COBISS Code 1.01

DOI: 10.2478/acas-2013-0008

Agrovoc descriptors: soil, top soil, sustainability, land management, tillage, cultivation, ploughing, soil fertility, nutrient availability, biomass, microorganisms, composts, mineralization, nitrogen, wheat straw, agricultural wastes, crop residues

Agris category code: P35, f07

Wheat straw decomposition, N-mineralization and microbial biomass after 5 years of conservation tillage in Gleysol field

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Received March 13, 2013; accepted March 21, 2013.
Delo je prispelo 13. marca 2013, sprejeto 21. marec 2013

ABSTRACT

Long-term field experiment to follow various effects of conservation soil tillage is conducted at Biotechnical faculty in Ljubljana. The soil is Eutric Gleysol. Conventional treatment with plowing, 22 cm deep P, and conservation treatment by rotary harrow to a depth of 10 cm N, and subplots with compost amendment (-c) and without fertilization (-n) were observed. After 5 years nutrient contents and organic matter were higher in N than P. Compost addition had a positive effect on microbial biomass, but the tillage system did not affect it. However, nitrogen mineralization and decomposition of straw were higher in P as in N, and in the soil depth of 15 – 20 cm than in the 5 – 10 cm.

Key words: soil, sustainable agriculture, conservation tillage, minimum tillage, mouldboard plowing, soil fertility, residue decomposition

IZVLEČEK

RAZGRADNJA PŠENIČNE SLAME, MINERALIZACIJA-N IN MIKROBNA BIOMASA PO PETIH LETIH OHRANITVENE OBDELAVE OGLEJENIH TAL

V dolgoletnem poljskem poskusu na BF v Ljubljani, na evtričnih oglejenih tleh, merimo različne učinke ohranitvene obdelave tal. Obravnavamo konvencionalno obdelavo z oranjem 22 cm globoko P in ohranitveno obdelavo z vrtavkasto brano do 10 cm globine N, in podploskvi z dodatkom komposta (-c), in brez gnojenja (-n). Po 5 letih so bile višje vsebnosti hranil in organskih snovi v N v primerjavi P. Kompost je imel pozitiven učinek na mikrobno biomaso, obdelovani sistem pa nanjo značilno ni vplival. Mineralizacija dušika in razgradnja slame sta bila večja v P kot v N, ter v globini tal od 15 – 20 cm kot v 5-10 cm.

Ključne besede: tla, trajnostno kmetijstvo, ohranitvena obdelava, konzervacijska obdelava, minimalna obdelava, rodovitnost tal, razgradnja ostankov

1 INTRODUCTION

Modern conventional tillage includes a large number of serial passages in the preparation of soil for planting. After planting the soil surface remain uncovered until development of the crop and as such exposed to precipitation and wind. The result of such a situation is erosion, damage to soil structure and nutrient losses (run-off and leaching to deeper layers) (Wells et al., 2000). Decomposition is faster in areas with higher mean annual temperatures and higher annual total precipitation (Franzluebbers, 2002, Balota et al., 2003). In such conditions, soil cultivation additionally speeds up the decomposition; the more intense, the faster is the decomposition of organic matter. Deep intensive tillage incorporates plant residues into the soil, and also physically damages soil aggregates and exposes humus which was before protected in the structural aggregates, which facilitates decomposition of soil organic matter by soil organisms (Wright et al., 2005). By leaving

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substantial amounts of crop residue (at least 30%) on the soil surface, conservation tillage reduces soil erosion from wind and water, increases water retention, and reduces soil decomposition as well as water and chemical runoff. In addition, conservation tillage reduces the carbon footprint of agriculture (Ilan and Lal, 2013). It has been established that, after prolonged period of more than 10 years practising conservation tillage, soil organic matter can be increased to new higher equilibrium, with accompanying increases in microbial activity (Ilan and Lal, 2013). One of the main agronomical challenges is achieving or maintaining a high level of soil organic matter, while keeping the concentration of inorganic nitrogen low during periods subject to leaching losses. Compared with conventional tillage, conservation tillage creates more compact and cooler soil. The result is slower mineralization and the release of plant nutrients from soil organic matter (Doran and Werner, 1990).

