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Ability of the larval ectoparasitoid *Habrobracon hebetor* (Say, 1836) (Hymenoptera: Braconidae) to locate the rice moth *Corcyra cephalonica* (Stainton, 1865) (Lepidoptera: Pyralidae) in bagged and bulk stored rice

Wirtsfindung des Larvalparasitoiden *Habrobracon hebetor* (Say, 1836) (Hymenoptera: Braconidae) in gesacktem und geschüttetem Reis gegenüber der Reismotte *Corcyra cephalonica* (Stainton, 1865) (Lepidoptera: Pyralidae)

C. Adarkwah[1,2,*], C. Büttner[1], C. Reichmuth[2,*], D. Obeng-Ofori[3], S. Prozell[4] & M. Schöller[2]

[1] Humboldt University of Berlin, Institute for Horticultural Sciences, Section Phytomedicine, Berlin, Germany

[2] Federal Research Centre for Cultivated Plants – Julius Kühn-Institut, Institute for Ecological Chemistry, Plant Analysis and Stored Product Protection, Berlin, Germany

[3] University of Ghana, Department of Crop Science, School of Agriculture, College of Agriculture and Consumer Sciences, Legon, Ghana

[4] Biological Consultants Ltd., Berlin, Germany

[*] Corresponding authors, e-mail christoph.reichmuth@jki.bund.de, adarkwac@cms.hu-berlin.de, lesadark@yahoo.com

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Abstract

The potential of using *Habrobracon hebetor* for the inundative biological control of *Corcyra cephalonica* in rice stored in jute bags and in bulk was assessed. Host-finding in the situation of bag storage was tested by preparing small jute bags measuring 18 × 16 cm filled with 5 kg of un-infested rice grains. In the first experiment, 60 larvae of *C. cephalonica* were released into the bag. The bag was placed in an empty climatized room with an area of 12.3 m². 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 the jute bag was counted daily for 8 days by opening the bag and counting the parasitoids. Only 3% of the parasitoids entered the jute bag. In a second experiment, 60 *C. cephalonica* larvae were placed inside a wire gauze cage within the jute bag. Ten *H. hebetor* adults were released into the jute bag. The bag was sealed. After 1 week the cage was removed, and the number of *C. cephalonica* as well as F_1 generation of *H. hebetor* that emerged was recorded. *H. hebetor* was able to significantly reduce the number of *C. cephalonica* emerging from the bagged rice; the corrected mortality due to the parasitoid release was 92.13%. The emergence of *H. hebetor* progeny started on day 9 after the introduction of the parasitoids and continued until day 21.

Host-finding in the situation of bulk rice was tested in glass cylinders (50 cm height, Ø = 25 cm) containing caged larvae at horizontal depths of 7 and 14 cm. *H. hebetor* was able to find its host *C. cephalonica* in both depths; significantly more F1 *H. hebetor* adults emerged from hosts placed 7 cm deep. The implications of these results with respect to the suitability of *H. hebetor* for the biological control of *C. cephalonica* in bagged and bulk rice are discussed.

