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Managing *Plutella xylostella* in Crucifers: Field Application of *Diadegma semiclausum* in Cameron Highlands

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Abstract: *Diadegma semiclausum* is one of the promising biological control agents used to control the pest of cruciferous crops, *Plutella xylostella*. Its mechanism of action is by injecting its egg into the second and third instar larva of *P. xylostella*. The egg will develop inside the larva, causing the larva to weaken and reducing the population of *P. xylostella* in the field. This tiny parasitoid was introduced from Australia in the late 1970's and has since been utilized as a biological control agent in cruciferous vegetable farms across the Cameron Highlands. As a key component of Integrated Pest Management (IPM), the use of biological control agents promotes the reduction of synthetic pesticide applications, aligning with sustainable agricultural practices. In 2019, MARDI reintroduced *D. semiclausum* to the Cameron Highlands, where the parasitoids were mass-reared at the insect rearing laboratory and subsequently released into selected vegetable farms to evaluate their effectiveness and field population stability. Six farmers representing different zones; Habu and Batu 33 (southern zone), Sg. Palas and Sg. Menson (central zone), and Ulu Telom and Kg. Raja (northern zone) was selected for scheduled *D. semiclausum* releases. Each farm was visited three times within three months. During each visit, both *D. semiclausum* and *P. xylostella* populations were monitored, and pupa samples were collected for laboratory assessment of parasitism rates. Additionally, 100 to 200 adults of *D. semiclausum* were released per visit at each farm. Throughout the program, farmers received training to identify biological control agents and other beneficial insects, along with guidance on safe pesticide usage and the adoption of environmentally friendly alternatives. Field observations demonstrated a consistent increase in *D. semiclausum* populations, accompanied by a corresponding decline in *P. xylostella* populations over the three visits, indicating the parasitoid's potential as an effective biological control agent. Laboratory assessments recorded an average *D. semiclausum* parasitism rate of 83.33%, whereas field parasitism rates ranged from 43% to 73.33%. The comparatively lower field parasitism rates suggest that *D. semiclausum* populations were still establishing stability under field conditions. From the economic study, the biological control was costing RM57,491/ha with a net profit of RM32,989/ha and a Benefit-Cost Ratio (BCR) of 1.57. In contrast, conventional farming had lower costs (RM53,603/ha), higher profit (RM40,897/ha), and a better BCR of 1.76. While conventional methods currently yield better returns, long-term pesticide use may lead to insect resistance and rising costs. Thus, biological control offers a safer and more sustainable alternative for the long-term effects.

Keywords: Cameron Highlands, crucifers, IPM, biological control agent, *Diadegma semiclausum*, *Plutella xylostella*

1. Introduction

Plutella xylostella is the major pest of the crucifer's crop which is widely grown in the Cameron Highlands. Attacks by these pests cause up to 90% yield losses on farmers' yield (Iqbal et al., 1996). To overcome this problem, most farmers use synthetic chemical pesticides intensively and exceed the prescribed dosage (Ooi, 1992). This situation causes pollution to the environment and harms the health of consumers due to the effect of the remaining remnants of pesticides on the harvested vegetables. The use of biological control methods using natural enemies of these pests is one of the good strategies to reduce the use of chemical pesticides on farms.

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Biological control is one of the components of Integrated Pest Management (IPM) which uses the natural enemies of a pest to control the pest population. Among the natural enemies that are regularly used are predators and parasitoids. There are some predators or parasitoids that are natural enemies of *P. xylostella*, such as *Diadegma semiclausum, Diadromus collaris, Cotesia vestalis* and so on (Yarrow, 1970).

D. semiclausum is an endoparasitoid of the Ichneumonidae family that makes the larvae of *P. xylostella* a host to hatch their eggs (Huang et al., 2008). Usually, these parasitoid attacks the second and third in stars of the *P. xylostella* larvae by injecting its eggs into the body of the larvae and completing its life cycle inside the larvae before coming out as an adult (Henri et al., 2009). The life cycle of *D. semiclausum* is for 12 – 19 days compared to *P. xylostella* for 18 – 26 days. Their shorter life cycle gives them the advantage of reproducing faster than *P. xylostella* (Saiful Zaimi et al., 2019). This species is also more dominant in highland areas and have been found effective in controlling *P. xylostella*, especially in highland regions (Saucke et al., 2000).

2.Materials and Methods

2.1 *D. semiclausum* culture

D. semiclausum was reared in the biological control agent rearing laboratory at MARDI Cameron Highlands at temperatures between 20 – 27ºC and relative humidity (RH) between 80 – 90%. Adults of *D. semiclausum* were given a diet of diluted honey solution at a ratio of 30 (honey) : 70 (water), while the larvae of *P. xylostella* were used as a host for the breeding of *D. semiclausum*.

