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Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia

Moeskops[a], Bram, Sukristiyonubowo[b], Lenita Herawaty[b], Edi Husen[b], Rasti. Saraswati[b], David Buchan[a], Stefaan De Neve[a]

a Ghent University, Department Soil Management, Coupure Links 653, 9000 Gent, Belgium. E-mail Bram.Moeskops@UGent.be.
b Indonesian Soil Research Institute, Jalan Ir. H. Juanda 98, Bogor 16123, Indonesia.

Introduction

The continuous and strong increase in population pressure in many tropical regions, including Java (Indonesia), has caused agricultural land use to expand and intensify (VERBURG ET AL., 1999). This expansion has often been accompanied by the introduction or the multiplication of inputs. Throughout tropical Asia vegetables are generally overfertilized and even more serious are reports about pesticide overuse (RERKASEM, 2005). As a result of the concerns about the long-term sustainability of conventional production methods the potential for organic farming receives increasingly attention. Organic farming methods may reduce negative effects attributed to conventional farming (MÄDER ET AL., 2002). The on-going land degradation in Indonesia, and in the tropics in general, has not been well documented from the microbiological viewpoint. Nevertheless, the soil microbial community performs important functions such as residue decomposition, nitrogen fixation, nutrient cycling and carbon sequestration.
The objective of this research was to examine the effect of organic vegetable production on soil enzyme activities and on the soil microbial community as compared to conventional production systems in the humid tropical climate of West Java. A secondary forest was included in the study to obtain reference values under natural conditions. We expected that the large differences in management methods between organic and conventional farming would allow the identification of clear indicators of soil quality.

Materials and Methods

The study was conducted in two districts in West Java, Cisarua and Ciwidey. The climate in this region is characterized by two seasons: a rainy season from October to April with about 80% of the annual precipitation and a dry season from May to September. All soils included in the study were Andisols.
We compared organic and conventional vegetable production two times: in 2007 and in 2008. Selected organic farms were the same in both years, but conventional fields were different. The reason of this is that we selected fields with the same crops on both the organic and conventional fields. In Cisarua two organic farms were chosen. The one organic farm was established in 1999,

while the second consisted of an older part, established in 1984, and a more recent part, converted to organic agriculture in 2005. In Ciwidey, an organic farm founded in 2002 was included in the study. In 2007 we selelected four conventional fields in Cisarua and in 2008 only two. In Ciwidey, two conventional fields were chosen in 2007, while in 2008 one field in conversion to organic agriculture and one conventional field were selected. Finally, we selected a secondary forest to provide reference values for the parameters measured, situated in the Ciwidey district.

Dehydrogenase and β-glucosidase activity were determined in July 2007 and July 2008, shortly after transplantation of the crops, and in September 2008, around harvest. Soil samples for extraction of microbial biomass C and phospholipid fatty acid (PLFA) analysis were taken at the end of August/beginning of September 2007, around harvest. β-glucosidase is an enzyme involved in the C cycle that catalyses the conversion of disaccharides into glucose (ALEF AND NANNIPIERI, 1995). Its activity was measured according to a procedure modified from EIVAZI AND TABATABAI (1988; cited in ALEF AND NANNIPIERI, 1995). Dehydrogenase is an intracellular enzyme linked with microbial respiratory processes(ALEF AND NANNIPIERI, 1995). It is often used as measure for microbial activity. The procedure for dehydrogenase activity was modified from CASIDA ET AL. (1964). The patterns of PLFAs have been successfully used to provide insight into the structure of microbial communities (KOZDROJ & VAN ELSAS, 2001). Their determination followed a procedure modified from BALSER (2001). MBC was determined by the fumigation-extraction technique (JOERGENSEN, 1996).

Results and Discussion

Based on the absolute amounts of marker fatty acids, all microbial groups considered (i.e. Gram-positive, Gram-negative bacteria, actinomycetes, total bacteria, arbuscular mycorrhizal fungi and fungi) were significantly higher represented in organically managed soil than in soil from conventional farms (ANOVA, $P \leq 0.01$). The largest marker fatty acid concentrations were, however, found under secondary forest. Fisher's canonical discriminant analysis of relative PLFA concentrations resulted in a clear discrimination of forest soil, organically cultivated soil and soil from conventional farms with respect to microbial community structure (Fig. 1). ANOVA on relative PLFA data showed that the marker PLFA for arbuscular mycorrhizal fungi (C16:1ω5c) had a significantly larger proportion of total measured PLFAs under organic agriculture compared to conventional ($P \leq 0.01$). ANOVA demonstrated a significant ($P \leq 0.05$) positive impact of organic agriculture on MBC contents. The value under secondary forest was between 1.5 and 2.4 times higher than the values under organic horticulture. In 2007, enzyme activities, both of dehydrogenase and β-glucosidase, were strongly depressed under conventional management compared to the organic fields ($P \leq 0.01$) (Fig. 2a and b). β-glucosidase activities under organic management were close to activities under natural conditions.

