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Susceptibility of Different Potato Varieties to Infestation by Potato Tuber Moth and Role of the Plant Powders on their Protection

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Abstract: *laboratory evaluation of the susceptibility of tubers of 12 potato varieties locally available and cultivated in Egypt to infestation by PTM was carried out through the study of its ovipositional and feeding preferences using choice and non -choice tests. For protecting potato tubers from PTM infestation during storage, different concentration of five plant powders were tested as dusts against adults or dusts against neonate larvae. Tuber damage indices as well as persistence indices for tested materials were assessed. The choice test between 12 potato varieties indicated that the highly susceptible varieties were Bern and Nicola; while the moderately susceptible included Glob, Sanorata, Diamonda and Charisma. and the slightly susceptible varieties were Lady Rosetta, Mirakel, Monaliza, Oleva, Singa and CNK-007-021 which showed the lowest number of deposited eggs. The non-choice test showed that all tested varieties were infested by PTM; but the lowest number of eggs was deposited on variety CNK-007-021. Feeding preference indicated that the highest number of penetrating and surviving larvae of PTM was recorded inside tubers of Bern variety followed descendingly by varieties Glob > Charisma -Monaliza > Mirakel > CNK-007-021 > Diamonda > Sanorata > Singa > Nicola. Tubers of CNK-007-021, Nicola, Mirakel, Singa and Charisma varieties recorded the longest duration of the larval stage inside them. Other varieties as Diamonda, Bern and Oleva showed shorter larval duration. Dusting potato tubers with bulb powder of Allium cepa (50% cone. mixed with talcum powder) displayed a highly effective role in the reduction of deposited eggs as well as adult emergence there from. Allium cepa, Pelargonium graveolens and Cymbopogon citratus caused high reduction in larval penetration into treated tubers. Mixture of Pelargoniumor Allium mixed with talcum powder gave good protection for a long storage period (30-40 days).*
Key words: *Phthrenaea oprculell, Plant powders, Potato protection, Potato verities*

I. Introduction:

The potato tuber moth causes serious damage to stored potato through its larval tunneling and feeding which lead to partial or complete rotting by subsequent infection by fungi and/or bacteria. In this case, the infested tubers become completely unmarketable. In developing countries, most of the potato farmers cannot afford the increasing cost of storing potatoes in cold stores, so the tubers are often heaped under a tree or in rustic shelter and covered with a thick layer of straw, potato foliage or another handy materials (Essamete *et a*l, 1988).

Other farmers rely heavily on insecticides which are dusted or sprayed on the tubers at the beginning of the storage period. But the prophylactic use of insecticides, especially for stored table potatoes, causes serious problems. These include the development of insect resistance to insecticides, persistence of residues in tubers for consumption, emergence of new pests, destruction of beneficial organisms, human intoxication and contamination of the environment. Recently, several programs for pest control have been developed, including the use of powders and oils of natural plant origin, resistant potato strains (varieties), or using intercropping system, etc. Assem (1966) carried out three experiments to estimate the relative susceptibility of different potato varieties to the potato tuber moth (PTM), *Phthorimaea operculella* (Zelier) attack. He found that Surprise and Record varieties seemed to be less susceptible to the potato tuber moth infestation than other tested varieties: King Edward, Sponta, Ulsterdale, Claudia and Sieglande which were relatively susceptible to PTM infestation that ranged between 21-42% on the foliage. Ahmed *et al* (1990) in Bangladesh, determined the susceptibility of the potato varieties; Petrone, Cardinal, Multa, Diamonda and Lai Pakhri to PTM. Lai Pakhri was the least susceptible variety both in field and storage (17.67 and 23.30% damage, respectively); whereas Cardinal was the most susceptible variety in the field (46.67% damage); and Multa the most susceptible variety in storage (46.60% damage). Sharma *et al* (1981) studied the oviposition deterrent activity of some Lamiaceae plants and twelve plant species in the Family Labiaceae. They found that some species of these plants exhibited high oviposition deterrent activity against *Phthorimaea operculella* . Raman *et al* (1987) studied the influence of dried foliage of some plants occurring locally in Peru in protecting potato tubers from damaging by the potato tuber moth in storage. The plants tested were *Eucalyptus globulus*, *Lantana camara* and *Minthostachs sp.*, all in the dried shredded and powder form, which were effective in controlling PTM damage in potatoes stored for 4 months. Khashyap *et al* (1992) used eight plant species; *Vitex negundo* (L.), *Ageratum honstonianum.* (Mill), *Mentha longifolia* (L.), *Cinnamomum tamala, Cannabis sativa* (L.), *Lantana camara* (L.), *Murraya Koenigii* (L.) and *Eucalyptus sp,* as dried powder against the PTM infestation in stores. Application of powdered dry leaves of *Ageratum houstonianum* or *Canabis sativa,* 2cm. thick layer, to stored potato revealed no infestation by the PTM up to 120 days. Also, *Vitex negundo* and *Mentha longifolia* dry leaves powders were equally effective; and only 6% infestation was noticed into the potato kept in store up to 120 days. No significant rotting of potato tubers was observed in these treatments. Aim of this work is to determination of the susceptibility of different potato varieties to the PTM infestation. during storage , Screening -the effect of various plant powders for protecting the potato tubers from PTM infestation. , assessment of the damage indices of tubers after various treatments.and assessment of the persistence indices of various tested materials.

