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FERTILIZATION WITH GREEN FERTILIZERS FROM PAPILIONACEOUS PLANTS AND WITH STRAW IN RELATION TO THE YIELDING OF VEGETABLES

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ABSTRACT

A field experiment studied the aftereffect of the ploughed in organic substance of green fertilizers (winter vetch, faba bean) and straw (rye straw in the rate of 4 and 6 t·ha^{-1}) on the yield of vegetables. The vegetables were grown in a three-year crop rotation – white cabbage, onion and red beet. The intercrop plants were ploughed in both in full or in the form of aftercrop residue.
In the cultivation of cabbage, the most effective green fertilizer was the intercrop of winter vetch, while in the cultivation of onion and red beets it was the intercrop of faba bean.
Ploughing in the whole biomass of the green fertilizers contributed to higher yields of cabbage and red beet. Straw fertilization in the ratio of 4 t·ha^{-1} affected the increase of cabbage and onion yields. Its application together with winter vetch gave the highest yields of cabbage, while its joint application with faba bean gave the highest yields of onion.
Key words: green fertilizers, manure, straw, winter vetch, faba bean, yields, cabbage, onion, red beet

INTRODUCTION

Intensification of crop production, especially the use of both organic and mineral fertilization, affects the content and quality of the organic matter [10]. Manure is the traditional source of organic substance provided to the soil. However, numerous farms do not have its sufficient quantities that could satisfy the requirements of cultivated

crops, including vegetables. The consequences include cultivation without manure, which brings about impoverishment of the soil as regards its organic substances, leading to negative effects associated with the soil fertility [19]. In fact, however, there are considerable resources that can easily increase the amount of the organic matter in the soil [14]. Green fertilizers can constitute an accessible and economical source of organic substance. Saturation of the rotations with intercrops as green fertilizers is a basic element in the systems of ecological and integrated agriculture and horticulture [20].

Grześkiewicz [5] emphasises that the expenditure of labour in manure fertilization is much higher than when green fertilizers are used. A special role in increasing the soil fertility is ascribed to papilionaceous plants [18]. Laskowski et al. [13] emphasise the yield-forming effect of papilionaceous aftercrops, which exceed the effect of 20 tons per 1 ha of manure.

According to Debrück [2] and Kuduk [11], straw is also an important source of organic fertilization in field cultivation of vegetables. Dziadowiec [3] emphasises positive economic effects of straw as a fertilizer.

The purpose of the present paper was to determine the aftereffect of the ploughed in organic substance from summer intercrops and straw on the yields of vegetables cultivated in crop rotation.

MATERIALS AND METHODS

The studies were conducted at the Experimental Station of the Podlasie University in Siedlce in the years 1991-1998 on the soil of class IVa, belonging to the good rye complex. The content of humus in the soil was 1.63 – 1.70%, while the content of available forms of mineral elements included $N\text{-}NH_4$ – 58.7 $mg \cdot dm^{-3}$, $N\text{-}NO^3$ – 70 $mg \cdot dm^{-3}$, P – 51 $mg \cdot dm^{-3}$, K – 69.7 $mg \cdot dm^{-3}$, Mg – 55 $mg \cdot dm^{-3}$, pH in H_2O – 6.2. A statistical field experiment was set on the site after spring barley and it was conducted in three-year-long cultivation cycles. Each of the cycles included organic fertilization and cultivation of vegetables in three-year-long rotation of cabbage, onion and red beet. The experiment was set in three repetitions in the split-plot-split-block scheme. The area of the plots was 56 m^2.

The experiment studied the effect of the following factors:

1. Type of organic fertilization:
- control without organic fertilization,
- manure fertilization in the dose of 60 $t \cdot ha^{-1}$,
- intercrop of winter vetch,
- intercrop of faba bean.

2. Manner of ploughing in the intercrop:
- all the plant biomass ploughed in autumn,
- crop reside ploughed in autumn.

3. Straw fertilization:
- without straw,
- straw in the dose of 4 $t \cdot ha^{-1}$,
- straw in the dose of 6 $t \cdot ha^{-1}$.

