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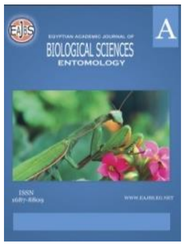

Bioactivity of Plant Essential Oil against Potato Tuber Moth, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae).

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ABSTRACT

Phthorimaea operculella (Potato tuber moth) is a destructive pest of stored potatoes and potato crops, primarily in subtropical areas of the globe. It is a pest of the field as well as storage, the larvae damage the crop through the foliage, stem, and tubers too. The manifestation of potato tuber moth primes to high economic damages in production worldwide. Post-harvest protection of the potato tubers becomes important and is challenging. A treatment with chemical agents is a possible strategy but cannot be recommended for food items hence alternative methods become important in control of these moths. The present study deals with the assessment of plant oils of *Cinnamomum verum, Cupressuss sempervirens* and *Cymbopogon nardus.* These plant oils were used to evaluate the larvicidal, adulticidal, Insect growth regulatory, repellency and oviposition deterrence activities against potato tuber moth. Results of the present work indicated that all the test oils show some promise as pest control agents against *P. operculella*. Oil of *C. verum* has exhibited promising toxic action (larvicidal LC_{50} = 110.10 µg/cm^2, adulticidal LC_{50} = 49.78 µg/cm^2). The oil of *C. nardus* caused promising IGR activity (delay in development = 16.2 days) All three plant oils have shown multifarious activity and can be a part of an eco-friendly and user-friendly method of control.

INTRODUCTION

Potato tuber moth, *Phthorimaea operculella* Zeller is a cosmopolitan major pest of potatoes belonging to order Lepidoptera and family Gelechiidae.), attacks several cultivated solanaceous plants including potato (*Solanum tubersum*), tobacco (*Nicotiana tabacum*), eggplant (*Solanum melonguene*), tomato (*Lycopersicom esculentum*), and bell pepper (*Capasicum annuum*). It has also been reported to be found on several wild plant hosts of the following genera: *Solanum, Datura, Nicotiana, Fabina, Hyoscyamus, Physalodes, Lycium*, and *Nicandra* (Schaub and Kroschel 2018).

Tubers suffer extensive damage due to *P. operculella.* This is caused by the larvae, which normally spend their entire lives in either one of these food sources. The only exception to this is when infested foliage is destroyed, the larvae abandon it and search for tubers. Foliar infestation may be sufficiently severe to destroy the plant. Tuber-mining larvae usually enter through the “eyes” from eggs laid near by and make slender, dirty-looking tunnels throughout the tuber. An infested tuber can be identified by mounds of droppings at the tunnel entrances. High levels of tuber infestation occur in the field during summer, and stored potatoes can suffer severe damage all the year-round.

Conventional synthetic insecticides, in spite of their undoubted pest control efficiency, have several disadvantages that have been brought into focus in recent years (Gonzalez et al 1977, Parmar and Devkumar1993, Edwards 1973). Some of these relate to their intrinsic high toxicities. Most, however, are due to their persistence which results in continuing, long term and widespread pollution of the environment. Many pesticides have an affinity for fatty tissue, resulting in accumulation there and leading to the phenomenon of biomagnifications in the ecological food chains and pyramids (Smith and Van den Bosch 1967).

Recently, numerous studies indicated that many wild medicinal and ornamental plants have pesticidal properties that show antifeedant, repellent, growth regulator effects, and toxic activities on a wide range of insect pests (Stevenson 2014 and Onu et al. 2015). Bioactive compounds of plant origin are considered as an ecologically safe alternative, and the plant extracts with complex mixtures of compounds have been widely investigated for their insecticidal repellent, ovicidal, antifeedant, and antioviposition properties. There is an increasing interest in the role of the plant products in insect-plant interaction, particularly in host acceptance and rejection (Akhtar and Isman 2004)

The control potential of several plant oils has been studied in order to develop a new strategy for the control of *P. operculella* (Kroschel and Koch 1999), still, there is enormous scope to explore various plant products as selective control agents for *P. operculella.* Compounds extracted from plants or the derivatives of such compounds may affect insect physiology in various ways (Shekari et al., 2008). This investigation aimed to investigate the repellency and toxicity effects of crude oils against *P. operculella*.

MATERIALS AND METHODS

Rearing Method:

The nucleus culture of Potato Tuber Moth was obtained from Entomology, National Chemical Laboratory, Pune. The colony was maintained at 28±2ºC and 60-70% R.H. Adults were maintained in plastic jars covered with a black muslin cloth, which is a preferred substrate for oviposition. Adults were provided with a 20 % honey solution, while the larvae were provided with pricked potato tubers. Infested potatoes were kept on sterilized soil, which was subsequently used for cocoon formation by larvae. Pupae were kept in separate containers for adult emergence.

