International Journal of Social Science, Educational, Economics, Agriculture Research and Technology (IJSET) | ISSN (e) : 2827-766X
Volumes 4 No. 12 (2025)

STUDY OF REFUGIA AND VARIETIES TO REDUCE THE INTENSITY OF SPODOPTERA FRUGIPERDA AND INCREASE PREDATORS OF SWEET CORN PESTS

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Received : 01 August 2025		Published	:22 September 2025
Revised : 11 August 2025		DOI	:https://doi.org/10.54443/ijset.v4i12.1159
Accepted : 30 August 2025		Publish Link	:https://www.ijset.org/index.php/ijset/index

Abstract

The research was conducted at the Experimental Field of the Faculty of Agriculture, University of Islam Sumatera Utara, Jln. Karya Wisata, Gedung Johor, Medan Johor District, Medan City, North Sumatra Province, at an altitude of approximately 25 metres above sea level, with flat topography. This research was conducted from January to March 2025. S. frugiferda is an important pest on corn plants that can cause losses with an attack intensity of up to 80%. The purpose of this research was to determine the effect of refugia plants and corn varieties on S. frugiferda attacks and the number of pest predators. This study used a split-plot design with two treatment factors, namely refugia plants Turnera subulata (B1), Tagetes erecta (B2), No Refugia (B0), and treatments of Pertiwi variety (V1) and Advanta Madu 59 variety (V2). The results showed that the Turnera subulata refugia plant and the Advanta Madu 59 variety produced lower S. frugiferda pest attacks and higher numbers of pest predators, although this was not statistically significant.

Keywords: ***Maize, varieties, refugia.***

INTRODUCTION

Sweet corn has bright prospects in the market. The popularity of sweet corn has increased rapidly in recent years around the world due to the increased focus on health and nutrition. The increase in sweet corn consumption over the past few years has shifted farmers' interest towards sweet corn cultivation. According to data from the Badan Pusat Statistik (2023), corn production increased in 2022 to 16.53 million tonnes. However, in 2023, production declined to only 14.46 million tonnes, a decrease of 2.07 million tonnes or 12.50%. This decline in corn production can be attributed to various factors, one of which is the attack of Plant Pests (OPT), namely S. frugiferda (Kementerian Pertanian, 2019). The fall armyworm S. frugiperda J.E. Smith is an invasive insect that has become a pest on corn plants (Zea mays L.) in Indonesia. This insect originates from America and has spread to various countries. In early 2019, this pest was found on corn plants in the Sumatra region (Ministry of Agriculture, 2019). In 2019, it was reported that S. frugiperda had infested an area of 31,856 ha with 120 ha of crop failure. Subsequently, in January 2020, there was an increase in the infested area to 82,000 ha, with the highest infestation occurring in January (Data as of 5 June 2020) (PEI Webinar, 2020). The damage caused by S. frugiperda ranges from 22.13 to 46.83% (Navik et al., 2021). Meanwhile, according to Kalqutny et al. (2021), this pest attacks corn crops with an attack intensity of 60.12 to 87.05%, which is classified as crop failure. S. frugiperda pest control can be carried out in an environmentally friendly manner by using refugia plants. Refugia are types of plants that can provide shelter, food sources or other resources and are beneficial to natural enemies such as predators and parasitoids (Amanda, 2017). Several studies have shown that the presence of refugia flowers can attract and increase the presence and diversity of natural enemies to suppress the population of S. frugiperda, the main pest of corn plants. (Widyastuti et al., 2020). Nine species were found to act as predators of S. frugiferda, including the spider Oxyopes salticus (Araneae: Oxypidae), Dermaptera, the robber fly Holcocephala sp. (Diptera:

Asilidae), Rainieria sp. flies (Diptera: Micropezidae), Orius insidiosus bugs (Hemiptera: Anthocoridae), Dolichoderus sp. ants, Paratrechina sp. ants, Oecophylla sp. ants (Hymenoptera: Formicidae) and grasshoppers Conocephalus longipennis (Orthoptera: Tettigoniidae) (Suroto, 2021). The author considers it necessary to conduct research to see how refugia plants and sweet corn varieties affect the intensity of S. frugiferda pest attacks and pest predator populations.

