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M. STAMPINI

Development observations of *Plodia interpunctella* (Hbn.) (Lepidoptera Pyralidae) on some dried medicinal plants

Abstract - The susceptibility of 17 dried medicinal plants to Indian meal moth *Plodia interpunctella* attack was evaluated. Tests were carried out at 26±1°C and 70±5% r.h., with photoperiod of 16:8 (L:D). The active ingredients present in the tested medicinal plants, mainly therpens, alkaloids and tannins, did not show ovicidal effects.
A 100% of mortality was observed within 5 days on *Althaea officinalis*, *Camellia sinensis*, *Cynara scolymus*, *Eucalyptus globulus*, *Ginkgo biloba*, *Humulus lupulus*, *Melissa officinalis*, *Myrtus communis*, *Passiflora incarnata*, *Ruta graveolens*, *Taxus baccata*, *Tilia cordata* and *Vitis vinifera*.
On the contrary 100% of mortality was reached, respectively, within 30 and 70 days on *Cassia angustifolia* pods and *Crataegus monogyna* flower heads.
Adults (respectively 80.0±3.21 and 50.0±3.80) were observed on minced achenes of *Silybum marianum* and on roots of *Angelica archangelica* in a mean development period of 36.7±0.33 and 43.7±0.67 days.

Riassunto - *Osservazioni sulla capacità di sviluppo di* Plodia interpunctella *(Hbn.) (Lepidoptera Pyralidae) su alcune piante officinali essiccate.*
È stata valutata la suscettibilità di 17 piante officinali essiccate all'attacco del lepidottero Piralide *Plodia interpunctella*. Le prove sono state effettuate in laboratorio a 26±1°C e 70±5% U.R. con fotoperiodo 16:8 (L:B). I principi attivi presenti nelle piante officinali saggiate, principalmente terpeni, alcaloidi e tannini, non hanno mostrato azione ovicida.
Su *Althaea officinalis*, *Camellia sinensis*, *Cynara scolymus*, *Eucalyptus globulus*, *Ginkgo biloba*, *Humulus lupulus*, *Melissa officinalis*, *Myrtus communis*, *Passiflora incarnata*, *Ruta graveolens*, *Taxus baccata*, *Tilia cordata* e *Vitis vinifera* il 100% di mortalità delle larve di I età è stato osservato entro 5 giorni. Su baccelli di *Cassia angustifolia* e su capolini di *Crataegus monogyna*, invece, il 100% di mortalità delle larve si è verificato rispettivamente entro 30 e 70 giorni.
Gli acheni tritati di *Silybum marianum* e le radici di *Angelica archangelica* hanno consentito rispettivamente lo sfarfallamento di 80,0±3,21 e 50,0±3,80 adulti in un tempo medio di sviluppo di 36,7±0,33 e 43,7±0,67 giorni.

Key words: Indian meal moth, medicinal plants, essential oils.

INTRODUCTION

The Pyralids *Cadra cautella* (Wlk.), *Corcyra cephalonica* (Staint.), *Ephestia kuehniella* Zell. and *Plodia interpunctella* (Hbn.) are the most dangerous Lepidoptera among those ones more frequently found in the areas where raw materials are processed or where finished products are stored. These species, highly polyphagous, can develop on various substrates which often have different physical and nourishing properties which can highly affect the insect development.

In these last 10 years, the cultivation of medicinal plants, which belong to the group of the foodstuffs, showed, in several areas of our country, a significant increase mainly as aromatic essences for pharmaceutical, cosmetic, food and spirits industry. Most of these herbs or their parts (blooms, leaves, roots and rhizomes) represent one of the main natural source from which molecules forming the active ingredients of aromas, extracts, essential oils and, more generally, phyto-complex, are drawn. These parts have been always considered useful elements in folk tradition and nowadays they have become economically very important (Giorgi *et al.*, 2003; 2005).

In the mean time, the number of cases of dried plants infested by the over mentioned species is progressively increased. One of the possible causes can be represented by dehydration of plants which determines an increase of the dried weight of the product with a consequent increase of percentage of nutrients that permit the development and the survival of the pest (Heykal *et al.*, 1978; Wahab *et al.*, 1978; Almasi & Stojanovic, 1986; Locatelli & Di Liddo, 2002).

