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Efficacy of Bio Control Measures on Pine Needles Caterpillar *Metanastria latipennis* Walker in *Pinus kesiya* Royel ex Gordon plantations at Southern Shan State, Myanmar

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ထင်းရှူးရွက်စားပိုး *Metanastria latipennis* Walker အား ဇီဝနည်းဖြင့်ကာကွယ်နှိမ်နင်းခြင်း၏ နည်းလမ်းများ၏ထိရောက်မှုကို လေ့လာခြင်း

ခင်မာမြင့်၊ လက်ထောက်သုတေသနအရာရှိ
ဒီလေးဘာထွေး၊ သုတေသနအရာရှိ

စာတမ်းအကျဉ်း

ထင်းရှူးစိုက်ခင်းများတွင် သဘာဝအလျောက် ရွက်စားပိုး ကျရောက်မှုအခြေအနေ အား ဇီဝ နည်းများဖြင့် ကာကွယ်နှိမ်နင်းနည်းများ၏ သက်ရောက်မှုအခြေအနေများ လေ့လာခြင်းကို ရှုမ်းပြည်နယ်တောင်ပိုင်း၊ ညောင်ရွှေမြို့နယ် တောင်လေးလုံးကြိုး ဝိုင်း၊ ၂၀၀၈ ခုနှစ်၊ ဧက (၅၀) ထင်းရှူး စိုက်ခင်း နှင့် ကလောမြို့နယ် အကွက် အမှတ် (၉)၊ ၃/၂၀၀၇ ခုနှစ်၊ ဧက(၅၀) ထင်းရှူးစိုက်ခင်းတို့တွင် ၂၀၁၆ ခုနှစ် မေလ မှ ၂၀၁၈ ခုနှစ် ဩဂုတ်လအထိ ဆောင်ရွက်ခဲ့ ပါသည်။ စမ်းသပ်ခြင်းလုပ်ငန်းတွင် စိုက်ခင်းတစ်ခင်း စီ၌ အကွက်ကြီး(၄) ကွက်သတ်မှတ်ပြီး တစ်ကွက်စီတွင် အကွက် ငယ် (၄) ကွက်ပါဝင်၍ နမူနာအပင် (၁၅) ပင်စီဖြင့် လေ့လာပါသည်။ သတ်မှတ်ထား သည့်အကွက်ငယ်များတွင် (က) ရေ (၁၀) လီတာ တွင် *Bacillus thuringiensis* sub sp. *kurstaki* (၃၀) မီလီလီတာ (ခ) ရေ (၁၀) လီတာ တွင် Azadirachtin (၁၁.၅) မီလီလီတာနှုန်းတို့ဖြင့် ဖျော်စပ်၍ ဖျန်းပေးခြင်း (ဂ) ဖျက်ပိုး ၏ သဘာဝရန်သူ ရှိခိုး ကောင်များ (Mantids) လွှတ်ပေးခြင်း (ဃ) သဘာဝ အတိုင်းထားရှိသည့် အကွက်တို့ သတ်မှတ်ပြီး လေ့လာပါသည်။ ဇီဝပိုးသတ်ဆေး *Btk* ၊ Azadirachtin တို့ အသုံး ပြုခြင်းသည် ထင်းရှူးရွက်စားပိုးသားလောင်း *Metanastria latipennis* အပေါ် အကျိုးသက်ရောက်မှုရှိပါသည်။ ဖျက်ပိုး၏ သဘာဝရန်သူ ရှိခိုး ကောင်များ လွှတ်ပေး ခြင်းသည် အနည်းငယ်လျော့ကျသော်လည်း သဘာဝ အတိုင်း ထားရှိသည့် အကွက်နှင့် statistic နည်းဖြင့် တွက်ချက်သည့် အဖြေအရ သိသာထင်ရှားသော ကွဲလွဲမှုမရှိသည် တွေ့ရှိရပါသည်။

Efficacy of Bio Control Measures on Pine Needles Caterpillar *Metanastria latipennis* Walker in *Pinus kesiya* Royel ex Gordon plantations at Southern Shan State, Myanmar

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Abstract

The study was carried out to investigate the efficacy of *Bacillus thuringiensis* sub sp.*kurstaki* (*Btk*), Azadirachtin insecticide and established the natural enemies on pine needles caterpillar *Metanastria latipennis* in *Pinus kesiya* Plantations in Southern Shan State of Myanmar. The experiment was conducted in 2010 grown pine plantation in Taung Lay Lone Reserved Forest, Taungyi Township, and the number of plantations (9) (3/2009), Kalaw Reserve Forest, Kalaw Township in Southern Shan State at about latitude 25˙ 40' N and longitude 96˙ 51' E at an altitude of approximately 1160 m. Research was started from May, 2016 to August, 2018. A Randomized Complete Block Design (RCBD) was used with four replications. Each block containing the four treatments randomly assigned to test the effect of *Bacillus thuringiensis* sub sp. *Kurstaki* (*Btk*), Azadirachtin and natural enemies (Mantids) on pine caterpillar *Metanastria latipennis*. Sampling was done on a sample plot measuring 15m x 15 m with 15 sample trees. In control measures, (i) 30 ml of *Btk* per 10 liters of water, (ii) 0.75 % Azadirachtin 112.5 ml per 10 liters of water, (iii) biological control (established the mantids), and (iv) control were tested. In this experiment, *Btk* and Azadirachtin treatments significantly reduced the level of infestation compared to the check of control. Biological control was not significantly difference with control.

Keywords: *Pinus kesiya* Royel ex Gordon plantation, Needles Caterpillar *Metanastria latipennis*, *Bacillus thuringiensis* sub sp. *kurstaki* (*Btk*), Azadirachtin, Natural enemies of pest (Mantids), Southern Shan State, Myanmar

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1. Introduction

The pine needles caterpillar *Metanastria latipennis* Walker is an important defoliating Lepidopteran pest of *Pinus kesiya* plantations in Myanmar. The account of the "Ecology and Control of the Forest Insects of India and the Neighbouring Countries" included *Metanastria grisea, M. ampla, Lebeda nobilis* and *Heliothis armigera* as Lepidonterous insect defoliators of *P. kesiya* in the Union of Burma (Beeson, 1941). *Metanastria latipennis* generally affects and widespread outbreak defoliation had been faced in one or two interval years since 1981 in *Pinus kesiya* plantations (Aung Zeya, 1984). The diameter decreases have been reported to be from 12% to 65% (Babur, 2002; Carus, 2004; Kanat et al., 2005). Defoliated trees can become highly prone to the incidence of secondary insects. These insects can cause to tree mortality (Akkuzu and Selmi, 2002; Avci and Ogurlu, 2002).