II. Materials & Methods :

A stock laboratory colony of the PTM has been raised on potato tubers which are the main natural host. The culture was maintained under laboratory conditions at 26 ± 2°C and 70 ± 5 %R.H.; following the technique mentioned by El-Sherif (1966).:

1-Determination of the susceptibility of different potato varieties to the PTM infestation under laboratory conditions .
Two methods were applied for evaluating potato varieties infestation with PTM according to external (epiphylaxis) and internal (endophylaxis.) factors . Twelve varieties namely : Nicola, Bern, Charisrria, Singa, CNK-007-021, Lady Rosetta, Mirakel, Monaliza, Sanorata; Glob, Diamonda and Oleva were tested for their infestation under laboratory conditions.

1.1. -Epiphylaxis factors:
In order to determine the ovipositional preference of PTM to different potato varieties, the following experiments were conducted:

1.1.a- . Multiple choice test.
An experiment was carried out in 30 x 30 x 40 cm wire screen cage over 72 hours, in darkness under laboratory conditions (26 ± 2 °C and 70 ± 5% R.H). Ten pairs of virgin males and females potato tuber moth were introduced into a cage which contained one tuber from each tested potato variety arranged in a circle inside the cage. Each test was replicated five times. After 72 hrs., the numbers of eggs deposited on each potato tuber variety were counted in order to determine the susceptibility of different potato varieties to PTM infestation.

1.1.b.- Non-choice test.
Each variety was also tested under a non-choice experiment for comparison by placing tubers of a single kind of the tested potato varieties in the cage; and then infested by five pairs of virgin females and males. Experiments were carried out under the aforementioned laboratory conditions. After 72 hrs., the numbers of deposited eggs on the tubers of the tested variety were counted and compared with those on other varieties.

1.2.- Endophylaxis factors;
In order to evaluate the response of neonate larvae of PTM toward the aforementioned potato varieties, the following tests were carried out.

1.2.a.-Feeding preference.
An experiment was conducted in 20 x 20 x 10cm glass container in darkness under laboratory conditions (26 ± 2°C and 70 ± 5% R.H.). Two tubers having almost the same shape and weight were selected from each tested variety; and then arranged in the container in a circle. At the centre of the container were placed fifty newly hatched larvae of PTM. After two weeks of artificial infestation, the numbers of larvae inside the potato tubers of each tested variety were counted. The percentage of penetrating larvae were estimated according to the following equation:

$$\text{Penetrating larvae \%} = \frac{Y}{X} \times 100$$

where; X = Total numbers of tested neonate larvae.
Y = Numbers of larvae inside tested variety.

1.2.b.- Tunnel length measurement

This test was carried out in 10 x 12cm. plastic cups through exposing each potato variety separately to infestation by two neonate larvae of PTM. After pupation, the length of tunnel was measured by using area meter thread according to Fenemore (1980). In addition, the duration of larval stage inside each tested variety was determined. Each test was replicated five times.

III. Protection of potato tubers from PTM infestation during storage.

2.1 Dusting potato tubers.

Five plant species including plant leaves, fruits and peels of certain vegetables, medicinal and ornamental plants were collected from different places The needed parts were washed in running tap water, dried in shade, then minced and ground into powders. Three concentrations (25, 50 and 100%) of plant powders mixed with talcum powder were prepared. In each experiment, 2-3 potato tubers (about 200gm) were dusted with one of the prepared dusting material. The dusted tubers were introduced into containers (20 *x* 20 x 10cm) where five pairs of virgin adults were confined. The following biological aspects were studied:
(1) Average number of deposited eggs., (2) Percentage of emerged offspring,
(3) Duration of life cycle (egg to adult)., (4) Damage index of potato tubers.
In another experiment, 50 neonate larvae were introduced in a test chamber (20 x 20 x 10cm) containing 1-2 dusted potato tubers (about 100 gm.). The percentage of penetrating larvae and percentage of pupation were determined. Each test was replicated five times.