However several medicinal plants, besides containing food elements such as amino-acids, carbohydrates, lipids, vitamins and mineral salts essential for the development, can contain, in variable percentage, natural active substances such as alkaloids, flavonoids, tannins and terpenes whose pesticide or insect repellent properties are known (Echeverri *et al.*, 1991; Huang *et al.*, 1997; Tripathi *et al.*, 2000 a,b; Neetu *et al.*, 2001). In literature there are many works concerning the research of natural substances to use as possible alternative to traditional pesticides, with particular attention to essential oils extracted from different aromatic plants (Singh & Singh, 1991; Shaaya *et al.*, 1991, 1997; Singh & Upadhyay, 1993; Ho *et al.*, 1996; Huang *et al.*, 1997; Tunç *et al.*, 2000).

The susceptibility of 17 dried medicinal plants to the attack of Lepidoptera Pyralidae *P. interpunctella* (Table 1) and their ovicidal effect by contact was evaluated.

MATERIALS AND METHODS

The substrates, collected since not longer than 6 months, were stored at 6±1°C; 70±5% r.h.. The moth was reared at Di.P.S.A. - Università degli Studi di Milano - by using an artificial diet (Locatelli & Limonta, 2004). Two different series of tests were carried out.

I Test. Tests were conducted for to evaluate which plants, among the available ones, were susceptible to the attack of *Plodia interpunctella*. Polyethylene containers (Ø: 12

Table 1 - Dried medicinal plants tested.

Medicinal plant	Family	Parts of tested plants
Althaea officinalis L.	Malvaceae	Leaves
Angelica archangelica L.	Umbelliferae	Roots
Camellia sinensis (L.)	Theaceae	Leaves
Cassia angustifolia Vahl.	Leguminosae	Pods
Crataegus monogyna L.	Rosaceae	Flower heads
Cynara scolymus L.	Compositae	Leaves
Eucalyptus globulus Labill.	Myrtaceae	Leaves
Ginkgo biloba L.	Ginkgoaceae	Leaves
Humulus lupulus L.	Cannabaceae	Flower heads
Melissa officinalis L.	Labiatae	Leaves
Myrtus communis L.	Myrtaceae	Leaves
Passiflora incarnata L.	Passifloraceae	Leaves
Ruta graveolens L.	Rutaceae	Leaves
Silybum marianum (L.)	Compositae	Minced achenes
Taxus baccata L.	Taxaceae	Leaves
Tilia cordata Miller.	Tiliaceae	Leaves
Vitis vinifera L.	Vitaceae	Leaves

cm; h: 6 cm) were used and 25 g of dried medicinal plant were put inside them. Groups of 100 eggs, laid in the previous 24-48 hours, were placed inside glass Petri dishes (Ø: 6 cm; h: 1 cm) on the surface of dried plant. The period time employed by larvae for to reach the adult stage was observed for each test.

Tests were carried out in a thermostatic cell at 26±1°C and 70±5% r.h. with photoperiod 16:8 (L:D).

Three replicates were carried out for every medicinal plant. At the end of each test the percentage of eggs hatching, the mean number of emerged adults, the mean period of development time and the mean susceptibility index were calculated (S.I.)[1] (Abbott, 1925; Howel & Games, 1974; Zarr, 1984).

II Test. The plants that, at the end of the I test, did not show pest attack or that, at the most, permitted the emerging of few individuals, were tested and the time required to stop the development with consequent death of the individuals, was recorded.

Tests were carried out in glass Petri dishes: 2 g of substrate and 20 larvae of I instar were added. At the end of the test the dishes were put inside glass containers (Ø: 15 cm; h: 2 cm) at the bottom of which a layer of paraffin (2 mm) was distributed, in order to prevent the individuals from escaping. Tests lasted from 5, to 10, 20, 30, 40, 50, 60 and 70 days.

(1) S.I. = [(logN)/t]x100

The surviving larvae were collected and measured. The conditions of temperature and relative humidity were the same of the previous test.

