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Impact of Catch Crops Use in the Systems of Conservation Soil Tillage

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Abstract: Ten selected plant species were studied for use as catch crops in conservation tillage technologies. In the field experiment, where the catch crops were sown in early and late terms, among other parameters, especially yield of dry biomass, nitrogen content in biomass and in soil profile in autumn and spring compared with no catch crop treatment were monitored. The highest yields of dry biomass were found in variants with radish, phacelia, crambe and mustard. The highest nitrogen content was found in aerial biomass of safflower, rye, canary grass, radish and mustard.
Monitoring of mineral nitrogen content in soil levels 0 – 0,3 and 0,3 – 0,6 m showed significant decrease of this nutrient content in soil profile of variants with catch crops in comparison to no catch crop treatment. The lowest mineral nitrogen content was recorded in variants with white mustard, radish, phacelia and crambe, while higher content in the soil profile was found below buckwheat and millet.
In the field experiment established in 1995, three species of catch crops (white mustard, phacelia and radish) were used after pre-crop winter wheat for subsequent spring barley in the period 2000 – 2003. In comparison with conventional treatment the best production in average of years was found in variant with phacelia. Furthermore, there was found significant positive effect of catch crop use on soil bulk density and porosity in conservation variants under reduced tillage.
Key words: catch crops, nitrogen losses, nitrogen fixation, cover of soil surface, evaporation decrease, soil organic matter, soil quality, crop yield increase.

INTRODUCTION

In recent years, rate of catch crops in crop rotations markedly increased and permanent interest for spreading of their utilization in agricultural practice confirm multilateral favourable impact of them. Use of catch crops helps to mitigate nitrate pollution of underground waters in consequence of immobilization unused and unfixed nitrogen in soil into biomass of catch crops. The level and intensity of immobilization depends on the weather course, especially on rainfalls in period from July to October, which influences both leaching intensity of nitrogen and production level of catch crop biomass. Decrease of nitrogen losses owing to soil cover during the intercrop periods *(Vach and Hermuth, 2007)* and fixation of nitrogen in catch crop biomass and its preservation for next crop belong to the most important properties of catch crops. Their antierosion effect, elimination of weeds, diseases and pests, evaporation decrease and creation of biomass with aim to enrich the soil with organic matter are the no less significant benefits of them.

Higher organic matter content in soil is connected with soil fertility enhancement, support of soil aggregate stability and with overall improvement of soil structure *(Williams and Coke, 1961; N´Dayegamiye and Angers, 1990; Hassink and Whitmore, 1997).* Frost-heaving or non-frost-heaving catch crops have wide possibilities of use in frame of conservation tillage technologies of sugar beet, maize and potatoes growing. Method of maize sowing into stands of catch crops is described for example by *Ammon and Scherrer (1996)* or by *Estler and Knittel (1996).*

The positive impact of catch crops on soil properties declared e.g. *Nitzsche et al. (2000)* when he presented positive influence of crop sowing into frost-killed white mustard as a catch crop on soil aggregate stability that was found 43.1 % comparing to aggregate stability 30.1 % under conventional technology. In conservation tillage treatment there was found higher infiltration ability as well and decrease of surface runoff of rainwater.

MATERIALS AND METHODS

Ten selected plant species (white mustard, *Sinapis alba L.*; phacelia, *Phacelia tanacetifolia Benth.*; oil radish, *Raphanus sativus L. var.oleiformis*; buckwheat, *Fagopyrum esculentum L. Moench*; millet, *Panicum miliaceum L.*; crambe, *Crambe abyssinica Hochst. ex. R.E.FR.*; rye, *Secale cereale L. var. Multicaule Metzg.*; mallow, *Malva verticillata L.;* canary grass, *Phalaris canariensis L.*; safflower, *Carthamus tinctorius L.*) were studied for use as catch crops in conservation tillage technologies for crop stand establishment.

