Journal of Plant Diseases and Protection, **117** (6), 268–272, 2010, ISSN 1861-3829. © Eugen Ulmer KG, Stuttgart

Seasonal fluctuations in *Agriotes* spp. (Coleoptera: Elateridae) at two sites in Austria and the efficiency of bait trap designs for monitoring wireworm populations in the soil

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Received 30 August 2010, accepted 06 November 2010

Abstract

Wireworms, the larvae of *Agriotes* spp. (Coleoptera: Elateridae), cause serious damage to a number of crops. To develop an effective management strategy, a reliable method of estimating the abundance of the *Agriotes* species is needed. This paper describes a trapping study of *Agriotes* in parts of Austria. Over two years, adult click beetles were monitored using YATLOR sex pheromone traps and wireworms were monitored using bait traps. Also, the efficiency of bait traps with different numbers of perforations was compared. In a location in Upper Austria, *A. lineatus* was by far the most common species and in a location in lower Austria, the majority of beetles caught were *A. ustulatus*. *A. brevis* was common in Upper Austria, but nearly absent in Lower Austria. There were large discrepancies between the species compositions of the adults and larvae caught, suggesting a low efficiency of the bait traps. More larvae were caught in bait traps with greater numbers of holes, but the difference was not statistically significant. Further improvements in bait traps or another sampling method will be needed to accurately estimate the density of wireworms.

Key words: *Agriotes ustulatus*, *A. lineatus*, *A. brevis*, flying activity, pheromone traps, bait traps

1 Introduction

Wireworms, the soil-dwelling larvae of *Agriotes* ssp. (Coleoptera: Elateridae) or click beetles, are a ubiquitous pest all over the world. The number of reports on wireworm damage in Austria has increased over the last decade. Although the amount of damage varies between years, the situation is, in general, alarming. At present, it is unknown which species are most common in Austria and which cause the most damage to crops.

Wireworms are feeding mainly on roots and tubers of different plant species. They can cause serious damage to cereals (maize, wheat), vegetables (beans, onion, carrot, celery, rhubarb, asparagus etc.), oil crops (sunflower, rape) and many other crops. Larvae are able to destroy up to 25% of crop yields but with root vegetables they mainly reduce the quality of the crop rather than the yield. Potatoes are the most susceptible crop. So far, the best way of preventing wireworm damage in potatoes has been to avoid growing a sensitive crop in infested fields (Parker & Howard 2001). To implement this preventative measure, it is necessary to be able to estimate the level of infestation. Considerable effort has been put into developing bait traps for wireworms (e.g. Ward & Keaster 1977, Kirfman et al. 1986, Parker 1994, Simmons et al. 1998) and pheromone traps for adult click beetles (e.g. Tóth et al. 2001, Subchev et al. 2004, Subchev et al. 2006). The estimation of infestation level using pheromone traps is based on the implicit assumption that the observed population of adults represents the larval population (e.g. Blackshaw & Vernon 2008). Despite continuing research efforts throughout Europe (Parker & Howard 2001), a reliable relationship between adult and larval populations has not yet emerged. This may be due to unreliable estimation of the number of larvae, unreliable estimation of the number of adults, or because the relationship between the number of adults and the number of larvae is not linear, because of substantial but unpredictable mortality, spatial or temporal segregation of adults and larvae, etc.

The objective of the present study was, therefore to characterize the changes in population density of three *Agriotes* spp. over the season in Austria and to try out different designs of bait traps to improve the capture efficiency of wireworms.

2 Materials and methods

2.1 Changes in population density of three *Agriotes* spp. over the season

Site description. Monitoring of adults and larvae was carried out simultaneously during the 2004–2005 growing season in two regions in Austrian.

The first site, in Untermallebarn, Korneuburg, Lower Austria (48° 25' 43″ N, 16° 10' 3″ E; 191 m above sea level), had a Chernozem soil type of loess with a humus content of 2.8%. It has been in organic cultivation since 1996. In 2004, potatoes (*Solanum tuberosum* cv. Ditta) were planted, followed by wheat (*Triticum aestivum* cv. Ebners Rotkorn).