2.2- Persistence index of the residual plant powders:

Residual effectiveness experiments were conducted to estimate the biological persistence of the tested , plant powders, when being applied at highly effective concentration (or the maximum concentration possible), either on potato tubers (dusting), on gunny sacks (spraying) The residual effectiveness was bioassayed using various stages of PTM according to the method of protection; thus: , neonate larval stage of PTM was used. Dusted potato tubers ,and sprayed sacks containers were kept at room temperature, alongside with untreated samples. At different time intervals, samples of dusted tubers, treated gunny sacks were taken for residual effectiveness assessment by subjecting them to neonate larvae or adult stage of PTM. According to the methods of protection, the following parameters were recorded; (1) Mean damage index, for the methods of application mentioned before. (2) Reduction percent of progeny found in the tubers kept in treated gunny sacks. (3) Percentage of larval mortality; when neonate larvae fed directly on the treated tubers. Tests for residual effectiveness were continued till reaching a degree of protection to > 5 0 %value.
Statistical analysis : . Statistical, all data were subjected to analysis of variance (ANOVA) through "SPSS" Computer program.

IV. Results & discussion:

Laboratory evaluation 0f PTM infestation to different potato varieties:

Each potato variety is characterized by epiphylaxis and endophylaxis factors. The susceptibility of potato tuber varieties to infestation by the PTM depends upon these tubers characters. The present work was carried out in order to evaluate such characters under laboratory conditions

Epiphylaxis factors (external protection agencies) were determined through ovipositional preference tests while endophylaxis factors (internal protection agencies) were determined through feeding preference tests. The effect of these factors was determined as follows:

1. Ovipositional preference

Results presented in table(1) shows the role of external protection agencies of the different potato varieties in the selection of the PTM to the site of oviposition.
The data of the choice test indicated that there was a significant difference (P<0,05) among the twelve potato varieties according to the number of eggs deposited by PTM on each potato tuber variety. Thus, the tested potato varieties could be classified into four categories according to their susceptibility to oviposition of the PTM. These categories are:
a-Highly susceptible varieties; which encouraged female to deposit the largest number of eggs as in case of Bern and Nicola varieties where the average number of deposited eggs was 23.8 ± 4.6 and 18.6 ± 2.9 eggs / female, respectively.
b-Moderately susceptible varieties; which were significantly less infested than the previous varieties (P < 0.05), as Glob, Sanorata, Diamonda and Charisma. The average number of laid eggs was 14.4 ± 3.9, 11.6 ± 2.6,11.4 ±2.07 and 10.6 ±1.5 eggs /female, respectively.
c-Slightly susceptible varieties; with highly significant difference from the latter varieties (P < 0.01); as Lady Rosetta, Mirakel, Monaliza, Oleva and Singa; where the average number of deposited eggs ranged between 9.6 ± 1.9 and 7.2 ± 1.4 eggs/femaie, respectively.

d- Slightly resistant varieties; which were significantly different from all the aforementioned categories. They discouraged oviposition of female PTM, as in case of CNK- 007- 021 variety; where the mean number of deposited eggs was 3.8 ± 1.1 eggs / female. On the other side, results of the non choice test showed that there was no significant difference among five varieties (P> 0.05), including Bern, Nicola, Sanorata, Oleva and Glob; on which the mean number of deposited eggs was 31.2 ± 2.9, 26.4 ± 2.9, 25.6 ±3.2, 22.4 ± 1.8 and 22.2 ± 4.02 eggs / female, respectively. At the same test, significantly lower numbers of eggs were laid on each of six-potato varieties including, Diamonda, Monaliza, Charisma, Mirakel, Singa and Lady Rosetta; where the mean number of eggs ranged between 20.2 ± 1.8 and 13.6 ± 1.6 eggs / female. Again, the lowest mean number of eggs was deposited on CNK-007-021 variety; being 8.2 ± 2.5 eggs / female.

Table (1) Ovipositional preference of the potato tuber moth, *Phillorimaen operculella*, to different potato varieties.

Potato varieties	Mean of deposited eggs/female	
	Choice test	Non choice test
Bern	23.8 ± 4.6[a]	31.2 ± 2.9[a.]
Charisma	10.6 ± 1.5[b]	19.8 ± 1.8 [b]
Diamonda	11.4 ± 2.07[b]	20.2 ± 1.8 [b]
CNK-007-021	3.8 ± 1.1[d]	8.2 ± 2.5[d]
Glob	14.4 ± 3.9[b]	22.2 ± 4.02[a]
ady Rosetta	9.6 ± 1.9[c]	13.6 ± 1.6[c']
Mirakel	9.2 ± 2.6[c]	19.4 ± 2.8[b]
Monaliza	9.0 ± 1.7[c]	20.0 ± 3.1 [b]
Nicola	18.6 ± 2.9[a]	26.4 ± 2.9[a]
Oleva	8.4 ± 2.4[c]	22.4 ± 1.8[a]
Sanorata	11.6 ± 2.6[b]	25.6 ± 3.2[a]
Singa	7.2 ± 1.4[c]	16.4 ± 4.2[c]

.L.S.D$_{0.05}$= 6.92 •• **I.S.D$_{0.05}$ = 5.5**

L.S.D$_{0.01}$= 9.70 **L.S.D$_{0.0}$ 7.26**

Means in vertical columns with the same knew arc not significantly different (P >0.05). Deviations in the table indicate thc standard deviation of means.

