Development and validation of an integrated pest management package for the control of major insect pests on cabbage in Lao PDR

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ABSTRACT

Brassicas vegetables are the most important crops grown for domestic consumption in Lao PDR. Lepidopteran caterpillars including diamondback moth (*Plutella xylostella*), common armyworm (*Spodoptera litura*), cabbage cluster caterpillar (*Crocidolomia pavonana*) and imported cabbage worm (*Pieris rapae*) and striped flea beetle (*Phyllotreta striolata*) are the most devastating pests of brassica vegetables in Lao PDR. Brassica producers mostly rely on the application of chemical pesticides to control these pests. In order to reduce pesticide overuse, we evaluated the effectiveness of an integrated pest management (IPM) package (*Bacillus thuringiensis* and neem oil formulations and a chemical pesticide, plus installation of *P. xylostella* and *S. litura* pheromone lures) on cabbage in Kasi district, Vientiane province during January–March 2016. The IPM package was compared with Farmers' practice (calendar-based application of abamectin) and an untreated control. The IPM package was able to reduce shot-hole damage by flea beetle, and the populations of *S. litura*, *P. xylostella*, *C. pavonana* and *P. rapae* significantly on cabbage across the locations. However, the IPM package was not as effective as Farmers' practice. The yield of cabbage was significantly higher in Farmers' practice plots, followed by the IPM package. The IPM package needs to be strengthened, before being validated in major brassica production locations, and then promoted for large-scale adoption.

Keywords

Brassicas, IPM, biopesticides, lepidopteran pests, striped flea beetle

INTRODUCTION

Brassica vegetables are the most important crops grown for domestic consumption in Laos, and also for exports within the region (Chanthasombath et al. 2012). Besides cabbage, leafy brassicas including green mustard, Chinese cabbage, Chinese kale, and pak-choi are also grown mainly for domestic consumption in Laos (Genova et al. 2010). Cabbage is cultivated for domestic and export markets as a high value crop. For instance, 460,000 t of cabbage (worth USD$74 million) was imported into Thailand from Laos. About 32% of income in the agriculture sector comes from cabbage alone, in major cabbage producing regions such as Champasak. However, the annual net profit from cabbage cultivation is only about USD 700 per hectare, and hence the production efficiency of cabbage is at a low level in Laos

(Supawadee 2013). Pests and diseases continue to be a major production constraint in cabbages and other leafy brassicas in Laos.

Lepidopteran caterpillars including diamondback moth (*Plutella xylostella*), the common armyworm (*Spodoptera litura*), the cabbage cluster caterpillar (*Crocidolomia pavonana*) and the imported cabbage worm (*Pieris rapae*), as well as the striped flea beetle (*Phyllotreta striolata*) are the most devastating pests of brassica vegetables in Laos (Schreinemachers et al. 2017; Srinivasan et al. 2019). Severe incidences of multiple pests limit the productivity of brassica vegetables. For instance, the marketable yield of leafy mustard is much lower in Laos (5.6 t/ha), compared to Cambodia (15 t/ha) and Vietnam (12.4 t/ha) (Schreinemachers et al. 2017). Hence, brassica producers mostly rely on the application of chemical pesticides to control the pests, with short spray intervals (two to three days) and the combination of more than ten types of insecticides per season (Mazlan and Mumford 2005; Grzywacz et al. 2010). A recent study found that 83% of the farmers used synthetic pesticides to manage the pests on leafy brassicas, and no farmers used any bio-pesticides (Schreinemachers et al. 2017). Farmers in Laos sprayed more frequently than their counterparts in Cambodia and Vietnam, and 63% of farmers mixed different pesticides in a single spray. Another study documented that 59% of the sampled farmers in Laos overused pesticides (Schreinemachers et al. 2020).

Integrated pest management (IPM) packages can be a better alternative to managing the key insect pests on vegetable brassicas. A bio-pesticide (*Bacillus thuringiensis* and *Metarhizium anisopliae* formulations, and neem leaf extract) based IPM package was similar in efficacy with farmers' practice of calendar-based pesticide application in reducing damage by key insect pests on Chinese mustard, leading to significant yield gains in Cambodia (Srinivasan et al. 2020). However, no such IPM packages have been tested on vegetable brassicas in Laos. Therefore, the objective of the current study was to evaluate an IPM package against major insect pests on cabbage in the Vientiane province of Laos.

