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THE FERTILIZING VALUE OF STRAW AND SUMMER CATCH CROPS FROM NON-PAPILIONACEOUS PLANTS IN RELATION TO VEGETABLE YIELDING

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ABSTRACT

The studies examined the fertilizing value of rye straw and green manure from non-papilionaceous plants in vegetable cultivation, in the soil and climatic conditions of central-eastern Poland against the background of the control, which was not organically fertilized, and farmyard manure. In the experimental conditions of the studies the size of the yields was related to the manner of using the intercrops. Higher yields of cabbage and red beets were obtained after ploughing in the whole intercrop biomass than after ploughing in the crop residues. The manner of using the catch crops did not cause any significant changes in onion yielding. The highest yields of vegetables were achieved after ploughing in the phacelia intercrop, which exceeded the effect of manure. Among the applied doses of rye straw, the best yield-forming effect during the studies was characteristic of straw in the dose of 4 t·ha^{-1}.

Key words: green manure, non-papilionaceous plants, rye straw, yield, cabbage, onion, red beet

INTRODUCTION

Organic fertilization is one of the most important agricultural treatments. When applied at the right time and in proper quantities, it is conducive to the maintenance or improvement of the soil fertility [9, 17]. Manure is the basic organic fertilizer. For many years its quantity has been sufficient for the needs. Nowadays, its production has decreased due to the drop in the number of farm cattle. The result is no-manure farming, which leads to negative changes connected with soil fertility [19]. In order to limit those changes, possibilities of using other sources of the organic matter are sought. Pro-ecological tendencies in agriculture caused a return to green manure and straw fertilization. A lot of authors point out that green manure can be an accessible and economical source of the organic matter [5, 8, 11]. Papilionaceous plants applied as green manure are ascribed a considerable role in increasing the soil fertility [13, 16, 20]. The opinions on the effect of non-papilionaceous plants vary [14].

The straw remaining on the field after the harvest can also be used as a fertilizer [4, 10, 12].

The purpose of the studies was to establish the possibilities of replacing manure in vegetable fertilization with an organic substance of non-papilionaceous plants cultivated in the summer catch crop, and with rye straw.

METHODS AND CONDITIONS OF STUDIES

The studies were conducted in the years 1991-1998 at the Experimental Station of Zawady affiliated within the Podlasie University in Siedlce, on the brown soil, in the climatic conditions of central-eastern Poland. The humus content in the soil was 1.63%-1.70%, pH in H_2O was 6.2. The soil was characterized by good content of available phosphorus and the sufficient content of available potassium.

A statistical field experiment was carried out in two three-year-long cycles of cultivation on a stand after spring barley. Each of the cultivation cycles comprised organic fertilization and vegetable cultivation in a three-year-long chain of rotation – cabbage, onion and red beet. The experiment was set in a split-plot-split-block scheme in three repetitions. The area of one plot was 56 m^2.

The experiment studied the effect of three factors:

1. The form of ploughing in the intercrop in autumn:
- the whole biomass ploughed in,
- the crop residues ploughed in.

2. Type of organic fertilization:
- control without organic fertilization,
- manure in the dose of 60 $t \cdot ha^{-1}$,
- phacelia intercrop (Phacelia tancetifolia Bantham),
- winter rye intercrop (Secale cereale).

3. Straw fertilization:
- without straw,
- straw in the dose of 4 $t \cdot ha^{-1}$.

The catch crop plants were sown in the third 10-days' period of July and they were ploughed in as green manure at the end of October of 1991 and 1995. They were ploughed in as the whole or in the form of crop residue. The crop residue consisted of stubble along with the root mass. Each time before the sowing of intercrop plants, mineral fertilization was applied in the quantity of 60 $kg \cdot ha^{-1}$ N, 40 $kg \cdot ha^{-1}$ P_2O_5 and 80 $kg \cdot ha^{-1}$ K_2O for both plants.

Immediately before the plough in, average samples of the whole biomass and crop residue of intercrop plants were taken from the area of 1 m^2 together with their root mass from the 30-cm-deep layer of the soil. The content of dry weight and the macroelements: N, P, K, Ca and Mg was determined in the plant material.

At the same time manure and straw fertilization was applied. Rye straw was cut for chaff, 5-10 cm in length so that it could be ploughed in more easily. Before the ploughing in, the content of dry weight and the macroelements: N, P, K, Ca and Mg introduced into the soil was established in manure and straw.

