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Intraguild interaction, attack patterns, and community structure of maize caterpillar in Bali province, Indonesia

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Abstract Research on intraguild interaction, attack patterns, and community structure of maize caterpillar has been carried out in Bali province, Indonesia. The results showed that the population abundance index value was low (R1 = 1.08-1.91), while the diversity index value (H') was moderate with a value of 1.18-1.67, the similarity index value was in the very high category, namely IS = 100% , and the dominance index is moderate to low (D) with a value of 0.33-0.43. Found 3 guilds associated with maize in the field, namely stem-eating groups *(Ostrinia furnacalis)*, leaf-eating groups *(Spodoptera frugiperda, Mythimna separata, Spodoptera litura* and *Cnaphalocrocis medinalis)*, and cob-eating groups *(Helicoverpa armigera)*. There is no competition between these caterpillars because each has a different profession. Caterpillar pest that attack corn plants are evenly distributed in all districts/cities in Bali Province with a random distribution pattern.

Keywords: Lepidopteran, Maize pest, Maize commodities, Maize caterpillar, Integrated pest management

Introduction

Maize (*Zea mays* L.) is one of the agricultural commodities utilized as a staple food in Indonesia, second only to rice. Maize is utilized by the community which is mostly processed into a variety of products, including flour, corn oil, animal feed, and others. Sweet maize variants may be prepared

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by boiled or grilled maize. The demand for maize as a source of animal feed was up to 55%. However, when compared to its usage as a food source, approximately 30%, the remainder is used for industrial purposes and seeds (Panikkai *et al*., 2017). Therefore, the need for maize in the agricultural sector has continued to rise every year.

Bali Province is one of the provinces in Indonesia with the potential to boost maize commodity output by occupying 16,952 hectares in 2018. However, maize production has continued to face various challenges, including land degradation, climate change, and attacked plant pests as the primary reason for decreasing maize productivity (Raza *et al*., 2019). According to Kalsum (2013) who stated that there are various species of pests attacking maize plants namely shoot flies (*Atherigona* sp.), corn stem borer (*Ostrinia furnacalis*), armyworm (*Spodoptera litura*, *Mythimna* sp., *Spodoptera frugiperda*), cob borer (*Helicoverpa armigera*), aphids (*Aphis* sp.), grasshoppers (*Oxya sinensis*). The majority of pests discovered in the field used to find the members of the Order Lepidoptera, including *Spodoptera litura*, *Spodoptera frugiperda*, *Mythimna separata*, *Cnaphallocrosis medinalis*, *Ostrinia furnacalis*, and *Helicoverpa armigera* (Surtikanti, 2011).

The intraguild interactions and attack patterns of plant pests in maize have a significant impact on to decline in yields (Peterson *et al*., 2016). The community structure showing the abundance, evenness, similarity, dominance, and species diversity in a community, might reveal attack patterns (Poolprasert *et al*., 2020). This information is critical since each species attacking maize plants has a different attack pattern dictated by the age of the plant. The lack of data on the intraguild interactions of many crop production systems makes it difficult for estimating the biocontrol potential of natural enemies and designing selective cropping systems to promote the emergence of natural enemies in controlling maize caterpillar pests.

The technique related to managing pests in crops is based on the idea of Integrated Pest Management (IPM) which considers the balanced ecosystem (Deguine *et al*., 2021). Maize caterpillar pest management may be carried out to be efficiently after maize is attacked by insect pests (Montezano *et al*., 2018). However, there is no information on intraguild relationships, attack patterns, or community structure of caterpillar insects in maize production in Bali Province. IPM programs are more likely to be effective along with the prevention of pest transmission (Radcliffe *et al*., 2010).

Thus, the purpose of this study was to 1) identify intraguild relationships, 2) attack patterns, and 3) community structure of caterpillar insects on maize in the fields in Bali Province. By monitoring intraguild relationships, attack patterns, and community structures, integrated pest management is expected to boost maize yields in Bali Province.

