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Field Evaluation of Attracticides in Managing Potato Tuber Moth, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechidae) in Bhutan

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Abstract

The Potato Tuber Moth (PTM) is the most important insect pest of potato in the world and is increasingly becoming a very important pest of potato in Bhutan as well. Attracticides, a formulation containing synthetic pheromone mixed with an insecticide and applied as drops, was introduced from International Potato Center and evaluated for its use to control the PTM. Field experiments were carried out to assess the efficacy of attracticides in controlling PTM populations in different locations of Bhutan in 2010 and 2011. After application of attracticides, significant difference in the weekly mean adult male population of the pest between the controlled and treated plots were observed in both the years. Application of attracticides reduced the male population by 63-100% in the treated fields over a period of four to eight weeks. Results indicate that this technology can be employed against PTM as an environment friendly alternative to insecticidal cover sprays. Attracticides are effective, affordable, and easy to use formulation especially in the field. However, this study should not be used to make recommendations at this stage since further studies on the effectiveness of attracticides on PTM over wider area covering various agroecological zones, optimum application rate, and frequency; considering both efficacy and cost benefit, are recommended.

Key words: Attracticide, Integrated Pest Management, pheromone, *Phthorimaea opercullela, Solanum tuberosum*

Introduction

In Bhutan, potato (*Solanum tuberosum* L.) is an important crop as it is a source of food, income, and employment. Production of potato was recorded at 50,390 MT in 2013 from an area of 13,391 acres (DOA, 2014). It is one of the most important cash crops, especially to the farmers in the higher altitudes, and is also a very important staple food. Most farmers producing potato export their produce to neighboring India. In terms of revenue generation, potato was listed as one of the top ten export commodities in 2009 and 2014 (MOF, 2010; MOF, 2015). Therefore, potato has tremendous socio-economic importance on the Bhutanese population since it contributes significantly to the national and household income.

Potato production is limited by many biotic and abiotic factors, among which the Potato Tuber Moth (PTM), *Phthorimaea opercullela* (Zeller), is one of the most damaging insect pests in fields and during storage, especially in warmer climatic regions. Importance of the pest is realised in many countries (Hanafi, 1999) and is considered as the most damaging potato pest in the developing world (Cisneros and Gregory, 1994; Kroschel and Sporleder, 2006). Its distribution is reported in more than 90 countries worldwide (Kroschel *et al*., 2012). In India, severe damages of 30 to 60% were recorded in the Kangra valley of Himachal Pradesh (Singh *et al*., 1990; Chandel *et al*., 2001), and up to 100% in Karnaraka (Trivedi *et al*., 1994). The PTM therefore poses a serious threat as an invasive pest particularly to the potato growers in warmer areas.

The PTM is a noted storage pest in areas that are located in the range of 1700 m to 2400 m above sea level in Bhutan (BPDP, 2006) as the storage temperature is warmer and optimum for its activity. Its larval stage is the most damaging stage. In a survey carried out in September, 2009, an average

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of 35% infestation was found in the farm stores in eastern Bhutan (Wangchuk, unpublished) with averages ranging from 21 to 42% in the three districts of Mongar, Trashigang, and Pema Gatshel. However, 100% and 50% infestations were also observed in 2% and 31% of the stores respectively from the 146 stores surveyed. In these three districts, farmers reported very high losses due to PTM infestation since the market value of infested tubers was completely lost.

As the PTM is relatively a new pest of potato in Bhutan, both the farmers and extension agents have very limited knowledge or experiences on its management. The current recommendation in managing this pest is an insecticidal treatment either in the field or storage, use of clean planting material, hilling up after tuber initiation and proper store sanitation (BPDP, 2006). However, apart from the chances of this pest developing resistance to insecticides, frequent use of cover sprays can have an adverse effect on human health, beneficial organisms, and the environment. Therefore, this warrants the need to evaluate novel and environmentally friendly techniques which can provide an alternative to broad spectrum insecticides. Hence, in order to provide farmers with an affordable, effective, and an easy to use technique; the attracticide, which employs the attract and kill mechanism, was introduced from the International Potato Center (CIP), Lima, Peru, in 2009, as one of the components of devising an efficient Integrated Pest Management (IPM) package in managing PTM through the Austrian Development Agency funded project.

