

Asymmetry effect of intercropping non host crops between cabbage and climatic factor on the population of the diamondback moth (*Plutella xylostella* L.) and yield

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Abstract: Diamondback Moth (DBM) is one of the major constraints for the profitable production of cabbage in Cameron Highlands, Malaysia. The loss in yield of cabbage caused by DBM could reach up to more than 80% if a severe infestation occurred in the field. Due to that problem, farmers in Cameron Highlands are preferred to apply the broad spectrum of synthetic insecticides rather than implementing other pest management strategies. The demand for insecticides in Cameron Highlands seems endless until today, but more aggressive. This paper highlighted the possibility of implementing intercropping cabbage with seven treatments in reducing adults and larvae populations of DBM in the polyculture system. The distributions of adults and larvae population of DBM against the factors of temperature and rainfall also have been addressed in this study. A total of seven treatments was implicated, including onion (*Allium cepa* L.), tomato (*Solanum lycopersicon* L.), marigold (*Tagetes erecta* L.), citronella grass (*Cymbopogon nardus* L. rendle), and mosquito plants (*Pelargonium citrosum*) which arranged in Randomized Complete Block Design (RCBD). The results indicated that insignificant variations ($P>0.05$) were observed among the population of adults and larvae at all seven treatments tested compared with the control. Moreover, adults and larvae of DBM were negatively correlated with temperature and rainfall factors. The results also showed that a critical period of DBM infestations was detected in the pre-heading stage (< 30 DAT). In terms of performance among treatments, our finding also has shown that mosquito plant was the best treatment acted as a repellent, however mosquito plant treatment contributed to the lowest yield due to the competition of plant growth resources and its wider canopy structure.

Keywords: Cabbage, Intercropping, *P. xylostella* (DBM), Polyculture System, Cameron Highlands

1. Introduction

In the present day, the Department of Agriculture (DOA), Malaysia is recognized *Plutella xylostella* as one of the limiting factors for a profitable cabbage production in the Cameron Highlands. Many vegetable farmers in this area are facing a serious cabbage yield loss if there is no earlier mitigation measure has been taken by cabbage farmers after detecting the infestations of *P. xylostella* in their farm [1]. The problems are arising whilst the larvae of *P. xylostella* feed undersurface of the leaves of cabbage plants and finally

created the transparent areas and holes on the leaves. To overcome these problems, most of cabbage farmers are aggressively applying the broad spectrum of synthetic insecticides in their farms. Generally, cabbage farmers were implementing synthetic insecticides for 20-30 applications at every 3-5 days interval of 90 days of cropping periods [2]. Thus, it has resulted in the increment percentage of insecticide resistance to many insect pests, particularly *P. xylostella*, additional operation costs, heavy reliance on chemical control and insecticide residues hazardous to farmer's health in the long run. Findings from the study done by [3] stated that the

implementation of a broad range of insecticides in the field has been contributed to the development of *P. xylostella* resistance. [4] also highlighted the similar issues which claimed that the excessive use of pesticides in the farm could be related to the pest incidences in one area. Due to over reliance on pesticides in Cameron Highlands, the trend of rapid developing resistance, environmental pollutions in all rivers and hazard to non targets organisms have become more serious today, the demand for insecticides are also seems to be endless but increasing year by year on.