In the first year after organic fertilization, i. e. in the years 1992 and 1996, white cabbage Stone Head cultivar was grown. In the second year after organic fertilization, i.e. in the years 1993 and 1997, 'Wolska' cv. was cultivated, while in the third year, i.e. in the years 1994 and 1998, red beet of 'Red Ball' cv. was grown The vegetables were cultivated in accordance with the accepted agricultural principles.

Cabbage was picked up in the third 10-days' period of October, while onion and red beet in the third 10-days' period of September. During the harvest the total and commercial yields were established.

In autumn of every year after the vegetables were picked up, deep plough was performed and the field was left furrowed.

The results were statistically analyzed by means of variance analysis. While comparing the means, the significance of differences was determined using Tukey's test with the level of significance of $\alpha = 0.05$.
The chemical analyses in the plant material, the manure and the straw were conducted by means of the following methods:

- the content of dry weight – by a dryer-weight method,
- the content of nitrogen – by Kijedahl's method,
- the content of phosphorus – by vanadium-molybdenum method,
- the content of potassium and calcium – by flame photometry method,
- the content of magnesium – by atomic absorption method.

Table 1. Mean air temperatures (°C) during the vegetation of catch crops and vegetables according to the meteorological station at Zawady

Years	Mean yearly temperature	Mean temerature during vegetation			
		intercrop plants	cabbage	onion	red beets
1991	7.2	14.2	-	-	-
1992	8.9	-	16.3	-	-
1993	7.9	-	-	14.8	-
1994	9.9	-	-	-	17.2
1995	8.4	16.2	-	-	-
1996	7.0	-	14.7	-	-
1997	8.1	-	-	15.3	
1998	7.7	-	-	-	15.9
Many years' means for the years 1951-1990	7.5	13.8	14.2	14.0	15.8

Table 2. Sums of atmospheric rainfalls (mm) during the vegetation of catch crops and vegetables according to the meteorological station at Zawady

Years	Yearly sum of rainfalls	Sum of rainfalls during vegetation			
		intercrop plants	cabbage	onion	red beets
1991	197.6	92.6	-	-	-
1992	645.5	-	335.0	-	-
1993	480.6	-	-	301.7	-
1994	553.0	-	-	-	145.0
1995	392.9	199.5	-	-	-
1996	466.7	-	343.8	-	-
1997	393.0	-	-	306.0	-
1998	518.7	-	-	-	285.4
Many years' means for the years 1951-1990	514.9	210.6	247.9	331.6	247.9

The years of studies were characterized by differentiated weather conditions (tab. 1, 2). The total rainfalls in 1991 during the vegetation of catch crops were lower than the mean value of many years for that region. In 1995 the moisture conditions were more favourable for the growth of intercrop plants. The weather conditions in 1992 in the period of cabbage vegetation and in 1998 in the period of red beet vegetation were positive for the cultivation of vegetables. Those years were characterized by a positive balance of atmospheric falls. In the years 1993-1997 the weather conditions had a negative effect on the cultivated vegetables. In each year of the studies there was a deficit of rainfalls or their distribution was unfavourable. In the studies years the thermal conditions were positive both for the growth of catch crops and vegetables.

RESULTS

The quantity of the ploughed in organic mass the macroelements introduced with it

The applied types of fertilization differed with the quantity of organic mass and macroelements introduced into the soil (tab. 3). The greatest quantity of dry matter and macroelements was introduced into the soil with manure. The amount of the dry matter introduced with intercrop plants was related to the plant species. Phacelia ploughed in as the whole introduced more than twice as much fresh matter as compared with rye. The amount of dry matter introduced into the soil with the whole plant biomass of catch crop was similar. However, the ploughed in biomass of phacelia had greater concentration of mineral elements, introducing more of them into the soil as compared with the whole biomass of winter rye.

Winter rye crop residue contained a greater quantity of dry mass and macroelements in comparison with the crop residue of phacelia.

Table 3. The amount of the ploughed in biomass and the mineral elements introduced with it (mean values from the years 1991 and 1995)

Type of fertilization	Fresh mass ($t \cdot ha^{-1}$)	Dry mass ($t \cdot ha^{-1}$)	N $kg \cdot ha^{-1}$	P $kg \cdot ha^{-1}$	K $kg \cdot ha^{-1}$	Ca $kg \cdot ha^{-1}$	Mg $kg \cdot ha^{-1}$
Manure	60	16.73	372.41	70.14	248.83	138.61	123.58
Rye straw	4	3.37	19.21	4.38	27.63	6.07	6.74
Rye straw	6	5.06	28.82	6.58	41.45	9.11	10.12
All biomass							
Phacelia	34.43	6.11	108.77	50.49	57.72	73.12	33.33
Winter rye	16.92	5.24	75.04	34.24	39.98	13.30	14.32
Aftercrop residue							
Phacelia	4.13	0.81	9.54	1.09	13.33	4.95	2.64
Winter rye	9.70	2.38	21.68	2.87	23.81	3.69	5.03

The quantity of dry mass and macroelements introduced with rye straw in the dose of 4 $t \cdot ha^{-1}$ as well as 6 $t \cdot ha^{-1}$ was smaller than in the manure and the whole biomass of intercrop plants, and slightly higher than in the crop residue of catch crops.