Materials and methods

Location

The study was conducted on a field and laboratory scale. Field-scale studies were conducted in all regencies/cities of Bali Province, while the laboratory-scale study was conducted at the Integrated Pest Management Laboratory (IPMLab), Faculty of Agriculture, Udayana University, Denpasar, Bali.

Procedure

Insect sampling

Insect sampling was carried out diagonally on infected maize plants in several plantation areas in Bali with a sample unit size of 5 m × 5 m. The sampling location was determined by purposive sampling in all regencies and cities of Bali Province.

Insect identification

The caterpillar insect samples were identified by studying morphological characteristics such as color and form. Identification was carried out by physically inspecting and matching with identification rules (Kalshoven, 1981).

Observation variable

The percentage of attack, population abundance, abundance index, uniformity index, dominance index, and distribution pattern at each sampling location was determined by the following equation:

Attack rate and population abundance were determined by taking insect pest samples found in the sample unit of maize plants and collecting them into sterile plastic bags. The equation used to determine the attack rate (Putrasamedja *et al*., 2016) is as follows:

$$P = \frac{a}{b}\ x\ 100\%$$

where P = proportion of infected plants (%), a = number of infected plants, b = number of plants observed.

The abundance index is used the Margalef index, (McCarthy and Magurran, 2004) as:

$$R1 = \frac{S-1}{lnN},$$

where *R1* = Abundance index, *S* = Number of insect pest found, *Ln* = Natural logarithm, *N* = Total number of individuals,

Value : *R1* < 3.5 = Low,
R1 > 3.5-5.0 = Moderate,
R1 > 5.0 = High.

Shannon-Wiener diversity index (McCarthy and Magurran, 2004) was determined as

$$H' = -\Sigma\, pi.lnpi$$

$$pi = \frac{ni}{N}$$

Where *H'* = Diversity index, *Pi* = number of 1st type individuals divided by the total number of individuals, *Ni* = number of the-I species individuals, *N* = total number of individuals,

Value : *R1* < 1.5 = Low,
R1 > 1.5-3.0 = Moderate,
R1 > 3.5 = High.

The similarity index was determined using the Sorensen species similarity index (McCarthy and Magurran, 2004) as :

$$IS = \frac{2C}{A+B} \times 100\%$$

Where *IS* = index similarity, *C* = number of species found in areas *A* and *B*, *A* = number of species found only in area *A*, *B* = number of species found only in area *B*,

Value: 0 < *IS* ≤ 25% = Very low,
25% < *IS* ≤ 50% = Low,
50% < *IS* ≤ 75% = High,
75% < *IS* ≤ 100% = Very high.

The dominance index was determined using the Menhinick Index (McCarthy and Magurran, 2004) as

$$D = \Sigma \frac{ni(ni-1)}{N(N-1)}$$

where *D* = dominance index, *N* = total number of individuals, *Ni* = number of the-I species individuals,

Value: 0.00 < D < 0.30 = Low,
0.30 < D < 0.60 = Moderate

0.60 < D < 1.00 = High.

The Fowler and Cohen population distribution pattern (Jim *et al.*, 1998) as :

$$S^2 = \frac{\Sigma(Xi - X)}{n - 1}$$

where S^2 = Variance, Xi = i-th X, ΣX = average X, N = total sampling,

Value : $S^2/X < 1$: regular distribution pattern,
$S^2/X = 1$: random distribution pattern
$S^2/X > 1$: group distribution pattern.

Data analysis

The collected data were analyzed using the descriptive statistical analysis method and Ms. software. Excel 2019 (Microsoft, USA). Descriptive statistics were used for the data description by applying numerical and graphic methods to recognize the pattern, summarize the information which contained the data, and present the data. The insect pest distribution map was made using Quantum GIS software version 2.18.24 and CorelDraw.

Results

Intraguild interaction of caterpillar pests on maize

Field surveys revealed that there were six species of caterpillar insect pest in maize planting in Bali Province. Maize leaves were attacked by insect pests such as *Spodoptera frugiperda*, *Mythima separata*, *Spodoptera litura*, and *Cnaphalocrocis medinalis*. The maize stems were attacked by the caterpillar *Ostrinia furnacalis*, while the cobs were attacked by *Helicoverpa armigera*. The number of caterpillars detected on maize plants in Bali is presented in Figure 1.