Implementation of other pest management strategies is now looking more crucial in order to avoid these problems turn into more chronic. Intercropping system is one of the possible methods to employ as the management tactics to reduce the infestations created by *P. xylostella*. [5] and [6] have mentioned in details in the intercropping system where this cropping system is involved with the different crops in one field. This cropping system is also unlikely to share the same insect pests and disease-causing pathogens, and also creates a great opportunity to conserve the soil. Intercropping system is suitable for vegetable production [4] due to its ability to limits outbreak of insect pests [7]. Previous research by [8] has been revealed that intercropping cabbage with tomato reduced the infestation of *P. xylostella* in cabbage cultivation. Some evidences of previous research work also have shown beneficial plants such as marigold [9], citronella grass [10] onion and garlic could play as pest repellent plants and they were found to have a potential repellent effect on *P. xylostella*. Pest repellent plant can be used as an alternative option in controlling pests in the field area [11]. This statement has been supported by Kianmatee and Ranamukhaarachchi [12] where they highlighted that some plant species have been recognized as pest repellent plant for the particular pests. It was further agreed by [13] stated that some plants contained organic substances that keeping pests away from crops and avoiding potential damage. For example, marigold plant was reported to contain bioactive compounds [9]. Intercropping system would be offer a great alternative strategy if the combination of pest and repellent plant successfully identified [12]. Furthermore, climatic conditions such as temperature and rainfall are also playing crucial factors in DBM expansion, migration and reproduction. By correlating these two climatic factors with the population of DBM, the population dynamics of DBM could be patterned and measured. Hence, the present study was carried out with two main objectives: (1) To evaluate the effectiveness of intercropping cabbage with non-host crops on the population of *P. xylostella*, and (2) To determine the relationship between adults and larvae population of *P. xylostella* with the climatic conditions throughout cropping periods.

2. Materials and Methods

2.1. Experimental Site and Experimental Design

The study was undertaken in a farmer's field located at Tanah Rata, Cameron Highland, Pahang, Malaysia from

January to July 2012. The study area was consistently cultivated with the various types of highland vegetables. The annual rainfall is an average of 2000 mm with the minimum temperatures means ranging from 11 to 15°C and 21 to 25°C for the maximum. Minimum slope area (less than 5%) of experimental site was chosen for homogeneity of plant growth. The soil pH is found 4.0-5.5 and then corrected to 6.0-6.5 with the liming compound for better plant growth. A total of seven treatments was arranged in the Randomized Complete Block Design (RCBD) with four blocks as replicates.

Treatments: T1 (Cabbage + Onion), T2 (Cabbage + Tomato), T3 (Cabbage + Marigold), T4 (Cabbage + Citronella grass), T5 (Cabbage + Insecticides and Fungicide spray=positive control), T6 (Cabbage + Control, cabbage only=negative control), T7 (Cabbage + Mosquito plants).

2.2. Plot preparation and Plant Materials

The total size of experiment plot was 8m x 23m (184m²). All raised beds were constructed manually. Each block was divided into seven raised beds. The sizing of each unit of raised beds was 1m x 5m (5m²) with spacing between rows was 0.3m. Each constructed raised bed was occupied with two rows of cabbage plants as a main crop from variety K.Y Cross. Each row consisted of ten cabbage plants. Four-weeks-old of K.Y Cross cabbage was intercropped with onion (*Allium cepa* L.), tomato (*Solanum lycopersicon* L.), marigold (*Tagetes erecta* L.), citronella grass (*Cymbopogon nardus* L. *rendle*), and mosquito plants (*Pelargonium citrosum*). The planting distance between each cabbage plant was 50 cm and intercrops were 30 cm for onion, 50 cm (tomato), 50 cm (marigold), 35 cm (citronella grass) and 50 cm (mosquito plants). The cabbage seedlings were cultivated in the nursery in a month advanced due to its rapid growth period than other intercrops plants. Three seeds were sown consistently in the polyethylene seedling tray and only healthy cabbage plants with three to four leaf stages were chosen to transplant at all raised beds. Organic manure (treated chicken dung) was mixed with soils as a basal dressing after transplanting cabbage plants in the field. The NPK 15:15:15 and NPK 12:12:17:2 were spread at each cabbage plant stand over thirty days of transplanting period (DAT). At 60 DAT, NPK 12:12:17:2 was applied for the second time fertilization.