The yielding of white cabbage

On the basis of statistical analysis the studies showed a significant influence of the examined types of organic fertilization in the first year after application on the yielding of white cabbage as compared with the control without organic fertilization (tab. 4). The highest total yield (108.40 $t \cdot ha^{-1}$) and commercial yield (102.71 $t \cdot ha^{-1}$) were obtained on the combinations fertilized with phacelia intercrop. In the case of the total yield it was by 10.77% higher than the control combination and by 6.65% greater as compared with the combinations fertilized with manure. The commercial yield of cabbage cultivated after phacelia intercrop was by 16.22% higher than the control combination and by 10.21% greater as compared with the combination fertilized with manure.

Table 4. The yielding of white cabbage depending on the kind and manner of ploughing in the catch crops (mean values from the years 1992 and 1996)

Type of fertilization	Total yield (t·ha^{-1})				Commercial yield (t·ha^{-1})			
	Form of ploughing in		Mean		Form of ploughing in		Mean	
			t·ha^{-1}	%			t·ha^{-1}	%
Control	97.86		97.86	100.00	88.38		88.38	100.00
Manure	101.89		101.89	104.12	93.69		93.63	106.01
	All biomass	Aftercrop residue			All biomass	Aftercrop residue		
Phacelia	117.63	99.17	108.40	110.77	111.96	93.47	102.71	116.22
Winter rye	110.03	103.16	106.59	108.92	104.11	96.30	100.20	113.38
Mean	106.85	100.52			99.53	92.96		

$LSD_{0.05}$		
Kind of fertilization	3.05	4.50
Form of ploughing in	2.90	5.27
Form of ploughing in × kind of fertilization	5.51	10.31

Besides, differences in cabbage yields were observed between the combinations fertilized with the intercrops of rye and phacelia. However, those differences were not statistically proved.

The studies found out a significant effect of the form of ploughing in the intercrop biomass in the first year after ploughing in on the yielding of cabbage. Ploughing the whole biomass of intercrops was conducive to higher cabbage yields. The greatest differences, by over 18 t·ha^{-1} were found between the objects fertilized with the whole biomass of phacelia and its aftercrop residue. Also, a significant consecutive effect of straw fertilization was observed in cabbage cultivation (tab. 5). The dose of 4 t·ha^{-1} was the most yield-forming. The mean yield of cabbage obtained without straw fertilization was significantly smaller.

Table 5. The yielding of white cabbage depending on the kind of the ploughed in intercrop and straw fertilization (mean values from the years 1992 and 1995)

Type of fertilization	Total yield (t·ha^{-1})			Commercial yield (t·ha^{-1})		
	Straw dose (t·ha^{-1})					
	0	4	6	0	4	6
Control	83.90	105.67	104.02	74.20	95.72	95.24
Manure	106.35	101.23	98.11	97.10	92.15	91.84
Phacelia	106.64	113.71	104.86	100.37	107.50	10.29
Winter rye	109.59	105.12	105.07	103.53	99.32	97.77
Mean	101.62	106.43	103.01	93.80	98.67	96.28

$LSD_{0.05}$		
Straw fertilization	2.66	3.45
Type of intercrop × straw dose	7.54	9.78

Simultaneous fertilization with intercrop plants and straw caused significant changes in cabbage yielding. Additional fertilization with straw in the dose of 4 t·ha^{-1} on the objects fertilized with phacelia resulted in the highest yields of cabbage. On the objects fertilized with winter rye additional fertilization with straw caused a significant decrease of cabbage yields. A similar relationship was observed on the objects fertilized with manure.