Key words: horizontal depth, host finding, jute bags, stored product pests

Zusammenfassung

Das Potential der Mehlmottenschlupfwespe *Habrobracon hebetor* für die inundative biologische Bekämpfung der Reismotte *Corcyra cephalonica* in Reis gelagert in Jutesäcken oder geschüttet wurde untersucht. Die Wirtsfindung bei Sacklagerung wurde mit Hilfe kleiner Jutesäcke mit den Maßen 18 × 16 cm getestet, die mit 5 kg unbefallenem Reis gefüllt wurden. In einem ersten Experiment wurden sechzig Reismottenlarven in den Sack entlassen. Der Sack wurde in einen leeren Klimaraum mit einer Grundfläche von 12,3 m² gelagert. Sechzig Imagines von *H. hebetor* (Geschlechterverhältnis ein Männchen zu zwei Weibchen) wurden in 1.6 m Entfernung des Sacks freigelassen. Die Anzahl *H. hebetor* in den Säcken wurde über 8 Tage täglich gezählt, indem die Säcke geöffnet wurden. Nur 3% der Parasitoide drangen in den Jutesack ein. In einem zweiten Experiment wurden 60 Larven von *C. cephalonica* gekäfigt und im Innern des Jutesacks deponiert. Zehn Imagines von *H. hebetor* wurden in den Sack entlassen, welcher daraufhin verschlossen wurde. Nach 1 Woche wurde der Käfig entnommen und die Anzahl geschlüpfter *C. cephalonica* und F1 *H. hebetor* gezählt. *H. hebetor* reduzierte signifikant die Anzahl von *C. cephalonica*; die korrigierte Mortalität betrug 92.13%. Der Schlupf der Nachkommen von *H. hebetor* begann am 9. Tag nach Freilassung und hielt bis zum 21. Tag an. Die Wirtsfindung in geschüttetem Reis wurde in Glaszylindern (Höhe 50 cm, Ø = 25 cm) getestet, in denen in 7 and 14 cm Tiefe gekäfigte Reismottenlarven eingebracht wurden. *H. hebetor* konnte die Wirte in beiden Tiefen erreichen; signifikant mehr F_1 *H. hebetor* schlüpften von Wirten in 7 cm Tiefe. Die Bedeutung der Ergebnisse für die Eignung von *H. hebetor* für die biologische Bekämpfung der Reismotte in geschüttetem und gesacktem Reis wird diskutiert.

Stichwörter: Eindringtiefe, Jutesäcke, Nachkommen, Vorratschädlinge, Wirtsfindung

1 Introduction

Rice is the most important food in many countries, especially in the tropics (FAO 2004). The rice moth *Corcyra cephalonica* (Stainton, 1865) is one of the most serious pests of durable stored produce throughout the world. Besides, the pest infests all types of produce from plant origin including maize, wheat, cocoa beans, dried fruits, nuts and cereal products (Haines 1992).

The use of natural enemies such as parasitoids and biopesticides for the control of stored-product pests has been considered for many years (Hase 1925; Ryabov 1926), but insecticides are still the primary tool for controlling pests in stored goods worldwide. A major change is expected within the next few years, however, as a result of the global phase-out of widely used fumigants such methyl bromide. Biological control using natural enemies is receiving greater attention as an environmentally friendly management option for stored product protection (Schöller et al. 2006).

Habrobracon hebetor (Say, 1836) is a gregarious larval ectoparasitoid of several species of pyralids attacking stored grains (Hase 1925). It naturally occurs mostly in bulk storage facilities where large numbers of moths are present to provide the wasp with ample food and breeding sources (Keever et al.

1985; ANTOLIN and STRAND 1992). Its two major hosts are *Plodia interpunctella* (Hübner, 1813) and *Ephestia* spp.-larvae which are gregarious feeders on grains, nuts and dried fruits (ULLYETT 1945; HAGSTRUM and SMITTLE 1978). It was also reported from *C. cephalonica* (NIKAM and PAWAR 1993), but aspects of augmentative biological control were not studied yet for this parasitoid-host system. The response of *H. hebetor* to high density populations of hosts, its high reproductive rate and short generation render it a good candidate as biological control agent for the control of stored product moths in warehouses (HAGSTRUM and SMITTLE 1978). This study sought to assess the host finding of *H. hebetor* towards the rice moth *C. cephalonica* in rice stored in jute bags and bulk.

2 Materials and methods

2.1 *Culturing of insects*

C. cephalonica and *H. hebetor* were reared in the laboratory maintained at 65 ± 5% relative humidity, a constant temperature of 25°C and a photoperiod of 16 h: 8 h (L: D). Strains of *C. cephalonica* were taken from the permanent stock culture of the Department for Stored Product Protection, Federal Research Centre for Cultivated Plants – Julius Kühn-Institut, Institute for Ecological Chemistry, Plant Analysis and Stored Product Protection, Berlin, Germany. The parasitoid, *H. hebetor* was obtained from the German producer of beneficials, Biologische Beratung Ltd., Berlin.