2.3. Insecticide Application

All treatments were sprayed with fungicides and insecticides using the agricultural knapsack sprayer (Model PB-16) with a tank capacity of 16 litres respectively. Both insecticides and fungicides were sprayed starting at seedling stage until late heading stage. Application of insecticides combined with fungicides sprayed only for treatment five (T5) at every seven day interval based on the following sequence; (1) Florbac (*Bacillus thuringiensis* subspecies *aizawai*) and Succes 25SC (spinosad), (2) Prevathon 5SC (chlorantraniliprole) and Antrocol 70 WP (propineb), (3)

Amistar (azoxystrobin) and Equation (famoxadone and cyamoxanil), and Funguran OH (copper hydroxide). Combination of pesticide and bio-pesticide (*Bacillus thuringiensis* subspecies *aizawai*). Application through cocktail application is a preferred practice applied by most farmers in the Cameron Highlands. The cocktail application with two or more mixing pesticides applied in one spraying application done by vegetable farmers in the Cameron Highlands with two reasons; to save the labour time and operation cost in the field. Other treatments except T5 were applied with a single application of fungicide involved Antrocol 70 WP (propineb), Blucozeb M-45 (mancozeb), Terrachlor 75 (quintozene), and Equation (famoxadone and cyamoxanil) based on the product label.

2.4. Plant Maintenance

All standard maintenance practice requirements for cabbage plants, including irrigation, fertilization, weeding, insect pests and disease controls were followed the guidelines from MARDI Research Station in the Cameron Highland and also from DOA. Weekly inspections on crops were carried out starting from a vegetative stage until the harvesting period.

2.5. Data Collection and Analysis

Data collections were embarked consistently at 0800 am, where adults' *P. xylostella* were less active and easier to sample. A total of 14 samplings (S1-S14) by five days interval have been conducted during the experimental period. First sampling was undertaken seven days after the cabbage plants were sown. In each plot, adults and larvae of *P. xylostella* population was counted at all leaves of each selected plant. Each leaf of cabbage plants was checked to detect adult and larvae population at every sampling interval. Visual counting of adults and larvae was done *via* systematic zig-zag pattern from ten cabbages out of 20 cabbages per row per plot. Data recorded are included (1) number of *P. xylostella*' adult and larvae populations per treatment, (2) climatic data (temperature and rainfall) provided by MARDI

Cameron Highland and (3) weight of cabbage head (g). At harvesting stage, a similar number of cabbage plants were incised just above soil level and weighted individually using a weighing scale (Brand MK-01, China) with the capacity of 3 kg. Before weighing, all damaged leaves were removed by a cutter. The mean weight of cabbage heads harvested per treatment was recorded and categorized as a marketable yield (>700 g per cabbage head) as determined by the Federal Agricultural Marketing Authority (FAMA), Cameron Highlands. The mean weight of cabbage head harvested per treatment was recorded as a yield. The relationship between climatic factors and *P. xylostella* population using Pearson Correlation was measured. All data collected from the field were coded, entered, and subjected to analysis of variance (ANOVA) at $P < 0.05$ level and means comparison using the Statistical Analysis System software (SPSS ver. 18 Software Packages). Mean separations were conducted by using the Tukey HSD test. All results are expressed as mean with standard error. Each bar represents mean \pm standard deviation. Asterisks (*) show a significant difference from the control at $P < 0.05$.

3. Results

Population Abundance of *Plutella Xylostella* (L.) at Different Treatments

Figure 1 is presented the cumulative total mean adult and larvae populations of *P. xylostella* at each treatment from samplings S1 to S14 for the entire cabbage growth period. No significant difference ($P > 0.05$) was found between the number of adult and larvae populations at each treatment. It was observed that the highest densities of adult were recorded at T2, followed by T1 and T4. According to our data, the lowest adult population among the treatments was found at T7. While T3 and T5 were showed a quite similar in the total cumulative mean number of adult. In comparison, the total mean larvae populations at all treatments were not much different during the cropping period.

