Effect of carbon sequestration of wheat (*Triticum aestivum* L) varieties on soil organic matter

Mária Katalin Kassai, Ákos Tarnawa, Ferenc Nyárai Horváth, Barnabás Pósa and Márton Jolánkai*

Szent István University, 2100 Gödöllő, Páter Károly utca 1. Hungary

**e-mail: jolankai.marton@mkk.szie.hu*

Abstract

Soil fertility is often related to soil organic matter (SOM) in general. Various crop species and varieties, as well as plant nutrition applications may have an impact on the amount of soil organic matter.

In a series of small plot field experiments run at the Nagygombos experimental site of the Szent István University, Hungary, the most characteristic agronomic impacts (biological bases, plant nutrition and crop year effects) influencing the efficiency of carbon sequestration of wheat *Triticum aestivum* L. has been studied. The aim of the research was to observe, identify and quantify agronomic impacts and their interactions that may have an influence on organic matter formation and so on carbon sequestration. The present paper provides information concerning the results of the trial. Crop variety and plant nutrition proved to be powerful factors influencing organic matter production. Interactions have been found between crop plant genotypes and N levels applied. Wheat straw by-products represent a considerable source for soil organic carbon.

Keywords: carbon sequestration, winter wheat, plant nutrition, soil organic matter

Összefoglalás

A talaj szervesanyag tartalma (SOM) a talaj termőképességének egyik legáltalánosabb mutatószáma. Növényfajok és fajták termesztése, valamint a növények tápanyagellátása befolyással lehet a talaj szervesanyagtartalmára.

A Szent István Egyetem Növénytermesztési Intézetének kísérleti terén, Nagygomboson egy többéves kisparcellás kísérletsorozat keretei között vizsgáltuk az őszi búza *Triticum aestivum* L. fajták szénmegkötését befolyásoló legjellemzőbb tényezők (biológiai alapok, tápanyagellátás, évjárat) hatását. A kutatás célja a szénmegkötésre ható az agrotechnikai elemek meghatározása, a hatás mértékének megállapítása, illetve a kölcsönhatások megfigyelése volt. Jelen dolgozat e kísérletek eredményeit foglalja össze. Vizsgálataink szerint a növényfajták, valamint a tápanyagellátás jelentős mértékben befolyásolták a szervesanyag képződést. A vizsgált genotípusok és az alkalmazott N adagok között kölcsönhatások is igazolhatók voltak. A kapott eredmények szerint a búzaszalma jelentős szénforrást biztosít a talajok szervesanyagtartalom-képződéséhez.

Kulcsszavak: szénmegkötés, őszi búza, növénytáplálás, talaj szervesanyag

Introduction

Human activities are significantly altering the natural carbon cycle (Lal 2004). Long-term rise in atmospheric CO_2 highlights crop production regarding both adaptation and mitigation (Jolánkai et al 2005). The negative effects of climate change can be limited by changes in crops and crop varieties, improved water-management and irrigation systems, adapted plant nutrition, protection and tillage practices, and better watershed management and land-use planning (Pepó 2010). The global potential of carbon sequestration through crop production, land use and soil management practices may offset one-fourth to one-third of the annual increase in atmospheric CO_2, a most endangering GHG (Lawlor 2005).

Soil organic matter (SOM) is a result of carbon sequestration based on the photosynthetic activities of plants. Any organic matter manufactured by plants is originated from atmospheric CO_2. Plants (crop plants and natural vegetation) capture C and produce vegetative material, a biomass that comprises yield and by products. The prior one is regularly taken away from the crop site however the latter remains there providing a resource for SOM formation. Recent land use technologies aim the removal of plant residues in favour of using them as biofuels and so endangering soil remediation. The pool of organic C exists in dynamic equilibrium between gains and losses; soil may therefore serve as either a sink or source of C, through sequestration or greenhouse gas emissions respectively, depending on exogenous factors (Lal 2004). As vegetal material undergoes decomposition, some microbial resistant compounds are formed. These include modified lignins, oils, fats and waxes. Also, some new compounds are synthesized, like polysaccharides and polyuronids. These materials form the basis for humus (Brady 1984).