The other site in Oberschaden, Eferding, Upper Austria (48° 19' 0″ N, 14° 2' 0″ E; 271 m above sea level), had a grey alluvial soil next to the river Danube with a humus content of 1.9%. The site was farmed conventionally. In the 2004, potatoes (*Solanum tuberosum* cv. Evita, Ditta, Impala, Agata) were planted, followed by sugar beet (*Beta vulgaris* cv. Avia). Both fields had a history of wireworm activity.

Trial design. A study area measuring 60 m × 300 m (1.8 ha) was established in each field, in which traps were placed on a grid of 3 × 16 (48 bait traps), with 20 m between the rows and 30 m between traps in each row. Along the middle row of bait traps, row four pheromone traps per species (12 pheromone traps) were placed (40 m from each other). Bait and pheromone traps were in the field from 21 April to 31 August in 2004 and 2005. Crops were growing in the field during the whole trial period.

Pheromone traps – Monitoring of adults. Adults of *Agriotes ustulatus* Schaller, *A. lineatus* L. and *A. brevis* Candèze were monitored using YATLOR sex pheromone traps (Furlan et al. 2001) in 2004 and 2005. Pheromone traps were deployed from mid March to the end of August. Lures were replaced once a month; traps were emptied every third day, the adults caught were counted and frozen until determination.

Bait traps – Monitoring of larvae. Traps were made and used according to the description given by Chabert & Blot (1992) and a modified version of the trap described by Kirfman et al. (1986). The traps were made out of flower pots (12 cm diameter) with a perforated bottom (eight evenly spaced holes). The pots were filled with a wheat/maize mixture (30 ml of each) and vermiculite (ca 420 ml). The grain seeds were soaked in water for 24 hours before addition. The traps were moistened before being dug into the soil and covered with an upside-down saucer placed a few centimetres above the rim of the pot. The bait traps were emptied every 16 to 20 days and refilled with fresh bait. The trap contents were hand sorted in the laboratory for 10 minutes on average. For more precise extraction the samples were put into funnels (26 cm diameter) fitted with a 0.5 cm mesh and a vial at the bottom according to the Tullgren method (Furlan 1998). The samples were allowed to dry for at least 30 days in a dry and sheltered place.

2.2 Comparing the efficiency of bait traps

Site description. The trial was conducted during the 2006 growing season in Raasdorf (48° 13' 0″ N, 16° 33' 0″ E), Gänserndorf, Lower Austria. Raasdorf is part of the Marchfeld, a region of intensive crop cultivation. The soil was a dry Chernozem of calcareous fine sediment with a humus content of 3.4%. The experiment was done in a field known to be infested with wireworms. The field was being used to grow spinach for production of deep frozen food. At the time of the trial, the spinach was at the growth stage BBCH 12, with the second true leaf unfolded. Soil temperature at 5 to 15 cm depth was recorded throughout the experiment.

Trial design. An area of 40 × 56 m (0.22 ha) was used for the experiment. The traps were placed in the ground on a 5 m × 9 m grid (45 bait points), at intervals of 7 m in one direction and 5 m in the other. Fifteen of each trap type (see below) were used. The assignment of trap type to bait point was random.

Trap types. Three different traps were used: (A) Flowerpot, round (12 cm diameter) perforated bottom with 8 holes, covered with an upside-down saucer. (B) Plastic pot, square (11 cm) with 81 holes in the bottom. (C) Plastic pot, square (11 cm) with 81 holes in the bottom and 81 holes on each sidewall (total of 405 holes per trap). A lid perforated with nine holes was placed on the square plastic pots of trap types B and C. The additional holes in trap types B and C were made using a 4 mm soldering iron. All bait traps were filled with a wheat/maize mixture (30 ml of each) and vermiculite. The traps were put in position on 11 September 2006 and dug up two weeks later. The trap contents were analysed as described above (2.1).

