



Detection of *Spodoptera exigua* (Hübner) Larval Infestation on Leeks and Shallots: A Case Study in North Tapanuli and Karo, North Sumatra, Indonesia

Ameilia Zuliyanti Siregar ^{a,*}, Suputa ^b, Lindung Tri Puspasari ^c, Abdul Hafiz Ab. Majid ^d

^a Agrotechnology Study Program, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia

^b Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Gadjah Mada, Sleman, Indonesia

^c Faculty of Agriculture, Universitas Padjadjaran, Sumedang, Indonesia

^d School of Biological Sciences, Universiti Sains Malaysia, Pulau Pinang, Malaysia

Abstract. North Sumatra Province is the eighth largest producer of shallots (*Allium cepa*) in Indonesia (1.09%, 53,962 tons). Declining shallot production is primarily caused by attacks by pests and pathogens, which are responsible for 20–100% decreases in yields. *Spodoptera exigua* larvae are among pests with significant effects on shallot productivity. This study aimed to determine the effectiveness of various methods of monitoring *Spodoptera exigua* infestation on shallots, particularly of the Batu Ijo and Brebes varieties, including the use of yellow sticky traps, blue ball traps, sweep nets, and hand-picking, for the purpose of increasing farmers' income in North Tapanuli and Karo, Sumatra Utara. The research was conducted in Parhorboan Village, Pagaran Sub-district, North Tapanuli Regency, and Juhar Sub-district, Karo Regency, North Sumatra, from June to July 2024. To be precise, it was conducted in three farmers' planting areas, using the diagonal slice method with five sub-plots and observations with one-week intervals at the sampling locations. The results showed that the infestation by *S. exigua* larvae was higher on shallots than on leeks. The highest average number of larvae recorded on leeks was 0.78 larva per plant, while shallots had an average of 1.84 larvae per plant. Furthermore, the highest average percentage of *S. exigua* larval infestation on leeks was 16.78%, while the infestation on shallots reached 32.15%. The intensity of *S. exigua* infestation fell within the 3–5 categories, which correspond to medium to very high levels. The independent sample *t*-test results showed significant differences in both the population and infestation percentage of *S. exigua* larvae in the leek and shallot planting areas.

Keywords: shallot; *Spodoptera exigua*; pest monitoring; infestation intensity; trap variation.

Type of the Paper: Regular Article.



1. Introduction

This study focused on pheromone-assisted mating disruption strategies to control *Spodoptera exigua* moth populations in centers of shallot production in Indonesia, which are crucial for addressing the growing problem of insecticidal resistance and for reducing chemical residues in shallot bulbs. It explored the potential of the polyculture system, where shallots are intercropped with peanuts and beans, as a strategy for managing *S. exigua*. It has been found that the number of *S. exigua* eggs laid in the polyculture system was significantly lower than that in the monoculture system, indicating potential for its development for more sustainable farming. In

addition, there have been reports on a novel biocontrol approach using colonies of the endophytic fungus *Serendipita indica* on shallot roots. This fungus was found to significantly reduce leaf damage caused by *S. exigua* larvae and inhibit larval weight gain, demonstrating its potential application as a biostimulant to enhance plant innate resistance to pests.

The shallot (*Allium ascolonicum*) is a superior commodity that has long been intensively cultivated by farmers, notably through horticulture. It is commonly used as seasoning, family herbal medicine, and industrial material, and it has been known to have significantly contributed to regional economic development [1]. Besides the shallot, a related plant from the *Allium* genus that also has high economic value and is susceptible to pest attacks is the leek (*Allium ampeloprasum* var. *porrum*, also frequently called scallions). Although leeks and shallots are different morphologically and cultivated in unlike manners, where leeks are harvested for their thick stems and leaves, while shallots are harvested for their bulbs, they are often cultivated in close proximity and, therefore, share similar pests.

Leeks' presence in the research area is considered important as they can serve as alternative hosts for *S. exigua* larvae, which can influence pest population dynamics and control strategies in shallot fields. Based on data from BPS North Sumatra [2], shallot production has decreased in the course from 2020 to 2023. Despite considerable interest in shallots, farmers are often met with numerous technical and financial obstacles in their cultivation, as is the case with farmers in Malaysia [3] and Indonesia [4]. Among the most persistent issues affecting shallot cultivation and productivity are attacks by shallot pests and diseases [5], including *S. exigua*, *Thrips tabaci*, *Liriomyza chinensis*, and *Agrotis ipsilon* [6]. These pests' ability to reproduce affects their abundance within their habitats, a process influenced by various environmental factors [7]. While their incubation period is not affected by their host plants, their larval development and pupal period are [5].