When plant residues are returned to the soil, various organic compounds undergo decomposition. Decomposition is a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules (Juma, 1999).

The continual addition of decaying plant residues to the soil surface contributes to the biological activity and the carbon cycling process in the soil. Breakdown of soil organic matter and root growth and decay also contribute to these processes. Carbon cycling is the continuous transformation of organic and inorganic carbon compounds by plants and micro- and macro-organisms between the soil, plants and the atmosphere. Decomposition of organic matter is largely a biological process that occurs naturally and determined by three factors: soil organisms, the physical environment and the quality of the organic matter (Brussaard, 2012; Jolánkai et al 2013). Soil organic carbon (SOM) contains approximately 58 % C, therefore a factor of 1.72 can be used to convert organic carbon (OC) to SOM. There is more inorganic C in calcareous soils in general (Edwards et al. 1999). Non appropriate land use methods and some false renewable energy concepts often result in soil organic matter losses (Birkás et al 2012; Mesic et al. 2014).

The aim of the present study was to observe, identify and quantify agronomic impacts and their interactions that may have an influence on organic matter formation and so on carbon sequestration.

Material and method

The Szent István University Crop Production Institute started a research programme exploring the most characteristic agronomic impacts (biological bases, production sites, plant nutrition and crop year effects) influencing the efficiency of carbon sequestration of winter wheat *Triticum aestivum* L. The aim of the research was to observe, identify and quantify agronomic impacts and their interactions that may have an influence on organic matter formation and so on carbon sequestration.

The trials were set up at the Nagygombos experimental site in a three years consecutive series between 2007-2010. Five wheat varieties (Mv Magdaléna, Alföld 90, Mv Suba, Mv Csárdás, Mv Toborzó) were exposed to ascending levels of nitrogen applications. 10 m^2 plots were designed in randomized blocks in split-plot arrangement for wheat crop with four replications. The nitrogen applications were as follows: N 0, N 80 kg/ha, and N 120 kg/ha respectively. Basic plant nutrition and plant protection treatments were identical and appropriate regarding the agronomic requirements of the experimental field and providing ceteris paribus conditions to the trial.

Phenological, herbological, phytosanitary observations and yield characteristics have been evaluated. Yield samples were analysed for quality features (protein, carbohydrate, starch, cellulose, fat, ash etc). Carbon sequestration values were estimated on the basis of grain yield and total above ground biomass dry matter production. The paper presents three years average data of the experiment

Results and discussion

The results obtained suggest that crop variety and plant nutrition proved to be the most powerful factors influencing organic matter production. Interactions have been found between crop plant genotypes and N levels applied. Table 1 comprises values of grain yield, plant dry matter and C content of above ground biomass.

Table 1. Carbon sequestration of winter wheat (*Triticum aestivum* L.) varieties, kg/m^2, Nagygombos 2007-2010

0 N variety	Grain yield kg/m^2	Plant dry matter kg/m^2	AG biomass C content estimate, kg
Mv Magdaléna	0.54	0.59	0.45
Alföld 90	0.68	0.75	0.55
Mv Suba	0.76	0.83	0.62
Mv Csárdás	0.69	0.76	0.58
Mv Toborzó	0.70	0.75	0.58

80 N variety	Grain yield, kg/m^2	Plant dry matter, kg/m^2	AG biomass C content estimate, kg
Mv Magdaléna	0.74	0.85	0.64
Alföld 90	0.71	0.77	0.59
Mv Suba	0.80	0.89	0.68
Mv Csárdás	0.81	0.88	0.65
Mv Toborzó	0.84	0.91	0.69

120 N variety	Grain yield, kg/m^2	Plant dry matter, kg/m^2	AG biomass C content estimate, kg
Mv Magdaléna	0.78	0.85	0.65
Alföld 90	0.84	0.84	0.67
Mv Suba	0.75	0.82	0.63
Mv Csárdás	0.79	0.75	0.62
Mv Toborzó	0.80	0.86	0.66

C value $LSD_{0.05}$ Variety 0.092
Nitrogen 0.067

The photosynthetic activities of plants determine soil organic matter (SOM). The organic matter manufactured by plants is originated from atmospheric CO_2. All plants, like winter wheat in this study capture C and produce vegetative material, a biomass that comprises yield and by products. Figure 1 provides information on the magnitude of carbon sequestration in relation with the ascending N supply applied. Since there were no major differences between crop years, three years average results were processed in this study. Wheat varieties regardless to the yield differences of the crops produced almost identical amount of C within the above ground biomass.