2.3 Statistical analysis

The homogeneity of the data for bait trap comparison was confirmed using a Leven-Test. Data were analysed using a one-way ANOVA. Statistics were calculated with SPSS version 15.0.

3 Results

3.1 Changes in population density of three *Agriotes* spp. over the season

A total of 2641 adult *Agriotes ustulatus*, *A. lineatus* and *A. brevis* were captured by the pheromone traps. In Upper Austria, 91.3% of the click beetles captured were *A. lineatus*, and only a few individuals of *A. ustulatus* (8.2%) and *A. brevis* (0.4%) were trapped. In Lower Austria, *A. ustulatus* (58.1%) was the most common species, followed by *A. brevis* (21.7%) and *A. lineatus* (20.1%).

A. ustulatus males began to appear in the traps towards the end of June and were present continuously until the beginning of August (Fig. 1a). Two peaks were observed in July. The pattern in 2005 was similar to that in 2004, but with somewhat lower numbers in Lower Austria and only a few individuals being caught in Upper Austria. No *A. ustulatus* were observed in August.

The first *A. lineatus* beetle catch was recorded at the end of April and the species continued to be found until the end of August (Fig. 1b). In 2004, two peaks were observed, one at the end of May and beginning of June, and another in late July. In 2005, the pattern was similar but the second peak was less well defined, especially in Upper Austria.

Adult *A. brevis* males were first observed in Lower Austria on 21 April 2004 and numbers declined to near zero by the middle of June (Fig. 1c). The same pattern was observed in 2005. Only very few *A. brevis* adults were caught in Upper Austria.

At the trial site in Upper Austria no wireworms (larvae) were caught. In Lower Austria, a total of 144 wireworms were captured (Fig. 2) which were nearly all *A. ustulatus*. In 2004, the most wireworms were caught in July and in 2005 from the end of June until the end of July.

3.2 Comparing the efficiency of bait traps

In the experiment comparing different types of bait trap, a total of 163 wireworms were found (Fig. 3). More larvae were found in the traps with more holes, but the differences were not statistically significant ($F = 1.84$; df = 2.33; $P = 0.17$).

4 Discussion

The present study was done to find out which species of the genus *Agriotes* are common in parts of Austria and to discover whether the sensitivity of bait traps could be improved.

4.1 Seasonal fluctuation of three click beetle species (*Agriotes* spp.) in two parts of Austria

We observed *A. ustulatus* adults above-ground activity from the end of June to the beginning of August in both years with a capture peak at the beginning of July. These data are in agreement with those of Furlan (1996), who studied *A. ustulatus* over a five-year period near Venice (Italy). Subchev et al. (2004) observed a similar swarming period of *A. ustulatus* in Bulgaria in 2000, and so did Kovács et al. (2008) in Hungary 2005. By and large, the swarming period seems to be uniform from July to August, although the exact timing of the peak activity varies, probably depending on the weather.

The species *A. lineatus* spends the winter as adults in the soil (Kabanov 1975, Tóth 1984), therefore, the adults appear earlier in the year than adults of *A. ustulatus* beetles, which overwinter as larvae (Furlan 1998). We observed the flight of *A. lineatus* from May to the beginning of August, which agrees with results from Bulgaria (Subchev et al. 2004) and Hungary (Tóth et al. 2001). The first *A. lineatus* beetles appeared at the end of April, as was also observed by Kovács et al. (2008) in Hungary and Kabanov (1975) in Krasnodar, Russia. In Belgorod, 650 km north of Krasnodar, *A. lineatus* specimens appeared later, in the first half of May (Kabanov 1975). Initial catches were also observed between 24 April and 5 May in British Columbia and Washington State by Vernon et al. (2001). In both years, we found two peaks of activity, the main