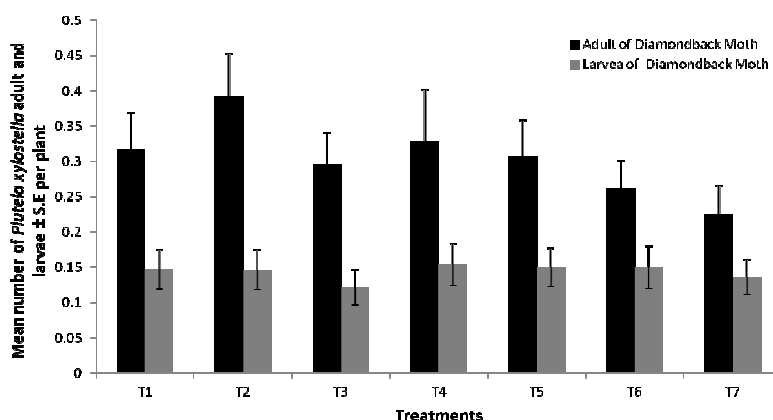


Figure 1. The overall cumulative total mean adult and larvae populations of *P. xylostella* on cabbage plants from S1-S14 during cropping period (\bar{x} = standard error of the mean). Treatment: T1 (Cabbage + Onion), T2 (Cabbage + Tomato), T3 (Cabbage + Marigold), T4 (Cabbage + Citronella grass), T5 (Cabbage + Insecticides and Fungicide spray=positive control), T6 (Cabbage + Control, cabbage only=negative control), T7 (Cabbage + Mosquito plants).

Adults and Larvae of *P. Xylostella* at Different Sampling Date

Figures 2 (A) and (B) showed the trends of average adults and larvae populations on the respective sampling dates at all treatments. In figure 2 (A), results have shown that, the overall mean numbers of adults from S1-S4 was ranging between 0.3 - 2.1 per treatment. Samplings from S1 to S4 were considered as seedling stage of cabbage plants. The adult population was increased at S2-S3. However, the trend mean number of the adult population per treatment was initiated to drastically decrease at heading formation stage to the harvesting stage (S4 - S14) with less varying among treatments. The highest peak of the adult population was recorded at pre-heading stage (S3). At this stage, T4 (2.1) was

recorded the highest number of adults, followed by T2 and T5 (1.6), T1 (1.1), T6 (1.0), while T3 and T7 (0.7) respectively, were recorded as the lowest. Stages of S3 and S4 were considered as an early growth stage of cabbage plants where the mean density of adult populations was observed higher (> 1.0) compared to the other treatments. In figure 2 (B), the graph shows the mean values of the larvae population for all treatments at all sampling dates. The numbers of the larvae population in all treatments were started to increase at S1 and S2 and happening decreased from S3 to S10 of lower than 0.8 mean number with a slight fluctuation. The highest peaked of the larvae population was observed at S11 for T1, T4 and T6 and considered slightly higher than the other sampling dates since S11 was the very last of heading stage.