Five replicates were carried out for each medicinal plant; the same number of replicates was carried out for the control, by using the artificial diet as rearing substrate. The results were subjected to analysis of variance (ANOVA) and to the Duncan range test (SPSS 11.5 for Windows).

RESULTS

I Test. No significantly difference regarding the ovicidal activity exerted by dried medicinal plants by contact on eggs was observed. Values of mean percentage of hatching varied between 92 and 96%; these results were similar if compared with the one obtained on artificial diet (94-97%).

The highest mean number of emerged adults (80.0±3.21), the shortest mean period of development (36.7±0.33 days) and the highest mean susceptibility index (5.2±0.09) were observed on *Silybum marianum* (minced achenes). On the contrary 50.0±3.80 adults emerged after 43.7±0.67 days on roots of *Angelica archangelica*: for this substrate the mean susceptibility index was 3.8±0.17 (Table 2).

Table 2 - Plodia interpunctella *(Hbn.) mean adults number, mean development time and mean susceptibility index observed on* Angelica archangelica, Silybum marianum *and artificial diet (3 replicates).*

Medicinal Plant	Mean adults number (±S.D.)	Mean development time (±S.D.)	Mean susceptibility index (±S.D.)
Angelica archangelica	50.0±3.80 b	43.7±0.67 a	3.8±0.17 c
Silybum marianum	80.0±3.21 a	36.7±0.33 b	5.2±0.09 b
Artificial diet	85.7±3.17 a	25.3±0.33 c	7.6±0.06 a

Equal letters indicate homogenous wholes for a confidence interval of 95% (Duncan test).

II Test. The total mortality of I instar larvae was observed after 5 days on *Althaea officinalis*, *Camellia sinensis*, *Cynara scolymus*, *Eucalyptus globulus*, *Ginkgo biloba*, *Humulus lupulus*, *Melissa officinalis*, *Myrtus communis*, *Passiflora incarnata*, *Ruta graveolens*, *Taxus baccata*, *Tilia cordata* and *Vitis vinifera*.

As to *Cassia angustifolia* the mean number of I instar larvae surviving after 5 days was 3.8±1.44 (Table 3); 2.8±2.33 and 0.6±0.24 larvae respectively after 10 and 20 days. After 5, 10 and 20 days the mean length of I instar larvae was respectively 0.7±0.03; 1.6±0.46 and 1.6±0.33 mm (Table 4). No cases of cannibalism were reported among the surviving larvae. *Plodia interpunctella* larvae (1.2±0.65) survived for 60 days on *Crataegus monogyna* and the individuals reached the III instar.

The mean length of I instar larvae (11.6±3.58 i^[2]) (Table 3) after 5 days was 1.5±0.35

(2) i^ mean number of individuals

Table 3 - Mean number (±S.D.) of Plodia interpunctella *(Hbn.) larvae survived after 5-60 days from the hatching of 20 eggs (24-48 hours) reared on* Cassia angustifolia, Crataegus monogyna *and artificial diet (5 replicates).*

Medicinal plant	Days	Mean number of survived larvae (±S.D.)
Cassia angustifolia (1)	5	3.8±1.44
	10	2.8±2.33
	20	0.6±0.24
	30	0.0±0.00
Crataegus monogyna (2)	5	11.6±3.58
	10	9.2±0.66
	20	4.8±1.62
	30	2.6±0.55
	40	2.2±1.79
	50	1.4±0.89
	60	1.2±0.65
	70	0.0±0.00
Artificial diet	5	18.4±0.89
	10	16.6±0.60
	20	14.2±0.92
	30	17.8±0.66 *

(1) pods, (2) flower heads, (*) adults.

mm (Table 4). II instar (9.2±0.66 i^) was observed after 10 days and it lasted up to 20th day (4.8±1.62 i^); the mean length were respectively 2.4±0.15 and 3.4±0.98 mm. III instar was observed after 30 days (2.6±0.55 i^; 6.5±1.18 mm) and it lasted up to 60 days (1.2±0.65 i^; 7.4±0.16 mm). The total mortality was reached within 70 days. On the contrary *P. interpunctella* larvae reached the II instar (18.4±0.89 i^) already after 5 days (2.3±0.39 mm) on artificial diet. The III (16.6±0.60 i^) and IV (14.2±0.92i^) instars were observed after 10 and 20 days, with mean lengths respectively 6.8±1.32 and 8.1±0.00 mm.