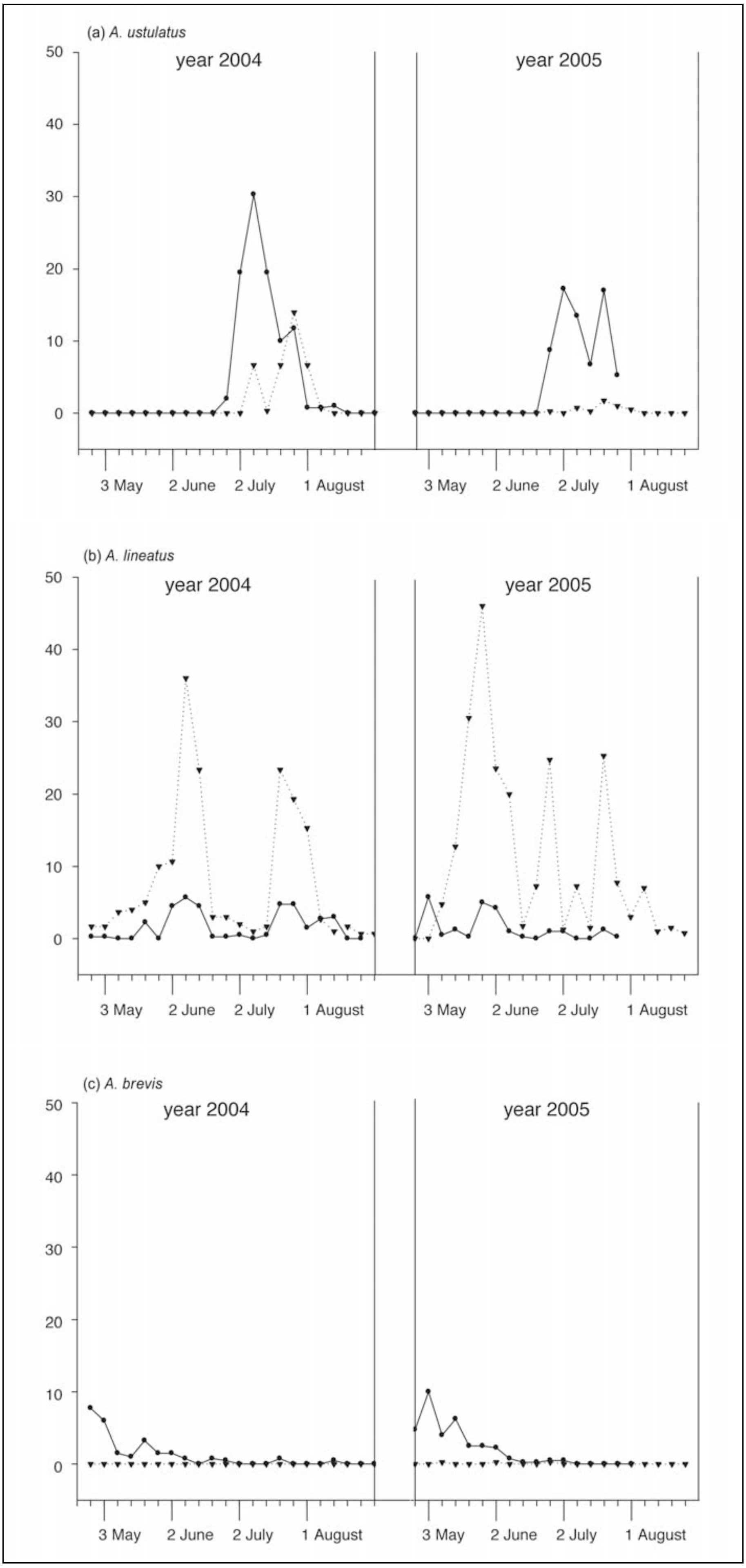

Fig. 1: Mean number of adult (a) *A. ustulatus* Schaller, (b) *A. lineatus* L. and (c) *A. brevis* Candèze caught by pheromone traps at ——●—— Untermallebarn, Lower Austria and ···▼··· Oberschaden, Upper Austria in the years 2004 and 2005.