C. cephalonica was cultured in 1 l glass jars filled with 150 g of organic rice grain with a moisture content of 14%. Five percent organic rice germs were added and the jars were placed on a mechanical roller to mix the content properly. Two-hundred and fifty *C. cephalonica* eggs were added to each jar and were kept at the culturing room. After 3-4 weeks, *C. cephalonica* eggs developed into larvae, which were then used to culture the wasps *H. hebetor* in Petri dishes measuring 1.6 cm diameter × 5 cm height. A drop of honey was added to the Petri dish to feed *H. hebetor*.

2.2 *Host finding by* H. hebetor *in bagged rice*

In the first experiment, a small jute bag measuring 18 × 16 cm filled with 5 kg organic rice grains containing sixty larvae of *C. cephalonica* was placed in an empty climatized room with 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 the jute bag was counted daily for 8 days by opening the bag and counting the parasitoids.

In a second experiment, 60 *C. cephalonica* larvae were placed inside a wire gauze cage (Fig. 1a, b) which was immersed 4 cm deep into un-infested rice kernels within the jute bag. Ten *H. hebetor* adults aged 2 days old were released into the jute bag for 12 days. The bag was sealed and kept in the empty climatized chamber on wooden pallet. After the 12 days exposure period the cage was removed from the bag, the content placed in a 250 ml glass jar and kept in the growth cabinet. The emergence of *C. cephalonica* was recorded daily in both *H. hebetor* treated and untreated rice samples until the 21st day. The number of F1 generation of *H. hebetor* that emerged was recorded as well. Each treatment was repeated five times while the five reference samples contained no parasitoids.

2.3 *Host finding by* H. hebetor *in bulk rice*

To quantify the distance travelled by the parasitoids between the rice kernels more precisely, another experiment was carried out in glass cylinders (50 cm height, Ø = 25 cm) with organic rice with a moisture content of 14%. Sixty larvae of *C. cephalonica* were placed into wire mesh gauze cages (width 0.5 mm) as described in SCHMIDT (1979), consisting of aluminium plates (9 × 12 cm, 5 mm thick) with holes of 5 cm Ø, closed with the gauze. The larvae were exposed at depths of 7 and 14 cm for 23 d in the middle of the column. On top of this layer 60 *H. hebetor* aged 1 day were released. The cylinder was covered using a nylon cloth and tied with a rubber band. After 7 days, the cages were removed from the cylinder and placed in a 250 l glass jar which was kept in the growth cabinet at 25°C and 65% rh. The number of F1 adult progeny of *H. hebetor* that emerged was recorded daily after 7 days for a period of 14 days.

2.4 *Statistical analysis of data*

Statistical analyses were performed using the statistical package SIGMASTAT 3.1. Means of independent comparisons for the experiment described in 2.2 were separated using the t-test, paired samples t-test was set at 95.0% confidence interval for the experiment described in 2.3.

3 Results

Altogether only 3%, i.e. two out of 40 female and 20 male adult *H. hebetor* released into the climatized room 1.6 m away from the jute bag entered the jute bag.

When *H. hebetor* adults were inserted into the jute bag, they were able to locate the host larvae between the rice kernels, to parasitize *C. cephalonica* and produce F1 progeny. The emergence of *H. hebetor* progeny started on day 9 after the introduction of the parasitoids. The highest number of F1 adults was recorded on the 16th day, and emergence continued until day 21 (Fig. 2). *H. hebetor* was able to significantly reduce the number of *C. cephalonica* emerging from the bagged rice (Student-Newman-Keuls Test, $P < 0.05$) (Fig. 3), the ABBOTT (1925) corrected mortality due to the parasitoid release was 92.13%.

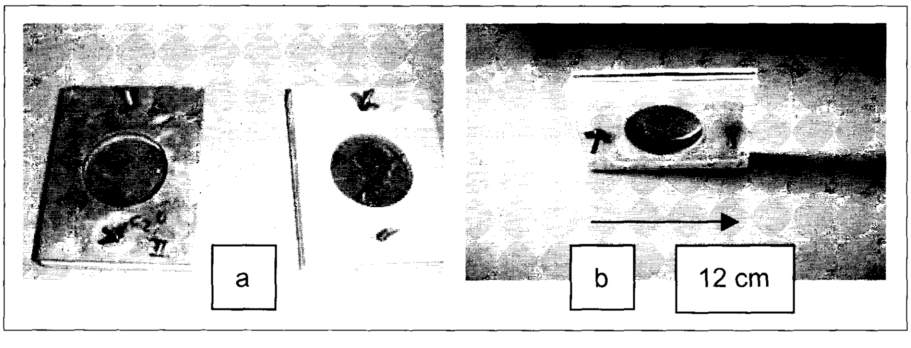

Fig. 1: Wire mesh gauze cage (a: top and basal metal plates, b: cage containing 60 larvae of *Corcyra cephalonica* ready to apply) used in trials on host-finding of *Habrobracon hebetor*.

