# Field Infestation of *Phaseolus vulgaris* by *Acanthoscelides obtectus* (Coleoptera: Bruchidae), Parasitoid Abundance, and Consequences for Storage Pest Control

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**ABSTRACT** Over a period of 3 yr we collected 19 samples (1 kg each) of recently harvested beans (*Phaseolus vulgaris* L.) from eight small-scale farms in Restrepo, Valle de Cauca, Colombia. Initial infestation by *Acanthoscelides obtectus* (Say) was low, but frequent. At harvest, 90% of the bean samples were infested by the weevil. The average level of infestation was 16 weevils per 1,000 beans, with a maximum of 55 weevils. Infested beans usually carried multiple larvae with a maximum of 13 larvae per bean. Emergence data indicate that oviposition by *A. obtectus* in the field is confined to a very short period before harvest. This relatively narrow time window can be exploited for proper timing of control measures. Only one species of parasitoid, *Horismenus ashmeadii* (Dalla Torre) (Hymenoptera: Eulophidae), was recorded, emerging from 21% of the samples. Samples with parasitoids had an average of five parasitoids per 1,000 beans, with a maximum of 12 parasitoids. This represented a parasitization level of 18%. During the 16 wk of storage, two weevil generations emerged, which caused visible damage in 0.5 and 34% of the beans (average of 14%). Although *H. ashmeadii* was successful in attacking the first generation of *A. obtectus* in the field, it failed to attack or develop under storage conditions. This indivates *H. ashmeadii* cannot serve as a postharvest control agent.

**KEY WORDS** *Acanthoscelides obtectus,*beans, Bruchidae, parasitoids, oviposition behavior, storage pest

Many species from the family Bruchidae are worldwide pests of beans both in the field and in storage. After hatching from the eggs, first instars penetrate the bean seeds. The beetles develop within the seeds to emerge as adults leaving typical damage in the form of the empty feeding chambers. In addition, to this direct damage, indirect damage arises from contamination by excrement, pheromone, and dead insects, which can cause allergic reactions in humans (CIAT 1986). Weevil damage can also lead to a lower germination rate of damaged bean seeds (Zacher 1930).

In 1986, CIAT (1986) estimated economic losses due to bruchid damage in Colombian warehouses to be 7.4% after 45 d of storage. Other sources reported damage levels of 35% losses in Mexico and Central America, and 13% in Brazil after different storage times (cited in CIAT 1986). However, these data are difficult to compare, because the types of beans and storage varied, and losses are known to be directly correlated with duration of storage.

Colombian farmers respond to the bruchid problem by selling their commodity at the time of harvest, even though market prices are then usually at their lowest. CIAT (1986) estimated that this results in a 50% income loss compared with prices that could be obtained if beans were safely stored for a few month. Furthermore, it is expected that spreading the bean supply over a longer period would stabilize bean prices in general (van Schoonhoven 1976).

*Acanthoscelides obtectus* is one of two major bruchid species causing damage to stored beans in Latin America. It prefers cooler climates at higher elevations, and thus, can be found in mountainous and subtropical regions where it is the only insect pest of stored beans (Cardona 1989). *A. obtectus* is known to infest beans in the field by ovipositing eggs loosely in growing pods (Cardona 1989). Despite its economic importance, little or no information is available on the timing and level of this field infestations. Available observations indicate that females deposit their eggs in the drying pods (Thiery and Jarry 1985). In addition, to this lack of knowledge on herbivore-plant interactions, little is known about natural enemies attacking *A. obtectus* in the field.

In this study we wanted to quantify natural levels and the timing of field infestations by *A. obtectus,* and to investigate the subsequent dynamics of the herbivore populations under typical Andean storage con-

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ditions. We also surveyed parasitoids attacking *A. obtectus* in the field by taking samples of various sites over 3 yr.

## Materials and Methods

All observations were made using the commonly cultivated susceptible bean variety *Phaseolus vulgaris* L. variety Diacol-Calima (Leguminosae).

