Agronomy Research **7**(Special issue I), 263–268, 2009

Changes the content of organic matter in soil during the whole cycle of crop rotation

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Abstract. The ecological crop rotation in the present trial has been established as a 10-field rotation. The crop sequence was based on calculation of how much of the nutrients does one or another crop take from the soil and how much will be left in the soil after yield harvesting. The crop sequence in ecological crop rotation was: spring wheat, barley with undersown clover, clover, clover, potato, oat, pea, barley with undersown clover, spring turnip rape. The field experiments were carried out in northem Estonia during 2003–2008.

After having analyzed the soil organic matter content throughout all the fields of crop rotation it became evident that the alterations of organic matter content in soil were dissimilar. The alterations of organic matter content in all fields were in linear correlation (r_{95} higher than 0.549, number of pairs 10). Although more than a half rotation has already passed after the beginning of the trial the results are still probably affected by the number of times the clover has been grown on any particular field.

Key words: soil humidity, soil organic matter, crop rotation

INTRODUCTION

A proper succession of crops is the basics of ecological production which does ensures the preservation and improvement of both crop yield and soil fertility. Soil organic matter (SOM) plays a number of essential roles in cropping systems and its dynamics merit special interest (Sanchez et al., 1989). SOM contributes significantly to soil nutrient resilience (Baldock and Skjemstad, 2000), renders the physical environment of soil suitable for plant growth. SOM is one in the important indicators of soil quality (Larson and Pierce, 1994; Rosell, et al., 2001) and its management is envisaged to maintain soil fertility and promote sustainable agriculture (Martin et al., 1990). In the soil management it is very important to take into the consideration the humus state of soil to assure an adequate annual input of locally grown residue into the soil and to supervise that the soil would contain enough of organic matter or humus adequate to the humus capacity characteristic to the according soil type (Kõlli, 1996). While in traditional agriculture it is possible to use short cycle crop rotations then in an ecological production it is essential to use at least a 7-field or longer crop rotation. The cause for it is a maximum prevention of disease and pest spreading using crop sequence. In ecological crop rotation, the diversity of different crops is essential as a too frequent cultivation of botanically close species in the crop rotation do promotes not only the mass spread of diseases, but also of certain weed communities (Ilumäe et al., 2006). From the viewpoint of nature economics the emphasis is not as much on the field production needed for human consuming but on the ability to use the product not necessary to consumers for inside stabilizing of ecosystem (Penu, 1998).

In Estonian Research Institute of Agriculture a 10-field ecological production trial was started in 2003 to study options for preservation of soil nutrient and organic matter content throughout the whole crop rotation cycle. The present paper is discussing the changes in soil organic matter during six trial years.

MATERIALS AND METHODS

At Kõbu trial field of Estonian Research Institute of Agriculture the preparations to establish an ecological field trial began in 2001. Before starting the trial a systemic broad-spectrum herbicide Roundup was used to clear the area of rooted weeds. The transient stage lasted for 2 years. The field trial was established on clayed sandy loam soil, at the beginning of the period of transition to ecological production the organic matter content in soil was 5.9%, content of assimilable P was 92 mg kg^{-1}, K content 40.2 mg kg^{-1} and pH_{KCl} 5,3–6,1(Appropriative nutrients were analyzed by the Plant Biochemistry Laboratory of Estonian University of Life Sciences; pH_{KCl} was established according ISO 10390, P and K by the TL-method and % of humus according to the Tjurin method). Field trial was established in 10 fields, 3 replicates per field, plot size 250 m^2. The sequence of crops in ecological crop rotation was the following: spring wheat, spring barley with presown clover, clover, clover, potato, oat, pie, spring barley with presown clover, clover, rape. The crop sequence is based on calculations of how many nutrients will one or another crop take from the soil and which amount of them will remain in soil after the harvest. For weed control the crops were harrowed using eco-harrow right after the emergence on the first opportunity as soon as harrowing was possible without harming crops. Harrowing was repeated twice with interval of 7–10 days. During the whole vegetation period the crops were assessed regularly to register possible plant diseases. In spring (beginning of the vegetation period), in July (the intensive plant growth period) and in autumn after the harvesting soil samples were taken from the ploughed stratum layer(in depth of 0-20 cm) from all trial plots to establish the content of nutrients and organic matter. After harvest the yield of every plot was determined, its moisture content measured and then the yield data over calculated according to the standard moisture content. The straw was not removed after the harvest, but ploughed into the soil. Statistical analyses were done by two-factor without replication and regression analysis methods.

The trial has been established taking in consideration strictly plant production farms only – thus not taking into account animal husbandry (i.e. use of organic manure).