Belonging to the family Lasiocampidae are large moths which have been the only insects reported to have caused sporadic damage to the foliage of *Pinus kesiya* in Burma/Myanmar (Beeson, 1941). The hosts *of Metanastria latipennis* (Lasiocampidae) include *Eucalyptus* spp., *Mangifera indica, Mesua ferrea, Pinus kesiya, Shorea robusta,* and *Syzygium cuminii* (Beeson, 1941, Mathur and Singh 1954-61). Its synonym is *Metanastria grisea* Moore (Browne, 1968).

The caterpillar *Dendrolimus punctatus* (Lasiocampidae) is mainly a pest of *Pinus massioniana* in China and Vietnam. The female moths lay their eggs in groups on needles and small branches, and the caterpillars feed gregariously on the needles. Two to five generations may occur per year, depending on the climate. When the population is high, complete defoliation may occur and repeated defoliation may cause death of the trees. Frequent outbreaks have been reported in young plantations of *Pinus massioniana* and *P. merkusii* in Vietnam (Billings, 1991) and annual outbreaks covering about a million ha of *P. massioniana* are common in southern China (CABI, 2005).

Pine caterpillar *Dendrolimus punctatus* (other scientific names *Metanastria punctate*) is a major pest of pine plantations in central and southern China. It is a leaf-feeding caterpillar that eats *Pinus* spp.; in particular it feeds on the foliage of the indigenous *Pinus massoniana.* It is also known to feed on *Pinus radiata* and *Pinus taeda*. Young pine plantations and pure natural stands ranging in age from 8 to 15 years are susceptible to outbreaks of this caterpillar. There are between 2 and 4 generations per year depending on climatic conditions. Usually trees are not killed by this caterpillar; the main affect is retardation in growth of trees. The newly emerged larvae are dispersed on air currents. Over longer distances, this species is spread by transport of material infested with egg masses (FAO, 2007)

Azadirachtin (Botanical insecticides)

Biological insecticide and Botanical insecticides can be an alternative to use of synthetic pesticides, because they are rapidly degraded in the environment and have low toxicity to natural enemies and mammals (Copping and Menn, 2000). Botanical pesticides are widely used for the control of insect pests (Curzio *et al*., 2009; Abdullah *et al*., 2011). Therefore the use of botanical pesticides has been recommended ever more as a suitable alternative of plant protection with minimum negative risks (Isman, 2006; Pavela, 2007).

The neem tree, *Azadirachta indica* A. Juss, (Meliaceae) extracts have been used as a natural insecticide, recently (Koul et al., 1990; Ascher, 1993). The effects of Azadirachtin on insects include feeding and oviposition deterrence, growth inhibition, fecundity and fitness reductions, low mammalian toxicity and low persistence in the environment (Schmutterer, 1990; Koul, 1992). Several studies have reported the effect of Azadirachtin on nutrition, growth and development in Lepidoptera (Barnby and Klocke, 1987; Isman, 1993; Osman, 1993). As neem extracts have little impact on non-target organisms such as parasitoids, predators and pollinators (Naumann, 1996).

Bio Insecticide *Bacillus thuringiensis* sub sp. *kurstaki* (*Btk)*

There are many different strains of *Bacillus thuringiensis* that attack specific kinds of insects. For example, *Bacillus thuringiensis* sub sp. *israeliensis* is used to control mosquitoes, and *Bacillus thuringiensis* sub sp. *tenebrionis* is used to treat some pest beetles specie. *Bacillus thuringiensis* sub sp. *kurstaki* (*Btk)* is used to control leaf (or) needles caterpillar pests (Van Netten, et.al, 2000). The *Bacillus thuringiensis* is used worldwide as a bio-insecticide for the control of several Lepidopteran, coleopteran, and dipteran pests (Schnepf et al. 1998). Since the use of *Btk* preparations for 40 years, they have the acceptance for field and laboratory treatments by international organizations (WHO, 1999).

Predators and parasitoids

Predators of pine needle caterpillar include praying mantids, wasps, katydids, predatory true bugs (e.g., Pentatomidae, Reduviidae), spiders and birds (CABI, 2011b). The egg parasitoid *Trichogramma dendrolimi* was used in practice in China for control (CABI, 2005) and an IPM approach involving a combination of mechanical, biological, silvicultural and chemical methods has been advocated for Vietnam (Billings, 1991).

2. Objectives

In Pine plantations seriously suffer from needle caterpillar attack and outbreak of infestation has been reported in Myanmar. Various control methods need to be deployed for the future. There is little published information on the current status of pine needle caterpillar control measures in Myanmar. The problem is getting worse year after year. Therefore, the present investigations were carried out to investigate the efficacy of (a) bio insecticide; *Bacillus thuringiensis* sub sp *kurstaki*, (b) botanical insecticide, *Azadirachtin* and (c) a predator, mantid on pine caterpillar *Metanastria latipennis* under field conditions.

3. Materials and Methods

The study was carried out in pine plantation (2010 grown) in Taung Lay Lone Reserved Forest Taungyi Township, and the number of plantations (9) (3/2009), Kalaw Reserved Forest, Kalaw Township, Southern Shan State at about latitude 25˙ 43' N and longitude 96˙ 50' E at an altitude of approximately 1170 m. Research was started from May, 2016 to August, 2018. Individual trees were between 3 m to 5 m in height and 5.9 cm to 12.5 cm in diameter. At the time of survey, plantations were already 9 years and 11 years old. Present studies were carried out in *Pinus kesiya* plantations established with 9 ft. x 9 ft x 9 ft. spacing.

A Randomized Complete Block Design (RCBD) was used with four replications having a size of 25 hectares. Each block containing the four treatments randomly assigned to test the effect of biological pesticides using the *Bacillus thuringiensis* sub sp. *kurstaki* (*Btk*), Azadirachtin and mantids. Sampling was done on a sample plot measuring 15m x 15 m with 15 sample trees. The buffer zones were then established to avoid cross contamination from treatments between the blocks and plots.

3.1. Inspect of infestation and treatment applications

To assess the average number of caterpillar in each plant, three small branches (top, middle and lowest) of main branches at 3 sites were collected randomly in each tree and observed for the presence number of caterpillars. This was conducted at varying intervals and average number of branches infested with pests was calculated and the values were recorded.