The yielding of onion

In the second year after ploughing in the studies observed a significant effect of the examined types of organic fertilization on onion yielding (tab. 6). The best yield-forming effect, like in the first year, was characteristic of the intercrop of phacelia. The total yield of onion cultivated after phacelia fertilization was 34.62 t·ha^{-1}, and the commercial yield was 28.60 t·ha^{-1}. The total yield was higher than the yield obtained from the control combination by 9.58 t·ha^{-1}, higher than the combination fertilized with manure by 3.88 t·ha^{-1}, and higher than the combination fertilized with rye by 4.03 t·ha^{-1}. The differences in the commercial yields were 8.66, 3.92 and 3.86

t·ha^{-1}, respectively. The consecutive effect of the ploughed in biomass of catch crop or the aftercrop residue had no significant effect on the onion yield.

Table 6. The yielding of onion depending on the kind and manner of ploughing in the catch crops (mean values from the years 1993 and 1997)

Type of fertilization	Total yield (t·ha^{-1})				Commercial yield (t·ha^{-1})			
	Form of ploughing in		Mean		Form of ploughing in		Mean	
			t·ha^{-1}	%			t·ha^{-1}	%
Control	25.04		25.04	100.00	19.94		19.94	100.00
Manure	30.74		30.74	122.76	24.68		24.68	123.77
	All biomass	Aftercrop residue			All biomass	Aftercrop residue		
Phacelia	34.47	34.78	34.62	138.28	29.15	28.05	28.60	143.43
Winter rye	30.36	30.83	30.59	122.18	24.99	24.49	24.74	124.07
Mean	30.15	30.35			24.68	24.29		

$LSD_{0.05}$		
Kind of fertilization	1.59	1.93
Form of ploughing in	n.i.	n.i.
Form of ploughin in × kind of fertilization	n.i.	n.i.

The mean yields of onion cultivated in combinations in the second years after fertilization with straw in the dose of 4 t·ha^{-1} were higher than the yields that were obtained without straw fertilization or with straw fertilization in the dose of 6 t·ha^{-1} (tab. 7).

Table 7. The yielding of onion depending on the kind and manner of ploughing in the catch crops (mean values from the years 1993 and 1997)

Type of fertilization	Total yield (t·ha^{-1})			Commercial yield (t·ha^{-1})		
	Straw dose (t·ha^{-1})					
	0	4	6	0	4	6
Control	20.96	29.21	24.96	15.48	22.99	19.89
Manure	31.47	31.00	29.76	26.16	23.69	24.21
Phacelia	33.57	36.37	33.93	27.55	29.93	28.32
Winter rye	31.46	30.12	30.20	25.44	25.29	23.49
Mean	29.36	31.67	29.71	23.66	25.47	23.98

$LSD_{0.05}$		
Straw fertilization	0.95	0.99
Kind of intercrop × straw dose	2.69	n.i.

Interaction of fertilization with catch crop and with straw was observed on the objects fertilized with phacelia, where additional fertilization with straw in the dose of 4 t·ha^{-1} favoured a significantly higher onion yield by 2.80 t·ha^{-1}.

The yielding of red beet

The studies found a consecutive effect of the studied types of organic fertilization in the third year after being applied in the cultivation of red beet (tab. 8). Like in the previous years, an intercrop of phacelia was the most yield-forming. The total yield of red beet obtained from the cultivation on combinations fertilized with phacelia was 77.58 t·ha^{-1} and it was by 21.18% higher than that obtained on the combinations without organic fertilization. It was higher by more than 10% as compared to that which was obtained after manure fertilization as well as after winter rye intercrop. The same relations were found out in the commercial yield of red beet. The biggest, i.e. 69.35 t·ha^{-1}, was obtained after phacelia fertilization. It was significantly smaller with the other studied types of organic fertilization.

The yield-forming effect of winter rye intercrop in the third year after ploughing in was similar to the effect of manure.

Table 8. The yielding of red beet depending on the kind and manner of ploughin in the catch crops (mean values from the years 1994 and 1998)

Type of fertilization	Total yield (t·ha^{-1})				Commercial yield (t·ha^{-1})			
	Form of ploughing in		Mean		Form of ploughing in		Mean	
			t·ha^{-1}	%			t·ha^{-1}	%
Control	64.02		64.02	100			57.05	100
Manure	70.61		70.61	110.29			63.03	110.48
	All biomass	Aftercrop residue			All biomass	Aftercrop residue		
Phacelia	83.06	72.10	77.58	121.81	73.68	65.03	69.35	121.56
Winter rye	72.54	69.06	70.80	110.59	65.41	61.41	63.41	111.15
Mean	72.56	68.95			64.79	61.63		

$LSD_{0.05}$		
Kind of fertilization	2.27	2.86
Form of ploughing in	3.65	2.86
Form of ploughin in × kind of fertilization	4.04	3.33

Table 9. The yielding of red beet depending on the kind of ploughed in intercrop and straw fertilization (mean values from the years 1994 and 1998)