RESULTS AND DISCUSSION

Since no mineral fertilizers are used in conditions of ecological production therefore the organic matter left in soil after crop harvesting does have an essential importance in preservation and reproduction of soil fertility in crop rotation. Thus the crop rotation forms the fundamental base for organic production (Dawson et al., 2008) and growing of legumes has a very important role in an ecological crop rotation.

Namely the legumes have strong roots and take nutrients from deeper soil layers (up to 1.5 m) and then bring them into surface layers of soil where these nutrients are easily assimilable by the following crops. Clover is irreplaceable in maintaining the organic matter and nutrient content in the soil (Soon et al., 2001). It is important to know that growing clover in crop rotation will decrease the occurrence of disease causing pathogens in subsequent crops (Cook et al., 1987).

In the trial clover was sown with presown clover. The positive effect of clover on the soil organic matter content did not show during the first growth year but by the second growth year it was already noticeable (E.g., 9th field in 2005 or 6th field in 2008, Figure 1). There were no significant differences between the soil organic matter content of 2nd and 3rd year clover fields (8th field in 2006 and in 2007, 7th field in 2007 and in 2008) as only after ploughing the clover into the soil both ground-up parts and roots will decompose and the aerial nitrogen tied up by the nitrogen-fixing bacteria will slowly become available, ensuring the following crops in crop rotation with stable nitrogen supply.

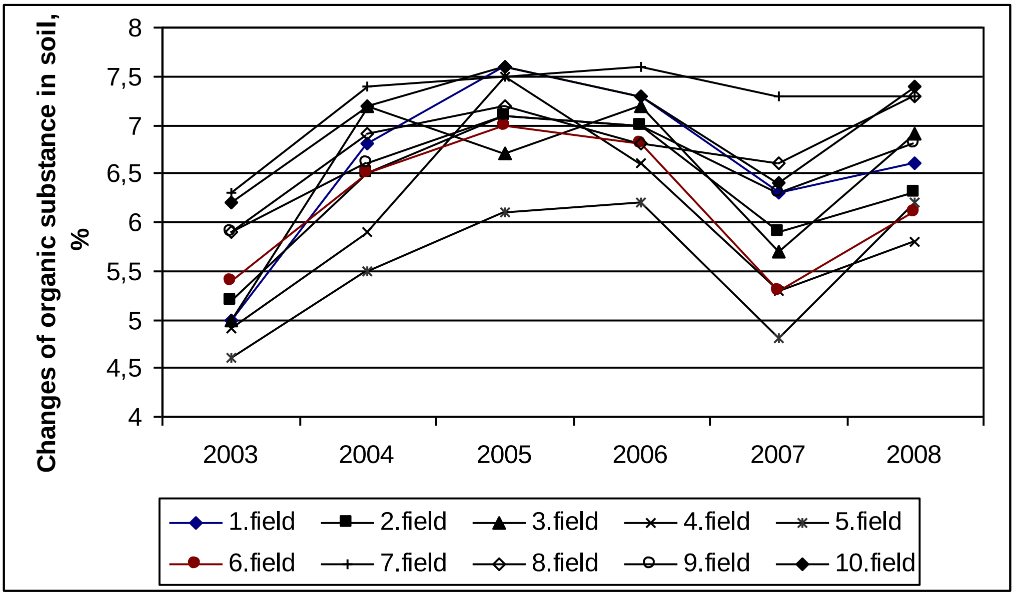

Fig. 1. Changes of organic substance content (%) in the fields of different ecological crop rotation in 2003–2008 in Saku.

Compared to the clover, the field pie has weaker roots but it is well capable of typing up aerial nitrogen using the bacteria in its root nodes. In crop rotation the pie has first of all, the role of keeper of the soil organic matter and nutrients (Fig. 1, 2nd field in 2006). Seed-producing legumes have relatively shallow roots and consequently, they have a weaker positive impact to the soil than clover. Also turnip rape with its deep-reaching roots does improves the structure of soil, bring nutrients up from deeper layers of soil and incorporate much of organic matter, into the soil, although it cannot tie up the aerial nitrogen. Three of the six trial years in observation could conditionally be considered relatively dry years, whereas the other three moist.

During the dry years the soil organic matter content was on average 0.4% lower, however during the moist years the soil organic matter content was on average 0.8% higher. In long term studies in southern Germany, higher yield in wheat has been linked to the improved root density and penetration associated with favourable effect of spring rape on components of soil structure including aggregate stability and porosity, both of which were reduced by wheat and barley in the rotation (Schönhammer and Fischbeck, 1987). Also the turnip rape excretes into the soil glycosinolate decomposition products which act as natural fungicides and break the development cycle of common root rot causing pathogens. Therefore the occurrence of several pathogens will decrease at the time of turnip rape root and upper decomposition in the soil (Kirkegaard et al., 2000). Growing potato in the crop rotation will decrease the soil organic matter content (Carter et al., 2003) as potato will leave very little plant residues into the soil (Grandy et al., 2002). For weed control in organic potato production mainly harrowing and earthing are used. Hence the soil organic matter content in case of growing potato in the crop rotation will decrease also due to intensive soil cultivation. Nevertheless, in conditions of suitable moisture content the mechanical cultivation of potato will mellow the soil and enable the so-called soil ripening. As in the crop rotation trial the clover does has a very high relative percentage and the potato comes right after the clover, no major changes in soil organic matter content were observed. It has been established by many researchers that the long crop rotations containing legumes, where potato nitrogen needs are covered by the precrop (Lunch et al., 2008). Also it has been found that the best timescale to grow potatoes in a long crop rotation on the same field and still preserve the soil fertility is once over 9 years (Angers et al., 1999).

