots, stems, and leaves to increase plant height [16].

Table 5. Average number of leaves of Shallots with various control treatments

Treatment	Shallot Plant Height (cm) in age (DAP)																			
	7		11		15		19		23		27		31		35		39		43	
Monoculture	10	a	17,5	A	23	a	25	a	27	a	30	a	34	a	38	a	41	b	43	b
Celery Intercropping	11	a	20	B	25	a	26	a	29	a	31	a	34	a	37	a	40	ab	41	ab
Mint Intercropping	11	a	18	Ab	23	a	26	a	28	a	30	a	33	a	36	a	38	ab	40	ab
Rosemary Intercropping	11	a	18	Ab	24	a	26	a	28	a	31	a	34	a	35	a	37	a	39	a

Note: Numbers followed by different letters (notations) in the same column indicate that there is a significant difference with Duncan's test at the 5% level.

3.6 The Number of Leaves of the Onion Plant

Observation of the number of leaves of shallot plants was carried out at the age of 7 DAP to 43 DAP. Observation interval 4 days. The results of the analysis of the variance of shallots with aromatic plants did not significantly affect the number of leaves of shallot plants. The average number of shallot leaves with various control treatments can be seen in Table 5.

Table 5 shows that among the 4 treatments, the best treatment was monoculture treatment. Competition in intercropping patterns is unavoidable so that it affects plant growth. In addition, one of the factors that determine the growth of the number of leaves is genetic traits and weather factors [15]. Nutrient N is involved in the formation of amino acids, proteins, nucleic acids, enzymes, nucleoproteins, and alkaloids, which are needed in the growth process, leaf development, increasing the green color of leaves, and forming branches or tillers [16]. Elemental N is able to increase the number of leaves and the number of clumps in plants because it includes macro nutrients needed by plants as a basic material to build protein for growth [17].

3.7 Onion Bulb Weight

The results of the analysis of the variance of shallots with aromatic plants had a significant effect on the weight of the bulbs of shallots. Table 6 shows that among the 4 treatments, the best treatment was monoculture treatment. This is presumably due to the number of leaves on the shallot plant. Long and numerous plant leaves can affect the tuber formation process. Leaf growth that is not optimal or attacked by pests will affect the process of forming onion bulbs [18]. Several factors can affect the production of shallots, namely the attack of the pest Spodoptera exigua H., and environmental influences. In addition, solar competition can also affect tuber weight [19]. The aromatic plants of celery, mint, and rosemary have leaves that are thick enough so that the aromatic plants cause the onion plants to get less sunlight. Lack of sunlight can inhibit the process of photosynthesis. The process of photosynthesis can stimulate the formation of large

Table 6. Average weight of Shallot bulbs with various control treatments

Treatment	Shallot Bulb Weight (gr)	
	BB	BK
Monoculture	65 b	58
Celery Intercropping	44 a	39
Mint Intercropping	48 a	41
Rosemary Intercropping	47 a	40

Note: Numbers followed by different letters (notations) in the same column indicate that there is a significant difference with Duncan's test at 5% level.
BB = Wet Weight
BK = Dry Weight

Table 7. Average number of Shallot bulbs with various control treatments

Treatment	Number of Bulbs
Monoculture	13 a
Celery Intercropping	10 a
Mint Intercropping	11 a
Rosemary Intercropping	12 a

Note: Numbers followed by different letters (notations) in the same column indicate that there is a significant difference with Duncan's test at 5% level.

onion bulbs [20]. In addition, other factors that can affect the weight of shallot bulbs are nutrient competition in plants. The application of the same fertilizer in each treatment caused differences between monoculture and polyculture plants due to competition for nutrients from shallots and aromatic plants. Two or more plants planted with a distance between plants of less than 100 cm will result in nutrient competition [21].

3.8 Number of Onion Bulbs

The results of the analysis of the variance of shallots with aromatic plants did not significantly affect the number of bulbs of shallot plants. Table 7 shows that among the 4 treatments, the best treatment was monoculture treatment. The application of the same fertilizer in each treatment resulted in lower intercropping treatment than monoculture treatment. The application of NPK fertilizer can produce a large number of tubers [17]. This could be due to the formation and development of shallot bulbs requiring a balanced application of NPK fertilizer [22].

Table 8. Average analysis of onion farming with various treatments

Treatment	Farming Business Analysis				
	TC	TR	π	R/C Ratio	B/C Ratio
Monoculture	Rp 66.508.148	Rp 147.675.000	Rp 81.166.852	2,2	1,2
Celery Intercropping	Rp 72.286.148	Rp 98.675.000	Rp 248.611.074	4,4	3,4
Mint Intercropping	Rp 77.842.148	Rp 101.000.000	Rp 217.602.296	3,8	2,8
Rosemary Intercropping	Rp 80.620.148	Rp 103.700.000	Rp 300.857.630	4,7	3,7

Description:
TC = Total Production Cost
TR = Total Farming Revenue
Π = Total Farming Income
R/C Ratio = Farming Business Efficiency Analysis
B/C Ratio = Farming Business Efficiency Analysis

3.9 Analysis of Onion Farming

The results of the analysis of onion farming with aromatic and conventional plants have different values. Conventional is obtained from the analysis of the efforts carried out by farmers on the land. There is a high difference between rosemary and conventional intercropping. The average analysis of onion farming with various treatments can be seen in Table 8.

Table 8 shows the data from the analysis of farming from 4 treatments and conventional (farmers). The business analysis includes production inputs, land rent, land cultivation, to the cooperation of labor in each treatment, and compared to farmers' cultivation, the difference lies in the handling of pests. The largest farm income was found in the intercropping of shallots with rosemary plants, which was Rp. 300,857,630 with an R/C Ratio of 4.7 and a B/C Ratio of 3.7.

4 Conclusion

Intercropping shallots with rosemary plants is the best treatment in handling pest attacks with 0% attack and farming business analysis with an R/C Ratio of 4.7.

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