**© 2011 Triveni Enterprises**
Vikas Nagar, Lucknow, INDIA
editor@jeb.co.in
Full paper available on: www.jeb.co.in

**J. Environ. Biol.**
**32,** 793-799 (2011)
ISSN: 0254-8704
CODEN: JEBIDP



# Effects of granulated baits on meso and macrofauna in soybean soil system

**Author Details**

| | |
|---|---|
| **C. Salvio** (*Corresponding author*) | Faculty of Agricultural Sciences, National University Mar del Plata – Experimental Station of the National Institute of Agricultural Technology (INTA). C.C. 276 (7620) Balcarce, Argentina<br>e-mail: carlasalvio@hotmail.com |
| **A.N. Lopez** | Faculty of Agricultural Sciences, National University Mar del Plata – Experimental Station of the National Institute of Agricultural Technology (INTA). C.C. 276 (7620) Balcarce, Argentina |
| **P.L. Manetti** | Faculty of Agricultural Sciences, National University Mar del Plata – Experimental Station of the National Institute of Agricultural Technology (INTA). C.C. 276 (7620) Balcarce, Argentina |
| **N.L. Clemente** | Faculty of Agricultural Sciences, National University Mar del Plata – Experimental Station of the National Institute of Agricultural Technology (INTA). C.C. 276 (7620) Balcarce, Argentina |

**Publication Data**

*Paper received:*
05 March 2010

*Revised received:*
10 September 2010

*Re-revised received:*
10 December 2010

*Accepted:*
08 January 2011

**Abstract**

Studies were done to see the effects of five toxic baits based on metaldehyde and/or carbaryl on the taxonomic composition of soil meso and macrofauna, and determined the density of beneficial organisms in soybean under no tillage. Six treatments were tested and soil monoliths were taken before application and at 45 and 75 days after application (DAA). Before application, 1601 individuals were recorded, belonging 1086 to mesofauna and 515 to macrofauna. In soil mesofauna such as Annelida: Enchytraeidae (44%), Nematoda (33%) and Arthropoda (23%) were found. In the macrofauna Arthropoda 93% and Annelida: Oligochaeta, Megadrilli 7% were observed. No differences were observed among the treatments (p>0.05) in the total mesofauna density, at 45 and 75 DAA. The density of enchytraeids, mites, collembolans and symphylids showed no differences at 45 and 75 DAA (p>0.05). The total macrofauna density showed differences (p<0.05) at 45 and 75 DAA. The highest density was obtained with 4 kg $ha^{-1}$ MataBibos Acay at 45 and 75 DAA. Earthworm and diplopod densities at 45 and 75 DAA showed no differences (p>0.05). The diversity of meso and macrofauna was not affected at 45 and 75 DAA. Bait application did not affect either the abundance or the diversity of soil beneficial invertebrates.

**Key words**

Toxic baits, Metaldehyde, Carbaryl, No tillage, Soil mesofauna and macrofauna

## Introduction

Cultivation of agricultural soil has until recently predominantly been achieved by intensive agricultural practices. The tendency at present is to carry out conservation tillage practices, such as no tillage (NT), reduced tillage and minimum tillage, because these systems contribute to protect soil from wind and water erosion (Holland, 2004). Thus, no-tillage (direct-drill or zero tillage) is the extreme form of reduced tillage where essentially no soil manipulation is performed prior to planting and prior crop residues are left on the soil surface (Stinner and House, 1990; Studdert and Echeverría, 2000a). Moreover, plowing acts as a physical disturbance affecting the horizontal and vertical distribution of soil biota. In a general sense, plowing should be viewed as a perturbation to soil invertebrate communities and has been associated with a reduction in the abundance and the diversity of several invertebrate and plant species (Stinner and House, 1990).

As noted Lavelle (2000), soil invertebrates play an essential role in suppressing specific plant pathogens, improving soil physical properties, decomposing organic matter and supplying nutrients to plants. Also, they are partly responsible for degradation of detritus and cycling of organic matter, whose nutrients are required by other organisms (Giesy *et al.,* 2000). In addition, soil fauna and biodiversity prevent pest outbreaks in agroecosystems by balancing the predator-herbivore ratio (Tillman *et al.,* 2004).

Soil invertebrates have relatively limited abilities to digest soil organic detritus, and rely, to a large extent, on micro-organisms to derive the assimilates they need from soil organic resources. Additionally, the attraction of micro-organisms by larger organisms appears to be essential to the maintenance and enhancement of the activity of microbial communities (Lavelle, 1997). This determines that one way to understand soil biota functions is to classify the biota on the basis of their body size *i.e.* micro-, meso and macrofauna (Swift *et al.,* 1979). Moreover, their responses to extreme climatic conditions, ploughing, indiscriminate agrochemical use and monoculture, suggest that larger organisms are more sensitive than smaller ones (Holland, 2004).

