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Observations of the development of *Idaea inquinata* (Scop.) (Lepidoptera Geometridae) on medicinal plants and other food substrates

Abstract - The development of the moth *Idaea inquinata* (Scop.) on 20 medicinal plants and on 13 foodstuffs was tested at 26±1°C and 70±5% r.h..
The insect was not able to complete its development on: *Camellia sinensis* and *Vitis vinifera* leaves, whole *Illicium verum* fruits, *Cinnamomum zeylanicum* bark, pieces of *Quassia amara* wood, whole capsules of *Vanilla planifolia*, and *Zingiber officinale* rhizomes, soft-wheat flour, hazel-nut flour, almond flour, raisins and cocoa powder.
As far as medicinal plants, the highest number of adults was found on whole fruits of *Foeniculum vulgare*, and the highest susceptibility indexes were recorded on *Angelica archangelica* roots and on *Crataegus monogyna* flower heads respectively. The highest mean number of adults was recorded on bran (≥20 mesh), with a mean developmental period of 62 days. The highest susceptibility indexes were recorded on bran and maize meal. The shortest mean developmental period was observed on wheat germ (58.5±0.96).

Riassunto - *Osservazioni sulla capacità di sviluppo di* Idaea inquinata *(Scop.) (Lepidoptera Geometridae) su piante officinali e altri substrati alimentari.*

È stata saggiata la capacità di sviluppo di *Idaea inquinata* (Scop.) su 20 piante officinali e su 13 derrate alimentari. Le prove sono state condotte in termostato a 26±1°C e 70±5% U.R..
L'insetto non è stato in grado di completare lo sviluppo su foglie di *Camellia sinensis* e *Vitis vinifera*, su frutti interi di *Illicium verum*, su corteccia di *Cinnamomum zeylanicum*, su frammenti di legno di *Quassia amara*, su capsule intere di *Vanilla planifolia*, su rizomi di *Zingiber officinale*, farina di frumento 00, farina di nocciole e di mandorle, uva sultanina e cacao in polvere.
Per quanto riguarda le piante officinali, il maggior numero di adulti è stato osservato su frutti interi di *Foeniculum vulgare*, mentre gli indici di suscettibilità più alti sono stati riscontrati rispettivamente su radici di *Angelica archangelica* e su sommità fiorite di *Crataegus monogyna.* Il numero medio di adulti più elevato è stato notato su crusca (≥20 mesh), con un periodo medio di sviluppo di circa 62 giorni. Gli indici di suscettibilità più alti sono stati riscontrati su crusca e farina

di mais; su cariossidi di frumento è stato osservato il periodo medio di sviluppo più breve (58,5±0,96).

Key words: *Idaea inquinata*, dried medicinal plants, foodstuffs.

INTRODUCTION

Idaea inquinata (Scop.), described by Scopoli in 1763 as *Phalaena inquinata,* [sin. *Geometra herbariata* F.; *Acidalia herbariata* (F.); *Ptycopoda herbariata* (F.); *Sterrha inquinata* (Scop.)], is distributed over the European-Mediterranean-Macaronesian region (Ghiliani, 1852; Mariani, 1941; Corbet & Tams, 1943; Flamigni & Bastia, 1998; Hausmann, 1997; Gianti, 2001); it has appeared in Belgium (Heylaerts, 1878) and in the Netherlands (Naves, 1995). In Great Britain its presence is probably due to the importation of infested plants (Skinner, 1984). In Italy the moth was first recorded by Bertoloni (1876) who found the species in some herbaria in the Bologna area and by Candura (1931a,b) who discovered the insect on *Matricaria chamomilla* L. in the Naples area. The latter author described in detail every developmental stage of *I. inquinata*, and evaluated its methods of attack and the different kind of damage the moth caused in warehouses containing various dried medicinal plants.

The insect is mostly found in hay-lofts and in barns (South, 1961; Koch, 1984; Skinner, 1984) where the infestations are more frequent during summers with high temperatures and low humidity (Lempke, 1949).

Various medicinal plants are more or less susceptible to attack by this species (Candura, 1931a, b; Tempel, 1941; Kratochvìl, 1948) but the length of the developmental cycle and the survival of the insect on various diets have not been investigated.

The object of the present study was to evaluate the developmental ability of the moth on certain medicinal plants and foodstuffs.

MATERIALS AND METHODS

The tests were carried out on 20 dried medicinal plants (table 1), collected over a period of 6 months and stored in refrigerators (6±1°C; 60±5% r.h.).

