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EFFECT OF HEAVY METALS ON MICROARTHROPOD COMMUNITY STRUCTURE AS AN INDICATOR OF SOIL ECOSYSTEM HEALTH

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Abstract

Microarthropod community structure reflects soil ecosystem health and is influenced by the soil environment directly and/or indirectly by affecting the soil micro-flora and fauna that they graze. In this study, ecological indices for soil microarthropod community structure in soil contaminated (CS) with heavy metals in Plovdiv region and of a nearby non-contaminated area (NC) were examined during the three seasons from April through November 2011 to reveal influence of heavy metals on the soil microarthropod community structure. The QBS index as a tool has been applied to assess soil biological quality. Comparison of QBS index between CS and NC indicates that it was decreased in CS, indicating that soil health and function were adversely affected. Seasonal changes in the QBS index during the study period showed that the effect of heavy metals on microarthropod community structure is influenced by seasonal changes in environmental conditions.

Key words: *microarthropods, heavy metals, soil health, QBS, Plovdiv.*

INTRODUCTION

Humans have extensively altered the environment and caused a reduction in the level of biodiversity. Disturbances linked to human activity can alter the quantity and quality of detritus availability and the chemical-physical properties of habitats of soil organisms. Soil as a non-renewable resource is a key factor for agriculture; preservation of high soil quality is one of the main goals of sustainable agriculture. In this context the monitoring of soil quality plays an important role in preserving biodiversity to achieve sustainable management of renewable resources.

The number of bio-indicator systems using soil invertebrates is relatively high; some approaches use nematodes, mites, collembolans, dipterans, coleopterans or all of the microarthropod communities (Pankhurst, 1997; Gilley et al., 2001: Ruf at al., 2003). According to the soil heavy metals pollution many authors use the nematodes as bio-indicator of the soil health. Nematodes are among the simplest metazoan occupy key position in soil food webs. They do not rapidly migrate from stressful condition but respond rapidly to disturbance and enrichment (Bongers and Ferris, 1999). Likewise the microathropod are very abundant, sensitive to changes of soil properties and most of them are sedentary and unable to respond spatially and temporally to soil property changes (Bird et al., 2000).

In the last decade, different authors proposed new methods for soil health assessment, based on soil microarthropods. Some of these methods are based on the general evaluation of microarhropods (Parisi, 2001), while others are based of evaluation of single taxon (Paoletti, 1999; Cassagne et al., 2004; Hodkinson and Jackson, 2005). The QBS index-i.e. "Qualità Biologica del Suolo" evaluates the entire microarhropod community (Parisi, 2001). This index is based on the concept that the higher the soil quality is the higher the number of microarthropod groups well adapted to soil habitats (Parisi and Menta, 2008).

In Bulgaria an evaluation of the soil quality using QBS index has not presented until our study. The aim of this article is to present the results of the research carried out in the region of Plovdiv, (south Bulgaria), a region characterized by very intensive agroecosystems and heavy metals pollution of the soil in small parts of this region. Particular attention was focused on comparison of microarthropod communities in two different types of soil (contaminated (CS) and non-contaminated (NC) with heavy metals) during the three seasons in 2011.

MATERIALS AND METHODS

Study areas

The sampled areas are located in the region of Plovdiv. The five CS sites are nearby the production plant for mineral raw materials processing, and production of different kind of metal products (14 kilometres south from Plovdiv). The five NC sites are located in 25 kilometres north-east from Plovdiv.

The soil type of the two different areas is cinnamon forest soils, and the landscape is dominated by agricultural land use.

According to the climatic data (National Institute of Meteorology and Hydrology, BAS – branch in Plovdiv), the average air temperature from April through November 2011 was 22.5°C. The average rainfall for the investigation period was 295 mm.

Soil sampling

In each site three soil cores, 10 cm × 10 cm and 10 cm depth were picked up in the spring, summer and autumn in 2011. In the study sites above plant cover was removed before sampling and only soil was taken. Soil samples for QBS calculation were collected when soil moisture ranged between 30 and 70% of field capacity.

Because of climate and logistical reasons the sites were not sampled simultaneously. The soil samples were placed in plastic bags and transported to the laboratory.