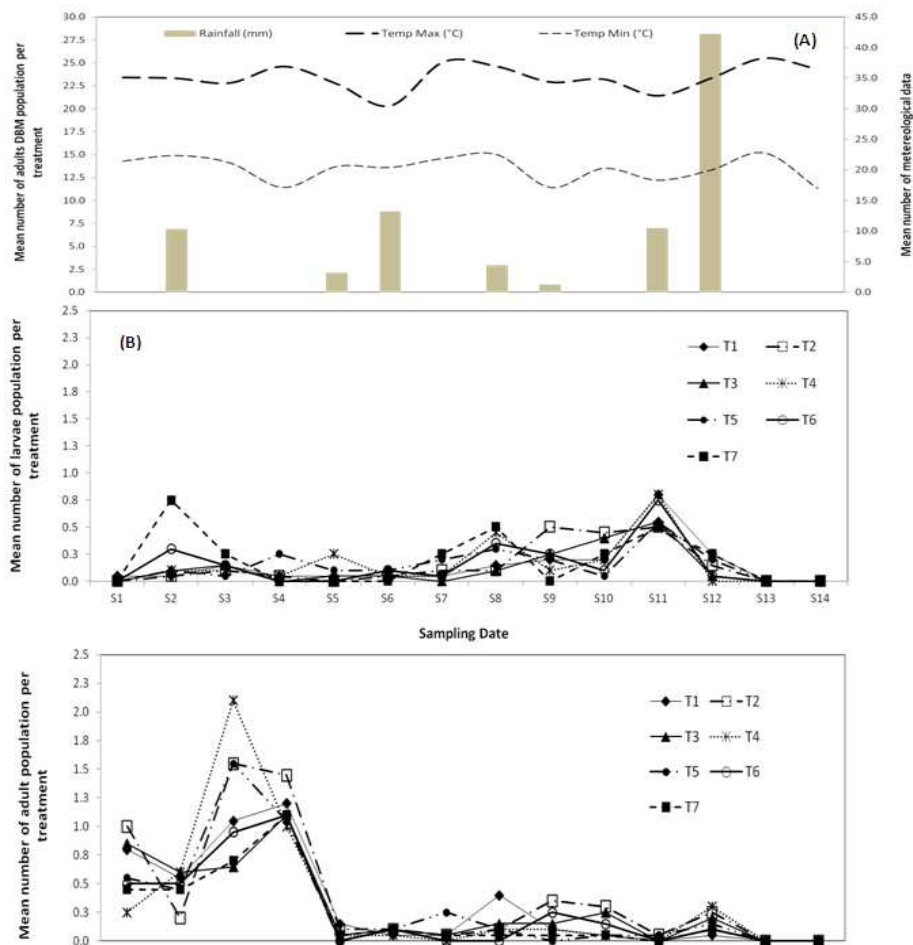


Figure 2. Relationship between mean population of adults (2A) and larvae (2B) with the climatic conditions (rainfall and temperature) at the respective sampling dates. T1 (Cabbage + Onion), T2 (Cabbage + Tomato), T3 (Cabbage + Marigold), T4 (Cabbage + Citronella grass), T5 (Cabbage + Insecticides and Fungicide spray=positive control), T6 (Cabbage + Control, cabbage only=negative control), T7 (Cabbage + Mosquito plants)

Effects of Climatic Conditions on Population Abundance of *P. Xylostella* at Different Treatments

The relationship between rainfall and temperature conditions with the population abundance of adults and larvae *P. xylostella* in the experimental plot also was measured. Pearson’s correlation analysis was conducted to evaluate the relationship between adults and larvae

population in all treatments with temperature and rainfall and is summarized in Table 1. Through the coefficient of correlation analysis, we found that the mean adult and larvae population in all treatments were negatively correlated with the temperature and rainfall data. The negative relationship between adult and larvae populations with temperature and rainfall suggested that these populations were not affected by temperature and rainfall in the field conditions.

Effects of Intercropping on the Cumulative Weight (g) of Cabbage Yield

Results on the effects of intercropped on the cumulative weight of cabbage head produced at each treatment are shown in Figure 3.

Table 1. Correlation analysis between P. xylostella (adult and larvae) and climatic conditions

Stage	Treatment	Rainfall			Max. Temperature			Min Temperature		
		Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N
Adult	T1	-.242	.405	14	.119	.685	14	.043	.884	14
	T2	-.210	.471	14	.032	.912	14	-.169	.564	14
	T3	-.188	.521	14	.115	.695	14	-.030	.920	14
	T4	-.095	.748	14	-.039	.895	14	.031	.916	14
	T5	-.171	.558	14	.052	.859	14	.037	.900	14
	T6	-.216	.457	14	.031	.916	14	-.166	.571	14
	T7	-.200	.494	14	.122	.678	14	-.103	.726	14
Larvae	T1	.289	.316	14	-.454	.103	14	-.286	.322	14
	T2	.110	.707	14	-.375	.187	14	-.409	.146	14
	T3	.070	.812	14	-.551	.041	14	-.287	.320	14
	T4	-.016	.956	14	-.327	.254	14	-.060	.838	14
	T5	.212	.468	14	-.238	.412	14	-.310	.281	14
	T6	.138	.637	14	-.381	.179	14	-.086	.770	14
	T7	.267	.357	14	-.042	.887	14	.386	.173	14

