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Effect of different set-aside management systems on soil nematode community and soil fertility in North, Central and South Italy

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ABSTRACT

The current Common Agricultural Policy (CAP) 2014–2020 of the European Union (EU) proposed some environmental attempts to contrast the biodiversity decline and mitigate the effects of intensive agricultural management systems. In the present work, the results of the effectiveness of set-aside management to enhance soil nematode biodiversity and soil fertility are reported. In a mid-term experimental trial, three different set-aside managements, with mowing in May or July and without mowing, were compared through conventional rotation to provide management indications in the context of Good Agricultural and Environmental Condition (GAEC) Standard 4.2 in fields located in three sites (North, Central and South Italy). Soil fertility was evaluated by determining available phosphorous, total organic carbon and carbon humification. Soil nematode diversity was explored by examining soil nematode community structure, assessing Maturity (MI), Plant Parasitic (PPI), Basal (BI), Enrichment (EI), Structure (SI), Channel (CI) indices and diversity-weighted abundance.

The results indicated that set-aside management moderately increased the available phosphorous and organic carbon content and humification remained low; the greatest increase in organic matter was obtained with mowing in May, period not permitted by Standard 4.2. The set-aside efficiency was associated with the previous crop rotations, and the major advantages were found after intensive crop rotations.

In general, under set-aside management the nematode colonizer species, mainly bacterivores, increased in abundance and richness while plant parasitic nematodes and predators remained constant. Mowing carried out in July (the permitted period by Standard 4.2), weakly improved the soil nematode community structure by increasing k-strategies within nematode populations. Interestingly, the indices confirm that shifts in nematode community composition occurred more as a result of previous management than of five years of set-aside managements: specifically, the site characterized by the longest and the most conservative rotation, showed the highest values in MI, PPI, EI, SI indices. The use of diversity-weighted abundance expressed as biomass showed that free living nematodes involved in nutrient mineralization (bacterial and fungal feeders) and plant parasitic nematodes are not efficiently regulated by predation. Finally, as many nematode families are affected by soil organic carbon content, the low organic carbon increases found under set-aside management systems likely determined a low improvement of soil nematode biodiversity.

1. Introduction

There is increasing evidence that wildlife inhabiting arable ecosystems in Europe has suffered a severe decline during the last 40 years. Land use and the change of farming systems towards more intensively managed monocultures are considered to be among the main causes (Tilman et al., 2002). Moreover, the repeated application of pesticides and chemical fertilizers has gradually reduced the state of soil health, reducing its physical-chemical and biological fertility, as well as the level of organic matter and biodiversity, reducing the ability of ecosystems to provide goods and services (Benton et al., 2003; Mocali et al., 2008). Sustainable and viable management of agricultural soils has become a top priority for European producers. Consequently, as the loss of biodiversity is considered a key driver of ecosystem change

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(Hooper et al., 2012), the current Common Agricultural Policy (CAP) 2014–2020 of the European Union (EU) proposed some environmental attempts such as ecological set-aside, pastures, rotations, orchard grasses and organic farming (greening) to offset the biodiversity decline and mitigate the effects of intensive agricultural management systems.

The set-aside has been applied for two decades (from the late 1980s to 2008) in Europe, but its efficacy for protecting farmland biodiversity is still debated. Several authors showed that rotational set-aside increased the population density of many early succession species, both plants and animals, in agricultural landscapes (Sotherton, 1998; van Buskirk and Willi, 2004; Tscharntke et al., 2001). Even though a number of studies have focused on the impact of set-aside on soil biodiversity, they have mainly studied arthropods (Biaggini et al., 2011; Mocali et al., 2015; Raglione et al., 2011), which are responsible for essential processes such as decomposition and nutrient mineralization. Mocali et al. (2015) reported that the mowing on set-aside land guaranteed the presence of higher biological emi/eu-edaphic arthropod diversity than conventional cropping systems, reducing the risk of the dominance of more aggressive edaphic groups. Soil nematodes also play a key role in the soil detritus food web, grazing on bacteria and fungi and thus regulating the decomposition and nitrogen mineralization in soil ecosystems (Sohlenius et al., 1988). It is well known that soil organic matter influences diverse and important soil biological activities and that set-aside practice increases the overall organic matter content as compared to cultivated soils (Smith, 2004). In addition, several studies have shown that populations of plant-parasitic nematodes have decreased and saprophytic nematodes increased with increases in organic matter (Barker and Koenning, 1998; Bird, 2000; Landi et al., 2016; McSorley and Gallaher, 1996). To date, several studies have been conducted on plant parasitic nematodes (Lawson et al., 1994; Boag et al., 1994; Boag et al., 1998) and entomopathogenic nematodes (Torrini et al., 2014) under set-aside regimes. By contrast, in set-aside systems few studies have been carried out to evaluate the whole free-living nematode community (Freckman and Ettema, 1993; Sánchez-Moreno et al., 2006) and its multiple roles within the soil food web. Many management factors still need to be addressed, such as the relative importance of different types of set-aside management on the different responses of species groups and the role of the landscape context for conservation of biodiversity and associated ecosystem services (Ferris et al., 2001; Ugarte et al., 2013, Ferris and Tuomisto, 2015).

