CARBON BALANCE IN ENVIRONMENTALLY-FRIENDLY TECHNOLOGIES

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Abstact: *The field experiment was carried out over the period 1999-2004 on Luvi-Haplic Chernozem in Borovce, Western Slovakia (E 17º75', N 48º58'). The location has a continental climate with an average annual temperature of 9.2 ºC and an average annual precipitation of 593 mm. A split-plot design experiment with four replicates of a six-course crop rotation was designed as follows: common pea – winter wheat and catch crops – early potato and catch crops – spring barley undersown with red clover – first year red clover – winter wheat and catch crops. The aim of the study was to calculate the input and output of carbon sources and the influence of the crop management rotation on the annual carbon balance in low-input and ecological farming system. Positive balance of carboneum in range of 2.442 ton C ha^{-1} in organic system and 2.66 C ha^{-1} in low input system was noted. Yearly balance was strongly influence by growing crops and their residue management. In organic system, the full balance (B_C) of organic matter expressed as carboneum balance was negative under growing of common peas (-0.909 ton C ha^{-1}) with surplus of 6.642 ton C ha^{-1} during growing the potatoes. Lack of residues in potatoes (Q_R = 1.201 ton C ha^{-1}) was compensating with FYM application with finally positive effect on yearly carboneum balance. Evaluation of crop rotation pattern productivity was expressed as production of dry matter. The winter wheat produced significantly the higher yield of dry matter from 12.74 to 14.4 followed by red clover (11.3-13.65 ton C ha^{-1}) and spring barley (9.08-9.79 ton C ha^{-1}).Designed crop rotation pattern growing in organic and low input system confirm sustainable use of natural resources.*

Key words: *crop rotation, organic matter, carboneum balance, organic system, low-input system*

INTRODUCTION

Organic matter balance in soils is one of the important indicators of sustainability of the agricultural systems on the whole country level and the regional and farm level, as well. The quantity of soil carbon present is controlled by a complex interaction of processes determined by carbon inputs and decomposition rates. Sequestration of carbon from plant biomass into organic matter is a key sequestration pathway in agriculture. The net change in SOC depends not only on the C loss as CO_2 emission but also on the C input by residue and manure (CVIJANOVIĆ ET AL, 2007). The annual organic matter turnover in arable soils is roughly estimated to amount 3.5 to 4.5t ha in the Czech Republic. Input of organic matter in crop residues is estimated to 2.0 to 2.5t ha organic matter annually (DOSTÁL, 2002). The similar situation is in Slovakia and soil carbon sequestration is influenced not only by tillage but also via suitable residues management (MACÁK ET AL., 2010). Development of environmentally sound production systems on arable land is great challenge of agricultural research and involves many partial targets (VALTÝNIOVÁ AND KŘEN, 2008 PORHAJAŠOVÁ ET AL., 2009; ONDRIŠÍK ET AL., 2009; TÝR ET AL., 2009; LACKO BARTOŠOVÁ, 2010; MOLNÁROVÁ, 2010). While the balance principle was suitable in mineral plant nutrition and it has been used in practical agriculture till the present time, its application in the soil organic matter (SOM) dynamics has been much more complicated and much less suitable. The SOM and plant and animal residues and products, so called primary organic matter (POM), are of many different kinds, they have rather different tissue and chemical structure and they are more or less stabilised due to their interactions with mineral soil particles (KUBÁT AND LIPAVSKÝ, 2006).

The aim of the study was to calculate the input and output of carbon sources and the influence of the crop management rotation on the annual carbon balance in low-input and ecological farming system.

MATERIAL AND METHODS

The field experiment was carried out over the period 1999-2004 on Luvi-Haplic Chernozem in Borovce, Western Slovakia (E 17º75', N 48º58'). The location has a continental climate with an average annual temperature of 9.2 ºC and an average annual precipitation of 593 mm. A split-plot design experiment with four replicates of a six-course crop rotation was designed as follows: common pea – winter wheat and catch crops – early potato and catch crops – spring barley undersown with red clover – first year red clover – winter wheat and catch crops. Experimental details of plant culture and weather conditions are shown in table 1.