In cropping systems under no-tillage, soil organisms benefit from the reduction in soil disturbance; crop residues concentrate on the surface creating more stable microclimate conditions regarding soil humidity and temperature, which provides a more suitable habitat for the increase of beneficial organisms and harmful pests (Wilson-Rummenie *et al.,* 1999). For example, slugs [*Deroceras reticulatum* (Müller), *D. laeve* (Müller), and *Milax gagates* (Draparnaud) (Mollusca, Pulmonata: Stylommatophora)] and pillbugs [*Armadillidium vulgare* (Latreille) (Crustacea: Isopoda)] frequently cause damage to crops such as oilseed rape, soybean and sunflower (Clemente *et al.,* 2008; Larsen *et al.,* 2007; Garavano *et al.,* 2009). Slug and pillbug control is performed mainly by toxic granulated baits formulated as pellets with food attract and metaldehyde as molluscicide (2,4,6,8-tetramethyl-1,3,5,7,-tetraxocane) or carbaryl (1-naphthol N-methyl carbamate) as crustacicide (Salvio *et al.,* 2008). Molluscicide and crustacicide application could also be toxic for the organisms beneficial to soil meso and macrofauna. However, very little is known about the effect of metaldehyde and carbaryl on non-target organisms (Iglesias *et al.,* 2003; Bieri *et al.,* 1989). Field evaluations on the impact of molluscicides and crustacicides over beneficial organisms are thus required.

The aims of this investigation were to examine the effects of five baits based on metaldehyde and/or carbaryl on the taxonomic composition (diversity) of soil meso and macrofauna, and to determine the density of beneficial organisms.

## Materials and Methods

**Study site:** The experiment was carried out in a field located in Balcarce, Southeast of Buenos Aires Province, Argentina [37° 45´ S, 58° 18´ N, altitude 130 m (a.s.l.)]. The climate is mesothermal, subhumidity-humidity with a mean temperature varying between 22°C for the hottest month (January) and 8°C for the coldest one (July). Mean annual rainfall is 928 mm (mean annual rainfall 1970-2000) with a rainy season from September to February. The field had a fine, mixed, thermic Typic Argiudoll (USDA classification) and the surface horizon had a pH of 6 (1:2.5 in water), loamy texture, 33.1 cmol kg$^{-1}$ cation-exchange capacity, 5.0 mg kg$^{-1}$ Bray and Kurtz P and 37.7 g kg$^{-1}$ soil organic C contents (Studdert and Echeverría, 2000b). The study was carried out on a soybean (*Glycine max* L.) crop cultivated under no-tillage (NT) to a 5 cm depth with a rotary tiller. The area presented a slug density of 8 ind m$^{-2}$ of *Milax gagates* (Draparnaud), and an isopod *Armadillidium vulgare* (Latreille) density of 70 ind m$^{-2}$.

**Experimental design and cropping system:** On November 2007, commercial soybean (*Glycine max* L. var. Nidera 4200) was sowed at a density of 450.000 p ha$^{-1}$ at 42 cm row spacing on a cropping system under no-tillage. Chemical fertilizers were applied at a sowing rate of 80 kg ha$^{-1}$ diamonic phosphate and 150 kg ha$^{-1}$ urinate. Glyphosate, at a dose of 1-1.5 l ha$^{-1}$ was also applied as herbicide.

The commercial products used (formulated as pelleted baits) were metaldehyde 4%+ carbaryl 8% Dual Acay, molluscicides 4% metaldehyde Acay and crustacicides 8% carbaryl Mata Bibos Acay (Acay Agro S.R.L.) and 5% metaldehyde Clartex and 8% carbaryl Clartex BB (Rizobacter Argentina S.A.).

Experimental design was arranged in randomized blocks with three replications. The treatments were: 6 kg ha$^{-1}$ Dual Acay; 4 kg ha$^{-1}$ molluscicide Acay; 4 kg ha$^{-1}$ molluscicide Clartex; 4 kg ha$^{-1}$ MataBibos Acay; 4 kg ha$^{-1}$ Clartex BB and control. The size of each experimental plot was 400 m$^2$, and the baits were applied by hand on 19 November, 2007.