Evaluations were carried out on the development of the insect on 13 foodstuffs (wheat kernels, wheat germ, bran (≥20 mesh), bran (<20 mesh), soft wheat flour, wheat semolina, maize kernels, maize meal, rice, almond flour, hazel-nut flour, raisins and cocoa powder).

Tests were carried out using polystyrene cylindrical containers (Ø: 12 cm; h: 6 cm), each furnished with a holed lid covered by a 120 mesh, metal net to allow for gas exchange. In each container 20g of substrate (after staying 30 days under the same temperature and humidity conditions of the test) were placed and 100 eggs (24-48 hours old) were added on the substrate. The containers were placed in an air-condi-

Table 1 - Tested dried medicinal plants.

Medicinal plants	Common name	Family	Plant part tested
Angelica archangelica L.	Angelica	Apiaceae	Roots
Camellia sinensis Kuntze	Tea	Theaceae	Leaves
Cassia angustifolia Vahl.	Senna	Fabaceae	Pods
Cinnamomum zeylanicum Blume	Cinnamon	Lauraceae	Corticle
Crataegus monogyna Jacq.	Hawthorn	Rosaceae	Flower heads
Cucurbita pepo L.	Pumpkin	Cucurbitaceae	Seeds
Foeniculum vulgare L.	Fennel	Apiaceae	Whole fruits
Illicium verum Hook. F.	Star anise	Illiciaceae	Whole fruits
Juniperus communis L.	Juniper	Cupressaceae	Whole berries
Matricaria chamomilla L.	Camomile	Asteraceae	Whole flower heads
Origanum vulgare L.	Marjoram	Lamiaceae	Leaves
Panax ginseng C. A. Mey	Ginseng	Araliaceae	Roots
Passiflora incarnata L.	Passion-flower	Passifloraceae	Leaves
Quassia amara L.	Quassia	Simaroubaceae	Wood fragments
Silybum marianum Gaertner.	Milk thistle	Asteraceae	Squeezed fruits
Tilia cordata Mill.	Lime	Tiliaceae	Flower heads
Valeriana officinalis L.	Valerian	Valerianaceae	Roots
Vanilla planifolia Andr.	Vanilla	Orchidaceae	Whole capsules
Vitis vinifera L.	Vine	Vitaceae	Leaves
Zingiber officinale Roscoe	Ginger	Zingiberaceae	Rhizomes

tioned chamber at 26±1°C and 70±5% r.h., environmental conditions that occur more frequently in warehouses of North Italy during summer. Hatching percentage was noted after 7 days.

Daily checks were made to observe adult emergence. Newly emerged insects were counted and removed. Each dried medicinal plant and the control were tested in four replicates. The mean period of development (T) was calculated as the time in days spent from the oviposition to the time at which 50% of the adults emerged. In order to define the potential rate of development of the insects on different substrates (Howell & Games, 1974; Zar, 1984) a susceptibility index (S.I.)[1] was calculated based on the total number of emerged adults (N) and the mean development period (T). Results were subjected to analysis of variance (ANOVA) and the Duncan multiple range test (SPSS 11.5 for Windows).

(1) S.I = [(log N/T)]x100

Table 2 - Mean number of adults of Idaea inquinata *(Scop.), mean period of development and mean index of susceptibility observed on dried medicinal plants at 26±1°C, 70±5% r.h..*

Medicinal plant	Mean number of adults (±S.E.)	Mean period (days) of development (±S.E.)	Mean index of susceptibility (±S.E.)
Angelica archangelica	93.0±0.70a	58.0±0.00gh	3.39±0.00a
Camellia sinensis	0.0±0.00i	-	-
Cassia angustifolia	31.8±2.56g	57.5±1.32h	2.61±0.12e
Cinnamomum zeylanicum	0.0±0.00i	-	-
Crataegus monogyna	91.5±0.87a	61.0±0.40fg	3.21±0.02b
Cucurbita pepo	70.3±1.18ef	85.8±1.93b	2.16±0.05f
Foeniculum vulgare	93.3±0.95a	73.0±0.40c	2.69±0.02de
Illicium verum	0.0±0.00i	-	-
Juniperus communis	67.3±1.31f	87.8±2.01b	2.09±0.05fg
Matricaria chamomilla	76.8±3.47bcd	88.8±1.03b	2.12±0.02fg
Origanum vulgare	12.0±1.47h	94.8±1.25a	1.13±0.07h
Panax ginseng	74.5±1.50cde	64.8±2.01ef	2.87±0.09c
Passiflora incarnata	72.3±1.70de	93.0±2.42a	2.00±0.05g
Quassia amara	0.0±0.00i	-	-
Silybum marianum	89.0±1.78a	70.5±0.64cd	2.76±0.03cde
Tilia cordata	78.8±1.55bc	71.3±1.65c	2.66±0.07e
Vanilla planifolia	0.0±0.00i	-	-
Valeriana officinalis	80.8±1.31b	66.8±1.10de	2.84±0.05cd
Vitis vinifera	0.0±0.00i	-	-
Zingiber officinale	0.0±0.00i	-	-

