SELECTED BIOLOGICAL AND BIOCHEMICAL CHARACTERISTICS OF SOIL IN A LONG-TERM ORGANIC FARMING EXPERIMENT*

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This paper focused on research of selected biological and biochemical soil characteristics on an experimental site in Prague-Uhříněves where an organic farming experiment (organic vs. conventional farming) started 13 years ago. The result of the research shows that the amount of organic matter brought into the soil was a determining factor in both the occurrence of epigeic fauna and biochemical activity. However, not only the supply of organic matter is important, but also soil-aeration and other soil parameters. Considerable disturbance of soil showed in the occurrence of edaphon in soil which brought better results for the conventional treatment. The research proved the complexity and integrity of agro-ecosystems in which individual actions considerably affect biological activity of soil and the occurrence of different groups of fauna, often even without any relation to a certain agricultural system.

farming system; organic farming; soil; quality; enzymes; activity; epigeic fauna; edaphon

INTRODUCTION

Intensification of agriculture within the last 50 years has remarkably affected biodiversity and quality of soil. At present, there is intense discussion on the impact of agricultural systems on biodiversity (e.g. the effect of organic agriculture – Hole et al., 2005), as well as changes in agro-environmental measures aiming towards more sustainable management of landscape. In this study, we focus on monitoring conventional and organic systems under a trial of the longest duration in CZ, particularly the impact of both the system and implemented agricultural activities on edaphon, epigeic fauna and the activity of selected soil enzymes.

Modification of soil environment by different farming practices can significantly affect crop growth. Tillage causes soil disturbance, altering the vertical distribution of soil organic matter and supplies of plant nutrients in the soil surface, it may also affect enzyme activity and microbial biomass which are responsible for transformation and cycling of organic matter and plant nutrients. (Curci et al., 1997).

Arthropods are frequently used as bioindicators for assessment of landscape and soil quality (Paoletti, 1999; Paoletti et al., 1999; Paoletti, Hassal, 1999). Soil organisms are assumed to be directly responsible for processes within soil ecosystem, especially the decomposition of soil organic matter and the cycle of nutrients (Wardle, Giller, 1997). Spiders are acceptable indicators of biological quality of the habitat because they are dependent on the quality of potential prey (Paoletti et al., 1993). In organic farming some groups of invertebrates have higher diversity – carabid beetles (Krompp, 1989, 1990), spiders (Feber et al., 1998), and earthworms (Brown, 1999). There is a considerable difference between management of organic and conventional agriculture. Physical disturbance of soil, such as tillage is a detrimental factor for diversity of soil fauna (Altieri, 1999).

Activity of soil enzymes as another monitored indicator can be one of the significant indicators of soil quality (Dick et al., 1996). Activity of soil enzymes is determined by numerous other factors in the agro-ecosystem, including the farming system. Besides chemical characteristics (Šarapatka, 2003), physical properties of soil are also very important. Organic farming is becoming a major tool for sustaining the soil quality degraded by intensive farming practices and the use of synthetic chemicals (Srivastava, 2007). Examination of enzymatic activity showed significant linear correlation with the content of organic matter in samples of compost-treated soil. (Chang et al., 2007). Organic management resulted in significant increases in total organic carbon and Kjeldahl-N, soil respiration, microbial biomass, and enzymatic activity compared with those found under conventional management (Melero, 2006). Bio-dynamic soils at the same fertilization intensity had higher dehydrogenase activity compared to integrated farming systems. Both C_{org} and biological soil quality indicators were clearly dependent on the quantity and quality of applied types of manure, but soil microbial biomass and activity were much more affected than C-org. (Fliessbach, 2007).

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MATERIAL AND METHODS

In our study we focused on research of selected biological and biochemical soil characteristics on an experimental site in Prague-Uhříněves (CZ) where various cultivars and other characteristics in organic vs. conventional farming have been monitored for 13 years.

