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Biological control of *Sitophilus oryzae* (Coleoptera: Curculionidae) in rice and combined effects with a polishing process

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Abstract: In order to study alternative control methods of the rice weevil *Sitophilus oryzae*, the effect of rice polishing process and parasitism by *Anisopteromalus calandrae* and *Lariophagus distinguendus* were evaluated. Mechanical treatment (polishing process), parasitoid inoculation and combined treatments were carried out in the laboratory for nine weeks. All treatments reduced significantly *S. oryzae* abundance (>55%). The polishing process, associated to a rice weight loss of 11%, reduced the weevil population by 85%. Optimal control (>90%) was achieved by the combined use of polishing process and parasitoid release. Development of *S. oryzae* and parasitoids were one week delayed in polished rice compared with brown rice. Parasitoid progeny was ten times higher in brown rice compared with polished rice. Future research is needed to confirm the potential of each parasitoid species.

Key words: *Sitophilus oryzae*, *Anisopteromalus calandrae*, *Lariophagus distinguendus*, rice, biological control

Introduction

Sitophilus oryzae (L.) (Coleoptera: Curculionidae) is a major pest of stored grain, and in Catalunya is the most important in rice and wheat. The female feeds on rice and lays eggs inside the grain kernel in a small hole covered with a gelatinous excretion near the grain surface (aprox. 90 micrometers deep, Estallé & Riudavets 1999). Larval and pupal development takes place inside the grain. Nowadays, fumigation with methyl bromide is the most commonly used method of controlling this species. Because of methyl bromide toxicity and ozone depletion, it is scheduled to be phased out in a few years. With the purpose of looking for alternatives to this fumigant, several biological and physical methodologies of insect control are currently studied (IWCSPP, 1998).

Biological control measures have not been developed since methyl bromide is effective and widely used. Among natural enemies, *Anisopteromalus calandrae* (Howard) and *Lariophagus distinguendus* (Förster) (Hymenoptera: Pteromalidae) are very abundant parasitoids found in our area. Both are ectoparasitic wasps parasitizing larvae of several weevil species and their potential for controlling *S. zeamais* Motschulsky and *S. oryzae* has already been demonstrated (Arbogast & Mullen, 1990; Wen *et al.*, 1994; Ryoo *et al.*, 1996; Li Zhaohui *et al.*, 1998).

The polishing process consists of rubbing grain kernels in order to remove their external layers. Then, brown rice becomes whitened. However, this process produces a quantitative and qualitative grain loss. Apart from commercial aspects, the polishing process produces a high reduction in *S. oryzae* populations due to a mechanical effect on eggs and larvae. Even if mechanical abrasion during the industrial process results in up to 98% mortality (Lucas &

Riudavets, in prep.), remaining contaminations are still above the zero-tolerance expected by consumers.

The objective of this study was to evaluate the compatibility of biological control of *S. oryzae* by these two parasitoid species and the conventional polishing process.

Materials and methods

Insects were originally collected from storage areas around Barcelona. *S.oryzae* was reared on polished rice since 1997. Both *A. calandrae* and *L. distinguendus* were collected from samples of infested rye. Parasitoid species and sexes were determined by using specimens identified by the International Institute of Entomology, CAB International, London, UK.

The experiment was conducted in a climatic chamber at 25 ± 1°C, 70 ± 10% RH, and a photoperiod of 16:8 (L:D) h. The experimental arena were ventilated 0.5-liter glass jars containing 83 g of brown rice (cv. Senia & Bahia). *S. oryzae* adults (aprox 120) were added and allowed to oviposit for 7 days. Adult weevils were removed with a sieve with a mesh wide of 2.0 mm. Four treatments were carried out: Control (n=15), Mechanical (n=15), Parasitoid (n=25) and Combined (n=25). In Mechanical and Combined treatments, rice was polished for one min using a laboratory polisher (A. Guid'etti, Universal Brevetto 65378). In Parasitoids and Combined treatments, ten adult parasitoids (females and males of *A. calandrae* and *L. distinguendus*) were introduced one week later. All adult parasitoids were removed and identified after 7 days. Species composition in both treatments was approx 51% females and 23% males of *A. calandrae* and 11% females and 15% males of *L. distinguendus*. Emerging parasitoid progeny and weevils were counted and removed weekly over a six-week period.