3.2. Insecticide application

The different formulations of each insecticide were used for checking the effectiveness on *Metanastria letipennis* in this study. Mixed 30 ml of *Bacillus thuringiensis* sub sp. *kurstaki* (*Btk*) per 10 liters of water and Azadirachtin 112.5 ml per 10 liters of water were applied using back pack sprayers in 1st week of May, June and July in field conditions.

Apply insecticides in a situation like the present one in which plantations of 11 year old pines are involved, ground equipment capable of reaching 5 m in height become necessary.

3.3. Releasing the predatory mantids

Thirty adult mantids and an egg case (ootheca) were released onto each relative sample plots in two times where pest population was sampled.

3.4. Data analysis

The data pertaining to the observations were analyzed in a randomized block design. The mean values of the observations were separated using Dunnett's t-tests treat one group as a control, and compare all other groups against it. Reject the null hypothesis if p-value ≤ 0.05.

4. Results

4.1. Habitat of Pest

Larvae of *Metanastria latipennis* emerge in late April and early May then complete feeding in July or August for 1^{st} generations and October or November for 2^{nd} generations. They pupate in large double-walled cocoons of mingled silk and hair, usually on the branches among leaves; etc., and a pupa period is 2-3 weeks. The moths emerge within August (generation one) and again in November (generation two). Eggs are laid in groups or rows on needles, branches and stem, and they hatch in about 10 days. The larvae spread out on the trees by wind with silk. There are two or more generations per year dependent on the weather.

4.2. Damage symptom

First-instar larvae prefer needles of the current year, but fourth and final instar larvae prefer one-year old needles. Severe defoliation has an impact on the growth of the trees. More data is needed on the biology of the pest.

4.3. Infestation

Mean infestation level of pine caterpillar *Metanastria latipennis* was about (38%) in May 2017 at Kalaw and (35%) at Taung Lay Lone Reserved Forest areas. The incidence was in progress to (45 %), (50 %) in June 2017. The pupae and adults stage were found in late

July and early August 2017. Therefore, we continually conducted the data collection of 2nd generations attacked on experimental plots in both study areas started from September to December 2017. Mean infestation level was about (48 %) in September 2017 at Kalaw and (40 %) at Taung Lay Lone Reserved Forest areas. The incidence was progress to (60 %), (57 %) at Kalaw and Taung Laylone experimental plot in November 2017. According to our finding, the biology of *M. latipennis* is two or more generations occur in a year.

4.4. Effect of different treatment on *Metanastria latipennis* in *Pinus kesiya* plantation in both areas.

In both study areas, in 95% confident level that all treatments differ with control infestation was the highest mean thrust. The bio insecticides *Bacillus thuringiensis* sub sp *kurstaki* and Azadirachtin provided acceptable results, as far as number of mean level was concerned after spraying. The mean number of caterpillars was about (30.18) at Kalaw and (27.78) at Taung Laylone Reserve Forest areas in May, 2018 before applying the control measures. We started the control measures from May to July 2018. Although *Btk* **a**nd Azadirachtin significantly reduced the number of caterpillar *Metanastria latipennis*, the natural enemies (mantids) could not show satisfactory result. The number of adult mantids released may be too small to see the impact.

The reduction of population was observed and the numbers in the treated plots were significantly greater than the population in the control plots in both study areas (Fig.7 and 8). In addition, there was no significant difference between the reducing rate from *Bacillus thuringiensis* sub sp *kurstaki*, and Azadirachtin. The statistical analysis did not show a significance difference between control and bio control. The plots treated with *Btk* had not statistically significant at $p<0.05$ level while Azadirachtin had a slight statistical contrast according to their effects on the percentage of larval mortality among the May, June and July.

The Infestation of *Metanastria latipennis* were decreasing one month after another after using *Bacillus thuringiensis* sub sp *Kurstaki* and Azadirachtin (Fig. 2, 3 and 5, 6). All control measures except bio control measure significantly reduced the infestation compared to the check (without any control measure) in both areas. The most effective one was *Btk* where the mean number was 7 and 7.75 while for check number was 52 and 53 in Taung Lay Lone and Kalaw. The second most effective control measure was Azadirachtin where the mean numbers of caterpillar were 10 and 11 respectively. However, the pest population in the plots where mantids were released was 41 and 47 and it was no significance difference from those of check plots (Fig. 7 and 8). At the $\alpha = 0.05$ significance level, there is enough evidence to conclude that the mean thrust differs among the four treatment.

Table.1. Results of an ANOVA, CRITERIA=ALPHA (.05) (Treatment, Replication and Monthly) on caterpillar *Metanastria latipennis* tested as the reduction of surviving larvae at the end of the experiment over the initial number of larvae. (Taung Lay Lone)

Source	Sum of Squares	df	Mean Square	F	Sig.
Treatment	5909.083	3	1969.694	24.247	.000
Replication	10.083	3	3.361	.041	.989
Monthly	6.000	2	3.000	.037	.964
Error	3168.083	39	81.233		
Corrected Total	9093.250	47			
CV% = 32					

Table.2. Results of an ANOVA, CRITERIA=ALPHA (0.05) (Treatment, Replication and Monthly) on caterpillar *Metanastria latipennis* tested as the reduction of surviving larvae at the end of the experiment over the initial number of larvae. (Kalaw)

Source	Sum of Squares	df	Mean Square	F	Sig.
Treatment	6226.250	3	2075.417	23.734	.000
Replication	2.250	3	.750	.009	.999
Monthly	33.042	2	16.521	.189	.829
Error	3410.375	39	87.446		
Corrected Total	9671.917	47			
CV% = 31.92427					

