POST HARVEST COVER CROP TECHNOLOGIES UNDER REDUCED TILLAGE CONDITIONS

Satkus Antanas, Velykis Aleksandras
Lithuanian Research Centre for Agriculture and Forestry
antanas.satkus@gmail.com

Abstract. Comparative investigation of ploughless tillage, ploughless tillage with cover crop for green manure and cover crop for winter mulch without autumn tillage was carried out in 2007-2010 at the Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry. The soil of the experimental site was clay loam. The cover crop (mixture of white mustard and oilseed radish) was sown after spring barley harvesting and stubble cultivation. Ploughless tillage and cover crop incorporation for green manure were performed by a combined stubble cultivator at 10-12 cm depth in the autumn. The cover crop for winter mulch was left without any tillage in the autumn. The field pea was sown in the following spring. The biomass yield of the cover crop was highly dependent on the year weather conditions during the autumn. Due to the application of the cover crop for winter mulch without any autumn tillage the field pea grain yield was reduced significantly compared to ploughless tillage. Post harvest cultivation of the cover crop and shallow incorporation of its biomass for green manure or leaving for mulch during winter reduced the migration of accumulated mineral nitrogen from topsoil into subsoil.

Keywords: clay loam *Cambisol*, ploughless tillage, cover crop, green manure, mulch, mineral nitrogen, field pea yield, energy costs.

Introduction

One of the most important means of land use is an appropriate tillage system. If conventional ploughing is applied as the main tillage method, a lot of energy and time costs are required. Searching of the possibilities to reduce tillage is conditioned by several factors: the necessity of retaining organic materials in soil, new environmental requirements, increasing costliness of energy sources, etc. [1; 2]. Having performed investigations in different countries it was established that the efficiency of reduced primary tillage depended on the soil and climatic conditions, type of crops cultivated and other factors [1; 3-5].

While reducing the intensity and depth of tillage, biological means become very important in reducing soil degradation. Cover crops can loosen an untilled layer of soil biologically by their strong roots [6-8]. A long lasting period between harvesting of the main crops and sowing of spring crops, when a field is left without plants, determines a possibility of soil physical, chemical and biological degradation. In terms of environmental protection an important function of cover crops is to assimilate mineral nitrogen that was left in soil unused by the main crops and to protect it from leaching and waters – from pollution as well as to retain an important nutrition element for plants. Expanding the diversification of crops, speeding up the deterioration of their residues and improving their phytosanitary condition is also a very important purpose of the plants cultivated as cover crops [3; 9-16]. In order to improve the environmental condition and reduce soil degradation after the cultivation of cover crops left over winter the so called mulch sowing is becoming more popular. It allows further simplification of tillage, extending the improving biological impact of cover crops and the protection of soil against negative environmental factors [6; 2; 15].

The research objective is to establish the influence of the technological combinations of ploughless tillage with the cultivation of cover crops after the main crop harvesting on the accumulation of mineral nitrogen in soil, the variation of field pea productivity, the need of energy costs and the maintenance of productive and safe biocenosis.

Materials and methods

Soil. The field experiments were carried out in 2007-2010 at the Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in clay loam on silty clay *Endocalcari Endohypogleyic Cambisol*. The clay particles <0.002 mm in Aa horizon (0-30 cm) accounted for 27.0 %, and in B_1 horizon (52-76 cm) – 51.6 %. The topsoil agrochemical characteristic was: pH_{KCl} – 6.4, mobile P_2O_5 and K_2O – 118-120 and 240-265 $mg \cdot kg^{-1}$ of soil respectively, humus – 2.1-2.2 %.