LITERATURE REVIEW

The classification and morphology of the S. frugiperda pest according to Plessis et al. (2020) are as follows: Kingdom: Animalia; Phylum: Arthropoda; Class: Insecta; Order: Lepidoptera; Family: Noctuidae; Genus: Spodoptera; Species: Spodoptera frugiperdai. Based on the results of Rusisah's (2021) research, the S. frugiperda pest attacks corn crops at 1 week of age. This pest attacks from the vegetative phase to the generative phase. Pest attacks in the vegetative phase are characterised by the presence of coarse brown sawdust-like powder, while in the generative phase, this pest attacks the cobs and male flowers.

The tips of corn leaves that have not fully opened (buds) will appear hollow and contain a lot of larval faeces if attacked by larvae. If the leaves have opened, many parts of the leaves will appear damaged and hollow from the larvae's movements. S. frugiferda larvae usually settle on the tips of plants. The symptoms of S. frugiperda attack on corn shoots are similar to those caused by Mythimna separata (Lepidoptera: Noctuidae) larvae, so the determination of S. frugiperda attack will be biased if not observed directly on the affected parts of the plant (Maharani et al., 2019). Refugia plants can be utilised as part of a biological control strategy, as they have been proven to have a significant impact on suppressing the population of S. frugiperda, the main invasive pest of maize crops. Refugia serve as alternative habitats for the survival of natural enemies such as parasitoids and insect predators, thereby increasing the number of natural enemies and their effectiveness in controlling pest populations (Gurr et al., 2017). Several studies have shown that planting refuge plants such as sunflowers, cosmos (Cosmos sulphureus), and other flowering plants can increase the diversity and abundance of natural enemies, such as Cotesia marginiventris and Trichogramma spp., which are important control agents against S. frugiperda eggs and larvae (Wyckhuys et al., 2020; Rwomushana et al., 2019). By providing additional food sources in the form of nectar and shelter, refugia support a more stable and sustainable life cycle for natural enemies. Refugia plants are also considered environmentally friendly because they reduce dependence on chemical pesticides (FAO, 2021). Therefore, the application of refugia plants in integrated farming systems is an effective and sustainable approach to managing S. frugiperda pest populations.

METHOD

The research was conducted at the Experimental Field of the Faculty of Agriculture, University of Islam Sumatera Utara, Jln. Karya Wisata, Gedung Johor, Medan Johor District, Medan City, North Sumatra Province, at an altitude of ± 25 metres above sea level, with flat topography. This research was conducted from January to March 2025. This study used a split-plot design (RPT) with two treatment factors, namely refugia plants Turnera subulata (B1), Tagetes erecta (B2), No Refugia (B0) and Pertiwi variety treatment (V1), Advanta Madu 59 variety treatment (V2) with four treatment repetitions. The research data were analysed using Analysis of Variance (ANOVA) and followed by Duncan's Multiple Range Test (DMRT) at a 5% confidence level.

The observations conducted consisted of: 1. Intensity of S. frugiperda attacks; 2. Number of S. frugiperda pest predators.

1. Intensity of S. frugiperda attacks

The calculation of the intensity of attacks (IS) caused by S. frugiferda was obtained using Equation (Natawigena, 1993).

Is = Attack Intensity

$$I = \frac{\sum_{i=0}^{z}(n_i \times v_i)}{Z \times N} \times 100\%$$

ni = Number of damaged plants from each attack category
vi = Damage scale value for the i-th category
N = Number of plants observed
Z = Highest score assigned

The observation method was carried out by determining the scale of damage to plant leaves (scale 0–5 or 0–9), which indicates the severity of the attack on each plant. The higher the IS value, the greater the level of damage to the corn plants. Calculating the attack intensity is very important in determining the level of S. frugiperda pest attacks and in making control decisions. By knowing the IS value, farmers or researchers can evaluate the effectiveness of the control methods used, determine the economic control threshold, and develop more efficient and environmentally friendly integrated pest management (IPM) strategies. The damage score/scale (vi) refers to the Davis scoring (Nonci et al., 2019).

Table 1. S. frugiperda pest attack scores.