Table 1

Soil-climatic characteristics of the site Borovce, Slovakia

Parameter		Value
Altitude		167 m
Growing region		maize-barley
Average daily air temperature	for year	9.2°C
	for vegetation period (IV-IX)	15.5°C
Average sum of precipitation	for year	593 mm
	for vegetation period (IV-IX)	358 mm
Soil class		medium-heavy
Soil type		Luvi haplic chernozem
pH/KCl		5.5 – 7.2
Content of available	P (Egner)	187 – 234 mg kg^{-1} (average)
	K (Schachtschabel)	173 – 219 mg kg^{-1} (good)
	Mg (Mehlich II)	255 – 307 mg kg^{-1} (high)
	Humus (Tyurin)	1.8 – 2.0 %

In organic system, the cultural practices were performed in accordance with the IFOAM rules. Well composted farmyard manure (FYM) was applied under potato (30 t ha^{-1}) and winter wheat (15 t ha^{-1}). Top-dressing of 50 L ha^{-1} Vermisol was applied on common peas on fertilized treatments since 2003. Straw and crops residues were ploughed in by tillage and catch crops phacelia and mustard were sown.

The low input system uses the same production practices as organic farming but allows limited use of pesticides and mineral fertilizers inputs. Well composted farmyard manure (FYM) was applied only under potato (30 t ha^{-1}). The dose of 30 + 30 N kg ha^{-1} for winter wheat, 30 kg ha^{-1} for spring barley and 20 kg ha^{-1} for common peas; and P, K mineral fertilizers calculated according to input output balance were applied (BUJNOVSKÝ AND LOŽEK, 1996). On winter wheat, spring barley, and common peas, a top-dressing of 50 L ha^{-1} Vermisol was applied since 2003 on fertilized treatments. Straw and crops residues were ploughed in by tillage and catch crops phacelia and mustard were sown. When winter wheat on particular stands was matured, plant samples from an area of 0.5 m^2 were uprooted and used for analysis from each subplot replication. After, the rests of total subplot area from each replication were harvested for grain and straw yield. The carbon balance was calculated according JURČOVÁ AND BIELEK (1997) modified by BIELEK AND JURČOVÁ (2010) by calculation formulas as follows:

Input from roots and aboveground biomass residues $Q_R = u \times K_C$;

Input from organic manure $Q_H = D_H$ x C_H; total inputs $QZ = Q_R + Q_H$
Total loses of carboneum $Qs = C_m$ x K_m
Full balance equation of carboneum in ton C ha^{-1} $year^{-1}$ as follows: B_C= ([u x K_C] +[D_H x C_H]) – (C_m x K_m)
x – multiplication; u – yield of crop main product; KC – coefficient of residues related to the yield of grain or main product; D_H – dose of organic manure in calculated year; C_H – calculation coefficient from organic manure to dose of carboneum in ton; C_m – main lost of soil carbon via mineralization in three soil categories, K_m – coefficient modified the carboneum lost related to growing crops. The data were statistically evaluated by analysis of variance using the Statg. plus version 5.0 and the Fisher's protected LSD test.

RESULTS AND DISCUSSIONS

A characteristic of different weather conditions is described in table 2.

Table 2

Precipitation, temperature and long term means, Borovce, Slovakia, 1999 – 2004

Month	n30 (1971 – 2000)	1999	2000	2001	2002	2003	2004
Precipitation (mm)							
IV-IX	326.0	354.0(N)	217.5(D)	348.1(N)	347.3(N)	210.1(D)	202.1(D)
X-III	218.9	175.3(N)	307.0(VV)	184.3(N)	280.4(V)	174.2(N)	268.6(V)
I-XII	544.9	529.3(N)	524.5(N)	532.4(N)	627.7(V)	384.3(VD)	470.(D)
temperature (°C)							
IV-IX	15.6	17.44(VT)	16.31(N)	14.96(N)	18.39(MT)	18.58(MT)	16.57(N)
X-III	2.5	2.47(N)	3.52(T)	1.51(T)	3.54(T)	3.00(N)	3.50(T)
I-XII	9.1	9.95(T)	9.92(T)	8.24(T)	10.96(MT)	10.79(MT)	10.04(T)

N – normal; D– dry; - V – wet; VV - very wet; VD – very dry; N – normal; T – warm; VT - very warm; MT – extraordinarily warm

