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DARIA PATRIZIA LOCATELLI [a] - FATIMA BEATRIZ PEREZ GARCIA [a] - LIDIA LIMONTA [a]

THE EFFECTS OF COMPETITION BETWEEN LARVAE OF STORED-PRODUCT MOTHS

[a] *Department of Food, Environmental and Nutritional Sciences, Università degli Studi di Milano, Via Giovanni Celoria 2, 20133 Milano, Italy.*
Corresponding Author: Lidia Limonta; lidia.limonta@unimi.it

Locatelli D.P., Perez Garcia F.B., Limonta L. – The effects of competition between larvae of stored-product moths.

The competition between *Idaea inquinata*, *Corcyra cephalonica*, and *Plodia interpunctella* on an artificial diet was investigated. The experiments were carried out with eggs laid within 24 hours. In the first experiment, 20 eggs of one species were placed in a ventilated Petri dish with 10 g of diet and 20 eggs of one of the other species; in the second experiment, 20 eggs of one species and, after 7 days, 20 eggs of one of the other species were added. Experiments were carried out at 27±1 °C, 70±5% R.H. Each experiment was replicated 5 times and the number of days to complete the development and the number of emerged adults were recorded.

The number of *P. interpunctella* adults was not affected by the presence of *C. cephalonica* or *I. inquinata*. A delay in the development was only observed when *P. interpunctella* eggs were added to the medium already colonized by the other species. *I. inquinata* was the less competitive, as the number of adults decreased and the days to complete the cycle increased. The development of *I. inquinata* was prevented if *P. interpunctella* eggs were started at the same time. Larvae of this last species cannibalized eggs of the other two species.

I. inquinata was the least competitive due to the longer cycle, the lower mobility and the aggressiveness of the larvae of the other two species that cannibalized its eggs.

KEY-WORDS: *Plodia interpunctella*, *Corcyra cephalonica*, *Idaea inquinata*, Pyralidae, Geometridae.

INTRODUCTION

Plodia interpunctella (Hübner) and *Corcyra cephalonica* (Stainton) (Lepidoptera Pyralidae) are cosmopolitan and polyphagous species. *P. interpunctella* is less demanding in relation to temperatures, as the lower threshold of egg development is 15 °C (ARBOGAST, 2007), and of pupae 13.8 °C (JOHNSON *et al*., 1995); larvae develop between 18 and 32 °C, the optimum temperature is 28 °C (SAVOV, 1973). *C. cephalonica* requires higher temperatures, the optimum temperature is at 30-32 °C, and the minimum temperature for reproduction is 20 °C (COX *et al*., 1981). *Idaea inquinata* (Scopoli) (Lepidoptera Geometridae) is present all over Europe (SKINNER, 1984; NAVES, 1995; FLAMIGNI & BASTIA, 1998; GIANTI, 2001), develops on withered plants, hay and officinal plants (dried spices, herbs, and medicinal plants), but it can also consume cereal products (CANDURA, 1931a, b; TEMPEL, 1941; KRATOCHVIL, 1948; LOCATELLI *et al.,* 2005). The trade in dried aromatic plants or vegetable packaging can favor the spread of this species in food plants and warehouses (NAVES, 1995). The optimum temperature, in a laboratory experiment on an artificial diet, is 26 °C (LIMONTA & LOCATELLI, 2013). Larvae are grey-green colored and adults are brown-yellow colored, so an infestation can be underestimated as this species is mimetic with the stored products.

These three species can develop on the same food products, and they could compete in warehouses. In the literature, papers deal with competition in natural habitats (DUDLEY *et al*., 1990; FABRE *et al*., 2004), or competition among phytophagous species (KARBAN, 1986; KAPLAN & DENNO, 2007; DEVESCOVI *et al*., 2015; EATOUGH JONES *et al*., 2015; SIGMON, 2015; NTIRI *et al*., 2016; TUEHELER *et al*., 2016). Also, competition in stored-product insects has been studied (SMITH, 1986; GIGA & CANHAO, 1993; OLLSON *et al*. 2006; CUI *et al*., 2006; SAKKA & ATHANASSIOU, 2018). In particular, ALLOTEY & KUMAR (1985) published results on competition between *C. cephalonica* and *Cadra cautella* (Walker) on cocoa beans, and *C. cephalonica* was the predominant species. In another paper *P. interpunctella* and *C. cautella* were reared on peanuts and the predominant species was *C. cautella*, as it can develop on rearing media with a high content in fat; however, with an artificial diet as a rearing medium, *P. interpunctella* was more competitive (ALLOTEY & GOSWAMI, 2002).

In this paper, we consider the intraspecific competition between *P. interpunctella* and *C. cephalonica,* two widespread species, and *I. inquinata* that can develop on the same stored foods. Experiments were carried out on an artificial diet that contains a balanced amount of nutrients, as insects perform better on this than on natural diets (SHOONHOVEN *et al.*, 2005).

The research aims to verify the hierarchy between species that can coexist on the same commodity in order to guide the choice and timing of control measures.