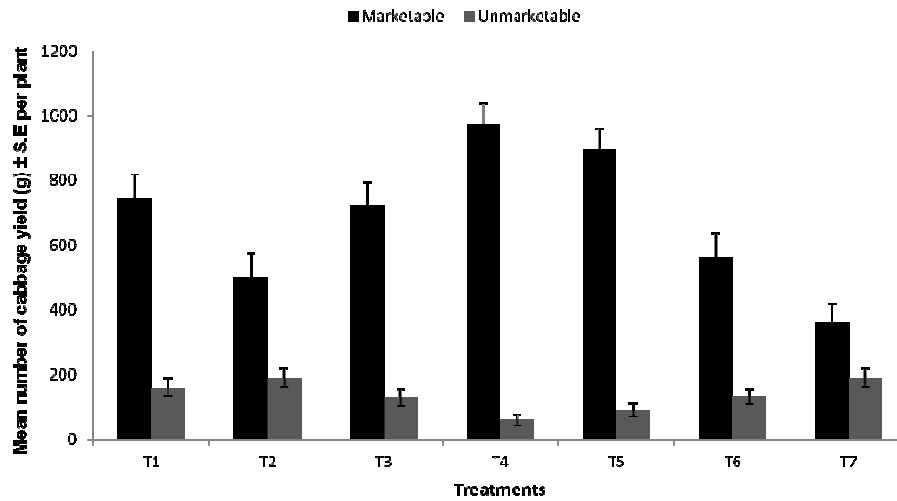


Figure 3. The overall mean cumulative weight of marketable (>700g) and unmarketable (<700g) cabbage head (τ = standard error of the mean). T1 (Cabbage + Onion), T2 (Cabbage + Tomato), T3 (Cabbage + Marigold), T4 (Cabbage + Citronella grass), T5 (Cabbage + Insecticides and Fungicide spray=positive control), T6 (Cabbage + Control, cabbage only=negative control), T7 (Cabbage + Mosquito plants)

According to Tukey HSD results in Table 2, T4 (973 g) was observed to have a significant difference (<0.05) while compared with sole crop (562 g) and other treatments.

Table 2. Yield of cabbage head in response to different intercropping treatments

Intercrops	The total mean weight of marketable head cabbage yield at each treatment (>700 g/ cabbage head)
T1 (Cabbage+Onion)	743 ab
T2 (Cabbage+Tomato)	500 c
T3 (Cabbage+Marigold)	722 ab
T4 (Cabbage+Citronella grass)	973 a
T5 (Cabbage+Insecticides+Fungicide spray)	895 b
T6 (Cabbage+Control, cabbage only)	562 c
T7 (Cabbage+Mosquito plants)	361 bc

* Numbers with the same letters are not statistically different according to Tukey HSD test (P < 0.05).

4. Discussion

The combination of all tested intercrops trials under field conditions were not caused their effective suppression action in controlling adult and larvae populations throughout the experimental period. The suppressing ability performed by all tested intercrops in this study was found reasonably low. Plant distance, densities, growth stage and the layout of testing intercropped in the trial plots could be possibly give some direct or indirect influences to their performance effects. [3] the performance effects of pest repellent plant depend on the crop combinations and the host range of pests. In our experiment, we found that cabbage plants intercropped with the mosquito plant was performed better by giving the lowest population abundance of adult *P. xylostella* followed by other treatments named marigold, insecticides and fungicide sprays, citronella grass, onion and tomato. It can be seen that mosquito plants more repellent to

adult *P. xylostella* whilst tomato was the poorest in performance as a pest repellent plant function. Although citronella grass was found to have a moderate performance in repelling adult *P. xylostella*, but we observed that citronella grass still has a high potential to be used as a pest repellent plant. A similar situation as also observed in another study [14].