RESULTS

No significant differences were observed with regard to the hatching of the eggs on the various substrates, with a mean percentage of 98.8±0.25 (S.E.). However, *Idaea inquinata* was not able to complete its development on *Illicium verum*, *Cinnamomum zeylanicum*, *Quassia amara*, *Camellia sinensis*, *Vanilla planifolia*, *Vitis vinifera* and *Zingiber officinale*, soft-wheat flour, hazel-nut flour, almond flour, raisins and cocoa powder (Tables 2 and 3).

As far as the medicinal plants are concerned, the highest mean number of adults (93.3±0.95) was observed on *Foeniculum vulgare*, while the highest susceptibility indexes were recorded on *Angelica archangelica* and *Crataegus monogyna*.

The shortest mean developmental period was recorded on *Cassia angustifolia*

Table 3 - Mean number of adults of Idaea inquinata *(Scop.), mean period of development and mean index of susceptibility observed on different foodstuffs at 26±1°C, 70±5% r. h..*

Medicinal plant	Mean number of adults (±S.E.)	Mean period (days) of development (±S.E.)	Mean index of susceptibility (±S.E.)
Wheat kernels	31.8±4.96d	58.5±0.96de	2.5±0.14ab
Wheat germ	6.0±1.35fg	53.8±0.75f	1.4±0.27d
Bran (1)	58.3±4.50a	62.0±0.71c	2.8±0.08a
Bran (2)	39.0±0.91c	68.3±0.85b	2.3±0.04b
Soft-wheat flour	0.0±0.00h	-	-
Semolina	2.8±0.48g	71.3±1.93ab	0.6±0.11e
Maize kernels	15.5±2.06e	59.8±1.31cde	2.0±0.08c
Maize meal (flour)	49.0±0.91b	60.0±0.41cde	2.8±0.03a
Rice	28.0±2.83d	61.8±0.48bc	2.3±0.08b
Almond flour	0.0±0.00h	-	-
Hazel-nut flour	0.0±0.00h	-	-
Raisin	0.0±0.00h	-	-
Cocoa powder	0.0±0.00h	-	-

(1) ≥ 20 mesh; (2) < 20 mesh.

(57.5±1.32); the lowest number of adults (12.0±1.47) and the longest developmental period (94.8±1.25) were observed on *Origanum vulgare.*

The highest number of adults on foodstuffs (58.3±4.50), was noticed on bran (≥20 mesh), with a developmental period of 62.0±0.71. The highest susceptibility indexes were recorded on bran (≥20 mesh) (2.8±0.08) and maize meal (2.8±0.03). The shortest mean developmental period (58.5±0.96) was observed on wheat germ. From 2 to 3 adults were observed on semolina after 71.3±1.93 days.

DISCUSSION

Idaea inquinata manifested a great ability for development on medicinal plants, confirming its natural preference for dried vegetal substrates which are rich in polysaccharides, mineral salts and vitamins.

The moth was not able to complete its development on *Camellia sinensis* and *Vitis vinifera*, probably due to their high tannin content. Tannis extracted from the bark of some species of *Betula*, *Pinus* and *Salix*, are able to act on enzymes such as ß-glucosidase and esterase (Juntheikki & Julkunene-Tiitto, 2000). In 1982 Pospisil showed that larvae and adults of *Leptinotarsa decemlineata* (Say) (Coleoptera Chrysomelidae) are not able to feed on potato leaves treated with tannins (5 mg/100 cm^2) while

Manuwoto & Scriber (1986) observed that *Spodoptera eridania* larvae (Cramer) (Lepidoptera Noctuidae) develop very slowly when tannins are added to the artificial diet.

The resistant and smooth structure of the *Zingiber officinale* rhizomes prevented the insect from developing on this plant. *Illicium verum* and *Vanilla planifolia* did not promote insect development possibly due to the presence of strong aromatical components which acted as repellents (Deseö, 1977).