From the aforementioned results, it was noticed that Bern and Nicola varieties were the most preferred varieties for oviposition by PTM; while CNK-007-021 was the least suitable variety of all tested varieties. These observations may be related to the external protection agencies (epiphylaxis) as was noticed by Mumford(1931). In this respect, Fenemore (1978) confirmed the importance of the surface texture of potato varieties in determining the ovipositional preference. He found that full fecundity of PTM was only achieved in the presence of suitable substrate. Indeed, there was no much difference among the most of the tested potato cultivars under a non choice condition. This agrees with Fenemore (1980) who suggested that, under normal conditions with a sizeable area of a single cultivar, the PTM females deposited their eggs and did not care to their suitability for oviposition.

2. Feeding preference .

To evaluate the susceptibility of different potato cultivars according to endophylaxis factors, the feeding preference of PTM was determined through the following points:

2.1. Penetration and survival of larvae inside potato tubers (choice test),

Results given in table (2)indicated that the highest number of surviving larvae was recorded inside tubers of Bern variety, being 14,4%. The other varieties were descendingly arranged according to the percentage of larval penetration and survival as follows: Lady Rosetta > Oleva > Glob > Charisma= Monaliza > Mirakel > CNK - 007-021 > Diamonde > Sanorata> Singa > Nicola; being 12.4, 10.8- 10.4, 10.0, 10.0, 8.4, 8.0, 7.6, 4.8, 4.4, and 1.2%; respectively.

Table (2) Feeding (tasting) preference, larval duration and tunnel length of the ***potato*** tuber larvae, ***in different*** potato varieties.

Potato varieties	Choice test	Non cho ce test	
	Survived larvae inside potato varieties (%)	Mean duration of larval stage (days)	Mean length of tunnel (cm.)
Bern	14.4	20.4 + 3.4^{b}	8.3 ± 0.9^{a}
Charisma	10.0	22 2 ± 2.2^{a}	3.6 ± 0.5^{d}
Diamonda	7.6	20.6 ± 1.2^{b}	5.02 ± 0.7^{c}
CNK-007-021	8.0	26.0 ± 2.02^{a}	6.0 ± 1.3^{b}
Glob	10.4	19.2 ± 0.7^{c}	5.9 + 0.2^{c}
Lady Rosetta	12.4	19.4 ± 0.4^{c}	3.9 ± 0.6^{c}
Mirakel	8.4	24.0 ± 1.9^{a}	8.9 ± 0.9^{a}
Monaliza	10.0	19.2 ± 0.4^{c}	2.5 ± 0.2^{d}
Nicola	1.2	24.6 ± 3.5^{a}	8.7 ± 0.3^{a}
Oleva	10.8	20.0 ± 0.8^{b}	4.5 ± 0.4^{c}
Sanorata	4.8	19.2 ± 0.5^{c}	5.7 ± 0.8^{c}
Singa	4,4	22.4 ± 3.2^{a}	5.7 ± 0.8^{c}
		$L.S.D_{0.05}$ = 5.2	$L.S.D_{0.05}$ = 1.4
		$L.S.D_{001}$ = 6.6	$L.S.D_{0.01}$ = 2.04

Means in vertical columns with the same letters are not significantly different (I) > 0.05). Deviations in the table indicate thc standard deviation of means.

From these results, it can be concluded that the difference in larval penetration and survival inside the different potato tuber varieties may be related to the peel of the tuber which may act as a barrier to the first instar larvae establishment as recorded by Fenemore (1980). Moreover, the variation between tested potato varieties maybe attributed to different levels of sugar or glycoid and amino acid contents (Yathom, 1968). This author concluded that *Phthorimaea operculella* attacked wilting, non irrigated potato plants which were flaccid and had high sugar content particularly fructose and sucrose. Many other substances such as glycoalkaloid content (Schreiber, 1957 and Sinden and Webb, 1972) and amino acids (Weaver *et a!.*, 1978 a,b) also differed among potato varieties and could play a role in the resistance of the potato variety to PTM.

