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Research Article

Management of Potato Tuber Moth, *Phthorimaea operculella* (Zeller), using Entomopathogens, Botanicals and Insecticide under Storage Conditions

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ABSTRACT

Potato (*Solanum tuberosum L.*) is one of the widely grown crops in Ethiopia and has been listed as one of the major commodities in the 15 years Agriculture research strategy Plan. The potato tuber moth (PTM), *Phthorimaea operculella* (*Zeller*), is a world-wide pest of potato and other solanaceous vegetables. PTM is a serious pest of potato, under DLS condition, where the use of entomopathogens or botanicals is an environmentally sound than synthetic pesticides in IPM principles but is not practiced well rather using synthetic insecticides in the whole potato production system. An experiment was conducted to evaluate the efficacy of entomopathogens, botanicals and insecticides for their control of PTM at Holeta under DLS conditions at Holetta Agricultural Research Center, central Ethiopia in 2016/17 cropping season. Potato varieties; 'Belete' were used with randomized complete block design by three replications. The following bio-pesticides were included Birbira seed (*Miletia ferugenus*) powder and solution, Pyrethrum flower (*Chrysanthemum cineraraefolium)* powder and solution; entomopathogens *Metarizum anosipele and Beuberia basiana* powder (@125g/ 25kg of tuber) and synthetic insecticide Ethiozinon (Diazinon 60% EC) and untreated control were evaluated against PTM natural infestation in locally constructed DLS store. All the treatments were found significantly superior to control (76.67% tuber infestation) but among the treatments, Berbera seed extract powder were most effective each with an average of 6% tuber infestation up to 4.5 months followed by Berbera seed extract solution (21.67%) and both Pyrethrum flower powder and solution responds equally; 22% and 23% respectively. Under different treatments, the numbers of infestation holes per tuber varied from 5 in Berbera seed extract powder to 26.9 in Metarhizium anisopliae fungus; all responded differently, as compared to control (26.9 holes per tuber). Under DLS, all botanicals and fungi treatments showed good protection to potato seed tubers from the pest up to the first two weeks.

Key words: Metarizum anosipele, Beuberia basiana, bio-pesticides, Pyrethrum flower, Berbera seed extract, DLS, Phthorimaea operculella, bio-pesticides, potato tuber moth (PTM)

INTRODUCTION

The cultivated potato (*S. tuberosum L.)* was originated in the highlands of Andes in South America and was brought to Europe in the 16th Century and to Ethiopia in the 19th Century; Potato is one of the very important food and cash crops in Ethiopia, especially in the high and mid-altitude areas. Potato was introduced to Ethiopia first by Schimper, a German botanist, in 1858 (Horton, 1987 and Pankhurst, 1964 cited by Gebremedhin *et al*., 2006). Despite the significant potential contributions of horticultural crops, particularly of root and tuber crops, for food security, income generation, and resource base conservation, they have not yet been fully exploited and utilized (Woldegiorgis *et al*., 2008). The highest yield of potato is produced in the highlands where the temperature is relatively low. Today, however, due to the tremendous genetic diversity of potato and the development of appropriate cultural practices, it can be successfully and profitably grown in warmer areas, which are referred to as non-tradition potato growing areas. In recent years, the production of this crop is expanding rapidly owing to the presence of improved technologies and expansion of irrigation culture (Asresie Hassen et al, 2015). Additional areas in the different agro-ecological zones (AEZs) are also considered suitable for potato production. The crop is grown mainly during the main season and where irrigation is available and frost is not