Fig. 1: *D. semiclausum* culture in the laboratory and their host, *P. xylostella*

2.2 Farm location

The location of the farm for the study was divided into three zones, namely south, central, and north according to the direction of the wind and the altitude of the zone from sea level. The southern zone includes Ringet, Bertam Valley and Habu (ca. 1000 – 1100m), the central zone covers Tanah Rata, Brinchang, Kea Farm, Sg. Mensun and Sg. Palas (ca. 1200 – 1650m) and the northern zone cover Kuala Terla, Kg. Raja and Blue Valley (ca. 1200 – 1450m) (Norida & John, 2005). There were six (6) farms that were the study site which were two (2) farms for each zone, namely Habu and Batu 33 (southern zone), Sg. Mensun and Sg. Palas (central zone) and Ulu Telom and Kg. Raja (northern zone).

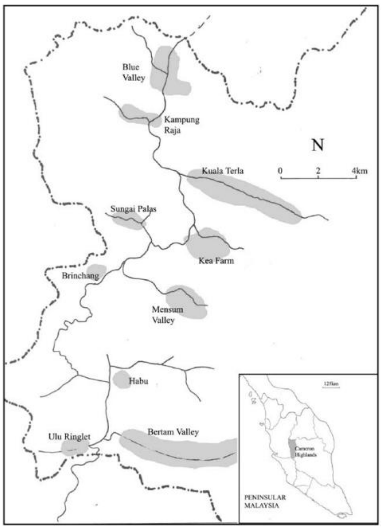

Fig. 2: Map of the Cameron Highlands

2.3 Data collection

The data collection was taken between January to March 2022. Each farm was visited three times during the study period with the duration for each visit within one month. For each visit, the number of populations of *D. semiclausum* and *P. xylostella* on the farm was recorded. About 10 – 20 samples of pupa *P. xylostella* was taken back to the laboratory to record the rate of parasitism of *D. semiclausum* on the farm. In addition to taking the study data, 100 – 200 adults of *D. semiclausum* were also released to the farmers' farm for each visit session and the farmers were also given the training to identify biological control agents and beneficial insects on their farms. Farmers were also given guidance on the procedure for the proper use of pesticides and selecting more environmentally friendly pesticides.

Fig. 3: Parasitoid release activities and data collection in the field

3. Results and Discussion

3.1 *P.xylostella* and *D.semiclausum* population

Population data for *P. xylostella* and *D.semiclausum* recorded in the study farms showed that there was a change from the first to the third visit. The population of *P. xylostella* was found to be decreasing while the population of *D. semiclausum* was found to be increasing on most farms.

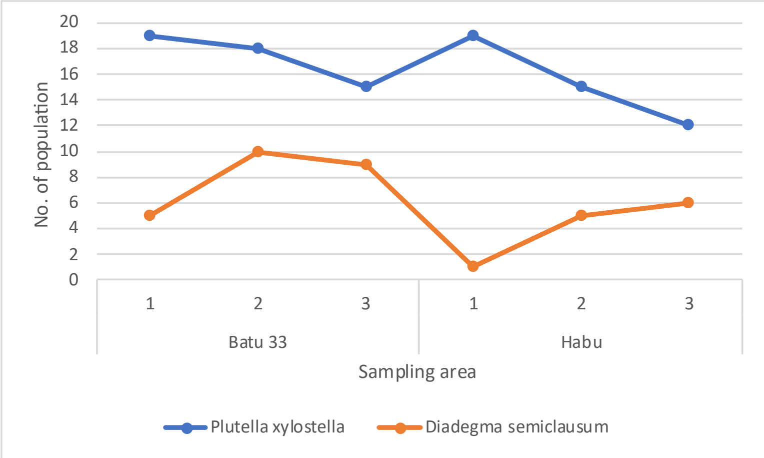

Fig. 4: Distribution of populations *P. xylostella* and *D. semiclausum* for three times visited in the southern zone (Habu and Batu 33)

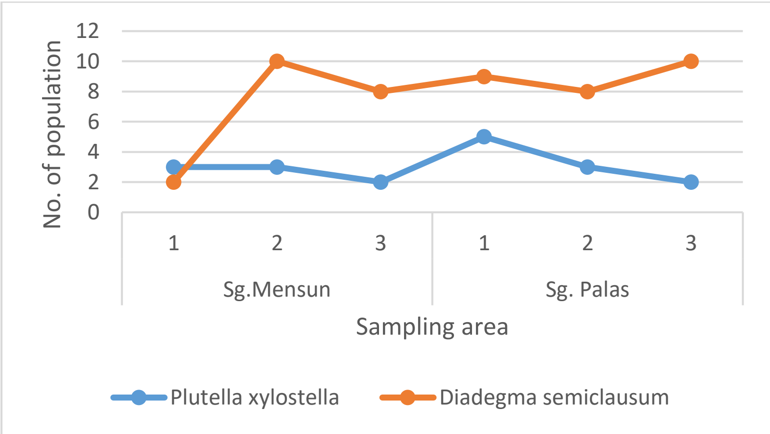

Fig. 5: **Distribution of populations *P. xylostella* and *D. semiclausum* for three times visited in the central zone (Sg. Palas dan Sg. Mensun)**

