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Using bait lamina and litterbags, two functional methods to monitor biological activity in soil contaminated by dieldrin. Preliminary results from Dakar (Senegal) sahelian region

Ibrahima MBODJ [2], Makhfousse SARR [1] and Karamoko DIARRA [2*]

[1] *Ceres/Locustox, km 16 route de Rufisque, BP 3300 Dakar.*
[2] *Département de Biologie Animale, Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar.*
[*] *Corresponding author: Email: kdiarra@ucad.sn / karamoko.diarra@ucad.edu.sn*
Tel: +221 77 450 27 54

ABSTRACT

The capability of bait lamina to assess biological activity of soil fauna in semi-arid zone was studied in a peri-urban area polluted by dieldrin. This method was compared to litter bags usually used in this savannah region to monitor the activity of soil macro-invertebrates. The study site is used for agriculture and the irrigation water contains known concentrations of dieldrin residues. Three plots were chosen: One plot was soaked with water containing 1.4 µg dieldrin/l; another with 1.96 µg dieldrin/l and a control without dieldrin. Analysis of dieldrin residue were done from water samples taken from wells used for watering. The feeding activity of soil macro-invertebrates monitored with bait lamina was significantly different between the two contaminated plots and the control, both in absolute numbers and in the vertical distribution. A similar trend had been observed between bait lamina and litter bags despite their differences such as study duration (10 days and 60 days, respectively). Soil dwelling organisms which attack bait lamina were not identified but further study could verify if termites, which are the main soil macro-fauna group in savannah, are responsible for these attacks.

Keywords: Bait lamina, dieldrin, sahelian zone, biological activity, litter bags, ecotoxicology.

INTRODUCTION

In sahelian countries a lot of pesticides are imported to fight the desert locust pest. These agrochemicals cannot entirely be used and then often constitute obsolete stocks. It is the case of dieldrin in many countries plagued by desert locust plagues in the Seventies.

The environmental impact studies of the antiacridian pesticides on terrestrial and aquatic non-target organisms were regularly carried out (Everts and Bâ, 1997; Van der Valk et al., 2000; Danfa et al., 2002). For the terrestrial ecosystem, soil macro-fauna are the main biological indicators; termites, ants and beetles are the dominant groups in the sahelian terrestrial ecosystem (Sarr, 1999). They play an important role in the dynamics of soil fertility in the savannah (Garnier-Sillam et al., 1988; Lobry De Bruyn and Conacher, 1990; Black and Okwakol, 1997; Mando and Brussaard, 1999; Dangerfield, 1990; Sarr et al., 2001). For the monitoring of these organisms methods such as pitfall traps are used (Van der Valk and Camara, 2002; Danfa et al., 2002) or other methods recommended by the Tropical Soil Biology and Fertility program (Anderson and Ingram, 1993). However, the latter usually disturb the soil structure. In addition, litter bags are used to assess the decomposition of organic matter (Bernhard-Reversat et al., 2000), but this functional method requires a rather long time.

The assessment of the feeding activity with bait lamina was very recently integrated in ecotoxicological studies (Kula and Rombke, 1998; Paulus et al., 1999). This method, developed by Von Törne (1990), has been used in various temperate ecosystems (Kratz, 1998; Larink and Sommer, 2002) and also in tropical rainforests zones (Römbke et al., 2006). With the exception of one study comparing land use types in Benin (Geissen et al., 2001), no work was carried out in the sahelian zone until now.

The objective of this work was to study the potential of the bait lamina method as a quick screening method for the assessment of feeding activity in contaminated soils of the sahelian zone. For this purpose, the results were compared with those obtained from a litterbag study performed at the same site.

MATERIALS AND METHODS

The study was carried out near a stored dieldrin site located at 14°43' 47 N', 17°25' 49 W in a periurban area of Dakar (Senegal). Thousands of litres of dieldrin were stored under non-recommended conditions for several years. In 2002 an important removal campaign of these obsolete stocks was managed by the Senegalese Ministry of Environment and the whole amount of pesticides was removed. A study carried out by TAUW (2002) revealed a contamination of the soil and ground water in nearby inhabited areas and in plots where vegetable are cultivated. The assessment of the biological activity has been carried out in plots located around wells where irrigation water used for vegetable plants had known concentrations of dieldrin. These plots are 10 m^2 of surface where vegetables are cultivated. Five litres of water was used daily in plots during 10 days. During experiments, plots had not been disturbed. The plot (P1) was watered with a concentration of dieldrin of 1, 4 µg/l and the plot (P2) with a concentration of 1.96 µg/l. These concentrations of underground water were analysed in the laboratory of CERES/Locustox with the standards NF EN 12393-2 for pesticides residues in soil and underground water. A control plot was chosen 3 km upstream of the storage place.

