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The integrated evaluation of the influence of catch crops and manure on spring barley agrocenosis in organic farming

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Abstract. Details of the field experiments which were carried out in the Kazliskiai organic farm from 1999–2001 were needed for our investigations. The integrated evaluation method enabled us to make complex evaluation of the influence of catch crops (red clover, common ryegrass, white mustard and winter rape) for green manure and animal manure on spring barley agrocenosis in organic farming. The variances of the 11 indicators were subdivided into scales of 9 points. The resulting evaluation points were marked in a network diagram. The evaluation threshold, which is equal to 5 points, was also marked. The integrated evaluation index, consisting of the average of evaluation points, its standard deviation and standard deviation of the average of evaluation points which are below the evaluation threshold, was calculated. The influence of red clover for green manure on barley agrocenosis, according to the calculated integrated evaluation indices, is stronger than that of other catch crops and manure.

Key words: catch crops, manure, barley, integrated evaluation method

INTRODUCTION

Organic farming is currently of great interest in Lithuania. The main reason is the striving to conserve Lithuanian farming traditions, to grow agricultural produce without synthetic fertilizers and pesticides, to conserve the environment, to reduce production costs and to sell more produce to foreign markets. A total number of 2,858 organic and transition period farms, with total area 125,457 were certified in Lithuania in 2007.

Organic farming is based on complete exploitation of the natural resources of agrocenosis and stabilization of a closed cycle of chemical elements. In many countries of Western Europe this problem is solved by using crop rotations with catch crops – undersowing and postharvest (spring and winter). Catch crop is a crop that grows quickly and can be planted between two regular crops grown in successive seasons or between two rows of crops in the same season. Catch crops perform optimal uptake of the nutrients existing in the soil, solar energy and precipitation, while the incorporated aboveground and underground mass of these plants enrich the soil with organic matter (Hampl, 1996). Indicators determining the influence of catch crops and manure on spring barley agrocenosis are usually analysed separately, and not integrated into a complex system of evaluation. Owing to that, it is difficult to estimate the influence of catch crops and manure on spring barley agrocenosis when there are many interacting

indicators, and to decide which of them are more and which less important. A method of integrated evaluation has been designed to overcome this problem.

Other methods of complex evaluation are also being developed, one, a method of multiple analyses. Evaluation results are presented using ordinate diagrams (Kent & Coker, 1992; Leps & Smilauer, 1999). The integrated evaluation method is quite simple, and does not require complicated computer programs. Until now this method has been mainly used in other research fields, but not in plant science. Thus the aim of our work was to investigate the possibility of using the integrated evaluation method for estimation of the influence of catch crops and animal manure on spring barley agrocenosis.

MATERIALS AND METHODS

Details of the field experiments, which were carried out in the Kazliskiai organic farm (Kaunas distr.) (54º53´N, 23º50´E) from 1999–2001 were needed for the investigations. According to soil classification of the year 1999 (LTDK–99) the soil of the experiment site was deeper gleyic saturated planosoil (*Endohypogleyic–Eutric Planosoil*), medium loam on light sandy loam.

The soil's chemical characteristics were: pH 6.6–7.1, 2.16–2.60% humus, 126–162 mg kg^{-1} available potassium, 166–227 mg kg^{-1} available phosphorus.

Treatments of the experiment are presented in Fig. 1. Catch crop species for green manure were sown into winter wheat (*Triticum aestivum* L.) 'Zentos' or after their harvesting (factor B). Red clover (*Trifolium pretense* L.) 'Liepsna' (8 kg ha^{-1}) and Italian ryegrass (*Lolium multiflorum* Lam.) 'Rapid' (14 kg ha^{-1}) were undersown into wheat in early spring. White mustard (*Sinapis alba* L.) 'Karla' (35 kg ha^{-1}) and winter rape (*Brassica napus* L.) (in 1999 – 'Accord', in 2000 – 'Valesca' 20 kg ha^{-1}) after wheat harvesting were direct drilled into stubble. After wheat harvesting in the plots without a catch crop the stubble was no-tilled until the main soil tillage. The plots planned for fertilization with animal manure after wheat harvesting were shallowly ploughed at the depth of 10–12 cm. Catch crops for green manure and animal manure (40 Mg ha^{-1}) were incorporated by soil tillage in autumn or in spring (factor A). In one area catch crops for green manure and animal manure were deeply ploughed (at the depth of 23–25 cm) in late autumn. In the other section they were left not incorporated during winter until the following spring. In the spring of 2000 and 2001 catch crops for green manure were shallowly ploughed at the depth of 10–12 cm.

Barley (*Hordeum vulgare* L.) 'Ūla' (180 kg ha^{-1}) was grown every year. Barley was sown with 'Saxonia' anchor ploughshares.