North Sumatra produced 72,295 tons of shallots per hectare in 2023, a significantly smaller yield compared to 2015. This decline in production resulted in a shallot undersupply in the market, which subsequently caused shallot price to skyrocket from the normal price [1]. Shallot is generally propagated using its bulbs as planting materials or seed sources. However, quality seeds so obtained are highly limited in quantity, around 15–16% per year [8]. Alternatively, to address this limitation, one may use botanical seeds or true shallot seeds (TSS).

As stated by Sembiring et al. [9], *S. exigua* Hübner (Lepidoptera; Noctuidae) is a cosmopolitan insect and an important pest of shallots. It has the ability to spread rapidly in lowlands and highlands both in the dry and rainy seasons. As with other organisms living in agricultural lands, climate change also affects the growth and development of this pest species. In the last few decades, the growing presence and intensity of plant pest attacks along with changes

in environmental quality has been reported [10]. Supartha et al. [11] and Sembiring et al. [9], for example, detected several symptoms of *S. exigua* larval attacks on shallots, such as transparent spots on leaf tissue and leaves drying and falling, which affect shallot quality and quantity. This pest attacks the leaves and bulbs of shallots, which can reduce their quality and productivity, thus decreasing farmers' income [12]. The early instars mostly scrape the leaf tissue, leaving the epidermal layer intact, while the later instars cause extensive defoliation [5].

Efforts to control *S. exigua* have been focused on the intensive use of insecticides, such as spinosad, chlorpyrifos, triazophos, methomyl, beta-cyfluthrin, cyromazine, and carbosulfan [10], which frequently involves high-dose applications, resulting in high control costs (30–50% of the total production cost per hectare). In addition, insecticide applications also risk eliminating non-target organisms such as natural enemies and causing insect pest resistance to insecticides [13]. Therefore, it is deemed necessary to find alternative means to control *S. exigua*, such as using shallot varieties resistant to its attacks [14]. Among various varieties of shallots, Batu Ijo and Bima Brebes are the most commonly cultivated by farmers in Indonesia. Control can also be carried out by using botanical pesticides or by varying the shapes and colors of insect traps. Finally, a control threshold may be applied to suppress the intensive use of insecticides to control *S. exigua* attacks on shallots [15].

An *S. exigua* attack on shallots begin with pest invasion of the shallot planting area, followed by the appearance of symptoms of attack. To date, no detailed information on *S. exigua* invasion and colonization, as well as the effect of shallot varieties on *S. exigua* attacks, in North Sumatra has been reported. Information related to *S. exigua* in Indonesia is generally concerned with the intensity of attacks and insecticide testing [16]. Therefore, this study aimed to provide comprehensive information on *S. exigua* invasion and colonization and the relationship between *S. exigua* attacks and productivity of shallots, particularly of the Batu Ijo and Bima Brebes varieties. A previous study used specimens from Rurukan, which were longer than those sourced from Satiman et al. [17]. Almost all farmers (93.3%) in the three sub-districts under study agreed that *S. exigua* was the major insect pest of shallots, and 84.4% described it as difficult to control [18].

This study sought to determine the effectiveness of various methods of monitoring *S. exigua* Hübner larval attacks on leeks and shallots (*Allium ascalonicum* L.) in Parhaboran Village, Pagaragan Sub-district, North Tapanuli Regency, and Juhar Sub-district, Karo Regency, North Sumatra, namely, entrapment with yellow sticky traps, blue ball traps, and sweep nets as well as hand-picking. Data were collected by interviewing 30 shallot farmers, who came from four sub-districts.

2. Materials and Methods

The study was conducted in shallot fields in Pagaran Sub-district, North Tapanuli Regency (1°20'–2°41'N, 98°05'–99°16'E), which covers an area of 3,800.31 km², and Juhar Sub-district, Karo Regency (3°59'–3°73'N, 98°28'–98°45'E), from June to July 2024. The materials used included true shallot seeds (TSS) of the Bima Brebes variety, yellow paper, glue, plastic rope, formaldehyde, detergent, and 80% alcohol. The samples obtained were identified at the Pest Laboratory, Faculty of Agriculture, Universitas Sumatera Utara. This study used five replications, with 10 sample plants selected in each replication. The plants were selected systematically following a U-shape pattern.

Survey was used as the research method. In addition, observations were carried out using the absolute method weekly for six weeks. The variables observed were invasion and colonization time, intensity of infestation, and productivity.