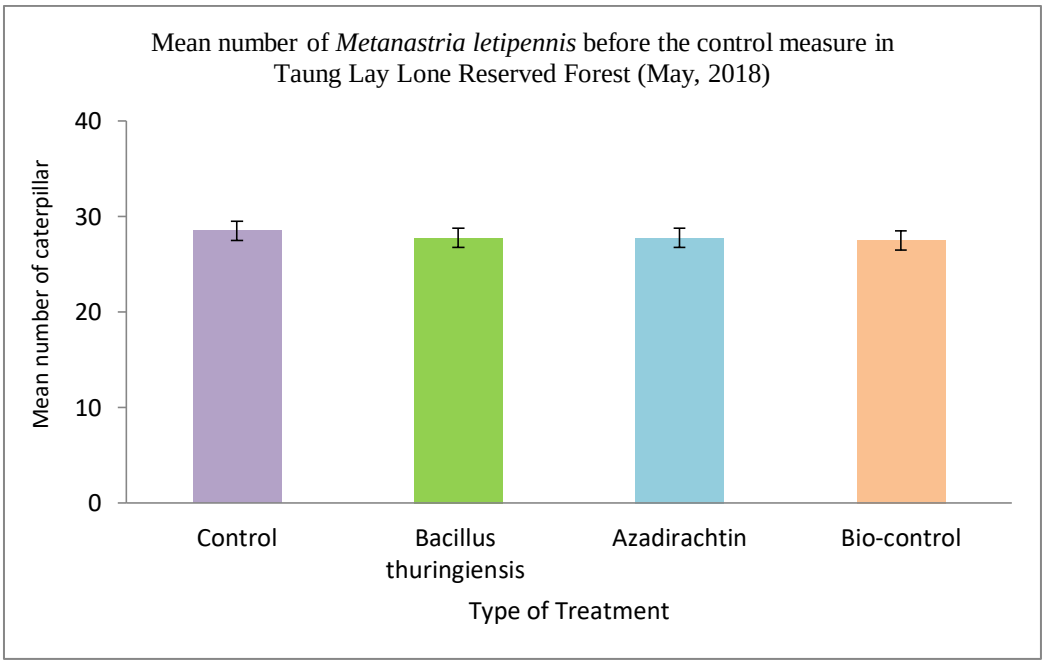

Fig.1. Mean number of *Metanastria letipennis* before conducted the control measure at Taung Lay Lone Reserved Forest (May, 2018). Error bars indicate standard errors

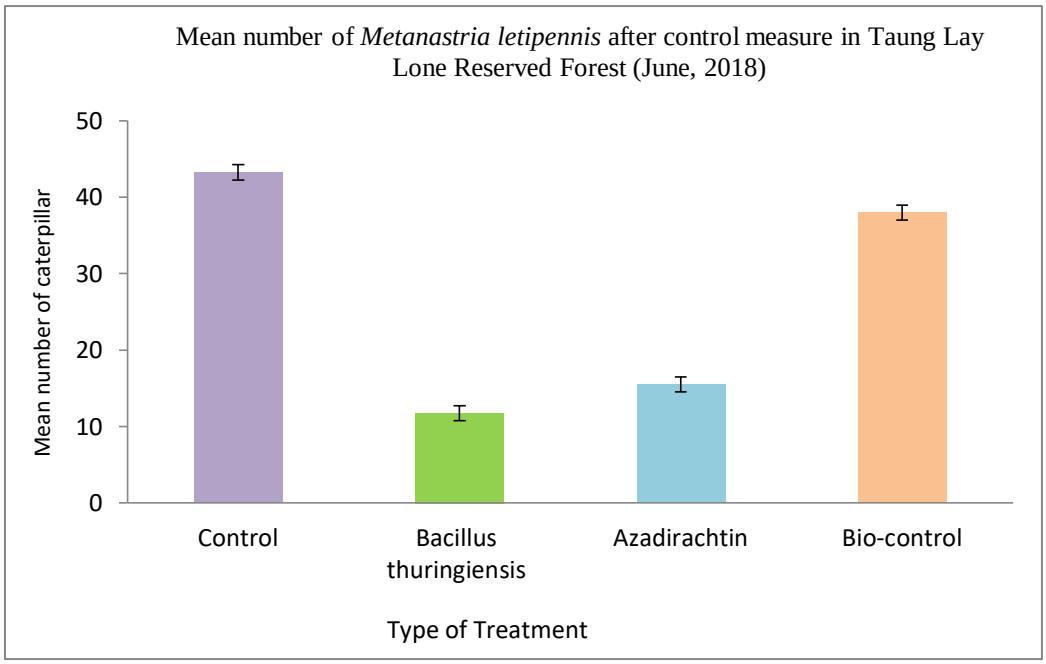

Fig.2. Mean number of *Metanastria letipennis* after conducted the control measure at Taung Lay Lone Reserved Forest (June, 2018).Error bars indicate standard errors

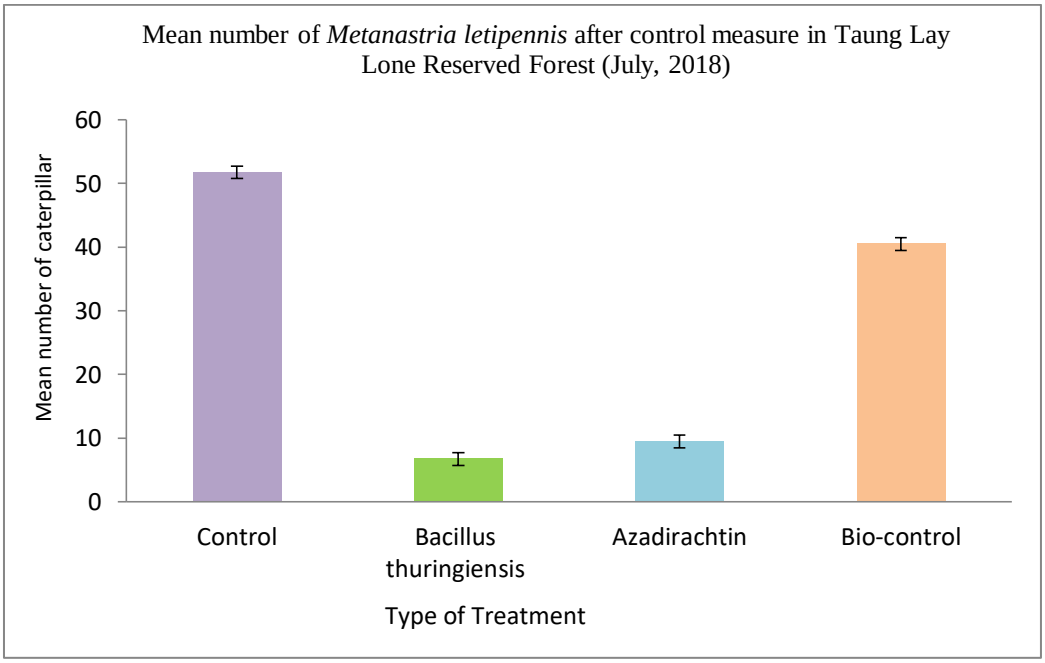

Fig.3. Infestation of *Metanastria letipennis* after conducted the control measure at Taung Lay Lone Reserve Forest (July, 2018). Error bars indicate standard errors