Experimental design and practices. Tillage methods and their combinations with cover crops were analysed: 1) ploughless tillage at 10-12 cm depth; 2) ploughless tillage at 10-12 cm depth with cover crop biomass incorporating as green manure in the autumn; 3) cover crop leaving over the winter as mulch without tillage in the autumn. The experiments were carried out in the following crop rotation: field pea→ winter wheat→ spring oilseed rape→ spring barley. The research treatments were randomized with four replications. The size of the record plots was 13 x 2.3 = 29.9 m^2. After spring barley harvesting white mustard cv. *Braco* (10 $kg \cdot ha^{-1}$ of seeds) and oilseed radish cv. *Rufus* (13 $kg \cdot ha^{-1}$ of seeds) mixture was cultivated as a cover crop. It was sown by the *Amazone D7* drilling machine right after spring barley harvesting and stubble cultivation. The straw of spring barley was chopped during harvesting and incorporated into the soil during stubble cultivation by a combined stubble cultivator SL-2.5 at 6-8 cm depth. Ploughless tillage (treatment 1) was carried out by the same combined cultivator. The cover crop for green manure was chopped late in the autumn and incorporated into the soil by the combined cultivator SL-2.5 (treatment 2). The cover crop plants (treatment 3) were left over the winter for mulch without autumn tillage. They got frozen by spring and their residues covered the soil surface. After the application of the analysed means field pea cv. *Tinker* was grown having sown at a rate of 1.2 million of fertile seeds per ha by the *Amazone D7* drilling machine.

Experimental methods and assessments. The soil samples to establish the amount of mineral nitrogen were taken early in spring. The amount of mineral nitrogen was established by the following methods: $N\text{-}NO_3$ – ionometric; $N\text{-}NH_4$ – spectrophotometric. The yield of field pea grain was calculated at a standard 15 % moisture rate. The results were processed by the variance analysis using the software *ANOVA*.

Results and discussion

White mustard dominated in the cover crop of white mustard and oilseed radish mixture cultivated after spring barley. White mustard accounted for 78.7-78.8 % of the total number of plants in the crop and 69.8-69.9 % of the dry mater yield of the cover crop biomass (Table 1). The total biomass yield of the cover crop depended substantially on the climatic conditions of certain years and ranged from 0.19 $t \cdot ha^{-1}$ in an unfavourable year to 3.7 $t \cdot ha^{-1}$ in a favourable year (data not shown). That implies that under the conditions of northern Lithuania, if the mixture of white mustard and oilseed radish is cultivated after spring barley harvest as a cover crop, there is no possibility to achieve high biomass yields of it on the regular basis.

Table 1

Structure and productivity of cover crop
Average 2006-2009

Technology	Crop dominants	Plant count per m^2	Dry matter % in biomass	Biomass yield dry matter $Mg \cdot ha^{-1}$
Ploughless tillage with cover crop for green manure	white mustard	130	11.4	0.88
	oil radish	35	9.7	0.38
	total crop	165	–	1.26
Cover crop for mulch without tillage	white mustard	143	10.8	0.86
	oil radish	39	9.1	0.37
	total crop	182	–	1.23

The mineral nitrogen concentration established in spring before sowing of field pea in the topsoil layer (0-30 cm) did not depend substantially on ploughless tillage and its combinations with cover crops (Table 2). The application of ploughless tillage with the incorporation of cover crop as green manure and leaving the cover crop as mulch over the winter without autumn tillage resulted in a significant decrease of mineral nitrogen concentration in the subsoil layer (31-60 cm) by 25.1 and 25.0 % respectively compared to ploughless tillage without cover crop. These results indicate that the cover crops fixed the residual nitrogen from the soil after the main crop cultivation within its biomass and prevented it from migration from the topsoil to the subsoil layer.

The use of residual nitrogen to grow the cover crop biomass during the post harvest period and the reduction of mineral nitrogen migration into deeper layers of soil during the intensive leaching regime period (in late autumn and in early spring) is important in terms of environmental protection. With the decomposition of cover crop biomass nitrogen is returned into soil. That ensures the uniformity nitrogen metabolism [5; 7; 9; 12; 16].

