Restoration of soil fertility and management of mineral nutrition in a peach orchard under a sustainable farming system in semi-arid conditions

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Abstract

One of the main environmental challenges of the 21st century is to face the increase in soil degradation. Nowadays, there is evidence that sustainable orchard management practices can contribute to increasing the SOC, reducing soil CO_2 emissions, recovering soil fertility and increasing yields. The main objective of this research was to improve the mineral nutrition management, considering soil fertility parameters and N mineralization, in a peach orchard managed under alternative agricultural practices. One of the most important agronomic practices is irrigation, which is essential for plant production and can increase nutrients availability through soil N and C mineralization, with a direct effect on soil quality. The monitoring of soil nitrates and soil quality index (N_c/N_k ratio) along the row (R), wetted and along the inter-row (I), rain-fed, in the orchard under localized irrigation was performed. The results revealed spatial (R, I) and seasonal variability of soil nitrates and soil quality. This study shows that the long-term adoption of localized irrigation and of sustainable agricultural practices has positive effects on soil quality, with benefits to the stability of the whole agro-ecosystem.

Keywords: sustainable soil management, localized irrigation, microbial biomass, nitrate soil content

INTRODUCTION

Soil is a non-renewable resource and its degradation, characterized by decline in quality and decrease in ecosystem goods and services, affects agricultural production (Lal, 2009, 2015a; Scherr, 2001). Improving activity and species diversity of soil micro-organisms is essential to restore and improve soil quality, reducing risks of soil degradation (Lal, 2015b). Farming systems could affect the type, rate and severity of soil degradation by altering the SOC pool, structural morphology and other properties (Autret et al., 2016; Ryan et al., 2008).

Fruit tree ecosystems have the potential to reverse soil degradation trend by the adoption of sustainable orchard management practices that increase the sequestration of atmospheric CO_2 into soil, tree biomass and litter, enhancing soil organic carbon (SOC) and biodiversity (Montanaro et al., 2017; IPCC, 2006). Soil fertility is mainly related to the variability, abundance and richness of micro-organisms (Zornoza et al., 2015). They are responsible for the cycling of organic matter and the generation of nutrients for plants through enzymatic processes (Nannipieri et al., 1990).

One of the most important agronomic practices is irrigation, which is essential for plant production and plays a role in the performance of soil microbial communities in natural and agricultural ecosystems at the level of microbial growth biomass (Fierer et al., 2003; Hueso et al., 2012) and microbial composition (Placella et al., 2012; Bastida et al., 2017). Soil micro-organisms can increase nutrients availability through the processes of soil N and C mineralization, with a direct effect on the soil quality (Malik et al., 2013). For this

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reason, it is urgent and important to identify a biochemical indicator related to soil microbial dynamics in order to quantify soil quality (Pascazio et al., 2018; Gil-Sotres et al., 2005). Soil moisture, together with soil temperature, pH and oxygen strongly affects population growth, mobility, nutrient consumption of soil microorganisms, having a direct effect on the N mineralization rate (Sofo et al., 2014). In addition, the monitoring of soil nitrates along R (wetted soil portion) and I (rain-fed soil portion) in the orchard, with a localized irrigation, is crucial to avoid N leaching, soil and water pollution.

On this basis, the main objective of this study was to improve the mineral nutrition management, studying soil fertility parameters and N mineralization, in a peach orchard managed under alternative agricultural practices.

MATERIALS AND METHODS

Experimental site and trial

The experimental site was a peach orchard managed under alternative agricultural practices for 8 years (long-medium term period) and located in Basilicata region (Southern Italy). It was managed according to the EU Regulation 834/07 "Organic agriculture", including the use of compost and drip irrigation. Plants were drip irrigated from March to October with freshwater (3300 m^3 ha^{-1} $year^{-1}$) by two drip emitters per plant discharging 16 L h^{-1}, placed at a distance of 4 m from each other.

During three different months (March, June, October) of the experimental year (2015), three composite soil samples (0-20 cm) were collected for biochemical analyses. Each composite sample was formed from ten subsamples pooled on site. Two sampling areas were identified: along the row (wetted, under the emitters; R) and along the inter-row (rain-fed, I).

Soil quality index

The degree of soil quality was expressed by the biochemical index N_c/N_k ratio, where N_k is Kjeldahl total soil nitrogen and N_c is a linear function accounting for microbial biomass carbon, N mineralization capacity, and soil enzyme activities, calculated by the following Equation (Trasar-Cepeda et al., 2000):

$$N_c = (0.38 \cdot 10^{-3})\ \text{MBC} + (1.4 \cdot 10^{-3})\ N_m + (13.6 \cdot 10^{-3})\ \text{PME activity} + (8.9 \cdot 10^{-3})\ \beta\text{-glu activity} + (1.6 \cdot 10^{-3})\ \text{urease activity}$$

From each of the three composite soil samples, microbial biomass carbon (MBC) was determined by the fumigation-extraction method (Brookes, 1995). The microbial biomass carbon was calculated by the equation of Vance et al. (1987). Mineralizable N (N_m) was evaluated as the difference of inorganic N at the beginning and at the end of a 10-day incubation period (Trasar-Cepeda et al., 1997). Inorganic N was determined as reported by Bremner and Keeney (1966). Urease activity was measured according to Tabatabai and Bremner (1972). Phosphomonoesterase (PME) activity was measured by the method of Eivazi and Tabatabai (1977). The activity of β-glucosidase (β-glu) was determined by the method of Eivazi and Tabatabai (1988).

