Turkish Journal of Agricultural and Natural Sciences
Special Issue: 1, 2014

TÜRK
TARIM ve DOĞA BİLİMLERİ
DERGİSİ

TURKISH
JOURNAL of AGRICULTURAL
and NATURAL SCIENCES

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Assessment of Nematodes as Bioindicators of Soil Health in Agroecosystems

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Abstract

Soil is a multicomponent and multifunctional system, with definable operating limits and a characteristic spatial configuration. Soil health, term using by farmers, or soil quality – a term generally used by scientists, is defined as the continued capacity of soil to function as a vital living ecosystem that supports and sustains directly crop growth and indirectly animals, and humans. To evaluate soil quality reliable indicators that allow comparison across ecosystems are needed. Nematodes can be used as effective soil health bioindicators because they occur in any environment, that provides a source of organic carbon, in every soil type, easy to sample, and well classified into functional (feeding) groups, and nematode taxa are well classified. Nematodes have diverse life strategies, ranging from colonizers (short life but high reproduction rate) to persisters (long life, but low reproduction rate) which can provide an indication of the real condition or health of the soil in agricultural environment. Because Bulgaria is an agricultural country with developed vegetable crop production maintaining soil health is especially important for the economy and livelihood of the populations. The ability to monitor and assess the quality of agroecosystem soils would be of significant importance for stakeholders, who could change their farming strategies accordingly. Therefore the data collected from literature, recent and future research will be base to create "soil health maps" using GIS that will appropriate for local conditions

Keywords: soil health, nematodes, agroecosystems, vegetable crops, GIS.

Introduction

Soil is part of the vital living, natural terrestrial ecosystem. On agronomic point of view the soil is very important and relevant stakeholders pay attention on its physical and chemical characteristics. A very important component, which is neglected, is the biological aspect. It is known that all kinds of cultural practices affect directly or indirectly soil biota. In recent years, attention is focused on soil management practices that promote sustainable soil quality, productivity and health (Abawi &Widmer, 2000). Doran and Parkin (1994) give definition of soil quality - "The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health". Harris and Bezdicek (1994) think that terms *soil quality* and *soil health* are currently used substitutable in scientific literature and popular publications. In general, scientists prefer the term soil quality and farmers prefer soil health (Sherwood & Uphoff, 2000).

Nematodes are common in almost any soil type. According to the Technical Report 2010-049 of EC DG ENV :"Nematodes are ubiquitous on earth due to their high adaptability". They are important components of soil food webs (Coleman, 1984) and can be classified according to their feeding habits (Yeates, 1993). Some species feed on algae, others on bacteria, fungi or plant roots. Other species still are predatory, and feed on other nematodes and protists, while some are omnivores and will eat any of the above. This diversity in feeding habits is important for agriculture: the production of some predating nematode species in fermenters is an established tool in biological plant protection.

Soil mesofauna, especially nematodes are generally very adaptable within their environment to the

health and condition of the soil that they inhabit (Gupta & Yeates, 1997).

Healthy soil is a stable soil, with resilience to stress, high biological diversity, and high levels of internal cycling of nutrients. So far in Bulgaria related research using nematodes assemblages as indicators of ecosystem functioning was made in urban forest in Sofia (Mladenov et al., 2004) and ski runs at Pirin Mountain (Mincheva, 2009). There are only a few articles addressing the soil health in arable lands using nematode as indicators.

Based on the presently studied literature and personal research on soil health the aim of the study is to summarize, assess and outline future trends for the use of nematodes as bio-indicators.

Materials and Methods

For assessment of nematodes as bioindicators of soil quality the information from literature references and field work was used. Nematodes are easy to sample. Extraction of nematodes from soil is standardized through efficient, routine procedures - modified method of Cobb, 1918 is often used. Extracted nematodes can be preserved and stored for future analyzes. Nematodes can be identified to the family level using simple morphological characteristics. Nematode faunal profile analysis provides extraction analysis provides information on succession and changes in decomposition pathways in the soil food web, nutrient status and soil fertility and the effect of soil contamination.

Results

Nematodes as indicators of soil health - Current status and future perspectives.