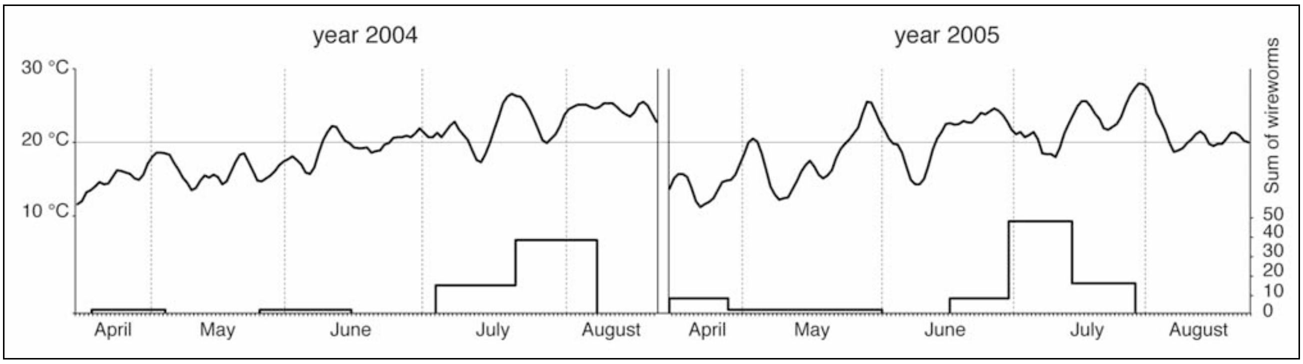

Fig. 2: Curves show soil temperature at a depth of 15 cm; Bars show the sum of wireworms caught by bait traps at Untermallebarn, Lower Austria.

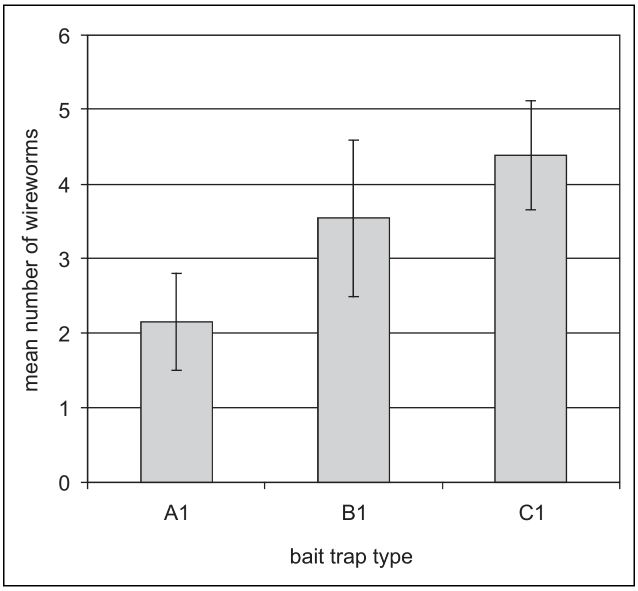

Fig. 3: Mean number of wireworms (counted wireworms were standardized as mean per trap type) found in different bait trap types at Raasdorf, Lower Austria 2006. Bait trap types: A1 = Flower pot with 8 holes, B1 = Plastic pot with 81 holes and C1 = 405 holes per trap. Error bars indicate standard error of the mean.

one at the end of May and a second smaller one in mid-July, which was less clearly defined in 2005. A similar trend was found by Tóth et al. (2001) and Kovács et al. (2008) in Hungary but the latter did not investigate the period after the first peak and observed a shift in swarming one year later. *A. lineatus* was by far the most abundant species at the site in Upper Austria, which was next to a riparian forest, which is their natural habitat (Koch 1989). According to Tóth (1984) and Kabanov (1975), the species generally prefers relatively moist conditions.