Observations of invasion were carried out by observing the emergence of *S. exigua* in the planting areas of both shallot varieties after seeds were planted. Observations of colonization commenced when the plants turned seven days old. The average *S. exigua* population size on each shallot variety was calculated as $P = n/N$, where P is the population size, n is the number of *S. exigua* individuals found on the sample plants, and N is the number of sample plants observed [12]. Meanwhile, infestation intensity was calculated as a percentage (%) using the Eq. (1) [19].

$$P = \frac{a}{a+b} \times 100\% \quad (1)$$

where P is the percentage of infestation, a is the number of leaves infested, and b is the number of leaves not infested. Infestation intensity was then categorized following Table 1.

Table 1. Categories of *S. exigua* infestation intensity on shallot leaves

Score	Percentage (%)	Category
0	0%	Healthy
1	0% < P ≤ 10%	Very Low
2	10% < P ≤ 20%	Low
3	20% < P ≤ 40%	Medium
4	40% < P ≤ 60%	High
5	60% < P ≤ 100%	Very High

Observations of productivity were carried out by taking bulbs of each variety and calculating their wet weights.

3. Results and Discussion

3.1. Pest Composition

In the samples from Parhoboran Village, Pagaran Sub-district, North Tapanuli Regency, nine pests were recorded, namely, *Micraspis crocea*, *Conoderus posticus*, *Liriomyza chinensis*, *Empoasca fabae*, *Mictis longicornis*, *Spodoptera exigua*, *Agrotis ipsilon*, *Valanga nigricornis*, and

Mantis religiosa. *S. exigua* was the most abundant (75.2 individuals), while *Mictis longicornis* was on the opposite extreme (4.6 individuals). The *S. exigua* counts recorded from leeks and shallots in two sites (Pagaran Sub-district of North Tapanuli Regency and Juhar Sub-district of Karo Regency) are provided in Table 2.

Table 2. Number of *S. exigua* individuals infesting shallot leaves and leeks in Pagaran and Juhar Sub-districts

Type of Plants	Pagaran Sub-district, North Tapanuli Regency							Juhar Sub-district, Karo Regency						
	S1	S2	S3	S4	S5	S6	Mean	S1	S2	S3	S4	S5	S6	Mean
Leeks	8.4	10.6	16.8	12.2	9.4	7.6	10.83	7.9	11.6	9.4	7.6	6.4	5.8	8.11
Shallots	10.2	12.4	22.4	12.0	10.0	8.2	12.53	8.4	10.6	19.2	14.6	12.2	9.4	12.40

The observation data show varying *S. exigua* population sizes among samples. According to Jannah et al. [20], uncertain weather conditions can affect insect diversity. The variety of insect population size on shallots can be attributed to insects' capability to move from plant to plant [21]. Adisty et al. [18] reported that clove essential oil (*Syzygium aromaticum*) application at a concentration of 9% produced the best outcomes, with the highest mortality of and the lowest intensity of infestation by *Spodoptera exigua*. Additionally, Astuti et al. [22] reported that male family labor and adhesive inputs could increase risk in shallot farming production.

According to Tran and Ngo [23], the optimal temperature range for the development of insect pests is 15–33°C. At 40 days after planting, a spurt of insect population occurred, reaching 198 insects within the population. This is thought to be because insects acquire abundant food sources at this time. According to Azidah et al. [5], plant height and the number of leaves increase with increasing plant size, and the use of insecticides that is not in accordance with recommendations may cause a burst in insect populations.

3.2. Invasion and colonization of *S. exigua*

S. exigua was observed to start invading and colonizing shallot plants on the seventh day after planting. Invasion was characterized by the presence of *S. exigua* imagos on the shallot plants, while invasion was identified based on the presence of *S. exigua* egg clusters on the shallot plants [10]. The patterns of *S. exigua* invasion on the Batu Ijo and Bima Brebes varieties were almost the same. On the Batu Ijo variety, *S. exigua* egg mass predominantly occurred seven to 21 days after planting. Invasion was followed by colonization, whose observed variables varied [24].

The infestation intensity on shallots in both study sites varied, as can be seen in Table 3.