Score	Description
0	No damage visible on leaves
1	Damage only as small as a pinhole
2	Damage as small as a pinhole and small circular holes on leaves
3	Damage visible as pinholes, small circular lesions, and a few small elongated (rectangular) lesions up to 1.3 cm long on leaf rolls and leaf blades
4	Several small to medium elongated lesions with a length of 1.3-2.5 cm are visible on the leaf rolls and blades
5	Several large elongated lesions measuring more than 2.5 cm are visible on a few leaf rolls and leaf blades and/or several small to medium-sized holes with a uniform to irregular shape (lower membrane eaten) are visible on leaf rolls or leaf blades
6	Several large elongated lesions are visible on some leaf rolls and/or leaf blades and/or several large holes with uniform to irregular shapes are visible on leaf rolls and leaf blades
7	Numerous elongated lesions of all sizes are visible on some leaf blades and rolls, plus several large holes with uniform to irregular shapes are visible on leaf rolls and leaf blades
8	Numerous elongated lesions of all sizes are present on most leaf rolls and leaf blades, plus numerous medium to large uniform to irregular holes are visible on leaf rolls and leaf blades
9	Leaf rolls and leaf blades are almost completely destroyed

The intensity categories of S. frugiperda damage are differentiated based on the damage intensity value and plant age (Table 2).

Table 2. Intensity categories of S. frugiperda damage on corn leaves.

Category	Plant Age		
	0-2 WAP	2-4 WAP	>4 WAP
Mild	0-10%	0-20%	0-40%
Moderate	11-20%	21-40%	41-60%
Severe	21-40%	41-60%	61-75%
Very severe	41-85%	61-85%	76-85%
Puso	>85%	>85%	>85%

Note: WAP (week after planting)

2. Number of S. frugiperda pest predators.

Observations of the presence of predators were carried out directly in the field using a sweep net. The catch from each sweep of the net was then placed in a transparent bottle filled with 70% alcohol as a preservative. The observation process was carried out in the morning, starting at 07:00 to 09:00 WIB, when insect activity tended to be higher. Each individual caught was then identified and counted based on the classification of predator types present in the planting area. Identification was carried out at the Indonesian Agricultural Quarantine Agency, Medan Petisah, using insect determination keys to ensure data accuracy.

RESULTS AND DISCUSSION

1. Intensity of S. frugiperda attacks

Data on the effect of refuge plants and sweet corn varieties on the intensity of S. frugiperda attacks (Table 1). The use of refuge plants, varieties, and the interaction between refuge plants and varieties had no significant effect on the intensity of S. frugiperda attacks.

Table 3. Intensity of S. frugiperda attacks 2-6 wap

Treatment	Plant Age (WA)				
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP
Refugia					
control	00,0	1,13	3,21	4,43	6,60
Turnera subulata	00,0	0,87	3,13	2,86	4,51
Tagetes erecta	00,0	0,87	2,95	4,51	5,47
Varieties					
Pertiwi	00,0	1,10	3,59	4,92	6,08
Advanta Madu 59	00,0	0,81	2,60	2,95	4,98
Interactions B * V					
B0V1	00,0	0,52	1,56	2,78	1,79
B0V2	00,0	1,74	4,86	6,08	2,73
B1V1	00,0	1,04	3,30	3,82	2,32
B1V2	00,0	0,69	2,95	1,91	1,50
B2V1	00,0	1,74	5,90	8,16	2,88
B2V2	00,0	0,00	0,00	0,87	1,53

Note: Figures followed by the same letter indicate no significant difference at the 5% level.

Based on Table 1, the results of the Analysis of Variance test at the 5% level show that the refugia treatment had no significant effect on the intensity of S. frugiperda attacks. However, the highest attack intensity was in the control treatment, which was 6.60%, which was not significantly different from the Turnera subulata treatment, which was 4.51%, and the Tagetes erecta treatment, which was 5.47%. Similarly, the variety treatment had no significant effect on the highest attack intensity of the Pertiwi treatment, which was 6.08% and not significantly different from the Advanta Madu 59 treatment, which was 4.98%. Likewise, there was no interaction between refugia flowers and varieties.

The main issue that can be highlighted from the results of this study is that refuge plants, which are grown to provide habitat for natural enemies of pests, are greatly influenced by climatic conditions, including temperature, rainfall, and light intensity. Climate variability can affect the growth and flowering time of refuge plants such as Tagetes erecta, Turnera subulata, and Cosmos sulphureus, which are sources of nectar and shelter for predatory and parasitoid insects. Extreme high temperatures can accelerate the life cycle of refuge plants but can reduce nectar content and flower aroma, potentially decreasing their attractiveness to beneficial insects (Jonsson et al., 2008). In addition, excessive rainfall can cause physical damage to the flowers and foliage of refuge plants, thereby disrupting their ecological function in supporting biodiversity in agricultural land (Gurr et al., 2017). Therefore, selecting refuge species that are adaptive to the local climate is very important to ensure their function in supporting optimal biological control.

