Woodlice (Isopoda) and millipedes (Diplopoda): control of rare greenhouse pests

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Woodlice (Isopoda) and millipedes (Diplododa) are saprophages that generally occur in soils. They are appreciated for returning nutrients to the soil. In greenhouse crops they may cause serious plant damage, especially in organic growing. Population development in different composts was monitored for the woodlouse *Armadillidium vulgare* and the millipede *Oxidus gracilis* and was found strongly correlated with compost maturity. The potential of soil dwelling predators (mites, centipedes and a staphilinid beetle) for biological control was evaluated, but without encouraging results.

Keywords: biological control, *Armadillidium vulgare*, *Oxidus gracilis*, compost, predators

Woodlice (Isopoda) and millipedes (Diplododa) are widely distributed saprophages generally occurring in soils. They are major consumers of organic debris and beneficial for return of nutrients to the soil. In organic growing in greenhouses, however, extreme populations may build up causing serious damage to vegetables. The large amounts of composts used in such cultures provide an ideal habitat for these arthropods. Occasional feeding on plants may there become a problem because of the excessive numbers involved. The woodlouse species *Armadillidium vulgare*, *Porcellio scaber* and *Porcellionides pruinosus* were observed to feed on young leaves and growing points of various vegetables, on the calyx of sweet pepper fruit and on the skin of cucumber fruit (Messelink, unpublished). The most abundant millipede found in Dutch greenhouses is *Oxidus gracilis* (Polydesmida). At high population levels this species injures cucumber plants by feeding on the upper roots parts and on the graft union (Messelink, unpublished).

Effective biological agents for controlling woodlice and millipedes are lacking. Organic growers currently use desperate methods, for example disseminating bran in the evening and destroying the attracted arthropods next morning with a gas burner. The objective of this study was to find methods to prevent

extreme population growth of woodlice and millipedes in greenhouse. An experiment was set up to assess the impact of compost characteristics on woodlice development. Secondly, the potential of some soil dwelling predators was evaluated in laboratory experiments. Woodlice do have many vertebrate natural enemies including little owls, hedgehogs and toads (Berg & Wijnhoven 1997). Most of them occur in far too low numbers, and are absent in greenhouses anyway. Invertebrate predators like Carabidae, Staphylinidae and Araneae are far more important. In a survey up to 80 arthropod predator species were found in a dune grassland ecosystem. The centipede *Lithobius forficatus* was believed to be the most important predator of woodlice (Sunderland & Sutton 1980). In our study we evaluated two centipede species isolated from organic vegetable greenhouses in The Netherlands. In addition some predatory mites and one commercially available staphilinid beetle were tested.

MATERIAL AND METHODS

Compost colonisation experiment

Population development of the woodlouse *A. vulgare* and the millipede *O. gracilis* was monitored in two types of compost of different ages. Both compost types were based on yard waste, but type B had some clay added at the start of the composting process for formatting of a clay-humus complex. At the start of the experiment, all composts were characterized by measuring the percentage of organic matter, respiration rate (Oxitop®-method according to Veeken *et al.* 2003), mean fraction size and acidity (pH) (Table 1). Fresh compost A was shredded before use and all other composts were sieved inorder to remove particles over the size of 10 mm. Plastic containers (30 x 40 cm) were filled with 6 liter of compost. 30 adult woodlice (*A. vulgare*) or 40 adult millipedes (*O. gracilis*) were added. The containers were kept in a climate room under long day illumination (L16:D8) at 20°C and 70% RH. Weight loss was compensated for every week by adding water. The experiment was carried out in 4 replicates. Numbers of woodlice were counted in each container after 16 and 29 weeks, and millipede numbers after 18 weeks. These numbers were transformed on a log scale before analyses of variance (ANOVA) and Fisher least significant differences (LSD) tests were applied.

