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Influence of organic and inorganic sources of nutrients on the functional diversity of microbial communities in the vegetable cropping system of the Indo-Gangetic plains

Mallappa Manjunath [a,b,*,1], Upendra Kumar [c,1], Raj Bahadur Yadava [a], Awadhesh Bahadur Rai [a], Bijendra Singh [a]

[a] ICAR-Indian Institute of Vegetable Research, Jakhini, Sahanshapur, 221305 Varanasi, Uttar Pradesh, India
[b] ICAR-Central Research Institute for Dryland Agriculture, 500059 Hyderabad, India
[c] ICAR-National Rice Research Institute, 753006 Cuttack, Odisha, India

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ABSTRACT

The aim of the present study was to assess the effects of different organic and inorganic fertilizers on the functional diversity of soil microbial community under a vegetable production system. The Biolog® Eco-plate technique and indices, such as average well-colour development (AWCD), McIntosh and Shannon diversity were employed to study the diversity of soil microorganisms. The AWCD, i.e. overall utilization of carbon sources, suggested that different organic treatments had a significant impact on the metabolic activity of soil microorganisms. After 120 h, the highest AWCD values were observed in poultry manure (2.5 t·ha^{-1}) + vermicompost (3.5 t·ha^{-1}) (0.63) and farm yard manure (FYM) (10 t·ha^{-1}) + vermicompost (3.5 t·ha^{-1}) (0.61). After 72 h, the highest value of the McIntosh diversity index was recorded in poultry manure (2.5 t·ha^{-1}) + vermicompost (3.5 t·ha^{-1}) (3.87), followed by poultry manure (2.5 t·ha^{-1}) + vermicompost (3.5 t·ha^{-1}) + biofertilizers (*Azotobacter* 500 g·ha^{-1} applied as seed treatment) (3.12). In the case of the Shannon diversity index, the highest values were noticed in organic treatments; however, there was no significant differences between organic and inorganic treatments. Biplot analysis showed a clear differentiation of organic treatments from the inorganic control. The amino acids, phenolics and polymer utilizing microorganisms were dominant in organic treatments. Inorganic control recorded the lowest values of the microbial diversity indices. Through this study, we have identified the best combination of organic nutrients, i.e. poultry manure (2.5 t·ha^{-1}) + vermicompost (3.5 t·ha^{-1}) for the stimulation of metabolically active soil microbial communities.

1. Introduction

Application of fertilizers is an essential practice in agricultural production that determines the quality of soil and its sustainable use [1]. Organic and inorganic fertilizers enhance the soil nutrient availability to plants, besides improving the soil physical, chemical, and biological properties [2–5]. Extensive use of chemical fertilizers in relation to organic fertilizers has led to a decrease in soil

* Corresponding author. Division of Crop Sciences, ICAR-Central Research Institute for Dryland Agriculture, 500059 Hyderabad, India.
E-mail address: manjumbl@gmail.com (M. Manjunath).
[1] Authors contributed equally.

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organic carbon and soil quality [6–9]. Soil microorganisms are important elements of soil ecosystems; they perform vital functions in the restoration and sustainability of ecosystems [10,11]. They are fundamental to the upkeep of soil function as they are known to help in the formation of soil structure, organic matter decomposition, removal of toxins and biogeochemical cycling of nitrogen, phosphorus, carbon, and sulphur [12–15]. Their diversity is influenced by different fertilizers [16,17]. Long-term application of inorganic fertilizers affects soil quality and productivity, composition of microbial community, and functional diversity [18–21]. Changes in soil microbial structure and activity will affect soil processes such as nitrogen fixation, nitrification and denitrification [22–24]. Soil microbial community structure and function are commonly used as indicators for soil quality and fertility [25]. Inclusion of organic fertilizers reduces the harmful effects of chemical fertilizers and enhances the soil microbial metabolic activities [26]. The functional diversity of soil microorganisms provides vital information about the soil biological quality and is ecologically more relevant [27]. Assessment of metabolic reactions performed by the microorganisms is essential for knowing and managing the ecosystems. It is very essential for optimizing the use of fertilizers and sustaining soil productivity [28,29]. However, the effects of different organic and inorganic fertilizers on soil microbial community structure and functional diversity are not well studied in vegetable production systems. The Biolog® assay is routinely used to monitor the soils, as it is simple and fast [27]. It does not depend on the laborious isolation process; instead it assesses the functional diversity of intact communities [30]. Our objective was to assess the influence of organic sources of nutrients in comparison with that of chemical fertilizers on soil microbial functional diversity in vegetable production.