C. medinalis larval attacking was discovered in the first week with an average population of 0.59 individuals. Furthermore, the population of *C. medinalis* larvae increased in the 2nd week after planting (wap), with an average population of 2.89 individuals. *C. medinalis* and *M. separata* larvae were detected in the highest population in 3rd (wap) with a population of 3.02 and 10.36 individuals, respectively. Meanwhile, the population of *S. frugiperda*, *S. litura*, and *M. separata* increased significantly at 2nd week after planting (wap) with a population of 43.58, 10.86, and 9.63 individuals. It is intriguingly when the larvae of *C. medinalis*, *S. frugiperda*, *S. litura*, and *M. separata* completed on 2-5 week after planting (wap) stems of maize plants.

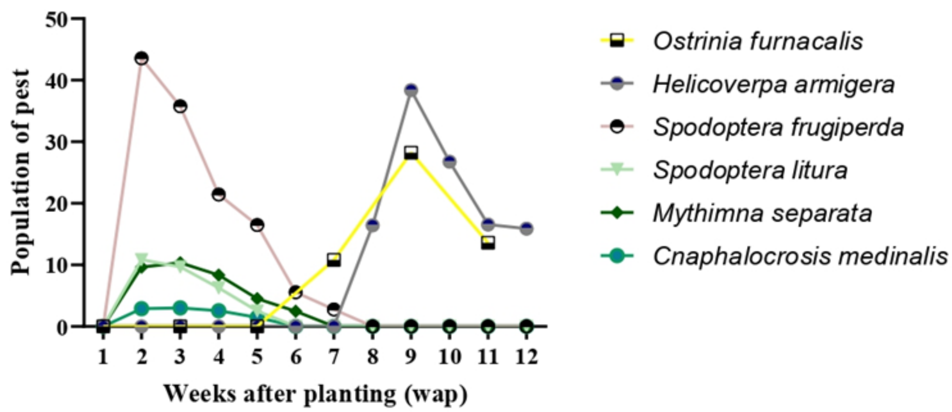

Figure 1. Caterpillar pest population rate based on corn plant age

The new population of *O. furnacalis* was found in 6 week after planting (wap) on stems of maize plants with a total population of 8.54 individuals, while the population of *C. medinalis* and *S. litura* were no longer found. *S. frugiperda* and *M. separata* competed, while *O. furnacalis* was not involved in the competition because they only damaged the maize stalks. Furthermore, *H. armigera* was only found on maize plants aged 7 week after planting (wap) or still young, while *M. separata* was not found.

The highest population of *O. furnacalis* was found in the 9th week after planting (wap) of maize plants namely 28.55 individuals, while *S. frugiperda* was not found. The highest population of *H. armigera* was found at 9th week after planting (wap) namely 38.40 individuals, and at 10th week after planting (wap), the population of *O. furnacalis* and *H. armigera* decreased.

Community structure of caterpillar pests in maize plantations in Bali Province

The abundance index value (*R1*) of caterpillar pests in each regency/city in Bali Province ranged from 1.08 to 1.91 or was included in the "Low" category. Furthermore, the diversity index (*H'*) of caterpillar pests on maize plantations in Bali Province was included in the "Medium" category, with the highest H' value found in Bangli Regency (1.68) and the lowest in Klungkung Regency (1.18). The dominance index value (*D*) of maize caterpillar pests in Bali Province was also included in the "Low" category in all regencies/cities ranging from 0.20 to 0.29. The similarity index (*SI*) of pests associated with maize in Bali had a value of 100% or in the "Very High" category. The community structure of maize caterpillar pests found in Bali Province can be seen in Table 1.