Based on observation results shown in Table 3, the intensity of larval attacks on the seventh day after planting was 6.00%, which increased to 12.61% on day 40 after planting. However, the intensity decreased to 9.73% on day 50 after planting and further decreased to 8.54% on day 70

after planting. On average, the infestation intensity value was 9.38%, which was categorized as very low. Larval attacks on shallots mainly came from *S. exigua* and *L. chinensis*. According to Ratnawati et al. [6], one of the symptoms of *S. exigua* larval attacks is that the inner leaf tissue is eaten up, leaving the outer epidermis layer, producing clear spots on the leaf. Aldini et al. [25] stated that, at high levels, larval attacks can cause death to shallot plants; because the leaves are eaten by larvae, the photosynthesis process becomes hindered and no nutrition is produced for the bulbs. Meanwhile, an *L. chinensis* attack begins with the insertion of its ovipositor into the shallot stem. The shallot will then start to develop small white spots on its surface as a symptom of attack. The mesophyll of the shallot leaves will be sucked by newly hatched larvae from the top to the rotting bulbs, and the leaves become dry and appear brownish white as if burned. More widespread attacks will increase the damage, leaving all plants with dried leaves and thus resulting in a crop failure.

Table 3. Infestation intensity (%) on shallots in Pagaran and Juhar Sub-districts

Time of Observation	Infestation Intensity (%) in Pagaran Sub-district						Mean	Infestation Intensity (%) in Juhar Sub-district						Mean
	S1	S2	S3	S4	S5	S6		S1	S2	S3	S4	S5	S6	
7 DAP	4.28	6.75	4.35	6.28	8.42	6.56	6.11	4.20	5.96	4.12	5.85	6.15	4.25	5.08
15 DAP	8.45	14.4	6.45	8.19	10.7	12.6	10.2	6.24	10.1	8.28	12.4	14.5	12.4	10.6
30 DAP	12.7	12.8	8.37	14.5	9.92	8.20	11.1	8.42	10.2	8.82	6.95	6.30	5.05	7.63
40 DAP	4	6		5			1		6					
40 DAP	14.7	16.8	8.63	10.4	12.3	9.42	12.0	8.48	12.6	6.45	10.4	10.5	8.42	9.51
50 DAP	6	2		6	8		8		9		7	4		
50 DAP	8.28	12.6	8.96	10.4	10.2	7.54	9.69	7.25	8.40	10.2	12.5	10.5	9.26	9.71
70 DAP		9		7	4					5	6	2		
70 DAP	8.56	10.5	8.63	6.26	8.69	6.23	8.15	8.45	14.4	10.7	8.19	8.45	7.62	9.65
		4							8	6				

The percentage of damage to shallot leaves was quite high. It is assumed that farmers used chemical pesticides not according to dosage recommendations [26]. In an interview a farmer in Medan Marelan Sub-district revealed that farmers use high concentrations of pesticides, 1–3 times as high as the recommended dosage, and they perform spraying 2–4 times a week, starting from the 14th day after planting [27].

As shown in Fig. 1, the average wet bulb weight of shallots of the Bima Brebes variety was higher than that of the Batu Ijo variety, with a difference of 11.2 g/bulb. The cultivation of the Bima Brebes variety saw a lower level of pest attacks compared to the Batu Ijo variety. According to Permadi et al. [28] and Nurhandani et al. [29], shallot productivity is considerably influenced by *S. exigua* pest attacks, which in turn is affected by altitude, temperature, pH, humidity, and rainfall. Pest attacks and productivity were correlated at a rate of -0.438 for the Bima Brebes variety and -0.374 for the Batu Ijo variety. The negative marks indicate that both were inversely correlated. In other words, the greater the attacks the lower the productivity. However, these

correlations were insignificant [30].

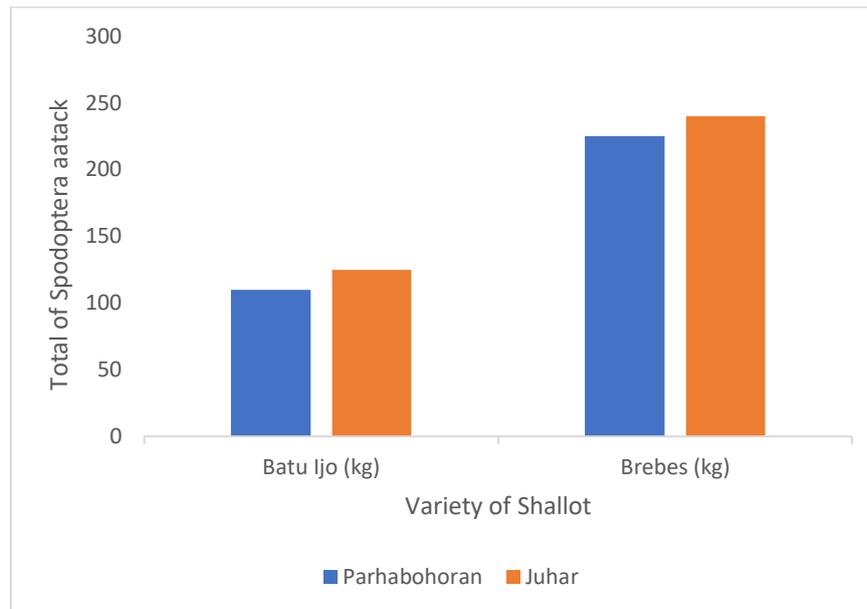


Fig. 1. Wet bulb weights of the Bima Brebes and Batu Ijo shallot varieties in Pagaran and Juhar Sub-districts