The field experiment has been running in Southern Moravia region (maize production type, Fluvisol, clay-loam soil, humus content 2,97 %, Mehlich 3 P 155 - 112 mg/kg, K 217 mg/kg, Mg 321 mg/kg and Ca 4289 mg/kg, pH(KCl) 6,8). Stands of catch crops were established in 2 terms: 1. early sowing in the middle of August; 2. late sowing in the middle of September. In the both terms the control variant (no catch crop) was included. A split-plot method, with four replications was used and grain yields were determined on a 15 m^2 test area at harvest. Stands of catch crops were established after spring wheat harvest. Catch crops were sown after wheat straw clearing away, shallow stubble ploughing, P and K fertilizing and regular seed bed preparation. Drill machine Oyjord with 1.5 m of working width was used for catch crop sowing. After drilling and under the proviso that soil moisture was suitable, soil surface was pressed by rolling. Production of fresh biomass and dry matter of catch crops grown, mineral nitrogen content in plant biomass and in soil profile compared with soil without catch crop were studied. Soil samples were collected before soil tillage from a depth 0-0.3 m for determination of pH, P, K, Mg, Ca and total N in soil at 12 sampling points of experimental area. For mineral N determination (NO_3^- and NH_4^+) the soil samples were taken from layers 0-0.3 m and 0.3-0.6 m at all experimental plots.

At the experimental site in Central Bohemia short crop rotation has been carried out from year 1995 on Luvisol, loam soil. Three crops (winter wheat, spring barley and pea) are grown and during period 1998-2001 3 species of catch crops (white mustard, phacelia and oil radish) were used for spring crops. The stands of catch crops were established as soon as possible after the main crop harvest. The catch crops were sowing after shallow tillage and the main crops directly into no tilled soil by drill machine John Deere 750A. The effect of catch crops on crop production of spring crops was evaluated by means of yields of the main product. The impact of catch crops on physical soil properties was assessed from measured data of bulk density and porosity of soil in individual treatments.

RESEARCH RESULTS

The results achieved of fresh and dry biomass production of catch crops (Table 1) show very good yield ability of tested species, especially of oil radish, phacelia, crambe and mustard. Fresh and dry biomass production data of other tested catch crops were found significantly lower. The species sequences according to yield level of fresh and dry biomass were practically the same in both sowing dates. From the Table 1 it is evident that most of the catch crops have larger fresh biomass production in early sowing date than in late one.

Mineral nitrogen content in dry matter biomass is thought as an important indicator of its quality. The highest contents of nitrogen (Table 2) were found in aerial biomass of safflower, rye, canary grass, oil radish and white mustard.

The species sequences according to N content in dry biomass of tested catch crop group were almost the same in both time-different sowing terms. It means, that these species are able to reduce the underground water pollution by mineral nitrogen the most effectively and to mitigate other nutrient leaching. Generally, it is possible to say that longer growing season meant decrease of mineral N values in the soil below all experimental catch crops.

Table 1. Yields of fresh and dry biomass of catch crops

Catch crop	Fresh biomass (t.ha^{-1})	Dry biomass (t.ha^{-1})
Early sowing date		
White mustard	14.66	1.69
Oil radish	16.10	2.20
Phacelia	15.72	1.87
Buckwheat	4.36	1.07
Rye	3.00	0.60
Millet	2.97	0.72
Crambe	12.78	1.56
Mallow	4.03	0.60
Canary grass	2.57	0.46
Safflower	4.17	0.48
Late sowing date		
Catch crop	**Fresh biomass (t.ha^{-1})**	**Dry biomass (t.ha^{-1})**
White mustard	9.85	1.08
Oil radish	11.43	1.25
Phacelia	10.14	1.16
Rye	2.04	0.42
Crambe	9.02	1.12
Mallow	2.30	0.51
Canary grass	1.85	0.34

Table 2. Nutrient content in dry matter of catch crops (%)

Catch crop	%				
	N	P	K	Ca	Mg
Early sowing date					
White mustard	3.14	0.59	5.63	2.77	0.28
Oil radish	3.22	0.44	4.77	3.57	0.34
Phacelia	2.68	0.55	4.78	4.30	0.26
Buckwheat	2.06	0.54	2.63	2.54	0.53
Rye	3.61	0.62	3.95	1.89	0.24
Millet	2.77	0.42	3.32	1.47	0.38
Crambe	2.65	0.48	2.89	3.23	0.22
Mallow	2.96	0.48	4.73	2.42	0.19
Canary grass	3.44	0.39	3.38	2.27	0.20
Safflower	3.74	0.37	3.86	1.71	0.25
Late sowing date					
White mustard	3.37	0.45	3.52	2.10	0.26
Oil radish	3.32	0.47	3.79	2.42	0.28
Phacelia	1.76	0.27	2.85	2.16	0.26

The higher nitrogen uptakes into aerial biomass were recorded in early sowing date (with regard to the highest yields) in oil radish, white mustard, phacelia and crambe. In the late sowing term the highest nitrogen was taken up by mustard and oil radish. Tables 3a and 3b show mineral nitrogen content in soil after ending of vegetation period of individual catch crops in depths 0-0.3 m and 0.3-0.6 m. The highest content of nitrates in the both soil layers was found in control variant – without catch crop.