Table 1. Community structure of caterpillar pests in maize plantations in districts/cities in Bali province

Pest types	The average population of caterpillar pests in each Regency/City *								
	Tbn	**Bdg**	**Jbr**	**Dps**	**Bll**	**Gnr**	**Bgl**	**Klk**	**Krs**
Ostrinia furnacalis	9.70	5.90	9.60	10.90	12.40	8.90	8.40	9.40	17.00
Helicoverpa armigera	14.10	5.80	8.60	12.90	8.80	9.10	5.60	19.70	17.90
Spodoptera frugiperda	27.80	15.90	45.80	16.40	20.40	31.30	10.60	64.20	52.10
Spodoptera litura	4.40	2.54	6.22	5.36	2.49	6.33	2.95	4.08	5.24
Mythimna separata	6.90	7.16	4.25	7.55	4.31	6.53	6.40	4.08	6.90
Cnaphalocrocis medinalis	3.40	1.89	3.53	3.12	1.68	2.61	2.45	2.38	3.00
N. Caterpillar pests	66.30	39.26	78.0	56.2	50.1	64.8	36.4	104.3	102.1
Abundance (R1)	1.91	1.36	1.51	1.24	1.28	1.20	1.39	1.08	1.08
Diversity (H)	1.54	1.57	1.31	1.67	1.49	1.49	1.68	1.18	1.38
Dominance (D)	0.26	0.25	0.38	0.21	0.27	0.29	0.20	0.43	0.33
Similarity (IS)	100	100	100	100	100	100	100	100	100

Note : Regency/cities* Tbn : Tabanan, Bdg : Badung, Jbr: Jembrana, Dps: Denpasar, Bll: Buleleng, Gnr: Gianyar, Bgl: Bangli, Klk: Klungkung, Krs: Karangasem. N : individual abundance.

Map of maize caterpillar pest distribution in bali province

It can be seen in Figure 2. Of the six types of pests found attacking maize in Bali, the distribution pattern was random.

Attack rate of maize caterpillar pest in different altitude

The results showed the attack rate of caterpillar pests was different at each altitude of the location. The highest attack rate by caterpillar pests was found at an altitude of 250 masl, with the highest attack rate was shown by *S. frugiperda* namely 23.22% and the lowest was *C. medinalis* namely 4.03%. At an altitude of 200 – 500 masl, the attack rate from the six types of pests decreased but *S. frugiperda* still had the highest attack percentage of 16.64% and the lowest was *C. medinalis* of 3.17%. Interestingly, at an altitude of >500 masl, there were no attacks from *S. frugiperda* and *C. medinalis*, but the highest attack rate was shown by *H. armigera* at 3.17%, followed by *O. furnacalis* (2.85%), *M. separata* (3.18 %), and *S. litura* (2.28%). The attack rate of caterpillars on maize plants based on altitude in the Bali Province is shown in Figure 3.

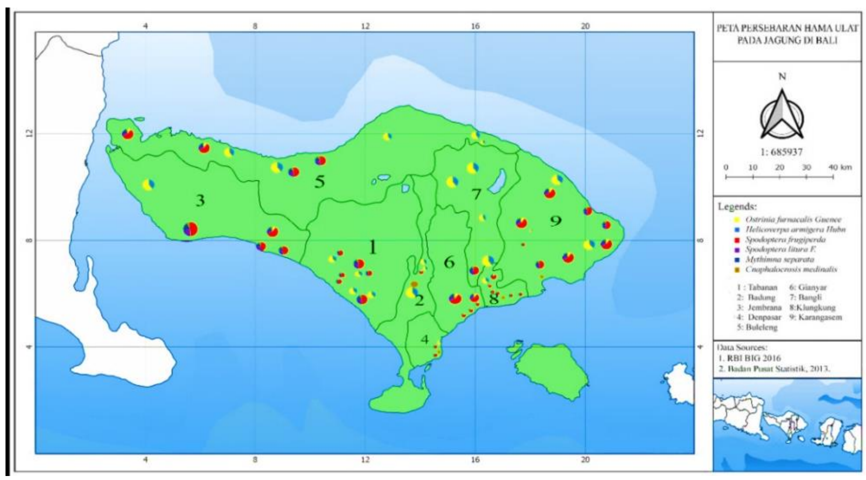

Figure 2. Map of distribution of caterpillar pests on maize plantations in Bali Province