Bioassays:

All test oils were dissolved in A.R. grade acetone (200 mg/ml) and serial dilutions were made as per requirement.

Toxicity:

a) Larvicidal Assay:

Toxicity assays were performed in small jars of 50 ml capacity covered with a muslin cloth. In each jar, a filter paper was placed lining the inner area including the bottom surface. It was treated uniformly with test oil concentrations ranging from 100 μg/cm^2 to 600 μg/cm^2. In case of control only carrier solvent i.e. acetone was added. Ten prepupal larvae were introduced in each jar. For each experiment, three to five replicates were taken and each experiment was repeated five times. Mortality count was taken after 24 hours. LC_{50} was calculated using log-probit analysis (Finney 1971). Data obtained were subjected to statistical analysis.

b) Adulticidal Assay:

The assay was carried out in appropriate jars (30cm × 10cm) covered with muslin cloth. Residual application method was used to study the adulticidal effects of test oils.

Filter paper was treated uniformly with different concentrations of test oils varying from 50 μg/cm^2 to 240 μg/cm^2. The treated filter paper was placed in the jars lining the inner area including the bottom surface. Ten adults were exposed to different doses of oils for 24 hours and mortality was observed. Each assay was carried out five times and for each set three replicates were taken. LC_{50} was calculated using log probit analysis (Finney 1971). Data obtained was subjected to statistical analysis.

Insect Growth Regulatory Assay:

The assay was carried out in separate trays (Sized 14" × 10" × 4") containing sterilized soil. Pricked potatoes treated with LC_{20} concentration of test oils were introduced in the trays. The muslin cloth with 20 eggs which were about hatch was kept on the treated potatoes to ensure easy entry of the newly hatched larvae. The period required for the development of first instar larvae to adult emergence was recorded. The period required for the development of the in-between stages up to the prepupal instar was not recorded, as they spend this entire period inside the potatoes. The resulting development and growth period along with abnormalities in the emerging stages were monitored and recorded. Each assay was carried out five times and for each set three replicates were taken. Data obtained were subjected to statistical analysis.

Attractant/Repellent Assay:

The double choice method was used for this assay. Twenty newly emerged adults were released in a cage (size 18"×18") containing two conical flasks. One flask contained 5 % test oil in honey solution while the other contained carrier solvent and honey solution. Funnels (4"diameter) were introduced in each flask to avoid the escape of the moths. The number of moths trapped in these flasks was counted for 24 hours. The results were expressed in terms of the percentage of attraction/repulsion. The percentage was determined by the number of adults trapped in each flask. Each assay was carried out five times and for each set three replicates were taken. Data obtained were subjected to statistical analysis.

Oviposition Attraction / Deterrent Assay:

Ten pairs of twenty-four hours old adults were released in plastic jars. Muslin cloth treated with 5 mg/cm^2 dose of test oils was used to cover these jars. The muslin cloth is a preferred substrate for oviposition. Egg count was recorded after 24 hours and % Oviposition Deterrence was determined by the following formula (Tare 1995):

% Oviposition Deterrence = T – E/ T x 100

T = Total number of eggs laid in both control and treated.

E= Number of eggs laid in treated.

Each assay was carried out five times and for each set three replicates were taken. Data obtained were subjected to statistical analysis.

RESULTS

Larvicidal Activity:

Table 1. reveals the results of the larvicidal activity of selected plant oils against *P. operculella*. Among the selected oils *C. verum* showed highest larvicidal activity at LC_{50} = 110.10 μg/cm^2 concentration while *C. nardus,* exhibited larvicidal activity at LC_{50} = 370.05 μg/cm^2. The oils of *C. sempervirens,* did not show significant activity.

Adulticidal Activity:

The adulticidal activities are depicted in Table 2. The highest adulticidal activity observed was LC_{50} = 49.78 μg/cm^2 in case of *C. verum* followed by the oils of, *C. nardus,* exhibited LC_{50} at174.69 μg/cm^2 while the lowest activity i.e. LC_{50}= 179.92μg/cm^2 was observed in case of *C. sempervirens.*

Table 1: Larvicidal Activity of selected plant oils.