DISCUSSION

The efficacy of natural extracts and essential oils obtained for steam distillation against insects is well documented in literature. Some Authors observed that the vapours of essential oils extracted from some medicinal plants such as *Artemisia annua*, *Elletaria cardamomum*, *Pimpinella anisum*, *Eucalyptus camaldulensis*, *Origanum vulgare* and *Rosmarinus officinalis* have degrees of toxicity variable against eggs of *Tribolium confusum* and *Ephestia kuehniella* (Tunç *et al.*, 2000; Huang *et al.*, 2000; Tripathi *et*

Table 4 - Mean length (values of min-max) of I-III instar larvae of Plodia interpunctella *(Hbn.) survived after 5-60 days on* Cassia angustifolia, Crataegus monogyna *and artificial diet (5 replicates).*

Medicinal plant	Days	N	Instar larvae	Length (mm)		
				Mean	Min	Max
Cassia angustifolia (1)	5	6	I	0.7±0.03	0.65	0.70
	10	20	I	1.6±0.46	0.65	2.50
	20	3	I	1.6±0.33	1.23	2.85
Crataegus monogyna (2)	5	58	I	1.5±0.35	1.02	2.08
	10	46	II	2.4±0.15	2.42	2.52
	20	47	II	3.4±0.98	1.25	7.75
	30	17	III	6.5±1.18	5.38	7.50
	40	13	III	6.8±1.37	5.00	8.75
	50	11	III	7.0±0.90	6.00	9.38
	60	5	III	7.4±0.16	7.13	9.38
	70	0	-	0.0±0.00	-	-
Artificial diet	5	94	II	2.3±0.39	1.25	3.25
	10	91	III	6.8±1.32	3.75	9.13
	20	15(*)	IV	8.1±0.00	7.50	9.80

(1) pods, (2) flower heads (*) larvae not jet pupate

N - Number of larvae survived and measured after 5, 10, 20, 30, 40, 50, 60 and 70 days. Live larvae registered in the 5 replicates were considered. Originally each replicate included 20 individuals (I instar larvae).

al., 2001). As regard the medicinal plants tested in this work ovicidal activity by eggs contact was not observed.

The total mortality of *Plodia interpunctella* I instar larvae was obtained within 5 days for *Althaea officinalis*, *Camellia sinensis*, *Cynara scolymus*, *Eucalyptus globulus*, *Ginkgo biloba*, *Humulus lupulus*, *Melissa officinalis*, *Myrtus communis*, *Passiflora incarnata*, *Ruta graveolens*, *Taxus baccata*, *Tilia cordata* and *Vitis vinifera*. This could be due to the presence of several substances belonging to different families of natural compounds, such as alkaloids, flavones, tannins and therpenes whose insecticide or insect repellent properties are known (Karr & Coats, 1988; Santos *et. al*, 1997; Prates *et al.*, 1998; Maga *et al.*, 2000; Tripathi *et al.*, 2000b; Neetu *et al.*, 2001). The monotherpenes, characterized by strong volatility and lypophily, can be easily absorbed by insect with consequent alteration of metabolism; up to today yet the mechanism of action is not completely clear (Lee *et al.*, 2003).

On the flower heads of *Crataegus monogyna* larvae were found in the inner part near pollen granules which contain sugars, lypids, mineral salts and vitamins (Maurizio & Grafl, 1981). On this plant *P. interpunctella* larvae could survive for 60 days, reaching the III instar, without completing larval development; however the length of the III instar larvae was shorter than the one observed on artificial diet. The main reason which could cause the extension of the mean period of larval development, with the relevant absence of adults emergence, is supposed to be linked to insufficient presence of food in the substrate. However in the flower heads of *C. monogyna*, besides the presence of nutrients, there are also active ingredients, in particular quercetin and rutin, flavonoids whose probable toxic activity are known. Gazzoni *et al.* (1997), in fact, observed that the addition of these active ingredients to the substrate used for the *Anticarsia gemmatalis* (Hbn.) rearing could determine a significant increase of larval mortality, the extension of the larval period and a decrease of the weight of the chrysalides.