In a study conducted in Taeno Atas Backwoods, Rumah Tiga Village, Teluk Ambon Sub-district, Central Maluku Regency, Kusumawati et al. [31] found that the exi pheromone trap (PF) was more effective in controlling *S. exigua* Hbn than the yellow + exi pheromone trap (PKF) and the yellow trap (PK). In East Lombok, Rachmawati et al. [32] and Witjaksono et al. [33] used pheromones and various organic pesticides, such as gadung tuber (*Dioscorea hispida*) extract, and investigated their effects on the mortality of *S. exigua* larvae on shallots (*Allium cepa*). Rachmawati et al. [32] reported that treatments with organic insecticides had a significant effect on the intensity of *S. exigua* attacks on shallot cultivars. The neem seed extract insecticide produced a shallot yield of 6.60 kg/plot or 28.57 tons/ha, making it the best treatment, particularly for the Ilokos cultivar. Meanwhile, Witjaksono et al. [33] found that installing 100 dispensers of pheromones per hectare could be a favorable option for farmers due to its low cost. Additionally, using pheromones before planting could serve as a control technique. Aldini et al. [25] identified populations of *S. exigua* in major shallot cultivation areas in Java which were highly resistant to chlorfenapyr and methomyl and less resistant to emamectin benzoate, but they were still susceptible to cyantraniliprole. The treatment with 18 × 20 cm spacing + traps resulted in the highest productivity of shallots (13.5 tons per hectare). Additionally, sex pheromone traps were more effective in controlling *S. exigua* pests than light traps and yellow traps [15].

4. Conclusions

The results of this study have important implications for the development of adaptive Integrated Pest Management (IPM) strategies in North Sumatra. Determination of Control

Thresholds: The peak infestation on day 40 after planting indicates that there is a need for intensification of control measures (especially continuous use of insecticides or biological agents) toward and at this point in time to prevent yield losses. Selection of Monitoring Methods: The significant population differences between shallots and leeks, along with the comparative data from the evaluated traps, allow farmers to select the most effective and cost-efficient monitoring techniques (e.g., sweep nets or hand-picking for rapid larval sampling), which is crucial for timely IPM decisions.

Dual Host Cultivation Strategy: Population differences between shallots and leeks need to be taken into account in rotational or polyculture host crop strategies in the region, where leeks may act as alternative hosts to shallots, thus influencing the regional species dynamics of *S. exigua*.

From the observations in Parhoboran Village, Pagaran Sub-district, North Tapanuli Regency, North Sumatra, nine pest species were detected, namely, *Micraspis crocea*, *Conoderus posticus*, *Liriomyza chinensis*, *Empoasca fabae*, *Mictis longicornis*, *Spodoptera exigua*, *Agrotis ipsilon*, *Valanga nigricornis*, and *Mantis religiosa*. *S. exigua* was the most common insect found on shallots (75.2 individuals), while *Mictis longicornis* was the least common (4.6 individuals). The insect population size on shallots from day 7 to day 70 after planting fluctuated. On the seventh day after planting, the intensity of larval attacks was 6.00%, which continuously increased until day 40 after planting to 12.61%. On day 50 after planting, the intensity decreased to 9.73%, and it went further down to 8.54% on day 70 after planting. Meanwhile, based on the damaged leaf area, the average damage intensity value was 9.38%, which was categorized as very low.

In the case of Juhar Sub-district, the *S. exigua* populations were different between the two host plants observed, being 12.40 individuals on shallots and 8.11 individuals on leeks on average. Although the *S. exigua* population in Juhar Sub-district was slightly lower than that in Pagaran Sub-district (12.53 individuals), it was still considered high, exceeding the *S. exigua* population on leeks in the same location. Population fluctuations are influenced by environmental factors, such as unpredictable weather conditions and the movement of pests from one plant to another.

Further research is recommended to examine the intensity of damage to local shallot varieties, such as Samosir shallots, on organic and inorganic land by biological agents.

Abbreviations

-

Data Availability Statement

Data will be made available on request.

CRediT Authorship Contribution Statement

Ameilia Zuliyanti Siregar: analysis data, drafting, corrections, and final manuscript.

