Biological control of *Sitophilus zeamais* (L.) (Coleoptera: Curculionidae) in bagged maize with *Lariophagus distinguendus* (FÖRSTER) (Hymenoptera: Pteromalidae) and *Corcyra cephalonica* (STAINTON) (Lepidoptera: Pyralidae) in rice with *Habrobracon hebetor* (SAY) (Hymenoptera: Braconidae)

Charles Adarkwah[1,3], Carmen Büttner[1], Sabine Prozell[2], Christoph Reichmuth[3], Daniel Obeng-Ofori[4] & Matthias Schöller[2]

[1] **Humboldt-Universität zu Berlin, Landwirtschaftlich-Gärtnerische Fakultät, Institut für Gartenbauwissenschaften, Fachgebiet Phytomedizin, Berlin, Germany**
[2] **Biologische Beratung Ltd., Berlin, Germany**
[3] **Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Vorratsschutz Berlin, Germany**
[4] **Department of Crop Science, School of Agriculture, College of Agriculture and Consumer Sciences, University of Ghana, Legon, Accra, Ghana**

Zusammenfassung: Biologische Bekämpfung des Maiskäfers *Sitophilus zeamais* (L.) (Coleoptera: Curculionidae) in Mais mit der Lagererzwespe *Lariophagus distinguendus* (FÖRSTER) (Hymenoptera: Pteromalidae) sowie der Reismotte *Corcyra cephalonica* (STAINTON) (Lepidoptera: Pyralidae) in Reis mit der Mehlmottenschlupfwespe *Habrobracon hebetor* (SAY) (Hymenoptera: Braconidae).

Wenn Vorratsschädlinge gefüllte Säcke befallen ist eine Bekämpfung mit Hilfe durchgreifender Methoden wie z.B. Begasung oder der Einsatz von Kälte möglich. Die Anwendung dieser Verfahren ist aber technisch nicht immer realisierbar. Verschiedene parasitoide Hymenopteren werden zur biologischen Bekämpfung von Vorratsschädlingen eingesetzt. Diese Wespen dringen in der Regel nicht in Verpackungen ein. Säcke aus Jute besitzen jedoch eine Maschenweite, die das Eindringen von Nützlingen erlauben könnte. Um die Möglichkeit des Nützlingseinsatzes in Sacklägern zu prüfen, wurden folgende Untersuchungen durchgeführt: (1) Wirtsfindung von *Habrobracon hebetor* in gesacktem Langkornreis (5 kg-Säcke, Raupen von *Corcyra cephalonica* 4 cm tief im Reis) (2) Wirtsfindung von *Lariophagus distinguendus* in gesacktem Mais (5 kg-Säcke, Befall durch *Sitophilus zeamais*). Es wurde täglich auf eindringende *L. distinguendus* bzw. *H. hebetor* hin kontrolliert. Der tägliche Schlupf der Nachkommen der Wespen wurde dokumentiert. *H. hebetor* war nur zu einem sehr geringen Anteil in der Lage, in die Säcke einzudringen. 50% der eingesetzten *L. distinguendus* drangen in die Jutesäcke ein und verringerten den Populationsaufbau der Maiskäfer. Begleitende Untersuchungen in unverpacktem, geschüttetem Reis ergaben, dass *H. hebetor* mindestens 14 cm tief eindringt und Reismottenraupen parasitiert.

Key words: biological control, stored product protection, stored grain, Africa

C. Adarkwah, Ch. Reichmuth, Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Vorratsschutz, Königin-Luise-Straße 19, 14195 Berlin; Germany, lesadark@yahoo.com, c.reichmuth@bba.de;

C. Büttner, Humboldt-Universität zu Berlin, Landwirtschaftlich-Gärtnerische Fakultät, Institut für Gartenbauwissenschaften, Fachgebiet Phytomedizin, Lentzeallee 55/57 14195 Berlin-Dahlem, Germany, carmen.buettner@agrar.hu-berlin.de;

S. Prozell, M. Schöller, Biologische Beratung Ltd., Hosemannstr. 8, 10409 Berlin, bip@biologische-beratung.de;

D. Obeng- Ofori, University of Ghana, College of Agriculture and Consumer Sciences, School of Agriculture, P.O. Box LG 68, Legon, Accra, Ghana, dobeng@ug.edu.gh.