2.2. Larval duration inside potato tubers (non - choice test): Results presented in table(2)showed that the duration of the larval stage inside potato tubers varied from one variety to another. It was clear that, tubers of CNK- 007- 021, Nicola, Mirakel, Singa and Charisma varieties recorded the longest duration of larval stage inside them; as the average larval duration under the same laboratory conditions was 26.0 ± 2.02, 24.6 ±3.5, 24.0 ± 1.9,22.4 ±3.2 and 22.2 ±2.2 days, respectively. Other varieties as Diamonda, Bern and Oleva varieties showed significantly shorter larval duration (P < 0.05); being 20.6 ± 1.2, 20.4+3.4 and 20.0 ±0.8 days, respectively. On the other hand, the shortest average of the larval duration was recorded on varieties; Lady Rosetta (19.4 ±0.4 days), Glob (19.2 ± 0.7 days) Sanorata (19.2 ± 0.5 days) and Monaliza (19.2 ±0.4 days). The difference was highly significant (P< 0.01) from that of CNK-007-021 variety. The variation in larval duration of the PTM inside tubers of different potato varieties may beattributed to the concentration of each potato variety contents which accelerate or retard the larval growth rate and hence the moulting process from one instar to the other as has been suggested by Raman *et al* (1994). Moreover, the larvae may need an extended time searching for the suitable variety as recorded by Varela and Bernays (1988) who studied the behaviour of neonate larvae of PTM and found that it spent 40 min, searching for a suitable host when placed on unfavorable host; but spent only 5 min, on a suitable host before mining and entering inside tubers.

2.3. Larval tunnel length (not- - choice test)

The palpability of the tissues of twelve potato varieties to the PTM larvae was determined by measuring the length of tunnels made by penetrating larvae. Results are given in table(2)The shortest average length of tunnel made by larvae of PTM was recorded in Monaliza, Charisma, and Lady Rosetta tubers, being 2.5 ± 0.2, 3.6 ± 0.5 and 3.9 ± 0.6 cm., respectively. A moderate length of larval tunnel was made in tubers of Oleva, Diamonda, Sanorata, Singa, Glob andCNK-007-02varieties,being4.5 ± 0.4, 5.02 ± 0.7, 5.7 ± 0.8,5.7 ± 0.8,: 5.9±0.2 and 6.0±1.3 cm, respectively.On the other hand, the longest tunnels were made by larvae inside Mirakel, Nicola and Bern varieties, being 8.9 ± 0.9, 8.7 ± 0.3 and 8.3 ± 0.9 cm. on the average, respectively. The difference between the shortest and longest tunnels was statistically highly significant (P < 0.01). Therefore, it can be inferred that the PTM larvae found Bern, Nicola and Mirackel varieties more suitable for freely feeding compared to the other varieties. These observations agree with Ojero and Mueke (1985) who measured the length of tunnels made by PTM larvae in four potato varieties, and found variations in the length of tunnels from one variety to another variety. They attributed that to flaccid tissues of some potato varieties.

Effect of plant powders on protection the tubers:

1- On the adult stage.

Potato tubers treated with different concentrations 25, 50 and 100% of different plant powders elicited variable effects mostly on moth fecundity and the percentage of produced offspring. Because the majority of tested plant powders were washed out when dusted pure (100%) and thus, became much less effective, talcum powder was used as a carrier and for adhering and distributing the plant powders on the tuber surface.

Results given in table (3) indicated that some dried plant powders could reduce oviposition and offspring released there from, but no evident effect on the life cycle. It was clear that, all tested plant powders at the tested concentrations had highly significant difference (P < 0.01) comparable to the two control parameters (untreated tubers and talcum powder treated tubers). Thus, plant powder of*Allium cepa* displayed a highly significant role (P< 0.01) in the reduction of deposited eggs at all concentrations comparable to the two control parameters. The average number of deposited eggs was 14.4 ±2.3, 9.2 ± 2.6 and 17.0 ± 1.8 eggs / female, at 25, 50 and 100% concentrations, respectively, comparable to the two controls 55.2 ± 2.9 and 41.6 ±2.2 eggs/female, respectively. This was followed by the dry powder of *Pelargonium graveolens* which also caused high depression in the average number of deposited eggs, being 21.2 ± 1.7, 16.2 ± 1.5 and 20.4 ± 1.9 eggs/female at 25,50 and 100% concentrations, respectively. The remaining plant powders, when used at 25 and 100% concentrations also caused highly significant reduction (P < 0.01) in deposited eggs comparable with the untreated control, but not significantly effective (P > 0.05) when compared with the control treated with talcum powder. In case of tuber treatment with 50% of powders of *C. citratus, Matricaria chamomilla and Colocasia antiquorum,* their average numbers of deposited eggs were reduced to 22.6 ± 2.8, 32.0 ± 1.9 and 32.4 ± 2.8 eggs/female, respectively.