Suputa: data curation, formal analysis, and acquisition; **Lindung Tri Puspasari:** funding methodology, project administration, and resources; **Abdul Hafiz Ab. Majid:** analysis data, supervision, validation, and supervised manuscript.

Declaration of Competing Interest

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

Declaration of Use of AI in the Writing Process

Nothing to disclose.

Acknowledgement

The researchers would like thank you to Rector University of Sumatera Utara, Director of Research Centre University Sumatera Utara, teams Indonesian Researcher Collaboration (IRC) from University of Gajah Mada, University of Padjajaran, and University of Sciences Malaysia (USM), Grant Number is 16773/UN5.1.R/PPM/2024 and 10/UN/5.4.10.K/PPM/KP-RKI/2024. Then thank you very much to farmers of horticulture from Northern Tapanuli Regency and Karo Regency of Northern Sumatera given some information and data, sampling together.

References

- [1] Badan Penelitian dan Pengembangan Pertanian. Teknologi Penanganan Pascapanen Bawang Merah di Indonesia. Jakarta: Balai Besar Penelitian Pengembangan Pascapanen; 2016. <https://hortikultura.pertanian.go.id/teknologi-penanganan-pascapanen-bawang-merah-di-indonesia/>
- [2] Statistik BP. Produksi Tanaman Sayuran Menurut Kabupaten/Kota dan Jenis Tanaman di Provinsi Sumatera Utara, 2023. sumutbpsgoid. Accessed On April 10, 2025 2024. <https://sumut.bps.go.id/id/statistics-table/3/ZUhFd1JtZzJWVVpqWTJsV05XTllhVmhRSzFoNFFUMDkjMw==/produksi-tanaman-sayuran-menurut-kabupaten-kota-dan-jenis-tanaman-di-provinsi-sumatera-utara--2023.html?year=2023>.
- [3] Norfadzilah AF, Rozita WEW, Hazlina MSN, Raimi AKM, Najah Y, Zamri KM, et al. Yield of Shallot (*Allium Cepa* Var. *Aggregatum* L.) From Different Harvesting Age. *Int J Agric* 2023;13:214–21. <https://doi.org/10.22146/ipas.26749>.
- [4] Tori H, Dyanasari, Kholil AY. Prospect Analysis of Onion (*Allium cepa* L) Production in Indonesia. *Int J Agric Environ Anal* 2023;2:1–14. <https://doi.org/10.55927/ijaea.v2i1.2705>.
- [5] Azidah AA, Sofian-Azirun M. Life History Of *Spodoptera Exigua* (Lepidoptera: Noctuidae) On Various Host Plants. *Bull Entomol Res* 2006;96:613–618. <https://doi.org/10.1079/BER2006461>.
- [6] Ratnawati, Sjam S, Rosmana A, Tresnaputra US, Jaya K. Impact Of Pesticide Application In High Frequency On Stomatal Number At Local Shallot In Palu Valley. *IOP Conf Ser Earth Environ Sci* 2020;486:1–7. <https://doi.org/10.1088/1755-1315/486/1/012168>.
- [7] Stewart SD, Graham LC, Gaylor MJ, Vanderberg, LA. Combining Exclusion Techniques and Larval Death-Rate Analyses to Evaluate Mortality Factors of *Spodoptera exigua* (Lepidoptera: Noctuidae) in Cotton. *The Florida Entomologist* 2001;84:7–22. <https://doi.org/10.2307/3496657>.
- [8] Badan Pusat Statistik. Statistik Tanaman Hortikultura Provinsi Sumatera Utara 2022. Medan: Badan Pusat Statistik Provinsi Sumatera Utara; 2023.

