

ENCHYTRAEIDS SUSTAINABILITY AND TOLERANCE AGAINST AGRO-CHEMICALS IN ZEA MAYS CROPLAND

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KEYWORDS

Enchytraeidae
Oligochaeta
Annelida
Toxicity
Ecotoxicology
Pesticides
Insecticides
Bioindicator

Received on :

24.09.2012

Accepted on :

22.12.2012

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ABSTRACT

Enchytraeids, a true soil layer dwellers and indicator organisms, serves as an early warning system of the changes in composition and functioning of the soil system. A field monitoring of enchytraeid community against fertilizers and biocide application in conventionally tilled and no-tilled agro-ecosystems for maize was done for a period of 12 months. Impact of DAP 50 kg/ha, Potash 22kg/ha, Urea 10 kg/ha and BHC on *Fridericia sp.*, *Achaeta sp.*, *Enchytraeus sp.*, *Hemienchytraeus sp.* and *Marionina sp.* of enchytraeids showed that overall population was reduced in treated plots at different dates of sampling by 45 to 55%. Among them *Achaeta sp.*, *Hemienchytraeus sp.* and *Marionina sp.* were more sensitive. However *Fridericia sp.* and *Enchytraeus sp.*, was dominant in both the agro-ecosystems addressing their sustainability. The time required for the restoration of their population ranged from several weeks to 8-10 months depending on the taxa.

INTRODUCTION

Gangetic plane from Samastipur to Naugachiya in north east Bihar is the largest producer of maize (*Zea mays*) in Asia and forms one of the major socio- economic bases of Bihar. Intensive agriculture over the last four decades has drastically changed the nutrient status of the soil. The soil system is gradually becoming non-sustainable. Even after the application of additional doses of fertilizers there is no impressive increase in the yield. One of the diagnoses for unsustainable productivity has been linked to loss of soil bio-diversity due to heavy inputs of fertilizers and pesticides. Among new farming management integrated aerable farming system is characterised by reduced tillage and low fertilizer and biocide application rate (Vereijken and Viaux, 1990).

A potential indicator organisms must fulfil several criteria (Edwards *et al.*, 1996). Enchytraeids (Annelida; Oligochaeta) are one among them that readily fulfil those criteria (Didden, 1993; RoKmbke and Moser, 1999), and may therefore be considered suitable animal as indicator organisms. Annelids have been duly and widely considered as an indicator organism in aquatic and terrestrial habitat by Baumart *et al.* (2011), Bacey, and Spurlock, (2007), Baumart, and Santos, (2010), Friberg *et al.* (2003), Nakagome, *et al.* (2006), Schulz and Liess (1999) and Stenert, *et al.* (2009).

Recently, effort has been made to the development of an enchytraeid test laboratory (RoKmbke and Moser, 2002) with which the effects of chemical stress on enchytraeid survival

and reproduction could be evaluated. However, it is important to realize, that from laboratory tests only direct effects can be predicted. Indirect effects are more difficult to establish, because of the inherent unpredictability associated with the way in which such effects will occur under field conditions. So field monitoring of enchytraeid communities is indispensable to serve as an early warning system of changes in composition and functioning of the soil system (Giani, 1983, 1984). Although in a number of older field investigations no effects on enchytraeids were established, this was very likely connected with the resolution of the methods applied *i.e.* reliable extraction methods and taxonomic keys were not available until around 1960. Studies taking the species composition into account often demonstrated species-related responses leading to a different enchytraeid community. It is very likely that a changed enchytraeid community will result in changed enchytraeid activity and therefore in changes in ecosystem processes such as decomposition and bioturbation. Although up to now only few studies have addressed this aspect, it certainly may be regarded an important and promising approach. The structure of enchytraeid communities can also be used either alone (Graefe, 1993a 1993b) or in combination with other soil organism groups (RoKmbke *et al.*, 1997) for soil quality assessment in the field. The basic approach is that at a site with given environmental factors such as physico-chemical soil properties or climate, a certain enchytraeid cenosis can be expected. If the cenosis found at a given site differs clearly from the one expected, give a strong indication that the soil of this site is somehow altered

concerning its function as a habitat for soil organisms. The present article concentrates on the effect of agro-chemicals on enchytraeids, and reviews the available data on the sensitivity and tolerance of enchytraeids as bioindicator toward chemical stress.

A high population of soil biota including enchytraeids signifies the good health of soil. Since they play an important role in creating a stable soil structure and porosity at the low level of earthworm densities, so their sensitivity and tolerance toward chemical stress and the nature of direct and indirect effects of chemical fertilizers/ insecticides/pesticides on them was one of the objectives of the study for the evaluation of toxic effects that may occur on bio-indicator like enchytraeids, or organisms that may be regarded as reflecting the quality of the soil system. Although up to now only few studies have considered this aspect, it certainly may be regarded as an important and promising approach, because enchytraeids almost doubles the availability of organic carbon (Cole et al., 2000).

