Suppression of insects in stored wheat by augmentation with parasitoid wasps[1]

P.W. Flinn, D.W. Hagstrum and W.H. McGaughey*

Abstract

Field studies were conducted to assess the effectiveness of the parasitoid wasps, *Cephalonomia waterstoni* for controlling *Cryptolestes ferrugineus* and *Choetospila elegans* for controlling *Rhyzopertha dominica*. Six bins were each filled with 27.2 t of hard red winter wheat in July 1992. Adults of both *C. ferrugineus* and *R. dominica* were released into each of the six bins at monthly intervals. Adults of both parasitoid species were released into three of the bins 21 days after the first beetle release. The amount of suppression of *C. ferrugineus* by *C. waterstoni* could not be measured in this study because large numbers of *C. waterstoni* entered the control bins. *Choetospila elegans* was very effective in suppressing *R. dominica* populations. *Rhyzopertha dominica* densities in the treatment bins remained well below economic levels during the storage season. After 198 days of storage, the control bins averaged 2.06 *R. dominica*/kg and the treatment bins averaged 0.05 *R. dominica*/kg.

Introduction

Biological control is an important component of integrated pest management of stored grain. Most of the parasitoids that attack the primary beetle pests are in the families Pteromalidae and Bethylidae (Hagstrum and Flinn 1992). These hymenopteran parasitoids are typically very small (1–2 mm), and do not feed on the grain. They will normally die within 5–10 days if no beetles are present in the grain. These parasitoids are found naturally in stored grain, which suggests that once released they may continue to suppress pests for many years (Sinha et al. 1979). Because the adult wasps are external to the grain, they can easily be removed from the grain using normal cleaning processes.

The rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), and the lesser grain borer, *Rhyzopertha dominica* (F.), are two of the most common and damaging insect pests of farm-stored wheat in the United States (Storey et al. 1984). Adults and larvae of *C. ferrugineus* feed primarily on the wheat germ and can cause considerable damage. *R.dominica* larvae develop within the grain kernel and cause major damage to grain stores.

Caphalonomia waterstoni Gahan is a hymenopteran parasitoid that is frequently found with *C. ferrugineus* in stored grain (Hagstrum and Flinn 1992). *C. waterstoni* is very host-specific (Finlayson 1950). Although this wasp will parasitise larvae of other *Cryptolestes* species, when given a choice, it almost invariably prefers *C. ferrugineus*. This wasp usually only parasitises fourth instars; however, it will paralyse and feed on first through third instars (Rilett 1949). After stinging the host, paralysis occurs within one minute. This wasp can paralyse up to 15 larvae per day (Flinn 1991); however, it normally lays only two eggs per day (Finlayson 1950). Wasp larvae feed externally on the host and mature rapidly. The generation time of the wasp is about 14 days at 30°C. If hosts are available, female wasps live for 15–20 days at 30°C.

Choetospila elegans Westwood is a small pteromalid wasp that attacks *R. dominica*, *Sitophilus* spp., *Stegobium paniceum* (L.), *Callosobruchus* spp. and *Sitotroga cerealella* (Olivier) (Burks 1979). The wasps will parasitise beetle larvae that are feeding within the grain kernels. Eggs will successfully develop when laid on fourth instar *R. dominica* (P. Flinn, unpublished data). They normally lay one egg externally on each host (Sharifi 1972). If more than one egg is present, only one completes development. At 30°C, it takes about 15 days to complete development on *R. dominica* (P. Flinn, unpublished data). The generation time of this wasp is less than half that of *R. dominica*. If hosts are available, female wasps will live for 10 to 20 days at 30°C. *Choetospila elegans* can parasitise up to six *R. dominica* per day (P. Flinn, unpublished data).

Only a few large-scale studies have been conducted on the use of beneficial insects to suppress insect pests in stored grain (Parker and Nilakhe 1990), and the results were not conclusive. The objective of this study is to assess the effectiveness of *C. waterstoni* and *C. elegans* to suppress population growth of *C. ferrugineus* and *R. dominica* respectively, in stored wheat.