The active ingredients of the attracticide are a pure pheromone (0.05%) and the contact insecticide Cyfluthrin, which are formulated with plant oils and UV absorbers (Kroschel *et al*., 2008). Attracticide provides a slow and uniform release of the powerful pheromone that only attracts the male moths, which are killed through contact with the insecticide. Once the male population is suppressed in the field, the chances of females finding a male to mate and produce fertile eggs is greatly reduced, which subsequently suppresses the population. This technique, known as attract-and-kill technique, disrupts the mating behavior of the pest and has been successfully employed against important pests like the codling moth, *Cydia pomonella* L. (Hofer and Brassel, 1992). This technology has received attention since mass trapping using a large number of pheromone traps was not practical and economical (Kroschel, 2008). This technique is considered a suitable substitute for traditional pesticides that can prevent negative effect on the non-target organisms and the environment (Haynes *et al*., 1986; Downham *et al*., 1995; Trematerra, 1995).

Although, this technology is consistent with the IPM principles, reports on a wide scale field testing does not exist and hitherto has not been carried out. Therefore, the objective of this study was to evaluate the field efficacy of the attracticide in suppressing the male PTM populations in fields in different locations in Bhutan.

Materials and Method

Location

The trial was set up in five locations of Bhutan located in the altitude range of 1500-2500 m at Drametse (2100 m), Kanglung (1940 m), Yangneer (1940 m), and Khaling (2080 m) in the east, and Lobneykha (2353 m) in Chapcha in the western part of the country in 2010 and 2011. However, a different location was selected for Drametse in 2011, which was situated at 1800 m. In all of these locations, very strong adult activities were observed in the field during crop growth and were also observed to cause heavy losses in the farmers' stores (personal observation). The observation fields were selected based on accessibility and farmers' willingness to monitor the pheromone traps on a daily basis.

Treatments

In each location, two fields of size ranging from 0.2 to 1.2 hectares were selected and marked as treated and control plot with a buffer space separating them. However, for Lobneykha, two treatment and two control plots were selected in 2010. Accordingly, the treated plots were applied with attracticide, at the rate of one drop per 8 m^2 in the Drametse, Yangneer, Kanglung, and Khaling, and one drop per 4 m^2 in Lobneykha in 2010. In 2011, the rate of application was uniform at one drop per 4 m^2 in all the locations. Attracticide was applied with the help of a hand-held applicator on leaves of potato variety Desiree. Treated

There was no objective involved in the different application rates of attracticide. The rates were adopted considering the quantity of attracticide available and efficacy of different rates reported by CIP. Accordingly, the above two rates were adopted to optimally utilise the resource available. Increase in application rate and adopting only one rate of application of attracticide in 2011 was suggested by CIP scientists to increase efficacy for better quality results. The application of the attracticide was done on the same day as the setting up of the pheromone trap in 2010 whereas in 2011, the application was made a week after the traps were set up. In both the

years, application was done only once. Attracticide was not applied in the control plots.

Evaluation

Pheromone based water traps were constructed using PTM pheromone lures. Pheromone traps were set up to monitor the male PTM populations in both the treatment and control plots, in all the locations on 2 April in 2010 (ca 45 DAP) and 18 April (ca 60 DAP) in 2011. Since most of the trial sites were located in remote villages, farmers undertook the responsibility of recording the total number of adult male PTM catches in the pheromone traps on a daily basis. Due to some anomaly observed in the data recorded by some farmers, only the data from Drametse, Kanglung, and Lobneykha for 2010 and Kanglung and Drametse for 2011 were included for analysis to determine the field efficacy of the attracticide. The daily data obtained on male PTM catches were converted to weekly means. The efficacy of the treatment (% of male PTM populations suppressed by attracticide application) was calculated using the formula:

Efficacy (%) = (Control - Treatment) / Control x 100

Where, the value for control and treatment is the weekly mean male PTM capture in each of the control and treatment plots. No data on tuber infestation in field during the time of harvest was recorded as the levels and symptoms of infestation on tubers, right after harvest, was usually at an early stage and not very conspicuous (personal observation).