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limiting; year round production is also possible. The low-cost diffused light store (DLS) for seed tubers developed by CIP has been evaluated under the Ethiopian condition. It was found to be very useful and efficient storage technique. Consequently, it has been adopted by many potato farmers' in many parts of the country. The vast majority of the Ethiopian population depends mainly on cereal food crops, as root and tuber crops are important non-cereal staples. As a food crop, the potato has a high potential to supply a cheap and quality food within a relatively short period. Moreover, it has the correct balance of protein calories and total calories. It is considered to be one of the cheapest sources of energy and the production of protein per unit land is the highest among the four major food crops (rice, maize, wheat and potato). The potato protein is of good composition with respect to essential amino acids for human nutrition. The average biological values of the potato protein are about 70% of whole egg, exceeded only by fish, sweet potatoes and rice each with about 75% (https://en.wikipedia.org/wiki/Potato). The potato tuber moth (*Phthorimaea opercuiella Zell.*) has been recognized since the beginning of this century (Attia & Mattar 1939) as a cosmopolitan pest of potato crops grown in subtropical and temperate climates. In the early 1080s, some insecticides that control potato tuber moth (PTM) have been recommended for mid- and lower altitude locations. In Ethiopia, currently the production and utilization of potato as staple food and side dish was increasing with the availability of research developed high yielding varieties. Among the major production constraints of the crop, the bacterial wilt, early and late blight disease of potato followed by potato tuber moth. The potato tuber moth, *Phthorimaea operculella* (Zeller), is a pest of many solanaceous crops such as potato, tomato, pepper, eggplant, tobacco, and nightshade (Langford, 1934).

Wildspecies of the Solanaceous family, including imp ortant weeds (black night shade, Solanum nigrum L.) are reported hosts. In total, the host range comprises 60 species (J. Kroschel, 2008). Moths lay eggs through soil cracks on the developing tubers, which can cause high tub er damage at harvest.Tuber infestation caused by first inst ar larvae can be hard to detect, such that even with precaut ionary measures infested tubers are transferred to potato st ores. Characteristic piles of feces indicate infestation; insi de tubers, larvae bore irregular galleries that may run into the interior of the tubers or remain directly under the skin (J. Kroschel, 2008). Larvae of this species mine leaves, stems, and petioles and excavate tunnels through potato tubers. Adhanom and Tesema (1981) have recorded 74% tuber infestation by the PTM on potato seeds stored for six months at Melkasa. Similarly, Bayeh and Tadesse (1992) were found the insect is highly important in store potatoes at the highlands around Holeta. Adequate control of PTM is critical because larval infestation of tubers renders potatoes unmarketable. There is zero tolerance for the presence of tuber moth larvae in raw processing product because they are classified as foreign material. Often, tubers are treated with insecticides at the beginning of the storage period to control the pest. Experiences from CASCAPE project potato demonstration and promotion intervention revealed that, spraying of 100 ml of Diazinon mixing in 20 liter of water every one to two weeks starting from January to planting (May or June) was found to be effective in controlling potato tuber moth in small scale diffused light store. According to the intensity and occurrence of the insect (potato tuber moth) farmers sprayed every two week to reduce potato tuber moth (Asresie Hassen et al, 2015). Synthetic pesticides are a costly input and repeated usage contaminates the environment, increases resistance to insecticides and can cause health hazard. In Ethiopia the economic damage is more important and it has established itself as an important pest in major potato growing areas. The importance of the pest is expected to increase because of the long distance movement of seed tubers to many places across the country from limited source locations mainly in the cool highlands of North and West Shoa (Ferdu et al, 2009a). Thus, protecting potatoes in an integrated manner is essential to the production of a high quality crop without PTM damage. Insect diseases caused by bacteria, viruses, and nematodes have been developed to control insect pests, including PTM. Microbial control of PTM is not yet developed for commercial use, but has potential in the future. Farmers appraisal on potato pests revealed that insect pests such as aphids, potato tuber moth (PTM) mole rat, cut worm and termites were recognized as production constraints (Bekele, 2016). Further in-door the experiment was then carried out to evaluate the efficacy of entomopathogens, botanicals and insecticide for their control of PTM at Holeta under DLS conditions.