Soil fauna have advantages over soil microbes as bioindicators. First, by being one or two steps higher in the food chain, they serve as integrators of physical, chemical, and biological properties related with their food resources (fig. 1). Second, their generation time (days to years) is longer than metabolically active microbes (hours to days), making them more stable temporally and not simply fluctuating with ephemeral nutrient ushes (Neher, 2001). Nematodes and mites are probably the most studied biological indicators of soil health ematodes as bio-indicators conform to the general five criteria required for indicators of soil health or soil quality– sensitivity to variations in management, well correlated with beneficial soil functions, useful for elucidating ecosystem processes, comprehensible and useful to land managers, easy and inexpensive to measure (Doran & Zeiss, 2000). Comprehensive studies on nematode faunal analysis have been conducted over the last decades to validate that nematodes are good soil health bioindicators (Bongers, 1990; Ettema, 1998; Ferris et al., 2001; 2010; Neher, 2001). Four nematode community indices commonly used as soil health indicators are maturity index (MI), enrichment index (EI), structural index (SI), and channel index (CI) (Bongers, 1990; Ferris et al., 2001). MI weighted mean of the colonizer-persister (c-p) values on a scale of 1 to 5 of nematodes in all trophic groups, it provides the stability of the nematode community in the soil food web (Yeates and Bird, 1994). Families on the lower end of the scale (*cp*-value 1-2) are so-called *colonizers*, roughly corresponding to *r*-strategists, and are relatively insensitive to disturbance. These nematodes are often small, present in high numbers, bacterial feeding, have a short generation time and can produce a lot of offspring (Bongers, 1999). Families at the higher end of the scale (*cp*-value 4-5) are so-called persisters, roughly corresponding to K-strategists, and are very sensitive to disturbance. They are generally relatively large nematodes, present in low numbers, are often predators or omnivorous, have long generation times and produce relatively little offspring. The assignment of families to these classes is based mainly on expert knowledge and there are no hard objective guidelines to determine to which *cp*-class a family should belong.

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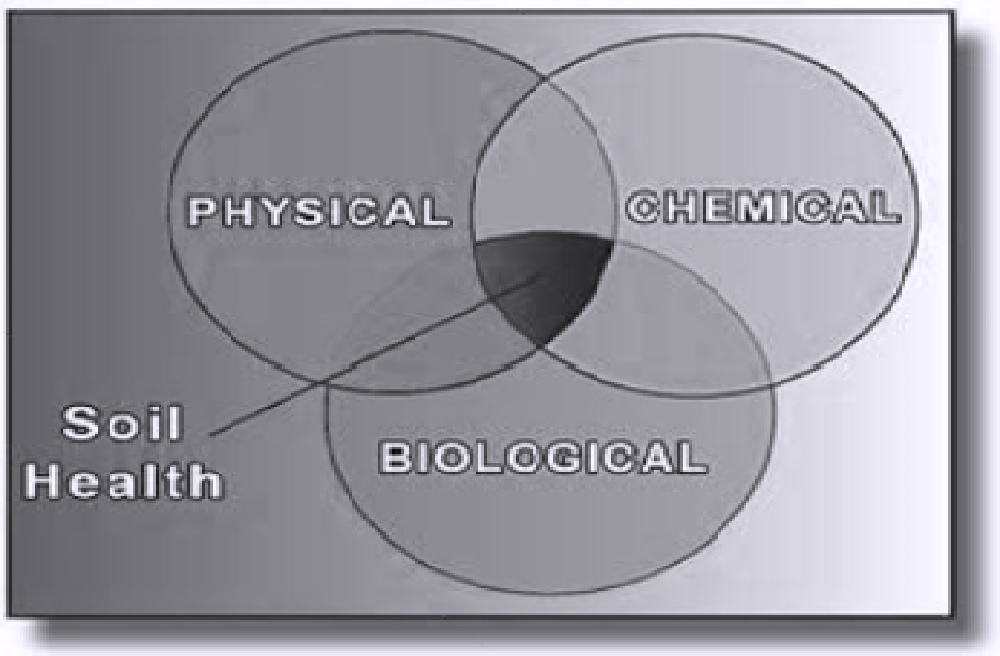

Figure 1. Soil health emphasizes the integration of biological with chemical and physical measures of "soil health" that affect farmers' profits, risks, and the environment.

EI depicts whether the soil food web is enriched with nutrients, whereas SI illustrates if the soil communities are stable and undisturbed. CI indicates whether the soil food web is diminished by stress or limited in nutrient resources. To give a general perspective, perennial cropping, reduced-till farming systems, and undisturbed natural ecosystems such as forests usually have higher MI and SI than most conventional tillage agro-ecosystems. Conversely, soil recently amended with manure or other organic matter with high N content would have higher EI than those fertilized synthetically. Soil that is drier or being fumigated would have higher CI than soil without external stress. Without high biological diversity, a soil ecosystem would be vulnerable to environmental changes, disturbances and other stresses. Nematode community indices were correlated with concentration of many soil nutrients, microbial biomass, plant growth, and ect. Therefore, using nematodes as bioindicators reflects both soil biotic and abiotic factors, and provides insight into soil health (Wang & Hooks, 2011). Nematodes, which are widespread, rich and diverse within soil ecosystems, and are closely involved in decomposition process, as well as in plant nutrient cycling, which makes them prospective bio-indicators (Gupta & Yeates, 1997).