Extraction of microarthropods

A Berlese-Tullgren funnel was used for microarthropd extraction (Phillipson, 1971). The soil core was carefully placed on mesh above the funnel together with all the soil lost from sample during handling before inserting a bottle filled with preservative liquid (2 parts 75% ethanol and 1 part 25% glycerine). Extraction duration was proportionate to the soil sample water content (never less than 5 days).

Specimen observation

Extracted specimens are observed under a stereomicroscope at low magnification (usually 20-40× is sufficient) in the same preservative liquid. The specimens were identified at different taxonomical levels: classes, orders and families.

Determination of biological forms and calculation of QBS index

Within each higher taxon, QBS method requires searching for the biological form (morpho-type) that is most adapted to soil. This type receive a score named the EMI (eco-morphological index), which ranged from 1 to 20 in proportion to degree of adaptation. As a general rile, eu-edaphic (i.e. deep soil-living) forms receive an EMI = 20, hemi-edaphic (i.e. intermediate) forms get an index rating proportionate to their degree of specialization, while epi-edaphic (surface-living) forms score EMI = 1. The QBS index value is obtained from the sum of the EMI of all collected groups. If in a group, biological forms with different EMI scores are present, the higher value (more adapted to the soil form) is selected to represent the group in the QBS calculation (Parisi et al., 2005).

Table 1. Characteristics of sample sites

Site number	Land use	Crop	Sampling dates-2011	Heavy metals contamination mg/kg
	SC			
1.	Arable land	Cherry trees	28/04; 04/07; 29/10	Pb-301.8; Zn-641.6; Cu-82.1; Cd-9.01
2.	Arable land	Lavender	30/04; 07/07; 03/11	Pb-275.6; Zn-543.4; Cu-71.1; Cd-6.92
3.	Arable land	Alfalfa	01/05; 08/07; 04/11	Pb-253.2; Zn-528.6; Cu-69.1; Cd-6.03
4.	Arable land	Lavender	01/05; 08/07; 04/11	Pb-270.8; Zn-550.2; Cu-76.2; Cd-5.98
5	Permanent grassland	-	03/05; 11/07; 06/11	Pb-223.4; Zn-502.1; Cu-53.5; Cd-5.74
	NC			
1.	Arable land	Apple trees	06/05; 15/07; 09/11	Pb-17.2; Zn-53.6; Cu-4.2; Cd-0.22
2.	Shrubland	-	06/05; 15/07; 09/11	Pb-19.8; Zn-63.5; Cu-5.6; Cd-0.26
3	Arable land	Alfalfa	06/05; 15/07; 09/11	Pb-15.1; Zn-42.6; Cu-3.7; Cd-0.17
4.	Permanent grassland	-	09/05; 18/07; 11/11	Pb-17.9; Zn-55.1; Cu-4.3; Cd-0.20
5.	Arable land	Spearmint	09/05; 18/07; 11/11	Pb-14.3; Zn-39.2; Cu-2.8; Cd-0.11

RESULTS AND DISCUSSIONS

In the soil under study microarthropodial fauna was well differentiated. In both CS and NC soils of different land agroecosystem have been determined species belong to 6 classes, 9 orders and 7 families.

Phylum *Arthropoda*
Class *Entognata*
Order *Collembola*
Class *Chilopoda*
Class *Diplopoda*
Class *Malocostrata*
Order *Isopoda*
Class *Insecta*
Order *Diplura*
Order *Orthoptera*
Order *Hemiptera*
Family *Membracidae*
Order *Coleoptera*
Family *Elateridae*
Family *Staphylinidae*
Family *Tenebrionidae*
Family *Curculionidae*
Family *Carabidae*
Family *Melolonthidae*
Order *Lepidoptera*
Order *Hymenoptera*
Class *Arachnida*
Order *Orbitida*

The taxa of the three edaphic forms were represented in the sampling sites. The eu-edaphic forms were presented from *Collembola, Chilopoda, Diplopoda, Diplura* and *Arachnida*. The semi-edaphic microarthropods were presented from *Isopoda, Orthoptera, Coleoptera, Lepidoptera* and *Hymenoptera*. Hemipterans were representative for epi-edaphic biological forms.