The first individuals of *A. brevis* were found on 21 April. Unfortunately the numbers of primary catches were already high (in Lower Austria), indicating that the beginning of the emergence period had been missed. According to our data and observations by Rusek (1972a, 1972b), who trapped the first imagines on 25 April, we suspect that swarming began in the second or third week of April. In Bulgaria *A. brevis* started flying later; Subchev et al. (2004) reported on first catches in the third week of May. Our investigations showed that *A. brevis* was most active in May, with a gradual decline to near zero activity by the middle of June. This agrees approximately with the study by Rusek in the Czech Republic, though there *A. brevis* was active until the end of June (Rusek 1972a, 1972b). Like Rusek, we found a few adults in August. Rusek assumed that these “late” adults were newly hatched, which was contrary to the general belief that adult *A. brevis* overwintered in the soil. Much stronger late-season activity was observed in Bulgaria, where *A. brevis* continued swarming until the middle of August in Belchin (60 km south of Sofia), and even longer near Sofia, until the beginning of October (Subchev et al. 2004).

Overall our observations show that the above-ground activity of *Agriotes* spp. adults varies according to different localities and years (Furlan 1996, Kabanov 1975, Rusek 1972a, 1972b), but is similar if climatic conditions are comparable. Other variables include the composition and dominance of species between years. It is assumed that various climate conditions and different development cycles are the reason for these varieties (Kovács et al. 2008).

Whilst all three species were attracted to pheromone traps, no wireworms were captured by bait traps in Oberschaden and only individuals of *A. ustulatus* were attracted by bait traps in Untermallebarn. This indicates that either species composition of larvae is different from that of adults – i.e., that the adults move to a different location from where they hatched –, or that bait traps are not efficient enough to reflect the actual larvae present. As the soil was not bare during the trial, the wireworms may have been more attracted to the roots of the crops than to the traps. However, it is unlikely that the attractiveness of roots selects so cleanly between species, and more probable that the bait traps are simple too inefficient to provide a picture of the wireworm populations. Because of this, we decided to test modifications of the bait traps to see whether their efficiency could be improved.

4.2 Comparing the efficiency of bait traps

Efforts are being made to develop a system in which the monitored population of adults represents the larval population. The most effective tools for monitoring the latter are bait traps, but so far they are at best only a qualitative presence/absence indicator (Parker 1994) and do not give useful estimates of the larval population densities. To obtain more meaningful results with bait traps, their efficiency must be improved, which we tried to do by multiplying the number of holes. This measure should increase the spread of CO_2, which is the main attractant in bait traps (Klingler 1957, Doane et al. 1975). Our study indicated that traps with more holes tended to be more effective than those with fewer. Parker (1994) found a similar trend when he compared cereal baits put in traps (30 holes; 24 in the side and 6 in the base) with those that were just put into holes in the ground. The latter were more attractive. This clearly proves that the more permeable traps are, the better they work.

Additionally, we achieved higher trap catches by closing the traps with a lid. Closing the trap is likely to stimulate seed germination and raise the temperature, as Ward & Keaster (1977) observed in traps covered with polyethylene. An increased temperature in traps may attract wireworms from a wider radius around the trap, especially in spring when soil temperatures are low.

To conclude, it appears that pheromone traps work well and can be part of an assessment system for integrated pest management of *Agriotes* species. However, further investigations are needed to prove: (a) if making bait traps more sensitive leads to a more reliable estimation of the wireworm population and (b) if through the use of the new bait trap design the correlation of adults (caught by pheromone traps) and wireworms has become more reliable. If it is not possible to prove these two points, then bait traps need substantial improvement, or alternatively, a different method needs to be developed to enable useful quantification of wireworm populations.

Acknowledgements

We wish to thank Mr. Anton Riedl and Mr. Helmut Winklehner for providing the fields for our investigations.

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