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Integrated Management of *Phthorimaea operculella* (Zeller) Infesting *Solanum tuberosum* L. in Storage in MT Elgon Region, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The production of potato, a second major staple food crop in Kenya is being constrained by an insect pest potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae). The present study investigated two Integrated Pest Management techniques which would reduce (PTM) population in potato storage, four potato cultivars and two botanical quantities were used in storage in Mt Elgon region of Western Kenya. The insecticidal efficacy of *Lantana camara* L. and *Azandiracta indica* A. Jusss (Sapindales: Meliaceae) and in storage at Kapsokwony and Chemoremo villages were investigated in the present study years. In each of the studied site the experiment was laid down in randomized block Design (RBD) in a split plot arrangement at room temperature of 27 ± 2. Four cultivars (Tigoni, Sherekea, Mayan gold and Asante) were the first factor and treatments (*L. camara* and *A. indica* leaves powder and control) as the second factor, each of which was repeated three. The room was partitioned at the center into two (3m x3m) using a PVC sheet to separate two portions for the two botanical and to prevented insect migration. We set up 4 caring bags per cultivar per botanical. We placed 2 kg PTM-free tubers per each cultivar in

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one caring bag hence 4 caring bags/split/ cultivar and 16 caring bags / block, therefore the total number of caring bags was (4 x 4)= 16 bags per cultivar hence (16 x 4) = 64 caring bags/ botanical. The splits had four 2kg caring bags hence (2x4) = 8 kg per split and (8x16) = 32kg/cultivar hence N =128kg. The caring bags were covered with a layer of the botanicals at a rate 100g, 150g, 200g, and untreated control respectively. Twenty (10♀ + 10♂) newly emerged moths were introduced inside the storage. We assessed for week one number of tubers infested and tunnels of PTM larvae, at week two for number of tubers infested and tunneling length. Week three number of tubers infested, tunneling length in tubers and number of second generation larva. Analysis was done by comparison of the means and there mean differences using R software. Results indicated use of 200g/ 2kg of the botanicals significantly reduced number of PTM larvae. *Lantana camara* was the most effective insecticide followed by *Azadrachta indica* compared to the controlled tubers. Thus the use of 200g of *L. camara* and Tigoni cultivar may be promising components of IPM strategies for reducing *P. operculella* population in potato fields and storage.

Keywords: Phthorimaea operculella; cultivars; and botanicals.

1. INTRODUCTION

The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) is one of the most destructive pests of potato in both fields and storage [1, 2]. According to Hooshang *et al*. [2] damage of the pest in suitable conditions in storage is more than in the field [3]. Kroschel *et al*. [4] documented that insect pests are major biotic factors affecting potato yield and tuber quality. Rondon, [5], Kroschel *et al.* [4] documented that potato tuber moths (PTM) *P. opercullela*, Guatemalan potato tuber moth, *Tecia solanivora* (Povolny), [6]. Andean potato tuber moth, *Symmetrischema tangolias* (Gyen.) Sporleder *et al. [7]*, are common in attacking and damaging potato in the fields and in storage, Furthermore Olanya *et al*. [8] reported that *P. operculella* occur today as serious potato pests. Hooshang *et al*. [2] reports that the PTM larvae cause severe damage to stored potatoes through mining into tubers that lead to rotting by penetration of fungal and bacterial agents. In addition, the high cost of insecticides and there hazardous effects make us to seek and use other safe means such as medicinal plants for pest control. Essential oils (EOs) are volatile and natural compounds which are characterized by a strong odor and are formed as secondary metabolites by plants belonging to botanical families, like *Myrtaceae, Lauraceae, Lamiaceae, Asteraceae*. These compounds have functions in chemical defense, either by acting as repellents or insecticides or acaricides and by attracting natural enemies of herbivores [9,10,11]. According to Hooshang *et al*. [2] normally this compounds are extracted by hydro-distillation and they comprise terpenes and terpenoids and other aromatic and aliphatic constituents. EOs affects several targets at the same time, because of their great number of constituents; this fact decreases the target organisms' resistance or adaptation. More so, EOs induces cytotoxicity, damage the cellular membranes, act as prooxidants on proteins and DNA and produce reactive oxygen species. Such activity is mostly induced by phenols, aldehydes and alcohols. In some cases, essential oils and their components have demonstrated nuclear and cytoplasmic mutagenicity, acting on mitochondria and the respiratory system [11]. In addition to that [3] documents that the biological activity of EOs and their components on pest insects comprise behavior and feeding deterrence effects, fumigant toxicity, knockdown activity and lethal toxicity via contact. Furthermore these substances are generally active against a broad spectrum of pests. Isman, [12] argues that the most favorable aspect of using EOs and their constituents in pest management is their non-mammalian toxicity and their non-persistence in the environment. According to Muthoni et al. [13] little literature exists on the knowledge of pest control for most of the potato pests including *P. operculella*. On the other hand Hooshang et al. [2] reports that there are many researches to show the role of some plant oils as control agents against storage pests but there is less knowledge about their effects on PTM. Moawed [14] reported that applying the 1% oils of *Mentha citrate* (Ehrh.), *Cymbopogon citratu* (DC.) Staf and *Myristica fragrans* Houtt. decrease larval penetration of *P. operculella*. In present study efficacy of different quantities of 100g, 150g and 200g of *L. camara* and *A. indica* leaf powder were evaluated in the control of *P. operculella* Infesting *S. tuberosum* in storage in Mt Elgon region.