**Sampling technique:** From the study area, 10 soil monoliths (25.2 cm side; 30 cm depth) were taken randomly before baits application. The sampling was done at 45 and 75 days after bait application (DAA) and in each plot, one soil monolith was taken on each sampling date (total samples = 18). In order to separate specimens, the soil was sequentially sifted through two screens of 10 and 2.5 mm opening diameter. Stones and large pieces of debris were removed by hand from the first screen; smaller organisms were removed from the second screen. Then, the soil was separated in visually homogeneous layers 1-4 mm thick, which were analyzed by hand-sorting. They were recorded and examined by means of a stereomicroscope at a 160 magnification and of a microscope at a 400 magnification to verify species identification of the meso and macrofauna.

**Statistical analysis:** Macro and mesofauna density data were analyzed using generalized lineal models assuming a binomial negative distribution. Poisson distribution was used for nematodes. Both analyses were made using the SAS GLM procedure (SAS v. 8 software 2001). When significant effects were detected among treatments, contrasts were carried out with control ($\alpha$ = 0.05) (Mc Cullagh and Nelder, 1989).

Meso and macrofauna family diversity was obtained applying the Shannon-Weaver index (*H´*), and evenness Pielou index (E) (Brévault *et al.,* 2007) at both 45 and 75 days after application (DAA) of baits.

## Results and Discussion

**Mesofauna and macrofauna before bait application:** A total of 1601 individuals were recorded, belonging 1086 to mesofauna and 515 to macrofauna. Mainly 3 phyla were found in soil mesofauna (Table 1). Annelida organisms were the most abundant, accounting for 44%, followed by nematoda and arthropoda with 33 and 23%, respectively. In Insecta, collembola was the most abundant class, accounting for 13% of the arthropod density and there were few Acarina 7% and Symphyla 3% (Table 1). Regarding macrofauna, 2 phyla were observed, Arthropoda 93% and Annelida 7%. Within Arthropoda, Diplopoda (54%) and Insecta (31%) were the most numerous arthropod groups. Diplopoda essentially consisted of Polydesmida, and Insecta; mainly of Diptera, Coleoptera larvae and adults of Hymenoptera (Table 1).

In general, the Arthropoda was the most abundant organism group of soil meso and macrofauna in soybean crop under no-tillage before bait application (Table 1). In agreement with Rodriguez *et al.* (2006), the arthropod density in conservation tillage practices, such as no tillage (NT), is higher.

**Table - 1:** Density (ind $m^{-2}$) of mesofauna and macrofauna before bait application (BBA), 45 and 75 days after application (DAA)

| | Phylum | Class | Order | Family | Density (ind $m^{-2}$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | BBA | 45 DAA | 75 DAA |
| **Mesofauna** | Annelida | Oligochaeta | | Enchytraeidae | 1203 | 227 | 73 |
| | Nematoda | | | | 907 | 334 | 303 |
| | Arthropoda | Insecta | Collembola | Onychiuridae | 189 | 93 | 157 |
| | | | | Isotomidae | 157 | 71 | 106 |
| | | Arachnida | Acarina | Crytostigmata= Oribatida | 28 | 13 | 8 |
| | | | | Prostigmata= Actinedida | 106 | 38 | 28 |
| | | | | Mesostigmata= Gamasida | 61 | 8 | 3 |
| | | Symphyla | | Scutigerellidae | 93 | 81 | 51 |
| **Macrofauna** | Arthropoda | Chilopoda | Lithobiomorpha | Lithobiidae | 5 | 0 | 0 |
| | | | Scolopendromorpha | Scolopendridae | 23 | 43 | 18 |
| | | Diplopoda | Juliformia | Julidae | 298 | 268 | 245 |
| | | | Polydesmida | Polydesmidae | 407 | 147 | 20 |
| | | Insecta | Diptera | Diverse Diptera larvae | 139 | 149 | 51 |
| | | | Coleoptera | Scarabaeidae | 3 | 0 | 0 |
| | | | | Curculionidae | 28 | 5 | 0 |
| | | | | Elateridae | 0 | 5 | 0 |
| | | | | Chrysomelidae | 5 | 3 | 5 |
| | | | | Staphylinidae | 48 | 8 | 10 |
| | | | | Histeridae | 20 | 0 | 0 |
| | | | | Carabidae | 0 | 8 | 5 |
| | | | | Cucujidae | 10 | 10 | 18 |
| | | | | Dasytidae | 3 | 10 | 0 |
| | | | Hymenoptera | Formicidae | 111 | 83 | 323 |
| | | | Homoptera | Psyllidae | 28 | 45 | 76 |
| | | | | Aphididae | 10 | 8 | 0 |
| | | Crustacea | Isopoda | Armadillidae | 53 | 20 | 13 |
| | | Arachnida | Araneae | Diverse Araneae | 23 | 20 | 23 |
| | Annelida | Oligochaeta | Megadrilli | Diverse Megadrilli | 88 | 73 | 136 |

