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Microbial Populations, Activity and Gene Abundance in Tropical Vertisols Under Intensive Chemical Farming

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ABSTRACT

There are increasing concerns on the environmental impacts of intensive chemical agriculture. The effect of high agrochemical inputs used in intensive chemical farming was assessed on soil microbiological, molecular and biochemical properties in tropical Vertisols in India. Farm field sites under normal cultivation of arable crops using high inputs of fertilizers and pesticides in chili (*Capsicum annum* L., 5.0× dose for fertilizers and 1.5× dose for pesticides over normal inputs) and black gram (*Vigna mungo* L. Hepper, 2.2× dose for fertilizers and 2.3× dose for pesticides over normal inputs) were compared with adjacent sites using normal recommended doses. Organic carbon and basal respiration showed no response to high inputs of fertilizers and pesticides in soils of both crops. Labile carbon decreased by 10% in chili soils and increased by 24% in black gram soils under high input farming system. The proportion of soil labile carbon as a fraction of soil organic carbon was unaffected by high inputs. The labile carbon mineralization coefficient ($q\mathrm{M}_{\mathrm{LC}}$) increased by 50.0% in chili soils, indicating that the soil microorganisms were under stress due to high agochemical inputs, whereas $q\mathrm{M}_{\mathrm{LC}}$ decreased by 36.4% in black gram soils. Copiotrophs increased due to high inputs in soils of both chili (63.1%) and black gram (47.1%). Oligotrophs increased by 10.8% in black gram soils but not in chili soils. The abundance of *amoA* gene reduced by 39.3% in chili soils due to high inputs and increased significantly by 110.8% in black gram soils. β-Glucosidase also increased by 27.2% and 325.0%, respectively. Acid phosphatase activity reduced by 29.2% due to high inputs in chili soils and increased by 105.0% in black gram soils. The use of high agrochemical inputs thus had adverse consequences on biological health in chili but not in black gram soils. In soils cultivated with black gram, the moderating effect of cultivating legumes and their beneficial effect on soil health were evident from the increase in soil labile carbon, lower $q\mathrm{M}_{\mathrm{LC}}$, higher *amoA* gene and enzyme activities. Overall results showed that cultivation of legumes permits intensive chemical farming without deteriorating soil biological health.

Key Words: *amoA* gene, copiotrophs, high agrochemical input, legumes, oligotrophs, soil enzymes

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INTRODUCTION

To meet the food needs of an ever-expanding population, the immediate response by farmers has been the extensive use of chemical inputs such as fertilizers, pesticides, herbicides, *etc*. The application of agrochemicals in agricultural fields has continuously grown in terms of quantity and the types of pesticides and fertilizers (Carvalho, 2006), leading to concerns about their adverse impacts on soil biological health and water quality. For sustainable agriculture, it is important to not only maintain or increase crop productivity but also improve the quality of the production base, *i.e.*, soil quality must also be maintained or improved. Thus, identifying and practicing management practices that sustain soil health are important to maintain a balance between high productivity and soil quality (Doran and Zeiss, 2000). Crop rotations with legumes have been known for long to increase the yields of succeeding non-legume crops through biological nitrogen fixation. Non-nitrogen rotational effects of legumes on improvement of soil health have also been shown: Pankhurst *et al.* (2003) showed that legume rotations reduce pathogens and parasites and have a positive effect on beneficial soil biota.

Extensive work on soil microbiological processes has shown that pesticides, with the exception of some fumigants and broad spectrum fungicides, have little deleterious influence when applied at field rates (Ahtiainen *et al.*, 2003; Girvan *et al.*, 2004; Griffiths *et al.*, 2008; Lupwayi *et al.*, 2009). However, the earlier investigations have reported microbial changes induced by applying single herbicides, fungicides or insecticides (Haney *et al.*, 2000; Floch *et al.*, 2011; Pesce *et al.*,

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2013). However, in intensive chemical farming, several of the above pesticides and fertilizers are used together in high doses to achieve complete plant protection and high crop production (Lichtfouse *et al.*, 2009). Studies on microbial changes in such situations in actual farming conditions have not been conducted. Soil microorganisms take part in 90% of the processes occurring in soil (Nannipieri *et al.*, 2003), play a critical role in soil ecosystem functioning and respond rapidly to the changes in soil environment (Bell *et al.*, 2005). Therefore, monitoring the microbial community and their genes and gene products like enzymes reflects the biological condition of the soil more accurately.