- <https://sumut.bps.go.id/id/publication/2023/12/07/5f93b27f91659c9552bb1c0b/statistik-tanaman-hortikultura-provinsi-sumatera-utara-2022-.html>
- [9] Sembiring A, Prabaningrum, L. Moekasan TK. Farmers, Traders and Households' Preference to IVegRI's Open-Pollinated Chili Varieties in Lembang, West Java, Indonesia. *Caraka Tani J Sustain Agric* 2022;37:321–332. <https://doi.org/10.20961/carakatani.v37i2.58346>.
- [10] Ujiyanti F, Trisyono YA, Witjaksono W, Suputa S. Population of Spodoptera Exigua Hübner During On- and Off-Season Of Shallot In Bantul Regency, Yogyakarta. *J Perlindungan Tanam Indones* 2019;23:1–9. <https://doi.org/10.22146/jpti.36740>.
- [11] Supartha IW, Susila IW, Sumiartha IK, Rauf A, Cruz LBDC, Yudha IKW, et al. Preference, Population Development, And Molecular Characteristics Of Spodoptera Exigua (Lepidoptera: Noctuidae) On Shallot Cultivars: A Field Trial Scale. *Biodiversitas* 2022;23:783–92. <https://doi.org/10.13057/biodiv/d230224>.
- [12] Ekawanti A, Kurnia NRD, Arifin FAM, Mahdalena LA, Mujahidin I, Novenda IL. Sistem Pengendalian Hama Ulat Grayak (Spodoptera Exigua) Di Lahan Bawang Merah Berbasis Pertanian Berkelanjutan Pada Kelompok Tani Desa Karanggeger Probolinggo. *J Abdidas* 2023;4:465–72. <https://doi.org/10.31004/abdidas.v4i6.856>.
- [13] Pangestu RAD, Hadiwiyono, Supriyadi. The Effect Of Application Of Control Techniques To The Population, Damage Intensity Of Onion Caterpillar (Spodoptera exigua Hubner) And Yield Of Shallots. *IOP Conf Ser Earth Environ Sci* 2021;905:1–10. <https://doi.org/10.1088/1755-1315/905/1/012109>.
- [14] Hafeez M, Ullah F, Khan MM, Li X, Zhang Z, Shah S, et al. Metabolic-Based Insecticide Resistance Mechanism And Ecofriendly Approaches For Controlling Of Beet Armyworm Spodoptera Exigua: A Review. *Environ Sci Pollut Res* 2021;29:1746–1762. <https://doi.org/10.1007/s11356-021-16974-w>.
- [15] Moekasan TK, Setiawati W, Hasan F, Runa R, Somantri A. Penetapan Ambang Pengendalian Spodoptera exigua pada Tanaman Bawang Merah Menggunakan Feromonoid Seks. *J Hortik* 2013;23:80–90. <https://repository.pertanian.go.id/handle/123456789/968>
- [16] García-Marín E, Gamir J, Crava CM. Proteomic Variation in the Oral Secretion Of Spodoptera Exigua And Spodoptera Littoralis Larvae In Response To Different Food Sources. *J Chem Ecol* 2025;51:1–10. <https://doi.org/10.1007/s10886-025-01571-9>.
- [17] Satiman U, Tulung M, Pelealu J, Salaki CL, Kolondam BJ, Tallei TE, et al. Morphology, Diversity And Phylogenetic Analysis Of Spodoptera Exigua (Lepidoptera: Noctuidae) in North Sulawesi By Employing Partial Mitochondrial Cytochrome Oxidase 1 Gene Sequences. *J Adv Biotechnol Exp Ther* 2022;5:136–147. <https://doi.org/10.5455/jabet.2022.d103>.
- [18] Adisty Z, Taofik A, Yusidah I, Firmansyah E. Mortality and Attack Intensity of Spodoptera exigua on Shallots With Clove Essential Oil Application (ICOSEAT 2022). *Proc Int Conf Sustain Environ Agric Tour* 2023;29:1–4. https://doi.org/10.2991/978-94-6463-086-2_37.
- [19] Mehta V, CS J, Koranga R, Negi N. Developmental Biology Of Spodoptera Exigua (Hubner) (Lepidoptera : Noctuidae) On Tomato Under Mid hills (Sub-Humid) Conditions of India. *Biol Forum – An Int J* 2021;13:11–5. https://www.researchtrend.net/bfij/pdf/2_Developmental_Biology_of_Spodoptera_exigua_Hubner_Lepidoptera_Noctuidae_on_Tomato_under_Mid_hills_sub-humid_Conditions_of_India_Vasu_Mehta_1253.pdf
- [20] Jannah M, Supeno B, Windarningsih M. Membangun Sinergi antar Perguruan Tinggi dan Industri Pertanian dalam Rangka Implementasi Merdeka Belajar Kampus Merdeka. Keragaman Predator Ulat Gerayak Jagung (Spodoptera frugiperda) Selama Pertumbuhan Tanaman Jagung (Zea mays L) Di Desa Ireng Lombok B. *Semin Nas Dalam Rangka Dies Natalis Ke-45 UNS Tahun 2021* 2021;5:1134–1152. <https://jurnal.fp.uns.ac.id/index.php/semnas/article/view/1851>
- [21] Peni M. Keanekaragaman Serangga Pada Tanaman Bawang Merah Di Desa Oetefu Besar, Kecamatan Semau Selatan, Kabupaten Kupang. Kupang: UPT Perpustakaan Undana; 2022.