Type of fertilization	Total yield (t·ha^{-1})			Commercial yield (t·ha^{-1})		
	Straw dose (t·ha^{-1})					
	0	4	6	0	4	6
Control	64.25	64.49	63.31	55.04	59.19	59.92
Manure	69.47	70.54	71.82	61.21	63.52	64.36
Phacelia	72.63	81.26	78.85	66.62	72.95	68.42
Winter rye	72.39	69.71	70.29	64.62	62.87	62.73
Mean	69.68	71.50	71.07	61.89	64.63	63.11

$LSD_{0.05}$		
Straw fertilization	1.63	1.52
Kind of intercrop × straw dose	4.61	4.31

In the third year after ploughing in, the studies found out a significant effect of the form of ploughing in the intercrop biomass on the yielding of red beet. The cultivation of beets on the objects fertilized with the whole biomass of intercrops, especially of phacelia, was conducive to the higher total yield by 10.96 t·ha^{-1} and the commercial yield by 8.65 t·ha^{-1} as compared to yields of beets cultivated after ploughing in the crop residue. The yield-forming effect of straw fertilization was also marked in the third year after application (tab. 9). A significant increase of the total yield was obtained growing the red beets in the combination fertilized with straw in the dose of 4 t·ha^{-1} in comparison to the combination without this type of fertilization. In the case of the commercial yield, the increase was obtained after fertilization both in the dose of 4 and 6 t·ha^{-1}. Simultaneous ploughing in of catch crops and straw brought about significant changes in the yielding of red beet. The yield of red beets cultivated on the combinations fertilized with phacelia together with straw was higher in comparison with the combinations fertilized with phacelia only. A significant difference was found after applying straw in the dose of 4 t·ha^{-1}. A decrease of the yields of red beet grown on the objects fertilized with winter rye after additional fertilization with straw was not statistically proved.

DISCUSSION

The studies showed a positive influence of autumn ploughing in of the intercrops of non-papilionaceous plants on the yielding of vegetables. The effect of green manure on the yielding of vegetables was positive although the quantity of macroorganisms introduced into the soil was smaller than in the case of farmyard manure. According to Nowak [16], the effect of green manure on the yielding of plants can be more positive than the effect of farmyard manure fertilization.

The effects of green fertilizers are largely dependent on the quantity of the ploughed in organic matter, the content of nutritious elements in it and the demand of cultivated plants for those elements [3, 22]. The intercrop

of phacelia was characterized by better fertilization value than the intercrop of winter rye. The former introduced only a slightly greater amount of dry matter than winter rye but it contained more mineral elements. High productivity of phacelia is confirmed in the studies by other authors [2, 6, 8, 18, 21].

The effect of plants used as green fertilizer on the yielding of vegetables is marked not only in the first year but, like in the case of manure, it extends over the following years [6]. In the experimental conditions the studies observed a better consecutive effect of green manure than in the case of farmyard manure. The yields of onion grown in the second year and the yields of red beets in the third after ploughing in the green manure were higher than on manure.

Evaluating the effect of the form of ploughing in the intercrop biomass on the yielding of vegetables it was observed that ploughing in the whole biomass favoured higher yields. This confirms the thesis that increasing the ploughed in mass of green manure causes simultaneous increase of the yield of the consecutive plant [1, 7, 8]. Ploughing in the aftercrop residue matched the effect of manure, despite a smaller fertilizing value. During vegetation, the root system of plants gets constantly renewed and in this way the amount of the substance remaining in the soil in the form of roots is considerably higher than it is observed when a sample is taken once [15].

A positive effect of green manure can be increased by adding straw to the ploughed in plants [16]. The best results in the experimental conditions were obtained ploughing in the intercrop of phacelia together with rye straw in the dose of 4 $t \cdot ha^{-1}$.

CONCLUSIONS

1. Among the studies types of intercrops, the ploughed in whole biomass of phacelia introduced more fresh mass and macroelements into the soil than winter rye.
2. The yield-forming effect of green manure from non-papilionaceous plants was more positive than the effect of farmyard manure fertilization or matched it.
3. In a 3-year-long rotation, the intercrop of phacelia was characterized by the best yield-forming effect out of all the applied types of organic fertilization.
4. Ploughing in the whole biomass of catch crops affected higher yields of cabbage and red beets more than ploughing in the aftercrop residue.
5. Fertilization with straw in the dose of 4 $t \cdot ha^{-1}$ caused increased yields of vegetables as compared to the combinations without straw fertilization.

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