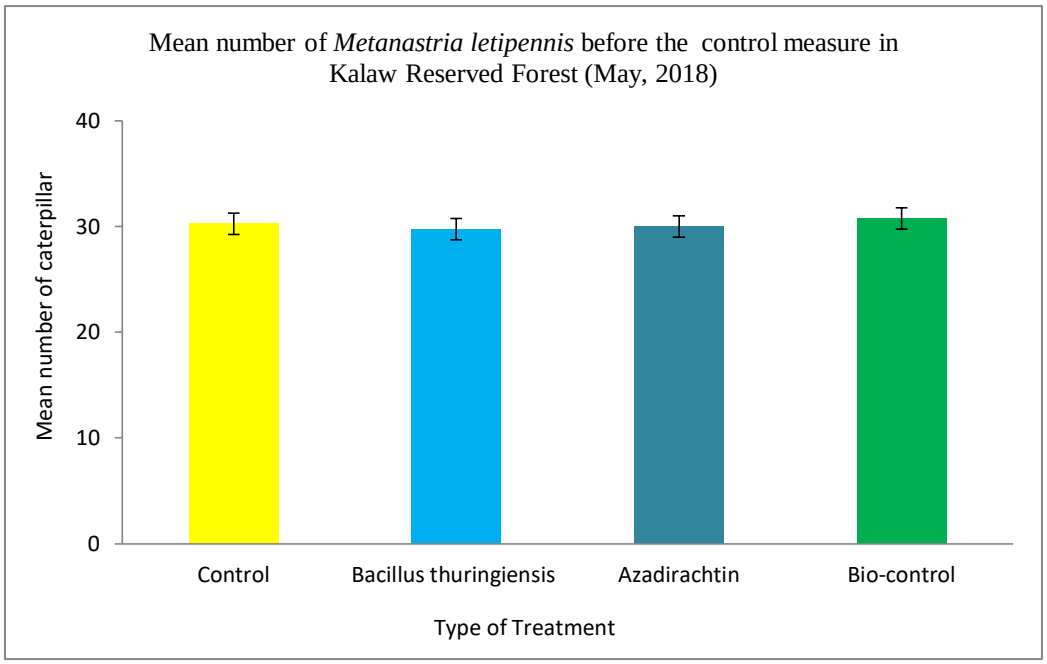

Fig.4. Mean number of *Metanastria letipennis* before conducted the control measure at Kalaw Township (May, 2018).Error bars indicate standard errors

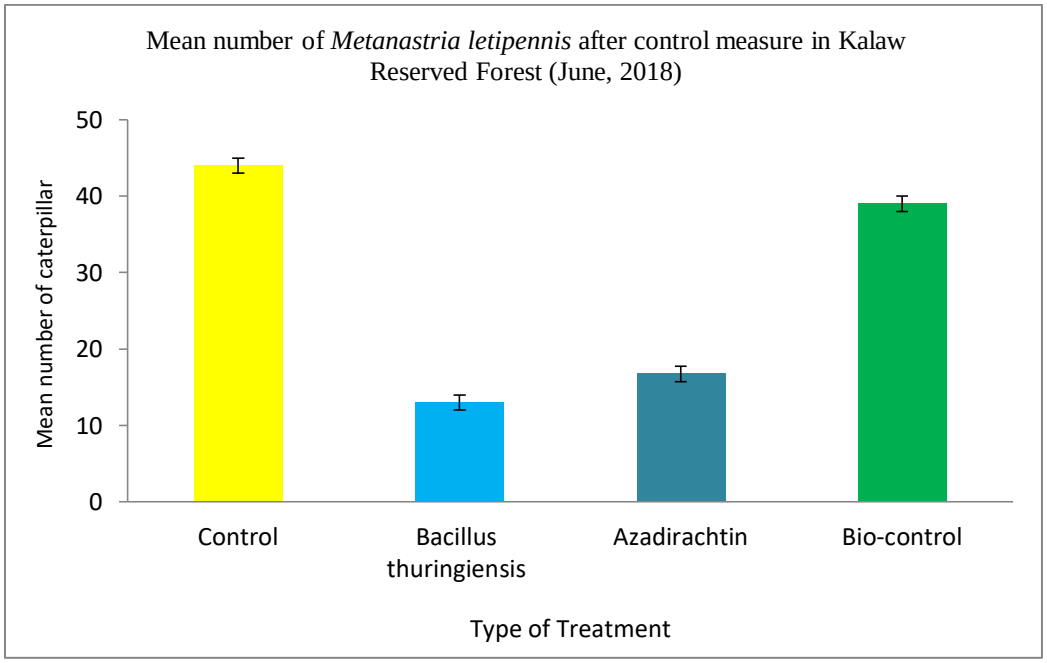

Fig.5. Mean number of *Metanastria letipennis* after conducted the control measure at Kalaw area (June, 2018).Error bars indicate standard errors

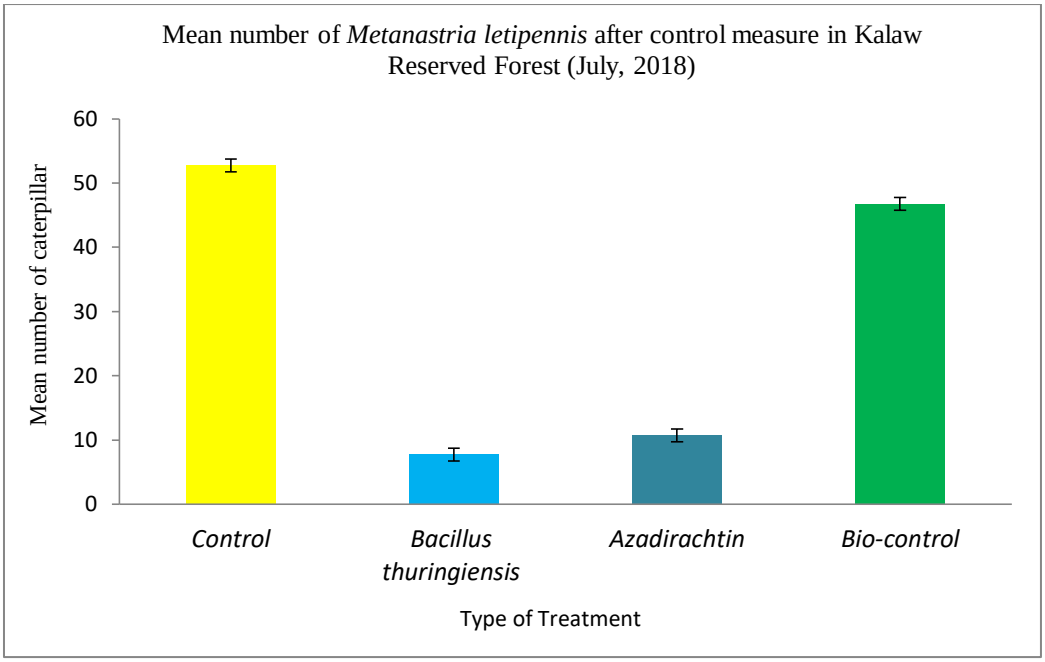

Fig.6. Mean number of *Metanastria letipennis* after control measure at Kalaw Reserved Forest (July, 2018).Error bars indicate standard errors