The experiments were carried out in three replicates, split-plot design. The size of the sampling plot was 52.9 m^2. Content of available phosphorus and available potassium was determined by A–L method, pH_{KCl} by potentiometric method, content of humus by Tiurin method. Barley was harvested by combine and the yield determined by the weight method. Weed infestation in barley was evaluated in the stage of intensive germination of weeds (in May) and at the barley milky ripeness stage. In spring the number of weed sprouts was calculated, while at the barley milky ripeness stage – the number of weeds m^{-2} and the dry matter mass g m^{-2}. The projective cover of the aboveground part of weeds was visually evaluated in late autumn by using

a 1 m^2 frame, divided into 16 squares (0.06 m^2). The activity of soil urease was determined in dry samples according to Hofmann and Schmidt (1953), that of saccharase – according to Hofmann and Seegerer (1950) methods, modified by Ciunderova (1973). Energetical evaluation of catch crops for green manure and manure incorporation was performed on the basis of the standards published by the Service of Economics and Teaching Methodics, Lithuanian Ministry of Agriculture (2001a; 2001b) and energy equivalents, presented by Jankauskas et al. (2000). The degree of energy efficiency, expressed by energy transformation or energetical coefficient, was calculated following the methodics, presented by Aleksynas (1990).

The integrated evaluation method is described in the publications of Lohmann (1994) and Heyland (1998), and shows variances of the individual indicators and their interactions and makes it possible to achieve comprehensive evaluation of investigation results. In this method of integrated evaluation, the following investigations and calculations should be carried out: 1) Determine values of various indicators; 2) Calculate evaluation points (EP) of various indicators, expressed in different units of measurement, with the aim to integrate the data into a unified scale. Evaluation point 1 corresponds to the worst or minimal value, point 9 to the best or maximal value. Evaluation points of all other data of the same indicator are calculated according to the following formula:

$$EP_i = (X_i - X_{min}) \times (X_{max} - X_{min}) \times 8 + 1$$

where EP_i is the evaluation point of a certain value of the corresponding indicator; X_i is the value of a certain indicator; X_{max} is the maximal value of the corresponding indicator; X_{min} is the minimal value of the coorresponding indicator (Weinschenk et al., 1992); 3) After these calculations, mark evaluation points in a network diagram with the radius scaled from 1 to 9; 4). Depict on the scale the medium value of evaluation points, i.e. evaluation threshold (ET), which is equal to 5 points and differentiates positive and negative assesssment. Efficiency of the treatment application is indicated by the area, limited by values of all evaluation points; 5) Produce the integrated evaluation index (IEI), consisting of the average of evaluation points, its standard deviation and standard deviation of the average of the evaluation points which are below the ET. Standard deviation of the average of the evaluation points below the ET indicates frequency and dimension of negative assessments.

RESULTS AND DISCUSSION

Results of the complex evaluation of the influence of catch crops and manure on spring barley agrocenosis according to 11 indicators (Table 1) are given in Fig. 1. The influence of different indicators is presented in the layout of evaluation points using the scale from 1 to 9. According to the data of Lewan (1994) green manure of catch crops significantly increased the productivity of barley in the sandy soil. On the contrary, the data of Andersen & Olsen (1993) showed that green manure of catch crops had no significant effect on the barley productivity.

Animal manure and green manure of the red clover catch crop had the same influence on barley productivity. The evaluation points of grain yield were above the evaluation threshold. The influence of manure and red clover for green manure on barley productivity, compared to other treatments, was stronger due to shallow incorporation in spring.

Table 1. Values of different indicators used for calculation of the evaluation points to estimate the influence of catch crops and manure on spring barley agrocenosis in organic farming, 1999–2001.

Indicators	Units	Values			
		Catch crops for green manure and animal manure			
		In autumn		In spring	
		max–min	average of interval	max–min	average of interval
1. Productivity of barley	Mg ha^{-1}	2.99–6.54	4.77	2.49–7.46	4.98
1.1. Yield of grain					
2. Infestation of weeds					
2.1. Projective cover	%	2.26–8.68	5.47	2.26–8.68	5.47
of weeds in autumn	sprouts m^{-2}	2.69–7.00	4.85	3.81–5.72	4.77
2.2. Weed density in spring	g m^{-2}	4.10–5.87	4.99	4.73–7.03	5.88
2.3. Dry matter mass of annual weeds	g m^{-2}	3.91–7.96	5.94	1.67–7.80	4.74
2.4. Dry matter mass of perennial weeds	%	3.37–5.79	4.58	5.00–6.56	5.78
3. Soil fertility	mg NH_3				
3.1. Content of humus	g^{-1} soil 24 h^{-1}	3.89–5..34	4.62	3.45–6.29	4.87
3.2. Activity of urease	mg glucose g^{-1} soil 48 h^{-1}	3.77–5.92	4.85	3.99–7.22	5.61
3.3. Activity of saccharase	GJ ha^{-1}	1.00–9.00	5.00	1.00–9.00	5.00
	h ha^{-1}	1.00–9.00	5.00	1.00–9.00	5.00
4. Energetical evaluation		1.52–7.76	4.64	1.22–7.84	4.53
4.1. Total energy expenditure					
4.2. Man–hours					
4.3. Energetical efficiency					