The site of dieldrin storage is located in the isohyets 200-300 mm. The climate is a sahelian type with two distinct seasons: One dry season which extends from November to June with monthly average temperatures between 15 °C and 20 °C and a wet season from July to October with monthly average temperatures between 25 °C and 35 °C. The study area is a part of a landscape of Dakar called “Niayes” which is characterized by a succession of dunes and lowlands.

The tropical ferruginous non-lessivated soil constitutes the main texture on dunes and occupies the major part of the Niayes. These soils are low in organic matter content and often affected by wind erosion and water runoff. In low lands, the mineral soils with pseudo gley are predominant. They are of a great interest in the agricultural production, particularly for vegetable cultivation. The underground water is not deep, quite superficial in some places. The three observed plots are located in lowlands and were chosen around wells where residues of dieldrin had been detected. In plot 2, the farmer applies manure during cycle of cultivation.

The feeding activity of soil fauna was analysed by using bait-lamina obtained from Terra Protecta GMBH (Berlin, Germany). Bait lamina consists of plastic strips 120 mm*6 mm* 1 mm, which have a pointed tip at the lower end. In the lower part (85 mm) of each strip 16 holes of 1.5 mm diameter are drilled, which are 5 mm apart from each other. They are filled with bait material. A mixture of cellulose (70%) and bran (30%) powder together with a small amount of activated carbon has been used successfully in many studies performed in temperate regions (Kratz, 1998).

The bait-lamina were established in the two plots soaked with water containing respectively 1.4 µg/l (P 1) and 1.96 µg/l (P 2) of dieldrin residues and in the control plot (T). At each plot, three batches of sixteen bait-lamina sticks were used once in the dry season. However this area was regularly soaked because of vegetable cultivation. The 3 batches are aligned at a distance of 2 m from each other. The bait-lamina was put vertically into the soil, covering a depth from 5 cm to 15 cm because of the texture of soil and its dryness. The distance between two neighbouring bait-lamina was 8 cm.

Bait lamina sticks were removed 10 days after setting. Emptied holes were counted for each bait-lamina. For the vertical distribution of the activity, the number of holes perforated per millimetre was also recorded.

The litter bags had a size of 18 to 15 cm and were made using metal netting. A mesh size of 4 mm was selected in order to allow access of all soil fauna. For each litter bag, 50 g of litter were dried at 40 °C during 24 hours before being introduced into each bag. The litter was taken from small branches of wood (*Eucalyptus sp*). They were buried in the same plots like the bait lamina but at depth of 10 cm. For each plot 6 litter bags were randomly distributed. All bags were removed 60 days later. Litter was cleaned with a brush and dried as previously described. The percentage of weight lost is determined by the following relation:

$$\mathbf{X} = \frac{(\text{initial dry weight} - \text{final dry weight}) * 100}{\text{initial dry weight}}$$

No correction for ash content was made.

Statistical analysis

The statistical analysis was performed with the software Statview 4.55 (Statview, 1996). The data were subjected to analysis of variance (ANOVA). When differences were detected, Fisher's test ($P < 0.05$) was applied to separate means.

RESULTS

Feeding activity as assessed by bait lamina was significantly lower in the plot P2 (watered with a concentration of 1.96 µg/l dieldrin) compared to plot P1 (watered with 1.4 µg/l dieldrin) and the control T ($F=16,401$, $p<0.0001$). No significant difference was observed between plot P1 and the control T (Figure 1).

The vertical distribution of feeding activities shows characteristic differences between the three plots. In plot P 1 the activity is clearly higher in greater depths compared to the top soil layers (nearly 50% of the biological activity is observed in the horizon 40 to 80 mm (Figure 2 A). In the plot 2, high feeding activity occurs mainly close to the soil surface, i.e. in the first holes located between the 5 to 10 cm soil layers (Fig. 2 B). In control plot T biological activity was almost homogeneous with a slight decrease in the uppermost 2 cm of the soil column (Fig. 2 C). The litter bag study revealed that mass loss was significantly lower in both contaminated plots P1 and P2 compared to the control ($F = 20.27$, $p < 0.0001$). This weight loss is however not significantly different between plot P 1 and plot P 2 (Figure 3).