**Table - 2:** Abundance, taxonomic richness, diversity and evenness index of soil mesofauna in the different treatments at both 45 and 75 days after application (DAA)

| Treatments | Number of individuals $m^{-2}$ | | Number of families | | Shannon-Weaver index | | Evenness Pielou index | |
|---|---|---|---|---|---|---|---|---|
| | 45 DAA | 75 DAA | 45 DAA | 75 DAA | 45 DAA | 75 DAA | 45 DAA | 75 DAA |
| Control | 36 | 34 | 6 | 6 | 2.28 | 2.06 | 0.88 | 0.80 |
| 6 kg $ha^{-1}$ Dual Acay | 29 | 26 | 5 | 6 | 1.88 | 2.22 | 0.81 | 0.86 |
| 4 kg $ha^{-1}$ Molluscicide Acay | 26 | 20 | 7 | 4 | 2.48 | 1.93 | 0.88 | 0.97 |
| 4 kg $ha^{-1}$ Molluscicide Clartex | 26 | 28 | 6 | 5 | 2.28 | 2.06 | 0.88 | 0.89 |
| 4 kg $ha^{-1}$ MataBibos Acay | 29 | 16 | 5 | 4 | 1.65 | 1.59 | 0.71 | 0.80 |
| 4 kg $ha^{-1}$ Clartex BB | 33 | 21 | 5 | 6 | 1.96 | 2.26 | 0.84 | 0.87 |

**Table - 3:** Abundance, taxonomic richness, diversity and evenness index of soil macrofauna in the different treatments at both 45 and 75 days after application (DAA)

| Treatments | Number of individuals $m^{-2}$ | | Number of families | | Shannon-Weaver index | | Evenness Pielou index | |
|---|---|---|---|---|---|---|---|---|
| | 45 DAA | 75 DAA | 45 DAA | 75 DAA | 45 DAA | 75 DAA | 45 DAA | 75 DAA |
| Control | 58 | 89 | 9 | 8 | 2.91 | 2.61 | 0.92 | 0.87 |
| 6 kg $ha^{-1}$ Dual Acay | 97 | 72 | 11 | 10 | 3.15 | 3.00 | 0.91 | 0.90 |
| 4 kg $ha^{-1}$ Molluscicide Acay | 50 | 49 | 7 | 6 | 2.29 | 2.24 | 0.82 | 0.87 |
| 4 kg $ha^{-1}$ Mollucicide Clartex | 42 | 45 | 7 | 9 | 2.60 | 2.99 | 0.93 | 0.94 |
| 4 kg $ha^{-1}$ MataBibos Acay | 180 | 99 | 11 | 9 | 2.67 | 2.77 | 0.77 | 0.87 |
| 4 kg $ha^{-1}$ Clartex BB | 62 | 61 | 7 | 7 | 2.35 | 2.61 | 0.84 | 0.93 |

Similar to the findings of Rodriguez *et al.* (2006), collembolans were the most abundant arthropods within soil mesofauna. Under NT, these organisms probably find a favourable environment because of the reduction of soil disturbance and of the increase of crop residues on the soil surface. These crop residues form a soil protection surface layer increasing the development of bacteria and fungi, main feeding resources of these organisms (López-Fando and Bello Peréz, 1997; Doles *et al.*, 2001). Our findings were in consistent with those of Baquero *et al.* (2003) and López *et al.* (2005) who also reported enchytraeids as the most frequent in soil mesofauna in the southeast of Buenos Aires Province (Argentina). Moreover, Manetti *et al.* (2008) and Gizzi *et al.* (2009) reported that there are collembolans in addition to enchytraeids, and that, in macrofauna, soil insects are the most abundant. However, in our study, as well as in what has been reported by Wyss and Glasstetter (1992), a low density of earthworms was obtained under no tillage, whereas the enchytraeid density was higher: 1203 ind $m^{-2}$, as has previously been mentioned (Table 1).

In view of the above, the lower density of earthworms obtained (Table 1) favours the dominance of enchytraeids to a large extent due to the abundant feeding resources and highly stable environment, without perturbations. As a result, the low density of earthworms was compensated by a higher density and activity of enchytraeids, which may account for an increased soil porosity and biogenic structures (cast and fecal pellets) (Parmelee *et al.,* 1990).

**Mesofauna and macrofauna after bait application:** The population of mesofauna showed a higher density, 864 ind $m^{-2}$ at 45 DAA, than at 75 DAA, 728 ind $m^{-2}$, expressed as the sum of the individuals from all treatments. In this case, samples were collected in summer when the abundance of mites and collembolans was low (Table 1). It was observed that, during this period, the rainfalls were scarce and the soil was dry.