It is interesting to note that some important groups, such as *Protura* and *Pauropoda* were entirely lacking in both CS and NC soils. Similarly Gardi et al. (2002) and Menta et al. (2008) observed that these two taxa were not presented in five evaluating site in north Italy even the condition are favorable. The authors also observed that *Chilopoda* occurs only in two soil samples. In contrast we found species belong to this taxon in 4 CS sites and all NC sites. In Tables 2 and 3, the soil microarthropod taxa extracted from soil samples and associated EMI are shown.

Table 2. Soil microarthropod taxa, associated EMI and QBS value (bold row) with soils contaminated with heavy metals

Microarthropods groups	Site 1	Site 2	Site 3	Site 4	Site 5
	Spring				
Collembola	10	10	10	10	-
Chilopoda	10	10	-	-	20
Diplopoda	-	-	-	5	5
Isopoda	-	-	10	-	-
Diplura	-	-	20	20	-
Orthoptera	-	-	-	-	-
Hemiptera	-	-	-	-	-
Coleoptera-larvae	-	10	10	-	10
Coleoptera – adults	-	-	5	5	10
Hymenoptera	-	-	5	5	-
Lepidoptera-larvae	-	-	-	-	-
Arachnida	-	20	20	-	20
QBS value	**20**	**50**	**80**	**45**	**65**
	Summer				
Collembola	10	10	10	10	-
Chilopoda	-	-	10	-	20
Diplopoda	-	-	-	-	5
Isopoda	-	-	-	-	-
Diplura	-	-	20	20	-
Hemiptera	-	-	-	-	-
Orthoptera	-	-	-	-	-
Coleoptera-larvae	-	-	-	-	-
Coleoptera – adults	-	10	10	10	10
Hymenoptera	-	5	-	-	-
Lepidoptera -larvae	5	-	10	10	-
Arachnida	-	20	20	-	20
QBS value	**15**	**45**	**70**	**50**	**55**
	Autumn				
Collembola	10	10	20	10	-
Chilopoda	-	-	10	-	10
Diplopoda	-	-	-	5	5
Isopoda	-	10	10	-	10
Diplura	-	-	-	20	20
Orthoptera	-	-	-	-	-
Hemiptera	1	-	1	-	-
Coleoptera-larvae	5	10	10	-	10
Coleoptera – adults	5	10	-	-	5
Hymenoptera	-	5	5	5	-
Lepidoptera -larvae	5	-	10	-	-
Arachnida	-	20	20	20	20
QBS value	**26**	**65**	**86**	**60**	**80**

There are visible differences between QBS value of CS and NC soils in all sites during the three evaluation seasons. QBS values of SC sites ranged between 40 and 90, while the index value of NC soil was obviously higher – above 90, except site 5 in the summer (Table 2). The lowest QBS value (15-26) was found in site 1 of CS (Table 2). In this site QBS value was affected by the highest level of heavy metals contamination. According to van Straalen (2004) biodiversity of soil microarthropods is influenced by heavy metals contamination in the soil, especially by Zink (Zn). Zn content in site 1 ranged from 502 to 641 during our research work (Table 1). Others authors such as Cortet et al. (1999) and Brussaard et al. (2007) reported that the

Pb content in the soil affected microarthropod communities in the high level and QBS index of contaminated with Pb soils is lower than 40. In the present research the Pb content in the soils nearby the production plant was about 14.2-17.4 times higher than the soils of the non-contaminated area. Probably because of this reason QBS value of CS soils was 1.6-5.4 times lower than index value of NC. The highest QBS value (101-151) was observed in site 1 of NC soils, following by site 3 with index value ranged between 95 and 145 (Table 3).

In CS sites all the arable land parcels, except site 1, have a quite similar QBS value and higher than 45. Site 3 was an old alfalfa (*Medicago sativa*) meadow and the highest QBS value may have resulted from the lowest heavy metal content compared with the other arable land sites (1, 2 and 4, Table 2). Parisi et al. (2005) also reported the highest QBS value in alfalfa sites but as a result from the long period without any soil disturbance.

Many authors discussed that the highest QBS value is usually calculated in the shrublands and grassland (Gardi et al., 2009; Menta et al., 2011; Blasi et al., 2012). In contrast our research showed that the highest QBS value was calculated in arable areas with apple trees. This probably due to the relatively well preserved habitats of soil microarthropods in this site, because of presence of grass in/between rows of growing apple trees.