In spring and summer of 2007 we analysed conventional and organic agro-ecosystems in which we monitored epigeic fauna (beetles, harvestmen, spiders, diptera, centipedes, millipedes) and edaphon (beetles, beetle larvae, mites, springtails, centipedes, millipedes) using the pitfall trap method (4% formaldehyd, 7.5 cm diameter, metal cover). The traps were placed in batches of five on every variant from 28. 5. to 16. 7. 2007 and were taken out monthly. Material caught in the traps included the following taxons: beetles, beetle larvae, spiders, harvestmen, diptera, centipedes and milipedes. Soil samples were taken on 28. 5. and 16. 7. 2007 (5 samples from each locality, sampling area 1/30 m^2) from a depth of 0–15 cm. These were consequently processed in modified Tullgren extractors (T u f , T v a r d í k , 2005). Material from the soil samples included the following taxons: beetles, beetle larvae, mites, springtails, spiders, diptera, centipedes and millipedes. We also studied activity of soil enzymes (acid and alkaline phosphatase, dehydrogenase, protease, urease, nitrate reductase and cellulase) using methods described in the publication (S c h i n n e r et al., 1993).

The research was carried out with winter wheat and winter rape. In the conventional farming system both these crops were grown after a grain-leguminous mix, while in the organic farming system the preceding crop was two-year clover, which was mulched and ploughed in.

RESULTS

Soil invertebrates

Beetles were the most plentiful group of the catch from the ground traps (Figs 1 and 2). In general, the growth of rape was more convenient regarding the occurrence of beetles, especially due to microclimate provided by the growth. A correlating fact is that in the field of rape with taller plants and denser coverage, the dominance of beetles is most pronounced. This variation was the only one where, regarding the number of beetles, a conventional field beat the organic one. The number of spiders was similar in all cases, and generally wheat was more suitable for them, as they probably did not mind dry conditions so much. Millipedes clearly preferred organic options of both plants, which probably relates to the preceding crop rotation as it brought quite an amount of organic material into the soil and thus provided a rich supply of feed for this type of invertebrates. Diptera, being able to fly, occurred in all variants in relatively equal numbers. Epigeic fauna in most cases confirmed a significant preference for organic farming.

In soil samples the most numerous group was that of springtails. Together with beetle larvae and acarina they represent typical soil fauna, which is strongly dependent on chemical and mechanical properties of soil. Such dependence can explain their much denser occurrence in conventional fields, which are not tilled so many times within a year. Centipedes, on the other hand, were more abundant in organic variations. Occurrence of beetles was quite balanced in all types of fields. Overall results of the soil sample study show that, in contrast to epigeic fauna, invertebrates living deeper in the soil rather prefer conventional farming.

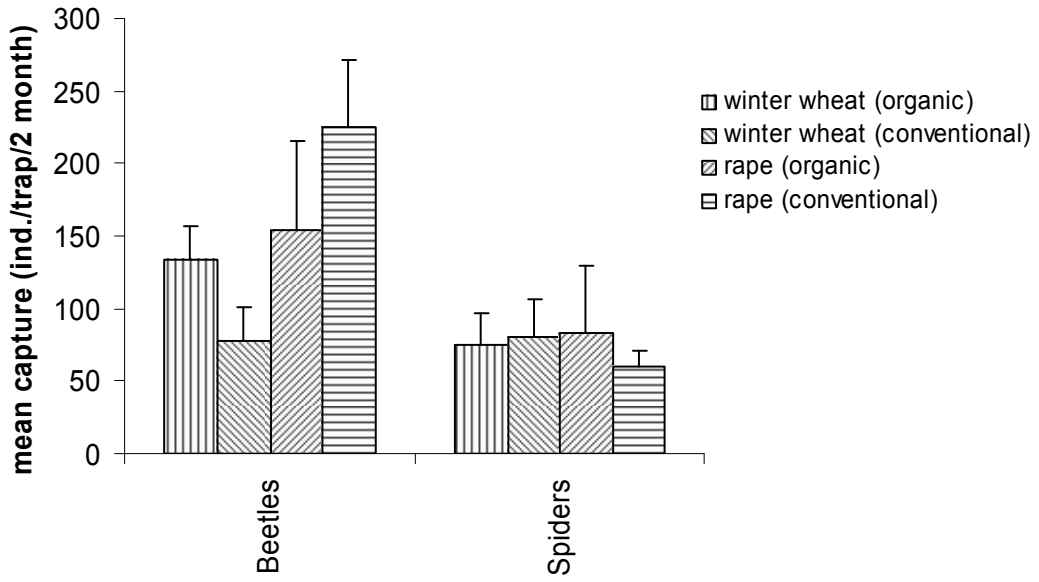

Fig. 1. Average capture rate for more abundant taxons, with standard deviation, in pitfall traps