Conservation tillage should be developed within the context of specific climates and soils (Abadalla et al., 2013). In Slovenia, there is a lack of experimental evidence on conservation tillage effects on the soil organic matter decomposition and mineralization. To fill the gap and to get the knowledge about conservation tillage effects we established in year 2000 a long-term field experiment of conservation vs. conventional tillage in Ljubljana, Slovenia. Relatively warm and humid climate (in Ljubljana: 10.9 °C average year temperature, 1400 mm precipitation), and Eutric Gleysol present a specific agro-ecological conditions. In this work we are testing following hypotheses:

- Conservational tilled soil N consecutively for 5 years inhabit higher soil microbial biomass and has greater ability to decompose fresh organic residue (wheat straw) in the top 10 cm compared to conventional ploughing system (P).
- Mineralization of soil nitrogen is slower in the top soil at conservation tillage (N) was compared to conventional plowing system (P).

2 MATERIALS AND METHODS

Long-term field experiment comparing conservation and conventional plowing soil tillage systems are conducted at Biotechnical faculty; Agronomy experimental field in Ljubljana from year 2000.

Field conditions and experiment design

The soil is Eutric Gleysol, with silty-clay-loam texture, with good nutritional status (Tab. 1; soil P and K supply are in desired, C-level of according to fertilization guidelines; Mihelič et al., 2010). The climate is relatively warm and humid (10.9 °C average year temperature, 1400 mm precipitation).

The experiment was divided into the block of conventional treatment with plowing 20 – 25 cm deep (P) and the block of conservation treatment by rotary harrow to a depth of 10 cm (N). Within each block, we considered two variants: unfertilised and fertilized with compost. The plots were without fertilization from year 2000 (-n); at plots (-c) compost made of source separated municipal biogenic waste from Komunalno podjetje Vrhnika d.d. composting plant was surface applied in the end of March, after oat seeding. With it we supplied 105 kg N/ha, 30 kg P_2O_5/ha and 28 kg K_2O/ha. Average yearly N input from the compost in the period 2000 to 2005 was 113 kg/ha. The compost was applied every second year. Each treatment is designed with three replications.

Soil sampling

Soil samples were collected 18th April 2005 from two depths (0-10 cm and 10-20 cm) and stored until analyses in a refrigerator at 4 °C up to one three days or frozen for long term storage.

Straw decomposition test in litter bags (Schinner, 1996)

Nylon litter bags were filled with wheat straw (straw particles ca. 1 – 2 cm long; Pict. 1) and exposed to field conditions by burying them into the soil at depths of 5 - 10 and 15 – 20 cm 1st June, 2005 in 6 repetitions per soil depth and treatment. 10 g of straw was put into each bag. Filled bags were first dried at a temperature of 95 °C 24 hours, and then cooled for two hours in a desiccator. Cold bags were weighed, and then buried into the soil. After incubation period bags were dug out the soil the 2nd August, 2005. The bags were dried 2-3 hours at room temperature, and then we carefully removed the soil stuck to the outer walls of the bags with soft brush for clothes. Caution was necessary to remove roots that grew into bags. After cleaning bags were dried at a temperature of 95 °C for 24 hours, followed by cooling in desiccator and weighing it. Straw decomposition was calculated by mass differences.

Picture 1: Litter bag with straw before field installation

Crop management at the experimental field

In the August 2004 we planted oil rape (*Brassica napus var. oleifera*) as a green manure. The oil rape was desiccated with total herbicide (glyphosate: Boom Effect) in the late autumn. In early March 2005 the soil was either plowed 22 cm deep + rotary harrowed 10 cm deep: treatment P or just rotary harrowed: treatment N. Oat (*Avena Sativa* L.) cv. Expander was then seeded in to the field 24th March 2005.

Laboratory analyses

Kjeldahl total nitrogen analysis was done using titanium dioxide as catalyst (ISO 11261).

Determination of soluble nitrogen forms (NO_3-N, NH_4-N) was done in 0.01 M $CaCl_2$ extraction following SIST ISO 14255 and measured by flow injection analyses (FIAS Perkin-Elmer 3000).

Determination of total carbon was done following the protocol ISO/DIS 10694 (1994): a method for the determination of the total carbon content in soil after dry combustion. Organic matter was calculated by multiplying C with a factor of 1.72.