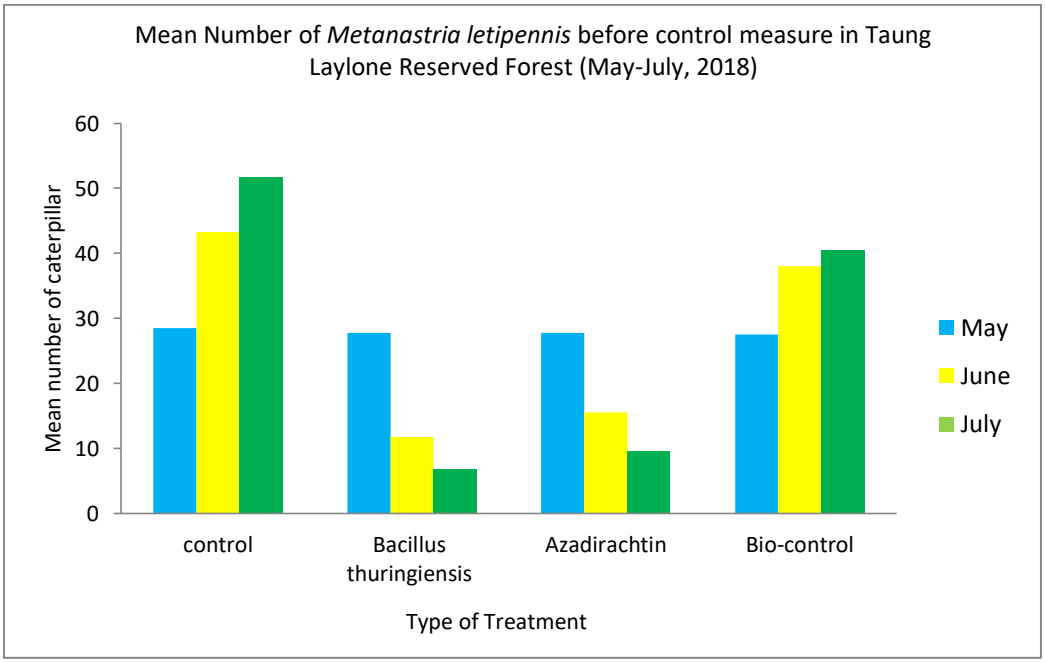

Fig.7. Reducing means value before and after conducting control measure in Taung Lay Lone Reserved Forest (May-July, 2018).

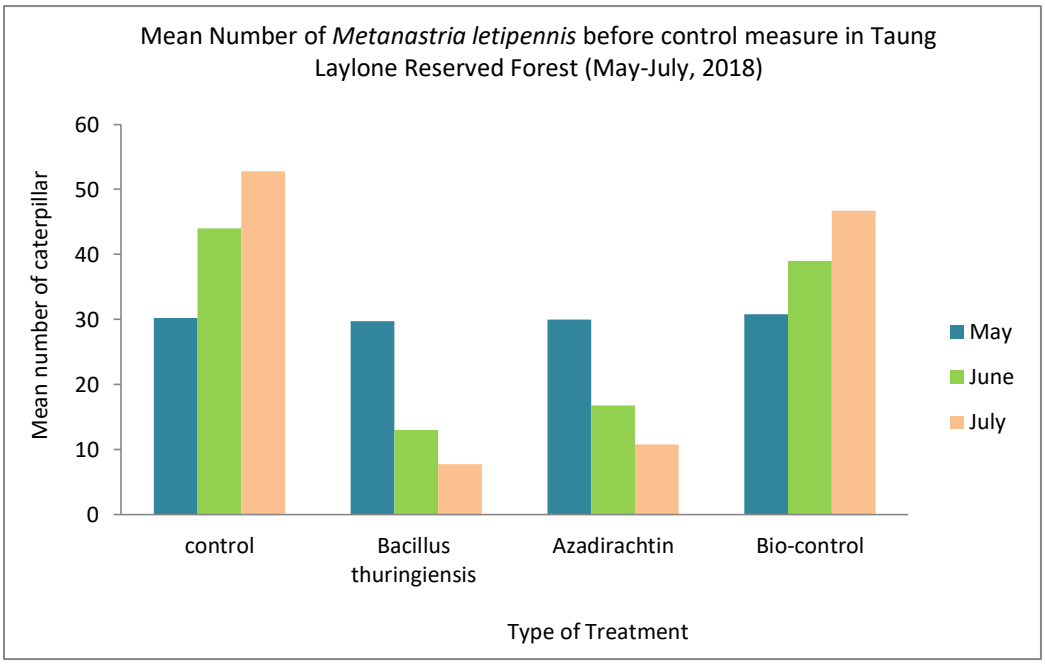

Fig.8. Reducing means value of before and after conducting control measure in Kalaw study area (May-July, 2018).

5. Discussions

Commercial preparations of various *Bacillus thuringiensis* sub sp *Kurstaki* (*Btk*) were used against pine needle caterpillar under the family Lasiocampidae by several researchers. According to their studies, the larval mortality rates were 71-80% (Niccoli and Pelagatti, 1986), 89-100% (Avtzis, 1998), 95-98% (Ghent, 2003), 85% (Orphanides et al., 2003). The results of our analysis gave about 45 % using *Btk* and 42 % using Azadirachtin. In the control plots, mean number of caterpillar showed increasing throughout the survey periods than other using treatment plots. Although, was not statistically significance different with bio control. These results suggest that the application of *Btk* and Azadirachtin gave the satisfactory results against on *Metanastria latipennis*.

Pine caterpillar populations should be monitored to maintain tree health. Heavy infestation may require treatment with insecticide such as *Btk*. *Bacillus thuringiensis* sub sp *Kurstaki* is often recommended to control Lepidoptera because it only affects the caterpillar stage of moths and butterflies. Spray the tree's leaves with *Btk* or Azadirachtin from early May to late June and early August to late September when caterpillars first hatch. However, the use of Azadirachtin is preferable as it is much cheaper than *Btk* and readily available in Myanmar.

In China, the use of *Trichogramma dendrolimi* to control siberian silk moth has been effective with reported egg parasitism levels as high as 97%, and with levels of parasitism as high as 76% with the release of only 550 wasps per ha (Yu, 1982). However, the parasitoids could not be used in the present study. It will be explored the possibility to use next time.