Table (3) Effects of dusting potato tubers with different concentrations of dried plant powders on some biological **aspects of adult** stage **of.PTM**

Tested plant powders	Cone. (%)	Number of deposited eggs/femal		Offspring emergence (%)	Duration of life cycle (days)	
		Range	I Average ±S.D		Range	Mean ±tS.D
A•Vegetable plants						
/Mum cepa	25	6 -19	14.4 ± 2.3^{dd}	34.7	29 -40	37.2 t 2.08^{a}
	50	0.0•15	9.2 + 2.6^{dd}	21.4	30 -45	34.4 ±2.9^{a}
	100	4 -22	17.0 t1.8^{dd}	16.5	32 -40	37.2 ± 1.5^{a}
Colocasia onfiquorum	25	31 -52	41.0 ±3.4^{ca}	75.1	31 -40	36.6 t 1.5^{a}
	50	29-40	32.4 ±2.8^{cb}	75.9	33 -65	42.8 ± 5.7^{a}
	100	33 -45	**38.2 2.3^{ca}**	70.7	41 -60	49.0 ± 3.6^{b}
B-Ornamental and	medicine	plants:				
Cymbopogon cifralut	25	19- 43	35.8 ±2.9^{ca}	43.6	26-39	34.2 ± 2.3^{a}
	50	15 -32	22.6 ± 2.8^{cc}	17.7	29 38	33.6 ± 1.7^{a}
	100	23 -41	33.0* 3.4^{ca}	15.2	23 -38	30.6 t 2.6^{a}
Pelargonium gracenkm	25	17 -26	21.2 ± 1.7^{dc}	613	29 -49	35.6 t 3.7^{a}
	50	11 - 20	16.2 t 1.5^{dd}	29.6	33 - 52	41.0 *4.01^{a}
	100	14 - 26	20.4 ± 1.9^{dc}	37.3	34 - 57	49.2 ±4.1^{b}
Marlicaria chamomilla	25	26 - 48	36.2 3 3.6^{ca}	79.6	23 -40	32.8 t 3.1'
	50	28 -39	32.0 ± 1.9^{cb}	68.1	26 - 52	40.2 ±4.6^{a}
	100	22 - 41	33.8 ± 33^{cb}	68.05	21 -52	40.2 ± 5.1^{a}
Talcum powder	100	36 -49	41.6 ± 2.2^{ca}	87.5	34 -46	37.0 *2.5^{a}
Control	0	44 - 60	55.2 ± 2.9^{a}	90.6	30- 40	37.4 ± 1.9^{a}

L.S.D 0.05 = 7.3 L.S.1) 0.05 = 9.6

L.S.D 0.01 = 9.8 L.S.D 0.01 = 12.6

Means with the same letters in vertical columns for each plant powder concentration have no significant difference (P > 0.05).

The difference was highly significant (P < 0.01) from the control treated with talcum powder. On the other hand, the most impressive effect on produced offspring was displayed by powders of C. *citratus* which caused 43.6, 17.7 and 15.2% emerged offspring at 25, 50 and 100%, respectively; followed by *A. cepa* giving 34.7, 21.4 and 16.5% emerged offspring at the same concentrations, respectively. Powders of *P. graveolens* caused a moderate depression in the percentage of emerged offspring which reached 61.3, 29.6 and 37.3% at 25, 50 and 100% concentrations, respectively; comparable to the two control parameters (treated tuber with talcum powder & untreated tubers), being 87.5 and 90.6% emerged offspring, respectively. The remaining plant powders showed only slight effects on emerged offspring. Concerning the effect of treated plant powders on the life cycle of PTM in treated tubers, it was found that only *Colocasia antiquorum* and *Pelargonium graveolens* could elongate the life cycle at concentration 100%, to reach 49.0 ±3.6 and 49.2 ± 4.1 days, respectively; comparable to talcum powder treated and untreated control, being 37.0 ±2.5 and 37.4 ±1.9 days on the average, respectively. Other plant powders at different tested concentrations showed insignificant difference (P > 0.05) in the life cycle comparable to the two control parameters.

From the present results, it could be concluded that, plant powders of *A. cepa* (bulbs powder), *P. graveolens and C. citratus* caused high oviposition deterrence and great reduction in emerged offspring; while *C. antiquorum* (cortex powder) and *M. chamomilla* although caused reduction in the number of deposited eggs, did not significantly reduce the emerged offspring.