The active ingredients contained in *Quassia amara* (quassins) and *Cinnamomum zeylanicum* (carvacrol and cinnamaldehyde) have strong insecticidal properties (Evans & Raj, 1991; Mancebo *et al.*, 2000; Muthukrishnan & Pushpalatha, 2001; Tesoriero *et al.*, 2003). Evans & Kaleysa (1992) showed that quassins can inhibit the activity of tyrosinase with consequent alteration of cuticle formation in *Culex quinquefasciatus* larvae (Say) (Diptera Culicidae).

A solution containing 5% active ingredients present in *C. zeylanicum* can cause 90% of deaths in *Ceratitis capitata* adults (Wiedemann) (Diptera Tephritidae) (Moretti *et al.*, 1998).

A limited number of adults emerged from *Cassia angustifolia*; the products probably arising from the metabolism of galactose and arabinose, forming the mucilage present in the pods of this plant. This exercised a toxic effect on the insect (Applebaum & Konijin, 1965; Applebaum, 1966). On the other hand, the limited development of the moth on *Origanum vulgare* could be related to the presence of various toxic substances such as alcohols, terpenes and tannins contained in the essential oil (Regnault-Roger & Hamraoui, 1993; Kalinovic *et al.*, 1997). Clemente *et al.* (2003) observed that the active ingredients present in this aromatic plant have a sublethal effect on *Tribolium castaneum* adults (Herbst) (Coleoptera Tenebrionidae). Papachristos and Stamopoulos (2002) stated that the essential oil contained in *O. vulgare* and in other aromatic plants has a repellent and lethal effect on Bruchidae *Acanthoscelides obtectus* (Say) eggs and larvae. Candura (1931 a,b) noticed that the insect is able to complete only one generation on this aromatic plant, unlike what happens on other herbaceous plants, such as *Hedysarum coronarium, Trifolium pratense, Trigonella corniculata, Lotus corniculatus, Papaver rhoeas e Matricaria chamomilla*, where 2-3 generations develop in a year.

The number of emerged adults from wheat, maize and rice was not particularly high; probably due to the fact that larvae, mostly of I instar, have difficulty in damaging the kernel's pericarp.

A similar mean number of adults was observed on rice and on wheat, even though the latter contain a lower percentage of proteins and lipids; however the polished rice has a weaker consistency than wheat.

Maize was found to be the least susceptible among the tested cereals as probably the smooth seed coat can prevent insect attack. These kernels, from a nutritional point of view, are suitable for the insect. The flour, obtained by grinding the maize, is, in fact, the one (among the tested substrates) with the highest susceptibility to attack by this moth.

The highest number of emerged adults was observed on bran (≥20 mesh) which is rich in fibre, proteins, lipids, mineral salts (Na, K, Fe, Ca and P) and vitamins (B_1, B_2, B_6, E). Bran with a granulometry <20 mesh, has a lower quantity of fibre, mineral salts and vitamins and consequently permitted the emergence of fewer adults. No individual was able to complete its development on soft-wheat flour, while only some individuals were able to reach the adult stage on semolina. These substrates are poor in cellulose, essential fatty acids, mineral salts and vitamins, which are necessary for moth development (Chapman, 1924; Richardson, 1926; Good, 1932; Fraenkel & Blewett, 1941, 1946; Friend, 1958; House, 1965; Morére, 1971; Hämäläinen & Lo Schiavo, 1977; Biglia, 1994). In particular a lack of riboflavin and vitamin A, removed during the process of milling and sieving, was recorded (Andrews *et al.*, 1942; Tepley *et al.,* 1942; Thomas *et al.,* 1942).

Only some adults were able to emerge on wheat germ, while almond flour and hazel-nut flour and cocoa powder, although rich in nutrients, did not permit insect development. The high lipid content can act as a pesticide on larvae and on adults of many species (Mansingh, 1981). Moreover Johnson *et al.* (1992) observed that aldehydes, ketones and alcohols, toxic products from rancid fats can negatively affect the hatching of the eggs and the development of *P. interpunctella*. Oxidative rancidity is promoted by high temperatures and by grinding (Musco & Cruess, 1954).

I. inquinata was not able to develop on raisins although they are rich in thiamine and essential fatty acids which are necessary for the development of Pyralidae moths (Morére & Le Berre, 1967; Fraenkel & Blewett, 1943). The high concentration of monosaccharides could have negatively affected the development of this moth, which seems to require the presence of polysaccharides in its diet.

It would be useful to carry out further studies about the biology of this insect as the optimum temperature and humidity conditions for its development are still unknown.

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