6. Conclusions

The objective of this research was to assess the efficacy of *Bacillus thuringiensis* sub sp *kurstaki* (*Btk*)**,** Azadirachtin and Mantids on caterpillar *Mentanastria latipennis*. Results show that *Btk* and azadirachtin reduced the number of caterpillars. Although released the natural enemies (Mantids) of pests, not significance effect on *M. latipennis*.

In natural conditions, biological control plays an important role in regulating the population densities of all pine needles caterpillars and in some cases, in suppressing outbreaks. Biological control is an important component in forest ecosystems. Creating the environmental conditions that favor the existence of these biological control agents will greatly help in controlling pine-tree moth populations and minimize the use of pesticides (Sierpinska, 1998).

Larvae emerge from Late April and early May according to our findings. During the first instar, the tiny larvae may be blown by the wind to spread the infestation. *Bacillus thuringiensis* sub sp *kurstaki* (*Btk*) and Azadirachtin insecticide should be applying at this time. Natural enemies of pest should be released or established in the same time whenever conditions are favorable. Biological control focuses on the long-term prevention.

Metanastria latipennis is considered as a very serious defoliator of pine forests in Myanmar where it occurs. Pines are important forest trees in the Shan State. Control action should be taken immediately upon discovery of *M. letipennis* detection in the plantation.

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References

1. Abdullahi, N., Majeed, Q. and Oyeyi, T. I. 2011. Studies on efficacy of *Vitallaria paradoxa* seed oil on the oviposition, hatchability of eggs and emergence of *Callasobruchus maculates* (F.) (Coleoptera: Bruchidae) on treated cowpea seed. *Journal of Entomology*, **8**: 391-397.
2. Akkuzu, E. and E. Selmi (2002). The use of microbial control agents against Thaumetopoea pityocampa (Den. and Schiff.). In: Proceedings of the pine proces sionary moth s ymposium (Eds.: M. Kanat). Kahramanmaras, Turkey, 96, 67-74
3. Ascher KRS (1993). Non-conventional insecticidal effects of pesticides available from the Neem tree, *Azadirachta indica.* Arch. Insect Biochem. Physiol. 22: 433-449.
4. Atakan, A.: Biology of harmful insects of Forests in Turkey. Forest General Directorate Publication, Ankara (1991).
5. Avtzis, N.D.: The use of *Bacillus thuringiensis* against Thaumetopoea pityocampa Schiff. (Lepidoptera:Thaumetopoeidae) in Greece. In: Proceedings of Population Dynamics, Impacts and Integrated Management of Forest Defoliating Insects, USDA Forest Service, General Technical Report NE-247, 311-316 (1998).
6. Aung Zeya (1984). A Preliminary Report on the Mortality of *Pinus khasya* Royle in Kalaw Area.
7. Avci, M. and I. Ogurlu (2002). The importance, biology and natural enemies of the pine processionary moth (Thaumetopoea pityocampa (Den. And Schiff.)) in the lakes district. In: Proceedings of the pine processionary moth symposium (Eds.: M. Kanat). Kahramanmaras, Turkey, 96, 28-36
8. Babur, H. (2002). The effect of Thaumetopoea pityocampa (Schiff.) damage in Calabrian pine seedlings in Turkey. In: Proceedings of the pine processionary moth symposium (Eds.: M. Kanat). Kahramanmaras, Turkey, 96, 37-43
9. Barnby MA, Klocke JA (1987). Effects of azadirachtin on the nutrition and development of the tobacco budworm, Heliothis virescens (Fabr.) (Noctuidae). J. Insect Physiol. 33: 69-75.
10. Beeson, C. F. C. (1941). Ecology and Control of the Forest Insects of India and the Neighbouring Countries. Vansant Press, dehra Dun, India.476-478.
11. Billings, R. F. (1991). The pine caterpillar *Dendrolimus punctatus* in Vietnam and recommendations for integrated pest management. Forest Ecology and Management, 97–106.
12. Brown, F.G (1968). Pest and Diseases of Forest Plantation Trees.
13. CABI (Commonwealth Agricultural Bureau International). (2005). Forestry Compendium, 2005 edn., (CD version). Wallingford, UK: CAB International.
14. CABI. 2011b. Crop Protection Compendium. *Dendrolimus punctatus* (Masson pine caterpillar). (Archived at PERAL). http://www.cabi.org/cpc/?compid=1&dsid=18368&loadmodule=datasheet&page=868&site=161.
15. Chen, C. (1990). Integrated management of pine caterpillars in China. China Forestry Publishing House, Beijing, China. 463 pp.
16. Carus, S. (2004). Impact of defolation by pine processionary moth (Thaumetopoea pityocampa) on radial, height and volume growth of Calabrian pine (Pinus brutia) trees in Turkey. Phytoparasitica, 32, 459-469
17. Copping, LG, Menn, JJ (2000). Biopesticides: a review of their action, applications and efficacy. Pest. Manag. Sci. 56: 651-676

