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Observations on natural mortality factors in wireworm populations and evaluation of management options

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Abstract: Wireworms (*Agriotes sordidus, Agriotes ustulatus*) have been reared in rearing cages placed into fields over a five year period (2004 – 2008) in order to evaluate the effect of rotation on larval development and the potential role of biocidal plants (*Brassica juncea* var. ISCI 99) to reduce wireworm populations in comparison with other mortality factors. Wireworm populations in cages planted with different rotations (**continuous rotation**, very short interruption between different crops, **discontinuous rotation**, long periods with bare soil between crops, meadow) were estimated by using bait traps at monthly intervals. Soil with continuous vegetation cover allowed more larvae to survive. Biocidal plant root systems did not cause significant larval mortality. The incorporation of the above ground material of *Brassica juncea* sel. ISCI 99 at a dosage of 55 t ha^{-1} of fresh matter corresponding to about 290 µmoles of GLs l^{-1} of soil, significantly reduced wireworm populations. In the end of the rotation period the larvae were placed in vials inspected twice per week in order to establish larval mortality. According the cause of dead, dead larvae were divided into the following groups: *Metarhizium* spp., *Beauveria* spp., Nematodes, Uncertain. The percentage of larvae found dead because of insect pathogen infection was low and did not differ between larvae coming from different rotations.

Key words: Wireworms, *Agriotes*, mortality factors, rotation, biocidal plants, pathogens

Introduction

Wireworms, the soil-dwelling larvae of click beetles (Elateridae), are widely distributed throughout the world and are important pests of several crops. In Europe, the species of economic importance predominantly belong to the genus *Agriotes*. Traditionally, control of wireworms has relied on conventional pesticide chemistry. However, these treatments are not always fully effective and their use poses potential environmental risks. Therefore, studies on the alternative, sustainable strategies for managing wireworms were performed over the last years. The effects of different rotations and particularly of biocidal plants on wireworm population dynamics were studied. The potential role of wireworm pathogens was also investigated.

Material and methods

Facilities and experimental layout

The rearing facility cages were placed at the border of an open field. They were made of concrete 1 m^2 x 1 m deep, open at the bottom to allow drainage. The cages were closed on the top with netted cages (1-2 mm mesh) 1m^2 x 1m high that allowed rain to penetrate. The cages were filled with a sandy soil, which had been dried in the open air for two months. During dry (low rainfall) periods, the cages were irrigated at least once a week to maintain a suitable soil moisture level in the upper part of the soil.

The following rotations were compared with 4 replications in cages, which were divided into two parts (each half cage was a replication): 1) **Continuous rotation** (very short interruption between different crops, continuous soil cover with plants): Year 1 (04-05): pea seeds (cv. Corallo) – hemp; Year 2 (2006) spring barley, biocidal plant (*Brassica juncea* sel. ISCI 99, after barley harvest), which subsequently was incorporated into the soil at flowering, Year 3 (2007): sugar beet; 2) **discontinuous rotation** (long periods with bare soil between crops and more tillage disturbance); maize (2005), winter wheat (2005-2006), sugar beet (2007); 3) **meadow** (continuous soil cover with plants, no soil disturbance, optimal conditions for wireworms): rye grass - *Festuca* spp. 2004 – 2006; sugar beet 2007.

In order to evaluate the effect of individual factors on wireworm populations eight additional cages were planted with continuous rotation and split into two groups after barley harvest: A) four cages were half kept with bare soil and half planted with *B. juncea*; B) four cages were planted with *B. juncea*. In one half of each of the four cages, plants were incorporated as described below and in the other half the above ground plant parts were cut at flowering and removed from the cages (untreated - no incorporation). Removed plant material was used to arrange the required dosage (described below) to be incorporated in any other cage sectors where needed.

In cage sectors with plant incorporation the *B. juncea* plants were cut and chopped into 2-5 mm pieces and were immediately homogeneously mixed and incorporated (55,5 t ha^{-1}) into the upper 17 cm of soil; sinigrin glucosinolate content of the fresh plants was about 9 µmoles/g; the average sinigrin dosage was about 290 µmoles of GLs l^{-1} of soil;

The biological activity of *Brassica juncea* is linked to the cellular presence of the glucosinolate (GLs) - myrosinase system which, in the presence of water, produces a number of biologically active compounds including isothiocyanates, nitriles, epithionitriles and thiocyanates (Fahey *et al.*, 2001).

Groups of 50-100 adults of *A. sordidus* Illiger (late spring) and of *A. ustulatus* Schäller (summer) were put into each cage every 7-15 days from early May to mid June. A total of about 200 adult females per cage was used.