Wheat straw had a higher C content in higher N applications, and as a result of that expected SOM has shown differences. The results suggest, that wheat by-products may provide a considerable source of soil organic matter within a range of 0,17 to 0,20 kg/m^2.

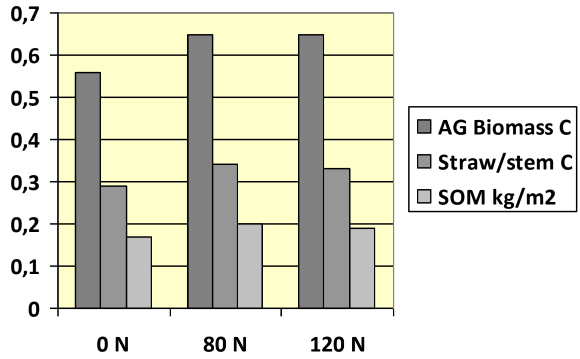

Figure 1. Average carbon content of above ground biomass, straw/stem residues, and the possibly derived soil organic matter by N application levels, kg/m^2

Conclusions

Wheat varieties and plant nutrition proved to be powerful factors influencing organic matter production. Interactions have been found between crop plant genotypes and N levels applied. Atmospheric C budget can be balanced by photosynthetic dry matter production of natural vegetation and agricultural crops. The latter can be influenced by agronomic applications. Soil organic matter is based on the sequestration of C derived from plant residues. Wheat straw by-products represent a considerable source for soil organic carbon.

Acknowledgement

The authors are indebted regarding the financial support of VKSZ, TÁMOP and KTIA funds of the Government of Hungary.

References

Birkás M., Pósa B. and Sallai A. 2012. Conditions of sustainable soil quality vs. energetic use of field-land by-products. Hungarian Agricultural Engineering. 24. 9-12.

Brady, N. C. 1984. The Nature and Properties of Soils. New York. MacMillan Publ.

Brussaard L. 2012. Ecosystem services provided by the soil biota. In: Soil ecology and ecosystem services. Eds: Wall D.H. et al. Oxford University Press. 45-58.

Edwards, J.H., Wood, C.H., Thurlow, D.I.and Ruf M.E. 1999. Tillage and crop rotation effects on fertility status of a Hapludalf soil. Soil Sci. Soc. Am. J. 56. 1577-1582.

Jolánkai M., Kassai K., Nyárai H.F., Tarnawa Á., Balla I. and Szentpétery Zs. 2013. Carbon sequestration of grain crop species influenced by nitrogen fertilization. Hungarian Agricultural Engineering. 24. 23-26 pp.

Jolánkai M., Máté A. and Nyárai H.F. 2005. The carbon cycle: a sink-source role of crop plants. Cereal Research Communications. 33(1): 13-17.

Juma, N. G. 1999. Introduction to Soil Science and Soil Resources, Volume 1 of the Series “The Pedosphere and Its Dynamics: A Systems Approach to Soil Science”. Salman Productions Inc.

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. Geoderma. 123: 1-22.

Lawlor D.W. 2002. Carbon and nitrogen assimilation in relation to yield: mechanisms are the key to understanding production systems. Journal of Experimental Botany 53: 773-787.

Mesic M., Birkas M., Zgorelec Z., Kisic I., Sestak I., Jurisic A. and Husnjak S. 2014. Soil carbon variability in some Hungarian and Croatian soils. In: Soil carbon. Hartemink A. – McSweeney K /Eds/. Dordrecht, Springer. 419-426.

Pepó P. 2010. Adaptive capacity of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) crop models to ecological conditions. Növénytermelés. 59. Suppl. 325-328.