DISCUSSION

This study was focused on the capacity of the bait lamina method to evaluate the biological activity of soils in the sahelian zone. The method was proposed as a quick screening technique to determine the feeding activity of soil invertebrates. Knacker et al. (2003) noted that bait lamina method is reliable, sensitive and reproducible for the assessment of ecological risks (in particular pesticides) in the soil. However, it has not been used for this ecotoxicological purpose in the sahelian zone so far. In fact, rather the litter bags were used to effectively measure the activity of termites which are prevalent in

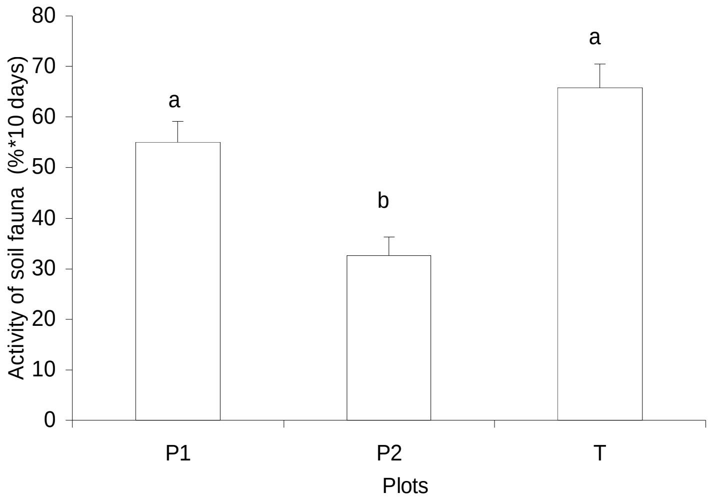

Figure 1: Feeding activity measured by bait lamina in contaminated plots P1, P2 and the control T. Bars with the same letter are not significantly different.

these ecosystems (Lavelle et al., 2001; Ouédraogo et al., 2004).

In this study, both methods were used to assess the impact of dieldrin on the biological (feeding and organic matter decomposition) activity of the soil fauna. With bait lamina, the feeding activity in the plots P1 and P2 is not different in 20 cm soil layers. In deeper horizon, feeding activities was considerably reduced in P2. This could be attributed to a longer exposure of soil organisms. The dieldrin may be adsorbed by the soil organic matter and thus allows a longer exposure of the soil organisms. Belfroid et al. (1996) and UNEP and IPCS (1989) reported that the presence of clay particles supports the adsorption and the retention of dieldrin with water. In addition, the vertical distribution showed that feeding activity was high in deeper layers in P1 and control plot. The soil texture of these plots is sandy, so after soaking, the water infiltrated quickly meaning that the exposure of organisms could be reduced in deeper layers.

The litter bag method revealed clear differences between the two contaminated plots and the control. However, while this information was obtained after 60 days the results from the bait lamina method were obtained already 10 days after their installation. These results show the utility of bait lamina in evaluating the feeding activity of the soil rapidly. In addition, these results indicate that the results of bait-lamina studies can be influenced by contaminants but also by soil properties; the difference between P1 and P2 may have been caused by edaphic factors like soil texture. However, the output of these two functional methods is different: with bait-lamina the feeding activity and with litter bags the decomposition of organic matter is measured.

In the temperate zone, Van Gestel et al. (2003) and Förster et al. (2004) had noted that the activity of the earthworms is often correlated with bait lamina results. While other authors highlight the role of mesofauna groups (Helling et al., 1998). In the sahelian arid and semi-arid zone, termites represent nearly 60% of biomass and density of the soil macro-fauna (Sarr et al., 1998; Fall et al., 2000) and they are responsible of the