In this respect, AbdEl-Samea(1990) recorded that *C. antiquorum* at lower concentrations (2 - 10% dry leaves) did not significatly affect *Ostrinia nubilalis.* While Moawad (1995) recorded that the efficiency of *C.*

antiquorum (leaves powder) at 5% cone, had the ability to reduce oviposition of PTM. The same author, found that dusting *A. cepa* (leaves powder), on the potato tubers caused high depression in the number of deposited eggs by PTM and emerged offspring therefrom. Raman *et al* (1987) found that covering the potato tubers in a wooden crate with sun dried and shedded foliage (200 gm. below the tubers and 500 gm. above the tuber / 20 kg. tubers) of *C. citratus* (lemongrass) provided a repellent barrier against the PTM during storage. Other plant species which caused repellent effect against the PTM were recorded by Raman *et al* (1987) who mentioned that foliage powders of *Eucalyptus globulus, Lantana camara and Minthostachys sp.* acted as a physical barrier when covered the tested tubers in different thicknesses. Khashyap *et al.* (1992) found that the dry leaves powder of *Cannabis sativa* could protect the tubers from the PTM infestation. They found that 2 cm. thick layer of *C. sativa* protected potatoes for up to 120 days.

2. On the larval stage. Data presented in table(4) revealed that the tested plant powders could variably reduce the percentages of larval penetration, pupation and adults emerged there from. Moreover, plant powders half mixed with talcum powder were the most effective, while pure plant powders were less effective because of their washing out of the tubers. Thus, treatment of potato tubers by the powder of*Pelargonium igraveolens* caused the highest reduction in the percentage of penetrating larvae into treated tubers; as only 35.2, 23.6 and 26.8% of larvae could penetrate at 25, 50 and 100% concentrations, respectively. Plant powders of *A. cepa and C. citratus* also caused a highly repellent action, resulting in a depression in the percentage of penetrating larvae, particularly at 50% cone, being 27.6 and 31.2% larval penetration, respectively; comparable to talcum treated and untreated controls which were 83.2 and 97.6%, respectively. The remaining plant powders elicited less repellent action against larval penetration at the three tested concentrations. On the other hand, it was noticed that there was a latent effect of tested plant powders which led to reduction in the percentages of pupation and adults produced from larvae feeding on dusted tubers. Therefore, it was apparent that the percentages of pupation and adult emergence were related to the percentage of penetrated larvae which had the ability to complete development.

Thus, the plant powder of *P. graveolens* caused the highest reduction in pupation and adult emergence; as the percentage of pupation reached 33.6, 19.6 and 20.4% at 25, 50 & 100% concentrations, respectively; while adult emergence reached 31.2, 17.6 and 18.0% at the same concentrations, respectively. Treatment by *A. cepa and C. citratus* caused also a high reduction in % pupation and % adult emergence there from, particularly at 50% concentration, as the percentage of pupation reached 23.2 and 22.8%, respectively; while the percentage of adult emergence was 21.2 and 20.0%, respectively; comparable to talcum powder treated and untreated controls which showed 82.4 and 96.8% pupation, and 80.4 and 96.0% adult emergence, respectively. The remaining plant powders caused less reduction in % pupation and % adult emergence.

Generally, from the present data, it was quite evident that the tested plants, particularly *P.graveolens:, A. cepa and* C *citratus* had not only repellent action against the neonate larvae of PTM but also had accumulative latent effect which led to reduction in pupation and adult emergence therefrom.

Similar observations were almost reached with other plant powders, as recorded by Raman *et al.* (1987) who found that larval penetration into potato tubers covered with plant powders of *Eucalyptus globulus, Lantana camara and straw barley* was severely restricted and so the lower level of pupation due to lower larval penetration. Aschalew *et al* ,(2012) concluded that *Lantana camara, Eucalyptus globules* plant leaves and Pyrethrum flowers fine powders can be used to protect seed potatoes from (PTM) moth damage in storage. Mesbah *et.al,* (20120) elucidate the effect of potato tubers treatment using fine dust of *Pesidium guajava*, *Cymbopogon citratus,* Talc powder and their progressive dilution (w/w) on the fitness components of raised generations of the PTM moth. Results showed a direct as well as cumulative delayed effect of the tested plant fine dusts, either alone or admixed with talc powder in progressive dilutions from 5% up to 50% W/W on the viability of developing immature and potentiality of adult moths. *Psidium guajava* and (20%w/w) *Cymbopogon citratus* plant fine powder dust, resulted in fewer number of emerged moth that were unviable,weak, sterile and died before induction the F_1 progeny. *Psidium guajava* fine dust alone or its preparation dilution of (5%w/w)and *Cynbopogon citratus* dilution of (10%w/w)gave unviable weak and sterile moths unable to induce the F_2 progeny. The complete failure of each generation could be attributed to the cumulative effect of induced recessive lethal genes in both sexes along the extended period of each of these following generation, post former treatment of parent one, causing apparent undesirable effect, that appeared at the beginning of each of them.