Introduction

Maize and rice constitute some of the most important cereals cultivated in the world, being used as staple food for people especially in Africa. The rice moth, *Corcyra cephalonica*, and the maize weevil, *Sitophilus zeamais*, are major pests of stored grains in the tropics. The use of parasitoids in biological pest control is already common in different agricultural and horticultural fields. At present, grain managers tend to look at alternatives to chemicals to control insects in stored grain. *Lariophagus distinguendus* (Förster) is a synovigenic, solitary larval and pupal ectoparasitoid of several beetle species that infest stored goods. The ability for long-range host finding of this parasitoid mediated by volatiles has been shown (Steidle & Schöller 1997). *Habrobracon hebetor* (Say) is a gregarious ectoparasitoid of many lepidopterous pests. This wasp occurs naturally in the stored grain ecosystem (Keever & al. 1985) where it attacks several pyralid moths, including the rice moth, *Corcyra cephalonica*. The present study was conducted to assess the host finding of the two parasitoids *H. hebetor* and *L. distinguendus.*

Materials and methods

Insect culture

All insect cultures were kept at 65±5% relative humidity, a constant temperature of 25°C and a photoperiod of 16h : 8h (L : D). For all experiments, rice or maize grains were used. Strains of *S. zeamais* and *C. cephalonica* were taken from the permanent rearings of the Institute for Stored Product Protection. Parasitoids were obtained from the company Biologische Beratung Ltd. Maize weevils were reared by placing 10 ml of unsexed adults in glass jars of 250 ml, filled with 150 g of maize grain that was previously cleaned and with a moisture content of 12.5%. Adult weevils were removed after 14 d. This process continued every 7 days to generate known-aged insects for the experiments. To rear *L. distinguendus*, about 50 newly emerged parasitoids were placed in 1 l glass jars filled with 150 g of infested maize kernels. These wasps were kept in the growth cabinet until their death after about 8–14 d to enable mating and oviposition. After 20 d, emerged parasitoids from the next generation were collected and used for the experiments. Rice moths were cultured in 1 l glass jars filled with 150 g of organic rice with a moisture content of 14% that was previously cleaned. Five percent organic rice germs were added and the glasses then placed on a mechanical roller to mix the content of the glasses properly. Two hundred and fifty *C. cephalonica* eggs were added to each glass. After 3-4 weeks, *C. cephalonica* larvae were used to culture *H. hebetor* in Petri-dishes measuring 1.6 cm in height and a diameter of 9 cm. The parasitoids were provided with drop of honey.

Bioassays

In the experiment on host finding by *H. hebetor* a five kg jute bag filled with organic rice grains containing larvae of *C. cephalonica* were placed in an empty room of an area of 12.3 m^2. Sixty *H. hebetor* adults (sex ratio of 1 male: 2 females) were released at a distance of 1.6 m away from the jute bag. The number of *H. hebetor* adults that entered through the jute bag were counted by opening the bag daily for 8 days.

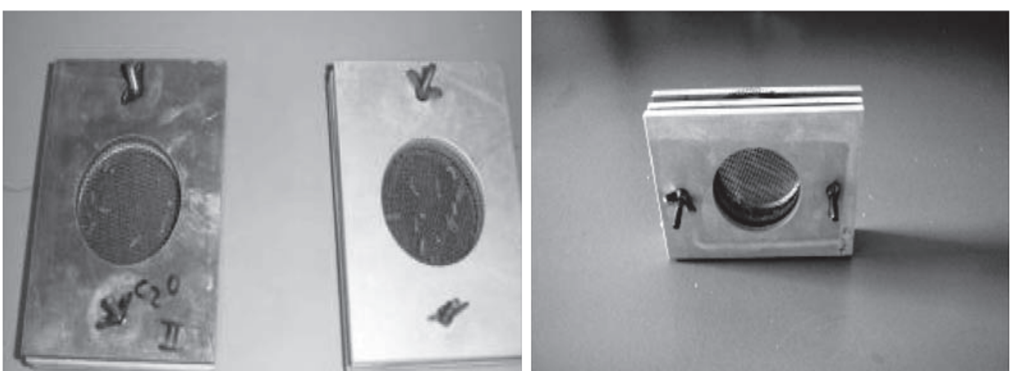

Fig. 1: Wire gauze cage (9 cm x 12 cm, opening 5 cm) containing 60 larvae of *C. cephalonica*, used in trials on host-finding of *Habrobracon hebetor*.

In a second experiment, 60 *C. cephalonica* larvae were placed inside wire gauze cages (Fig. 1), which were immersed 4 cm deep into the jute bags. Sixty *H. hebetor* adults were released into the jute bag which was afterwards closed. After one week the cages were removed from the bags, the content placed in glass jars and kept in a climatic chamber. The emergence and number of F_1 of *H. hebetor* was counted. The same procedure was repeated by the use of a 1 m-glass cylinder instead of jute bags, filled with organic rice, with *C. cephalonica* larvae exposed at depths of 7 cm and 14 cm, respectively for 23 days. In this trial, *H. hebetor* adults were released on top of the rice column.