MATERIALS AND METHODS

Influence of traditionally used different agro-chemical input intensities upon soil biological activity of enchytraeids in the topsoil profile (0–10cm depth) in tilled fields for maize crop and no-tilled fields for comparison were evaluated. The soil samples were taken by a cylindrical corer, bagged, tagged and brought to the laboratory. The worms were extracted by standard O'Connor's wet funnel extraction technique. The methods used also consisted of identifying and counting components (enchytraeids) in soil horizons, fixed into ethyl alcohol to evaluate the hazards of stress on system level.

Usual cultivation practices adopted by farmers of this locality

Table 1: Qualitative occurrence of enchytraeid fauna

Enchytraeid Genera	Control plot	Treated plot
Fridericia sp.	+++***	+*
Achaeta sp.	++**	-
Enchytraeus sp.	+++	++
Hemienchytraeus sp.	+	-
Marionina sp.	++	-

- absent, *poor, ** moderate, *** abundant

Table 2: Average number of enchytraeids tillers, ear length and weight of 100 grains

Field	Population/m ²	Average Tillers No.	Average Ear length cm	Weight of 100 grain g.
Control	10813	1.4	50.3	27.20
Treated	9896	1.9	67.8	33.5

Table 3: Correlation coefficient of enchytraeids with other parameters

DTA	Population/m ² in tilled plot	Average Tillers no.	Average ear length cm	Weight of 100 grains g.
Pre sowing	16161	0	0	0
2	17336.4	0	0	0
32	15251	2	0	0
89	8534.8	1	28	20
187	13278	1	32	150
372	16357	1	33	200
Average	14486.37	0.83	15.5	61.67
STDEV	3221.56	0.75	17.06	89.54
Correlation	-0.31	-0.21	-0.47	0.15

DTA = days after treatment

for maize crop with reference to enchytraeids as bio-indicator of the soil health were considered. Enchytraeid densities were sampled over 12 month period in conventional tilled and no-tillage agro-ecosystems.

High yielding hybrid maize seeds 30 V 92, a product of Pioneer Industry, was the choice of local farmers for Baishakhi crop. For second crop (in the months of September–October) only non hybrid seeds are preferred because this crop totally relies upon rain and is often subjected to draught or flood.

Impact of DAP 50 kg/ha, Potash 22kg/ha, Urea 10 kg/ha and BHC with seed plus lime (used by conscious cultivators) at the time of sowing on enchytraeid population was evaluated. Infection appears at the seedling stage so either Phorate is sprayed or is dusted with BHC. In case of severe infection Sevin @ 1 to 2 granules/pod is applied. No spray is done at flowering stage. A sharp decline in the enchytraeids population by 55-60% was recorded in tilled plots. Soil samples were taken before treatment and after treatments at aforesaid different stages to evaluate their impact on enchytraeid fauna in relation to the maize yield.

Sampling was performed on 2, 32, (panicle initiation stage) 89, 187 and 372 days after treatment (DAT), the harvesting stage of the crop. A control plot for comparison was also evaluated by sampling at the same interval. The taxonomic groups assessed were enchytraeids, up to the genus level.

RESULTS

Qualitative composition and Abundance

Fridericia sp., *Achaeta sp.*, *Enchytraeus sp.*, *Hemienchytraeus sp.* and *Marionina sp.* were among five different species of enchytraeids recorded from the study area. *Fridericia* and *Enchytraeus* were the two dominant species in both the control and treated plots. *Achaeta* and *Marionina sp.* were moderately represented, while *Hemienchytraeus* had the poor representation (Table 1). The average densities of enchytraeids, at pre-sowing stage, were 16161/m² in no tilled plots and 15575.8 /m² in treated plots respectively. The population sharply declined to around 58.3% at 32 DAT in treated plots. At the pre-sowing stage the difference in population density between control and treated plots accounted for only 3.62% but raised to 49.58% at 2 DAT and 58.3% at 32 DAT (the panicle initiation stage) and continued to 28.75% up to 372 DAT (the harvesting stage). This indicates a direct effect on enchytraeid population density (Fig. 1). Young individuals could not be identified and thus were not included in data analysis. No surface-dwelling (epigeic) enchytraeids were