The intensive use of synthetic chemical pesticides on agricultural land planted with refuge crops can interfere with the effectiveness of the biological control system expected from the presence of these refuge crops. Broad-spectrum pesticides can kill or repel natural enemies such as Coccinellidae, Syrphidae, and Trichogramma spp. parasitoids that shelter and feed around refuge plants (Gurr et al., 2012). In addition, pesticide residues carried by wind or rainwater can contaminate refuge plants, thereby reducing the quality of nectar and pollen that are important for the survival of natural enemies. Biondi et al. (2012) showed that systemic pesticides such as neonicotinoids can even translocate to the flowers of refuge plants, resulting in the death of pollinating insects and natural enemies that visit the flowers. According to Liu et al. (2018), Marigold (Tagetes spp.) refugia emit certain volatile compounds that are known to repel or prevent pest attacks. These compounds, such as limonene and oxime, act as natural insect repellents, disrupting the host-seeking behaviour of pests such as S. Exigua. Refugia

plants typically have striking colours and distinctive aromas. The decline in the population of T. erecta flowers will also affect the population of natural enemies found on Tagetes erecta flowers (Wardana et al., 2017).
However, even though refuge plants do not grow well and make pest attacks easier, the intensity of corn borer attacks remains low. Despite the weaknesses in the function of refuge plants, this shows that there are other factors that may contribute to the low intensity of pest attacks, such as the presence of natural enemies of pests or environmental conditions that are not conducive to the reproduction of S. frugiferda pests and the success of pest attacks. In addition, corn borer pests may also have a more selective or preferential attack pattern towards certain plant varieties, which explains why attacks are not too intense even though there are gaps that allow attacks to occur. Overall, even though the refugia plants did not grow optimally, the presence of pests.

2. Number of S. frugiferda Pest Predators

Data on the number of S. frugiferda pest predators observed on refuge plants and varieties can be seen in Figure 1. Treatment using refuge plants, varieties, and the interaction between refuge plant treatment and varieties had no significant effect on the number of S. frugiperda pest predators.

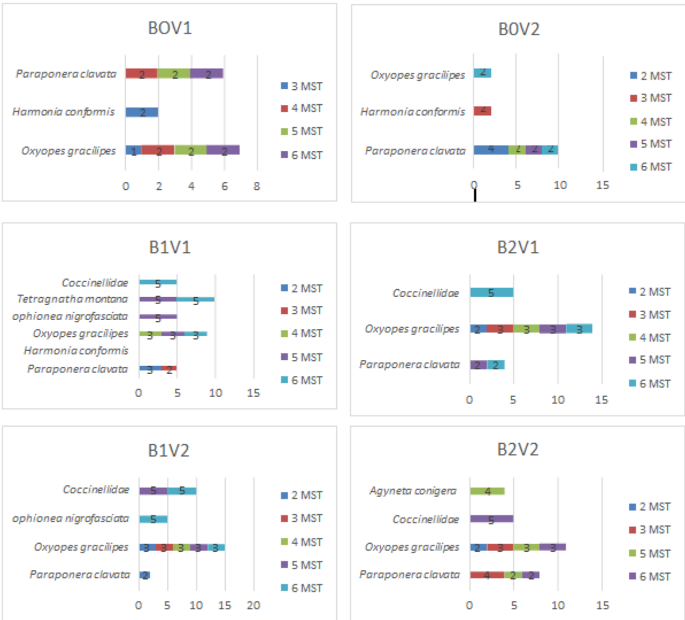

Figure 1. Natural Enemy Graph 2-6 MST

Although there was no significant effect on the use of refuge plants, varieties, and the interaction between refuge plant treatments and varieties on the number of S. frugiperda pest predators, it can be seen that the refuge plant species Turnera subulata and the Advanta Madu 59 variety produced higher numbers of pest predators. This indicates that certain types of refuge plants and sweet corn varieties can attract more pest predators to approach the plants.Planting edge plants can encourage the conservation of natural enemies such as predators (Mahmud, 2006). According to Septariani et al. (2019), refugia are flowering plants that serve as microhabitats for natural enemies, both predators and parasitoids, with the aim of preserving natural enemies. According to Sunariah et al. (2016), long-jawed spiders are a species of the Tetragnathidae family that act as predators. Insects from the Formicidae family, known as ants, can live and thrive in habitats that are disturbed by human activity. Furthermore, the abundance of ants in corn habitats can be influenced by the availability of food and environmental conditions suitable for ant nesting (Adhi et al., 2018). Ants can act as predatory insects and decomposers in ecosystems.