Figure 1 presents seasonal changes in QBS value in CS and NC soils. In both spring and summer the climatic conditions were favorable for soil microarthropods development, especially for the typical eu-edaphic forms, such as *Diplura* and *Arachnida*.

As a result of that, the QBS value was 96-25.4% higher than the summer. The effect of climatic impact was more distinguishable in NC sites. The difference between QBS value in CS sites during the study period seasons was less remarkable. In NC soils QBS value of 53, 47 and 63.4 was recorded in spring, summer and autumn, respectively. It have been discussed the seasonal changes in climatic factors affect predominantly semi-edaphic and ep-edaphic microarthropods and some species from orders *Collembola* and *Diplura*.

In agreement with this hypothesis, the present data demonstrated the highest seasonal fluctuation in orders *Hemiptera, Orthoptera, Coleoptera* and *Lepidoptera* and some species of *Collembola* and *Chilopoda*.

Table 3. Soil microarthropod taxa, associated EMI and QBS value (bold row) with non-contaminated with heavy metals soils

Microarthropods groups	Site 1	Site 2	Site 3	Site 4	Site 5
	Spring				
Collembola	20	20	10	20	10
Chilopoda	20	10	10	20	20
Diplopoda	5	5	5	5	-
Isopoda	10	10	10	10	10
Diplura	20	20	20	20	-
Orthoptera	20	-	20	-	20
Hemiptera	1	-	-	1	1
Coleoptera-larvae	10	10	10	10	10
Coleoptera-adults	10	5	5	5	10
Hymenoptera	5	5	-	5	5
Lepidoptera-larvae	10	-	10	-	-
Arachnida	20	20	20	20	20
QBS value	**151**	**100**	**120**	**116**	**106**
	Summer				
Collembola	10	10	10	10	10
Chilopoda	10	10	10	10	10
Diplopoda	5	5	5	-	-
Isopoda	10	10	10	10	10
Diplura	20	20	20	20	-
Orthoptera	-	-	-	-	-
Hemiptera	-	1	-	1	1
Coleoptera-larvae	10	10	10	10	10
Coleoptera-adults	10	-	-	5	10
Hymenoptera	5	5	-	-	5
Lepidoptera -larvae	10	-	10	10	-
Arachnida	20	20	20	20	20
QBS value	**101**	**96**	**95**	**96**	**76**
	Autumn				
Collembola	20	20	10	20	20
Chilopoda	10	20	20	20	10
Diplopoda	5	5	5	5	5
Isopoda	10	10	10	10	10
Diplura	20	20	20	20	20
Orthoptera	20	-	20	-	20
Hemiptera	-	-	-	-	-
Coleoptera-larvae	10	10	10	10	-
Coleoptera – adults	10	10	5	10	5
Hymenoptera	5	5	5	5	-
Lepidoptera -larvae	10	-	10	-	-
Arachnida	20	20	20	20	20
QBS value	**140**	**120**	**145**	**120**	**110**

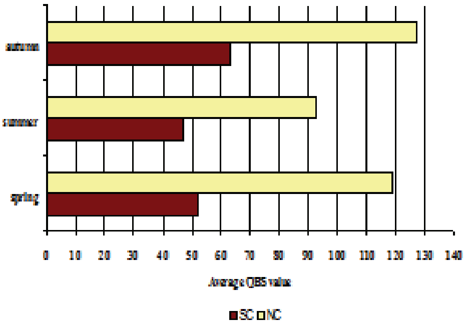

Figure 1. QBS value in three different seasons

CONCLUSIONS

In the period April-September 2011 for the first time in Bulgaria QBS index have been applied for assessment of microarthropod community structure in contaminated soil (CS) with heavy metals and non-contaminated soils (NC).

Differences between QBS value of the polluted with heavy metal soils and non-contaminated soils allows assessing the degradation level of soil. Nevertheless this method is biotic index and as such its diagnosis capability can be limited.

The results of this study suggest that not only the permanent grassland but also the arable land can be appropriate agroecosystems for preserving the soil microarthropod communities even in the heavy metals contaminated soils.

Differences among the studied habitats were not only observed in taxa diversity but also in seasonal population dynamics, another factor of diversity in soil communities.

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