Catch crops are an alternative to chemical weed control in organic farming (Liebman & Davis, 2000; Barberi, 2002). Catch crops suppress weeds by competing for the use of light, nutrients and moisture (Auler, 1998; Kahnt & Eusterschulte, 1998). In heavy catch crops, higher shading ability significantly reduced weed infestation (Börner, 1995; Ivaschenko, 1996), but in unfavourable conditions in a thin catch crop, weed infestation can increase (Kvist, 1992).

The evaluation points of weed infestation in barley were above the evaluation threshold after deep ploughing of manure, white mustard and winter rape for green manure in autumn. The evaluation points of weed infestation in barley were widely variable (located above or below the evaluation threshold) after deep ploughing of red clover and common ryegrass for green manure in autumn. Without the catch crop the evaluation points of weed infestation in barley were located below the evaluation thresold.

When manure, red clover and common ryegrass catch crops were shallowly ploughed in spring the evaluation points of weed infestation in barley were variable. The evaluation points of weed infestation in barley were very close to the evaluation threshold after shallow ploughing of white mustard and winter rape for green manure in spring. Without the catch crop only the evaluation point of dry matter mass of perennial weeds was above the evaluation threshold.

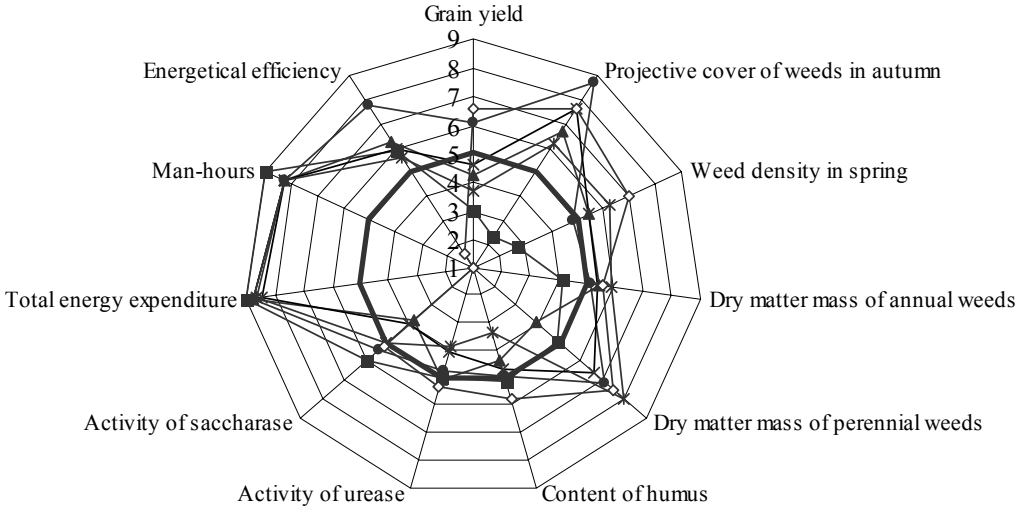
Soil enzyme activity is one of the main indicators of soil biological activity and fertility (Mikhailovskaya, Tarasyuk, 2008). Scientists of many countries investigated the positive effect of incorporation of catch crops for green manure on soil enzyme activity (Bandick & Dick, 1999; Abdallahi & N'Dayegamiye, 2000; Kara & Penezoglu, 2000). Enzyme activities were greater in long-term manured soils compared to unmanured soils amended with various levels of manure (Goyal et al., 1993). According to the data of Kahnt & Eusterschulte (1998), soil biological activity was most improved by shallow green manure incorporation, compared to other treatments.

The evaluation points of humus content and urease activity were above the evaluation threshold after deep ploughing of manure in autumn. The evaluation points of the above-mentioned indicators were coincident with the evaluation threshold after using other treatments. When common ryegrass and white mustard catch crops were deeply ploughed in autumn the evaluation point of saccharase activity was below the evaluation threshold. The evaluation point of above mentioned indicator was close to the evaluation threshold after use of other treatments.

The evaluation points of humus content and saccharase activity were below the evaluation threshold, while the evaluation point of urease activity was above it after shallow ploughing of manure in spring. When the white mustard catch crop was shallowly ploughed in spring the evaluation point of saccharase activity was below the evaluation threshold, while the evaluation point of humus content was furthermost from the evaluation threshold, compared to other catch crops for green manure. The evaluation point of saccharase activity was furthermost from the evaluation threshold after shallow ploughing of red clover catch crop, compared to common ryegrass and winter rape catch crops for green manure.