The detail evaluation of obtained data shows significant decrease of nitrogen content in soil profile in comparison to variant without catch crop. With reference to the individual catch crops this reduction represents 40.2-83.4 % in horizon from 0 to 0.3 m and 35.3-74.4 % in horizon 0.3-0.6 m. The lowest nitrogen content was recorded in variants with white mustard, oil radish, phacelia and crambe. Higher N contents were found in the soil below buckwheat and millet.

In the table 4, the catch crop impacts on yields of spring barley and soybean and on physical soil properties are shown. All three species of catch crops caused yield increase of both spring barley and soybean comparing with no catch crop treatment. The highest yield of spring barley was achieved with use of phacelia (significant increase) and statistically significant effect on soybean production had mustard and phacelia as well. The yield increase caused by oil radish was insignificant. The use of catch crops had an influence on soil environment as well. Mainly because of organic matter increase in soil, bulk density was reduced and total porosity was higher in all catch crop variants but only in mustard variant for spring barley the difference was statistically significant.

DISCUSSION AND CONCLUSIONS

To identify the benefits of selected catch crops growing from standpoint of soil and environment quality, especially for decrease of nitrate leaching risk and organic matter supply into the soil were the main aims of the research. There were obtained the data of the influence of site conditions on growth processes of catch crops in view, on nitrogen accumulation in catch crop biomass and on nitrogen concentration in soil. In general, evaluation of catch crop benefit for environment is based on nitrogen amount fixed in plant biomass.

Production of catch crop biomass varied depending on species of plants, sowing date, the weather course and duration of vegetation period. According to results of *Michelmann (1975 and 1976)* production of dry shoot biomass of mustard, grown as a catch crop, ranged from 2.5 to 4.3 $t.ha^{-1}$, phacelia from 2.9 to 5.4 $t.ha^{-1}$, oil radish from 2.0 to 3.2 $t.ha^{-1}$. *Vos et al. (1997)* mention their results from catch crop experiment where total average production of dry shoot biomass of rye, oil seed rape and oil radish varied depending on sowing date from 0.28 – 0.58 $t.ha^{-1}$.

Table 3a. Mineral nitrogen content in soil (spring sampling, soil layer 0 – 0.3 m)

Variant	NO_3^-		NH_4^+		N_{min}	
	($mg.kg^{-1}$)	(%)	($mg.kg^{-1}$)	($mg.kg^{-1}$)	(%)	($mg.kg^{-1}$)
Early sowing date						
White mustard	17.20	46.7	1.9	105.6	19.10	49.4
Oil radish	18.32	49.7	1.8	100.0	20.12	52.1
Phacelia	20.27	55.0	1.5	83.3	21.77	56.4
Buckwheat	26.17	71.0	1.3	72.2	27.47	71.1
Rye	14.42	39.2	1.1	61.1	15.52	40.2
Millet	31.13	84.5	1.1	61.1	32.23	83.4
Crambe	16.08	43.7	1.7	94.4	17.78	46.0
Mallow	24.76	67.2	1.4	77.8	26.16	67.7
Canary grass	21.50	58.4	1.2	66.7	22.70	58.8
Safflower	16.74	45.5	1.1	61.1	17.84	46.2
No catch crop=control	**36.83**	**100.0**	**1.8**	**100.0**	**38.63**	**100.0**

Table 3b. Mineral nitrogen content in soil (spring sampling, soil layer 0.3- 0.6 m)