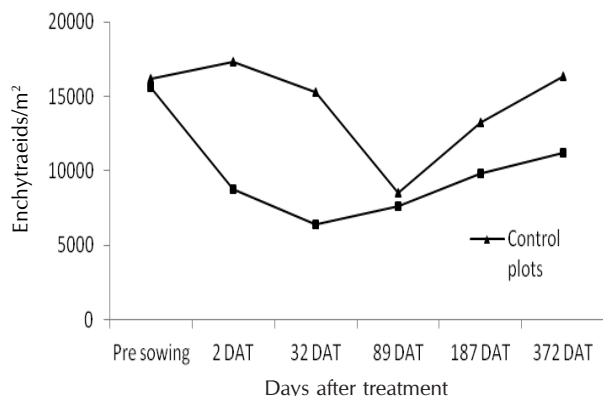


Figure 1: Population dynamics of enchytraeids in treated and control plots

found. Overall comparison with control plot, the enchytraeids on the reference plots was apparently reduced by around 55-60% at individual sampling dates, thus validating the test design. The test substance showed an unexplained reduction of enchytraeids at the 4th sampling date. Genera of enchytraeids behaved slightly differently, suggesting that in future studies the species level should be addressed.

Effect on population dynamics, average tillers number, ear length and weight of grains

The maximum population of enchytraeid (16161/m²) was observed at the time of sowing in control plots. The minimum population (6359.2/m²) was recorded in the plots where DAP 50 kg/ha, Pottash 22kg/ha, Urea 10 kg/ha and BHC were applied in combination. On 32 DAT of pesticide application, maximum number of tillers (15.66), maximum ear length (24.66cm), maximum 100 grain weight (31.20g) were observed. Maximum yield (4926.33 kg/ha) were obtained from the plots where phorate, butachlor and quinalphos in combination were applied. Minimum number of tillers (13.66), minimum ear length (22.03 cm), minimum 100 grain weight (28.09g) and minimum yield (4390.33 kg/ha) were recorded from control plots (Table 2). Regression analysis (Fig. 2) and correlation coefficient analysis showed a negative impact on enchytraeid population and other parameters except for the number of grains per cone (Table 3).

DISCUSSION

Direct effect of pesticides on enchytraeids, for instance on mortality or reproduction, will mainly occur through uptake of the substance via the soil solution. This implies that pesticides with high solubility (~ 30 mg/L ~ 1) are more likely to come into contact with enchytraeids. Strong adsorption to soil particles ($K_0 \# 500$) will reduce the bioavailability of a pesticide in the soil solution, but the chance of uptake via ingestion will be relatively increased.

Referring to the experiences made in our study it is concluded that the use of soil mesofauna groups in field condition is a practical and promising tool in the environmental risk assessment of pesticides/insecticide application. Proper functioning of the soil is essential for terrestrial ecosystems and consequently for human activity and any risk of impairing

this should be taken very seriously. Abawi and Widmer (2000) laid emphasis on the impact of soil health management practices for soil borne pathogens, nematodes and root diseases of vegetable crops. Naturally there is a growing awareness of the risks that may be involved in the use of vast amount (both quantitatively and qualitatively) of contaminating substances in the soil. Large scale monoculture of crops or of stock animals makes insects thrive and multiply fast. Use of insecticides leads to an outbreak in three ways: (i) it kills natural enemies and lifts natural control, (ii) it kills non target animals and removes competition and struggle for existence, (iii) it causes selective eradication of insects susceptible to insecticides so as to leave only the resistant ones to breed unaffected by the use of insecticides in the future.

Enchytraeid tolerance against chemical stress and the nature of direct and indirect effects that may occur are discussed for the evaluation of toxic effects. Parmelee *et al.* (1990) observed that high rates of fertilizer and biocide application is detrimental to enchytraeid populations. They found that overall earthworm densities and biomass in the no-till system were 70% greater than under conventional tilling and enchytraeid densities and biomass in the no-till system were 50 to 60% greater.

For a number of pesticides the sensitivity of individual enchytraeid species has also been established in field condition (Bacey and Spurlock, 2007) and in the laboratory (Vavrek *et al.*, 1996) condition which confirm the findings of Friberg *et al.* (2003), who suggest that application of agro-chemicals in agricultural land reflects the soil type and the fauna therein. Oligochaete worms has characterised for ecotoxicological assessment of soil and sediments. Rokmbke and Egeler (2009).

With the intensification of agriculture over the last four decades, deterioration of soil structure and increases in soil pollution have emerged as major issues. Among those new systems, integrated arable farming system is characterised by reduced tillage 1. Arable land that is worked by ploughing and sowing and rising crops 2. The cultivation of soil for raising crops. Cultivation of land and low fertilizer and biocide application rate compared with conventional agriculture (Vereijken and Viaux, 1990). Many studies have shown that conventional farming practices influence in a negative way the activity and biodiversity of soil fauna, especially earthworms and enchytraeids (Zwart and Brussaard, 1991). Though Baumart *et al.* (2011) concluded that in spite of the possible negative effects of the pesticides on the benthic community, the assemblages recovered rapidly. In our study, the most critical time for enchytraeid assemblages was seen on the 32 DAT when a general reduction in all taxa was observed. However, over time, the density of this community recovered.