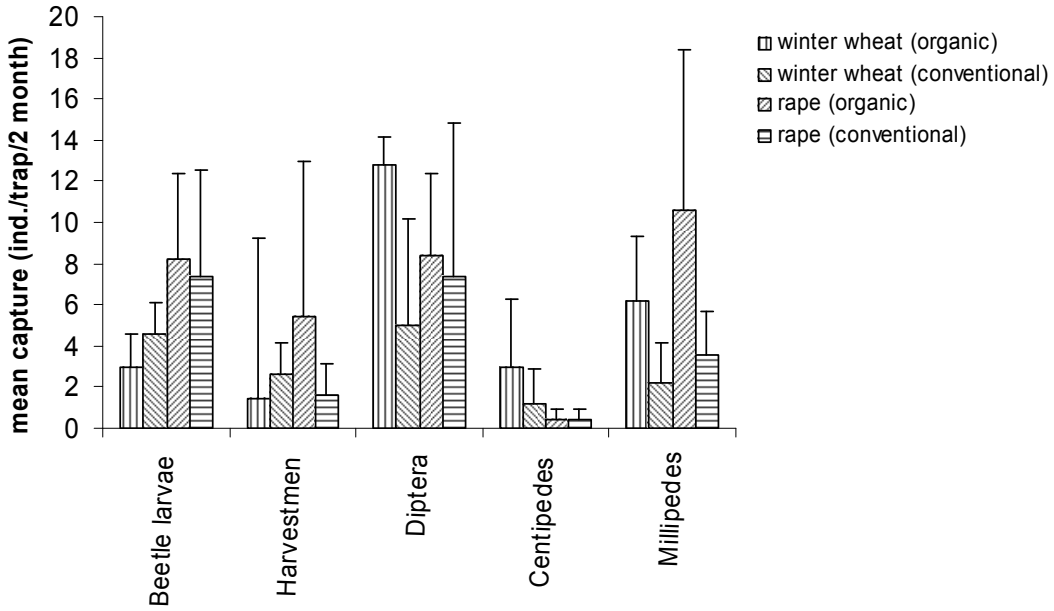

Fig. 2. Average capture rate for less abundant taxons, with standard deviation, in pitfall traps

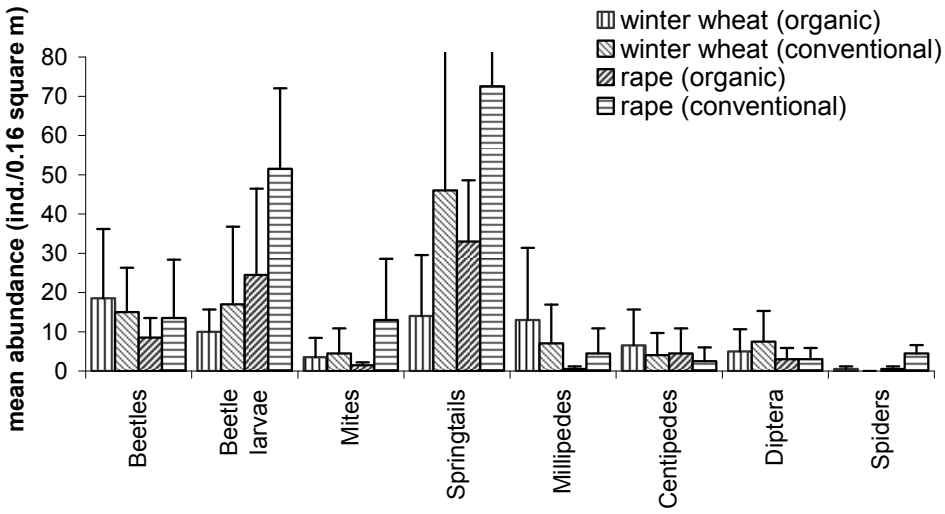

Fig. 3. Mean abundance with standard deviation in soil samples (0.16 m^2)