Total density of mesofauna from 45 to 75 DAA did not differ among treatments (P = 0.6822 and P = 0.1396) (Fig. 1).

Within mesofauna, the enchytraeid, mite, collembolan and symphylid densities were not significantly different ($p>0.05$) between 45 and 75 DAA, averaging density from 1 to 18 ind $m^{-2}$.

The population density of nematodes was significantly different at both 45 and 75 DAA; (P = 0.0123 and $p<0.001$, respectively). Nematode density with 4 kg $ha^{-1}$ of molluscicide Clartex and Clartex BB differed significantly from the control. In the other treatments, the baits did not affect the density of nematodes as it increased throughout and differences in relation to the control were not observed (Fig. 2). There was a higher density in the population of nematodes at 75 DAA with 6 kg $ha^{-1}$ Dual Acay and 4 kg $ha^{-1}$ molluscicide Clartex $p<0.05$), 35 and 22 ind $m^{-2}$, respectively (Fig. 2). The action of baits did not affect the organisms in the other treatments, as a similar or relatively higher density in relation to the control was observed.

The community diversity index of soil mesofauna at 45 DAA with 6 kg $ha^{-1}$ Dual Acay, 4 kg $ha^{-1}$ MataBibos Acay and 4 kg $ha^{-1}$ Clartex BB decreased in relation to the control and there was a difference in the population diversity of 0.4, 0.63 and of 0.32, respectively (Table 2). As regards molluscicides it was observed that the diversity increased or was similar to the control. At 75 days after application, diversity index with 4 kg $ha^{-1}$ MataBibos Acay decreased to 0.47, in relation to the control.

The highest diversity was obtained at 45 DAA with 4 kg $ha^{-1}$ molluscicide Acay and with 4 kg $ha^{-1}$ Clartex BB at 75 DAA (Table 2).

In cropping systems, higher rates of pesticides (particularly insecticides) and fertilizer application results in higher mortality, and in some cases, the disappearance of soil organisms (Bedano and Ruf, 2007). However, our results demonstrated that the soil mesofauna density was not affected by pesticides formulated as bait pellets (Fig. 1). In accordance with Iglesias *et al.* (2003), the density of microarthropods as mites and collembolans after application of metaldehyde (molluscicide) was not reduced. The molluscicide application at doses of 50 g metaldehyde $ha^{-1}$ did not produce any negative effect on those organisms (Iglesias *et al.,* 2003). On the other hand, spreading carbaryl at 1.1 and 11.3 kg active ingredient (A.I.) $ha^{-1}$ produced a variation on density depending on each different population of organisms (Spain, 1974). When the symphylid density was compared at different doses, it was observed that the population density was affected at the highest dose of carbaryl. On the contrary,

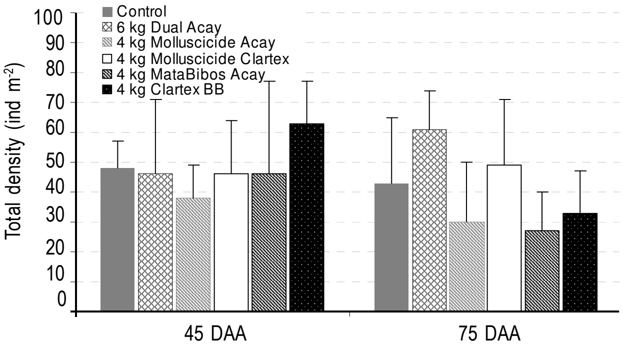


**Fig. 1:** Total density (ind $m^{-2}$) of mesofauna at both 45 and 75 days after application (DAA) in different treatments. Values are mean of 3 replicates ± SD

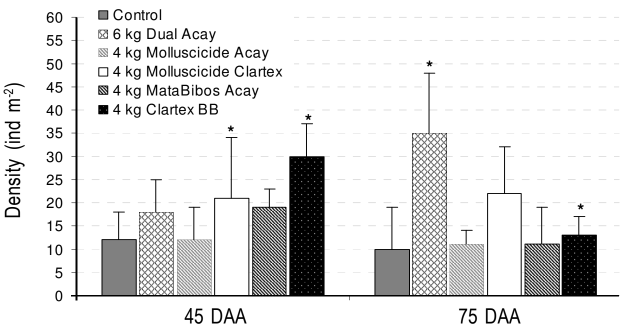


**Fig. 2:** Density (ind $m^{-2}$) of nematlodes between treatments at 45 and 75 days after application (DAA) in different treatments. * significant differences with the control are indicated by $p < 0.05$. Values are mean of 3 replicates ± SD