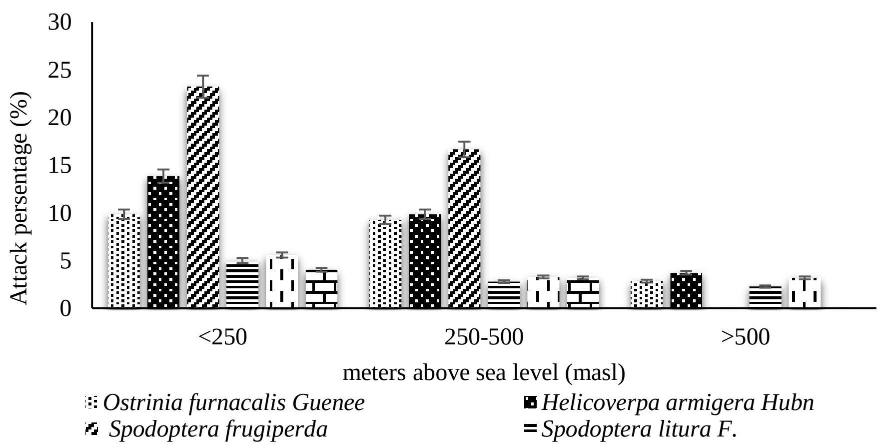

Figure 3. The attack rate of maize caterpillar pests at different altitudes in Bali Province

Discussion

The caterpillar attacks have different occurrences adjusted to feeding activities and environmental conditions in maize plantations. The appearance of caterpillar pests on maize plants is also related to the plant growth phase. Based on the results, there has been competing at the beginning of the growth phase or the age of 2–5 weeks after planting (wap) on *C. medinalis*, *S. frugiperda*, *S. litura*, and *M. separata*.

S. frugiperda is a polyphagous pest identified mostly eating strains of maize, cotton, and sorghum, and most of the others are reported to be associated with rice and grasslands (Nagoshi and Meagher, 2004). This finding is also supported by previous research that *S. frugiperda* lays eggs on the surface of 1–3 days old maize plants. After 3-5 days, the larvae hatch and are immediately active in eating the young leaves of maize plants (Supartha *et al*., 2021). *Spodoptera litura* also includes polyphagous, multivoltine, cosmopolitan pests of various vegetable and agronomic crops such as cotton, maize, peanuts, castor, and other grains (Ahmad *et al*., 2020). The emergence of this pest at the beginning of maize growth is possible because it has a short life cycle of about five weeks. After hatching, the pest can cause damage to the host plant by hypognathous (Amate *et al*., 2000; Dhir *et al*., 1992). *M. separata* is a typical insect capable of migrating long distances and has a wide host range, including maize (Yan *et al*., 2021). The report stated that the maize yield was positively correlated with the population density of the pest *M. separata* (Li *et al*., 2013). In addition, grass plants growing around maize plantations are also very beneficial for the growth of this caterpillar pest population (Jiang *et al*., 2014).

Surprisingly, only three varieties of caterpillars survived and did not compete with one another: *S. frugiperda*, *O. furnacalis*, and *H. armigera*. This is because each caterpillar has varied nutritional preferences. For example, only *S. frugipeda* ate the leaves, whereas *O. furnacalis* ate the stem and *H. armigera* ate the cob. This may also be used to confirm that pests on maize plants in Bali Province have intraguild interactions.

When two insects share a resource, such as food (typically plant-eating prey or host species), an intraguild is characterized as a pest or natural enemy consuming the other pests (Frago, 2016). Each population can devour other populations, compete for food, kill each other, and engage in unidirectional or bidirectional relationships. In this scenario, *S. frugiperda* larvae are cannibalistic and consume other caterpillars resulting in a high population rate. According to reports, the 2nd and 3rd *S. frugiperda* instar larvae are cannibalistic towards other caterpillar pests if the host plant has been depleted with inadequate nutrients in the host plant (Nochi and Hishar, 2019).