In 2008, differences in enzyme activity between organic and conventional production were less pronounced than in 2007 (Fig. 3a and b). However, enzyme activities were still higher under organic agriculture than under conventional agriculture but mostly not significantly. The high enzyme activity in July in the field under conversion to organic agriculture was striking. This may be explained by the high amount of compost (53 Mg ha^{-1}) applied as starting dose for the organic management. β-glucosidase activities under secondary forest and organic farms were again similar. Dehydrogenase activity remained higher under secondary forest in September, while in July variation on the dehydrogenase activity under forest was too high to draw conclusions.

None of the measured parameters demonstrated a clear difference between the fields two years after conversion to organic agriculture and those already 25 years under organic cultivation on the particular organic farm in Cisarua.

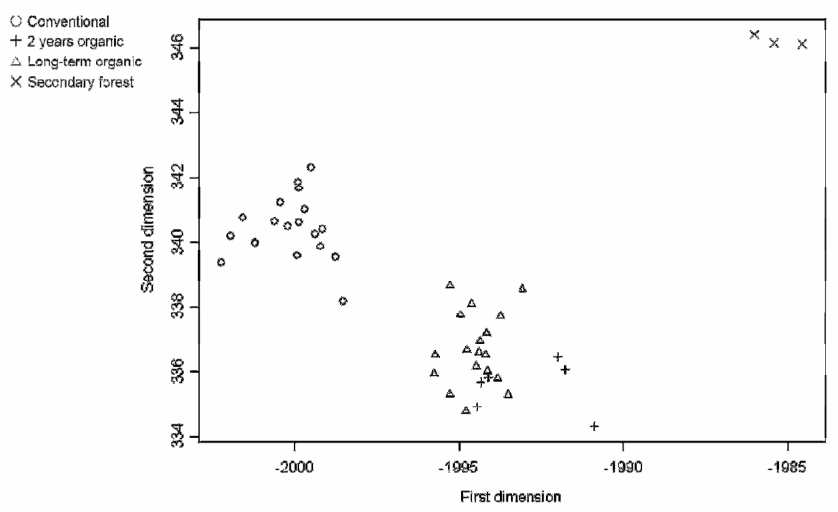

Figure 1: Scatter plot of the first two canonical discriminant functions of Fisher's can. discriminant analysis

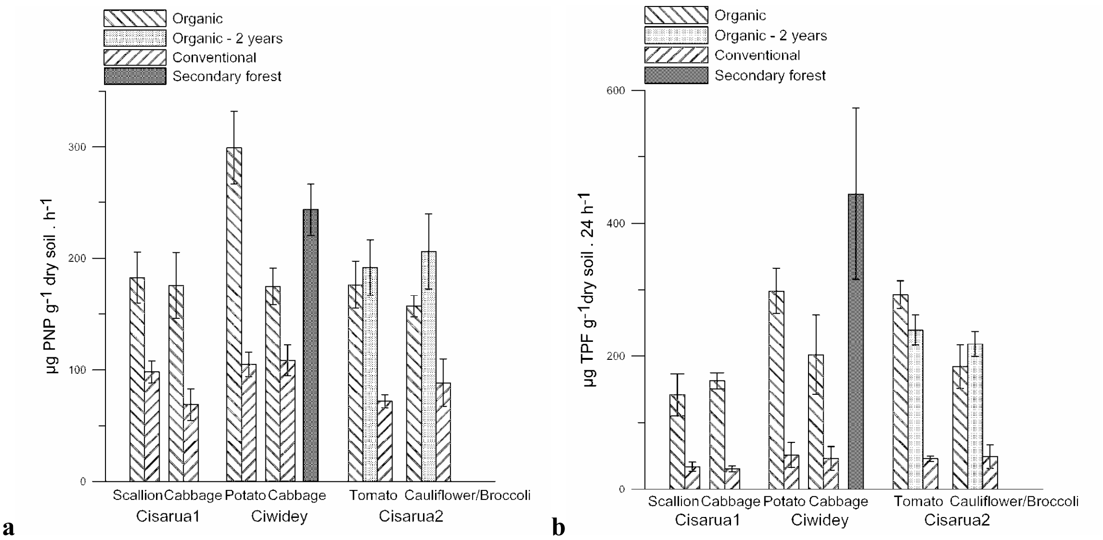

Figure 2: Enzyme activities in 2007, a. β-glucosidase, b. dehydrogenase; error bars indicate standard deviations