MATERIALS AND METHODS

REARING

Laboratory cultures of *Plodia interpunctella* (Hübner), *Corcyra cephalonica* (Stainton) and *Idaea inquinata* (Scopoli), maintained in a rearing room at 27±1 °C, 70±5% R.H. and L16:D8 photoperiod, were used for the experiments. The ingredients of the diet were 62 g bran, 8 g cornflour, 7 g wheat flour, 4 g wheat germ, 3 g dried yeast, 9 g glycerol, and 7 g honey (LIMONTA & LOCATELLI, 2013). Previous development tests proved this diet suitable for all the species studied.

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Experiments

All the experiments were carried out with eggs laid within 24 hours. The eggs were obtained by placing newly emerged adults in a glass jar closed with tulle, turned upside down on a ventilated Petri dish with filter paper.

For each species, groups of 20 eggs were placed in a Petri dish with 5 g of diet, an amount sufficient for the development of the specimen.

Two sets of experiments were carried out in order to observe the competition among the species. In the first set of experiments, 20 eggs of one species were placed in a ventilated Petri dish with 10 g of diet and 20 eggs of one of the other species, namely 20 eggs of *P. interpunctella* and 20 eggs of *C. cephalonica*; 20 eggs of *P. interpunctella* and 20 eggs of *I. inquinata*; 20 eggs of *C. cephalonica* and 20 eggs of *I. inquinata*.

In the second set of experiments, 20 eggs of one species were placed in a ventilated Petri dish with 10 g of diet and, after 7 days, 20 eggs of one of the other species were added; namely 20 eggs of *P. interpunctella* and after 7 days 20 eggs of *C. cephalonica*, 20 eggs of *P. interpunctella* and after 7 days 20 eggs of *I. inquinata*, 20 eggs of *C. cephalonica* and after 7 days 20 eggs of *P. interpunctella*, 20 eggs of *C. cephalonica* and after 7 days 20 eggs of *I. inquinata*, 20 eggs of *I. inquinata* and after 7 days 20 eggs of *P. interpunctella*, 20 eggs of *I. inquinata* and after 7 days 20 eggs of *C. cephalonica*.

Each experiment was replicated 5 times and the number of days to complete the postembryonic development, in the tables indicated as development, and the number of adults emerged was recorded daily.

Statistical analysis

Data, when normally distributed, were submitted to One-way ANOVA and LSD test (α=0.05), otherwise, the Kruskal-Wallis test and Multiple comparisons of groups were performed (IBM SPSS Statistics 24).

RESULTS

The number of *Plodia interpunctella*, *Corcyra cephalonica,* and *Idaea inquinata* adults, developed from 20 eggs of each species reared alone on the artificial diet, was 18.8±0.58, 17.4±0.75, and 16.2±1.28 respectively, and not significantly different (One-way ANOVA: $F_{2, 12}$= 2.292 P=0.144). The development time of the three species was significantly different (χ^2= 266,666 P<0.001), it was 82.8±2.16 days in *I. inquinata*, 37.9±0.31 days in *C. cephalonica*, and 22.3±0.25 days in *P. interpunctella*.

As shown in Table 1, the number of *P. interpunctella* adults was never influenced by the presence of *C. cephalonica*. On the contrary, when *P. interpunctella* eggs were started seven days before, the number of *C. cephalonica* that developed into adults decreased. Both species developed in a significantly shorter time when reared alone.

In the experiments with *I. inquinata*, the number of *P. interpunctella* adults was not significantly different (Tab. 2), only the development into an adult took longer. When the two species were started at the same time, no *I. inquinata* adults were observed. The number of adults and the development period of this species were negatively influenced by the presence of *P. interpunctella*, as the number of emerged adults was significantly lower and the development time was significantly higher.

C. cephalonica was not influenced by the presence of *I. inquinata* as regards the number of emerged adults, while the days required to develop into adults significantly increased (Tab. 3). In the presence of *C. cephalonica*, the number of *I. inquinata* adults decreased and the development days increased. However, the development days of *I. inquinata* significantly increased and decreased when *C. cephalonica* eggs were added 7 days before and after, respectively.

Table 1 – Number of emerged adults (±S.E.) and development days (±S.E.) of *Plodia interpunctella* (Hübner) (P.i.) reared alone, with *Corcyra cephalonica* (Stainton) (C.c.), and with the other species added 7 days after or before the experiment started.

Experiment	*Plodia interpunctella*		*Corcyra cephalonica*	
	Adults (±S.E.)	Development (±S.E.)	Adults (±S.E.)	Development (±S.E.)
One species	18.8±0.58	22.3±0.25c	17.4±0.75a	37.9±0.31c
P.i. + C.c.	17.8±1.02	27.9±0.17b	18.6±0.98a	40.6±0.22b
P.i. + after 7 dd C.c.	19.8±0.20	30.3±0.49a	12.2±1.88b	56.5±2.69a
C.c. + after 7 dd P.i.	16.4±2.71	30.2±0.43a	20.0±0.00a	40.0±0.39b

One-way ANOVA: *Plodia interpunctella* adults $F_{3, 16}$= 0.960 P=0.436; Development time χ^2 = 197.331 P<0.001. *Corcyra cephalonica* adults $F_{3, 16}$= 54.733 P<0.001; Development time χ^2 = 87.282 P<0.001. Values followed by different letters are significantly different (LSD test and Kruskal-Wallis test).