The intercrop plants were sown in the third decade of July and they were ploughed in as green fertilizers on the last days of October of 1991 and 1995. They were ploughed in full or in the form of aftercrop residue. The crop reside was made up of stubble together with the root weight. At the same time, fertilization with manure and straw was applied. Samples of intercrop plants, manure and straw were taken before ploughing in the organic fertilizers in order to determine the yields of fresh and dry weight as well as the content of macroelements.

In the first year after organic fertilization, i.e. in 1992 and 1996, cabbage ‘Kamienna Głowa’ cultivar was grown. In the second year after organic fertilization, i.e. in 1993 and 1997, onion ‘Wolska’ cultivar was cultivated, while in the third year, i.e. in 1994 and 1998, red beet ‘Czerwona Kula’ cultivar was grown. Vegetable cultivation was conducted according to the accepted agricultural measures.

The harvest of cabbage took place in the third 10-days' period of October while the harvest of onion and red beet was in the third 10-days' period of October. The total and commercial yields were established during the harvest.

The results were statistically analysed and the significance of differences was determined by means of Tukey's test, with the level of significance of 0.05.

RESULTS

The amount of the ploughed organic weight and the mineral elements introduced with it were related to the kind of fertilizer (tab. 1).

Table 1. The amount of the ploughed biomass and mineral elements introduced with it (mean figures from 1991 and 1995)

Type of fertilization	Fresh weight $t \cdot ha^{-1}$	Dry weight $t \cdot ha^{-1}$	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
Whole biomass							
Winter vetch	16.66	3.36	110.52	19.07	62.49	10.74	15.29
Faba bean	29.62	7.60	234.01	52.23	142.37	44.07	39.18
Aftercrop residue							
Winter vetch	2.36	0.77	13.61	1.22	11.09	1.31	2.17
Faba bean	4.69	1.38	14.51	2.92	23.07	2.43	3.79

Manure had the highest fertilizing value. With the dose of 60 $t \cdot ha^{-1}$ the highest amount of dry weight and macroelements were introduced into the soil.

Smaller quantities of mineral elements were introduced with intercrop plants as compared with the manure. Out of the intercrop plants, faba bean formed almost twice as high the amount of biomass than winter vetch. Ploughing in the whole biomass of faba bean, a more than a double amount of mineral elements were introduced as compared to the quantity introduced after ploughing winter vetch. The aftercrop residue of faba bean was also characterized by higher quantities of mineral elements. The fertilizer value of rye straw ploughed in the dose of 5 and 6 $t \cdot ha^{-1}$ was lower than the value of manure and the whole biomass of intercrop plants, and slightly higher than the aftercrop residue of intercrop plants.

The kinds of organic fertilization applied in the experiment had a significant effect on the increase of the yields of vegetables as compared to the objects without organic fertilization. The yields of cabbage increased by 4.12-12.94% for the total yield, and by 6.01-19.52% for the commercial yield. The yields of onion increased respectively by 22.76-59.70% and 17.30-48.65%, while the yields of red beet increased by 10.29-21.60% and 10.48-22.75% (tables 2, 4, 6). In the first year after ploughing, the intercrop of winter vetch was the most effective organic fertilizer. After ploughing it, significantly higher yields of cabbage were achieved as compared to the other kinds of organic fertilizers (tab. 2). The total yield of cabbage cultivated after winter vetch was 110.52 $t \cdot ha^{-1}$ and it was higher by 12.66 $t \cdot ha^{-1}$ in comparison to the control, by 8.63 $t \cdot ha^{-1}$ as compared to manure fertilization, and by 2.87 $t \cdot ha^{-1}$ in comparison to faba bean fertilization. The commercial yield of cabbage achieved after winter vetch was 105.64 $t \cdot ha^{-1}$ and it was higher by 17.62 $t \cdot ha^{-1}$ in comparison to the control, by 11.95 $t \cdot ha^{-1}$ as compared to manure fertilization and by 5.32 $t \cdot ha^{-1}$ in comparison to faba bean fertilization.