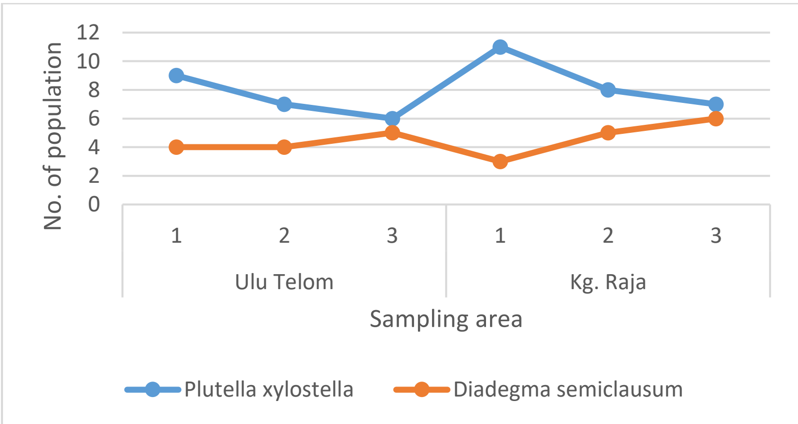

Fig. 6: **Distribution of populations *P. xylostella* and *D. semiclausum* for three visits in the northern zone (Ulu Telom dan Kg. Raja)**

The results from this study showed the population dynamics of *P. xylostella* and its parasitoid *D. semiclausum* across three zones in Cameron Highlands from January to March 2022. It showed the significant difference among the population of these two insects across the sampling areas. These differences suggest the complexity of ecological interactions and environmental factors.

In the southernmost area of Cameron Highlands, which is at Batu 33 and Habu, *P. xylostella* populations were consistently higher compared to its parasitoid, *D. semiclausum*. Nevertheless, the population of *D. semiclausum* was increased at each visit, while the population of *P. xylostella* was decreased. This showed that there was a positive interaction between pests and their natural enemies. For the information, Batu 33 and Habu areas were the cabbage cultivation areas that practice fully conventional agricultural methods and have relatively open areas and lack of crop diversity. This data shows inefficient biological management in these locations, possibly due to environmental variables such as improper microclimatic conditions, pesticide interference, or habitat fragmentation (Furlong et al., 2013; Sivapragasam et al., 2014). This had happened results to the limited availability of suitable hosts during certain periods, affecting parasitoid reproduction and persistence.

Conversely, in Sg. Mensun and Sg. Palas, the central area of Cameron Highlands, *D. semiclausum* populations were relatively higher compared to the *P. xylostella* populations. This result was believed to be facilitated by favorable environmental conditions and reduced chemical pesticide exposure which established the population of natural enemies earlier. One of the contribution factors for this result is because mostly vegetable farms in this area practice fully or semi organic farming. These results are consistent with research showing improved biological control when natural enemies are shielded from environmental disruptions and chemical exposure (Sarfraz et al., 2005; Wang & Keller, 2002).

Meanwhile, in Ulu Telom and Kg. Raja, the population of the population was found to be high at the beginning of the project but the gap between the populations was decreasing towards the end of the project. This is similar to the situation in the southern area. In addition, most vegetable farms in this area also practice conventional methods. The introduction of biological control agents takes time to stabilize and adapt. Furthermore, the parasitoid population might have been damaged by competition from other natural enemies or predators (Grzywacz et al., 2010).

The results emphasize how crucial integrated pest management (IPM) techniques are for controlling *P. xylostella* or other pests. Pest suppression can be improved by increasing the number of *D. semiclausum* through habitat modification, parasitoid releases, or conservation biological control. Reducing the use of pesticides and switching to less toxic, selective alternatives and biopesticides which less harmful can improve biological control and lessen the effects on natural enemies. To assess the efficacy of biological control agents and make any adjustments to management procedures, routine monitoring is crucial.

3.2 Parasitism rate of *D.semiclausum*

Regarding the parasitism rate depicted in Fig. 7, the laboratory rate for *D. semiclausum* is 83.33%, whereas the parasitism rate on the farm varies between 43.00% to 73.33%.