Management of organic mater in form of FYM application and incorporation of post harvest residues is the crucial for sustainability of agroecosystem. The positive balance of organic mater in organic and low input system was ascertained. Low input system has significantly more positive balance (8.9%, B_C) of organic matter and significantly higher yield of dry matter (9.4%) with comparison to organic system (Table 3). Better results of low input were supported by significantly higher input of organic matter with average input of 5.42 ton C ha^{-1} per year with comparison to 5.21 ton C ha^{-1}in organic system. The balance of organic matter is strongly dependent on residue management and suitable crop rotation pattern. The crop rotation has significant influence on soil organic matter, residue amount and composition (LACKO BARTOŠOVÁ, 2006; MARTIN-RUEDA ET AL., 2007; TOBIÁŠOVÁ, 2010). Yearly balance was strongly influence by growing crops and their residue management. In organic system, the full balance (B_C) of organic matter expressed as carboneum balance was negative under growing of common peas (-0.909 ton C ha^{-1}) with surplus of 6.642 ton C ha^{-1} during growing the potatoes. Lack of residues in potatoes (Q_R = 1.201 ton C ha^{-1}) was compensating with FYM application with finally positive effect on yearly carboneum balance. The same pictures was in low input system with negative balance of common peas (-0.594 ton C ha^{-1}) to 6.856 ton C ha^{-1} during growing the potatoes. The positive balance of carboneum B_C in particular growing system during potatoes phase of rotation was significantly higher, with comparison to other evaluated crops. The same results were reached in phase of winter wheat with significantly higher carboneum balance with comparison to common peas, red clover and spring barley.

Table 3

Yield of dry matter and balance carboneum items (ton C ha^{-1}) growing in organic and low-input system during 1999-2004

Crops	Q_S - total loses	Q_R - residues	Q_Z – total input	B_C – full balance	Yield of dry matter
	Organic system				
Common peas	2.81	1.901	1.901	-0.909	3.56
Winter wheat + FYM	2.81	4.377	7.606	4.796	13.44
Potatoes + FYM	3.09	1.201	9.732	6.642	6.60
Spring barley	2.81	2.760	2.760	-0.050	9.08
Red clever	2.25	1.668	1.668	-0.582	11.30
Winter wheat + FYM	2.81	4.218	7.566	4.756	12.74
Average for system	***2.763***	***2.688***	***5.206***	***2.442***	***9.45***
	Low-input system				
Common peas	2,81	2.216	2.216	-0.594	4.48
Winter wheat + FYM	2,81	4.659	7.956	5.146	14.40
Potatoes + FYM	3,09	1.361	9.946	6.856	7.60
Spring barley	2,81	2.892	2.892	0.082	9.79
Red clever	2,25	1.675	1.675	-0.575	12.14
Winter wheat + FYM	2,81	4.440	7.850	5.040	13.65
Average for system	***2,763***	***2.874***	***5.423***	***2.660***	***10.34***
$LSD_{0.01}$ system		0.05	0.10	0.10	0.25
Significance		++	++	++	++
$LSD_{0.01}$ crops		0.10	0.17	0.18	0.43
Significance		++	++	++	++

Forecrop has no significant influence on carboneum balance of winter wheat. Calculated balance of winter wheat after common peas was 7.606 ton C ha^{-1} and after red clover 7.566 ton C ha^{-1} in organic system or 7.959 ton C ha^{-1} and 7.850 ton C ha^{-1}in low input system, respectively. Positive balance of carboneum in range of 2.442 ton C ha^{-1} in organic system and 2.66 C ha^{-1} in low input system was calculated. Evaluation of crop rotation pattern productivity was expressed as production of dry matter. The winter wheat produced significantly the higher yield of dry matter from 12.74 to 14.4 followed by red clover (11.3-13.65 ton C ha^{-1}) and spring barley (9.08-9.79 ton C ha^{-1}) stage.

CONCLUSIONS

Management of organic mater is the crucial for sustainability of agroecosystem. For designing of sustainable agricultural systems suitable crop rotation pattern is needed. Quantification of the carbon balance of particular crops and their management help to clarify some approaches to sustainable crop rotation. Low input system has significantly more positive balance (8.9%, B_C) of organic matter and significantly higher yield of dry matter (9.4%) with comparison to organic system. Yearly balance was strongly influence by growing crops and their residue management. Positive balance of carboneum in range of 2.442 ton C ha^{-1} in organic system and 2.66 C ha^{-1} in low input system was confirmed. The winter wheat produced significantly the higher yield of dry matter from 12.74 to 14.4 followed by red clover (11.3-13.65 ton C ha^{-1}) and spring barley (9.08-9.79 ton C ha^{-1}). For carboneum balance, the common peas and red clover have comparable forecrop values for winter wheat.

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