Study of larval development and mortality factors

From July onwards, two bait traps (Chabert and Blot, 1992) per cage were placed in the centre of each cage once per month. These were assessed by hand after 7-10 days. In order to recover all the larvae, all material from the trap was first manually sorted and then put into Tullgren funnels and allowed to dry for 15-20 days. Larvae were collected in vials containing moist soil as described above. The head width of all the larvae collected was measured and recorded before returning them to the cage. The larvae were assigned to the respective instar based on the head measurements found in laboratory studies taking into account the standard deviation ranges (Furlan, 1998 and 2004).

The larvae were returned to the cages until the beginning of the last year; from this point on all the larvae were placed individually in plastic vials (2,8 cm in diameter and 8,7 cm high and closed by an airtight plastic lid), filled with moistened sandy soil to half-height and inspected twice per week. The vials were put in small chambers maintained at 25°C.

Statistical analysis

Data were subjected to a $\sqrt{(n+0.5)}$ transformation and analyzed by analysis of variance (ANOVA). Tukey test was used to determine differences between means.

Results and discussion

Rotation effect

Population levels were significantly affected by the rotation (Table 1). Soil with continuous vegetation cover allowed more larvae to survive as observed for the same species *Agriotes sordidus* Illiger in field conditions (Furlan and Talon, 1997). In the first years meadow competition reduced the number of larvae caught by bait traps; in the last year after the removal of previous crops the highest populations were found in cage sectors planted with meadow where there was no disturbance during the first two growing seasons.

Table 1. Effects of rotation on wireworm populations (number of larvae/cage sector/ inspection). Means with different letters are significantly different at P = 0,05

	Before biocidal incorporation (3/3/2006 - 12/10/2006)			**After biocidal incorporation** (27/10/2006 - 7/10/2007)		
Continuous rotation	0,60		b	0,79	a	b
Discontinuous rotation	0,28	a		0,38	a	
Meadow	0,22	a		1,11		b

Effect of the growing biocidal crop

Biocidal plant root systems allowed wireworm development and did not cause significant larval mortality (Table 2). The rotation including the biocidal crops without incorporation of the above ground part of the plants allowed the establishment of a population comparable to that found in meadow, but significantly higher than in discontinuous rotation.

Table 2. Effect of cultivation of biocidal plants on wireworm populations (number of larvae/ cage sector/inspection). Means with different letters are significantly different at P = 0,05

	Before biocidal plants 3/03/2006 - 17/08/2006		**During biocidal plants** 5/09/2006 - 9/10/2006		**After biocidal plants** 27/10/2006 - 7/10/2007	
Biocidal plants in rotation	0,47	a	0,44	a	1,17	b
Untreated (bare soil)	0,24	a	0,44	a	0,38	a

Effect of the incorporation of the above ground part of biocidal plants

Broadcast incorporation of chopped plants of *B. juncea* sel. ISCI 99 at a dosage of 55 t ha^{-1} of fresh matter corresponding to about 290 μmoles of GLs l^{-1} of soil caused a high larval mortality (Table 3). This confirmed the preliminary results obtained in laboratory conditions (Furlan *et al.*, 2004)

Larval mortality

The number of larvae affected by pathogens did not differ between different rotations (Table 4). Since the observations were limited to developed larvae (6^{th} to 8^{th} instars for *A. sordidus* and 9^{th} to 11^{th} instars for *A. ustulatus*) it was not possible to evaluate the effect of pathogens on the first instars.

Rotation was the primary factor influencing larval populations and pathogens were not capable to decrease wireworm populations.

Table 3. Effect of biocidal plant incorporation on wireworm populations (number of larvae /cage sector/inspection). Means with different letters are significantly different at P = 0,05

	Before biocidal incorporation (3/3/2006 - 12/10/2006)		**After biocidal incorporation** (27/10/2006 - 7/10/2007)	
Incorporation of chopped biocidal plants	0,43	a	0,65	a
Untreated (no incorporation)	0,30	a	1,90	b

Table 4. Mortality factors: number of larvae killed by pathogens within 90 days from collection from cages planted with the different rotations under study

	Caught larvae	**Metarhizium spp.**	**Beauveria spp.**	**Nematodes**	**Uncertain**
Continuous rotation	41	1	0	0	2
Discontinuous rotation	30	1	0	0	1
Meadow	58	2	1	1	3
Total	**129**	**4 (3,1%)**	**1 (0,7%)**	**1 (0,7%)**	**6 (4,5%)**

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