- http://skripsi.undana.ac.id/index.php?p=show_detail&id=8957&keywords=
- [22] Astuti WTL, Daryanto A, Syaikat Y, Daryanto HK. Analisis Resiko Produksi Usahatani Bawang Merah Pada Musim Kering Dan Musim Hujan Di Kabupaten Brebes. *J Ekon Pertan Agribisnis* 2019;3:840–852. <https://doi.org/10.21776/ub.jepa.2019.003.04.19>
<https://jepa.ub.ac.id/index.php/jepa/article/view/298>
- [23] Tran GB, Ngo TMT. The Effect Of Thermal Treatment On Antioxidant And Physicochemical Properties Of Black Shallot (*Allium Ascalonicum*). *J Teknol* 2023;85:179–87. <https://doi.org/10.11113/jurnalteknologi.v85.19244>.
- [24] Siregar WS, Ginting TY, Lubis N. The effectiveness Assay Of Vegetable Pesticides Papaya And Mahogany Leaf Extracts In Pest Control of Spodoptera Exigua (Lepidoptera: Noctuidae) On Onion (*Allium ascalonicum* L) Cultivation. *J Pembelajaran Dan Biol Nukl* 2024;10:304–16. <https://doi.org/10.36987/jpbn.v10i1.5394>.
- [25] Aldini GM, Trisyono YA, Wijonarko A, Witjaksono W, De Putter H. Farmers' Practices in Using Insecticides To Control Spodoptera Exigua Infesting Shallot *Allium cepa* var. *Aggregatum* In The Shallot Production Centers Of Java. *J Perlindungan Tanam Indones* 2020;24:75–81. <https://doi.org/10.22146/jpti.47893>.
- [26] Aldini GM, Wijonarko A, Witjaksono W, De Putter H, Hengsdijk H, Trisyono YA. Insecticide Resistance in Spodoptera Exigua (Lepidoptera: Noctuidae) Populations In Shallot Areas of Java, Indonesia. *J Econ Entomol* 2021;114:2505–2511. <https://academic.oup.com/jee/article/114/6/2505/6372260>
- [27] Harahap N, Lestari YM, Siregar AZ. Pemberdayaan dalam Meningkatkan Kesejahteraan Petani Bawang Merah Di Kecamatan Medan Marelan. *J Penyul* 2023;19:170–180. <https://doi.org/10.25015/19202340349>.
- [28] Permadi MA, Lubis RA, Syawaludin S, Pasaribu NS. Utilization Of Papaya Leaves (*Carica papaya* L.) To Control Onion Pest Spodoptera Exigua (Lepidoptera: Noctuidae). *J Biol Lingkung Ind Kesehat* 2020;7:1–7. <https://doi.org/10.31289/biolink.v7i1.2856>.
- [29] Nurhandani P, Maerheni, Safni I, Girsang S. Keanekaragaman Jenis Serangga Pada Pertanaman Bawang Merah (*Allium ascalonicum* L) Asal Biji di Berbagai Ketinggian Pertanian Tropik. Universitas Sumatera Utara, 2015. <https://repositori.usu.ac.id/handle/123456789/11637>
- [30] Hidrayani, Nurbailis N, Yeni F, Ikhsan Z. Interactive Effects Of Rhizobacteria For Managing Spodoptera Exigua On Shallot Plants (*Allium cepa* Linnaeus) Under Field Conditions. *J Prot Tanam* 2024;8:12–20. <https://doi.org/10.25077/jpt.8.1.12-20.2024>.
- [31] Kusumawati R, Sahetapy B, Noya SH. Uji Ketertarikan Imago Spodoptera Exigua Hubner Terhadap Beberapa Perangkap Pada Tanaman Bawang Merah (*Allium cepa* var *ascalonicum*). *Agrologia* 2022;11:59–66. <https://ojs.unpatti.ac.id/index.php/agrologia/article/download/1543/720>
- [32] Rachmawati VE, Maarif MS, Maharani M, Deden D, Dukat D, Umiyati U. The Effect of Organic Insecticide and Various Cultivars On Attack Intensity of Spodoptera exigua and Results Shallots (*Allium Ascalonicum* L.). *J Univers Stud* 2023;3:1340–6. <https://doi.org/10.59188/eduvest.v3i7.867>.
- [33] Witjaksono, Trisyono YA, Tanjung HR, Azzahra Z. Population Dynamic And Pheromone Use For Early Monitoring Of Spodoptera Exigua Hübner (Lepidoptera: Noctuidae) In Indonesia. *J Trop Plant Pests Dis* 2024;24:91–7. <https://doi.org/10.23960/jhptt.12491-97>.