Weevil progeny and parasitoid progeny were compared in the different treatments using a one-way analysis of variance (ANOVA) and post-hoc Tukey tests. When required, data were log-transformed. Pearson correlations between initial number of released females and corresponding progeny were performed in Combined and Parasitoid treatments.

Results and discussion

Abundance of *S. oryzae* was significantly reduced in Parasitoid, Mechanical and Combined treatments (df=3, F=116.22, P<0,0001) (Figure 1). The mechanical process of polishing rice reduced *S. oryzae* descendants by 86%. Rice weight loss was approximately 11%, value a little smaller than that obtained during standard industrial process. Since eggs of *S. oryzae* are laid near the grain surface, weevil mortality should be higher as the degree of polishing increases. Biological control with both parasitoids reduced *S. oryzae* descendants by 57%. The most efficient treatment (reduction greater than 90%) was the combination of both biological control and polishing process. The estimated reduction of *S. oryzae* density due to parasitoids in the Combined treatment (comparing Mechanical and Combined treatments) was about 48%.

As shown in Figure 2, adult emergence of *S. oryzae* started by week 5. Maximum emergence in brown rice (Control and Parasitoid treatments) was observed by week 6, with a steady decrease from this week onwards. In comparison, a delay of weevil development was observed in polished rice (Mechanical and Combined treatments) and adult emergence per week never exceeded more than 35% of the total progeny. Therefore, there is an important effect of the polishing process on *S. oryzae* development. Damaged kernels and pericarp removal were identified as factors affecting insect oviposition, kernel localisation, survival, developmental time and fecundity (McGaughey, 1970; Singh, 1981; Ryoo & Cho, 1992; Haryadi & Fleurat-Lessard, 1994; Trematerra *et al.*, 1999).

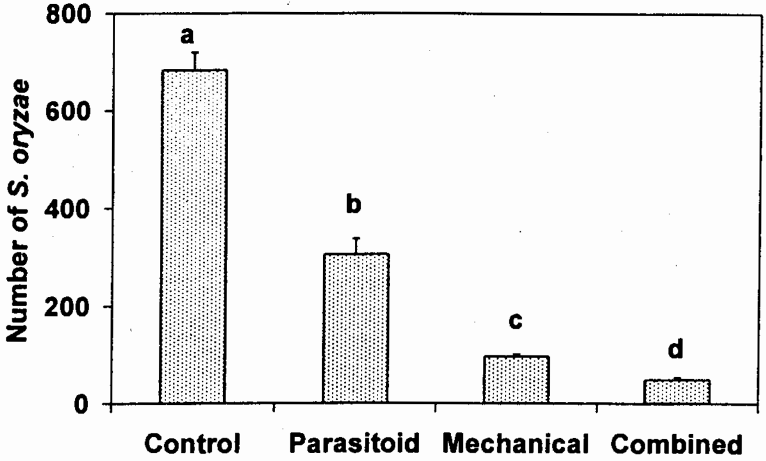

Figure 1: Total number of emerged adults of *S. oryzae* collected during nine weeks in each treatment. Different letters indicate significant differences (*P*<0.5, Tukey test).

