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Microbial Biomass Dynamics in a Tropical Agroecosystem: Influence of Herbicide and Soil Amendments

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ABSTRACT

The influences of herbicide alone and in combination with the soil amendments with contrasting resource qualities on dynamics of soil microbial biomass C (MBC), N (MBN), and P (MBP) were studied through two annual cycles in rice-wheat-summer fallow crop sequence in a tropical dryland agroecosystem. The experiment included application of herbicide (butachlor) alone or in combination with various soil amendments having equivalent amount of N in the forms of chemical fertilizer, wheat straw, *Sesbania aculeata*, and farm yard manure (FYM). Soil microbial biomass showed distinct temporal variations in both crop cycles, decreased from vegetative to grain-forming stage, and then increased to maximum at crop maturity stage. Soil MBC was the highest in herbicide + *Sesbania aculeata* treatment followed by herbicide + FYM, herbicide + wheat straw, herbicide + chemical fertilizer, and herbicide alone treatments in decreasing order during the rice-growing period. During wheat-growing period and summer fallow, soil MBC attained maximum for herbicide + wheat straw treatment whereas herbicide + FYM, herbicide + *Sesbania*, and herbicide + chemical fertilizer treatments showed similar levels. The overall trend of soil MBN was similar to those of soil MBC and MBP except that soil MBN was higher in herbicide + chemical fertilizer treatment over the herbicide + wheat straw treatment during rice-growing period. In spite of the addition of equivalent amount of N through exogenous soil amendments in combination with the herbicide, soil microbial biomass responded differentially to the treatments. The resource quality of the amendments had more pronounced impact on the dynamics of soil microbial biomass, which may have implications for long-term sustainability of rainfed agroecosystems in dry tropics.

Key Words: chemical fertilizer, farmyard manure, organic amendment, *Sesbania aculeata*, wheat straw

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INTRODUCTION

Tropical dryland agroecosystems generally have low crop productivity, and the factors responsible are not only limitations of soil moisture and/or nutrients but also the severe weed infestation. Weeds are generally controlled by herbicides (Hyvönen and Salonen, 2002). The exogenous soil amendments are also commonly needed for maintaining optimal crop productivity in such nutrient-poor agroecosystems. Herbicides, when added with soil amendments of different resource qualities in the soil may end up with interactive effects. These have important implications for soil microbial biomass dynamics, weed and crop growth, and the long-term soil fertility and crop productivity (Wardle and Rahman, 1992; Moreno *et al.*, 2007).

In tropical dryland agroecosystems, addition of organic soil amendments have been recommended over chemical fertilizers as they can improve soil quality, especially soil moisture regime, which is one of the critical factors controlling soil productivity. Soil organic inputs, however, vary in their resource qualities, which in turn have major influence on the size of microbial biomass and microbial activity in croplands (Singh *et al.*, 2007; Singh and Ghoshal *et al.*, 2013).

Soil microbial biomass, the small and labile fraction of soil organic matter, regulates the availability of major nutrients in soil, and hence is considered widely as an index of soil fertility (Marumoto, 1984; Hassink *et al.*, 1991). An increase in soil microbial biomass is generally linked with improvement in soil fertility. Soil microbial biomass provides a sensitive and early indication of changes in soil quality, as it responds much faster compared to the total soil organic matter in response to changes in agronomic practices (Powlson *et al.*, 1987). Dynamics of soil microbial biomass is reported widely to be influenced by addition of soil amendments (Kandeler *et al.*, 1999; Nayak *et al.*, 2007; Kong *et al.*, 2008) and herbicides alone (Wang *et al.*, 2007; Mahía *et al.*, 2008). However, studies on the interacti-

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on of herbicide and soil amendments with varying resource qualities on soil microbial biomass (Singh and Ghoshal, 2010) are limited in general, and the rainfed dryland agroecosystem in particular.

The main objective of this study, carried out in a tropical dryland agroecosystem with rice-wheat-summer fallow crop sequence, was to evaluate the impact of application of herbicide alone and in combination with soil amendments having contrasting chemical qualities on the dynamics of soil microbial biomass C (MBC), N (MBN), and P (MBP).