**Initial Bean Damage.** To investigate the level of natural field infestation by *A. obtectus*, a total of 19 bean samples of ≈1 kg each were taken from eight small-scale farms in Restrepo, Valle de Cauca, Colombia (1,360 m above MSL). Four farms had their fields situated in the center of the bean-growing area, where beans are permanently present in the field, the other four farms had their fields situated outside the center of the bean-growing area, where crop rotation resulted in bean-free periods. Sampling took place at 15 dates over a 3-yr period (1997–1999). Samples were taken on-farm within the first week after harvest. Time of harvest was recorded for each sample.

At the time of collecting the sample, every bean seed was examined for insect damage, in particular weevil or parasitoid emergence holes. Subsequently, the samples were kept in glass jars in a laboratory chamber at 20–25°C and 70% RH. All newly emerged insects were removed from the jars and counted at weekly intervals. Samples were discarded after 5 wk, which covers the development time of the weevil under the given conditions. This ensured that the majority of emerging adults was recorded, but prevented the counting of $F_1$ generation individuals.

**Storage Monitoring.** To investigate the population dynamics of *A. obtectus,* beans were harvested in 1998 and 1999 from seven representative fields in Restrepo. Three fields were situated in the center of the bean-growing area, where beans are permanently present in the field, and four fields were situated outside the center of the bean-growing area, where crop rotation resulted in bean-free periods. Bags containing 40 kg of bean seeds each were filled and stored on-farm. The climatic conditions over 25 yr in this region are 19.6°C; 82.25% RH, and 86.75 mm precipitation (GIS, Centro Internacional de Agricultura Tropical, Cali, Colombia). Precipitation during the experimental period was elevated due to the climatic phenomenon 'El Niño' and rainy and dry seasons were less distinct than normal. After harvest, bean pods were spread out for sun drying and subsequently threshed. A 1-kg sample of beans was removed to evaluate field infestation levels, and 40 kg of seeds each were poured into seven polypropylene bags and stored on-farm for 16 wk. Over this period, 0.5 kg of beans were removed at weekly intervals by inserting a sampling tube through the polypropylene bag. Sampling holes were taped shut. To control for variation in vertical distribution of the insects, half a sample was taken from the lower and half from the upper part of the bag. To avoid removal of beans from the same place twice, 32 sample sites were chosen randomly and marked at the beginning of the experiment. The bean samples were brought to the laboratory and kept in glass jars in a chamber at 20–25°C and 70% RH. All newly emerged insects were removed from the jars and counted at weekly intervals. Samples were discarded after 5 wk, which covers the development time of the weevil under given conditions. This ensured recovery of the majority of emerging adults and prevented counting $F_1$-generation individuals.

Percentage bean damage was calculated. Beans were counted as 'damaged' when at least one emergence hole made by *A. obtectus* was visible at the time the samples were collected. Because larvae inside the seeds are not visible they have no direct impact on value, and thus were not counted as 'damaged'.

Also, the intensity of infestation was calculated using the following formula: intensity of infestation = total number of emergence holes/number of damaged seeds.

## Results

**Initial Bean Damage: Weevil Emergence.** An average of 26, 13, and 14 *A. obtectus* adults emerged from 1,000 bean seeds collected at harvest in the years 1997, 1998, and 1999, respectively. Therefore, the mean field infestation over the whole period was 16 weevils per 1,000 seeds, with a maximum of 55 weevils. Only two of the 19 samples were uninfested (both in 1998). In the 3 yr, emergence started the third, the fourth, and the fifth week after harvest, respectively (Fig. 1). *Acanthoscelides obtectus* adults emerged over a period of 3 wk, following a roughly normal distribution.

**Parasitoid Emergence.** Hymenopteran parasitoids were observed in 11 samples collected from four farms in the center of the village. They uniformly belonged to a species in the genus *Horismenus* (Hymenoptera: Eulophidae), which was determined to be either *Horismenus ashmeadii* (Dalla Torre) or an undescribed species close to *H. ashmeadii* (with a longer female gaster) (det.: Christer Hansson, Institute of Zoology, Lund, Sweden). In this article, the species is referred to as *H. ashmeadii.* Emergence of *H. ashmeadii* occurred over the same period as emergence of *A. obtectus,* but there was greater variation between farms with respect to the peak of emergence (Fig. 2). The fraction of samples yielding parasitoids was 100, 55, and 25% in 1997, 1998, and 1999, respectively. In parasitized samples, an average of 6, 3, and 18 *H. ashmeadii* adults emerged from 1,000 bean seeds in these same years. Over the whole period, a maximum of 12 parasitoids per 1,000 seeds emerged representing a parasitization rate of 18%.