The toxic effects of some active substances do not always act immediately against the insect; in some cases the effect becomes evident only after some days or weeks, as the active ingredient progressively accumulates inside the body of the insect. *P. interpunctella* larvae were not able to survive more than 30 days on pods of *Cassia angustifolia*. In this plant, in particular on the leaves, the presence of monosacharides, such as arabinose, galactose and rhamnose is recorded. As observed by some Authors galactose is progressively transformed into galactitol, a toxic alcohol for some insects of foodstuffs (Applebaum & Konijin, 1965; Applebaum, 1966). In that case, therefore, the mortality observed on this plant after a month could be due to the progressive accumulation of toxic metabolite in larval tissues.

On the contrary *Angelica archangelica* and *Silybum marianum*, favoured the development of the insect permitting the emerging of a high number of adults. In these medicinal plants there are carbohydrates (saccharose, glucose and fructose), fatty acids (in particular oleic, linoleic, linolenic, stearic acid) and vitamins, considered nourishing ingredients essential for moth development (Fraenkel & Blewett, 1942, 1946; Thompson *et al.*, 1973; Rodriguez-Menendez *et al.*, 1988).

In conclusion, the insect's development can be influenced by several variables. The presence of nourishing substances essential to moth on some plants permitted to complete the development in a period of time very similar to the one obtained in laboratory on artificial diet. On the contrary the slow development observed on other medicinal plants such as *C. angustifolia* and *C. monogyna*, presupposes a double action. In *C. angustifolia* the stop of the development depends, more than on the lack of nourishing substances, for the accumulation of active substances, normally present in the plant tissues, toxic for insects. Due to the swallowing of the plant, the larvae death, observed after a medium long period, could be therefore justified on the one hand, by the gradual metabolic transformation of galactose into galactitol and, on the other hand, by the progressive accumulation of toxic alcohol in the hemolymph, till to reach that concentration able to cause the death of the insect. On the contrary *C. monogyna*, do not present insecticidal active ingredients; the absence of development is mainly due to an insufficient nourishing supply. As to the plants which did not permit post-embryonal development of *P. interpunctella*, probably what observed depends on the presence of active ingredients which have insecticide properties. This is confirmed by literature that shows how most of the main substances with insecticide effect are present in the plants tested in this work (Leung & Foster, 1986).

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REFERENCES

ABBOTT W.S., 1925 - A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

ALMASI R., STOJANOVIC T., 1986 - Polyphagy of the Indian meal moth (*Plodia interpunctella* Hbn. Lep., Phycitidae) on different foods and possibility of larval development on dried vegetables. Zastita Bilja 37 (4): 321-326.

APPLEBAUM S.W., KONIJIN A.M., 1965 - The utilization of starch by larvae of the flour beetle, *Tribolium castaneum* Herbst. J. Nutr., 85: 275-282.

APPLEBAUM S.W., 1966 - The digestion of potato starch by larvae of flour beetle, *Tribolium castaneum* Herbst. J. Nutr., 90: 235-239.

ECHEVERRI F., CARDONA G., TORRES F., PELAEZ C., QUINONES W., RENTEIRA E., 1991 - Ermanin: an insect deterrent flavonoid from *Passiflora foetida* resin. Phytochem., 30 (1): 153-155.

FRAENKEL G., BLEWETT M., 1942 - Biotin, vitamin B, riboflavin, nicitin acid B6 and pantotenic acid as growth factors for insects. Nature, Lond., 150: 177-178.

FRAENKEL G., BLEWETT M., 1946 - The dietetics of the caterpillars of three *Ephestia* species, *E. kuehniella*, *E. elutella* and *E. cautella*, and of a closely related species, *Plodia interpunctella*. J. exp. Biol., 22: 162-171.

