THE EFFECTS OF COMPETITION BETWEEN LARVAE OF STORED-PRODUCT MOTHS

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 (arboagast, 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 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 (karlan, 1986; Kaplan & Denno, 2007; devescovi et al., 2015; eautical Jones et al., 2015; sigmon, 2015; ntib et al., 2016; tuheler et al., 2016). Also, competition in stored-product insects has been studied (smith, 1986; gia & canhao, 1993; ollson et al., 2006; cui et al., 2006; sakka & athanassou, 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 (shoownoven 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 the first species studied.

Key-words: *Plodia interpunctella*, *Corcyra cephalonica*, *Idaea inquinata*, Pyralidae, Geometridae.
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 *I. inquinata*; 20 eggs of *C. cephalonica* and after 7 days 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: F2,17=2.292 P=0.144). The development time of the three species was significantly different (χ²= 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.

*Corcyra 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.

| Experiment | Plodia interpunctella | Corexyra cephalonica |
|------------|-----------------------|----------------------|
| One species | 18.8±0.58 | 22±0.25 | 17.4±0.75a | 37.9±0.31c |
| Pi. + C.c. | 17.8±1.02 | 27.9±0.17b | 18.6±0.98a | 40.6±0.22b |
| Pi. + 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 Pi. | 16.4±2.71 | 30.2±0.43a | 20.0±0.00a | 40.0±0.39b |

One-way ANOVA: *P. interpunctella* adults F3, 16=0.960 P=0.436; Development time χ²= 197.331 P<0.001. *C. cephalonica* adults F3, 16= 74.733 P<0.001; Development time χ²= 197.331 P<0.001. Values followed by different letters are significantly different (LSD 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     | 68.2±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        |
| One-way ANOVA:           |                       |                 |               |                   |
| Corcyra cephalonica      |                       |                 |               |                   |
| Adults F3, 16=            | 1=403 P<0.027 ;     | 176.183 P>0.001 ; | 74.447 P<0.001 |                       |
| Development time χ²=74.447|                   |                 |               |                   |
| Adults F3, 16=            |                     |                 |               |                   |
| Development time χ²=       |                       |                 |               |                   |

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 Pseudaletes guildini (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 (WHITI & 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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