The halt of the feeding and reproductive activities owing to the age of the host plant might induce a decline in the population rate of a certain pest (Skendžić *et al*., 2021). Furthermore, unsuitable nutrition may cause development and the reproductive process to be less than optimum, such that in certain cases, insects will postpone egg-laying activities and seek more acceptable reproductive locations (Supartha *et al*., 2020).

The structure is a term investigating the amount of variety or species composition in an ecosystem, as well as its composition (Herlianadewi *et al*., 2013). Several biotic and abiotic variables might contribute to a poor community structure in an environment. The distribution of species also influences whether an ecosystem has a high or low level of variety. The behaviors in each location, on the other hand, contribute to the decrease in the population of natural enemies and other biological agents produced by the extensive use of synthetic pesticides on agricultural land (Yuliadhi *et al*., 2021). The diversity index and species dominance are measures indicating species freedom in a community. Damage to one of the component ecosystems may produce unstable energy flows in an ecosystem due to the amount of variety and dominance in a community (Wahyuni *et al*., 2017).

Surprisingly, the distribution pattern shown in this study was random. This may have occurred as a result of a discrepancy in the amount of caterpillar pest populations at each observation point. Identical insects spread or have a decreasing population is due to the need to breed, forage, natural enemies, the impacts of climate change, habitat fragmentation, and the use of synthetic pesticides (Raven and Wagner, 2021). Therefore, the limited dispersion of pests in regions such as Badung and Denpasar City is due to a lack of agricultural land. This is more common in places with a high rate of population urbanization reducing the amount of agricultural land converted into urban landscapes and having an influence on the distribution of insects in this area (Wan *et al*., 2021). Climate change, on the other hand, has the potential to contribute to the extension of insect ranges, allowing them to continue their survival and reproduction at regional and local scales (Osawa *et al*., 2018).

The negative effect of the invasive alien species (IAS) has grown and affected biodiversity and agricultural output in general. According to the findings, the proportion of caterpillar infestations on maize farms in Bali Province varies based on altitude. The availability of host plants in a given location has a considerable impact on the attack rate of caterpillars on host plants. The variety and richness of feed supplies and other biological resources available in certain habitats are positively connected with an increase in the proportion of pest attacks (Snyder, 2019). Temperature changes, for example, have an impact on the dispersal of phytophagous insects, particularly those in the order Lepidoptera (Supartha *et al*., 2021). Higher environments may slow down the reproductive cycle of insects, resulting in fewer generations and a lower proportion of attacks (Skendžić *et al*., 2021). However, the results were significant because in the highlands (> 500 masl) there was a proportion of attacks by *H. armigera*, *O. furnacalis*, *M. separata*, and *S. litura* with the potential to inflict more harm in conjunction with the emergence of maize plants.

In conclusion, caterpillar attacks on maize begin at two weeks old. The competition starts when the maize enters the vegetative phase, particularly *C. medinalis*, *S. frugiperda*, *S. litura*, and *M. separata*. Meanwhile, there is no competition in the generative phase since pests have begun to target specific plant components. The abundance and dominance indexes of the caterpillar pest community structure discovered in maize plantations in Bali Province were low, while the diversity index was medium. Caterpillar pests, on the other hand, spread uniformly across the Bali Province. At an altitude of 250 masl, a substantial proportion of attacks still occur. This is highly valuable for the appropriate authorities to utilize as a reference in policymaking in an attempt to implement integrated pests on maize, particularly in the Bali Province. Future study on the management of maize caterpillar pests by exploiting the potential of natural enemies is required.