2. Materials and methods

2.1. Study site

The experimental site was located at the research farm of the ICAR-Indian Institute of Vegetable Research, Varanasi, India (82.52 °E longitude; 25.10 °N latitude). Average rainfall of the area is about 1000 mm, which is spread over 100 days. The temperature ranges from 5 °C to 42 °C. The coldest month is January, while the maximum temperature is observed during May and June.

2.2. Soil characteristics

The soil was silt loam in texture with organic carbon content of 0.44–0.50%. The pH (7.81–7.83) of the soil was slightly alkaline with electrical conductivity 0.410–0.413 $dS \cdot m^{-1}$.

2.3. Experimental details; Soil sampling and processing

Okra crop (*Abelmoschus esculentus*) was taken during summer season after the harvest of cabbage (*Brassica oleracea*), which was grown during the winter season. Land was ploughed, seeds were sown at a spacing of 45 cm × 30 cm and irrigation was given at 7–10-day intervals. Soil samples were collected randomly; aseptically from the treatments from the top 150 mm, at three positions in each plot/replication (size: 10 m × 7 m) at the final harvest stage of Okra using tube auger and samples from each plot were pooled and mixed. After sieving (< 2 mm), 300 g of each sample were stored at 5 °C and subsequently used for microbiological analysis [31]. The present study comprised of eleven treatments, *viz.*, T1–FYM (20 $t \cdot ha^{-1}$); T2–poultry manure (5 $t \cdot ha^{-1}$); T3–vermicompost (7 $t \cdot ha^{-1}$); T4–FYM (10 $t \cdot ha^{-1}$) + poultry manure (2.5 $t \cdot ha^{-1}$); T5–FYM (10 $t \cdot ha^{-1}$) + vermicompost (3.5 $t \cdot ha^{-1}$); T6–poultry manure (2.5 $t \cdot ha^{-1}$) + vermicompost (3.5 $t \cdot ha^{-1}$); T7–FYM (10 $t \cdot ha^{-1}$) + poultry manure (2.5 $t \cdot ha^{-1}$) + biofertilizers (*Azotobacter* 500 $g \cdot ha^{-1}$ applied as seed treatment); T8–FYM (10 $t \cdot ha^{-1}$) + vermicompost (3.5 $t \cdot ha^{-1}$) + biofertilizers (*Azotobacter* 500 $g \cdot ha^{-1}$ applied as seed treatment); T9–poultry manure (2.5 $t \cdot ha^{-1}$) + vermicompost (3.5 $t \cdot ha^{-1}$) + biofertilizers (*Azotobacter* 500 $g \cdot ha^{-1}$ applied as seed treatment); T10–inorganic control (120:60:60 kg NPK ha^{-1}); T11–absolute control (no fertilizers). For the inorganic control, NPK was applied through urea, single super phosphate and muriate of potash, respectively. Half of the N and full dose of P and K were applied as basal, while the remaining amount of N was applied as top dressing after 30 days of planting.

2.4. Functional diversity analysis of soil microbial community

Microbial community analysis was done by using 96 well Biolog® Eco-plates (Biolog® Inc., CA, USA) containing 31 different carbon sources and control well in triplicates (Table 1). The metabolic functional variation of the soil microbial community was assessed by measuring OD values in a colour change reaction involving 31 different carbon sources [32]. The experiment was set up as per the procedure described by Li et al. [32] and Kumar et al. [33]. In brief, 10 g of fresh soil were mixed well in 100 ml of distilled water in a 250-ml Erlenmeyer flask kept on a shaker for 30 min at 250 rpm. The final suspension was diluted to 10^{-3} and 100 µl of the water extracts were inoculated into each well of the Biolog® Eco-microtiter plate. The plates were incubated at 25 °C. All used materials were sterilized using an autoclave at 121 °C for 1 h. The absorbance of colour of each well resulting from the utilization of carbon sources by the microorganisms was measured at 590 nm with the aid of a microplate reader. The first measurement was taken immediately after inoculation. Then, the microplates were incubated at constant temperature (25 °C) for five days and readings were taken at optical density (OD) 590 nm using Microlog 4.01 after incubation of 0, 24, 48, 72, 96 and 120 h. The average well colour development (AWCD) for 31 different carbon sources was calculated to assess the total microbial activity [32]. The AWCD reflects the overall situation of microorganisms utilizing different carbon sources and it was calculated by using the formula [34]:

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