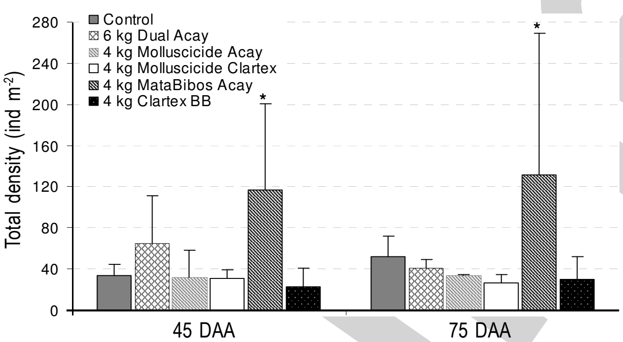


**Fig. 3:** Total density (ind $m^{-2}$) of macrofauna at both 45 and 75 days after application (DAA) in different treatments. * significant differences with control are indicated by $p < 0.05$. Values are mean of 3 replicates ± SD

a reduction in the collembolan density was found at both carbaryl doses, whereas the effect over mites was insignificant (Cryptostigmata, Mesostigmata and Prostigmata). Barret (1968) considered that 2.24 kg carbaryl $ha^{-1}$ reduced the decomposition of crop residues, main feeding resource of detritivores microarthropods, and indirectly affected the number of these organisms. The indirect action of carbaryl took place when the crop residues came into contact with the carbaryl once it had degraded. However, in this work, carbaryl baits did not affect the density or the taxonomic composition (diversity) of the microarthropod community, probably due to the different formulation type and application mode (Figs. 1 and 2; Table 2).

The total density of macrofauna at 45 and 75 days after application was 904 and 942 ind $m^{-2}$ respectively, expressed as the sum of the individuals from all the treatments. Phylum Arthropoda animals were the most abundant group (Table 1).

The total density of macrofauna at 45 and at 75 DAA showed significant differences among treatments, P = 0.0648 and P = 0.0168, respectively (Fig. 3). With 4 kg $ha^{-1}$ MataBibos Acay the highest density was obtained, 117 and 131 ind $m^{-2}$ ($p<0.05$) at 45 and 75 DAA, respectively, in relation to the control (Fig. 3).

Two groups of soil organism macrofauna were considered according to their trophic function and density: Oligochaeta: Megadrilli (earthworms), and Diplopoda, mainly Julidae. Earthworms and diplopods showed no significant differences ($p>0.05$) in the populations at both sampling times, 45 and 75 days after applications. The average density of earthworms was between 1-8 and 3-14 ind $m^{-2}$ and for the diplopods 13-67 and 5-29 ind $m^{-2}$ at 45 and 75 DAA, respectively.

The diversity index decreased with metaldehyde or carbaryl alone at 45 days after application, while at 75 days after application with molluscicide Acay 4 kg $ha^{-1}$, the index decreased to 0.37 in relation to the control (Table 3). A higher diversity was obtained at both 45 and 75 DAA, with 6 kg $ha^{-1}$ Dual Acay, 3.15 and 3.00, respectively.

The mollucicides based on metaldehyde and applied under field conditions did not reduce the density of *Lumbricus* spp. (Iglesias *et al.,* 2003). As has been observed by Bieri *et al.* (1989), when earthworms are exposed to a metaldehyde dose similar to the one used in the field, the negative effect is insignificant. However, these organisms can present signs such as discoloration and lesions on the tegument, due to a prolonged contact with the pellets. Furthermore, the abundance of spiders, diplopods, ants, staphylinid and carabid beetles larvae was not affected by the baits. In this study, Acay and Clartex molluscicides showed a similar behavior over the density of organisms previously cited.

There was no available information about the effects that crustacicides formulated as baits with carbaryl as active ingredient on beneficial organisms. Nevertheless, when carbaryl is used as insecticide, Stenersen *et al.* (1992) and Ville *et al.* (1997) reported that earthworms as *Eisenia fetida andrei* presented signs as tremor, size reduction, neurotoxicity and immunomodulator effects after exposure to the chemical. However, in this study, as carbaryl was formulated as bait, the earthworm density was not affected.

Bait application did not affect either the abundance or the diversity of edaphic beneficial organisms an assure their conservation to maintain the biological balance in the soybean crop system under no tillage.

## Acknowledgments

We thank Maria F. Mancebo advanced student of the Agricultural Sciences Faculty for help during the experiment. This study was supported by the National University of Mar del Plata, Buenos Aires, Argentina.