Methods

Six cylindrical bins, 4.72 m diameter by 3.35 m tall at the eaves, were constructed so that they were air tight, except for two roof ventilation ports that were covered with 80 mesh screen. Because of the uncertainty of obtaining new-crop wheat directly from farmers, we used 1992 crop wheat that was acquired one year before the experiment. Ten grain trier samples were taken per truckload, and no insects were found in any of the samples. The grain was tested for insecticides using *Sitophilus oryzae* (L.) as a bioassay, none was found or expected because it was obtained directly from farmers as new-crop wheat. This wheat was stored in the U.S. Grain Marketing Research Laboratory (USGMRL) elevator during the summer. It was fumigated twice with phosphine during the summer of 1992 to insure that no insects would be present in the grain. Each of the six bins were filled with 27.2 t of hard red winter wheat in September 1992. The grain was cooled to 10°C with aeration during the month of September. The grain was warmed starting on June 15, 1993, using aeration (0.2 cfm). The fans were screened with no. 80 mesh screen to prevent insects from entering. By July 6 1993 the grain was warmed to 26.66±12°C and the average grain moisture was 13.18±0.03%.

On 6 July 1993, 270, 1-week-old *R. dominica* and 270 1-week-old *C. ferrugineus* adults were released on the surface of each of the six bins. Releases were reported at monthly intervals until October 1. These insects were obtained from a

[1] This paper reports the results of research only. Mention of a proprietary product does not constitute an endorsement by the USDA.

* U.S. Grain Marketing Research Laboratory, USDA-ARS, 1515 College Ave., Manhattan, Kansas 66502, USA.

USGMRL culture which had wild strains added to it in October 1992 to maintain genetic diversity. Beetles were released by inverting nine, 1-pint jars (each containing 30 insects) on top of the grain surface and letting them crawl down into the grain.

Parasitoids were released into three of the six bins 20 days after initial beetle infestation. The parasitoids were obtained from a USGMRL culture that had wild strains added in October 1992 to maintain genetic diversity. Five hundred and forty *C. waterstoni* adults and 540 *C. elegans* adults (both < 3 days old) were added to three of the six bins on July 26. Two additional releases were made in these same bins at weekly intervals. Parasites were released by inverting nine, 1-pint jars (each containing 60 parasitoids) on top of the grain surface at evenly spaced intervals. This was done in the morning to avoid high temperatures. Because densities of this parasitoid were low in the treatment bins, we released 900 *C. waterstoni* on September 9 into each of the three treatment bins.

Grain sampling was conducted at monthly intervals using a pneumatic grain sampler (Probe-A-Vac, Cargill Inc., Minneapolis Minnesota). Seven 3-kg samples in each 66.6 cm layer of wheat were taken at three points near the centre of the bin and at four points two-thirds the distance between the centre and the outer wall. Control bins were sampled first to minimise parasitoid introduction into these bins. Samples were immediately placed in plastic containers. Grain samples were processed over an inclined sieve (89 by 43 cm, 1.6 mm aperture) (Hagstrum 1989). Adult insects were identified and counted (live and dead determined). A test (Wilkinson 1989) was used to test for differences between treatment and control bins. Treatment effects were considered significant at $P<0.05$.

Results and Discussion

The three bins with parasitoids added to them had much lower densities of *R. dominica* than the control bins (Fig. 1). Densities of *R. dominica* were much more variable in the control bins compared to the treatment bins. Because of the high variance, there were no significant differences ($P>0.05$, $N=63$) in the treatment bins compared to the controls for a specific sampling date. However, there was a significant difference in treatment vs. control bins when the data were pooled for the last three sample dates (134, 166 and 198 days of storage)($P<0.05$, $N=189$).On the last three sample dates, the control bins averaged 2.09 *R. dominica*/kg and the treatment bins averaged 0.24 *R. dominica*/kg. Thus, *R. dominica* populations in the treatment bins were suppressed 88% compared to the controls. As expected, populations of *C. elegans* were much higher in the treatment bins than in the control bins (Fig. 2). A few *C. elegans* were detected in the control bins after 76 days of storage. However, none were detected in the control bins at 106, 134, and 166 days of storage.