Cereals are in the crop rotation foremost the consumers of nutrient and humus but decomposition of cereal straw helps to maintain the humus balance in soil. The oat root excretions have a phytosanitary effect, as well (Cotterill et al., 1988). In the trial years, the quantity of straw mass left on soil after harvesting the crops was 130–260 g m^2.

According to a model for calculating humus balance developed by German scientists for ecological production (Freyer, 2002) the crop rotation used in present trial has a positive humus balance (+1,25 humus units*). Taking in consideration the possible unfavourable agroecological conditions, the positive humus balance of the crop rotation is necessary to ensure that crops be provided with nutrients also in extreme situation of slower mineralization of organic matter. After six years the content of organic matter in soil of 4 fields of the crop rotation is considerably lower than the estimated value for organic matter content (Fig. 2). The lowest, almost at the same level as in the beginning of the trial, is the content of organic matter in soil of the 4^{th} field. The reason is probably that in 2007 turnip rape was grown on this field whereas the weather conditions were favourable for organic matter decomposition and in 2008 spring wheat was grown on the same field. On the 2^{nd} field initially clover was grown and the organic matter accumulated by it was used up by potato→oat→pie after that, the effect of new clover crop has not yet been able to show. On the 5^{th} field, there was barley with presown clover and during the first year the effect of clover will stay low, moreover, barley will use up to make up the harvest.

* 1 humus unit = 1 ton

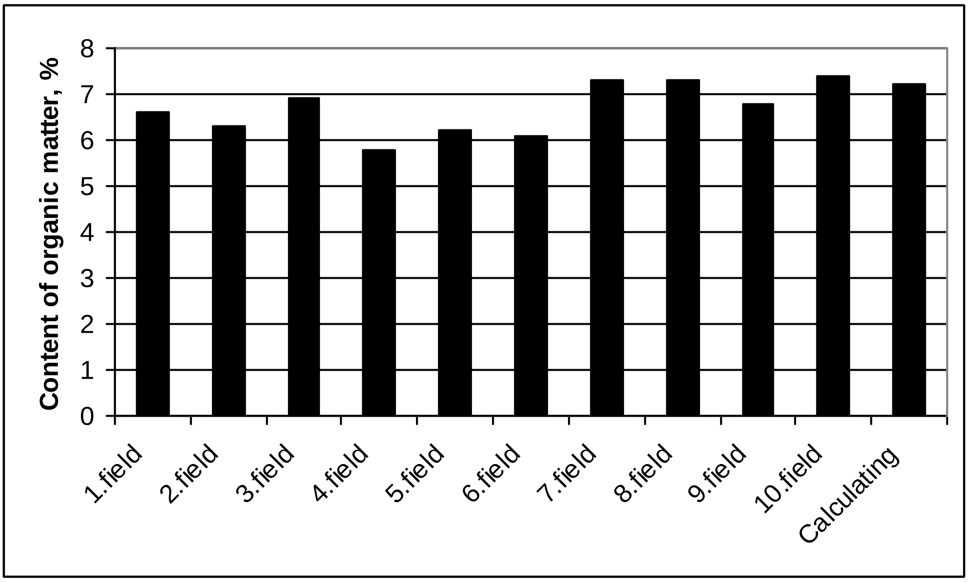

Fig. 2. Crops impact on soil fertility in 2008 in Saku

By the end of the first cycle of the crop rotation the content of organic matter in soil will probably be unified also in soil of these fields compared to the other fields.

After analyzing the soil organic matter content throughout all the fields of crop rotation it became evident that the alterations of organic matter content in soil were dissimilar: (Two-Factor Without Replication), F-statistic (F) was higher (13.98) than 0.05 - Fcrit (2.09) of the F-distribution. The alterations of organic matter content in all fields were in linear correlation (r_{95} higher than 0.549, number of pairs 10).

When using regression analysis to compute the alterations of organic matter content by fields, only in case of the 3rd and 6th field the correlation multiplier r was below 0.729 (r_{95}, number of pairs 6) and therefore the organic matter content alterations taking place in these crop rotation segments were statistically insignificant. Although more than a half rotation has already passed after the beginning of trial the results are still probably influenced by the number of times the clover has been grown on any particular field.