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References

Ahmad, J. N., Mushtaq, R., Ahmad, S. J. N., Malik, M. A., Manzoor, M., Tahir, M., Aslam, Z., Maqsood, S., Ahuja, I. and Bones, A. M. (2020). Sub-lethal Dose Reponses of Native Polyhydroviruses and Spinosad for Economical and Sustainable Management of Spodoptera litura in Pakistan. Pakistan Journal of Zoology, 52. https://doi.org/10.17582/journal.pjz/20181219121245

Amate, J., Barranco, P. and Cabello, Y. (2000). Biologá en condiciones controladas de especies de noctuidos plaga (Lepidoptera: Noctuidae). Biologá Sanidad Vegetal de

Plagas, 26:193-201.
Deguine, J. P., Aubertot, J. N., Flor, R. J., Lescourret, F., Wyckhuys, K. A. G. and Ratnadass, A. (2021). Integrated pest management: good intentions, hard realities. A review. Agronomy for Sustainable Development, 41:38.
Dhir, B., Mohapatra, H. and Senapati, B. (1992). Assessment of crop loss in groundnut due to tobacco caterpillar, Spodoptera litura (F.). Indian J. Plant Protection, 20:215-217.
Frago, E. (2016). Interactions between parasitoids and higher order natural enemies: intraguild predation and hyperparasitoids. Current Opinion in Insect Science, 14:81-86.
Herlianadewi, N. M. S., Supartha, I. W. and Sunari, A. A. A. A. S. (2013). Community Structure of Parasitoid Associated with Liriomyza sativae (Blanchard) (Diptera: Agromyzidae) on Several Host Plants in Lowlands. Journal of Tropical Agroecotechnology, 2.
Jiang, X., Zhang, L., Cheng, Y. and Luo, L. (2014). Current status and trends in research on the oriental armyworm, Mythimna separata (Walker) in China (In Chinese). Journal of Applied Entomology, 51:881-889.
Jim, F., Lou, C. and Philip, J. (1998). Practical Statistics for Field Biology, 2nd Edition. Wiley. Retried from https://www.wiley.com/en-us/Practical+Statistics+for+Field+Biology%2C+2nd+Edition-p-9780471982968
Kalshoven, L. G. E. (1981). *The Pests Of Crops In Indonesia*. Ichtiar Baru Van Hoeven.
Kalsum, U. (2013). Observation of Insect Pests on Corn Plants (*Zea Mays*.L). in Banyu Urip Village, Tanjung Lago Regency, Bayuasin Regency (In Bahasa).
Li, B., Wang, G., Xu, X., Fan, C. and Liang, S. (2013). Research on weed eco-economic threshold in no-tillage summer corn field (in Chinese). Chinese Agricultural Science Bulletin, 15:173-176.
McCarthy, B. C. and Magurran, A. E. (2004). Measuring Biological Diversity. Journal of the Torrey Botanical Society, 131:277.
Montezano, D. G., Specht, A., Sosa-Gómez, D. R., Roque-Specht, V. F., Sousa-Silva, J. C., Paula-Moraes, S. V., Peterson, J. A. and Hunt, T. E. (2018). Host Plants of Spodoptera frugiperda (Lepidoptera: Noctuidae) in the Americas. African Entomology, 26:286-300.
Nagoshi, R. N. and Meagher, R. L. (2004). Behavior and Distribution of the Two Fall Armyworm Host Strains in Florida. Florida Entomologist, 87:440-449.
Nochi, N. and Hishar, M. (2019). Introduction of the fall army worm (Spodoptera frugiperda J. E. Smith) a new pest on maize in Indonesia (in Bahasa). Balit Sereal.
Osawa, T., Yamasaki, K., Tabuchi, K., Yoshioka, A., Ishigooka, Y., Sudo, S. and Takada, M. B. (2018). Climate-mediated population dynamics enhance distribution range expansion in a rice pest insect. Basic and Applied Ecology, 30:41-51.
Panikkai, S., Nurmalina, R., Mulatsih, S. and Purwati, H. (2017). Analysis of National Corn Availability to Become Self-sufficiency Throught Dynamic Model Approachmen (in Bahasa). Informatika Pertanian, 26:41-48.
Peterson, J. A., Ode, P. J., Oliveira-Hofman, C. and Harwood, J. D. (2016). Integration of Plant Defense Traits with Biological Control of Arthropod Pests: Challenges and Opportunities. Frontiers in Plant Science, 7. https://doi.org/10.3389/fpls.2016.01794

Poolprasert, P., Berry, G., Tanruean, K., Napiroon, T., Saetang, W., Penpo, M. and Duangrod, S. (2020). The community structure of beneficial and harmful arthropod fauna in rice field ecosysterms in lower Northern Thailand. The Journal of Applied Science, 19:1-12.