**Storage Monitoring.** During 16 wk of storage, two bruchid generations emerged (Fig. 3). The first weevil generation represents offspring from weevils that oviposited in the field, i.e., the initial field infestation (see above). Field infestation was higher in both years on farms situated in the center area compared with farms with fields situated outside the bean-growing center. Samples collected from center fields had means of 19–40 weevils emerged from 1,000 bean seeds, whereas samples collected from fields outside the cen-

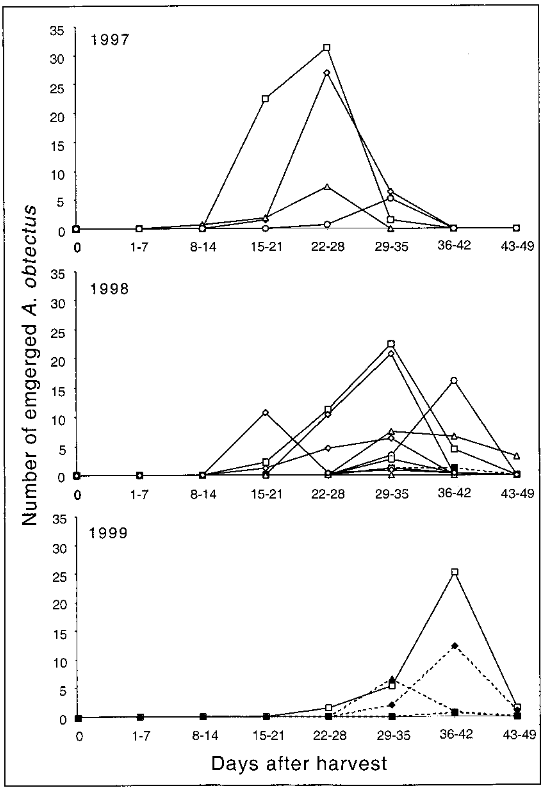


**Fig. 1.** Emergence of the bruchid *Acanthoscelides obtectus* from *P. vulgaris* variety Calima samples collected in Restrepo, Valle de Cauca, Colombia, in 1997, 1998, and 1999. Data are presented by field site, with hollow symbols representing fields situated in the bean-growing center and filled symbols representing fields situated outside the bean-growing center. Weevils were collected from samples of 1,000 bean seeds (≈500 g).

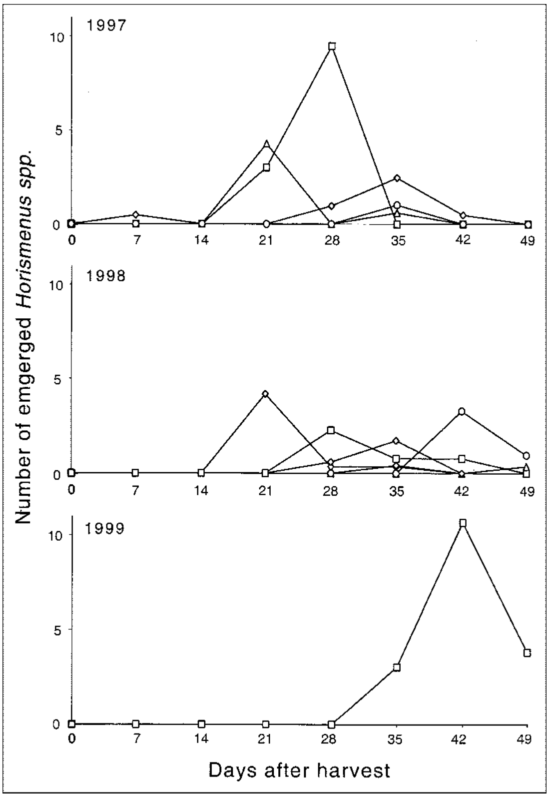


**Fig. 2.** Emergence of the parasitoid *Horismenus ashmeadii* from *P. vulgaris* variety Calima samples collected in Restrepo, Valle de Cauca, Colombia, within 3 yr. Data are presented by field site, with hollow symbols representing fields situated in the bean-growing center. Parasitoids were collected from samples of 1,000 bean seeds (≈500 g).