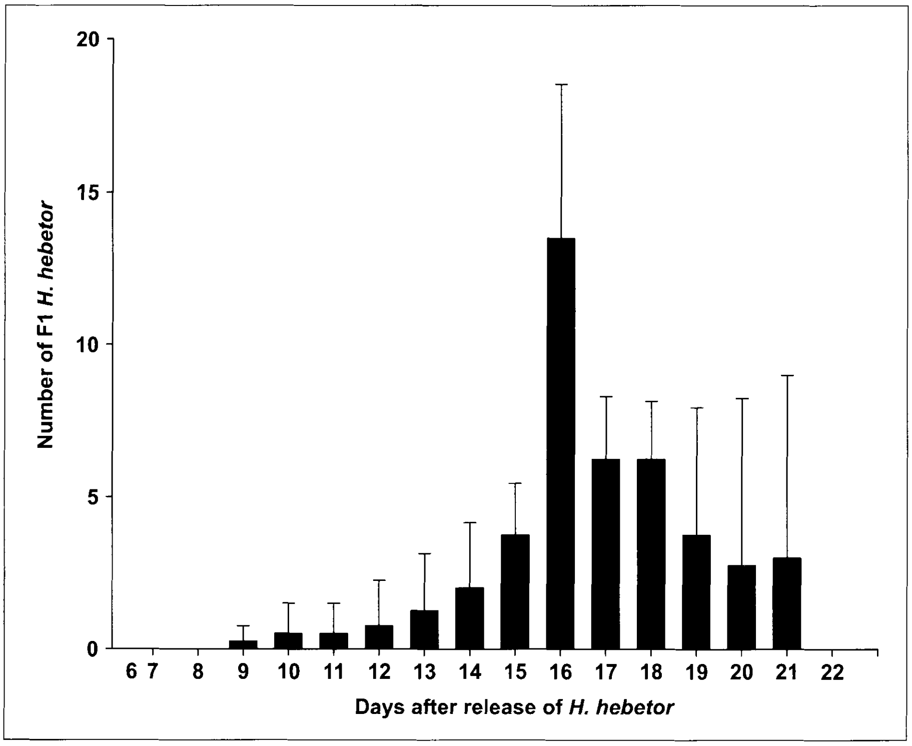

Fig. 2: Mean number and SD of *Habrobracon hebetor* F1 progeny that emerged from the wire gauze cage immersed in an small jute bag containing organic rice infested by *Corcyra cephalonica*; n = 5.

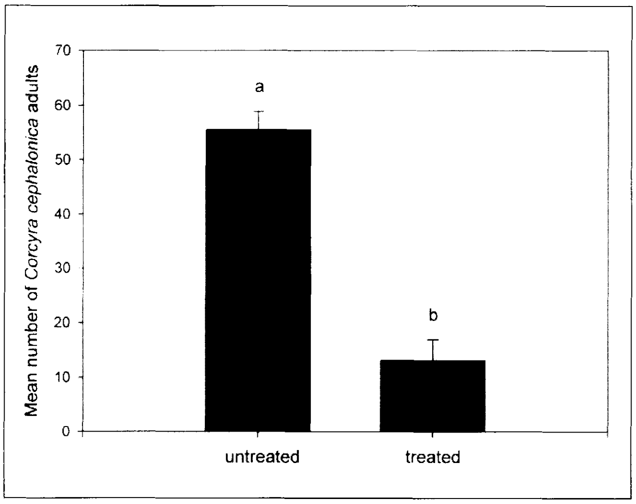

Fig. 3: Mean percentage adult emergence of *Corcyra cephalonica* (+ SD) recorded daily in both *Habrobracon hebetor* treated and untreated rice samples; t-test ($P< 0.001$).