Table 2 – Number of emerged adults (±S.E.) and development days (±S.E.) of *Plodia interpunctella* (Hübner) (P.i.) reared alone, with *Idaea inquinata* (Scopoli) (I.i.), and with the other species added 7 days after or before the experiment started.

Experiment	*Plodia interpunctella*		*Corcyra cephalonica*	
	Adults (±S.E.)	Development (±S.E.)	Adults (±S.E.)	Development (±S.E.)
One species	18.8±0.58	22.3±0.25c	17.4±0.75a	37.9±0.31c
P.i. + C.c.	17.8±1.02	27.9±0.17b	18.6±0.98a	40.6±0.22b
P.i. + after 7 dd C.c.	19.8±0.20	30.3±0.49a	12.2±1.88b	56.5±2.69a
C.c. + after 7 dd P.i.	16.4±2.71	30.2±0.43a	20.0±0.00a	40.0±0.39b

One-way ANOVA: *Plodia interpunctella* adults $F_{3, 16}$= 0.960 P=0.436; Development time χ^2 = 197.331 P<0.001. *Corcyra cephalonica* adults $F_{3, 16}$= 54.733 P<0.001; Development time χ^2 = 87.282 P<0.001. Values followed by different letters are significantly different (LSD test and Kruskal-Wallis test).

Table 3 – Number of emerged adults (±S.E.) and development days (±S.E.) of *Corcyra cephalonica* (Stainton) (C.c.) reared alone, with *Idaea inquinata* (Scopoli) (I.i.), and with the other species added 7 days after or before the experiment started.

Test	*Corcyra cephalonica*		*Idaea inquinata*	
	Adults (±S.E.)	Development (±S.E.)	Adults (±S.E.)	Development (±S.E.)
One species	17.4±0.75	37.9±0.31c	16.2±1.28a	82.8±2.16c
C.c.+I.i.	16.4±0.87	49.4±0.35b	9.2±2.27b	124.3±4.38a
C.c.+after 7 dd I.i.	15.0±0.89	51.6±0.84a	4.8±2.22bc	99.8±4.25b
I.i.+ after7 dd C.c.	15.6±0.98	48.9±0.49b	2.8±0.49c	69.1±1.50d

One-way ANOVA: *Corcyra cephalonica* adults $F_{3, 16}$= 1.403 P=0.278; Development time χ^2=182.664 P<0.001. *Idaea inquinata* adults $F_{3, 16}$= 176.183 P<0.001; Development time χ^2=74.447 P<0.001. Values followed by different letters are significantly different (LSD test and Kruskal-Wallis test).

CONCLUSIONS

Among the species considered in this study, *Plodia interpunctella* was the most competitive. In fact, the number of individuals of this species that became adults was not influenced by the presence of *Corcyra cephalonica* or *Idaea inquinata*. Only a delay in the development was observed when *P. interpunctella* eggs were added to the medium already colonized by the other species. Also in this case, however, the development required fewer days than for the other two species. The short life cycle could be an explanation for the competitiveness of this species, as observed in soybeans in Hemiptera Heteroptera *Euschistus heros* (F.), that presents a higher number of generations per year and was more competitive than *Piezodorus guildinii* (Westwood) (Tuehler *et al.*, 2016).

C. cephalonica was not influenced by the presence of *P. interpunctella*, whether the eggs of the other species were started at the same time or added seven days after. However, the number of *C. cephalonica* adults decreased and the days required to complete the development increased if the eggs of *P. interpunctella* were put in the rearing medium seven days before. In this case, the lower number of *C. cephalonica* adults can be explained by *P. interpunctella* larvae that cannibalize eggs (White & Huffaker, 1969, in Allotey & Goswami, 1992). In another study, it was observed that larvae of *T. castaneum* (Coleoptera) cannibalized eggs of *C. cephalonica* (Nagalakshmi & Balaji, 1999). The number of *C. cephalonica* adults was not affected by *I. inquinata*. In this case, *C. cephalonica* was the most competitive species, as was observed also in experiments with *Cadra cautella* (Allotey, 1986).

I. inquinata is the least competitive species, as it was affected by the presence of both *C. cephalonica* and *P. interpunctella*. In fact, the number of adults decreased and the number of days to adult emergence increased. Actually, *I. inquinata* development was prevented when eggs of *P. interpunctella* were started contemporaneously. In this case, it was observed that larvae of *P. interpunctella* cannibalized eggs of *I. inquinata*, even if the food was abundant.

I. inquinata development is slow and this characteristic makes it less competitive (Allotey, 1986). Usually, a higher number of generations per year is considered a favored biology (Tuehler *et al.*, 2016). Krijger *et al.* (2001) observed in *Drosophila* "species with a longer development time suffer more from interspecific competition".

I. inquinata is less competitive compared to the other pest species also due to the adults' lower mobility (Authors' observation). In addition, *C. cephalonica* and *P. interpunctella* larvae weave a silk thread that incorporates food and makes food accession for *I. inquinata* larvae more difficult.

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