Using the same experimental set-up as described for *H. hebetor*, host finding of *L. distinguendus* was investigated. The five kg jute bags contained three-week old *S. zeamais* larvae within infested maize kernels. Sixty *L. distinguendus* adults aged 0-14 days, sex-ratio 1 male : 2 females, were released. The number of *L. distinguendus* which entered the jute bag was recorded daily by opening the bag and sieving the maize grains. Sex ratio of entered wasps was determined by freezing them and studying the characters provided by ANASTASIOU (2003) with the help of a stereo-microscope (AHAH 475052-9901, manufactured by Zeiss).

Results and discussion

A total of two out of 60 adult H. hebetor released in a climatised room 1.6 m apart from the jute bag only entered the jute bag. The long-range host finding of *H. hebetor* was found to be effective (e.g. PAUST & al. 2006), but the mesh-width obviously prevents penetration. If the *H. hebetor* adults were inserted into the jute bag, they were capable to find the host larvae between the rice kernels (Fig. 2). To quantify the distance travelled by the parasitoids between the rice kernels more precisely, experiments were conducted in a glass cylinder. Both in 7 cm and 14 cm depth, respectively, larvae were parasitized (Fig. 3). The higher number of progeny produced from hosts located in 7 cm depth compared to 14 cm depth suggests a decrease in the number of females reaching 14 cm, or less time left for parasitism before the death of the females.

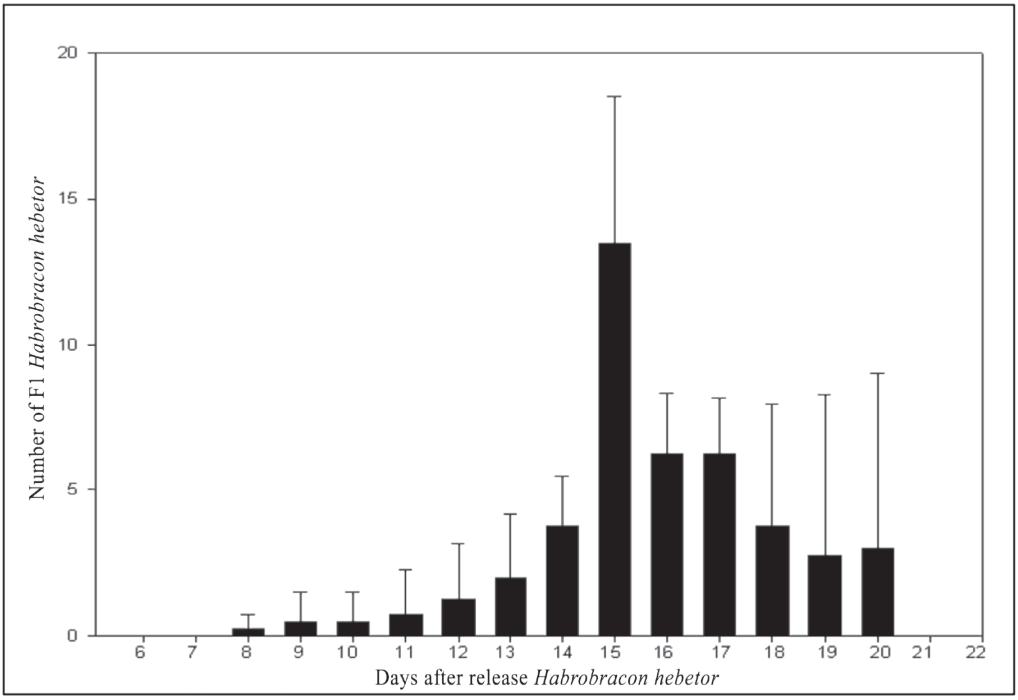

Fig. 2: Mean number and SD *Habrobracon hebetor* F_1 after release of 60 parental *H. hebetor* adults into a 5 kg jute bag with organic rice infested by *Corcyra cephalonica*, n=4.