Variant	NO_3^-		NH_4^+		N_{min}	
	($mg.kg^{-1}$)	(%)	($mg.kg^{-1}$)	(%)	($mg.kg^{-1}$)	(%)
Early sowing date						
White mustard	16.09	46.6	0.8	114.3	16.89	48.0
Oil radish	11.62	33.7	0.8	114.3	12.42	35.3
Phacelia	12.82	37.2	0.6	85.7	13.42	38.1
Buckwheat	23.33	67.6	0.5	71.4	23.83	67.7
Rye	16.93	49.1	0.5	71.4	17.43	49.5
Millet	25.58	74.2	0.6	85.7	26.18	74.4
Crambe	11.60	33.6	0.7	100.0	12.30	35.0
Mallow	19.56	56.7	0.7	100.0	20.26	57.6
Canary grass	19.40	56.2	0.5	71.4	19.90	56.6
Safflower	19.03	55.2	0.5	71.4	19.53	55.5
No catch crop=control	**34.49**	**100.0**	**0.7**	**100.0**	**35.19**	**100.0**

Table 4. The impact of catch crop use on yield of the main crops and on soil properties

Crop	Treatment	Yield		Bulk density ($g.cm^{-2}$)	Porosity (%)
		$t.ha^{-1}$	%		
Spring barley	1. No catch crop = control variant	5.03	100.0	1.61	37.3
	2. White mustard	5.18	103.0	1.39 $^{+}$	45.3 $^{+}$
	3. Phacelia	5.31^{+}	105.6	1.40	44.6
	4. Oil radish	5.13	102.1	1.42	44.0
	LSD 0.05	*0.21*	*X*	*0.21*	*7.5*
Soybean	1. No catch crop = control variant	2.10	100.0	1.56	37.8
	2. White mustard	2.28 $^{+}$	108.6	1.36	47.2
	3. Phacelia	2.30 $^{+}$	109.5	1.38	46.7
	4. Oil radish	2.19	104.3	1.39	45.8
	LSD 0.05	*0.14*	*X*	*0.23*	*9.7*

Utilization of catch crops as a possibility how to reduce nitrogen losses from crop rotation is a subject of interest of specialists from the beginning of 20. century and it is the focus of attention on the present *(e.g. Richards et al. 1996, Sturite et al. 2007 etc.).* The authors refer that efficiency of catch crops depends on nitrogen mineralization from catch crop biomass in relation to the demand of next crop for nitrogen. After catch crop biomass incorporating into the soil, nitrogen is being released for the next crop during mineralization processes. The effectiveness of nitrogen release fro catch crop biomass depends on range of factors including term of sowing, mineralization rate (depends on organic matter properties such as C/N rate, soil quality etc.) and demands of the next crop for nitrogen. Under optimal conditions, mineralization rate is greatest in vegetation period when demands of next crop for N are the greatest as well.

The results of *van Dam et al. (1996)* showed that growth rate of individual roots deep, length and their spacing in the soil are important characteristic properties of the individual catch crops. *Vos et al. (1997)* documented that 10 g N per m^{-2} and more can be accumulated by catch crops in period from August to October and potential of N accumulation decreases quickly with later sowing date.

Reducing of nitrogen leaching by catch crop stands decrease the risk of underground water pollution. *Kohler et al.(2006)* mention that catch crop use in crop rotation is one of the possibilities leading to effective decrease of NO_3^- concentration in underground waters on sand soils. Elimination ratio of NO_3^- in subterranean waters by catch crop stands depends relatively largely on their development. *Verloop et al. (2006)* found the positive influence of catch crop use in crop rotation on decrease of nitrate concentration in subterranean waters in frame of different crop rotation. According to their results, utilization of catch crops in crop rotations contributed to decrease of nitrate content in subterranean waters by about 23 %.

Many authors mention positive impact of catch crops on crop production in crop rotations. For example *Estler and Knittel 1996, Nitzsche et al. 2000 etc.* referred to the important impact of catch crops on sugar beet production, *Nitsch 2004, Surböck et al. 2004, Plaza and Ceglarek 2006* notified of definitely positive effect of catch crops on yield and duality of potatoes.

On the basis of the results from our field experiment it is possible to recommend the early sowing date as a more useful variant. In the beginning part of their vegetation, plants react on day-length, almost more suitable weather conditions characterized especially adequate and equable rainfalls and suitable temperatures more favourably and create sufficient amount of biomass. In agriculture practice, often use late sowing of catch crops in October do not bring, except government subsidy, expected positive effect because yield of biomass is often minimal.

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