The main purpose of the present study was to assess the potential effectiveness of set-aside management to enhance soil nematode biodiversity in a mid-term experimental trial. Three different set-aside management systems were compared to conventional rotation to provide management indications in the context of Good Agricultural and Environmental Condition (GAEC) Standard 4.2. To ensure the proper management of the set-aside fields, specific agronomic practices consisting in mowing (or equivalent operations) to conserve and protect biodiversity were used. The experimental areas were located in three sites (North, Central and South Italy) with different soils, climate and consequently crop rotations. In detail, the effects of set-aside were evaluated on: i) the organic matter and its fractions; ii) the diversity of soil free-living nematode community and its main ecosystem services such as mineralization and control of plant parasitic nematodes; iii) the relation between organic matter supplies and soil nematode community.

2. Materials and methods

2.1. Field site and treatments description

The experimental fields used in this study were managed as set-aside since 2008 in three different sites previously used for conventional cereal crops with different rotations (Table 1). In North Italy, the experimental site was located at the farm “Valle Vecchia” of Veneto Agricoltura (45°37′51.21”N − 12°58′10.29”E) in Caorle (Venezia), on a lagoon plain at 1 m a.s.l. The local climate was characterized by average maximum temperatures in July-August (28.4 °C) and average minimum temperatures in January (− 0.8 °C); the precipitation is concentrated in October (109 mm). In Central Italy, the experimental site was located at the farm “Centro Sperimentale di Fagna” of CREA (43°58′53.28”N − 11°21′01.15”E) in Scarperia (Firenze), on a hill at 253 m a.s.l. The local climate was characterized by average maximum temperatures in July–August (24.5 °C) and average minimum temperatures in February (2.0 °C); the precipitation is concentrated in October–December (420.8 mm). In South Italy, the experimental site was located at the farm “Pantanello” of the CREA (40°23′12.13”N − 16°47′40.08”E) Metaponto (Matera), on a plain at 4 m a.s.l. The local climate was characterized average maximum temperatures in July–August (33.2 °C) and average minimum temperatures in January-February (3.9 °C); the precipitation is concentrated in February–March (203 mm).

The same experimental design was applied in each site to compare three different set-aside managements with the conventional rotation: i) set-aside with a mowing in May (MM) without removal of the vegetation cover (period not permitted by CAP and Directive 2009 147/EC to preserve the bird breeding, but usually used in conventional grassland management); ii) set-aside with a mowing in July (MJ) avoiding the removal of the vegetation cover (period permitted by CAP and Directive 2009 147/EC to preserve bird breeding); iii) set-aside without mowing (NM), with plots without cutting (wild); iv) conventional rotation (CR), traditional of each site and with different grade of soil disturbance intensities as reported above. The total area of four plots was 2 ha (0.5 ha per plot) with an ecotonal belt on at least one side.

2.2. Soil sampling design

Soil samples were collected in each study area in 2012 and 2013, corresponding at the last two years of the trial (4th and 5th year), in spring (before mowing) and autumn (after mowing) in three different points of each plot, located at about 20 m, 40 m and 60 m from the ecotonal belt.

To characterize the main soil chemical properties, samples were taken at 0–20 cm depth following this time schedule: i) electrical conductivity, soil pH, available phosphorus and total organic carbon (TOC) were monitored during 2012 and 2013, in order to also evaluate annual shift (three samples per treatment and four times per location, corresponding to 144 samples as a whole); ii) TOC qualitative analysis was performed during 2013 at the end of the trial (three samples per treatment per twice per location, corresponding to 72 samples as a whole); iii) to characterize soil nematode structure, a further set of soil samples was collected close to previous ones during 2013, at the end of the trial (three samples per treatment, twice per location, corresponding to 72 samples as a whole). The sampling was carried out with a hand auger (5 cm inside diameter) from the 15 cm deep top layer of bulk soil after removing surface residues. For each soil sample, six cores were randomly sampled and then mixed to form one composite sample. Each sample was then placed in a sterile plastic bag, labeled and stored in a cold chamber at 4 °C.

2.3. Soil chemical analysis

The soil samples were air dried at room temperature (20 °C) and sieved through a 2 mm mesh for pH, electrical conductivity (EC) and available phosphorus (P) analyses, and a 0.5 mm mesh for soil total organic carbon (TOC), total extractable carbon (TEC) and humification analysis. EC was determined according to Violante and Adamo (2000). Soil pH was measured potentiometrically in a 1:2.5 soil-water suspension. Available P was determined by the Olsen method (Olsen and Sommers, 1982). Soil total organic carbon (TOC) was determined by hot oxidation with potassium dichromate and sulphuric acid (Yeomans