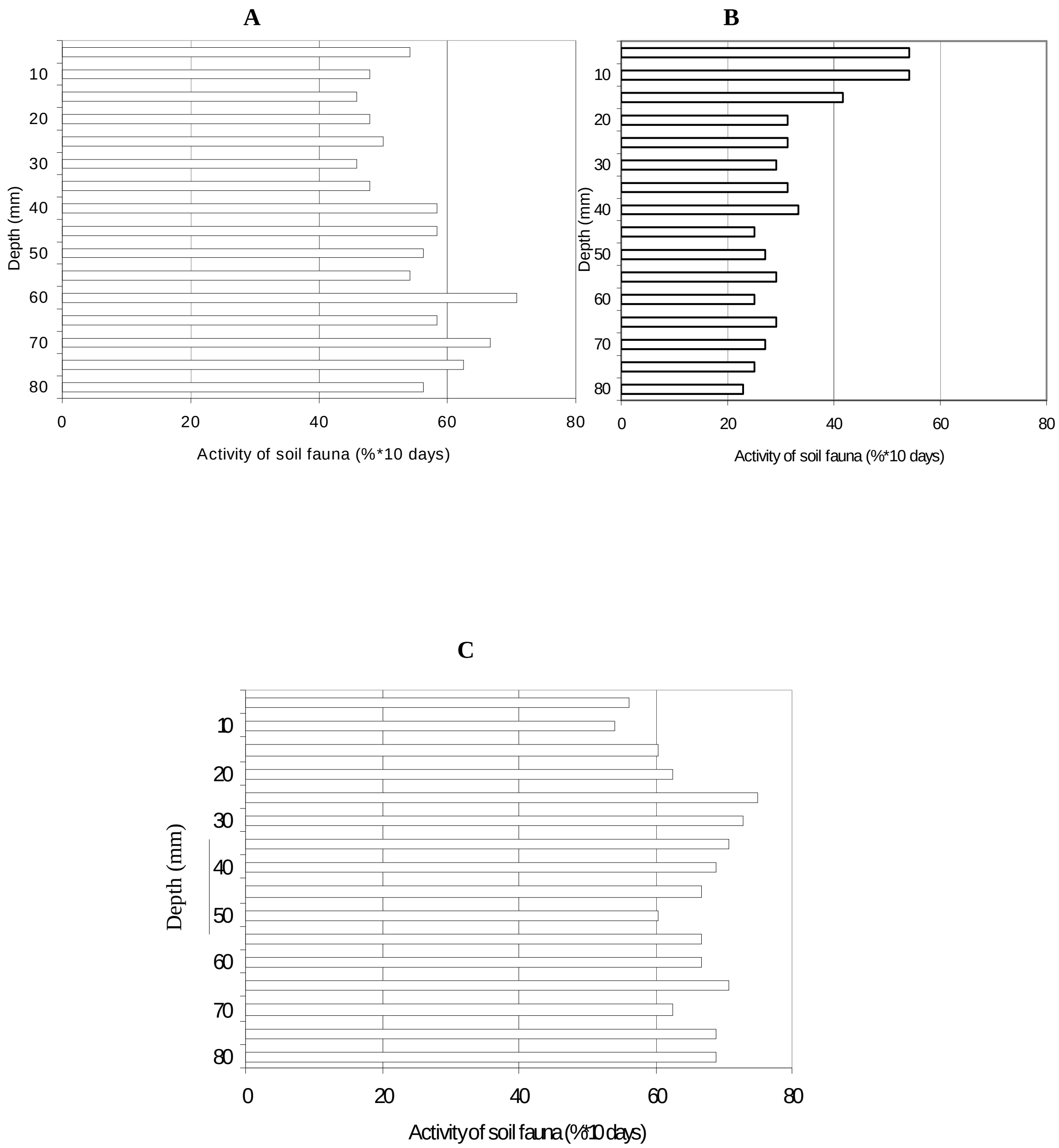

Figure 2: Vertical distribution of feeding activity in plot 1 (A), plot 2 (B) and the control (C).

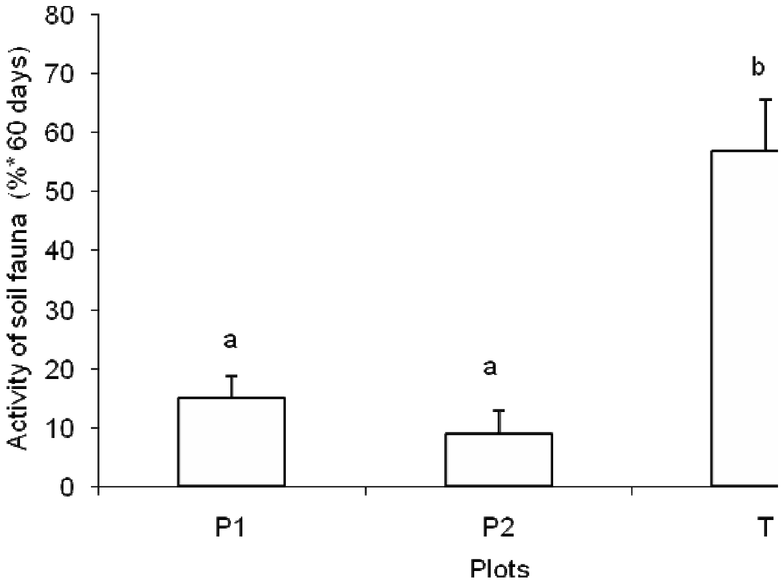

Figure 3: Biological activity measured by litter bags in contaminated plots P1, P2 and the control T. Bars with the same letter are not significantly different.

decomposition of organic matter (Ouédraogo et al., 2004). Their feeding on the bait lamina is probable but cannot be confirmed yet. Other studies would be needed. In addition, the role of microorganisms in the disappearance of the substrate of the lamina baits has to be specified.

Conclusion

The soil biological activity was evaluated by two functional methods (the bait-lamina and litter bags) in two plots which had been irrigated with pesticide-contaminated water. The activity of soil fauna was significantly reduced in both plots of the polluted site for both methods compared with a control plot. The method using the bait-lamina for a period of 10 days showed a similar trend compared to that of litter bags buried for 60 days. This rapid method for evaluating the biological activity could be used for future studies.

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