Statistical analysis

The data for the weekly mean male adult PTM capture were analysed using SPSS. Prior to analyses, normality of the data was checked using the Kolmogorov Simirnov test and homogeneity of variances was tested using the Levene's test. In order to normalise variances, the data were log transformed [log(x+1)]. The weekly mean male PTM capture data for the treated and control fields were subjected to a *t* test comparison. Differences in treatment means were considered statistically significant at $p = 0.05$ level.

Results and Discussion

For the 2010 experiment year, *t* test comparison showed significant difference (Table 1) in the weekly mean number of adult male PTM captured in the pheromone traps between the treated and control plots in Drametse ($t_{(5)} = 3.502$, $p = 0.017$), Kanglung ($t_{()} = 5.532$, $p = 0.012$), Lobneykha Field 1 ($t_{()} = 6.145$, $p = 0.009$) and Lobneykha Field 2 ($t_{()} = 7.060$, $p = 0.006$). The trials repeated in 2011 also indicated significant differences (Table 1) in the weekly mean number of adult male PTM captured in the pheromone traps between the treated and the control plots in Dremetse ($t_{(7)} = 5.861$, $p = 0.001$) and Kanglung ($t_{(7)} = 3.994$, $p = 0.005$).

In both the experimental years, a mean efficacy of 85% was observed within a range of 63% to 100%

Table 1. Weekly mean male PTM catch per trap

	2010					2011				
	N	Control	Treatment	Efficiency (%)[1]	*p*	*N*	Control	Treatment	Efficiency (%)	*p*
Drametse	6	9.3	1.1	88	0.017	8	117.0	16.0	86	0.001
Kanglung	4	12.9	4.8	63	0.012	8	22.1	3.7	83	0.005
Lobneykha Field 1	4	8.5	0.0	100	0.009	-	-	-	-	-
Lobneykha Field 2	4	4.4	0.4	91	0.006	-	-	-	-	-
Mean	-	8.8	1.6	85	-		69.6	9.9	85	

N = number of weeks; [1](control-treatment)/control x 100; $p \leq$ significant at 0.05

in 2010 and 83% to 86% in 2011 for a period ranging from four to eight weeks. The mean weekly population in the year 2011 was 8 and 6 times higher than that of the year 2010 in the control and treatment plots respectively. This can be mainly attributed to the higher population of male PTM catches in Drametse during 2011 as the experimental site was at lower altitude of 1800 m where the temperature and population dynamics could have been higher than at the site located at 2100 m in 2010.

The mean weekly male PTM population, as captured in the water based pheromone traps, in the treated plots was suppressed to 0 in Drametse, Lobneykha Field 1 and 2 and to < 5 in Kanglung in 2010 (Figure 1) within four to five weeks after application of the attracticide, whereas, in the control plots, the mean weekly male PTM population were 13, 25, 6 and 15 respectively. Similarly, the mean weekly population was significantly lower in the treated plots than the control plots in both locations of Drametse and Kanglung in the experiment year

2011 (Figure 2). In the course of eight weeks, the mean weekly population increased to 220 in the control plots whereas, in the treated plot, it remained at < 30 in Drametse. In Kanglung, during the same time, the mean weekly population in the control plot increased to 80 whereas it remained < 5 in the treated plot.