Discussion

Agricultural management

Plant-feeding nematodes are abundant in agricultural ecosystems (Wasilewska, 1979; Neher and Campbell, 1996). These nematodes may affect primary productivity of plants by altering uptake of water and nutrients. These abnormalities may result from changes in root morphology and/or physiology. Agricultural managements affect soil nematode communities.

For many agricultural crops (vegetables, vines and ect.), a negative relationship between crop yield and populations of plant-parasitic nematodes, such as *Meloidogyne, Xiphinema, Longidorus* spp*.,* has been observed (Choleva et al., 2007, Bileva, 2012, 2013). In previous our investigations GIS application was used for optimizing the aggregate composition of different soil types (Dallev et al, 2014 a,b) and GIS database was created for characterization of soil types, soil texture and pH in accordance with incidence, importance, and distribution of nematode species in vineyards in South Bulgaria. Using GIS techniques, maps were created for identifying hot spots of plant-parasitic nematodes from family Longidoridae in Plovdiv region of Bulgaria. That is proved to be helpful information on species habitat and ecological references and detecting sites that may require special attention in sustainable land use

and management of vineyards (Arnaudova, 2011, Bileva & Arnaudova, 2011).

However, when entire nematode communities, including free-living nematodes, are examined, a positive association has been observed between plant biomass production and total nematode populations not only in field conditions and pot experiments with economically important agricultural crops – tomato, zucchini and grapevines (Choleva, 1994, Bileva et al., 2009, Bileva, 2013, Haytova & Bileva, 2011).

Within rural lands, soil biodiversity tends to decrease with the increasing intensification of farming practices (e.g. use of pesticides, fertilisers, heavy machinery). However, not all soil management practices have a negative impact on soil biodiversity and related services. The assessment of soil quality is needed to monitor changes in sustainability and environmental quality as related to agriculture management and to assist governmental agencies in formulating realistic agricultural and land-use policies (fig. 2).

While in general chemical treatments and tillage aimed at improving soil fertility trade off with soil carbon storage and decontamination services, in contrast mulching, composting and crop rotations all contribute to improve soil structure, water transfer and carbon storage. In recent years especially actuality takes practice to improve soil fertility and crop yield by using organic amendments (e.g. algae, organic fertilizers containing humic acids) (Choleva et al., 2007, Bileva et al., 2009, Haytova & Bileva, 2011, Bileva, 2013). 2002).Grassland soils are the soils that present the richest biodiversity, before forests and cropped or urban lands.

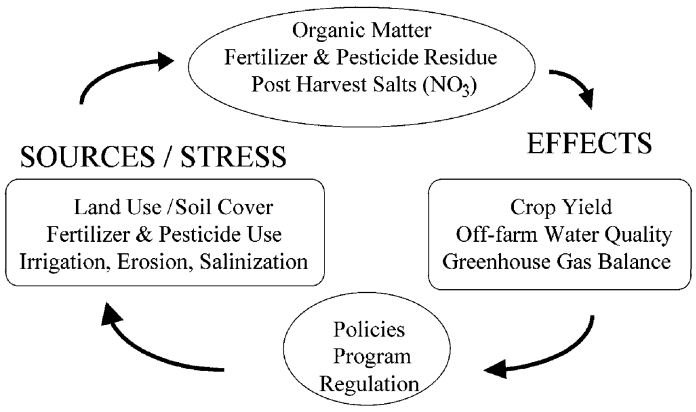

Figure 2. The politics of soil health (by Doran,

The increase of erosion processes could lead to the removal of organic layer and biota living within and a subsequent loss of soil system functions. Similarly, human activities (land use change, tourism, construction of ski runs, urbanization) affect negatively the diversity and relative abundance of soil biota (e.g. nematode communities) thus leading to changes in functional characteristics and their role in maintaining the ecological balance (Mincheva, 2009, Lazarova et al., 2011). The relationship between soil nematode communities as bioindicators and row crop yield in agricultural ecosystems in Bulgaria has yet to be determined.

Conclusion

Because Bulgaria is an agricultural country with developed vegetable crop production maintaining soil health is especially important for the economy and livelihood of the populations. The use of nematodes as bio-indicators of soil health cannot be a the only one measure for the determination of soil health, but should be an important component of an integrated system of measurements. It can be regarded as the first step in the establishment of key soil health indicators for the horticulture and minimize impact on the environment.

The ability to monitor and assess the quality of agroecosystem soils would be of significant importance for stakeholders, who could change their farming strategies accordingly. Therefore the data collected from literature, recent and future research

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Acknowledgment

This study was financially supported by Research Fund of Agricultural University of Plovdiv, Project № 5-14.

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