MATERIALS AND METHODS

Study site

This study involved two annual cycles (2008–2010) in the experimental plots of the Department of Botany, Banaras Hindu University at Varanasi (25°18′ N, 83°1′ E, and 76 m above sea level) characterized by three different seasons, *i.e.* summer, rainy, and winter, which is typical of the dry tropical region. The soil belongs to the order Inceptisol, suborder Orchrepts of the subgroup Udic Ustocrepts, with pale brown coloration and sandy loam texture. With a pH of 6.7, the soil had a bulk density of 1.36 g cm^{-3}, water holding capacity of 39.0%, organic C of 6 g kg^{-1}, total N of 0.58 g kg^{-1}, and total P of 92 mg kg^{-1}.

The experimental design included application of herbicide alone or in combination with various soil amendments having equivalent amount of N (*i.e.*, 80 kg N ha^{-1}). Butachlor was used as herbicide at the dose of 2 kg a.i. ha^{-1}. Three organic amendments, wheat straw, *Sesbania aculeata*, and farm yard manure (FYM), as well as an inorganic amendment, chemical fertilizer, were used. The experiment consisted of six treatments including a control (with no inputs), herbicide alone (HA), herbicide + chemical fertilizer (HC, chemical fertilizer application at 80-40-30 kg ha^{-1} N-P-K as urea, single super phosphate, and muriate of potash), herbicide + wheat straw (HW, C:N = 82:1), herbicide + *Sesbania aculeata* (HS, C:N = 16:1), and herbicide + farmyard manure (HF; C:N = 28:1). Periods for rice (*Oryza sativa* var. NDR 97) growing were from July to October in 2008 and 2009, respectively. Wheat (*Triticum aestivum* var. Malviya 533) cropping extended from November in 2008 to March in 2009 and November in 2009 to March in 2010. Summer fallows ranged from April to June in 2009 and 2010, respectively. The experimental plots (4 m × 4 m) were laid down in a randomized block design with three replicates, with a 1-m strip separated from each block. The inputs were applied 1 or 2 d before rice sowing once a year. Fresh *Sesbania aculeata* shoots were cut into pieces (2–3 cm) before incorporation. Wheat straw was air-dried, and then incorporated. Chemical fertilizer was surface applied. Herbicide was applied 1 or 2 d after sowing of rice crop. No exogenous inputs were applied to the wheat. Manual hoeing was thoroughly done up to 15-cm depth to prepare the plots for the sowing of rice or wheat. Both the crops were directly seeded in the soil. The experimental setup was maintained continuously since its establishment in June 2004.

Soil sampling and analysis

Soil samples were collected from each treatment at three growing stages of rice and wheat (vegetative, grain-forming, and maturity stage) and summer fallow for each annual cycle, amounting to 14 samples during the two-year study. In each replicate plot, soil samples were randomly collected from 0–10 cm depth from three spots, mixed, and then sieved through a mesh screen (2 mm), following removal of the visible plant debris. Field moist soil samples were preconditioned for 7 d at room temperature in a container with 100% humidity and CO_2 removed by alkali contained in a vial. Modified chloroform fumigation-extraction method was used for estimation of MBC (Vance *et al.*, 1987), MBN (Brookes *et al.*, 1985), and MBP (Brookes *et al.*, 1982).

Statistical analyses

Data were analysed using SPSS package. All the values were expressed as means ± standard errors. Means were compared using the least significant difference (LSD) test. Differences between treatments and crop cycles were tested using two-way analysis of variance (ANOVA). Significance of difference was indicated at $P < 0.05$.

RESULTS

Application of herbicide alone or in combination with soil amendments showed a trend of increase in the levels of soil microbial biomass compared to the control treatment throughout the annual cycle (Figs. 1–4). In all the treatments the levels of soil microbial biomass increased from rice- to wheat-growing period and reached the maximum level in summer fallow except in HS treatment. Temporal variations were distinct and similar in soil MBC, MBN, and MBP across all the treatments for rice and wheat growing periods. In both crop cycles, the microbial biomass decreased from vegetative to grain-forming stage, and then increased until maturity stage.