MATERIALS AND METHODS

Study sites

Field trials were conducted in Vientiane province (Phaxang village, Kasi district) to evaluate the efficacy of an IPM package based on bio-pesticides in comparison with Farmers' practices (calendar-based spraying of chemical pesticides) and an untreated check during January–March 2016.

Treatment and data collection

Four field trials were conducted to evaluate the efficacy of an IPM package against *P. xylostella, S. litura*, *C. pavonana*, *P. rapae* and *P. striolata* on cabbage. The package consisted of the sequential application of bio-pesticides [Zitarback F.C.™ (*Bacillus thuringiensis* subsp. *aizawai*), Redcat™ (*B. thuringiensis* subsp. *kurstaki*) and neem (Thai neem™) and the chemical pesticide (abamectin). The spraying order was designed based on the incidence of target pests in a given field. Pheromone lures of *P. xylostella* and *S. litura* were also installed in the IPM treatment. Three treatments, *viz*., IPM package, Farmers' practice (calendar-based application of abamectin) and an untreated control were used in all the trials, with four replications for each treatment, following a Completely Randomized Block Design. The individual replication plot size was 12 m^2. The crop was monitored for damage by target pests, and the treatments were initiated from one to three weeks after planting depending on pest incidence and continued at weekly intervals until a week before harvest. The number of larvae on five randomly selected plants in each plot were counted for *P. xylostella*, *S. litura*, *C. pavonana*, and *P. rapae*, whereas the number of 'shot-holes' in a 4 cm^2 area in two younger leaves from each plant were counted on five randomly selected plants in each replication for *P. striolata* damage. Marketable yield was recorded during harvest.

Data analysis

The data was averaged for each plot and analyzed using a combined analysis approach of several experiments (Petersen 1994; Moore and Dixon 2015). Preliminary analysis of variance (ANOVA) was completed for each individual analysis (each location), experimental errors were examined for heterogeneity and Shapiro-Wilkinson test for normality was performed in each individual analysis. The data was then analyzed using ANOVA with the Proc GLM MIXED of SAS, version 9.1 (SAS Institute, Cary, NC, USA). Each experimental site was considered a particular environment for the combined analysis. Random effects were considered for locations, whereas fixed effects were considered for treatments. When significant treatment differences were identified, means were separated by Tukey's HSD Test (SAS) (differences were considered significant at $\alpha = 0.05$). Data on pest incidences and

P. striolata damage were arcsine transformed. Non-transformed data are presented in the results section.

RESULTS

For *P. striolata* damage, *P. xylostella* larval population, and yield both location and treatment were highly significant, whereas *C. pavonana* population was only affected by treatment. In addition, the *P. rapae* larval population showed an interaction effect between location and treatment (Table 1). *Spodoptera litura* larval population was not significantly affected by location and treatment effects. Among the experimental locations, Sakhone farm was the most affected by *P. striolata* damage, but it did not have any significant impact on the marketable cabbage yield, since the same location was the one that recorded the highest yield compared to the other three locations (Table 2). In terms of *P. xylostella* larval population, Ot farm recorded almost twice as much larval incidence as observed in the other locations.

Table 1. Analyses for damage of *Phyllotreta striolata*, incidences of *Spodoptera litura*, *Crocidolomia pavonana*, *Plutella xylostella*, and *Pieris rapae*, and marketable yield of cabbage in Laos during 2016.

Source	df	No. of *P. striolata* shot-holes / leaf		No. of *S. litura* larvae/plant		No. of *C. pavonana* larvae/plant		No. of *P. xylostella* larvae/plant		No. of *P. rapae* larvae/plant		Marketable yield (t/ha)	
		F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Model	23	10.75	<*.0001*	3.04	*0.005*	2.89	*0.006*	19.32	<*.0001*	22.50	<*.0001*	21.63	<*.0001*
Location	3	20.49	<*.0001*	0.69	0.577	3.41	0.053	25.23	<*.0001*	3.86	*0.038*	7.17	*0.005*
Treatment	2	21.88	<*.0001*	3.29	0.055	8.57	*0.002*	105.88	<*.0001*	224.15	<*.0001*	203.72	<*.0001*
Location * Treatment	6	1.88	0.13	2.42	0.057	0.74	0.624	1.27	0.307	3.09	*0.022*	1.84	0.134

Table 2. Mean (±SD) damage of *Phyllotreta striolata*, *Plutella xylostella* larval incidence, and marketable yield by location in Laos during 2016.

Location	N	*P. striolata* shot-holes / leaf	*P. xylostella* larvae/plant	Cabbage yield (t/ha)
Buaodam farm	12	0.24 ± 0.06 b	0.90 ± 0.11 b	48.42 ± 0.99 ab
Mon farm	12	0.13 ± 0.05 b	0.69 ± 0.11 b	46.00 ± 1.33 bc
Ot farm	12	0.14 ± 0.07 b	1.38 ± 0.17 a	45.17 ± 2.02 c
Sakhone farm	12	0.42 ± 0.06 a	0.78 ± 0.12 b	48.92 ± 1.52 a

Means followed by the same letter(s) in a column are not significantly different (p<0.05) by Tukey's HSD

Among the treatments, farmers' practice significantly reduced *P. striolata* damage, and *P. xylostella* larval population, compared to the IPM treatment, but they were significantly higher in untreated control (Table 3). However, both IPM and the farmers' practice significantly reduced the *C. pavonana* larval population, compared to the untreated control. Similarly, the *P. rapae* larval population was significantly higher in untreated control plots compared to IPM and farmers' practice plots, where incidence was low to intermediate (Fig. 1). The marketable yield of cabbage was significantly higher in the farmers' practice (7% higher) compared to IPM plots, which recorded about 18% higher yield compared to the untreated control plots (Table 3)

Table 3. Mean (±SD) damage of *Phyllotreta striolata*, incidence of *Crocidolomia pavonana* and *Plutella xylostella*, and marketable cabbage yield by treatment in Laos during 2016.

Treatment	N	*P. striolata* shot-holes / leaf	*C. pavonana* larvae/plant	*P. xylostella* larvae/plant	Cabbage yield (t/ha)
Control	16	0.31 ± 0.08 a	0.15 ± 0.10 a	1.31 ± 0.13 a	41.12 ± 1.99 c
Farmers' practice	16	0.16 ± 0.03 c	0.05 ± 0.04 b	0.63 ± 0.09 c	51.87 ± 1.17 a
IPM	16	0.23 ± 0.07 b	0.06 ± 0.05 b	0.87 ± 0.16 b	48.37 ± 1.24 b

Means followed by the same letter(s) in a column are not significantly different ($p < 0.05$) by Tukey's HSD.

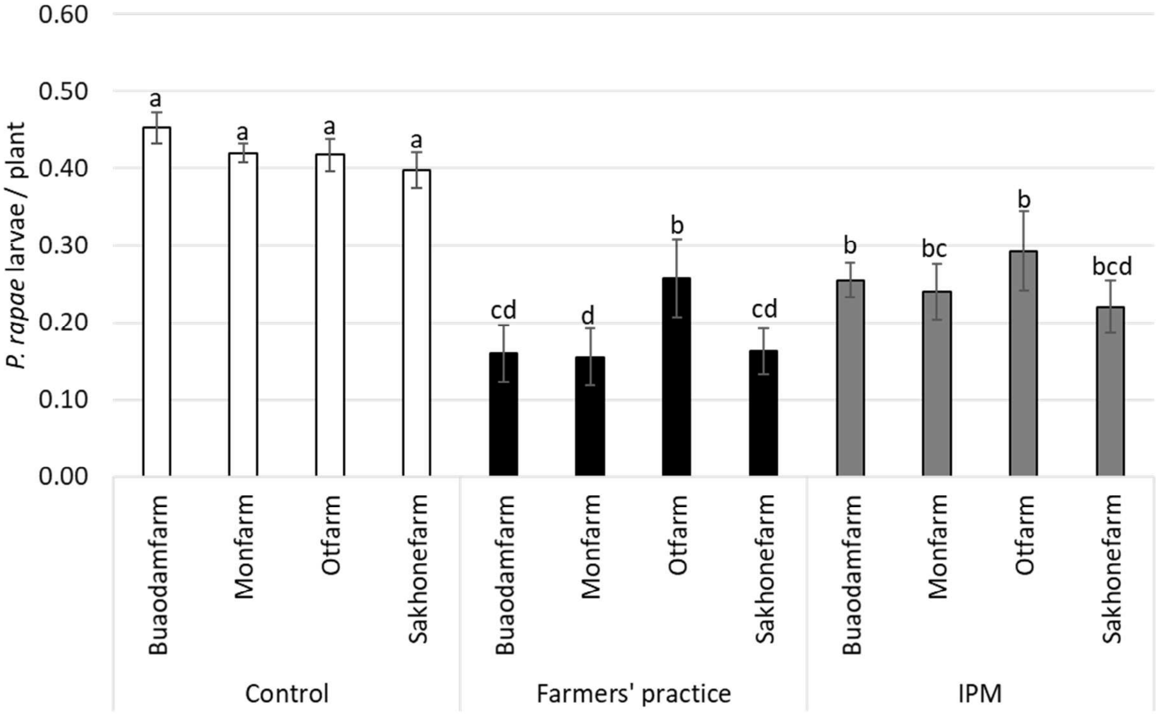

Fig. 1. Mean (±SD) number of *Pieris rapae* on cabbage in four locations in Laos during 2016. Significant differences are presented for the interaction Location*treatment. Locations with the same letter did not differ statistically across treatments.

DISCUSSION

The IPM package was shown to be consistent in reducing pest damage on cabbage, which led to significant yield increases across the four experimental sites in Laos. The IPM package, which predominantly consisted of *B. thuringiensis* and neem oil formulations, provided significant pest control on cabbage in Laos. It should be noted that use of bio-pesticides is highly uncommon in Laos (Schreinemachers et al. 2017), and the farmers have very limited or no access to quality bio-pesticides. Thus, the farmers in our trial locations have never applied bio-pesticides before. Hence, the target insects on cabbage were seemingly susceptible to the bio-pesticide formulations in the IPM package. In neighboring Cambodia, it was demonstrated that the major insect pests of vegetable brassicas were susceptible to various bio-pesticide formulations including *B. thuringiensis*, *M. anisopliae* and neem leaf extract (Srinivasan et al. 2020). Because of the no or limited application of bio-pesticides in those locations in Cambodia, the study confirmed that the insects on Chinese mustard have not developed any resistance and the bio-pesticides were able to provide significant control in field conditions. Due to the analogous situation in Laos, we conclude that the *B. thuringiensis* and neem oil formulations are able to provide adequate control of key insect pests on cabbage.

However, the efficacy and yield from the IPM package were less than the farmers' practice of calendar-based pesticide application. This was contradictory to the results from Cambodia, which showed that the IPM package performed on par with the farmers' practice in Chinese mustard (Srinivasan et al. 2020). It should be noted that the IPM packages in Laos and Cambodia were not the same. Besides *B. thuringiensis* and neem leaf extract, *M. anisopliae* was included in the IPM package in Cambodia. Since we did not have access to *M. anisopliae* in Laos, it was not included in the IPM package. Hence, the current results clearly revealed the need for the inclusion of additional components in the IPM package in Laos. Besides providing better pest control, an improved IPM package should also lead to better or similar yield to farmers' practice. The latter is extremely important to convince farmers to adopt IPM packages, since about 84% of the growers in Laos thought that bio-pesticides were not as effective as synthetic pesticides (Schreinemachers et al. 2017). In addition, the ecosystem services provided by the adoption of IPM packages should be clearly explained to the brassica producers, which could also convince them to reduce the application of hazardous pesticides. It was already documented in Laos that the reduction in the number of chemical pesticides in the IPM fields could augment the natural enemies in brassica fields (Srinivasan et al. 2017). Finally, it is equally important to increase the local availability of bio-pesticides in Laos. Since the Laos Government has planned to increase the organic agriculture and Good Agricultural Practices farms to 70,000 and 100,000 by 2025, respectively (Hoonthong and Manowalailao 2016), the policy environment is highly conducive for the introduction of bio-pesticides.

In conclusion, the IPM package based on *B. thuringiensis* and neem oil formulations provided significant control of *P. striolata*, *C. pavonana*, *P. xylostella* and *P. rapae* damage on cabbage in Laos, and increased the yield. However, the efficacy of the IPM package was less than the farmers' practice and had lower yield. Hence, this IPM package needs to be strengthened with additional bio-pesticide components, before being validated in major brassica production locations and promoted for large-scale adoption in Laos.

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