2. MATERIALS AND METHODS

2.1 Experimental Locations

The study was conducted in experimental farms of Kapsokwony Boys high school's store in Bugaa village and on Mary lokiring's farm store in Chemoremo village. The experiment was conducted between 15/8/2017 to 7/9/2017.

2.2 Source of Tubers

Certified potato seeds of varieties; Tigoni, Sherekea, Asante and Mayangold were bought from KALRO Tigoni in Limuru Kenya. Then planted in Kapsokwony boy's high school under normal farm practice and conditions. Freshly harvested tubers were used for the experiment.

2.3 Experiments Design

Each experiment was arranged in randomized block Design (RBD) in a split plot arrangement at room temperature of 27 ± 2. The room was partitioned at the center into two (3m x3m) using a PVC sheet to separate two portions for the two botanical and to prevented insect migration. A plywood base floor was raised 45cm from the ground avoid contact with the cold storage floor. We set up 4 caring bags per cultivar per botanical the caring bags allowed ventilation. We placed 2 kg PTM-free tubers per each cultivar in one caring bag hence 4 caring bags/split/ cultivar and 16 caring bags / block, therefore the total number of caring bags was (4 x 4)= 16 bags per cultivar hence (16 x 4) = 64 caring bags/ botanical. The splits had four 2kg caring bags hence (2x4) = 8 kg per split and (8x16) = 32kg/cultivar hence N =128kg. We left a buffer strip of 15cm wide between and around the four blocks. Each caring bag served as an independent sampling unit. The tubers in the experimental caring bags were of the 100g to 80 g size class. Each 2 kg caring bag therefore contained about 20 to 30 tubers.

The trials were replicated three times with repeats in site.

Botanical preparations: The tested plants powders indicated in Table 1 were collected from different fields. *L. camara* in the premises of Kapsokwony boy's high school and Neem (*A. indica*) leavers from Mrs. Mary lokiring's homestead in Chemoremo village a potato farmer. These plants were identified according the description of Migahed [15]. The botanicals were dried under the shade at room temperature (27 ± 2 °C) for two weeks the dried plant leaves were pulverized in fine powders with the aid of electric grinder and sieved. Then weighed using an electro balance. The obtained powders were packed in A2 Khaki envelops till be used in the experiments. Potato cultivars were covered with three concentrations (200g, 150g, and 100g) of the plant powder in different caring bags to study their effect on *P. operculella* and untreated potato tubers were used as control in each treatment. Each treatment was replicated three times.

2.4 Application of the Botanicals

The caring bags were covered with a layer of the botanical powder of *L. camara* and *A. indica* at a rate 100g, 150g, 200g, respectively, and one caring bag left without powder i.e untreated potato which were used as a control in each.

2.5 Insect Rearing

Twenty infested tubers were placed in a breeding cage (L x W x H = 45cm x 35cm x 35) the sides and back walls of the cage were covered with a plywood, and the front of each cage was a plate glass which served as a door. The cages were kept in a room at ambient temperature and humidity for two week without any destruction but daily checked for emergence of the moths. The emerging adults after eclosions, twenty (10♀ + 10♂) newly emerged moths were chosen from the stock culture and introduced inside a boiling tube, the open end of the boiling tube was coved using watman filter paper (diameter = 5 cm). The collected moths were placed in the two rooms portions. This was done once, at the onset of the experiment, in the single release and allowed free movement of insects. The boiling tubes were placed at the center of the room, opened to allow the moth to fly out freely.