Control of *C. ferrugineus* by *C. waterstoni* could not be measured in this study because large numbers of *C. waterstoni* entered the control bins (Fig. 3). Densities of *C. waterstoni* were very similar in both the treatment and control bins. The only significant difference ($P<0.05$, $N=124$) in *C.waterstoni* density between treatment and control bins occurred on day 166. The source of *C. waterstoni* that infested the control bins probably came from a nearby bin that contained milo that was highly infested with *C. ferrugineus* and *C. waterstoni*. Population densities of *C. ferrugineus* were not significantly different ($P<0.05$, $N=124$) in the control and treatment bins except on days 45 and 107 (Fig. 4). It is likely that *C. waterstoni* suppressed *C. ferrugineus*, but we can't say how much because of the absence of a control. *C. ferrugineus* densities normally reach densities of 10–20/kg by November in wheat stored under similar conditions in Kansas (Hagstrum 1989). The fact that *C. waterstoni* was present in the control bins should have no effect on *R. dominica* populations because *C. waterstoni* only attacks *C. ferrugineus*.

Grain temperatures in all six bins were very similar during the experiment (Fig. 5). The grain remained at 28°C until 76 days of storage, after which it steadily decreased to 7°C after 198 days of storage. The parasitoid wasps continued to parasitise beetle larvae and develop into adult wasps until the grain temperature fell below 20°C (Flinn 1991; P. Flinn, unpublished data). At this temperature beetle development and reproduction would also cease.

This study demonstrated that *C. elegans* can suppress *R. dominica* populations so that they remain well below economic levels during the storage season. It also inadvertently demonstrated the amazing ability of *C. waterstoni* to spread and colonise other grain bins, even though the bins were tightly sealed. In addition, it showed that relatively low parasitoid release rates can control insect pests, provided that the releases are made after approximately 3 weeks of storage.

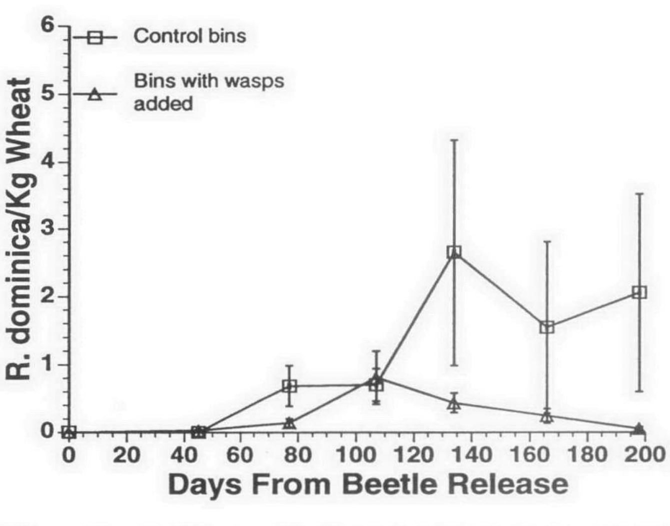

Fig. 1. Average *Rhyzopertha dominica* density in three control bins, and in three bins in which the parasitoid *Choetospila elegans* was released. Each of the six bins contained 27.2 t of hard red winter wheat. Vertical bars indicate standard error of the mean.