Tillage is also detrimental to enchytraeid populations (Parmelee *et al.*, 1990) and the associated negative impacts upon soil structure were stressed by Didden (1990). Rokmbke (2004) has reviewed the toxicological effects on enchytraeids in laboratory. Rokmbke *et al.* (2009) found that in comparison to the control, the number of enchytraeids on the reference plots was reduced by 60% at individual sampling dates, thus validating our the test design too.

The existing data on specific types of stressors such as insecticides, pesticides and fertilizers show clear responses of enchytraeids and in many cases interspecific differences in

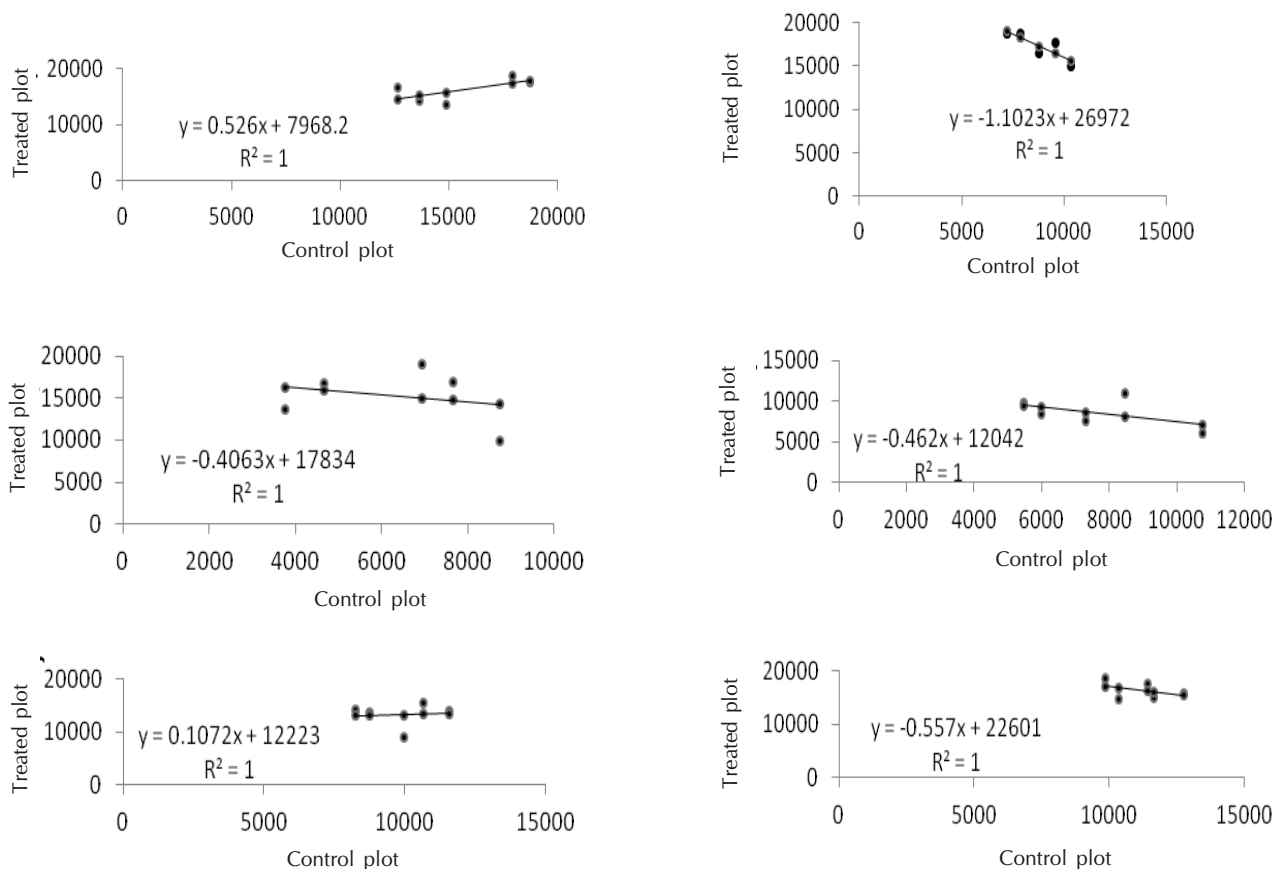


Figure 2: Regression analysis showing effect of agro-chemicals on enchytraeids population density in treated and control plots at different DAT (days after treatment)

sensitivity are also recorded. Stenert, et al. (2009) found that the richness and abundance of 91 taxa of macro-invertebrate in wet land did not change significantly over the rice cultivation cycle. However, the species composition of these groups in the irrigation channels varied between uncultivated and cultivated periods. It is concluded that, although in several fields additional data are required, there are good perspectives for the use of enchytraeids as indicator organisms.

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