Fumigation incubation method was done according to Schinner (1996). During the fumigation chloroform kills soil micro-organisms, so they become susceptible to mineralization. After fumigation we added inoculum (1% mass of non-fumigated soil), followed by incubation for 10 days in the dark at 25 °C. During this time, killed biomass partially mineralized (microorganisms from non-fumigated inoculum made the mineralization), resulting in an increased release of carbon dioxide. Extracted carbon dioxide binds to sodium hydroxide. From the consumption of acid for titration of the residual sodium hydroxide the amount of soil microbial biomass is calculated. Each treatment was measured in triplicates.

Determination of net nitrogen mineralization by incubation under controlled aerobic conditions (Drinkwater et al., 1996): samples in triplicates were incubated in 100 ml containers, at 60% of field capacity and at 20 °C for twenty-eight days. After incubation the extraction of samples with 0.01 M $CaCl_2$ to determine the quantity of extractable mineral nitrogen (NO_3-N and NH_4-N) was done. Extraction of the first batch of samples was performed on the first day, the second batch on the 14th and the third at 28th day after the start of the incubation.

3 RESULTS AND DISCUSSION

Nutrients and microbial biomass carbon in the soil

Microorganisms are the active component of soil organic matter. They rapidly respond to the changes in the soil temperature, moisture content, crop residues (Rice et al., 1996). Due to the quick response of microorganisms to the soil conditions, microbial biomass-C content could also be a good indicator of soil tillage induced changes (Alverez and Alverez, 2000).

Five years after the start of the experiment, nutrient content and organic matter were higher in conservation N vs. conventional tillage P, although the differences were not significant (Tab. 1).

Table1: Soil analysis (0 – 20 cm) after 5 years of the experiment

Treatment	pH	P_2O_5 AL-method (mg/100 g)	K_2O AL-method (mg/100 g)	Org. matter %	N %	C:N
Conservation tillage **N**	6,8	24	40	4,3	0,25	10,1
Confidence interval (±)	0,1	2	5	0,3	0,01	0,3
Plowing tillage **P**	6,7	21	32	4,0	0,23	10,0
Confidence interval (±)	0,1	2	3	0,2	0,01	0,4

The measurements of microbial biomass-C showed higher values at a depth of 0 – 10 cm in all treatments (Fig 2), however no significant differences were found between treatments, thus our first hypothesis was denied, which is contrary to established theory. For conservation vs. conventional tillage literature reports the increase of the content of microorganisms in the topsoil (0 – 10 cm), while the differences in the deeper layers are smaller (Mühlbachová and Růžek, 2002; Alvarez and Alvarez, 2000; Franzluebbers , 2002; Gonzales-Chavez et al., 2010).

Compost addition had a positive effect on microbial biomass in the plowed soil where microbial biomass was relatively high and consistent in the both soil depths. The differences between treatments were not significant, because a high variability found.