Predators/natural enemies that have the potential to be effective predators in controlling pest populations in the field are ladybirds (Coccinellidae). Coccinellidae predators are a family of the order Coleoptera. The Coccinellidae family consists of seven subfamilies, namely Epilachninae, Coccinellinae, Chilocorinae, Coccidulinae, Ortaliinae, Scymninae, and Sticholotidinae. Most members of these seven subfamilies are known as predators of small soft-bodied insects such as aphids, scale insects, and insect eggs, while others are known as predators of other insects (Amir, 2002). Based on observation data, the combination of treatments using Turnera subulata refugia and Advanta Madu 59 (B1V2) corn varieties showed the highest Coccinellidae sp population, namely 10 individuals, while no Coccinellidae sp were found in the control. In the control treatment, no

Coccinellidae were found due to the absence of Turnera subulata and Tagetes erecta refugia as alternative habitats that support the survival of natural enemies (Gurr et al., 2017).

CONCLUSION

Turnera subulata and Advanta Madu 59 varieties of refuge plants resulted in lower S. frugiferda pest attacks and higher numbers of pest predators, although this was not statistically significant. The use of Turnera subulata and Advanta Madu 59 varieties as refugia is recommended in the hope that low S. frugiperda pest intensity and high numbers of pest predators will indirectly optimise sweet corn productivity.

REFERENCES

Adhi, S. L., Hadi, M., & T, U. (2018). Keanekaragaman dan Kelimpahan Semut sebagai Predator Hama Tanaman Padi di Lahan Sawah Organik dan Anorganik Kecamatan Karanganom Kabupaten Klaten. Bioma : Berkala Ilmiah Biologi, 19(2), 125. https://doi.org/10.14710/bioma.19.2.125- 135

Amanda, U.M. 2017. Pemanfaatan Tanaman Refugia Untuk Mengendalikan Hama Dan Penyakit.ISSN: 9772088-8929. Vol. 7(2): 45-60.

Amir. 2002. Kumbang Lembing Pemangsa Coccinellidae Puslit Biologi - LIPI. Bogor. Indonesia.

Badan Pusat Statistik (BPS). 2023. Berita resmi statistic: In Sensus Pertanian 2023. https://www.bps.go.id/id/statistics-table/2/MjIwNCMy/luas-panen produksi dan produktivitas-jagung-menurut-provinsi.html

Biondi, A., Desneux, N., Siscaro, G., & Zappalà, L. (2012). Using organic-certified rather than synthetic pesticides may not be safer for biological control agents: Selectivity and side effects of 14 pesticides on the predator Orius laevigatus. Chemosphere, 87(7), 803–812.

FAO. (2021). Global action for fall armyworm control: Action framework 2021– 2023. Food and Agriculture Organization of the United Nations. https://www.fao.org/documents/card/en/c/cb2856en.

Gurr, G. M., Lu, Z., Zheng, X., Xu, H., Zhu, P., Chen, G., . & Heong, K. L. (2012). Multi-country evidence that crop diversification promotes ecological intensification of agriculture. Nature Plants, 2(3), 16014.

Gurr, G. M., Wratten, S. D., & Snyder, W. E. (2017). Biodiversity and Insect Pests: Key Issues for Sustainable Management. John Wiley & Sons.

Gurr, G. M., Wratten, S. D., Landis, D. A., & You, M. (2017). Habitat management to suppress pest populations: Progress and prospects. Annual Review of Entomology, 62, 91–109. https://doi.org/10.1146/annurev-ento-031616-035050

Jonsson, M., Wratten, S. D., Landis, D. A., & Gurr, G. M. (2008). Recent advances in conservation biological control of arthropods by arthropods. Biological Control, 45(2), 172–175.

Kalqutny, S. H., et al. 2021. The Incidence of Fall Armyworm Spodoptera frugiperda J.E. Smith (FAW) (Lepidoptera: Noctuidae), A Newly Invasive Corn Pest in Indonesia. IOP Conference Series Earth and Environmental Science 911(1): 1-10.

Kementerian Pertanian. 2019. Pengenalan Fall Armyworm (Spodoptera frugiperda J. E. Smith) Hama Baru pada Tanaman Jagung di Indonesia. Jakarta (ID): Balai Penelitian Tanaman Serealia. 64 p.

Liu, S., Zhang, S., & Wang, Z. (2018). The repelling mechanism of limonene on Spodoptera exigua. Journal of Chemical Ecology, 44(10), 973-980.