Table (4) Effect of plant powders at different concentrations on larval penetration, pupation and adult emergence of PTM.

Tested plant powders	Gone. (%)	Penetrating larvae (%)	Pupation (%)	adult emergence (%)
A- Vegetable plants:				
A Ilium cepa	25	54.4	52.0	50.4
	50	27.6	23.2	21.2
	100	63.2	57.6	56.4
Colocasia	25	61.2	56.0	56.0
antiquorum	50	49.2	46.8	44.4
	100	51.2	46.4	44.0
B- Ornamental and Medicinal plants:				
Cymbopogon citratus	25	42.8	38.8	34.8
	50	31.2	22.8	20.0
	100	66.8	54.0	48.0
Pelargonium	25	35.2	33.6	31.2
Rraveolens	50	23.6	19.6	17.6
	100	26.8	20.4	18.0
Matricaria	25	73.6	68.8	62.4
chamomilla	50	49.2	46.8	46.3
	100	50.0	48.4	46.0
Talcum powder	100	83.2	82.4	80.4
Control alone	0	97.6	96.8	96.0

Damage assessment of potato tubers dusted with plant powders.

The role of plant powders in the protection of potato tubers from infestation by the potato tuber moth is summarized in table(5) through assessment of tuber damage index. Results indicated that most of tested plant powders had highly significant effect in protecting tubers from damage ($P < 0.01$) comparable to the two control parameters (tubers treated with talcum powder and untreated tubers). Thus, the best protection to potato tubers occurred by dusting with plant powders of *P. graveolens* , *and A. cepa,* as their mean damage indices were 9.2 ±1.4 and 10.0 ± 1.1 tunnels/tuber at concentration 25%; 4.8 ± 0.8 and 6.6 ± 1.4 tunnels / tuber at concentration 50%, and 7.2 ± 1.02 and 8.8 ± 0.8 tunnels / tuber at concentration 100%, respectively. Meanwhile, plant powder of G *citratus* gave good protection at 50 and 100% concentrations, as the mean damage index was 6.4 ± 0.97 and 10.8 ± 1.9 tunnels / tuber, respectively; comparable to 29.6 ± 0.4 and 30.0 ± 0.0 tunnels / tuber, in case of tubers treated with talcum powder and untreated control, respectively. On the other hand, plant powder of G *antiquorum* caused slight significant protection ($P < 0.05$) at 50 and 100% concentrations, while M *chamomilla* did not elicit any significant ($P > 0.05$) effect comparable to the two control parameters. According to the present results, it can be concluded that powders of *A. cepa* (bulb), *Pelargonium graveolens* (leaves) and G *citratus* (herb) may be considered among plant powders that had the ability to protect potato tubers from PTM infestation, particularly at 50% cone.

In this respect, it is worth mentioning that Moawad (1995) found that dusting plant powder of *A. cepa* (leaves) at 5% could moderately reduce the tuber damage index. Also,Ramane (1987) reported that the best protection of potato tubers could be achieved through covering tubers with powders of G *citratus* during storage. In addition, other plant powders were used to protect potato tubers from PTM damage; for instance, powders of *Eucalyptus globulus* (Lal 1987;Nayer,1987 and Ramane, 1987)in .different countries and powders of *Cannabis sativa* (Khashyapef *al* ,1992) in India.

Table (5): Damage index of potato tubers treated with different concentrations of plant powders.

Tested plant powders	Cone. %	Mean damage index (tunnels / tuber)
A- Vegetable plant powders		
A Ilium cepa	25	10.0 ± 1.1 cc*
	50	6.6±1.4 dc *
	100	8.8±0.8 dc *
Colocasia antiquorum	25	22.4 ± 1.5 aa*
	50	17.2±2.2 bb*
	100	18.2±2.1 ba *
B- Ornamental and medicinal plants:		

Cymbopogon citratus	25	18.0 ± 1.1 ba *
	50	6.4 ± 0.97 dc *
	100	10.8 ± 1.9 dc *
Pelargonium graveolens	25	9.2±1.4 dc *
	50	4.8 ± 0.8 dc*
	100	7.2 ± 1.02 dc *
Matricaria chamomilla	25	24.4 ± 1.5 aa*
	50	21.2 ± 1.4
	100	26.0+ 1.1 M*
Talcum powder	100	29.6 ±0.4"**
Control alone	0	30.0 ± 0.0a

L.S.D. o.o5 =11-7 L.S.D.o.o1= 15.3

Means with the same letters in the vertical column have no significant difference (P < 0.05).

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