Predation experiment in arena

Laboratory predation tests were set up with a number of predators to evaluate each for their ability to feed on the youngest stages of the woodlice *A. vulgare* (up to 2 mm) and the millipede *O. gracilis* (up to 5 mm). In addition the predators were offered freshly killed (shortly frozen) woodlice and millipedes to assess their potential as scavengers. The following predators were tested: larvae of the staphylinid beetle *Atheta coriaria*, the centipedes *Lamyctinus coeculus* and *Lithobiidae* sp., and the soil-dwelling predatory mites *Hypoaspis miles* and

Table 1. Compost characteristics.

compost type[1]	organic matter (%)	respiration rate (mmol O_2/kg VS/h)[2]	mean fraction size (mm)[3]	pH
fresh compost A	52	22.4	2.17	7.8
half matured compost A	36	10.2	0.72	7.7
matured compost A	26	5.3	0.56	7.6
fresh compost B	41	14.2	2.37	7.0
matured compost B	17	6.4	0.95	7.6

[1]yard waste composts, compost B is with addition of clay; [2]according to Veeken *et al.* (2003), VS = volatile solids; [3]based on distribution over 8 sieves

Macrocheles robustulus. The predators were tested in small containers (ø 3 cm) on moist filter paper. Predatory mites were tested as a group of 10 female adults. The other predators were tested individually to avoid cannibalism. Predation ability was observed over a period of 7 days. As a control treatment the predators were offered five adults of the collembolan *Folsomia candida*.

Predation experiment in soil

A second experiment was set up with the predator *L. coeculus* to assess the effect on different stages of *A. vulgare* and *O. gracilis* under soil conditions and over a longer period. This experiment was carried out in plastic containers (10 x 15 cm) with 250 g potting soil and a fresh cucumber leaf as a food source. Both millipedes (*O. gracilis*) and woodlice (*A. vulgare*) were sorted according to size. Ten individuals of each size were incubated together with two adult predators of *L. coeculus* for a period of six weeks. Control containers remained without predators. The experiments were carried out in eight replicates for the predator treatments and four replicates for the control treatments. The containers were kept in a climate room under long day illumination (L16:D8), at 22°C and 70% RH. Moisture content was kept constant in all containers. Numbers of woodlice, millipedes and predators were counted in each container after six weeks and analysed using the REML (Restricted Maximum Likelyhood) statistical procedure.

RESULTS

Compost colonisation experiment

Populations of millipedes and woodlice increased strongly in the fresh composts, whereas in mature composts woodlice hardly survived (Table 2). Population development of woodlice was strongly correlated with the compost characteristic percentage organic matter and consequently with the respiration rate (Fig. 1). A similar but weaker trend was found for millipedes. On fresh compost with clay, millipedes developed better than woodlice did.

Table 2. Mean numbers of woodlice (*Armadillidium vulgare*) and millipedes (*Oxidus gracilis*) (±se) per container. Means in a column followed by the same letter are not significantly different ($p<0.05$).

	woodlice		millipedes
compost type[1]	after 16 weeks	after 29 weeks	after 18 weeks
fresh compost A	225 (25.7) a	381 (54.7) a	605 (150.0) a
half matured compost A	27 (18.1) bc	131 (50.8) b	37 (30.7) c
matured compost A	9 (0.9) cd	32 (7.8) c	180 (94.6) b
fresh compost B	31 (10.2) b	82 (16.3) bc	739 (71.5) a
matured compost B	5 (1.2) d	2 (0.9) d	162 (44.4) b

[1]yard waste composts, compost B is with addition of clay

Predation experiments in arena

All predators were observed feeding on the collembolan *F. candida* (Table 3). The staphylinid predator *A. coriaria*, the centipede *L. coeculus* and the predatory mite *H. miles* did not feed at all on woodlice or millipedes. The larger centipede *Lithobius* sp. did feed on dead woodlice, but not on the living ones, whereas millipedes were eaten alive and dead, although this was limited to the head part. Predatory mites did not feed on millipedes. *M. robustulus* was the only predator that attacked and killed living woodlice and also ate dead woodlice. Survival of *M. robustulus* in association with woodlice was, however, very low and cannibalism was observed. In the presence of collembolans predatory mites did not practice cannibalism.

Predation experiment in soil

The predator *L. coeculus* had no apparent effect on any instar of either woodlice or millipedes (Table 4, Fig. 2), which confirms the arena observations. However, in all containers except for the controls both original adults and progeny of the predators were present.