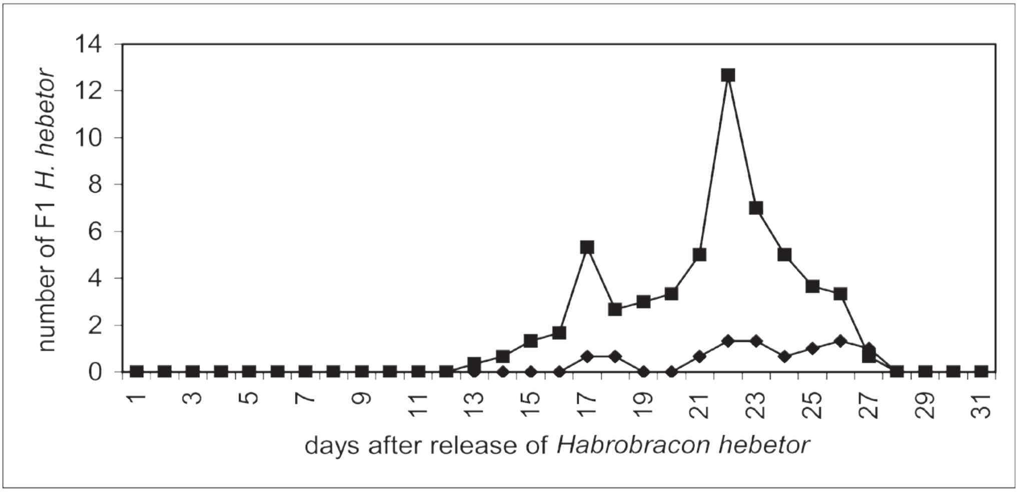

Fig.3. Mean number Habrobracon hebetor F1 after release of 60 parental H. hebetor adults into a glass cylinder with uninfested organic rice and wire gauze cages (see Fig. 1) immersed 7 cm (square) and 14 cm (rhomb) deep, respectively, at the bottom of the cylinder; n=3.

More than 50% of the adult *L. distinguendus* released entered the jute bag (Fig. 4). The high number *L. distinguendus* could be explained by the minor size of these parasitoids, allowing it to penetrate the jute bag, and a good long-range host finding. Faecal volatiles of the host *S. zeamais* are known to be attractive to *L. distinguendus* females (STEIDLE & al. 2001).

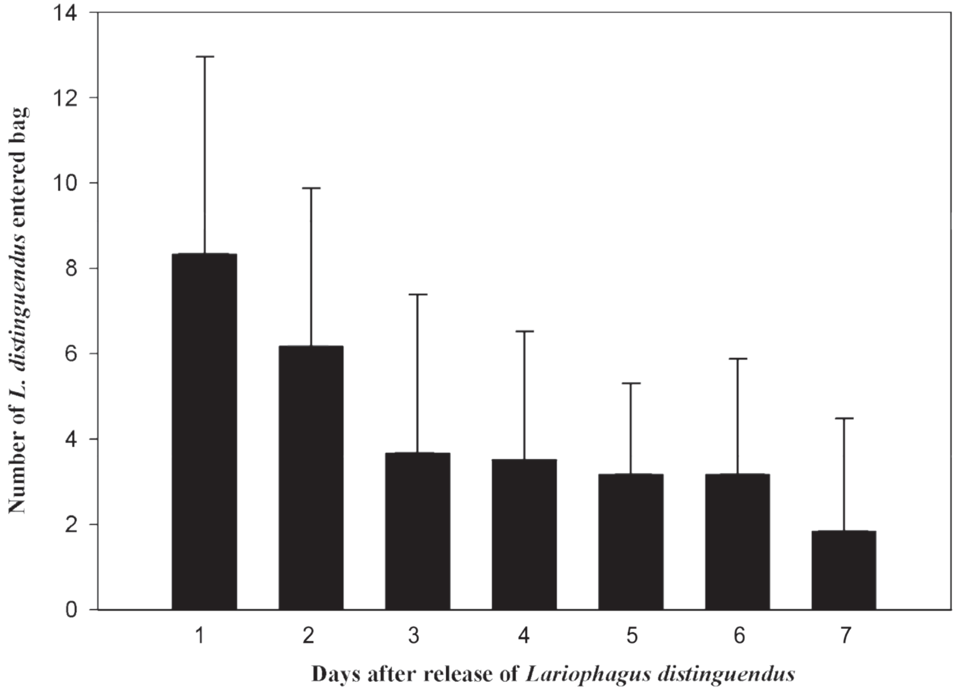

Fig.4. Mean number and SD *Lariophagus distinguendus* adults penetrating a jute bag containing 5 kg maize infested with *S. zeamais* depending on time, n=3.

More female *L. distinguendus* entered the bag per day compared to males (Fig. 5). The females are thought to be attracted by faecal volatiles into the bags, the reason for the penetration by males remain unclear. May be they were attracted by the females, since a female sex-pheromone is known to exist in *L. distinguendus* (Ruther, 2000).