The mineralization of organic matter is influenced by many factors independent of human activities such as soil humidity or aridity, temperature etc. In perfect conditions the mineralization of organic matter should be timed to the period of intensive crop growth.

CONCLUSIONS

Taking into the consideration the growth-time need for nutrients of different field crops and their impact on subsequent crops in rotation, it is possible to keep the soil organic matter content on the same level or even to increase it.

REFERENCES

Angers, D.A., Edwards, L.M., Sanderson, J.B. & Bissonnette, N. 1999. Soil organic matter guality and aggregate stability under eight potato cropping sequences in fine sandy loam of Prince Edward Island. *Can. J. Soil Sci*. **79**, 411–417.

Baldock, J.A. & Skjemstad, J.O. 2000. Role of the soil matrix and minerals in protecting natural organic materials against biological attack. *Organic Geochemistry* **31**, 697–710.

Carter, M.R., Kunelius, H.T., Sanderson, J.B., Kimpinski, J., Platt, H.W. & Bolinder, M.A. 2003. Productivity parameters and soil health dynamics under long-term 2-year potato rotations in Atlantic Canada. *Soil Till .Res*. **72**, 153–168.

Cotterill, P.J. & Sivasithamparam, K.1988. Reduction of take-oll inoculum by rotation with lupin, oats or field pea. *Journal Phytopathology* **121**, 125–134.

Cook, R.J., Sitton, J.W. & Haglund, W.A. 1987. Influence of soil treatments on growth and yield of wheat and implications for control of pythium root rot. *Phytopathology* **77**, 1192–1198.

Dawson, J.C., Huggins, D.R. & Jones, S.S. 2008. Characterizing nitrogen use efficiency in natural and agricultural ecosystems to improve the performance of cereal crops in low-input and organic agricultural systems. *Field Crops Research* **107**, 89–101.

Freyer, B. 2002. *Fruchtfolgen*, S.112–113.

Grandy, A.S., Portet, G.A. & Erich, S. 2002. Organic amendment and rotation crop effects on the recovery of soil organic matter and aggregation in potato cropping systems. *Soil Sci. Soc. Am. J*. **66**, 1311–1319.

Ilumäe, E., Hansson, A. & Akk, E. 2006. Põllukultuuride mõju ökoloogilises külvikorras mulla orgaanilise aine sisaldusele.EMVI Teadustööde kogumik **71**. Taimekasvatus, 103–108.

Kirkegaard, J.A., Sarwar, M., Wong, P.T.W., Mead, A., Howe, G., Newell, M. 2000. Field studies on the biofumigation of take-all by *Brassica* break crops. *Austr. J. Agric. Res*. **51**, 445–456.

Kõlli, R. 1996. *Transactions of the Estonian Agricultural University **187 A***. The pedoecological aspects of sustainable crop product production, pp. 51–54 (in Estonian).

Larson, W.E.; Pierce, F.J. 1994. Conservation and enhancement of soil quality. *IBSRAUM Proc*.**12**, 175–203.

Lynch, D.H., Zheng, Z., Zebarth, B.J. & Martin, R.C. 2008. Organic amendments effects on tuber yield, plant N uptake and soil mineral N under organic potato production. *Renew. Agric. Food Syst*. **23**, 250–259.

Martin, A., Mariotti, A., Balesdent, J., Lavelle, P. & Voattoux, R. 1990. Estimate of organic matter turnover rate in a savannah soil by ^{13}C natural abundance measurements. *Soil Biology and Biochemistry* **22**, 517–523.

Penu, P. 1998. *EPMÜ Teaduslike tööde kogumik. Põllumajanduskultuuride produktiivsus ja kvaliteet.**199***. Koristusjäätmete roll ökosüsteemides, 56–59 (in Estonian).

Rosell, R.A., Gasparoni, S.C. & Galatini, S.A. 2001. Soil organic matter evaluation. In Lal, R., Kimble, J.M., Follette, R.F., Stewart, B.A.(eds): Management of Carbon Sequestration in Soils. *Advances in Soil Science*. CRC Press, Boca Raton, FL.311–322.

Sanches, C.E. & Wood, M.K.1989. Infiltration rates and erosion associated with reclaimed coal mine spoils in west central New Mexico. *Landscape and Urban Planning* **17**, 151–168.

Soon, Y.K., Clayton, G.W. & Rice, W.A. 2001. Tillage and previous crop effects on dynamics of nitrogen in a wheat-soil systems. *Agronomy Journal* **93**, 842–849.

Schönhammer, A. & Fichbeck, G. 1987. Investigations on cereal crop rotation and monocultures. 1. Differences in yield under 15 rotations. *Bayerisches Landwirt. Jahrb*. **64**, 175–191.