Name of plant oil	LC_{50} (µg/cm^2)	Regression equatio (Y)	Fiducial Limit	
			Lower	Upper
Cinnamomum verum	110.10	0.322 + 2.291 X	36.292	150.148
Cupressuss sempervirens	549.68	-20.445 + 9.329 X	493.544	585.244
Cymbopogon nardus	370.05	-14.136 + 7.451 X	267.026	423.579

Table 2: Adulticidal Activity of selected plant oils.

Name of plant oil	LC_{50} (µg/cm^2)	Regression equation (Y)	Fiducial Limit	
			Lower	Upper
Cinnamomum verum	49.78	-3.2767 + 4.8894 X	40.980	71.705
Cupressuss sempervirens	179.92	-23.664 + 12.711 X	166.463	205.394
Cymbopogon nardus	174.69	-14.4569 + 8.6744 X	150.284	248.474

Insect Growth Regulatory Assay:

The oils of *C. nardus* affected the development, which was delayed by 16.2 days, while*, C. sempervirens* and *C. verum* delayed the development by 8.8 days, 6.8 days respectively. None of the other oils showed a significant delay in development (Table 3).

Attractant/Repellent Assay:

A perusal of Table-4 reveals that the maximum repellent activity was observed in the case of *C. nardus* which was 71.8% while *C. verum, C. sempervirens* repelled the Potato tuber moths as 68%, and 60.9% respectively.

Oviposition Attraction / Deterrent Assay:

In this case, none of the tested oils exhibited 100% oviposition deterrence against females of Potato Tuber Moth. Only one oil viz. *C. sempervirens* exhibited 80.1% oviposition deterrence, while the oil of *C. nardus caused* 45.7% deterreance in oviposition and *C. verum* exhibited the least deterrence of 28%.

Table 3: Effect of selected plant oils on Development**.**

Name of oil	Adult emergence (Days)
Control	46.0 (± 0.3331)
Cinnamomum verum	48.9 (± 0.4669)
Cupressus sempervirens	52.8 (± 0.3692)
Cymbopogon nardus	62.2 (± 0.3496)

Figures in parenthesis indicates standard error

Table 4: Repellent Activity assay of selected plant oils.

Name of oil	% Repellency
Cinnamomum verum	68.0 (±0.2983)
Cupressus sempervirens	60.9 (±0.2770)
Cymbopogon nardus	71.8 (±0.2907)

Figures in parenthesis indicates standard error

Table 5: Oviposition Deterrence Activity of selected plant oils.

Name of oil	%Oviposition deterrence
Cinnamomum verum	28.0 (±0.2001)
Cupressus sempervirens	80.1 (±0.3482)
Cymbopogon nardus	45.7 (±0.4958)

Figures in parenthesis indicates standard error

DISCUSSION

The most effective botanical oils would be those offering a broad spectrum of activity against various life stages of the pest. The control agent should reduce the insect population at all stages, and it should decrease the incidence of the pest (Lamiri et al., 2001). Plant odor acts as feeding and oviposition deterrents to a wide variety of insect pests. It was also effective as a fumigant (Koul et al. 2008). Sharaby (1988) found that reproduction in the PTM was significantly reduced when either males or females were exposed to the vapor of orange peel oil. Results of the present work revealed that all the test oils show some promise as pest control agents against *P. operculella*. Oil of *C. verum* has exhibited promising toxic action (larvicidal LC_{50} = 110.10 µg/cm^2, adulticidal LC_{50} = 49.78 µg/cm^2). The oil of *C. nardus* caused promising IGR activity (delay in development = 16.2 days).

The oils of *C. verum* and *C. nardus,* with further studies, can find a prominent place in the Potato Tuber Moth control programme. This approach is likely to be advantageous, as it is environmentally safe and socially acceptable. However, further studies need to be conducted to evaluate the cost of this essential oil when used in commercial storage applications. From the foregoing, it is apparent that present work definitely opens new avenues. Since the disadvantages of the conventional synthetic insecticides came into limelight, a focus has been mainly on the search for safer cheaper and eco-friendly alternatives. The availability and cost of the new molecules whether synthetic or natural is another important criterion of these alternatives. Considering all these aspects plant products find a place of prime importance. The present work definitely can find a place in this endeavor, as it has come out with some promising plant products which can be used in pest management programme after due testing such as field trial, toxicological data, formulations, etc.

These oils may be used either individually or in combination with some other synthetic/natural products which may enhance their activity. There is another advantage to the use of these oils as they are used for medicinal purposes for a long time, so they can be considered safe. The additional use of these plants may prove beneficial to cultivars also. It can be concluded that the present work has definitely provided the base as well as encouragement for further work on plant products.

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