MATERIALS AND METHODS

Area description

The present investigation was conducted at EIAR, Holetta agricultural research center, situated 40 km from Addis Ababa, Ethiopia at 37° N latitude, 77° E longitude and at about 2200 masl. The experiment was conducted in locally constructed storage DLS with an average room temperature ranging from 25-28°C with 60-70% relative humidity.

Test treatments and preparation of plant extracts

Botanical preparations of Berbera Seeds (*Miletia ferugenus)* were collected in the premises of the Holetta research center. The seed coats were removed and the cotyledons were crushed with mortar and pestle. Pyrethrum flower (*Chrysanthemum cineraraefolium*) of 1kg were dried and crushed with mortar to form powder. The stock solutions were prepared for one time use only. All treatments were evaluated against PTM natural infestation from the field through tubers at DLS. Thereafter, the preparation was thoroughly mixed and filtered through goose and squeezed to remove particulate matter and stored in transparent vials under refrigerator (Bayeh, 2007). The treatments were replicated three times with RCBD design. The *Metarizum anosipele, Beuberia basiana* powder formulations were applied @ 125g/ 25kg of tuber, whereas applied as per the method used by International Potato Centre (CIP, 1992). Accordingly, the tubers were put in buckets containing powdered preparations of the fungus @ 125 g/25kg tuber (0.1 LE per kg tuber) and shaken for proper coating of the preparation. The treated/untreated tubers were kept on the shelve at room temperature ranging from 25-28°C and 60-

Table 1: Detail experimental treatments

TN	Detail treatments	Category
1	Birbira seed *(Miletia ferugenus*) of 500 g were crushed with mortar and socked in 10 liter of water for 24 hr. One hundred clean potato tubers will be dipped for 10 minutes and placed in the store under normal storage condition.	Botanical
2	Birbira seed *(Miletia ferugenus*) of 500 g were crushed with mortar and One hundred clean potato tubers were coated and placed in the store under normal storage condition.	
3	Pyrethrum flower (*Chrysanthemum cineraraefolium*) of 35g were crushed and socked in 10liter of water for 24 hr. One hundred clean potato tubers will be dipped for 10 mints	
4	Pyrethrum flowers (Chrysanthemum cineraraefolium) of 35g were crushed and One hundred clean potato tubers were coated.	
5	*Metarizum anosipele* powder *(@125g/ 25kg of tuber)* were dissolved in 10 liter of water and then One hundred clean potato tubers were dipped/ soaked in the solution for 10minutes.	Fungi
6	*Beuberia basiana powder (@125g/ 25kg of tuber)* were dissolved in 10 liter of water and then One hundred clean potato tubers were dipped/ soaked in the solution for 10minutes.	
7	5 ml of Diazinon 60% EC were dissolved in 10 liter of water and then One hundred clean potato tubers were dipped in the solution for 10minutes	Chemical
8	Control; One hundred clean potato tubers were placed in the store under normal storage condition to serve as control treatment.	Control

70% relative humidity under diffused light for natural infestation by PTM. The number of infested tubers was counted at one week intervals up to 19 WAE of the treatment and calculated percent tubers damaged. The number of sprout damage, active holes, larvae and active galleries per tuber was also recorded from damaged tubers. An untreated control was run simultaneously to compare the effectiveness of the bio-pesticide treatments.

Statistical analysis

Data was subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD) using SAS statistical software and Minitab v 17.

RESULTS AND DISCUSSION

The analysis of variance on Table 2 shows that all the bio-pesticide treatments were statistically significant difference from the control treatment in preventing the damage to potato tubers by Potato tuber moth. Among the damaged tubers from the samples, significantly higher number of them had active PTM hole, which was identified by the accumulation of fresh excrement pushed out by the feeding larvae from their feeding galleries (Photo 1). All the treatments were found significantly superior to control (76.67 % tuber damage) but among the treatments, Berbera seed extract powder**,** *Millettia ferruginea* (Hochst.), were most effective 6.33% tuber infestation followed by Berbera seed extract solution and both Pyrethrum flower extract solution and powder*; Chrysanthemum cineraraefolium;* 21.67%, 22% and 23 % respectively. Under different treatments, the numbers of infestation holes per tuber varied from 5 in Berbera seed extract powder to 26.9 in Metarhizium anisopliae fungus. Both Berbera in the form of powder and solution and pyrethrum in the form of powder are better as compared to control (26.9 holes per tuber).