Soil water content and nitrates monitoring

The soil water content (SWC) was determined from the weight differences of soil samples before and after drying at 105°C for 24 h, and expressed as percentages of water on dry weight (DW). Nitracheck 404 meter (Merckoquant) was used to determine the concentration of soil nitrates (ppm), as described by Burns et al. (2005).

RESULTS AND DISCUSSION

Soil quality index

The N_c/N_k ratio varied according to the soil sampling position (R, I) and according to the sampling period (Figure 1). The higher the value of N_c/N_k ratio, the higher the soil quality (Trasar-Cepeda et al., 2000). In March and June, N_c/N_k ratios were significantly higher in R soil portions, compared to I soil areas, with no significant differences in October. The results revealed that N_c/N_k ratio is a reliable composite index for soil N availability and turnover and for microbial activities, being generally higher in wet R areas (Figure 1).

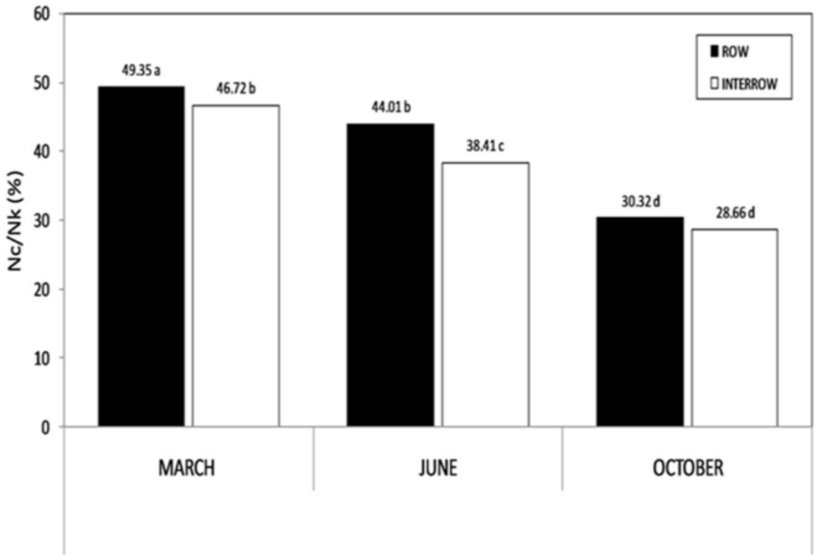

Figure 1. Biochemical index of soil fertility. N_c/N_k ratio in soil from peach orchard. The values are means of three independent replicates (n=3). Different letters indicate statistical differences at P<0.05 (redrawn from Pascazio et al., 2018).

Soil nitrates monitoring

Results of soil nitrates monitoring in the peach orchard are presented in Figure 2. In March and June, the soil nitrate content was higher in R soil portions, compared to I, with no significant differences in October.

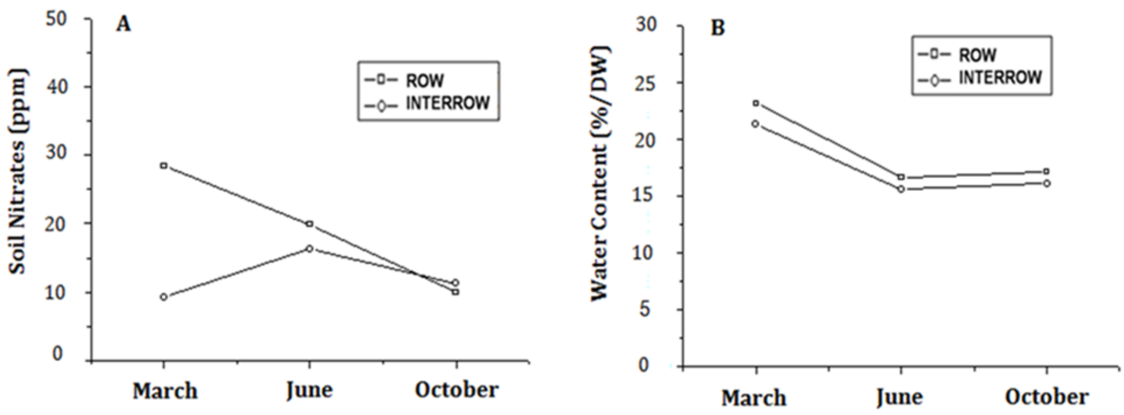

Figure 2. Soil nitrates monitoring results in peach orchard. Soil nitrates (A) and soil water content (B) in R and I soil portions at the three samplings at 0-20 cm depth.

A localized irrigation system reduces the wetted soil portion explored by roots for water and nutrient uptake, increasing nutrient efficiency (Pascazio et al., 2018). Indeed, in order to have an optimized nutrition management under localized irrigation, it is necessary to consider only the wetted soil volume along the rows, in which the main roots are present, and to exclude the I soil portion.

Due to the composition of the organic matter added to the soil, a higher amount of N was released under sustainable management practices, as observed in the soil solution (Figure 2). Indeed, based on monitoring of the soil N provided by the organic matter, no external inputs were needed in the peach orchard. This is in accordance with the results of Bastida et al. (2017) and Mikha et al. (2005), who found a slow-down of organic matter decomposition and a consequent N release during drying and wetting cycles.

CONCLUSIONS

This study highlighted the importance of soil water content in wetted/irrigated areas of a drip-irrigated orchard and the positive effect of soil water on the biological N mineralization process, suggesting the relevance of the irrigated soil volume on nutrient management. The monitoring of N_c/N_k ratio and soil nitrates could give a precise idea on N and C soil dynamics, which in turn positively or negatively affect the soil quality and fertility. The results revealed a positive effect of sustainable agricultural practices and irrigation on soil quality. Indeed, understanding soil processes could lead to optimize the irrigation management at farm scale in semi-arid conditions.

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