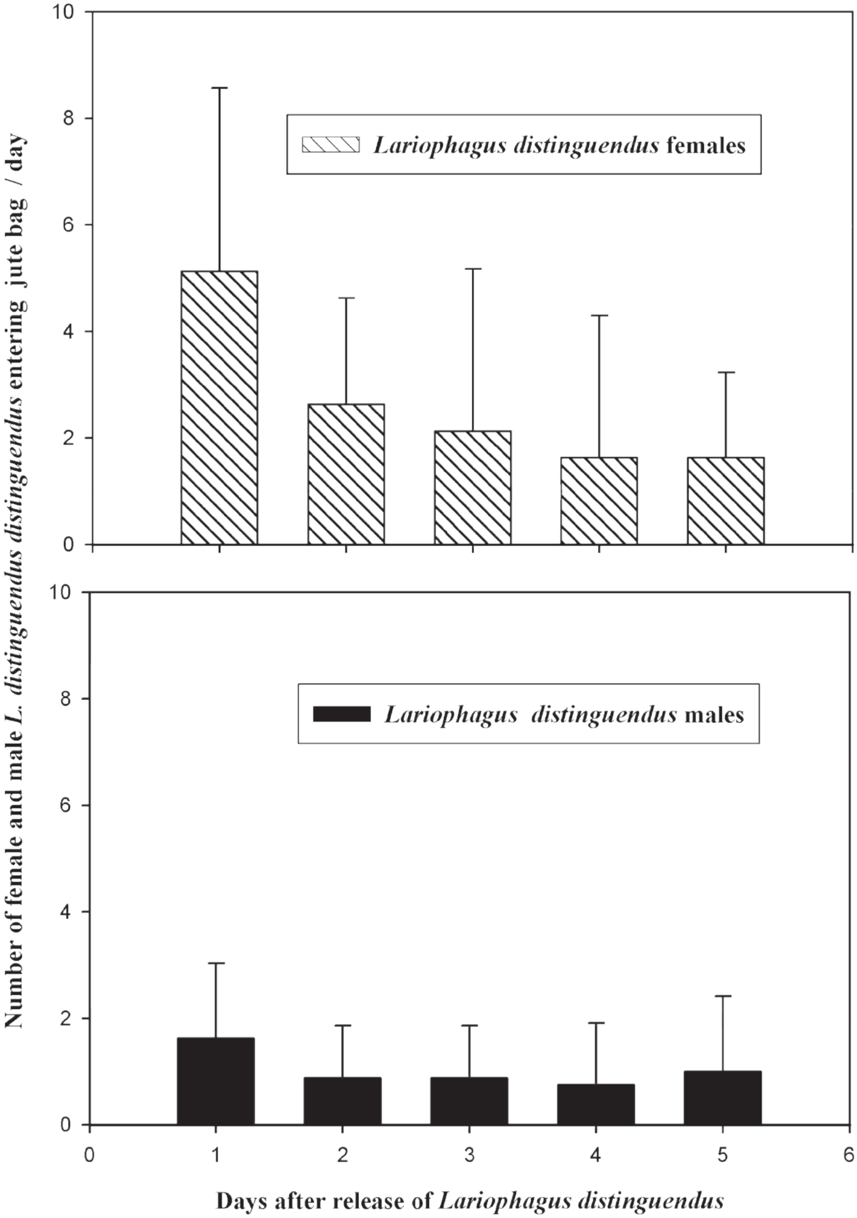

Fig. 5. Mean number and SD of female (top) and male (bottom) *Lariophagus distinguendus* penetrating a jute bag containing 5 kg maize infested with *S. zeamais* depending on time, n=3.

Grains are often stored in huge storage facilities, but also in jute bags, especially in Africa. Therefore, parasitoids suitable for biological control of stored-products pests should be able to find their hosts in a jute bag over a large distance in an empty room containing bag stacks, and as well at considerable depths within the bags. Most studies have so far focused on bulk storage (e. g. SCHÖLLER & al. 1996, CORTESERO & al. 1997, HANSEN & STEENBERG 2007). Only one study was conducted previously addressing bag storage, examining the pteromalid larval parasitoids *Anisopteromalus calandrae* (Howard) (PRESS & MULLEN 1992), showing that established, heavy infestations cannot be controlled by the parasitoids released into the empty room. In this study, we showed the failing of *H. hebetor* and the ability of *L. distinguendus* to penetrate and locate hosts in a jute bag. The results suggest a potential application of *L. distinguendus* in storage rooms with products stored in jute bags, and the introduction of *H. hebetor* into bags for control of stored product moths. Further conditions for biological control using these strategies will be evaluated.

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