2.6 Data Collection

We sampled caring bags randomly per variety at week one for number of tubers infested we used the frass and tunnels of PTM larvae as indicators of tuber infestation, at week two for number of tubers infested and tunneling length of the first

Table 1. Botanicals evaluated against potato tuber moth

Common Name	Scientific name	Plant parts used
Red sage	*Lantana camara*	Leaf powder
Neem	*Azadrachta indica*	Leaf powder

larval instar as described by Varela and Bernays [16, 2]. Week three number of tubers infested, tunneling length in tubers and number of second generation larva. During sampling we removed 4 tubers from each caring bag. We excluded sampled potatoes from the remainder of the experiment. To prevent contamination of control caring bags by the botanicals we always sampled the control boxes before handling the treated ones.

2.7 Data Analysis

Data was statistically analyzed using comparison of the means using R software.

3. RESULTS AND DISCUSSION

Results obtained in Tables 2 showed combined effects of botanical concentrations on the number of larvae and the length of tunneling in the potato cultivars by PTM after treated with three concentrations of the tested materials in the two sites. The length of tunneling after three weeks of treatment treated in case of Tigoni cultivar at the lowest concentration (100g) were1.325±0.0025, 2.1±0.0010 with *L. camara* and *A. indica* respectively. While they were 0.375±0.0002, 2.05±0.0021 at the highest concentration 200g for the two powder plants, *L. camara* and *A. indica* respectively. Compared with control which gave the highest numbers 1.325±0.0025 and 2.15±0.0010. Sherekea cultivar at lowest concentration (100g) was 2.025 ± 0.0041, 2.225±0.0007 with *L. camara* and *A. indica* respectively. While they were 0.675±0.0004, 2.225±0.0042 at the highest concentration 200g for the two powder plants, *L. camara* and *A. indica* respectively. Compared with control which gave the highest numbers 2.3±0.0016 and 2.3±0.00022. Mayan gold cultivars at lowest concentration (100g) were 3.25 ± 0.0031, 3.2±0.0069 with *L. camara* and *A. indica* respectively. While they were 1.725±0.0001, 3.1±0.0052 at the highest concentration 200g for the two powder plants, *L. camara* and *A. indica* respectively. Compared to the control which gave the highest numbers 3.45±0.0043 and 3.175±0.0061. Asante cultivars at lowest concentration (100g) were 2.325 ± 0.0031, 2.375±0.0056 with *L. camara* and *A. indica* respectively. While they were 0.75±0.0013, 1.575±0.0012 at the highest concentration 200g for the two powder plants, *L. camara* and *A. indica* respectively. Compared with control which gave the highest numbers 2.2±0.0028 and 2.2±0.0071.

The lengths of tunneling by potato tuber moth were significantly lower in *L. camara,* than the *A. indica* and the control treatments. The length of tunneling by PTM was significantly higher in *L. camara* at quantities (200gm, 1.725±0.0001) of Mayan gold and lower in Tigoni (200gm, 0.375±0.0002). Furthermore the varieties exhibited different protection levels Tigoni ≥ Asante ≥ Sherekea ≥ Mayan gold. Besides, the length of tunneling by PTM in *A. indica* (200g, 3.1±0.00052) of Mayan gold variety was higher unlike in *L. camara,* (200gm, 1.725±0.0001) this indicates that *L. camara,* ≥ *A. indica* in protecting the tubers against the PTM tunneling. Furthermore these results demonstrated that *L. camara* and *A. indica* at 100g had rather low inhibitory effects against the pest.

Our finding indicates that 200g of the tested botanicals were the best compared to 100g and the control. This finding is consisted to the finding of Shaaya *et al.* [17] who documents that at higher concentrations botanicals can cause 90% mortality of major stored product insects.

However our study proved that *L. camara* had better protection results compared to *A. indica* this finding is contrary to the findings on Meena and Chandla [18] who found out that *A. indica* was better than *L. camara*. On the other hand our finding was supported by the findings of (Rahman, 1944) who documented that *Lantana sp*p. Lantana (Verbenaceae) can drastically reduced damage of PTM by covering tubers with small cover of leaves of *L. camara* in India. The same results in the suppression of PTM were reported in Peru [19,20, 21,22], in Nepal by Pradhan [23], in Sri Lanka by Wahundeniya [24].