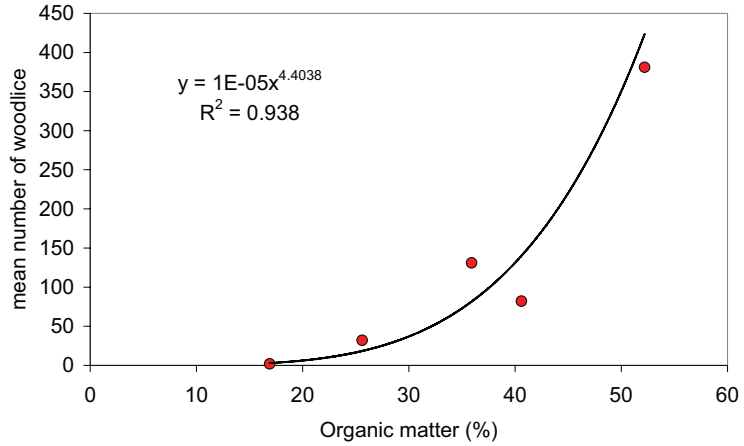

Figure 1. Correlation between percentage of organic matter of composts and the final number of woodlice.

Table 3. Feeding ability of predators on young stages of woodlice (*Armadillidium vulgare*),of millipedes (*Oxidus gracilis*) and adults of (*Folsomia candida*) in an arena. + = feeding observed, - = no feeding observed.

predator	woodlice		millipedes		springtails
	alive	dead	alive	dead	
Atheta coriaria larvae (Staphylinidae)	-	-	-	-	+
Lamyctinus coeculus (Chilopoda)	-	-	-	-	+
Lithobiidae sp. (Chilopoda)	-	+	+[1]	+[1]	+
Hypoaspis miles (Acari)	-	-	-	-	+
Macrocheles robustulus (Acari)	+	+	-	-	+

[1]feeding limited to the head part

Table 4. Mean survival of different stages of woodlice (*Armadillidium vulgare*) and millipedes (*Oxidus gracilis*) in the presence (+) or absence (-) of the centipede *L. coeculus* after six weeks. Means in a row did not differ significantly ($p<0.05$).

prey organism	mean length (mm)	- centipede	+ centipede
woodlice	2.7	8.0	7.0
woodlice	3.8	8.8	7.5
woodlice	5.1	9.0	9.0
woodlice	6.5	9.3	8.8
millipedes	4.8	5.8	6.4
millipedes	7.1	7.3	6.5
millipedes	10.9	6.8	7.3
millipedes	16.7	5.5	6.0

Figure 2. Adults of the centipede *Lamyctinus coeculus* with an early instar of the millipede *Oxidus gracilis* in the upper right corner.

DISCUSSION

The compost experiment indicates that development of millipedes and especially woodlice depends highly on the maturity of the compost. Fresh composts with a high respiration rate gave the highest population increase. As consumers of organic debris, woodlice and millipede are dependent on the presence of suitable and degradable organic matter. Some organic growers use huge amounts of fresh composts to fertilize during the growing period of their crop. Precomposting this material may help to manage millipede and woodlice populations on an acceptable level.

Control of woodlice and millipedes with soil dwelling arthropod predators appears less promising. None of the predators in the laboratory confrontation test was very convincing in killing these targets. Although the predatory mite *M. robustulus* was able to prey on living woodlice, their survival was low and cannibalism was observed, suggesting a low food quality. Millipedes were ignored by most predators, even when presented dead. Predation of *O. gracilis* by the centipede *Lithobiidae* sp. remained limited to the head parts, suggesting a strong repellant effect of the body. Millipedes secrete odors from glands on all body segments as a defense mechanism. Mandelonitrile is known as the major secretion component of *O. gracilis* (Taira *et al.* 2003), which is decomposed in the volatiles substances benzaldehyde and hydrogen cyanide (Towers *et al.* 1972). The experiment with *L. coeculus* in soil confirmed the negative results of the arena observation.

The results of these experiments suggest that compost composition rather than the associated predator population is the main factor controlling populations of woodlice and millipedes. Sunderland & Sutton (1980) concluded that centipedes are important predators of woodlice, based on a serological test. However, this indirect method does not distinct predation from scavenging. The tested Lithobiidae species in this experiment appeared to be a scavenger of woodlice. In this way, presence of woodlice may contribute to the reduction of other soil-borne pests by serving as an alternative food source, but they seem little affected by predators themselves.

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