These results show that the use of attracticides in controlling the PTM pest in fields is useful in reducing agricultural chemicals use, helping the country gradually to becoming an organic country, which is consistent with the IPM principles. However, use of attracticide to control PTM is still in an evaluation phase. Area-wide evaluations have not been documented so far and are limited only to the ones conducted by the International Potato Center (CIP). Therefore, we have not been able to find any reports on the use of attract and kill technology besides that of Kroschel and Zegarra (2006, 2007, 2008, 2010). Preliminary report on field experiments of this technique conducted by CIP in Peru did provide positive results. Evaluation of attracticide on a 250 m^2 plots at droplet densities of 1 drop per 1 m^2, 2 m^2, 4 m^2, and 8 m^2 suppressed the daily PTM male, compared with the control, by 89.4%, 83.8%, 64.5% and 51.8% respectively (Kroschel and Zeggara,

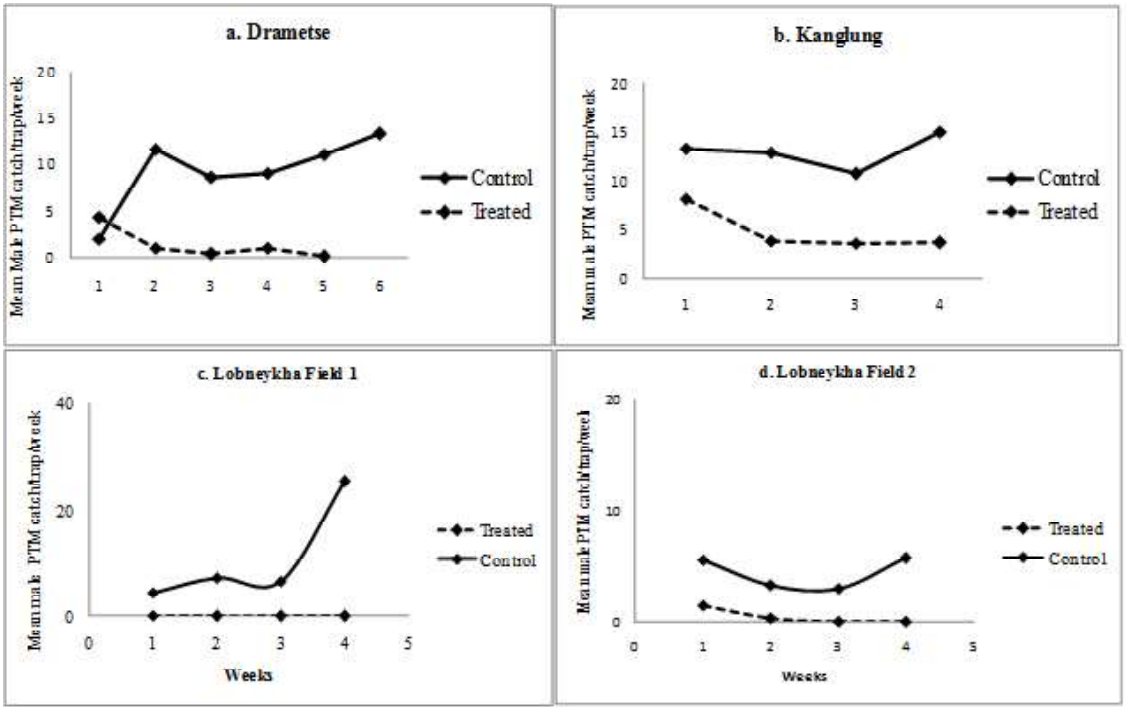

Figure 1. Mean male PTM catch per week in control and treatment plots in four locations in 2010

2007). The finding by Kroschel and Zeggara (2007) is consistent with the results obtained in this study, where the weekly male PTM population was suppressed within the range of 83% to 100% after application of attracticide at 1 drop per 4 m^2 and 63 to 88% after application at 1 drop per 8 m^2. However, considering that the previous study followed three applications at 10 day intervals against only one application in our study, it can be concluded that repetitive applications are not necessary.