Putrasamedja, S., Setiawati, W., Lukman, L. and Hasyim, A. (2016). Penampilan Beberapa Klon Bawang Merah dan Hubungannya dengan Intensitas Serangan Organisme Pengganggu Tumbuhan. Jurnal Hortikultura, 22:349.

Radcliffe, E. B., Hutchison, W. D. and Cancelado, R. E. (2010). Integrated Pest Management Concepts, Tactics, Strategies and Case Studies. Cambridge University Press. 523 p.

Raven, P. H. and Wagner, D. L. (2021). Agricultural intensification and climate change are rapidly decreasing insect biodiversity. Proceedings of the National Academy of Sciences, 118:e2002548117.

Raza, A., Razzaq, A., Mehmood, S., Zou, X., Zhang, X., Lv, Y. and Xu, J. (2019). Impact of Climate Change on Crops Adaptation and Strategies to Tackle Its Outcome: A Review. Plants, 8:34.

Skendžić, S., Zovko, M., Živković, I. P., Lešić, V. and Lemić, D. (2021). The Impact of Climate Change on Agricultural Insect Pests. Insects, 12:440.

Snyder, W. E. (2019). Give predators a complement: Conserving natural enemy biodiversity to improve biocontrol. Biological Control, 135:73-82.

Supartha, I. W., Susila, I. W., Sunari, A. A. A. A. S., Mahaputra, I. G. F., Yudha, I. K. W. and Wiradana, P. A. (2021). Damage characteristics and distribution patterns of invasive pest, Spodoptera frugiperda (J.E Smith) (Lepidoptera: Noctuidae) on maize crop in Bali, Indonesia. Biodiversitas Journal of Biological Diversity, 22(6). https://doi.org/10.13057/biodiv/d220645

Supartha, I. W., Yudha, I. K. W., Wiradana, P. A. and Susila, I. W. (2020). Response of parasitoids to invasive pest Phenacoccus manihoti Matile-Ferrero (Hemiptera: Pseudococcidae) on cassava crop in Bali, Indonesia. Biodiversitas Journal of Biological Diversity, 21(10). https://doi.org/10.13057/biodiv/d211011

Surtikanti. (2011). Important Pests And Diseases Of Corn Plants And Their Control (In Bahasa).

Wahyuni, S., Supartha, I. W., Ubaidillah, R. and Wijaya, I. N. (2017). Parasitoid community structure of leaf miner Liriomyza spp. (Diptera: Agromyzidae) and the rate of parasitization on vegetable crops in Lesser Sunda Islands, Indonesia. Biodiversitas, 18:593-600.

Wan, N.-F., Dainese, M., Zhu, F., Xiao, L.-B., Zhang, W., Ma, J., Wang, W.-M., Wang, M.-T., Zhu, J.-W., Wang, J.-Y., Cheng, W., Zhou, C., Chen, S.-J., Wei, Q., Jiang, Y.-P., Wu, X.-W., Yi, H.-J., Gan, H.-H., Shen, H.-M., Li, B. (2021). Decline of three farmland pest species in rapidly urbanizing landscapes. IScience, 24:103002.

Yan, M., Zhang, L., Cheng, Y., Sappington, T. W., Pan, W. and Jiang, X. (2021). Effect of a near-zero magnetic field on development and flight of oriental armyworm (Mythimna separata). Journal of Integrative Agriculture, 20:1336-1345.

Yuliadhi, K. A., Supartha, I. W., Darmiati, N. N., Bangun, A., Yudha, I. K. W., Utama, I. W. E. K. and Wiradana, P. A. (2021). Short Communication: Silba adipata (Diptera:

Lonchaeidae) parasitoids on cayenne pepper (Capsicum frutescens) in Bali, Indonesia. Biodiversitas Journal of Biological Diversity, 22. https://doi.org/10.13057/biodiv/d220939

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