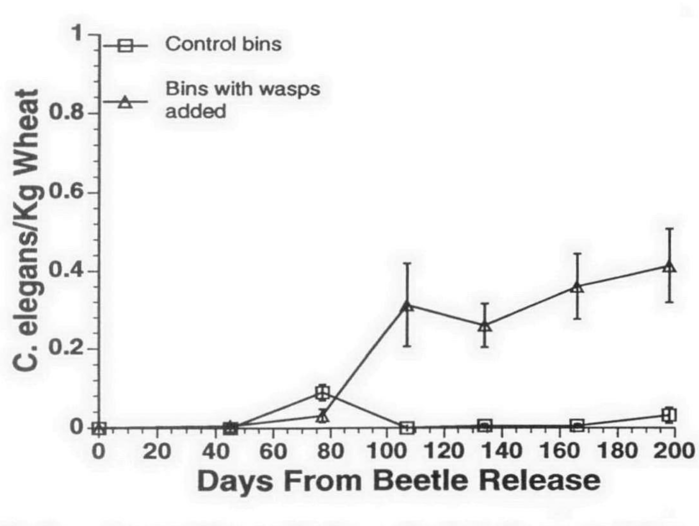

Fig. 2. Average *Choetospila elegans* density in three control bins, and in three bins in which this parasitoid wasp was released. Each of the six bins contained 27.2 t of hard red winter wheat. Vertical bars indicate standard error of the mean.

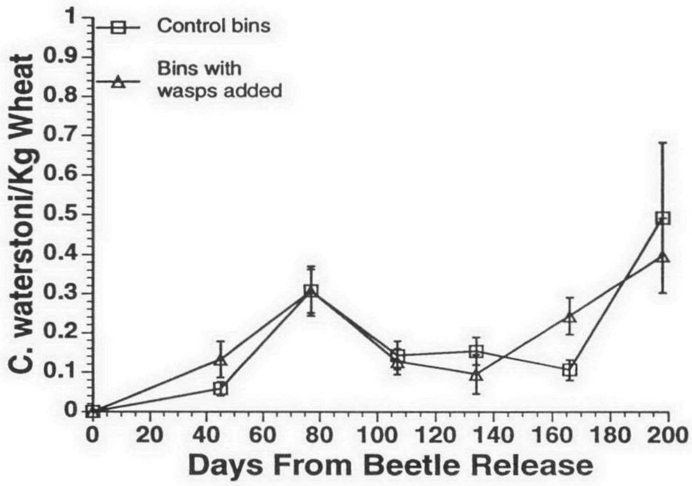

Fig. 3. Average *Cephalonomia waterstoni* density in three control bins, and in three bins in which this parasitoid wasp was released. Each of the six bins contained 27.2 t of hard red winter wheat. Vertical bars indicate standard error of the mean.

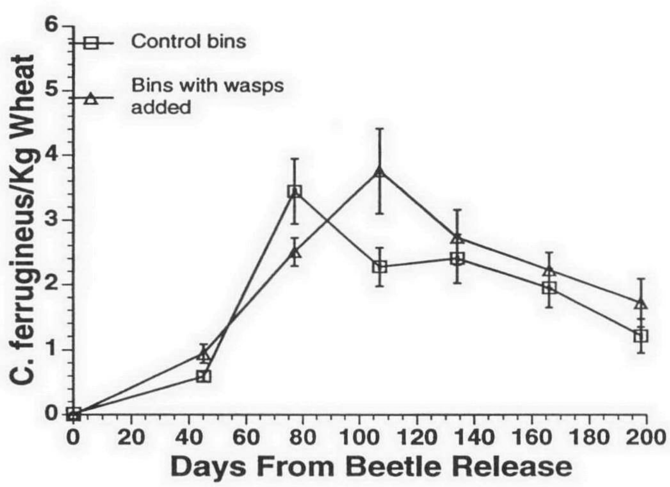

Fig. 4. Average *Cryptolestes ferrugineus* density in three control bins, and in three bins in which the parasitoid *Cephalonomia waterstoni* was released. Each of the six bins contained 27.2 t of hard red winter wheat. Vertical bars indicate standard error of the mean.