18. Curzio, L.G., Hernandez-Velazquez, V.M., Leon-Rivera, I., Guevara-Fefer, P. and Aranda-Escobar, E. (2009). Biological activity of methanolic extracts of *Ipomoea murucoides* Roem et Schult on *Spodoptera frugiperda* J. E. Smith. *Journal of Entomology*, **6**: 109-116.
19. EPPO/CABI (1997) European and Mediterranean Plant Protection Organization (EPPO)/CAB International (CABI) Quarantine Pests for Europe. 2nd ed. CAB International, Wallingford, UK.
20. FAO (2007). Overview of Forest Pests, Forest Health & Biosecurity Working Papers People's Republic of China
21. Frankenhuyzen VK (1995). The development of *Bacillus thuringiensis* for control of spruce budworm, Choristoneura fumiferana, in Canada. In: *Bacillus thuringiensis* Biotechnology and Environmental Benefits (Ed. JY Feng). Hua Shiang Yuan, Taipei, Taiwan, pp. 405–423.
22. Ghent, J.H.: Ecological risk assessment of Bacillus thuringiensis var. kurstaki. In: Proceedings of Integrated Pest Management for Pine Processionary Caterpillar in Cyprus (Eds.: W.M. Ciesla and N. Gulensoy), Technical Workshop. pp. 65-72 (2003).
23. Isman MB (1993). Growth inhibitory and antifeedant effects of azadirachtin on six noctuids of regional economic importance. Pesticide Sci. 38: 57-63.
24. Isman, M.B. 2006.The role of botanical insecticides, deterrents and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology, 51: 45-66.
25. Kanat, M., M.H. Alma and F. Sivrikaya (2005). Effect of defoliation by Thaumetopoea pityocampa (Den. and Schiff.) (Lepidoptera: Thaumetopoeidae) on annual diameter increment of Pinus brutia Ten. in Turkey. Ann. For. Sci., 62, 91-94
26. Koul O, Isman MB, Ketkar CM (1990). Properties and uses of Neem, Azadirachta indica. Can. J. Bot. 68: 1-11.
27. Koul O (1992). Neem allelochemicals and insect control. In: Rizvi RSJH, Rizvi VJ (eds) Allelopathy; basic and applied aspects. Chapman and Hall Ltd., London, pp. 389-412.
28. Mathur, R.N. and B. Singh, 1961. A list of insect pests of forest plants in India and adjacent countries, Part Co. Plant genera T to Z. Indian Forest Bull. (NS) Ent., 171: 1-166.
29. Murphy, S.T. 1998. Native and alien invasives in pine and eucalypt forestry: prospects for biological control. *In Proceedings: Congresso Internacional de Plagas Forestales, 18-20 de Agosto de 1997, Pucon, IX Region, Chile*. Corporacion Nacional Forestal, pp. 4- 14.
30. Naumann K (1996). Toxicity of a neem (*Azadirachta indica* A. Juss) insecticide to larval honey bees. Am. Bee J. 136: 518-520.
31. Niccoli, A. and O. Pelagatti: Persistenza di prodotti a base di *Bacillus thuringiensis* Berl. impiegati nel controllo di alcune specie di Lepidotteri (Persistence of *Bacillus thuringiensis* Berl. preparations used in controlling some Lepidoptera species). Redia, 69, 329-339 (1986).
32. Orphanides, G.M., S. Akamas, K. Nicolaou, I. Diola, P. Papadopoulos and S. Kotzikas: The pine processionary caterpillar problem in Cyprus: An overview. In: Proceedings of integrated pest management for pine processionary caterpillar in Cyprus (Eds.: W.M. Ciesla and N. Gulensoy). Technical Workshop. pp. 8-13 (2003).
33. Osman MZ (1993). Effects of neem seed extracts on growth and development of larvae of *Pieris brassicae* L. (Lepidopetra, Pieridae). J. Appl. Entomol. 115: 254-258.

34. Pavela, R. 2007: Possibilities of botanical insecticide exploitation in plant protection. *Pest Technology*, **1**: 47–52.
35. Rharrabe K., Amri H., Bouayad N., Sayah F. (2008). Effects of Azadirachtin on post-embryonic development, energy reserves and *α*-amylase activity of *Plodia interpunctella* Hübner (Lepidoptera: Pyralidae). J. Stored Prod. Res. 44, 290–294 10.1016/j.jspr.2008.03.003.
36. Roessler Y (1989): Control; insecticides; insecticidal bait and cover sprays. In: Robinson AS, Hooper G (eds) Fruit Flies: their Biology, Natural Enemies and Control. Elsevier, Amsterdam, pp. 329-336.
37. Schmutterer H (1990). Properties and potential of natural pesticides from the neem tree, Azadirachta indica. Annu. Rev. Entomol. 35: 271-297.
38. Schnepf E, Crickmore N, Van Rie J, Lereclus D, Baum J, Feitelson J, Zeigler DR, Dean DH (1998) *Bacillus thuringiensis* and its pesticidal crystal proteins. Microbiol Mol Biol Rev 62: 775–806.
39. Van Netten, C., K. Teshke, V. Leung, Y. Chow, and K. Bartlett. 2000. The measurement of volatile constituents in Foray 48B, an insecticide prepared from *Bacillus thuringiensis* var. *kurstaki*. The Science of the Total Environment 263:155-160.
40. WHO: Microbial pest control agent: *Bacillus thuringiensis*. Environmental Health Criteria 217, World Health Organization Publication, Geneva (1999).
41. Yu, E. 1982. Control of larch caterpillar *Dendrolimus superans* (Butler) with *Trichogramma dendrolimi* Matsumura. Proceedings of the Chinese Academy of Sciences United States National Academy of Sciences Joint Symposium on Biological Control of Insects: Sept: 295-301.

Appendix (I)

Taung Laylone

Multiple Comparisons

Dependent Variable: Infestation

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
con	Btk	25.75*	3.680	.000	18.31	33.19
	Aza	23.58*	3.680	.000	16.14	31.03
	Bio-con	5.83	3.680	.121	-1.61	13.28
Btk	con	-25.75*	3.680	.000	-33.19	-18.31
	Aza	-2.17	3.680	.559	-9.61	5.28
	Bio-con	-19.92*	3.680	.000	-27.36	-12.47
Aza	con	-23.58*	3.680	.000	-31.03	-16.14
	Btk	2.17	3.680	.559	-5.28	9.61
	Bio-con	-17.75*	3.680	.000	-25.19	-10.31
Bio-con	con	-5.83	3.680	.121	-13.28	1.61
	Btk	19.92*	3.680	.000	12.47	27.36
	Aza	17.75*	3.680	.000	10.31	25.19

Grand Mean

Dependent Variable: Infestation

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
27.375	1.301	24.744	30.006

Appendix (II)

Kalaw

Multiple Comparisons						
Dependent Variable: Infestation						
(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
con	Btk	25.50*	3.818	.000	17.78	33.22
	Aza	23.17*	3.818	.000	15.44	30.89
	Bio-con	3.50	3.818	.365	-4.22	11.22
Btk	con	-25.50*	3.818	.000	-33.22	-17.78
	Aza	-2.33	3.818	.545	-10.06	5.39
	Bio-con	-22.00*	3.818	.000	-29.72	-14.28
Aza	con	-23.17*	3.818	.000	-30.89	-15.44
	Btk	2.33	3.818	.545	-5.39	10.06
	Bio-con	-19.67*	3.818	.000	-27.39	-11.94
Bio-con	con	-3.50	3.818	.365	-11.22	4.22
	Btk	22.00*	3.818	.000	14.28	29.72
	Aza	19.67*	3.818	.000	11.94	27.39
Based on observed means. The error term is Mean Square (Error) = 87.446.						
*. The mean difference is significant at the .05 level.						
b. Dunnett t-tests treat one group as a control, and compare all other groups against it.						

Grand Mean		
Dependent Variable: Infestation		
Mean	Std.	95% Confidence Interval

	Error	Lower Bound	Upper Bound
29.292	1.350	26.562	32.022