All the bio-pesticide treatments meet the expense of protection to tubers against PTM up to 16 WAE of treatment and were significantly superior even 19 WAE of the treatment with an average tuber infestation ranging from 6.33-23% as compared to 76.67 % in the control. Among bio-pesticide treatments, significantly higher infestation was observed in control (check) and Metarhizium anisopliae fungus treatments at different weeks counting interval. Seven weeks after Establishment Berbera seed extract powder showed lowest active PTM created holes per tuber and the highest was recorded from Metarhizium anisopliae fungus, Control(check) and Diazinon 60% EC respectively. Similarly, between treatments in 9^{th}, 10^{th}, 12^{th}, 14^{th}, 16^{th} and 19^{th} WAE consecutive count there was significant difference among the treatment ($P<0.05$). Generally, from the ANOVA the treatments showed different responses with counting dates. But Berbera seed extract powder**,** *Millettia ferruginea* (Hochst.), treatment showed the lowest infestation in all weeks after establishment compared to other treatments even if the standard and control. As shown below (Graph 1) the reaction PTM in terms of active hole per tuber to exposed treatment have clear response. Minimum sprout damage was recorded from Berbera seed extracted powder treated tubers and that of maximum was from tubers treated with Diazinon 60 % EC and all the rest treated tubers showed almost the same response. This DLS experimental trial gives information to use pyrethrum in the form of powder for coating potato tuber rather in solution form for reducing sprout damage. But according to Bayeh Dipping of potato tubers in aqueous solutions of pyrethrum flower or Neem leaf powder were found to be effective in significantly reducing sprout damage by the PTM in Holetta and Shashemene DLS condition (Ferdu et al, 2009a).

Berbera seed extracted powder and Birbira seed extract Solution were the most effective each with an average of 0.3%-19.3% and 0.67%-29.3% tuber infestation respectively (graph 1). The infestation was below ETL up to 14 WAE but steady rise in infestation was observed when time goes. Consequently, on 16WAE highest tuber infestation was recorded in all bio-pesticides except Berbera seed extracted powder which is below ETL. After all at 19WAE all the test treatments showed highest infestation level spanned ETL and while working the significance of the treatments proved at par from the control (Table 3). This implies that the repeated application of bio-pesticide should be done at 16 WAE before reach over ETL otherwise the infestation will increase dramatically within weeks. These findings are in accordance with Chandel et al., (2008) who reported that the application of bio-pesticide to stored tubers provides a high degree of protection under rustic conditions. Similar

Table 2: ANOVA table for PTM management at DLS condition using botanicals and entomopathogens.