Enzymes

Statistically documented difference in the activity of soil enzymes was proven in the wheat option, namely in nitrate reductase (Fig. 4). In organic crop rotation, winter wheat was sown after two-year clover which was mulched and ploughed in. This brought into the soil a considerable amount of organic matter which was broken down by edaphon (increased numbers of millipedes and beetles in ground traps) with possibly more intensive soil respiration. In these conditions, higher activity of nitrate reductase was recorded together with low amount of mineral nitrogen in the soil. The soil probably contained more organic mass rich in N, therefore the nitrification assessment shows that communities of micro-organisms do not react to added N because of higher content of nitrogenous organic matter. In the conventional farming system the level of mineral nitrogen (both ammonium and nitrate) in winter wheat was higher, but due to a change in mineral-N management and probably greater lack of nitrogenous organic matter, communities are more sensitive in reaction to added mineral nitrogen.

The situation with winter rape was different. Although rape also follows mulched and ploughed-in clover in the crop rotation system, the agricultural methods are different (hoeing). The worked-in organic mass was intensively broken down, due to more aeration and better water conditions (compared to wheat the rape growth was more compact). The intensive break-down is proven by statistically

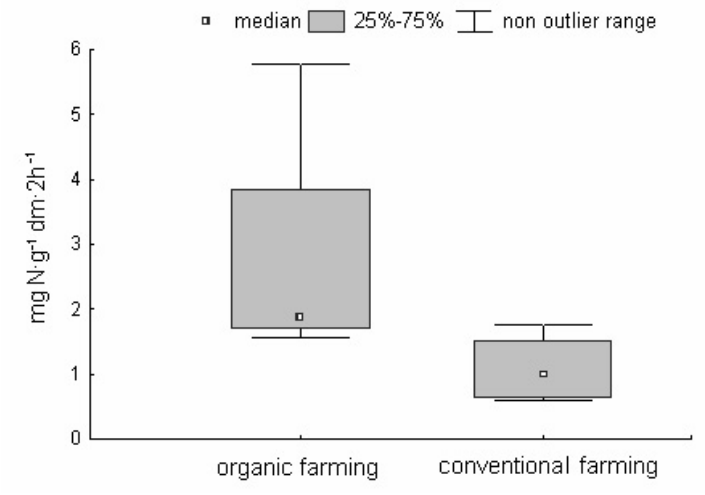

Fig. 4. Nitrate reductase activity – winter wheat

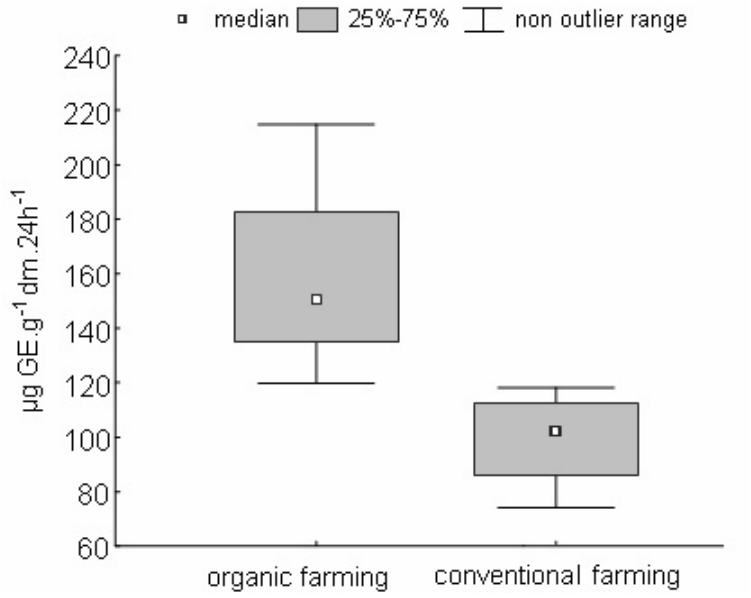

Fig. 5. Cellulase activity – rape

confirmed higher activity of cellulase (Fig. 5). Mineral nitrogen content was much the same in both variants – conventional and organic, while ammonification was higher in the latter, which is the result of either a richer or more active microbe community, better disintegration of organically bound nitrogen and creation of ammonium nitrogen as a source for consequential nitrification. Nitrification itself also registered higher levels in organic rape as the community of nitrificators in this variant reacts more sensitively to the supplied ammonium nitrogen which it processes. Thus, the community gets a higher potential and requires a greater source of substrate.

CONCLUSION

The result of the research shows that the amount of organic matter brought into the soil was a determining factor in both the occurrence of epigeic fauna and biochemical activity, which complies with results published e.g. by Hole et al. (2005) and Mäder et al. (2002). This was shown in millipedes, which process supplied vegetable material, or in rape and in cellulase activity, which relates to degradation processes, as well as in ammonification and nitrification. The increased activity of organic agricultural systems, even