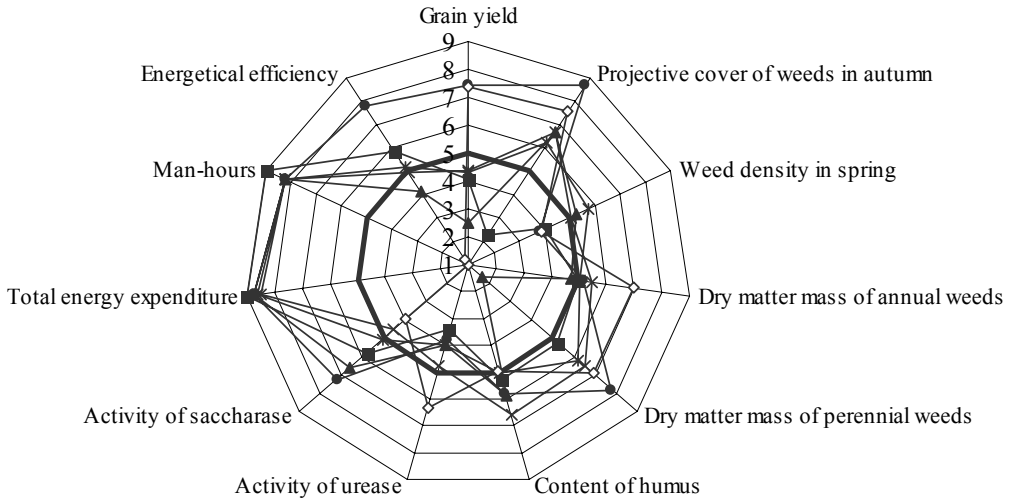
The evaluation points of total energy expenditure, man-hours and energetical efficiency were below the evaluation threshold after manure incorporation. The highest evaluation points of total energy expenditure and man-hours were estimated without a catch crop. The highest evaluation point of energetical efficiency was estimated after green manure with red clover incorporation. When common ryegrass, white mustard and winter rape catch crops were deeply ploughed in autumn the evaluation point of energetical efficiency was above the evaluation threshold. But it was lower, compared to the red clover catch crop for green manure.

The evaluation point of energetical efficiency was below the evaluation threshold after shallow ploughing of common ryegrass and white mustard catch crops in spring. When a winter rape catch crop was shallowly ploughed in spring the evaluation point of the above-mentioned indicator was close to the evaluation threshold.



Deep ploughing in autumn

Without catch crop (IEI = 5.17*–2.26**–1.17***)
Red clover (IEI = 6.51–1.64–0.08)
Italian ryegrass (IEI = 5.65–1.69–0.27)
White mustard (IEI = 5.92–1.63–0.36)
Winter rape (IEI = 5.88–1.84–0.26)
Manure (IEI = 4.91–2.54–0.30)
Evaluation threshold



Shallow ploughing in spring

Without catch crop (IEI = 5.36*–2.09**–1.01***)
Red clover (IEI = 6.79–1.83–1.22)
Italian ryegrass (IEI = 5.31–2.22–1.27)
White mustard (IEI = 5.97–1.44–0.23)
Winter rape (IEI = 5.78–1.49–0.53)
Manure (IEI = 4.66–2.63–1.84)
Evaluation threshold

Fig 1. The integrated evaluation of the influence of catch crops and manure on spring barley agrocenosis in organic farming, 1999–2001. IEI – integrated evaluation indices; * – average of evaluation points (EP); ** – standard deviation of EP; *** – standard deviation of the average of the evaluation points below the ET.

To generalize the experiment's data, integrated evaluation indices were calculated that consist of the average of all evaluation points, its standard deviation and standard deviation of the average of the evaluation points below the evaluation threshold. Standard deviation of the average of the evaluation points below the evaluation threshold was lower than that of the average of all evaluation points. This means that there were few very low evaluation points in the area of the diagram with negative assessments. The highest value of the standard deviation of the evaluation points below the evaluation threshold was obtained after shallow ploughing of animal manure in spring. The area demarcated by the evaluation points of all used indicators and calculated integrated evaluation index, showed that the influence of red clover for green manure on barley agrocenosis is stronger than that of other catch crops and manure.

CONCLUSIONS

Application of the integrated evaluation method makes it possible to combine many indicators, and enables accurate estimation of the influence of catch crops and animal manure on spring barley agrocenosis in organic farming.

The influence of red clover catch crop for green manure on barley agrocenosis, according to the calculated integrated evaluation indices, is stronger than that of other catch crops for green manure and animal manure.

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