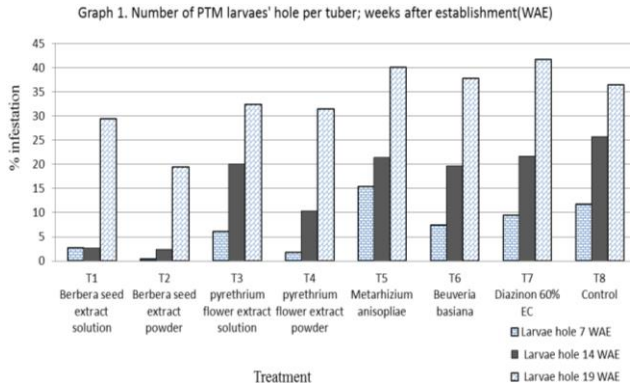
Treatments	Damage per 50 tubers at 150 DAE				Larvae	% of tubers after 4.5 months	
	Holes	Total	sprout	Galleries		Healthy	Damaged
Berbera seed extract solution	8.3DC	26C	38.67BC	2.67EDF	5.43	78.33B	21.67DE
Berbera seed extract powder	5D	12D	24.67C	0.33F	6.83	93.67A	6.33E
Pyrethrum flower extract solution	19.07B	31.33BC	56.67AB	6CDE	6.87	78B	22DE
Pyrethrum flower extract powder	10.37C	35.67AB	52AB	1.67EF	6.43	77B	23D
Metarhizium anisopliae fungus	26.9A	36.33AB	57.33AB	15.33A	7.5	58.33C	41.67BC
Beuveria Basiana fungus	23.76A	36AB	52.67AB	7.33BCD	7.73	51.67C	48.33B
Diazinon 60% EC	24.1A	40.33A	68A	9.33BC	5.23	72.67 B	27.33 CD
Control	26.9A	35AB	54.33AB	11.67AB	8.13	23.33 D	76.67A
LSD (0.05)	4.18	8.48	24.86	4.9	NS	55.69	14.33
CV	13.2	15.34	28.08	41.47	52.37	20.18	10.11

Means that do not share a letter are significantly different. LSD-least significant difference, %- percentage, DAE- days after experiment establishment.

Table 3: Effect of bio-pesticides on potato tuber infestation by potato tuber moth weekly response.

Treatment	Tuber infestation WAE						
	7	9	10	12	14	16	19
Berbera seed extract solution	2.67EDF	0.67D	2.3CD	2C	2.67C	12.67C	29.3D
Berbera seed extract powder	0.3F	2.3D	0.3D	1C	2.3C	4.67D	19.3E
Pyrethrum flower extract solution	6CDE	9C	10.3BC	17.67B	20A	25A	32.3BCD
Pyrethrum flower extract powder	1.67EF	0.67D	1.3CD	0 C	10.3B	18.67B	31.3CD
Metarhizium anisopliae fungus	15.3 A	22AB	22.3A	30.3A	21.3A	25.67A	40AB
Beuveria Basiana fungus	7.33BCD	15.67B	18.3AB	26AB	19.67A	25.3A	37.67ABC
Diazinon 60% EC	9.33AC	17.3AB	13AB	26.67AB	21.67A	24.3AB	36.3ABCD
Control(check)	11.67AB	23A	22.3A	27.67A	25.67A	26.3A	41.67A
LSD (0.05)	4.93	6.55	9.46	9.04	6.21	5.9	8.17
CV	41.5	32.99	29.09	31.46	22.96	16.6	13.9

LSD- least significance difference; Means with similar letters within a column are not significantly different at 5% probability level; WAE:week after experiment establishment.



Graph 1: Comparison of botanicals and entomopathogens on percent active PTM created hole per tuber recorded in weeks after experiment Establishment.

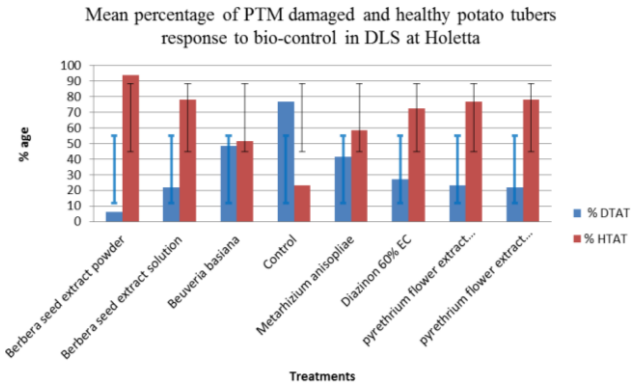


Fig 2: Evaluation after 4.5 month of treated tubers in DLS condition. DTAT=percent of Damaged tuber After Treatment; HTAT=percent of healthy tubers after treatment.

results were earlier obtained by Gualdron and Notz (2000) who reported significant reduction of PTM infestation with 97-100 percent larval mortality using bio-pesticide treated tubers. Potato tubers treated with Granulosis virus (GV) has also been reported to be extremely effective in reducing PTM damage under storage conditions by Chandel and Chandla (2005).