In response to the treatment insecticides and fungicide spray (T5), it is supposed to have lower total cumulative means of adult and larvae population but the result obtained in this study showed contradiction. From the observation and interviewed authors with workers in the experimental plot, they claimed that the experimental plot has a long story of excessive usage of pesticides. We could anticipate this situation has finally led to the rapid development of resistance to both chemical and biological pesticides (*Bacillus thuringiensis*) by adults and larvae *P. xylostella* as mentioned by [3]; [15]. This phenomenon is similar to the previous studies by [16]. Many researchers consider *P. xylostella* as the most difficult pest to be controlled in crucifers [17] due its capability developed resistance to a wide range of insecticides.

According to our data, the adults were commenced to increase drastically following the day of transplanting cabbage plants in the field. The highest peak of adult attacked was detected at ranged between 12 to 30 days (S3 and S4) and obviously dropped at S5 onwards until the harvesting. The highest peak of the attacker was occurring in a pre-heading stage of cabbage plants. During this period, the numbers of adult population were higher compared to the heading formation and harvesting stages. We considered this stage as a critical stage of adult damage. This finding is also consistent with the study done by [16] who mentioned that the most destructive of adult *P. xylostella* is at a pre-heading stage. It was remarked that this stage is crucial and must be monitored seriously by a cabbage farmer in management of *P. xylostella*. Added to that, a similar trend was also expressed by [18] via their study on the effects of intercropping beans and onions on populations of *Liriomyza* spp. which associated parasitic hymenoptera. They have also observed that the dense populations of insect pest reflect on the changes in leaf area with onion maturation. As we mentioned earlier, the first 30 days after transplanting, cabbage seedlings are considered as a critical attack by adult *P. xylostella*. In order to lessen a critical outbreak on a cabbage farm for the first 30 DAT, we strongly suggest that farmers ought to schedule the transplanting period of cabbage seedlings on the rainfall period as a farm management strategy. We consider this transplanting period as a corrective measure (time) for the cabbage farmer to apply insecticides effectively, particularly on the adult *P. xylostella*. It is essential for cabbage farmers to take immediate actions to shield the pre-heading stage and reduce damage at the growth stage. The results on cumulative mean larvae population, all treatments have shown quite similar in mean larvae population. Findings from this study showed that all treatments were insignificantly effective repelling

larvae populations of *P. xylostella*. For marigold (T3), similar trend (graph pattern) on the population of *P. xylostella* was recorded by [19] using marigolds (*Tagetes erecta* L.) to protect sole crop from the onion fly, *Delia antiqua* (Meigen).

Generally from the findings, the rainfall and temperature (as shown in Figure 3) were not the major factors influencing the severity infestation of adult *P. xylostella* to the cabbage plants in the field. As reported by [20] that *P. xylostella* could manage their population to develop and reproduce well in a wide range of temperature between 10 to 30°C since this range is considered as a temperature tolerance for *P. xylostella*. Furthermore, the adult densities (Figure 2A) on a cabbage farm have been slightly reduced after a rainfall. Under field conditions, rainfall intensity either heavy or little may influence changes in the adult population. However, the numbers of larvae (as presented in Figure 2B) did not show any significant difference in population size, even theoretically we can expect that rainfall to possibly lead to decrease the number of larvae population by wash-off them from the cabbage leaves, especially larvae at the lower part of the leaves due to direct or indirect cause of mud-splash [21]. We are notable that the subsequent generation of adult will be reduced if the numbers of larvae decrease due to the rainfall effects.

For the marketable cabbage head, citronella grass has contributed to the highest total cumulative mean of marketable weight cabbage head. On the contrary statement, [14] reported that citronella grass intercropped with Chinese kale had produced the lowest yield. Mosquito plant (T7) was performed better as a pest repellent plant nevertheless has resulted in the lowest production in total cumulative means of the cabbage head. The lowest production in the marketable of cabbage head in the treatment of mosquito plant possibly due to the direct effect of some significant factors include the wide canopy structure, nutrient availability, sunlight and space competition between mosquito plants and cabbage plants.

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