Table 2

Accumulation of mineral nitrogen in the soil
Average 2007-2010

Technology	Depth of soil layers cm	Mineral nitrogen	
		$mg \cdot kg^{-1}$ of soil	relative figures
Ploughless tillage	0-30	7.26	100
Ploughless tillage with cover crop for green manure		6.49	89.4
Cover crop for mulch without tillage		7.31	100.7
LSD_{05}	–	1.765	–
Ploughless tillage	31-60	7.44	100
Ploughless tillage with cover crop for green manure		5.57	74.9
Cover crop for mulch without tillage		5.58	75.0
LSD_{05}	–	1.420	–
Ploughless tillage	0-60	7.35	100
Ploughless tillage with cover crop for green manure		6.03	82.0
Cover crop for mulch without tillage		6.45	87.8
LSD_{05}	–	0.870	–

Our research showed that the field pea cultivated after the cover crop was sensitive to the reduction of tillage intensity. Having left the cover crop over winter for mulch without any tillage in the autumn resulted in a field pea grain yield which was significantly lower by 24.1 % compared to ploughless tillage without cover crop (Table 3). The incorporation of the cover crop biomass as green manure had no significant influence on the field pea yield when ploughless tillage had been applied. The application of catch crop as green manure is less relevant for field pea as leguminous plant.

The impact of cover crops, used as green manure, on nitrogen management has gained the most attention, because nitrogen is the most limiting nutrient in production of the crops grown. The application of green manure allows more uniform provision of crops with nitrogen [10; 16]. However, field pea requires a limited amount of nitrogen but it is sensitive to reduced tillage. Baigys at al. [9] indicated that field pea yield under the conventional ploughing amounted to 3.38 $t \cdot ha^{-1}$ and was by 34.7 % higher compared to shallow ploughing, and by 11.9 % higher compared to direct drilling. Therefore, the use of cover crop plants as mulch and leaving it over winter without any tillage in the autumn should be applied to the crops less sensitive to reduced tillage.

Table 3

Field pea grain yield
Average 2007-2010

Technology	Grain yield $Mg \cdot ha^{-1}$	Relative figures
Ploughless tillage	2.90	100
Ploughless tillage with cover crop for green manure	2.63	90.7
Cover crop for mulch without tillage	2.20	75.9
LSD_{05}	0.386	–

The application of the combination of ploughless tillage and cover crop as green manure results in a diesel fuel cost increase by 32.7 % and leaving of the cover crop as mulch over the winter without autumn tillage demonstrates a 67.3 % decrease compared to ploughless tillage (Table 4). Leaving of the cover crop over the winter saves 17.4 % of the total energy costs, however, the technology of cultivating and incorporating the cover crop as green manure requires 82.6 % more of these energy costs compared to ploughless tillage without cultivating cover crops.

Table 4

Energy evaluation of post harvest cover crop technologies

Technology and composition of implements	Labour efficiency $ha \cdot h^{-1}$	Diesel fuell costs $l \cdot ha^{-1}$	Energy costs $MJ \cdot ha^{-1}$				Efficiency coefficient	Indicator of cost economy %
			direct	in-direct	human work	total		
*Ploughless tillage with MTZ-1025 + SL-2.5 at 12 cm depth	0.87	10.7	850.7	121.9	49.9	1022.5	1.0	–
**Ploughless tillage with MTZ-1025 + SL-2.5 at 12 cm depth	0.87	10.7	850.7	121.9	49.9	1022.5	1.0	–
and cover crop sowing with MTZ-952 + Amazone D7	2.8	3.5	753.3	75.5	15.5	844.3	0.826	17.4
Total:	3.24	13.0	1604.0	197.4	65.4	1866.8	1.826	-82.6
***Cover crop sowing with MTZ-952 + Amazone D7	2.8	3.5	753.3	75.5	15.5	844.3	0.826	17.4

Technologies: * – ploughless tillage; ** – ploughless tillage with cover crop for green manure; *** – cover crop for mulch without tillage.