if enhanced by increased supply of organic matter into the soil, did not show in numerous other soil enzymes such as dehydrogenase which is connected to the general biological soil activity. In relation to soil enzyme activity, wheat in the organic variant created more anaerobic conditions which supported nitrate reductase activity (Dendooven, Anderson, 1995) and also affected ammonification and nitrification. However, not only the supply of organic matter is important, but also soil-aerating activity. Considerable disturbance of soil (e.g. when hoeing rape) showed in the occurrence of edaphon in soil (Altieri, 1999), which brought better results for the conventional variant. The research proved the complexity

and integrity of agro-ecosystems in which individual actions considerably affect biological activity of soil and the occurrence of different groups of fauna, often even without any relation to a certain agricultural system (organic vs. conventional). If we assess only the effects of different farming systems on diversity of edaphon, epigeic fauna and soil enzyme activity, we would have to file our results – compared to data published by H o l e et al. (2005) into the category of mixed effect. In their review H o l e et al. (2005) state positive effect of organic agriculture on biodiversity on the basis of 66 studies, mixed effect in 25 and negative in 8 studies.

A longer-term study of the whole crop rotation system (not just wheat and rape) in future will provide a more comprehensive view of the whole agro-ecosystem and its results can be then compared with this published data and referred publications.

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Vybrané biologické a biochemické charakteristiky půdy v dlouhodobém pokusu konverze na ekologické zemědělství.

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Článek je zaměřen na výzkum vybraných biologických a biochemických charakteristik půdy na experimentálních plochách České zemědělské univerzity v Praze-Uhříněvsi, kde probíhá 13 let experiment přechodu na ekologické zemědělství (ekologické vs. konvenční zemědělství). Ve variantách s ozimou pšenicí a ozimou řepkou byl studován epigeon ze zemních pastí, edafon z půdních vzorků a aktivita vybraných půdních enzymů z odebrané půdy.

V úlovku ze zemních pastí byli nejpočetnější skupinou brouci. Pro ně byl vhodnější porost řepky, a to zejména vzhledem k jeho mikroklimatu. Varianta s řepkou byla jediná, kde v početnosti brouků předstihla konvenční plocha ekologickou. Početnost pavouků byla na všech plochách poměrně vyrovnaná, z plodin jim více vyhovovala pšenice. Mnohonožky rovněž upřednostňovaly ekologické varianty obou plodin. Souvislost zde mohla být s předplodinami a s množstvím zapravené organické hmoty. Epigeon ve většině případů potvrdil, že ekologické hospodaření mu vyhovuje více než konvenční.