Two parasitoid generations occured during the nine weeks of the experiment, with an approximate developmental time of three weeks (Figure 3). As previously observed in the case of *S. oryzae*, parasitoid developmental time was delayed in polished rice. Parasitoid emergence started during the 5th week in brown rice and during the 6th week in polished rice. The developmental period of *L. distinguendus* on *S. oryzae* is 20 days at 25°C (Ryo *et al.*, 1991), and for *A. calandrae* on *S. zeamais* Motschulsky 17 days (Smith 1992). Progeny density was ten times as high in brown rice (Parasitoid treatment) as in polished rice (Combined treatment) (df=1, *F*=89.527, *P*<0.0001), although the initial number of parasitoid females was similar in both Parasitoid and Combined treatments. Moreover, a significant correlation was observed between the initial number of females and its descendants in brown rice (Parasitoid treatment) (r^2=0.60, *P*<0.0001), but not in polished rice (Combined treatment) (r^2=0.06, *P*=0.2295). Three main factors may explain the differential success of the parasitoids. Firstly, host (weevil) density was greater in brown rice than in white rice due to polishing process. Secondly, as previously stated, weevil development was delayed by the grain type. Then, as the parasitoids demonstrated a significant preference for the 4th instar larval stages (Smith, 1993; Ryoo *et al.*, 1996) their synchronisation with host should also be indirectly affected. Thirdly, *S. oryzae* females, after ovipositing inside a rice kernel, lay a chemical shield on the grain surface (Arbogast 1991) and this shield could be implicated in host-identification by parasitoids. Then, by damaging or destroying this shield, the polishing process could affect the host-localisation by parasitoids.

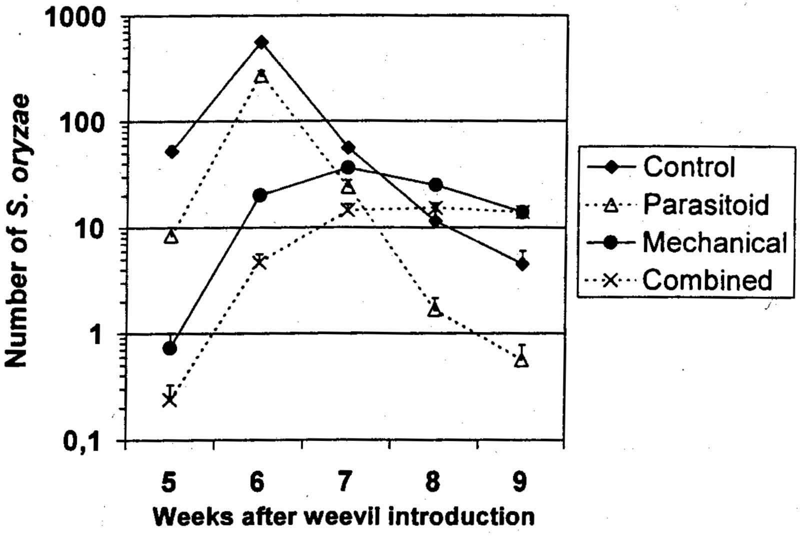

Figure 2: Number of emerged adults of *S. oryzae* collected weekly in each treatment.

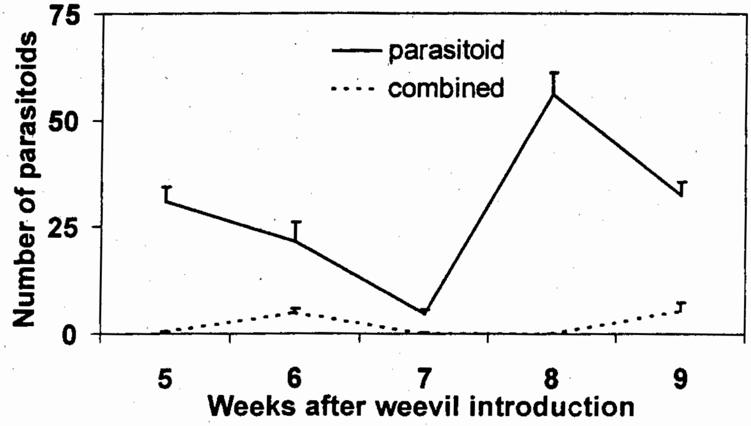

Figure 3: Number of emerged adult parasitoids collected weekly in the Parasitoid and Combined treatments.

These preliminary results clearly demonstrated the potential of *A. calandrae* and *L. distinguendus* for the biological control of *S. oryzae* before and after the polishing process. Further studies should evaluate the efficacy of each parasitoid species, and both the impact of different degrees of polishing on *S. oryzae* and the corresponding economical loss.

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