Farmers commonly believe that higher yields can be obtained by applying higher inputs of chemical fertilizers and pesticides. Therefore, the present investigation was to examine if the use of high rates of chemical fertilizers and pesticides together applied by farmers practicing intensive chemical agriculture has any adverse influence in comparison to activities in adjacent farms using the normally recommended rates. The aim of this study was to investigate the effects of such high input farming in tropical Vertisols on soil bacterial populations, abundances of eubacterial 16S rRNA, *nifH* and *amoA* genes and soil enzyme activities in soils cropped with chili (*Capsicum annuum* L.) and black gram (*Vigna mungo* L. Hepper).

MATERIALS AND METHODS

Study site and soil samples

The study sites for sample collection are located in the Guntur district of Andhra Pradesh, India (Table I). The climate of the Guntur district is tropical-warm to hot year-round; the mean annual maximum temperature ranges from 29.2 to 39.3 °C (average 33.4 °C) and the mean annual minimum from 18.9 to 28.0 (average 23.7 °C). The average annual rainfall is 905 mm. Soils were taken from agricultural fields cultivated with chili and black gram. The soils are swell-shrink black soils, Typic Chromusterts as per United States Department of Agriculture (USDA) classification. The chili field is at Jonnalagadda (16.24° N, 80.08° E) and the black gram field is at Munipalle (16.12° N, 80.54° E). The growing period was 90 d for chili and 120 d for black gram.

For each crop, two adjacent field sites with normal and high input rates of chemicals and pesticides were selected to minimize spatial variations in soil properties. In the chili field site with normal input rate, recommended chemical fertilizers (N, P, K, S and Zn) and pesticides were applied by the farmer at 272 and 5.8 kg ha^{-1}, respectively, whereas in the site with high input rate, chemical fertilizers and pesticides (9 agrochemicals in all) were applied by the farmer at 1 373 and 8.9 kg ha^{-1} (5.0× dose for fertilizers and 1.5× dose for pesticides over normal inputs), respectively (Table I). The chili farmer was applying such high inputs for last 6 years. In the black gram field site with normal input rate, recommended chemical fertilizers and pesticides were applied by the farmer at 203 and 4.47 kg ha^{-1}, respectively (one rice-black gram rotation), whereas in the site with high input rate, chemical fertilizers and pesticides (17 agrochemicals in all) were applied by the farmer at 466 and 10.15 kg ha^{-1} (2.2× dose for fertilizers and 2.3× dose for pesticides over normal inputs), respectively (Table I). The black gram farmer was applying such high inputs for last 10 years. Soil samples at each study site were collected from 13 random spots in one acre (4 047 m^2) area at

TABLE I

Normal and high input rates of agrochemicals in chili and black gram fields and the crop yields

Item	Chili		Black gram[a)]	
	Normal input	High input	Normal input	High input
Village	Jonnalagadda	Jonnalagadda	Munipalle, Ponnur	Munipalle, Ponnur
District	Guntur rural	Guntur rural	Guntur	Guntur
Fertilizer				
N (kg ha^{-1})	160	769	109, 23 (132)	246, 35 (281)
P (kg ha^{-1})	50	277	25, 0 (25)	50, 15 (65)
K (kg ha^{-1})	62	187	46, 0 (46)	94, 0 (94)
S (kg ha^{-1})	-	140	0, 0 (0)	10, 0 (10)
Zn (kg ha^{-1})	-	-	0, 0 (0)	16, 0 (16)
Total (kg ha^{-1})	272	1 373	180, 23 (203)	416, 50 (466)
Pesticide, fungicide (kg a.i.[b)] ha^{-1})	5.8	8.92 (plus 40 kg S)	3.50, 0.97 (4.47)	7.92, 2.22 (10.15)
Average yield (kg ha^{-1})	7 500	8 250	1 000	1 500

[a)]For the chemical input rate in black gram field, the input rates are used in one rice-black gram rotation with the first numbers for rice, the second numbers for black gram and the numbers in parentheses as the total inputs of each chemical.
[b)]Active ingredient.