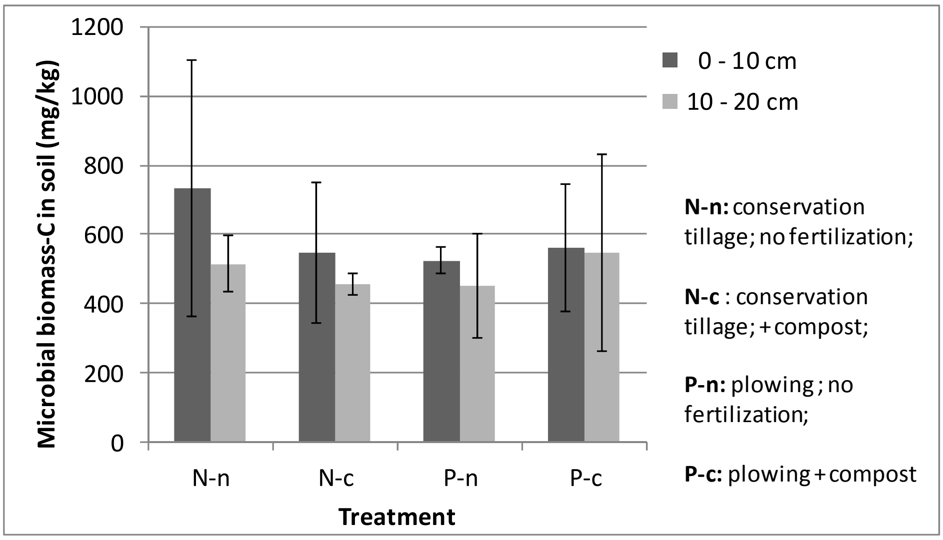

Figure 2: Microbial biomass in soil dependent on soil tillage and soil depth

Net nitrogen mineralization

N mineralization was higher in the plowed soils (P-n, P-c) in the both soil depths (Fig. 3). N-mineralization started faster in the plowed soils, especially in the upper 10 cm. This could be explained by more plant residue concentrated in the upper 10 cm at N treatment. Plant residue (fresh and from previous years) can cause temporary immobilization of N released from soil by mineralization. Immobilization is significant if the C/N ratio of plant residue is >20 – 25 (Nicolardot et al., 2001). Oil rape which was incorporated in a flowering stage in early autumn 2004 can have a C/N ratio around 30 or even higher. Kriauciuniene et al. (2008) report that oil rape plant residues contain a substantial amount of lignified matter especially roots and stems, which are very much resistant to decomposition.

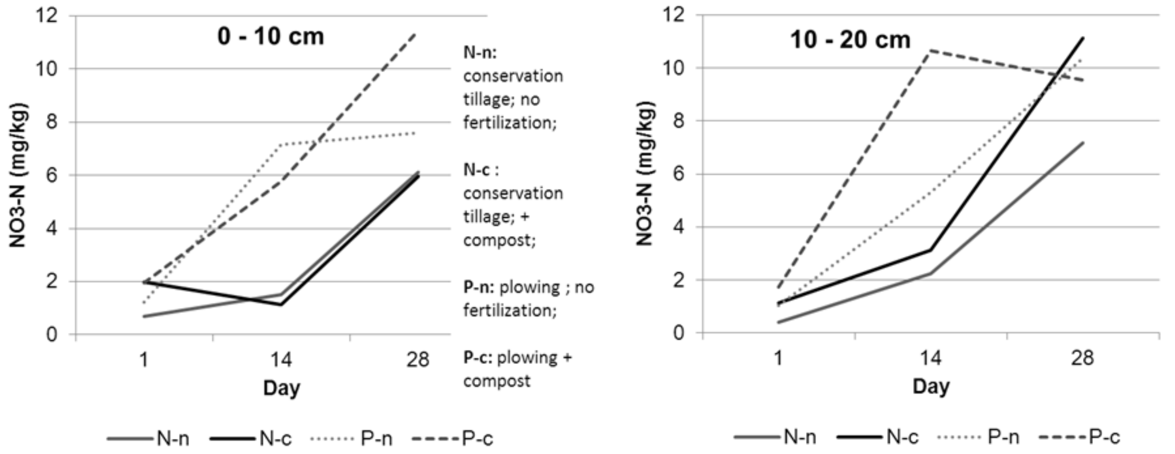

Figure 3: Nitrate-N accumulation during aerobic soil incubation

On the contrary to plant residues, the compost we used had a C/N ratio 17.0 and thus immediate net N-mineralization was expected with compost addition. Positive effect of the compost on N-mineralization was pronounced at P, but not at N where the mineralization had a lag period of 14 days with or without compost addition. Later, in the days 14 to 28, the concentration of NO_3-N in the upper 10 cm was still significantly higher in P than N at the end of incubation. Similar trend was in the layer 10 – 20 cm, although the N-c produced the same amount of NO_3-N as P-c at the end of incubation.

This confirms that conventional tillage promotes mineralization, reduces the level of organic matter in the soil, what can lead in a long term to decreases of soil fertility and can consequently deteriorate the economics of field crop production (Balota et al., 2003; Alvarez and Alvarez 2000; Wright et al., 2004). On the other hand, less mineralization at conservation treatment N could mean a need for higher doses of nitrogen fertilizer for crops, especially for good vegetative growing of young plants (Javůrek, 1998). Conservation tillage practices can thus lead to enhanced nitrous oxide emissions (Abadala et al., 2013).