Maharani Y., Dewi, V. K., Puspasari, L. T., Rizkie, L., Hidayat Y. and D. Dono. 2019. Cases of Fall army worm Spodoptera frugiperda J. E. Smith (Lepidoptera: Noctuidae) Attack on Maize in Bandung, Garut, and Sumedang District, West Java. Cropsaver, 2(1): 38-46.

Mahmud, T. (2006) Identifikasi serangga di sekitar tumbuhan kangkungan (Ipomoeas crassicaulis roob.) Universitas Islam Negeri Malang.

Natawigena H. 1993. Dasar-dasar Perlindungan Tanaman. Bandung (ID): Trigenda Karya.

Navik O, Shylesha AN, Patil J, Venkatesan T, Lalitha Y, Ashika TR. 2021. Damage, distribution and natural enemies of invasive fall armyworm Spodoptera frugiperda (J. E. smith) under rainfed maize in Karnataka, India. Crop Protection. 143:105536. DOI: https://doi.org/10.1016/j. cropro.2021.105536.

Nonci N., Kalqutny S. H., Mirsam H., Muis A., Azrai M., Aqil M. 2019. Pengenalan fall armyworm (Spodoptera frugiperda J.E. Smith) hama baru pada tanaman jagung di Indonesia. Maros: Balai Penelitian Tanaman Serealia.

Plessis, H. du, Schlemmer, M. L., & Van den Berg, J. 2020. The effect of temperature on the development of Spodoptera frugiperda (Lepidoptera: Noctuidae). Insects, 11(4). https://doi.org/10.3390/insects11040228. pp. 1 – 9.

Rusisah, A. M. (2021). Studi Perilaku Petani Terhadap Serangan Hama Spodoptera frugiperda J.E Smith (Lepidoptera: Noctuidae) Di Pertanaman Jagung Lingkungan Lare'e Kecamatan Pammana Kabupaten Wajo. Universitas Hasanudin.

Rwomushana, I., Bateman, M., Beale, T., Beseh, P., Cameron, K., Chiluba, M., & Day, R. (2019). Fall armyworm: Impacts and implications for Africa. Outlooks on Pest Management, 30(5), 220–226. https://doi.org/10.1564/v30_oct_02.

Septariani, D. N., Herawati, A. and Mujiyo., 2019. Pemanfaatan Berbagai Tanaman Refugia sebagai Pengendali Hama Alami pada Tanaman Cabai (Capsicum annum L.). PRIMA: Journal of Community Empowering and Services. 3(1),

Sunariah F, Siti H, Yuanita W. 2016. Kelimpahan arthropoda karnivora di pertanaman padiratun di sawah lebak yang diaplikasikan bioinsektisida Bacillus thruringiensis. Jurnal Penelitian Sains. 18(1): 22-28.

Suroto, A. Soesanto, L., Anik, N, W., Bahrudin, M. 2021. Tingkat Serangan dan Musuh Alami Spodoptera frugiperda J.E Smith pada Tanaman Jagung di Lima Kecamatan di Kabupaten Banyumas. Proceedings Series on Physical & Formal Sciences, Volume 2 Prosiding Seminar Nasional Fakultas Pertanian dan Perikanan ISBN: 978-602-6697-91-2 ISSN: 2808-7046

Wardana, R., Erdiyansyah, I., & Putri, S. U. (2017). Presistensi Hama (Pemanfaatan Tanaman Refugia Sebagai Sistem Pengendali Hama Padi) Pada Kelompok Tani Suren Jaya 01, Kecamatan Ledokombo. In Seminar Nasional Hasil Pengabdian Kepada Masyarakat(pp. 233–237).

Webinar PEI., 2020. Kebijakan Nasional Pengendalian Hama Ulat Grayak Jagung Spodoptera frugiperda. Departemen Proteksi Tanaman-IPB

Widyastuti, D., Prasetyo, L. B., & Santosa, D. A. (2020). Peran tanaman refugia dalam pengendalian hayati hama ulat grayak (Spodoptera frugiperda) pada pertanaman jagung. Jurnal Perlindungan Tanaman Indonesia, 24(1), 12– 20.

Wyckhuys, K. A. G., Hughes, A. C., Buisson, E., Bregaglio, S., Cavalieri, A. J., Ferrer, M. C., & Desneux, N. (2020). Biological control of fall armyworm: Exploring options for implementation and sustainability in Africa. Journal of Integrated Pest Management, 11(1), 1–13. https://doi.org/10.1093/jipm/pmaa001.