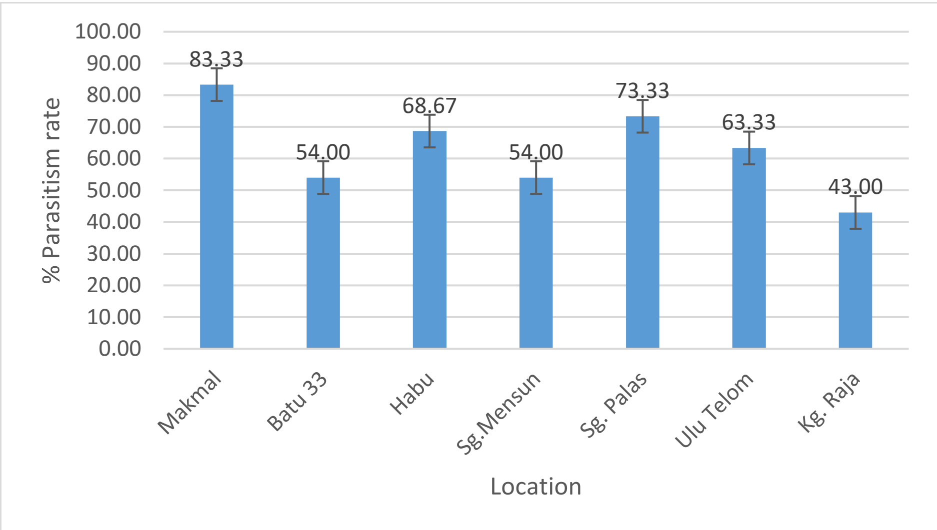

Fig. 7: **Comparison of parasitism rate of *D. semiclausum* between laboratory and farms population**

The comparison of parasitism rates of wild *D. semiclausum* from various locations in Cameron Highlands and laboratory-reared populations reveals significant insights into the efficiency and adaptability of parasitoids in natural and controlled environments. The laboratory-reared population exhibited the highest parasitism rate of 83.3%, suggesting optimal conditions for parasitism under controlled environments. Consistent temperature, humidity, and a healthy host population are examples of laboratory circumstances that improve parasitism performance by lowering stress and removing competition or predation (Wajnberg et al., 2016; Hardy et al., 2013).

Conversely, the parasitism rates in the field varied, ranging from 43.0% in Kg. Raja to 73.3% in Sg. Palas. These variations may be attributed to environmental factors, host density, and local ecological conditions. Favorable microclimates or larger host densities, which increase parasitoid efficiency, may be the cause of the higher parasitism rates in Sg. Palas (73.3%) and Habu (68.7%) (Hance et al., 2007). On the other hand, Kg. Raja recorded the lowest rate at 43.0%, potentially due to environmental stressors, predator interference, or competition from other natural enemies (Rosenheim et al., 1993).

These findings suggest the complexity of ecological interactions of biological control programs. While laboratory-reared parasitoids perform well in controlled environments, their effectiveness may diminish upon release due to environmental stresses (De Clercq et al., 2011). Therefore, strategies such as acclimatizing parasitoids before field release or developing in-situ rearing methods near target sites could enhance pest control effectiveness (van Lenteren et al., 2006).

Fig. 8: Parasitism rate data collection

3.3 Economic assessment

The economic assessment of introducing biological control agents against *P. xylostella* attacks on round cabbage crops developed by MARDI in Cameron Highlands shows that it is proven effective in controlling major pest attacks on cruciferous crops, particularly round cabbage. For round cabbage crops supported by biological control agents, the study found the total cost to be RM57,491/ha, with a net profit of RM32,989/ha. The Benefit-Cost Ratio (BCR) value is RM1.57. Meanwhile, for conventional round cabbage farming, the total cost is RM53,603/ha per year, with a net profit of RM40,897/ha per year. The BCR value is RM1.76. A comparison between the two agronomic practices for round cabbage shows that the net sales, benefit-cost ratio (BCR), and net profit for conventional round cabbage farming are better compared to the biological control method. These findings clearly indicate that the optimal use of insecticides can effectively control and eliminate DBM attacks. However, in the long term, DBM insects will gradually develop resistance to insecticides, requiring farmers to incur higher expenses to control DBM attacks using pesticides. Therefore, the biological control approach for DBM insects is seen as an initial step toward safer, environmentally friendly, and more productive agricultural practices.

Conclusion

This study concludes that biological control agents can effectively reduce *P. xylostella* populations on farms. Monthly releases of *D. semiclausum* are recommended to ensure establishment, especially in early stages. Proper pesticide use training is also essential. Further research is needed to optimize biological control in the Cameron Highlands, considering habitat suitability, climate, and integration with other agents for sustainable pest management.

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Conflict of Interest

The authors declare no conflicts of interest.

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