The results from this study strongly suggest that the use of "attract and kill" technology, using the PTM specific attracticide, can completely suppress the male PTM population in the field. Therefore, an area-wide control of PTM using this technology has the potential to completely eradicate the pest population if other factors like new introduction of PTM are regulated. Such a trend was noted in the results obtained from Lobneykha, which is geographically isolated, and PTM population suppression can be easily achieved in such locations if "attract and kill" technology is implemented over time. The results from this study indicated the effectiveness of attracticide in controlling the pest with a single application in a season. However, the number of applications can be determined by observing the population dynamics of the pest during the crop season.

The "attract and kill" technique seemed effective in controlling PTM in the study areas, which could prove useful for Bhutan in general. Attracticide is very specific and compared to cover sprays, its effect on human health, beneficial organisms, and non-target organisms would remain low. This is because compared to cover sprays, small amount of insecticide

is sprayed in the field, which significantly reduces the chances of beneficial and non-target organisms coming in contact with it. For instance, at an application rate of one drop (which is approximately 100µL) per 4 m^2, 62.5 droplets are required to treat a 250 m^2 plots or 2,500 droplets are required to treat a hectare plot (Kroschel and Zegarra, 2007). In addition, application of attracticides in the form of a droplet on the leaves of crop requires relatively lower investment both in terms of labour and money. Unlike cover sprays, attracticide application also does not require expensive spraying equipment in the field.

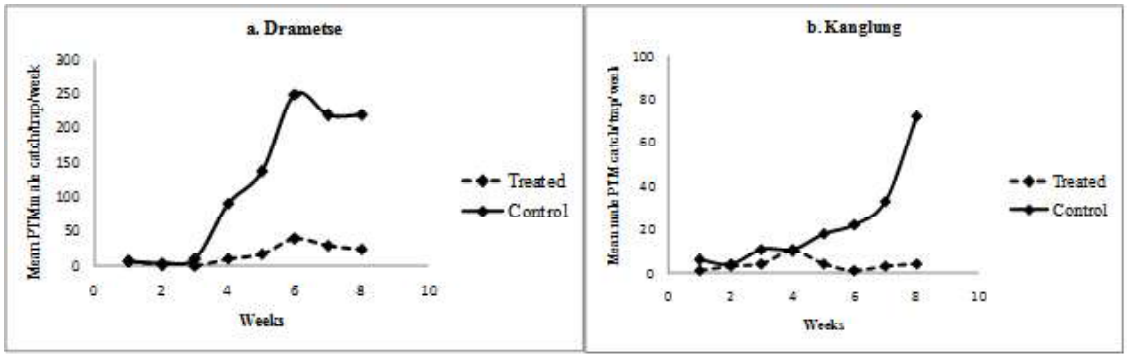

Figure 2. Mean male PTM catch per week in control and treatment plots in two locations in 2011

Conclusion

This first report on a wide scale test of attracticide in Bhutan in different agroecological zones gave promising results. This technology therefore has the potential to be an environmentally friendly alternative for cover sprays, compatible to the IPM principles. However, the findings of this study should not be used to make recommendations yet, as it is still in its preliminary stage and can only indicate the potential use of the technology. Therefore, it is recommended to expand the evaluation of attracticide in wider area covering different agroecological zones in order to understand the interactions of the pest agroecology and the technology. Evaluations for optimum application rate and frequency, considering both efficacy and cost-benefit, should also be conducted before recommendations are made for use by farmers. Also, future studies in Bhutan should evaluate the effectiveness of attracticide in potato store houses. Use of attracticides in stores can reduce PTM infestation by 87% (Kroschel, 2008). However, the attracticide is a product which was recently developed and is in the final stage of commercialisation. If introduced in the market, attracticides could be registered for wider use in Bhutan, following further evaluations in the fields as well as in potato store houses.

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