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Response of soil microbial activity on different ways of organic matter use for field crop stand establishment

ABSTRACT. Since 1997 the exact field experiment with crop rotation under conventional and protection soil tillage ploughless from 1995 has been conducted at Prague-Ruzyně site, where soil microbial activity was tested in both variants of soil tillage. The soil samples were taken in autumn from three depths of soil. The results show the positive influence of protection tillage, especially in variants where soil was supplied with organic matter, on the revival of upper layer of topsoil by microorganisms.

KEY WORDS: winter wheat, soil protection tillage, microbial activity, soil fertility

From the long-term point of view, conventional tillage may result in significant losses of soil organic matter inducing increased soil erosion and loss of soil structure [Haines, Uren 1990]. Conservation tillage, especially no-tillage, induces changes in the distribution of soil organic C and N. In the depths of 5 or 10 cm of the profile of no tilled soils there is usually significantly higher organic matter content than in mouldboard-ploughed soils [Alvarez et al. 1998a; Alvarez et al. 1988b]. In these systems, residues are incorporated slowly, providing a constant energy supply to soil biota [Doran 1980].

Soil organic matter is considered as an important indicator of soil quality. However, the content of organic matter changes very slowly. On the contrary, there is growing evidence that microbial processes may respond to disturbance over shorter time scales than other soil properties.

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The microbial biomass and soil microbial processes are affected mostly by the type of tillage [Kandeler et al. 1999]. According to Kladivko [2001], conversion of agricultural fields from conventional practices to no-till or other reduced tillage systems usually stimulates population of soil fauna and microorganisms. The increased soil moisture and smaller fluctuation in soil temperature under no-till are generally beneficial for microbial activity as well as for the faunal groups. No-till systems may therefore encourage greater biological complexity in agricultural fields and begin to approach the structure of "natural" ecosystems a little more closely than conventional fields. Powlson et al. [1987] showed that the microbial biomass and enzyme activities could be used as early indicators of changes in soil properties induced by tillage. Also Burns [1998] states that enzyme activities have been reported as critical indicators of soil quality because they control nutrient release for plant and microbial growth.

Evaluating the influence of tillage on biological activities of the soil, our laboratory concentrated on: 1. Micro-organisms activities (C-biomass, oxidizable organic carbon – Cox, potential respiration activity, potential nitrification activity – TPNIT and TPNITCa and potential ammonification activity – TPAM). 2. Enzyme activities (activity of dehydrogenase and activity of invertase). 3. Incidence of micro-organisms – total number of micro-organisms.

METHODS

Since 1997 (without ploughing in PT from 1995) field experiments have been conducted at the experimental site Praha – Ruzyne. This experimental site is located in sugar beet production type on orthic luvisol, loam soil. The experiment is run as a rotation of three crops: winter wheat (Czech cultivar Nela), spring barley (Czech cultivar Tolar) and pea (Czech cultivar Menhir). A split-plot design with four replications was used. Grain yield was determined on a 16 m^2 test area at harvest. Tillage methods: 1. Conventional tillage (CT): mouldboard ploughing to a depth of 0.20 m, seed bed preparation and sowing. 2. Protection tillage (PT): sowing with John Deere 750 drill machine a) into no-tilled soil without post harvest residues (WM), b) into forecrop residue biomass shallow incorporated into the soil (ES), c) into no tilled soil covered by herbicide killed biomass of winter catch crops for spring crops (MM), d) into no tilled soil covered by pea crop residues for winter wheat (DM). Catch crops were sown after shallow soil loosening, P and K fertilizing and regular seed bed preparation.

Figure 1. The influence of different soil tillage on biomass of soil microorganisms

Figure 2. The influence of different soil tillage on oxidizable organic carbon Cox

Figure 3. The influence of different soil tillage on potentional respiration activity NG

Figure 4. The influence of different soil tillage on potentional nitrification activity TPNIT

Figure 5. Different soil tillage on potentional amonification activity of soil TPAM

Figure 6. The influence of different soil tillage on dehydrogenases activity in soil

Figure 7. The influence of different soil tillage on invertase activity

Figure 8. The influence of different soil tillage on total number of bacteria CFU

Nitrogen fertilization was as follows: winter wheat 50, 100, 150; spring barley 40, 80, 120; pea 0, 20, 40 in kg per ha. The P and K fertilizers were applied before drilling of catch crops in all variants in universal rates 23.5 kg P and 83.0 kg K per ha. Standard herbicides were applied depending on the intensity of weed infestation.

Representative soil samples were collected at the beginning of October in a plot where winter wheat was grown, in variants CT; PT–WM; PT–ES; PT–DM, from the depths of 0–0.1 m; 0.1–0.3 m; 0.3–0.5 m and passed through a 2 mm sieve. Analyses were corried out three times; average values are given in figures.