Table 2. The yielding of white cabbage in relation to the kind and manner of ploughing in the intercrops (mean figures from 1992 and 1996)

Type of fertilization	Total yield, t·ha^{-1}				Commercial yield, t·ha^{-1}			
	Manner of ploughing the intercrop		Mean		Manner of ploughing the intercrop		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		93.69	106.01
	Whole biomass	Aftercrop residue			Whole biomass	Aftercrop residue		
Winter vetch	117.35	103.69	110.52	112.94	113.39	97.89	105.64	119.52
Faba bean	113.10	102.20	107.65	110.04	104.91	95.73	100.32	113.51
Mean	107.55	101.41			100.09	93.92		

NIR $_{0.05}$

Type of fertilization	**2.14**	**1.08**
Manner of ploughing in	**3.26**	**1.26**
Type of fertilization × manner of ploughing in	**5.31**	**3.27**

Table 3. The yielding of white cabbage in relation to the type of the ploughed intercrop and to straw fertilization (mean figures from 1992 and 1996)

Type of fertilization	Total yield			Commercial yield		
	Without straw	Straw 4 t·ha^{-1}	Straw 6 t·ha^{-1}	Without straw	Straw 4 t·ha^{-1}	Straw 6 t·ha^{-1}
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
Winter vetch	111.83	114.52	105.21	106.82	109.23	100.87
Faba bean	107.04	108.29	107.62	98.43	102.46	100.05
Mean	102.28	107.43	103.74	94.14	99.89	97.00

NIR $_{0.05}$
Type of fertilization x straw dose 7.30 9.48

In the second and third years after ploughing, the intercrop of faba bean was the most effective organic fertilizer (tables 4, 6).

The total yield of onion cultivated after faba bean was 39.99 t·ha^{-1} and it was higher by 14.95 t·ha^{-1} than the control, by 9.25 t·ha^{-1} as compared to manure fertilization and by 12.35 t·ha^{-1} in comparison to winter vetch. The commercial yield of onion grown after faba bean was 29.64 t·ha^{-1}. It was higher by 9.70 t·ha^{-1} than the control, by 4.96 t·ha^{-1} as compared to manure and by 6.25 t·ha^{-1} in comparison to fertilization with vetch. Similar relations were observed in the third year after organic fertilization in the cultivation of red beet.

Table 4. Onion yielding in relation to the type and manner of ploughing in the intercrops (mean figures from 1993 and 1997)

Type of fertilization	Total yield, t·ha^{-1}				Commercial yield, t·ha^{-1}			
	Manner of ploughing the intercrop		Mean		Manner of ploughing the intercrop		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
	Whole biomass	Aftercrop residue			Whole biomass	Aftercrop residue		
Winter vetch	27.82	27.46	27.64	110.38	23.88	22.91	23.39	117.30
Faba bean	34.60	35.39	39.99	159.70	29.20	30.09	29.64	148.64
Mean	29.55	29.65			24.42	24.40		

NIR $_{0.05}$

Type of fertilization	**1.08**	**1.54**
Manner of ploughing in	**n.i.**	**n.i.**
Type of fertilization × manner of ploughing in	**n.i.**	**n.i.**

Table 5. The yielding of onion in relation to the type of the ploughed in intercrop and straw fertilization (mean figures from 1993 and 1997)

Type of fertilization	Total yield			Commercial yield		
	Without straw	Straw 4 t·ha^{-1}	Straw 6 t·ha^{-1}	Without straw	Straw 4 t·ha^{-1}	Straw 6 t·ha^{-1}
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
Winter vetch	30.31	27.03	25.58	25.78	23.31	21.09
Faba bean	33.54	38.74	32.66	27.99	33.51	27.43
Mean	29.07	31.51	28.24	23.85	25.88	23.16

NIR $_{0.05}$

Straw dose	**1.27**	**0.99**
Type of fertilization × straw dose	**7.30**	**9.48**

Table 6. The yielding of red beet in relation to the type and manner of ploughing in the intercrops (mean figures from 1994 and 1998)

Type of fertilization	Total yield, t·ha^{-1}				Commercial yield, t·ha^{-1}			
	Manner of ploughing the intercrop		Mean		Manner of ploughing the intercrop		Mean	
			t·ha^{-1}	%			t·ha^{-1}	%
Control	64.02		64.02	100.00	57.05		57.05	100.00
Manure	70.61		70.61	110.29	63.03		63.03	110.48
	Whole biomass	Aftercrop residue			Whole biomass	Aftercrop residue		
Winter vetch	77.03	72.47	74.76	116.78	67.14	64.21	65.67	115.11
Faba bean	81.03	74.67	77.85	121.60	73.30	66.75	70.03	122.75
Mean	73.17	70.44			65.13	62.76		