Pyrethrum flower extract powder (1.67%) infestation was next best treatment followed by Berbera seed extract solution (2.67%) and Pyrethrum flower extract solution (6%) up to 19 WAE. Similar result was obtained using Pyrethrum flower extract powder in reducing potato tuber moth damage in storage conditions up to 4 months (Ferdu et al, 2009a). According to Anonymous, 2000; Lantana camara and Eucalyptus leaves has been recommended for use in stored tubers. Promising results of bio-pesticides have been obtained against other crop pests also (Saxena et al., 1992; Golob and Gudrups, 1999; Thakur et al., 2012).

The infestation increased when storage time goose and up to 49th day of observation but thereafter a dramatic rise in tuber damage was observed. This shows that additional treatments were needed to prevent the tuber damage. The damage reached up to 76.67% on 19th WAE in control untreated tubers as compared to an average of 6.33% (Berbera seed extract powder) to 23% (Pyrethrum flower extract powder) tuber damage in different treatments. The maximum healthy tuber was recorded in Berbera seed extract powder about 93.67 %. In general, Berbera seed extract powder gave the best protection to the seed tubers (Fig. 2). Significant reduction up to 97.3% in PTM infestation has been reported by Mariy et al. (2000b) in the treatments with L. camara extracts. The efficacy of Bt_k has been reported against PTM infestations

Photo 1: Infested tuber sign and active PTM Galleries of damaged potato tubers (*photo by Tilahun M.*).

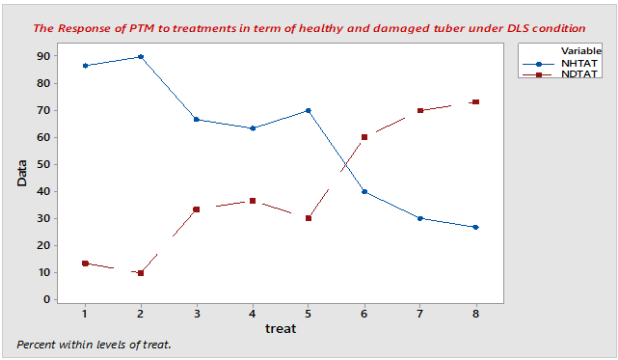


Fig 2: The response of PTM to treatments in terms of healthy and damaged tuber under DLS condition (using Minitab v 17).

by Arthurs et al. (2008). This study confirmed that both screened fungi respond almost similarly against PTM in all evaluations criteria. After four months of storage time Beuveria Basiana and Metarhizium anisopliae fungus showed equal response in damaged and healthy tubers about half percentage.

Conclusions and recommendation

The present studies lead to the conclusion that under storage conditions entomopathogens and plant based pesticides can be a safer and effective alternative for PTM management which is simple to prepare and apply. Under diffused light store (DLS) conditions Berbera extracted powder and solution were highly effective up to 14WAE even the powder Berbera exceeded up to 16WAE (table 1). All the exposed treatments were effective in controlling the infestation below ETL up to the first two weeks, but thereafter the PTM infestation increased dramatically. This shows that there should be repeated application of the treatment in order to manage PTM incidence below ETL level. This application interval may be a research gap for another study. In my recommendation on potato PTM: the most important insect pest in the field and storage at recent condition. Coating of potato tuber by Berbera seed extracted powder on DLS reduced the damage by PTM. Under this condition synthetic insecticide Diazinon 60% EC controlled the pest 27.33%.

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