Conclusions

1. The cultivation of the white mustard and oilseed radish mixture as a cover crop during the post harvest period and shallow (10-12 cm) incorporation of its biomass as green manure or leaving it for mulch during winter reduced the migration of accumulated mineral nitrogen from topsoil into deeper soil layers compared to ploughless tillage without a cover crop.
2. The cover crop incorporation as green manure during ploughless tillage did not determine the field pea yield significantly. Leaving of the cover crop as mulch during winter without any autumn tillage reduced the field pea yield significantly compared to ploughless tillage without a cover crop.
3. The cultivation of field pea after spring barley and the incorporation of the biomass of the post harvest white mustard and oilseed radish mixture as a cover crop during ploughless tillage is an effective environmental means reducing the possibility of nitrogen leaching apart from the increased energy costs. The application of the cover crop as mulch during the winter without autumn tillage is important in terms of environmental protection and saves energy costs for tillage, however reduces the field pea yield significantly.

References

1. Morris N. L., Miller P. C. H., Orson J. H., Froud-Williams R. J. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment – A review. Soil and Tillage Research, vol. 108, 2010, pp. 1-15.

2. Soane B. D., Ball B. C., Arvidsson J., etc. No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment. Soil and Tillage Research, vol. 118, 2012, pp. 66-87.
3. Abdollahi L., Munkholm L. J. Tillage system and cover crop effects on soil quality: I. Chemical, mechanical, and biological properties. Soil Science Society of America Journal, vol.78, No.1, 2014, pp. 262-270.
4. Feiza V., Feizienė D., Auškalnis A., Kadžienė G. Sustainable tillage: results from long-term field experiments on Cambisol. Žemdirbystė=Agriculture, vol. 98, No. 2, 2006, pp. 3-14.
5. Sainju U. M., Singh B. P., Whitehead W. F. Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil and Tillage Research, vol. 63, 2002, pp. 167-179.
6. Dabney S. M., Delgado J. A., Rieves D. W. Using winter cover crops to improve soil and water quality. Communication in Soil Science and Plant Analysis, vol. 32, 2001, pp. 1221-1250.
7. Munkholm L. J., Hansen E. M. Catch crop biomass production, nitrogen uptake and root development under different tillage systems. Soil Use and Management, vol. 28, No. 4, 2012, pp. 517-529.
8. Snapp S. S., Swinton S. M., Labarta R. etc. Evaluating cover crops for benefits, costs and performance within cropping system niches. Agronomy Journal, vol. 97, No. 1, 2005, pp. 322-332.
9. Baigys G., Gaigalis K., Kutra G. The influence of reduced tillage on water regime and nutrient leaching in a loamy soil. Zemdirbyste-Agriculture, vol. 93, No. 4, 2006, pp. 130-115.
10. Cherr C. M., Scholberg J. M. S., McSorley R. Green manure approaches to crop production: A synthesis. Agronomy Journal, vol. 98, 2006, pp. 302-319.
11. Fageria N. K., Baligar V. C., Bailey B. A. Role of cover crops in improving soil and row crop productivity. Communications in Soil Science and Plant Analysis, vol. 36, iss. 19-20, 2005, pp. 2733-2757.
12. Gabriel J. L., Garrido A., Quemada M. Cover crops effect on farm benefits and nitrate leaching: Linking economic and environmental analysis. Agricultural Systems, vol. 121, 2013, pp. 23-32.
13. Macdonald A. J., Poulton P. R., Howe M. T. etc. The use of cover crops in cereal-based cropping systems to control nitrate leaching in SE England. Plant and Soil, vol. 273, No. 1-2, 2005, pp. 355-373.
14. Prochazka J., Malek J., Prochazkova B., Hartman I. Catch crops and the soil environment. Soil: Agriculture, Environment, Landscape. Brno, 2005, pp. 33-37.
15. Schafer W., Vaisanen J., Pihala M. Technique of green mulch spreading. Vihti, 2001. 65 p.
16. Thorup-Kristensen K., Magid J., Jensen L. S. Catch crops and green manures as biological tools in nitrogen management in temperate zones. Advances in Agronomy, vol. 79, 2003, pp. 227-302.