GAZZONI D.L., HULSMEYER A., HOFFAMAN-CAMPO C.B., 1997 - Effect of different rates of rutin and quercetin on the biology of *Anticarsia gemmatalis*. Pesquisa Agropecuaria Brasileira 32 (7): 673-681.

GIORGI A., MALGIOGLIO A., DOMENGHINI M., COCUCCI M., 2003 - Produzione di piante officinali. Aspetti qualitativi e potenzialità. Erboristeria Domani (9): 36-39.

GIORGI A., BONONI M., TATEO F., COCUCCI M., 2005 - Yarrow (*Achillea millefolium* L.) Growth at Different Altitudes in Central Italian Alps: Biomass Yeld, Oil Content and Quality. J. Herbs, Spices & Medicinal Plants. Vol. 11 (3): 47-58.

HEYKAL A., EL HALFAWY M.A., WAHAB A.E.A., ASRAN A.M., 1978 - Biological studies on *Plodia interpunctella* Hbn. on certain medical and aromatical dried plants (Lepidoptera: Phycitidae). Agr. Res. Rev. 56 (1): 147-149.

HO S.H., KOH L., MA Y., HUANGH Y., SIM K.Y., 1996 - The oil of garlic, *Allium sativum* L. (Amaryllidaceae), as a potential grain protectant against *Tribolium castaneum* (Herbst) and *Sithophilus zeamais* Motsch. Postharvest Biology and Technology, 9: 41-48.

HOWELL N., GAMES P.A., 1974 - The effects of variance heterogeneity multiple. Comparison procedures with equal sample size. Brit. J. Math. Statist. Psychol., 27: 72-81.

HUANG Y., TAN J.M.W.L., KINI R.M., HO S.H., 1997 - Toxic and antifeedant action of nutmeg oil against *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. J. stored Prod. Res. 33: 289-298.

HUANG S.L., LAM S.L., HO S.H., 2000 - Bioactivities of essential oil from *Elletaria cardamomum* (L.) Marton. to *Sitophilus zeamais* Motschulsky and *Tribolium castaneum* (Herbst). J. stored Prod. Res. 36: 107-117.

KARR L.L., COATS J.R., 1988 - Insecticidal properties of *d*-limonene. J. Pestic. Sci., 13: 287-290.

LEE S., PETERSON C.J., COATS J.R., 2003 - Fumigation toxicity of monoterpenoids to several stored product insects. J. stored Prod. Res., 39: 77-85.

LEUNG A.Y., FOSTER S., 1996 - Enciclopedia delle piante medicinali utilizzate negli alimenti, nei farmaci e nei cosmetici. Ed. Aporie, Roma: 577 pp.

LOCATELLI D.P., DI LIDDO S., 2002 - Suscettibilità di alcuni vegetali disidratati all'attacco di *Plodia interpunctella* (Hbn.) (Lepidoptera: Pyralidae). Atti VII Simposio "La difesa antiparassitaria nelle industrie alimentari e la protezione degli alimenti", Piacenza: 157-162.

LOCATELLI D.P., LIMONTA L., 2004 - Ability of *Plodia interpunctella* (Hbn.) (Lepidoptera Pyralidae) larvae to find food and flavours. Boll. Zool. agr. Bachic., Ser. II, 36 (1): 149-154.

MAGA R., BROUSSALIS A., CLEMENTE S., MAREGGIANI G., FERRARO G., 2000 - 1,8-cineol: responsible for the insecticide activity of *Lavandula spica* Mill (lavender). Revta lat.-am. Quimica, 28 (3): 146-149.

MAURIZIO A., GRAFL I., 1981- THE BOOK OF BEE PLANTS. NECTAR AND POLLEN - THE MOST IMPORTANT FOOD SOURCES OF THE HONEYBEE. Das Trachtpflanzenbuch. Nektar und Pollen - die wichtigsten Nahrungsquellen der Honigbiene. Ehrenwirth Verlag München 3. Aufl: 338 pp.