## References

Baquero, V.G., A.N. López, A.M. Vincini, H.A. Álvarez Castillo, D.M. Carmona and P.L. Manetti: La mesofauna en diferentes sistemas de producción. Los enquitreidos como indicadores del grado de disturbio (Mesofauna in differents production systems. Enchytraeids as indicators of disturbance). *J. Sci. Technol. Scientific Series*, **8**, 65-73 (2003).

Barrett, G.W.: The effect of an acute insecticide stress on a semi-enclosed grassland ecosystem. *Ecology,* **49**, 1019-1035 (1968).

Bedano, J.C. and A. Ruf: Soil predadory mite communities (Acari: Gamasida) in agroecosystems of Central Argentina. *Appl. Soil Ecol.,* **36**, 22-31 (2007).

Bieri, M., H. Schweizer, K. Christensen and O. Daniel: The effect of metaldehyde and methiocarb slug pellets on *Lumbricus terrestris* L. *In*: Slugs and snails in world agriculture (*Ed.*: I. Henderson). British Crop Protection Council, Thornton Heath. pp. 237-244 (1989).

Brévaul, T., S. Bikay, J.M. Maldés and K. Naudin: Impact of a no-till with mulch soil management strategy on soil macrofauna communities in a cotton cropping system. *Soil Tillage Res.*, **97**, 140-149 (2007).

Clemente, N.L., A.N. López, M.G. Monterubbianesi, N.J. Cazzaniga and P.L. Manetti: Biological studies and phenology of the slug *Deroceras reticulatum* (Müller, 1774) (Pulmonata: Stylommatophora). *Invertebrate Reproduction and Development,* **52**, 23-30 (2008).

Doles, J.L., R.J. Zimmerman and J.C. Moore: Soil microarthropod community structure and dynamics in organic and conventionally managed apple orchards in Western Colorado, USA. *Appl. Soil Ecol.*, **18**, 83-96 (2001).

Garavano, M.E., A.J. Faberi, N.L. Clemente, C. Salvio, P.L. Manetti and A.N. López: Alternativas en el manejo de *Deroceras reticulatum* (Pulmonata: Stylomatophora) con cebos con metaldehído-carbaryl y con metaldehído líquido en el cultivo de colza. En Acta: XIII Jornadas Fitosanitarias. (Alternatives in the management of *Deroceras reticulatum* (Pulmonata: Stylomatophora) treated with metaldehyde, carbaryl baited and metaldehyde liquid oilseed rape crop. In Procceding: XIII Phytosanitary Conferences) Santiago del Estero, Argentina. pp. 40-45 (2009).

Giesy, J.P., S. Dobson and K.R. Solomon: Ecotoxicological risk assessment for roundup herbicide. *Rev. Environ. Contam. Toxicol.*, **167**, 35-120 (2000).

Gizzi, A. H., H. A. Álvarez Castillo, P. L. Manetti, A. N. López, N. L. Clemente and G. A. Studdert: Caracterización de la meso y de la macrofauna edáficas en sistemas de cultivo del sudeste bonaerense (Characterization of the meso and the macrofauna soil in cropping systems of Southeastern Buenos Aires). *Soil Science*, **27**, 1-9 (2009).

Holland, J.M.: The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. *Agric. Ecosys. Environ.* **103**, 1-25 (2004).

Iglesias, J., J. Castillejo and R. Castro: The effects of repeated applications of the molluscicide metaldehyde and the biocontrol nematodo *Phasmarhrabditis hermaphrodita* on mollusks, earthworms, nematodes, acarids and collembolans: A two-year study in Northwest Spain. *Pest Manag. Sci.*, **59**, 1217-1227 (2003).

Larsen, G., P.L., Manetti, N.L. Clemente, A.J. Faberi, C. Salvio, and A.N. López: Relevamiento de la densidad de babosas y bichos bolita en siembra directa. En Acta: 4º Congreso Argentino de Girasol (Survey of the density of slugs and pillbugs in no tillage. In Proceeding: 4° Sunflower Congress), Buenos Aires, Argentina. p. 3 (2007).

Lavelle, P.: Faunal activities and soil processes: Adaptive estrategies that determine ecosystem function. *In:* Advances in Ecological Research (*Ed.*: M. Begon). Academic Press, New York. pp. 93-132 (1997).

Lavelle, P.: Ecological challenges for soil science. *Soil Science,* **165**, 73-86 (2000).

López, A.N., A.M. Vincini, N.L. Clemente, P.L. Manetti, D.M. Carmona and H.A. Álvarez Castillo: Densidad estacional y distribución vertical de los Enchytraeidae (Annelida: Oligochaeta) en diferentes sistemas de producción (Seasonal density and vertical distribution of Enchytraeidae (Annelida: Oligochaeta) in different production systems). *Soil Science*, **23**, 115-121 (2005).