Colony forming units (CFU g^{-1} dry soil) of the total number of bacteria were determined by a modified plate dilution technique on Thornton agar [Angerer et al. 1999]. The activity of dehydrogenase enzymes was determined according to the formazan formation in the TTC-amended soil samples after a 24 hours incubation at 37°C. Reaction of dinitro-salycilyc acid was used to invert the monosaccharides according to Scherbakova [1968]. Invertase activity was calculated from the glucose release after the saccharose decomposition incubated for 4 hours at 37°C. Biomass of soil micro-organisms was determined by fumigation-extraction method $C_{biomass}$ [Vance et al. 1987]. TPAM (test of potential ammonification) shows ammonia released from peptone added within 24 hours, TPNIT (test of potential nitrification) shows the nitrates oxidized from ammonia sulphate added, TPANITCa the same, calcium carbonate was added before incubation modified method by Löbl and Novák [1964]. Potential respiration activity (RESPNG) is CO_2 produced within 20 hours of incubation after addition of glucose and ammonium sulphate.

RESULTS

Biomass of soil micro-organisms (C_{biomas}) is closely connected with the microbial revival of soil. The results given in Figure 1 show a significant decrease with the depth of sampling when the decrease of microflora is accompanied by the decrease of the biomass carbon. The lowest level of $C_{biomass}$ was measured in the conventional tillage variant. Also Patra et al. [1990] and Ananyeva et al. [1999] ascertained in their papers an inhibition of microbial biomass on tilled plots contrary to non-tilled plots.

Furthermore, oxidizable organic (soluble) carbon was determined. The results of oxidizable carbon (C_{ox}) are given in Fig. 2 and are in this case influenced by the organic matter content in soil. In the conventionally tilled variant

(ploughing), the organic matter was more mineralized and a decrease of C_{ox} was evident.

Respiration activity (Fig. 3) – mineralization of organic substrates by soil microflora expressed by CO_2 production is the most common manifestation of biological activity of soil. In this case, it was established by potential respiration with ammonium sulphate (N) and glucose (G). In the first and the second depth horizons, a higher C content in soil due to added straw and mulch positively influences respiration activity. In these two variants (PT–DM and PT–ES) the microflora activity was stimulated thanks to a better C supply and thus better responded to the added substract. In these variants, the decrease of respiration activity in the deepest sampling horizon is higher than in the variant with ploughing (CT). A slighter decrease in the conventionally tilled variant (CT) in comparison with the other variants in the deepest sampling horizon depends probably on a better aeration due to ploughing soil tillage. Tillage operations alter soil water and oxygen content, and the accessibility of organic substrates for microbial activity, factors that are directly and indirectly connected with soil biological activity [Curci et al. 1997].

The results of potential nitrification activity with added ammonium sulphate manifest a large variability and no conclusions can be drawn without further verification (Fig. 4). Ammonification activity as well as respiration activity is connected with the activity of soil micro-organisms. Figure 5 gives potential ammonification activity with the addition of peptone. The results manifest the same trend as those of respiration activity and a decrease is manifested only in the third depth horizon.

The results of dehydrogenase activity are given in Figure 6. The results of the dehydrogenase activity test indicate average metabolic activity of soil microorganisms. Dehydrogenase activity responds well to classic ploughing soil tillage. In this tillage, there is only a slight decrease depending on the depth of the horizon and its activity is slightly inhibited only in 0.5 m. In the other variants, the dehydrogenase activity in this depth is on the limits of measurability. Among enzymatic activities, the invertase activity was also determined (Fig. 7). The results document a difference between depths rather than between variants. Also Curci et al. [1997] document in their paper that the activity of enzymes decreased with the depth in the profile. Soil physical and chemical properties are very important factors affecting microbial growth and activity and, as consequence, they may determine changes in enzymatic activity.

In individual variants also the total number of microorganisms CFU (Fig. 8) was determined to illustrate the state of soil. In the variant with ploughing, the total number is lower than in variants with added substrate, but the decrease of

microorganisms in deeper horizons is not so quick and probably depends on the better aeration due to ploughing. Harris et al. [1995] also report that amount of crop residues was a positive influence on the number of microorganisms. On the contrary, Palma et al. [2000] report that bacterial counts would be a poor marker for use as a bioindicator.

Conclusions

The results of performed tests show that the so-called soil protective technologies of crop growing can, already after five years of application, significantly influence the revival of topsoil by microorganisms. This manifested mainly in soil horizon down to 0.1 m where the majority of crops root in the initial stages of growth and development, and in variants with added organic matter into soil (PT–ES, PT–DM). In lower depths, especially in the subsoil horizon, higher levels of microorganism activity were determined mostly in the conventionally tilled soil because of a more intensive aeration of deeper soil horizons by ploughing.

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