ter area had means of 0.7–15 weevils emerged. In 1998 and 1999, emergence of the second weevil generation started in the 10th and 11th week after harvest, respectively. By the 16th week of storage, the second weevil generation had emerged and overall damage level over both years reached 34% in fields in the center area and 5.7% in fields outside of the center area (Fig. 3).

Mean damage intensity was 3.9 holes per damaged bean in the generation originating from the field and 1.9 holes per damaged bean after the second generation had emerged.

*Horismenus ashmeadii* only appeared in one field generation. Attempts to rear *H. ashmeadii* under laboratory conditions failed, as females offered beans in combination with weevil eggs and females presented with various larval stages did not produce offspring.

## Discussion

**Initial Bean Damage.** Almost 90% of the bean samples taken at harvest were infested with the bruchid *A. obtectus.* Because these samples represent only a small part of the typical storage unit (0.5–1 kg of ≈65 kg), chances are extremely slim that storage bags escape infestation.

Because mean developing time from egg to adult in *A. obtectus* under the given storage conditions is ≈35 d (I.S., unpublished data), the timing of *A. obtectus* emergence in the samples indicates that infestation must have taken place during the last two (1997) or fewer (1998 and 1999) weeks before harvest. Different time windows of infestation in the three experimental years were likely due to different climatic conditions. The generally short infestation period shows that *A. obtectus* requires a particular stage of bean maturity for oviposition, as was previously reported for *C. chinensis* (Shinoda et al. 1992). This limited window of bean susceptibility translates into a rather narrow emergence peak. 1999 had the shortest window of susceptibility, in that weevil emergence was later and the emergence peak narrower than in the other 2 yr (Fig. 1). This also was the year with the lowest level of infestation. In contrast, the year with the longest window of susceptibility (1997) was the year with the earliest emergence, the broadest time span over which emergence occurred, and the highest infestation level.

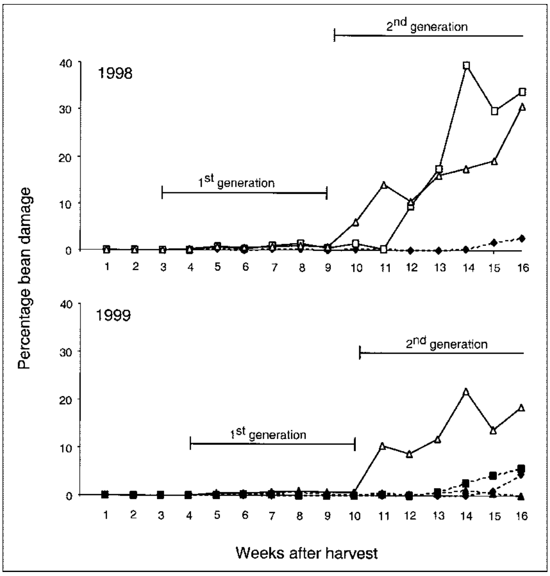


**Fig. 3.** Temporal development of bean damage by the bruchid *Acanthoscelides obtectus* in stored beans, 1998–1999. Data are presented by field site, with hollow symbols representing fields situated in the bean-growing center, and filled symbols representing fields situated outside the bean-growing center. Bean damage was evaluated in percentage damage: beans were considered 'damaged' when at least one *A. obtectus* emergence hole was visible.

Thus, a timely harvest can be an important tool in restricting weevil infestation. In practice, time of harvest depends on various factors. When time is limited, the harvest of perishable fresh vegetables is usually given priority over the harvest of drying beans. Advancing the date of bean harvest too far leaves beans moist and thus more susceptible to mold even when stored briefly. Therefore, the market price of these early harvested beans is lower then that of dry beans.