Acknowledgments

We thank B. Dover (Department of Entomology, Kansas State University), G. Cuperus (Department of Entomology, Oklahoma State University), and L. Smith (SPIRDL, USDA-ARS, Savannah) for critically reviewing the manuscript.

References

Burks, D.B. 1979. Family Ptermalidae. In: Krombein, V., Hurd, P.D., Smith, D.R., Burks, D.B., ed., Catalog of Hymenoptera in America North of Mexico, Smithsonian Institute, Washington, D.C., 768–834.

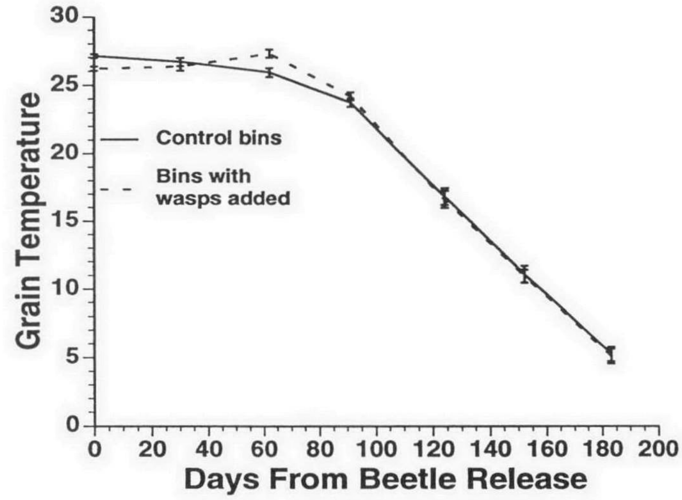

Fig. 5. Average grain temperature in three control bins, and three bins in which parasitoid wasps were released. Each of the six bins contained 27.2 t of hard red winter wheat. Vertical bars indicate standard error of the mean.

Flinn, P.W. 1991. Temperature-dependent functional response of the parasitoid *Cephalonomia waterstoni* (Gahan) (Hymenoptera: Bethylidae) attacking rusty grain beetle larvae (Coleoptera: Cucujidae). Environmental Entomology, 20, 872–876.

Finlayson, L.H. 1950. Host preference of *Caphalonomia waterstoni* Gahan, a bethylid parasitoid of *Laemophloeus* species. Behaviour, 2, 275–316.

Hagstrum, D.W. 1989. Infestation by *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) of newly harvested wheat stored on three Kansas farms. Journal of Economic Entomology, 82, 655–659.

Hagstrum, D.W., Flinn, P.W. 1992. Integrated pest management of stored-grain insects. In: Saurer, D.B. ed., Storage of cereal grains and their products. St Paul, Minnesota, USA, American Association of Cereal Chemists, 535–562.

Parker, R.D., and Nilakhe, S.S. 1990. Evaluation of predators and parasites and chemical grain protectants on insect pests of sorghum stored in commercial bins. In: Proceedings of the 3rd National Stored Grain Pest Management Training Conference, Kansas City, Missouri, 229–239.

Rilett, R.O. 1949. The biology of *Cephalonomia waterstoni* Gahan. Canadian Journal of Research, 27, 93–111.

Sharifi, S. 1972. Radiographic studies of the parasite *Choetospila elegans* on the maize weevil, *Sitophilus zeamays*. Annals of the Entomological Society of America, 65, 852–856.

Sinha, R.N., Wallace, H.A. H., Reiser, B., Lefkovitch, L.P. 1979. Interrelations of arthropods and microorganisms in damp bulk stored wheat—a multivariate study. Researches in Population Ecology, 21, 40–67.

Storey, C.L., Sauer, D.B. and Walker, D. 1984. Present use of pest management practices in wheat, corn, and oats stored on the farm. Journal of Economic Entomology, 77, 784–788.

Wilkinson, L. 1989. SYSTAT: the system for statistics. SYSTAT Inc., Evanston, Illinois.