V půdních vzorcích byli nejpočetnější skupinou chvostoskoci. Spolu s larvami brouků a s roztoči jsou to zástupci typické půdní fauny, která je silně závislá na chemických a mechanických vlastnostech půdy. Tyto skupiny byly mnohem početnější v konvenčních variantách, kdy tyto plochy nebyly tak často v průběhu sezony obdělávány. Oproti tomu stonožky se vyskytovaly více v ekologických variantách, brouci byli zastoupeni poměrně rovnoměrně v obou variantách. Výsledky získané z půdních vzorků ukazují, že bezobratlí žijící hlouběji v půdě preferovali na rozdíl od epigeonu u studovaných variant spíše konvenční zemědělství, což mohlo souviset s intenzitou zpracování půdy v zemědělství ekologickém.

U aktivity půdních enzymů byl u varianty s pšenicí prokázán statisticky významný rozdíl mezi konvenčním a ekologickým zemědělstvím u nitrát reduktázy. V podmínkách ekologického osevního postupu byla ozimá pšenice zařazena za dvouletou jetelovinu, která je mulčována a v závěru zaorána. Do půdy tak bylo zapraveno značné množství organické hmoty, která byla rozkládána edafonem (zvýšený výskyt mnohonožek a brouků v zemních pastech) s možným intenzivnějším půdním dýcháním. Za těchto podmínek je zaznamenatelná vyšší aktivita nitrát reduktázy při současném nízkém obsahu minerálního dusíku v půdě. V té byl pravděpodobně vyšší obsah organické hmoty bohaté na dusík, proto je z vyhodnocení nitrifikace zřejmé, že společenstva mikroorganismů z důvodu vyššího obsahu dusíkaté organické hmoty nereagují na přidaný dusík. V podmínkách konvenčního zemědělství byla u pšenice sice vyšší hladina minerálního dusíku (amonného i nitrátového), ale z důvodu změn v hospodaření s minerálním dusíkem a pravděpodobně většího nedostatku dusíkaté organické hmoty reagují společenstva citlivěji na dodaný zdroj dusíku. Rozdílná byla situace u ozimé řepky. Ta je sice zařazena v osevním postupu opět po mulčovaném a zapraveném jeteli, ale je u ní rozdílná agrotechnika (plečkování). Zapravená organická hmota byla v důsledku vyššího provzdušnění povrchové vrstvy a optimálnějších vodních poměrů (ve srovnání s pšenicí zapojenější porost) intenzivně rozkládána, o čemž svědčí statisticky průkazně vyšší aktivita celulázy. Obsah minerálního dusíku byl u obou variant (konvenční – ekologická) obdobný, u ekologické varianty byla však vyšší amonizace, kdy v důsledku bohatšího nebo aktivnějšího mikrobního společenstva je lépe rozkládán organicky vázaný dusík a vytvoří se tím amonný dusík jako zdroj pro následnou nitrifikaci. Rovněž u nitrifikace byly zaznamenány vyšší hodnoty u ekologické řepky, kdy společenstvo nitrifikátorů lépe v této variantě reaguje na dodaný amonný dusík, který je zpracováván. Společenstvo tak má vyšší potenciál a tím potřebuje větší zdroj substrátu.

Výsledky předloženého výzkumu ukazují, že organická hmota dostávající se do půdy je velmi důležitým faktorem při výskytu epigeické fauny a biochemické aktivity. Ne pouze dodávka organické hmoty, ale i charakteristiky související s provzdušněním půdy a další parametry jsou velmi důležité. Disturbance půdního prostředí (agrotechnickými zásahy) vykazuje rovněž značný vliv na studované charakteristiky, z čehož v některých případech profitovaly konvenční varianty pokusu. Výzkum naznačil komplexnost a integritu agroekosystému, ve kterém jednotlivé zásahy mají vliv na biologickou aktivitu půdy a výskyt různých skupin edafonu a epigeonu, často bez vlivu vlastního zemědělského systému (konvenční, resp. ekologické zemědělství). Dlouhodobější studie u celého osevního postupu (ne pouze u pšenice a řepky) může dát v budoucnu ucelenější pohled na celý agroekosystém a výsledky pak bude možné konfrontovat s těmito publikovanými daty a s literaturou.

zemědělské systémy; ekologické zemědělství; kvalita půdy; enzymy; aktivita; epigeon; edafon

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