The first weevil generation was consistently small, with on average of only 16 weevils emerged per 1,000 bean seeds. This result is consistent with the damage level of 2% reported for a natural field infestation of *A. obtectus* in the closely situated Colombian village of Darien (Baier and Webster 1992). Infestation was regularly higher in samples collected from fields in the bean-growing center of Restrepo, where beans are permanently present in the field, then in samples from fields situated outside the bean-growing center, where crop rotation resulted in bean-free periods. Therefore, beans from outlying areas may be better suited to storage than beans from bean-growing centers.

Infested beans from the field mostly contained multiple larvae, with a maximum of 13 larvae per bean recorded in our evaluations. *Acanthoscelides obtectus* females oviposit a cluster of eggs into the same pod. It is likely that only a few pods are infested, but due to the weevil's high intrinsic rate of increase under storage conditions this initial infestation is sufficient to cause a rapid destruction of stored beans by the subsequent weevil generation.

**Storage Monitoring.** After harvest, the weevil generation which penetrated bean seeds in the field emerge in the storerooms. Damage is little at this time, because clustered oviposition into pods results in a high damage intensity, but a small percentage of damaged seeds. The mean number of emergence holes decreased with the emergence of the second generation from approximately four to two holes per damaged bean. In *C. chinensis*, females choose undamaged seeds for oviposition (Ignacimuthu et al. 2000) likely to prevent larval competition (Credland et al. 1986). In *A. obtectus* the eggs are scattered freely over the seeds and first instars, rather than adult females, decide which seed to penetrate. Their entering behavior is induced by thigmotactic stimulation produced by a contact area between two seeds, or between a seed and the pod wall (Labeyrie 1962). Success in penetration depends on the hardness of the seed coat and on the length of time the larvae spend outside the seed (Thiery and Jarry 1985). Umeya and Kato (1970) stated that first instars use the entrance holes of previous larvae, resulting in clustered weevil damage. Our studies showed that, in the storage bags, more first instars penetrate undamaged than occupied seeds. It remains to be determined if the decrease of damage intensity in *A. obtectus* is due to avoidance of occupied seeds by first instars, or whether it reflects differences in spatial arrangements of beans between pods and storage bags.

With the emergence of the second weevil generation the percentage of bean damage increased to unacceptable levels. Total crop loss (exceeding 5% visible damage; Cardona, unpublished data) was reached after ≈10–12 wk of storage in three of seven bags. These three bags had been collected from farms in the center of the bean-growing area, suggesting that an unacceptable number of weevil larvae was already developing inside the bean seeds from the fifth week after harvest onwards.

About 20% of the samples collected at harvest contained the parasitic wasp *H. ashmeadii.* Its spatial distribution in our study coincided with the highest density of its bruchid host, because it was only found in the center of the bean-growing area. Although *H. ashmeadii* may reduce *A. obtectus* in the field, its failure to attack or develop under storage conditions indicates this parasitoid cannot serve as a possible postharvest control agent. However, introduction of other parasitoid species which are better adapted to storeroom conditions can be an effective tool in controlling weevil infestation. Effective bean weevil parasitoids, like the larval parasitoid *Dinarmus basalis* Ashmead (Hymenoptera: Pteromalidae), were found in grain stores in the Cauca Valley. Their absence in on-farm storage is likely due to a short or nonexistent storage period. Also, differences in climatic conditions between the grain stores in areas of lower elevation and farms on Andean hillsides may explain differences in parasitoid abundance.

Control of *A. obtectus* seems to be most promising when targeted against the first generation, because damage by this generation is small. At the time of harvest, weevil larvae are still in stages susceptible to parasitoid attack. Being able to predict emergence of the initial *A. obtectus* generation will help to fine-tune inoculative or inundative biological control programs. Predictions of the time of field infestation could open up opportunities for other control methods as well. The fact that the time window of infestation is very narrow may facilitate precise targeting of control methods such as early harvest, mating disruption, chemical control, and biological control, and control may be achieved with a single application.

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