López-Fando, C. and A. Bello Pérez: Efectos de los sistemas de laboreo en la biología del suelo (Effects of tillage systems on soil biology). *In*: Agricultura de conservación: Fundamentos Agronómicos. Medioambientales y Económicos (Conservation Agriculture: Agronomic Principles. Environmental and Economic) (*Eds*.: García Torres, L. and P. González Fernández) pp. 200-223 (1997).

Manetti, P.L., A.N. López, N.L. Clemente and A.J. Faberi: Abundancia de los organismos de la meso y de la macrofauna del suelo bajo labranza convencional y siembra directa En Acta: 21º Congreso Argentino de la Ciencia del Suelo (Abundance of organisms in the meso and macrofauna of the soil under conventional tillage and no tillage. In Proceeding: 21º Soil Science Congress) . San Luis, Argentina. p. 6 (2008).

Mc Cullagh, P. and J.A. Nelder: Generalized linear models (*Eds*.: Chapman and Hall) Cambridge, Great Britain. p. 541 (1989).

Parmelee, R.W., M.H. Beare, W. Cheng, P.F. Hendrix, S.J. Rider, D.A. Jr. Crossley and D.C. Coleman: Earthworms and enchytraeids in convetional and no-tillage agroecosystems: A biocide approach to assess their role in organic matter breakdown. *Biol. Fertil. Soils,* **10**, 1-10 (1990).

Rodriguez, E., F.J. Fernández-Anero, P. Ruiz and M. Campos: Soil arthropod abundance under conventional and no tillage in a Mediterranean climate. *Soil Tillage Res.*, **85**, 229-233 (2006).

Salvio, C., A.J. Faberi, A.N. López, P.L. Manetti and N.L. Clemente: The efficacy of three metaldehyde pellets marketed in Argentina, on the control of *Deroceras reticulatum* (Müller) (Pulmonata: Stylommatophora). *Span. J. Agric. Res.*, **6**, 70-77 (2008).

SAS: SAS user's guide: Statistics. Vers. 8. SAS Institute, Cary. NC. USA (2001).

Spain, A.V.: The effects of carbaryl and DDT on the litter fauna of a Corsican pine forest (*Pinus nigra* var. *maritima*): A multivariate comparison. *J. Appl. Ecol.*, **11**, 467-481 (1974).

Sternersen, J., E. Brekke and F. Engelstad: Earthworms for toxicity testing; species differences in response towards cholinesterase inhibiting insecticides. *Soil Biol. Biochem*., **24**, 1761-1764 (1992).

Stinner, B.R. and G.J. House: Arthropods and other invertebrates in conservation - tillage agriculture. *Annu. Rev. Entomol.*, **35**, 299-318 (1990).

Studdert, G.A. and H.E. Echeverría: Maíz, girasol y soja en los sistemas de cultivo del sudeste bonaerense (Corn, sunflower and soybean cropping systems southeast of Buenos Aires). *In*: Bases para el manejo del maíz, el girasol y la soja. (Bases for the management of maize, sunflower and soybean). (*Eds*.: Andrade, F.H. and V. Sadras). EEA Balcarce INTA-FCA, UNMdP. Balcarce, Argentina. pp. 407-437 (2000a).

Studdert, G.A. and H.E. Echeverría: Crop rotations and nitrogen fertilization to manage soil organic carbon dynamics. *Soil Sci. Soc. Am. J.,* **64**, 1496-1503 (2000b).

Swift, M., O. Heal and J. Anderson: The composition in terrestrial ecosystems. Blackwell Scientific, Oxford, UK. p. 373 (1979).

Tillman, G., H. Schomberg, S. Phatak, B. Mullinix, S. Lachnicht, P. Timper and D. Olson: Influence of cover crops on insect pests and predators in conservation tillage cotton. *J. Econ. Entomol.,* **97**, 1217-1232 (2004).

Ville, P., P. Roch, E. L. Cooper and J.F. Narbonne: Immuno-modulador effects of carbaryl and 2,4 D in the earthworm *Eisenia fetida* Andrei. *Arch. Environ. Contam. Toxicol.,* **385**, 291-297 (1997).

Wilson-Rummenie, A.C., B.J. Bradford, L.N. Robertson, G.B. Simpson and K.L. Bell: Reduced tillage increases population density of soil macrofauna in a semiarid environment in Central Queensland. *Environ. Entomol.*, **28**, 163-172 (1999).

Wyss, E. and M. Glasstetter: Tillage treatments and earthworm distribution in a Swiss experimental corn field. *Soil Biol. Biochem.,* **24**, 1635-1639 (1992).