Table 2. Number of larvae and the length of tunneling in potato cultivars by the *P. operculella* Zeller larvae in the two sites

	Number of larvae				Length of tunneling			
	A. indica		***L. camara***		***A. indica***		***L. camara***	
Variety		**Mean±SD**		**Mean±SD**		**Mean±SD**		**Mean±SD**
Tigoni	Control	2.25±0.002	Control	2.0±0.0004	Control	2.15±0.0010	Control	1.325±0.0025
	100gm	1.5±0.0013	100gm	0.75±0.0001	100gm	2.1±0.0022	100gm	1.075±0.00011
	150gm	1.25±0.0016	150gm	0.5±0.0002	150gm	2.025±0.0023	150gm	1.025±0.0001
	200gm	0.5±0.0019	200gm	0.5±0.0017	200gm	2.05±0.0021	200gm	0.375±0.0002
Sherekea	Control	3.0±0.0021	Control	2.25±0.0026	Control	2.3±0.00022	Control	2.3±0.0016
	100gm	1.75±0.0001	100gm	1.25±0.0012	100gm	2.025±0.0041	100gm	2.225±0.0007
	150gm	1.5±0.0029	150gm	1.5±0.0016	150gm	1.925±0.0058	150gm	1.65±0.00021
	200gm	1.0±0.0026	200gm	1.5±0.0013	200gm	2.225±0.0042	200gm	0.675±0.0004
Mayan gold	Control	3.25±0.0071	Control	2.5±0.0022	Control	3.175±0.0061	Control	3.45±0.0043
	100gm	2.0±0.0003	100gm	2.25±0.0054	100gm	3.2±0.0069	100gm	3.25±0.0031
	150gm	1.75±0.0001	150gm	2.25±0.0013	150gm	3.25±0.0056	150gm	3.125±0.0058
	200gm	1.25±0.0003	200gm	2.0±0.0031	200gm	3.1±0.00052	200gm	1.725±0.0001
Asante	Control	2.25±0.0004	Control	2.0±0.0022	Control	2.2±0.0071	Control	2.275±0.0028
	100gm	2.0±0.0017	100gm	1.5±0.0011	100gm	2.375±0.0056	100gm	2.325±0.0031
	150gm	1.5±0.0005	150gm	0.75±0.0010	150gm	2.175±0.0048	150gm	1.075±0.0001
	200gm	1.2±0.0003	200gm	0.25±0.0013	200gm	1.575±0.0012	200gm	0.75±0.00013

Source: (Researcher, 2021)

Table 3. Effect of the botanical (*Lantana camara* and Neem (*Azadiracta indica*) concentrations on the length of tunneling in potato cultivars by the *P. operculella* Zeller larvae

	Length of tunneling			
	A. indica		*L. camara*	
Variety		**Mean±SD**		**Mean±SD**
Tigoni	Control	2.15±0.0010	Control	1.325±0.0025
	100gm	2.1±0.0022	100gm	1.075±0.00011
	150gm	2.025±0.0023	150gm	1.025±0.0001
	200gm	2.05±0.0021	200gm	0.375±0.0002
Sherekea	Control	2.3±0.00022	Control	2.3±0.0016
	100gm	2.025±0.0041	100gm	2.225±0.0007
	150gm	1.925±0.0058	150gm	1.65±0.00021
	200gm	2.225±0.0042	200gm	0.675±0.0004
Mayan gold	Control	3.175±0.0061	Control	3.45±0.0043
	100gm	3.2±0.0069	100gm	3.25±0.0031
	150gm	3.25±0.0056	150gm	3.125±0.0058
	200gm	3.1±0.00052	200gm	1.725±0.0001
Asante	Control	2.2±0.0071	Control	2.275±0.0028
	100gm	2.375±0.0056	100gm	2.325±0.0031
	150gm	2.175±0.0048	150gm	1.075±0.0001
	200gm	1.575±0.0012	200gm	0.75±0.00013

Source: (Researcher, 2021)

Table 4. Effect of the botanical (*Lantana camara* and Neem (*Azadiracta indica*) concentrations on the Number of larvae in potatoes by the *P. Operculella* Zeller