NEETU V., TRIPATHI A.K., VEENA PRAJAPATI, BAHAL J.R., BANSAL, R.P., KHANUJA S.P.S, SUSHIL KUMAR, 2001 - Toxicity of essential oil extracted from *Lippia alba* towards stored grain insects. J. Medicinal & Aromatic Plant Sciences, 22/23: 4A/1A: 117-119.

PRATES H.T., SANTOS J.P., WAQUIL J.M., FABRIS J.D., OLIVEIRA A.B., FOSTER J.E., 1998 - Insecticidal Activity of Monoterpenes Against *Rhyzopertha dominica* (F.) and *Tribolium castaneum* (Herbst). J. stored Prod. Res., 34 (4): 243-249.

RODRIGUEZ-MENENDEZ E., CABELLO-GARCIA T., VARGAS P., 1988 - Influencia de la dieta en el desarollo de *Ephestia kuehniella* Zeller. Bol. Sanidad Veg. Plagas Espana, 18 (2): 363-369.

SANTOS J.P., PRATES H.T., WAQUIL J.M., OLIVERIA A.B., 1997 - Evaluation of plant-origin substances on the control of stored product pests. Pesquisa em Andamento - Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS), Sete Lagoas, Brasil, 19: 8-20.

SHAAYA E., RAVID U., PASTER N., JUVEN B., ZISMAN U., PISSAREV V. 1991 - Fumigant toxicity of essential oils against four major stored-product insects. J. chem.. Ecol., 17: 499-504.

SHAAYA E., KOSTJUKOVSKY M., EILBERG J., SUKPRAKARN C. 1997 - Plant oils as fumigants and contact insecticides for the control of stored-product insects. J. stored Prod. Res., 33: 7-15.

SINGH D, SINGH A.K., 1991- Repellent and insecticidal properties of essential oils against housefly, *Musca domestica* L. Insect Science and its Application, 12: 487-491.

SINGH G., UPADHYAY R.K., 1993 - Essential oils: a potent source of natural pesticides. J. Scient. Ind. Res., 52: 676-683.

THOMPSON S.N., KAPLANIS J.N., ROBBINS W.E., SVOBODA J.A., 1973 - Metabolism of steroids in insects. Adv. Lipid. Res., 11: 219-265.

TRIPATHI A.K., VEENA PRAJAPATI, AGGARWAL K.K., KHANUJA S.P.S., KUMAR S., 2000a - Repellency and toxicity of oil from *Artemisia annua* to certain stored product beetles. J. Econ. Entomol., 93: 43-47.

TRIPATHI A.K., VEENA PRAJAPATI., AGGARWAL K.K., SUSHIL KUMAR, 2000b - Effect of volatile oil constituents of *Mentha* species against the stored grain pests, *Callosobruchus maculatus* and *Tribolium castaneum*. J. Medicinal & Aromatic Plant Sciences, 22 (1): 549-556.

TRIPATHI A.K., VEENA PRAJAPATI, AGGARWAL K.K., KUMAR S., 2001 - Toxicity, Feeding Deterrence, and Effect activity of 1,8-cineole from *Artemisia annua* on Progeny Production of *Tribolium castaneum* (Coleoptera: Tenebrionidae). J. Econ. Entomol., 94: 979-983.

TUNÇ I, BERGER B.M., ERLER F., DAĞLI F., 2000 - Ovicidal activity of essential oils from five plants against two stored-product insects. J. stored Prod. Res., 36: 161-168.

WAHAB A.E.A., EL HALFAWY M.A., HEYKAL A., ASRAN A.M., 1978 - Biology of *Anagasta kuehniella* Zell. on certain medical and aromatical dried plants (Lepidoptera; Phycitidae). Agr. Res. Rev. 56 (1) : 143-146.

ZARR J.H., 1984 - Biostatistical Analysis. Prentice-Hall Inc., Englewood Cliffs, New Jersey, U.S.A.: 718 pp.

DR MASSIMILIANO STAMPINI - Dipartimento di Protezione dei Sistemi Agroalimentare e Urbano e Valorizzazione delle Biodiversità (Di.P.S.A.), Università degli Studi di Milano, Via Celoria 2, I-20133 Milano (Italy). E-mail: massimiliano.stampini@unimi.it.

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