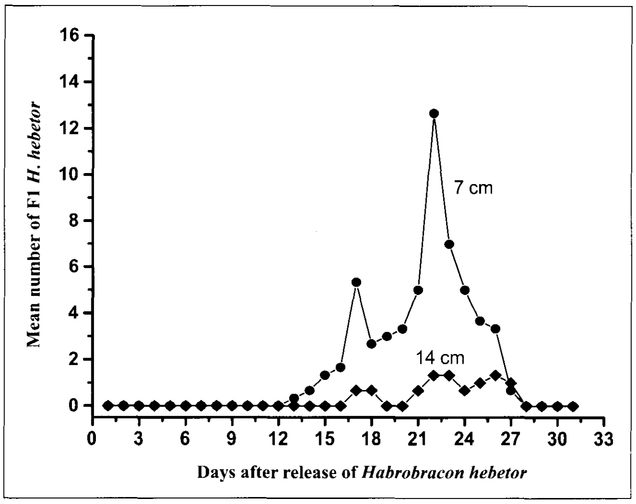

Fig. 4: Mean number *Habrobracon hebetor* F_1 progeny that emerged from wire gauze cages with *Corcyra cephalonica* larvae immersed 7 cm and 14 cm deep after release of parental *H. hebetor* adults on top of a glass cylinder with uninfested organic rice.

In the experiment where *C. cephalonica* larvae were inserted 7 and 14 cm deep inside the glass cylinders filled with rice, *H. hebetor* were able to locate its hosts in both depths. However, significantly more *H. hebetor* adults emerged from wire gauze cages placed 7 cm deep than those placed 14 cm deep within the grain column (paired samples t-test, $t = -4.3$, $df = 14$, $P = 0.001$). The highest number of F_1 adults was recorded between days 20 and 26 after the introduction of the parasitoids (Fig. 4).

4 Discussion

Durable agricultural products are often stored in huge storage facilities, but also in jute bags in tropical countries, e. g. maize, coffee and cocoa in Ghana. Bagged stored products are either infested from pests developing in product residues outside the bags, or from pests invading the storage building. Once the stored product pests are inside the bags, fumigation and freezing are the last choice for control. Therefore, biological control with parasitoids that are able to find their hosts in a jute bag over a large distance in an empty room containing bag stacks would be an interesting component for integrated stored product protection. However, in the present study only 3% of *H. hebetor* released actually entered the jute bags. It is most likely that the mesh of the jute has impeded their penetration into the bags. *H. hebetor* seems to be well suited to foraging in spillage and damaged packages (Paust et al. 2006; Grieshop et al. 2006) or bulk products as shown for rye in Schöller (2000) and for rice in the experiment here, but not for control of moths inside bags. Although labour-intensive, for infested grain stored in jute bags with small mesh sizes in relation to the size of *H. hebetor*, deliberate introduction of the parasitoids into the bags would seem to be more successful because *H. hebetor* significantly suppressed the population of *C. cephalonica* in infested rice stored in jute bags. Such a strategy has been shown to be applicable for biological control of bruchids in tropical storage systems by SCHMALE (2001).

As a preventative treatment of uninfested bags, GRIESHOP et al. (2006) suggested the combined release of both *Trichogramma* sp. and *H. hebetor*. In this combination, *H. hebetor* mainly attacks the wandering instar larvae of the pyralid moths, as it has been shown for *Cadra cautella* Walker, 1863 by CLINE and PRESS (1990).

To quantify the linear distance travelled by the parasitoids between the rice kernels more precisely, experiments were conducted in a glass cylinder. In both in 7 and 14 cm depth, host larvae were parasitized by *H. hebetor*. The higher number of progeny produced from hosts located within 7 compared to 14 cm depth suggests a decrease in the number of females reaching 14 cm, or limited time left for parasitism before the death of the females. The dynamics of progeny emergence over a period of 14 days indicated the females oviposited over their entire life span. Future studies should be conducted to evaluate the effectiveness in larger rice stores.

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