Wheat straw decomposition

Litter bags were buried in the soil for 62 days, throughout June and July 2005. The average temperature in June was 19.5 °C and in July 21.1 °C, precipitation being 83.9 mm and 141.9 mm, respectively (Meteorology yearbook, 2005), so the environmental conditions for straw decomposition were good.

More intense straw decomposition was found in P, 46% then in N, 42% (Fig. 4). In practice this would mean that wheat straw would almost completely decompose in just more than four months after the harvest. However, we must realize that the process takes longer, as autumn comes cooler weather.

Higher decomposition in P is in line with the N-mineralization rate and microbial biomass measurement. Similarly, as for the higher N-mineralization in conventional tillage can also be higher decomposition of straw favoured by less compact soil in this treatment P, which in turn means more air to soil organisms and hence their greater activity compared to conservation tillage N.

Soil depth had no significant influence on straw decomposition. The addition of compost slightly enhanced straw decomposition only in 15 – 20 cm, in spite that we spread the compost on the soil top after seeding of oat. This could also be an effect of compost additions from previous years.

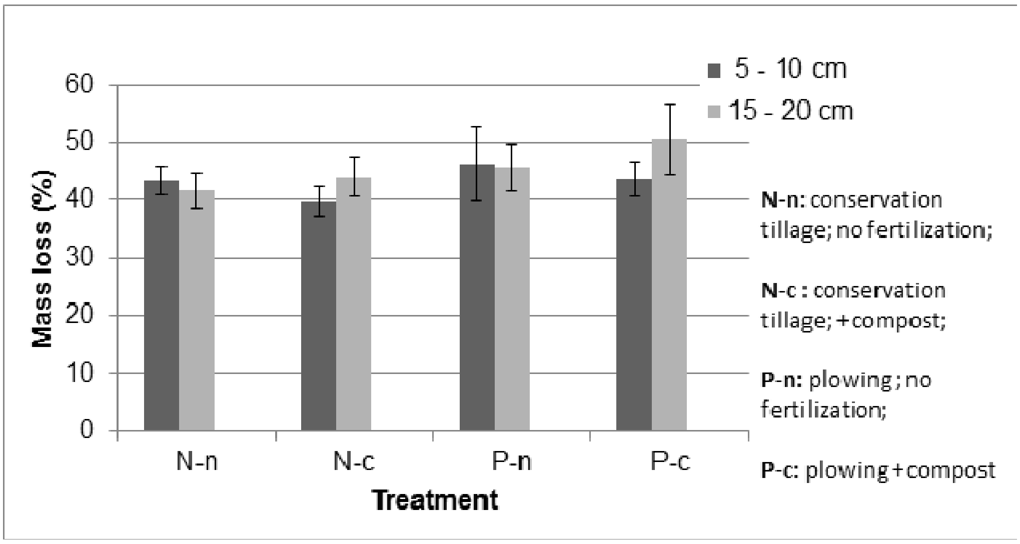

Figure 4: Wheat straw mass loss (% of initial) after 62 days of decomposition experiment (means and SD of 6 replicates are shown)

4 CONCLUSIONS

After five years of field experiment comparing conservation tillage N with the conventional plow tillage P the content of nutrients and organic matter increased in N, however biomass-C in soil was not significantly affected, although it was slightly higher at the plowed treatment P. Straw incorporated into the soil degraded relatively fast. On average 44% of straw decomposed in just two months. Soil conservation treatment using only rotary harrow N had slightly lower capacity for decomposition of wheat straw compared to P, but the differences were not significant. Such result is in line with the N-mineralization rate and microbial biomass measurement. Slower decomposition of organic matter results in a slower release of nutrients as shown by N-mineralization incubation test. This may indicate the need for more substantial fertilization with mineral nitrogen at conservation tillage system used in this experiment. We continue with the experiment to observe further long-term changes in the soil induced by conservation tillage.

5 ACKNOWLEDGEMENTS

The presented results were partly financed by the Slovene Ministry of Science and by the Ministry of Agriculture within the project CRP V4-450-01 (Konkurenčnost Slovenije 2001 – 2006); and by the Slovene Ministry of Education, Science, Culture and Sports by the project J4-4224 (C): Sustainable land use in relation to soil and crop quality (basic research project). (1.7.2011 - 30.6.2014).

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