NIR $_{0.05}$

Type of fertilization	**2.67**	**2.11**
Manner of ploughing in	**2.03**	**n.i**
Type of fertilization × manner of ploughing in	**2.91**	**3.72**

The highest total yield, 77.85 t·ha^{-1}, and commercial yield, 70.03 t·ha^{-1} of red beet were achieved in the third year after ploughing in faba bean. It was higher by 13.83 t·ha^{-1} and 12.98 t·ha^{-1} as compared to the yield from the control objects, by 7.24 t·ha^{-1} and 7.00 t·ha^{-1} higher than manure, and by 3.09 t·ha^{-1} and 4.36 t·ha^{-1} higher as compared to winter vetch.

The manner of ploughing in the intercrop had a significant effect on the yields of the cultivated vegetables. The whole ploughed weight of vetch and faba bean affected higher yields of cabbage in the first year after ploughing and red beet in the third year, as compared to the ploughed aftercrop residue.

Straw fertilization had a significant effect on the yields of cabbage grown in the first year and onion in the second year after organic fertilization (tables 3, 5). The yields of red beet, regardless of the straw dose introduced to the soil, were similar and did not differ in any significant way (tab. 7).

Table 7. The yielding of red beet in relation to the type of the ploughed in intercrop and straw fertilization (mean figures from 1994 and 1998)

Type of fertilization	Total yield			Commercial yield		
	Without straw	Straw 4 t·ha^{-1}	Straw 6 t·ha^{-1}	Without straw	Straw 4 t·ha^{-1}	Straw 6 t·ha^{-1}
Control	64.25	64.49	63.31	55.04	59.19	56.92
Manure	69.47	70.54	71.82	61.21	63.52	64.36
Winter vetch	76.46	73.29	74.51	67.77	64.43	65.42
Faba bean	77.04	78.52	77.99	68.95	70.73	70.40
Mean	71.81	71.71	71.90	63.09	64.47	64.28

NIR $_{0.05}$

Straw dose	**n.i.**	**n.i.**
Type of fertilization × straw dose	**n.i.**	**n.i**

The highest total yield (107.43 t·ha^{-1}) and commercial yield (99.89 t·ha^{-1}) of cabbage were obtained after ploughing straw in the dose of 4 t·ha^{-1} in comparison to the objects that were not fertilized with straw and those that were fertilized in the dose of 6 t·ha^{-1}. The straw dose of 4 t·ha^{-1} was also the most effective in onion cultivation, contributing to the highest total yield (31.51 t·ha^{-1}) and commercial yield (25.88 t·ha^{-1}).

Joint fertilization with intercrop plants and straw caused significant changes in the yielding of cabbage and onion. Ploughing winter vetch together with straw in the dose of 4 t·ha^{-1} contributed to the highest yield of cabbage (114.52 t·ha^{-1}) as compared to fertilization only with vetch or winter vetch jointly with straw in the dose of 6 t·ha^{-1}. In the second year after organic fertilization on the objects fertilized with faba bean intercrop, ploughing the straw in the dose of 4 t·ha^{-1} caused a significant increase of the total yield of onion by 5.67 t·ha^{-1} as compared to fertilization only with faba bean, and by 6.08 t·ha^{-1} as compared to fertilization with faba bean jointly with straw in the dose of 6 t·ha^{-1}.

Such a relation was also observed in the yielding of red beet grown in the third year after organic fertilization was applied. However, the differences were not proved statistically.

DISCUSSION

The studies showed a positive effect of intercrop green fertilizers ploughed in autumn on the yielding of vegetables cultivated in a three-year crop rotation as compared to the control without organic fertilization and with manure fertilization. The positive effect of green fertilizers on the yields of vegetables is also confirmed by Golubiev and Prońko [4], Jabłońska-Ceglarek [8] and Wadas [21].

The yields achieved in the successive years after organic fertilization was related to the type of the ploughed intercrop.

Hellwig [6], Jabłońska-Ceglarek [7] and Nowak [16] emphasise the priority of papilionaceous plants in the cultivation for green fertilizers.

The ploughed intercrop of faba bean introduced greater quantities of mineral elements to the soil as compared to winter vetch. Nevertheless, winter vetch was characterized by a better yield-forming effect in the first year after ploughing. