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Eco-friendly management of *Phthorimaea operculella* Zeller in farmers' potato store in Makwanpur, Nepal

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ABSTRACT

The evaluation of different eco-friendly management techniques of potato tuber moth, (*Phthorimaea operculella* Zeller) in farmers' potato store was done from June to October 2012 in Makwanpur district of Nepal. In this study evaluation of *Phop*GV, *Acorus calamus* L. and Abamectin solely and in combination with Lure and Kill along with farmers' practice was done. Total of 54 farmers were selected, 18 each from three locations: Palung, Daman and Bajrabarahi and the on-farm experiment was conducted in Randomized Completely Block Design (RCBD). In each storage, 100 kg of tubers were treated and other ≥100 kg was kept using farmers own practice. The treatments and their doses for treating each 100 kg of potato tuber were: *Phop*GV @ 500 g, *A. calamus* L. @ 150 g and Abamectin @ 1.5 ml l^{-1} of water sole or in combination with Lure and Kill @ 1 drop covering 4 m^2 area in both treated and farmers' practice. Data was recorded at 21, 42, 63 days after treatment application (on the basis of visual counting- number of damaged tubers were counted, out of 100 tubers' sample taken from treated and farmers practice separately). In the farmer's storage experiment, Abamectin+ Lure and Kill treatment was better among all the treatments and as compared to farmers' practice, which was followed by *A. calamus* treatment. The percentage of damage in *Phop*GV treated potatoes was found at par with farmers practice. The effect of Lure and Kill was found insignificant. This study showed that *Phop*GV, *Acorus* and Abamectin along with Lure and Kill could be used as potential control agent against *P. operculella* under farmers' storage condition.

Keywords: PTM, *Phop*GV, *Acorus calamus*, Abamectin, and Farmers' practice

INTRODUCTION

The potato tuber moth, *Phthorimaea operculella* (Zeller), is one of the major pest causing significant economic losses during potato storage. The farmers have been using the chemical pesticides to protect the tuber in the storage. The viable and sustainable management of *P. operculella* using the conventional method of chemical pesticides has failed. The primary cause of the failure of the use of the insecticides is development of resistance. Integrated pest management is considered the only option for effective control of PTM both in field and storage instead of relying on the pesticides (Raman *et al.*, 1987).

The alternative to the persistent chemical pesticides are necessary to prevent the environment from the side effects. The graulovirus infecting *P. operculella* (*Phop*GV) has been used as a dust formulation for protecting stored potatoes in South American and North American countries. *Phop*GV talcum based wet-mixed formulation was found to have ten times higher efficacy than dry-mixed formulation (Aryal *et al*., 2012). *A. calamus* L. rhizome dust @ 5 g/kg of potatoes showed high efficacy in protecting the tubers against PTM attack in farmer's rustic store for about three to four months (Giri *et al*., 2010). Abamectin, a bio-based chemical pesticide has been used against lepidopteran pests. Lure and Kill is a practice of using chemical pesticides only in a particular place out of contact with tubers to attract PTM males and kill them. This strategy is safe and very effective to manage the PTM population in storage. Due to the lack of effective alternative measures farmers are relying on chemical pesticides to prevent infestation. So, it is very much necessary to explore safe and effective measures to prevent infestation. The objective of our study is to compare the farmer's practice of using chemical pesticides with the safe and eco-friendly pesticides.

MATERIALS AND METHODS

An experiment in farmers' potato store was conducted to evaluate the efficacy of bio-based safe pesticides as compared to farmers practice of using chemical pesticides. For this, 18 farmers from each village i.e. Palung, Daman and Bajrabarahi were selected. In each farmer's storage 100 kg of potato tuber was weighted with the help of the spring balance and kept in a room with the application of the treatment. In case of *Acorus calamus* L., it was applied at 150 g per 100 kg potato tubers in different layers of the tubers while piling. For the application of *Phop*GV each of 25 kg of potato tubers was kept in a air tight plastic bag and 125 g of talcum based *Phop*GV formulation was dusted over the tubers inside the plastic bag. The plastic bag was then filled with air with the help of mouth and then the bag was sealed. The sealed bag was then rotated and swirled such that the thin layer of *Phop*GV gets attached on surface of potato tubers. This process was repeated to treat 100 kg of potato tubers in each farmer's storage. Abamectin solution was prepared at 1.5 ml/l of water and sprayed just to wet tubers. It was then dried in shade and piled up. If Lure and Kill was used, one drop of Lure and Kill was kept in a petridish and the dish was placed on the pile of the potato tubers of both treated (*Phop*GV or *Acorus* or Abamectin) and control (farmers' practice). In the farmer's storerooms where the potato tubers treated with the novel products have used the Lure and Kill then it was also kept in control i.e. farmers practice to prevent biasness. Lure and Kill was used at 1 drop per $4m^2$ area.

Observations were taken at 21, 42 and 63 days after the treatment application (DATA) (on the basis of the visual counting- number of damaged tubers were counted, out of 100 tubers' sample taken from both treated and farmer's practice separately). Hundred tubers were randomly sampled from the treated and control (farmer's practice) potato pile in each farmer's storeroom. The number of PTM-infested tubers from each sample was assessed. Those tubers with mines, irrespective of the number of mines, were registered as damaged and those without any mines were counted as undamaged.

The collected data (on percentages of damaged tubers) were analyzed using χ^2 -statistics for pair-wise comparison of treatments and farmers' practice over time. χ^2 values were calculated to test the differences between treatment and control (farmer's practice). The formula to test differences between two samples:

$$\chi 2 = \frac{\boldsymbol{n} \times (\boldsymbol{ad} - \boldsymbol{bc})^2}{(\boldsymbol{a}+\boldsymbol{b})(\boldsymbol{c}+\boldsymbol{d})(\boldsymbol{a}+\boldsymbol{c})(\boldsymbol{b}+\boldsymbol{d})}$$

Where n is sample size (n = 200; n = a + b+ c +d), a is the number of damage tubers, and b the number of healthy tubers in the sample from the treatment (n_1 = 100), and c and d are the number of damaged and healthy tubers, respectively, in the sample from the control (n_2 = 100) (with $n = n_1 + n_2$).

In second step, data were analyzed by generalized linear models (GLM) using logit-transformation as a linearizing link function. Akaike information criterion (AIC) was used to test the best model.

RESULTS AND DISCUSSION

This experiment revealed that *A. calamus* rhizome dust and Abamectin were found significantly better in most of the storage experiments at all three locations viz., Palung, Daman and Bajrabarahi in all three observations. In case of *Phop*GV, most of the storage showed no significant difference in infestation percentage in all three observations (Table 1, 2, 3).

Three models were fitted for tuber infestation by *P. operculella* for farmers' practice. The first model (null) assumed that the infestation percentage was same in all 54 storages. The first model had a deviance of 2811.41 and was considered inappropriate and further other models were tested with additional parameters (Table 4).

In the second model, the assumption was that the infestation varies across the three evaluation intervals. Compared to the null model, the deviance decreased from 2811.41 to 2256.18 in this model. According to Akaike Information Criterion (AIC), the second model was better than first (null) model. The variance ratio F-test revealed that the model with additional parameters for the evaluation interval (E_i) described infestation significantly better than the null model (F = 32.98, df = 270, 268 P≤ 0.001) (Table 4). Infestation increased from the first to the second evaluation and also from the second to the third but relatively less (Table 5).

The third model evaluated additional parameter, i.e. Lure and Kill, for the estimation of variation in infestation level with and without Lure and Kill (B_i with i =0,1). The deviance for this model was 2243.34. According to AIC the second was better than the third in describing the data (F =0.76, df = 268, 266, P =0.468) (Table 4).

In model 4, the treatment effect was added to model 3 and was tested that whether the treatment had any effect on each storage or not as compared to farmers practice. Model 4 explained the data more than the model 2. Variance ratio test or F test revealed that model 4 was better than model 2 (F = 57.37, df = 267, 268, P < 0.001). According to AIC, model 4 best explained the variability in farmers storage among all farmers storage (Table 4).

Model 5 was same as model 2 in terms of the variability. Model 5 included *Phop*GV whose effect was negligible in the damage as compared to farmers practice. According to AIC, model 5 was same as model 2 (Table 4). Infestation decreased from first to second evaluation and also from second to third evaluation (Table 5).

Model 6 was additional *Acorus calamus* L. with model 2. Model 6 better fitted to model 2 as F-test showed significantly better fit of model 2 indicating the effect of *A. calamus* significantly better (F=17.01, df = 265, 268, P≤0.001) (Table 4). In *A. calamus* treated store rooms, the estimate of infested tubers was decreased in second reading and increased in the third reading (Table 5).

Model 7 was additional Abamectin with model 2. Model 7 showed significantly better fit to model 2. This indicated that Abamectin had significantly better (F=26.26, df=265, 268, P≤0.001) result than farmers practice (Table 4). The proportion of damage at first evaluation period was -2.444 and decreased in the second (-4.055) and the third evaluation (-3.723). Abamectin showed significantly better result on infestation of potato tubers (Table 5).

In model 8a, *Phop*GV, *Acorus* and Abamectin were added to model 2. Model 8a better fitted to model 2 as F test showed significantly better fit (F = 11.83, df = 259, 268, P <0.001) (Table 4). In model 8b Lure and Kill was additional to model 8a. This revealed that the Lure and Kill had no significant effect (F=0.93, df= 257, 259, P=0.394) on infestation of potato tubers (Table 4).

In *A. calamus* treated stores, potato tubers infestation was lower in all observation periods as compared to farmer's practice. Giri *et al.* (2010) also reported that *A. calamus* stolon dust at 5 g/kg of potato tubers showed high efficacy to protect potato tubers against potato tuber moth for about three to four months in farmer's rustic potato stores. The dried rhizome of sweet flag was found to possess both the killing and deterrent effects against insect infestation in stored paddy (Ghose*et al*., 1960). *Phop*GV showed same damage as that of farmers practice. Ali (1999) reported that the use of *Phop*GV for controlling PTM in farmers' rustic potato storeroom was very successful. Alcazar *et al*. (1992) found the population of PTM was significantly reduced by 71.5% and 100% in infested tubers after 30 and 66 days of *Phop*GV application, respectively. Abamectin was found effective against the PTM. Arora*et al.* (1996) also reported the effectiveness of avermectin against Lepidopteran pests. In combination with Lure and Kill it showed same result as that of sole application. El-sayes *et al.* (2009) reported Lure and Kill was used for long term eradication of invasive species.

Table 1. Effect of novel and farmer's practice against *P. operculella* at Palung, Makwanpur, Nepal, 2012

Novel product	Infestation at 3 weeks (%)				Infestation at 6 weeks (%)				Infestation at 9 weeks (%)			
	Novel practice	Farmer's practice	χ^2	P	Novel practice	Farmer's practice	χ^2	P	Novel practice	Farmer's practice	χ^2	P
*Phop*GV	1	7	4.69	*	2	9	4.71	*	2	10	5.04	*
*Phop*GV	21	5	28.13	***	22	21	0.03	ns	35	2	17.74	***
*Phop*GV	34	5	26.79	***	38	3	37.58	***	41	2	45.06	***
A. Calamus	0	6	6.19	**	2	1	0.34	ns	1	7	4.69	*
A. Calamus	0	3	3.05	ns	1	10	7.79	**	1	8	5.70	*
A. Calamus	1	4	1.85	ns	2	9	4.71	*	6	15	4.31	*
Abamectin	1	1	0.00	ns	0	1	1.01	ns	1	7	4.69	*
Abamectin	1	4	1.85	ns	1	6	3.70	ns	1	8	5.70	*
Abamectin	3	12	5.84	*	2	14	9.78	***	6	16	5.11	*
*Phop*GV +L&K	3	8	2.41	ns	0	49	64.90	***	4	76	108.0	***
*Phop*GV +L&K	2	1	0.34	ns	4	3	0.15	ns	2	6	2.08	ns
*Phop*GV +L&K	9	22	6.45	**	8	27	12.50	***	12	32	11.66	***
A. Calamus+L&K	2	6	2.08	ns	4	12	4.35	*	13	30	8.56	***
A. Calamus+L&K	2	3	0.21	ns	0	39	48.45	***	12	62	53.63	***
A. Calamus+L&K	4	4	0.00	ns	2	9	4.71	*	6	14	3.56	ns
Abamectin +L&K	0	3	3.05	ns	0	4	4.08	*	0	18	19.78	***
Abamectin +L&K	0	1	1.01	ns	0	4	4.08	*	0	8	8.33	***
Abamectin +L&K	0	6	6.19	**	0	15	16.22	***	0	74	117.5	***

Significant differences between the alternative method and farmer's practices are indicated by asterisk χ^2 test : P < 0.001= ***, (0.001< P < 0.01)= **, P < 0.05= *, ns= not significant. Farmer's practice indicates method to protect potato tubers where the farmers apply their most trusted chemical pesticide

Table 2. Effect of novel and farmer's practice against *P. operculella* at Daman, Makwanpur, Nepal, 2012

Novel product	Infestation at 3 weeks (%)				Infestation at 6 weeks (%)				Infestation at 9 weeks (%)			
	Novel practice	Farmer's practice	χ^2	P	Novel practice	Farmer's practice	χ^2	P	Novel practice	Farmer's practice	χ^2	P
*Phop*GV	3	0	3.05	ns	2	0	2.02	ns	4	1	1.85	ns
*Phop*GV	13	0	13.9	***	18	0	19.78	***	21	0	23.46	***
*Phop*GV	13	13	0.00	ns	14	23	2.69	ns	15	18	0.33	ns
A. Calamus	0	1	1.01	ns	0	4	4.08	*	0	6	6.09	**
A. Calamus	3	2	0.21	ns	2	10	5.67	*	4	12	4.35	*
A. Calamus	0	3	3.05	ns	1	7	4.69	*	3	6	1.05	ns
Abamectin	0	3	3.05	ns	0	3	3.05	ns	0	5	5.13	*
Abamectin	3	4	0.15	ns	0	5	5.13	*	1	7	4.69	*
Abamectin	0	1	1.01	ns	0	3	3.05	ns	0	6	6.19	**
*Phop*GV +L&K	5	9	1.23	ns	2	13	8.72	***	7	10	0.58	ns
*Phop*GV +L&K	2	2	0.00	ns	4	1	1.85	ns	11	1	8.87	***
*Phop*GV +L&K	6	4	0.42	ns	5	10	1.80	ns	3	10	4.03	*
A. Calamus+L&K	1	7	4.69	*	1	10	7.79	**	4	10	2.76	ns
A. Calamus+L&K	7	4	0.87	ns	3	11	4.92	**	8	14	1.84	ns
A. Calamus+L&K	3	13	6.79	**	3	10	4.03	*	3	17	10.89	***
Abamectin +L&K	0	3	3.05	ns	0	5	5.13	*	0	7	7.25	**
Abamectin +L&K	0	6	6.19	**	1	5	2.75	ns	2	9	4.71	*
Abamectin +L&K	0	1	1.01	ns	0	3	3.05	ns	0	7	7.25	**

Significant differences between the alternative method and farmer's practices are indicated by asterisk χ^2 test : P < 0.001= ***, (0.001< P < 0.01)= **, P < 0.05= *, ns= not significant. Farmer's practice indicates method to protect potato tubers where the farmers apply their most trusted chemical pesticide

Table 3. Effect of novel and farmer's practice against *P. operculella* at Bajrabarahi, Makwanpur, Nepal, 2012

Novel product	Infestation at 3 weeks (%)				Infestation at 6 weeks (%)				Infestation at 9 weeks (%)			
	Novel practice	Farmer's practice	χ^2	P	Novel practice	Farmer's practice	χ^2	P	Novel practice	Farmer's practice	χ^2	P
*Phop*GV	2	26	23.92	***	4	30	23.95	***	7	35	23.63	***
*Phop*GV	7	6	0.08	ns	8	10	0.24	ns	5	13	3.91	*
*Phop*GV	1	0	1.01	ns	1	0	1.01	ns	1	1	0.00	ns
A. Calamus	3	4	0.15	ns	12	4	4.35	*	20	9	4.88	*
A. Calamus	0	20	22.22	***	3	55	65.66	***	7	76	4049.	***
A. Calamus	0	1	1.01	ns	3	10	4.03	*	9	26	10.01	***
Abamectin	0	4	4.08	*	0	3	3.05	ns	1	7	4.69	*
Abamectin	2	1	0.34	ns	0	5	5.13	*	0	3	3.05	ns
Abamectin	1	4	1.85	ns	0	6	6.19	**	0	8	8.33	***
*Phop*GV +L&K	47	70	10.89	***	83	48	27.10	***	79	59	9.35	***
*Phop*GV +L&K	38	12	18.03	***	63	25	29.30	***	79	37	36.21	***
*Phop*GV +L&K	5	8	0.74	ns	11	6	1.61	ns	14	13	0.04	ns
A. Calamus+L&K	1	0	1.01	ns	0	6	6.19	**	0	8	8.33	***
A. Calamus+L&K	2	30	29.17	***	15	40	15.67	***	9	76	91.85	***
A. Calamus+L&K	3	2	0.21	ns	0	7	7.25	**	3	13	6.79	**
Abamectin +L&K	0	1	1.01	ns	2	10	5.67	*	1	7	4.69	*
Abamectin +L&K	2	61	80.66	***	0	73	114.9	***	1	86	147.0	***
Abamectin +L&K	2	5	1.33	ns	0	8	8.33	***	1	6	3.70	ns

Significant differences between the alternative method and farmer's practices are indicated by asterisk χ^2 test: P < 0.001= ***, (0.001< P < 0.01)= **, P < 0.05= *, ns= not significant. Farmer's practice indicates method to protect potato tubers where the farmers apply their most trusted chemical pesticide

Table 4.Treatment deviance table by logit models among *Phop*GV, *A. calamus* and Abamectin with the interaction of Lure and Kill, Makwanpur, Nepal, 2012.

SN	Model	Logit (formula)	Deviance	df	AIC	F-test	P
	Farmers practice						
1	Intercept (null)	n	2811.41	270	4028.24		
2	Evaluation interval	$n + E_i$	2256.18	268	3595.13	32.98	***
3	Evaluation interval + Lure & Kill	$n + E_i + B_i$	2243.34	266	3592.75	0.76	ns
	Treatment factors						
4	Evaluation interval + Treatment	$n + E_i + T$	1857.16	267	3057.69	57.37	***
	Treatment effect (*Phop*GV)						
5	Evaluation interval + *Phop*GV	$n + E_i + A_i$	2242.94	265	3583.73	0.52	ns
	Treatment effect (*Acoruscalamus*)						
6	Evaluation interval + *Acoruscalamus*	$n + E_i + V_i$	1891.85	265	3150.73	17.01	***
	Treatment effect (Abamectin)						
7	Evaluation interval + Abamectin	$n + E_i + M_i$	1739.16	265	2866.40	26.26	***
	Treatment effect (Lure & Kill)						
8a	Evaluation interval + *Phop*GV + *A. calamus* + Abamectin	$n + E_i + A_i + V_i + M_i$	1360.29	259	2404.18	11.83	***
8b	Evaluation interval + *Phop*GV + *A. calamus* + Abamectin + Lure & Kill	$n + E_i + A_i + V_i + M_i + B_i$	1350.48	257	2398.46	0.93	ns

n = null model, E_i= Evaluation interval (21 Days After Treatment Application, 42 DATA, 63 DATA), E_1 = First observation, E_2 = Second observation, E_3 = Third observation, B_i = Biorational (Lure & Kill), V_i= *Phop*GV, M_i = Abamectin and A_i= *Acorus*; AIC = Akaike Information Criterion; χ^2 test: P(<0.001) = ***, P(<0.01) = **, P(≤0.05)= *

Table 5. Parameters and their values on logit transformation with standard error and confidence interval

Parameter		Value	SE	95% Wald confidence interval	Wald Chi-Square	df	Sig.
Null	(*n*)	-3.333	0.517	(-4.346) - (-2.319)	41.530	1	***
	E_1	0	-	-	-	-	-
Time	E_2	0.658	0.160	(0.350) - (0.972)	16.935	1	***
	E_3	1.279	0.152	(0.980) - (1.580)	70.352	1	***
	V_1	0.305	0.232	(-0.151) - (0.760)	1.720	1	ns
*Phop*GV	V_2	0.087	0.205	(-0.315) - (0.489)	0.180	1	ns
	V_3	-0.278	0.192	(-0.653) - (0.980)	2.099	1	ns
	A_1	-1.656	0.434	(-2.506) - (-0.805)	14.55	1	***
Acorus	A_2	-1.763	0.343	(-2.436) - (-1.090)	26.341	1	***
	A_3	-1.611	0.259	(-2.119) - (-1.102)	38.531	1	***
	M_1	-2.444	0.632	(-3.682) - (-1.206)	14.978	1	***
Abamectin	M_2	-4.055	0.954	(-5.924) - (-2.186)	18.076	1	***
	M_3	-3.723	0.628	(-4.554) - (-2.491)	35.106	1	***

Null= intercept; E_1= First evaluation (21 days after treatment application), E_2= Second evaluation (42 DATA), E_3= Third Evaluation (63 DATA); V_1= Effect of *Phop*GV at first evaluation, V_2= Effect of *Phop*GV at second evaluation, V_3= Effect of *Phop*GV at third evaluation; A_1= Effect of Acorus at first evaluation, A_2= Effect of Acorus at second evaluation, A_3= Effect of Acorus at third evaluation; M_1= Effect of Abamectin at first evaluation, M_2= Effect of Abamectin at second evaluation, M_3= Effect of Abamectin at third evaluation; Wald Chi-Square- P(<0.001) = ***, P(<0.01) = **, P(≤0.05)= *

CONCLUSION

A. calamus L.and Abamectin were significantly better than the farmers' practice that was mostly based on the use of chemical pesticides. *Phop*GV resulted in similar protection as the current farmers' practice (chemical control). As *Phop*GV is the microbial-based pesticide it could be used in the farmer's storage, where no direct sunlight could affect the activity of the product and where the temperature doesn't exceed the tolerant level.

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