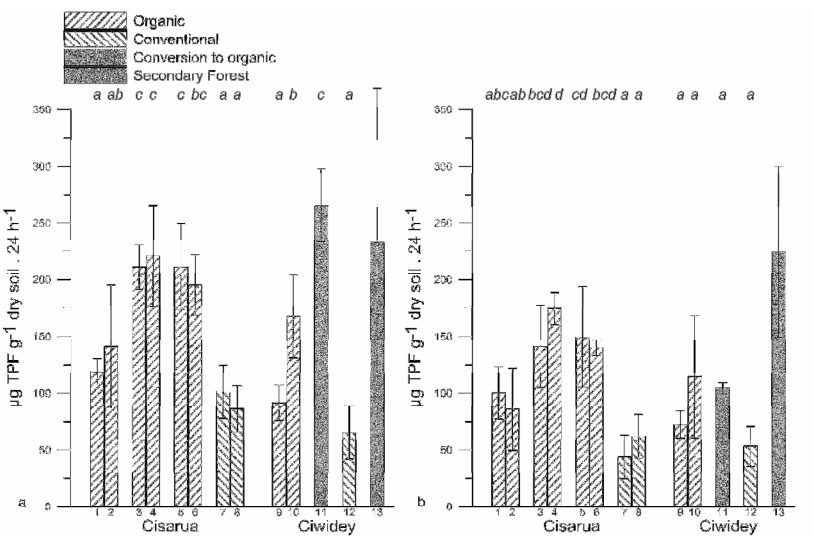

Figure 3: Dehydrogenase activity in 2008, a. July, b. September; error bars indicate standard deviations; different letters indicate significant differences within one district at one period (*P*≤0.05, ANOVA, Tukey's post-hoc test).

Paired T-tests showed that dehydrogenase and β-glucosidase activities were significantly (P<0.05) higher in July 2008 than in September 2008, both in Ciwidey and Cisarua. This is probably due to: (i) higher soil moisture content in July than at the end of the dry season, (ii) application of organic matter just before or together with transplantation of the crops.

One of the main reasons for the differences between organic and conventional management can probably be found in the use of pesticides (fungicides and insecticides) on the conventional fields. In Indonesia, pesticide use is poorly regulated and existing regulations are not enforced, resulting in excessive pesticide use. Fertilization practices differ less between organic and conventional agriculture in Indonesia. Both organic and conventional farmers apply large amounts of manure, although not composted on the conventional farms.

Conclusions and Outlook

A negative impact of conventional agriculture on enzyme activities and microbial biomass was shown. The composition of the soil microbial community strongly differs between forest and cultivated soil, and a less strong but still clear difference was observed between conventional and organic farming. Dehydrogenase activity and C16:1ω5c, marker fatty acid for arbuscular mycorrhiza, appeared particularly suited to highlight the impact of different agricultural practices on the soil microbial community. Changes in microbial community composition and activity probably affect important soil processes for crop growth such as carbon and nitrogen cycling. Further research will elaborate these links.

References

ALEF, K. AND Nannipieri, P. (Eds.) (1995). Methods in Applied Soil Microbiology and Biochemistry. Academic Press, London, 576 pp.

BALSER, T.C. (2001). The impact of long-term nitrogen addition on microbial community composition in three Hawaiian forest soils. Scientific World Journal 1: 500-504.

CASIDA, L.E., Klein, JR. D.A. AND SANTORO, T. (1964). Soil dehydrogenase activity. Soil Science 98: 371-376.

JOERGENSEN, R.G. (1996). The fumigation-extraction method to estimate soil microbial biomass: calibration of the k_{EC} value. Soil Biology & Biochemistry 28: 25-31.

KOZDROJ, J. AND VAN Elsas, J.D. (2001). Structural diversity of microorganisms in chemically perturbed soil assessed by molecular and cytochemical approaches. Journal of Microbiological Methods 43: 197-212.

MÄDER, P., FLIEßBACH, A., DUBOIS, D., GUNST, L., FRIED, P. AND NIGGLI, U. (2002). Soil fertility and biodiversity in organic farming. Science 296: 1694-1697.

RERKASEM, B. (2005). Transforming subsistence cropping in Asia. Plant Production Science 8: 275-287.

VERBURG, P.H., VELDKAMP, T.A. AND BOUMA, J. (1999). Land use change under conditions of high population pressure: the case of Java. Global Environmental Change 9: 303-312.