	Number of larvae			
	A. indica		*L. camara*	
Variety		**Mean ± SD**		**Mean ± SD**
Tigoni	Control	2.25±0.002	Control	2.0±0.0004
	100gm	1.5±0.0013	100gm	0.75±0.0001
	150gm	1.25±0.0016	150gm	0.5±0.0002
	200gm	0.5±0.0019	200gm	0.5±0.0017
Sherekea	Control	3.0±0.0021	Control	2.25±0.0026
	100gm	1.75±0.0001	100gm	1.25±0.0012
	150gm	1.5±0.0029	150gm	1.5±0.0016
	200gm	1.0±0.0026	200gm	1.5±0.0013
Mayan gold	Control	3.25±0.0071	Control	2.5±0.0022
	100gm	2.0±0.0003	100gm	2.25±0.0054
	150gm	1.75±0.0001	150gm	2.25±0.0013
	200gm	1.25±0.0003	200gm	2.0±0.0031
	Control	2.25±0.0004	Control	2.0±0.0022
Asante	100gm	2.0±0.0017	100gm	1.5±0.0011
	150gm	1.5±0.0005	150gm	0.75±0.0010
	200gm	1.2±0.0003	200gm	0.25±0.0013

Source: (Researcher, 2021)

Furthermore the varieties exhibited different protection levels Tigoni ≥ Asante ≥ Sherekea ≥ Mayan gold.

According to Table 3, applying 200g extracts of two medicinal plants on potato tubers reduced tunneling levels of the *P. operculella* whereas the pest preferred to tunnel mostly in un-treated tubers. The length of tunneling was reduced in tubers treated with 200g of *L. camara* in Tigoni and Asante varieties were the lowest unlike in Mayan gold with was the highest , therefore the pest preferred to tunneling on non-treated tubers. These results demonstrated that *L. camara* at 100g had rather low inhibitory effects against the pest, this supports the findings of Shaaya et al.

[17] who documented on botanicals being effective at high concentrations.

According to Table 4, applying 200g extracts of the two medicinal plants on potato tubers reduced the number of larvae of the *P. operculella* whereas the pest preferred to lay more eggs mostly in un-treated tubers resulting in an increase in the number of larvae. The number of larvae reduced in tubers treated with 200g of *L. camara* in Tigoni and Sherekea varieties was the lowest unlike in Mayan gold with was the highest at 200g. These results demonstrated that *L. camara* at 100g had rather low inhibitory effects against the pest.

4. CONCLUSION

Different quantities of *L. camara* and *A. indica* leaf powder have varying efficacy levels. Results from the hypothesis testing different quantities of *L. camara* and *A. indica* leaf powder to have varying efficacy levels confirmation revealed that 200g of *L. camara* had a lower larvae population than 150g and 100g this findings are in consistent with those of Shaaya *et al*. [17] who found that at higher concentrations botanicals caused 90% mortality of major stored product insects. Our results demonstrated that the *L. camara* powder was the most effective against larvae of *P. operculella*, followed by *A. indica*. The larval mortality of the PTM with the two powders was increased by increasing the concentrations. However the tested materials showed a significant effect in increasing the mortality rate of larvae of the tested insects on the four potato cultivars. These findings agreed with the research results reported by International Potato Center (IPC) that the use of some plant materials such as *Lantana camara* could control pest attack in stored potatoes [25]. These botanicals might possess antifeedent, repellent, insecticidal properties or a combination of them in reducing the damage level caused by insect pests. According to the result of the work of [26, 27] and the International Potato Center, it was possible to control PTM by storing potatoes on the bed of *Eucalyptus* leaves [25]. Much research has been conducted on the effectiveness of plant products against insect stored potato [28]. Promising results were obtained by several investigators [29, 30,; 31, 32]. Using plant extracts, dust and oils as pest control agents against stored product pests. On the other hand, some plants and weeds like Muna (*Minthosstachys* spp), Eucalyptus (*Eucalyptus globulus*), Chilca (*Baccharis* spp), Curry plants, Indian pivets, *Lantana camara*, *Mentha arvensis* and *Artemesi vulgaris*, *Lycopersicon hirsutum* etc were effective in controlling PTM [33, 27]. Furthermore *Azadirachtin* is known to block molting in some insects [34]. The neem-based insecticides assessed in our study show some short-term potential as a means of PTM control in potato. However, neem-based botanicals often lose effectiveness within days, as also shown by others [35, 36, 37, 38, 39].

5. RECOMMENDATIONS

An interesting subject for future studies could be done on a comparative analysis in other potato growing regions to affirm the findings in this study. A Genetic study on the predominant PTM variant can be done so as to inform farmers on which larvae to be controlled. Another target survey should be contacted on *L. camara* isolates in storage management of PTM rather than the leaves powders to ascertain whether the botanical results in this study were as a result of antifeedent, or repellent and to test different ways of using them, such as spraying, dipping or applying them in different traps.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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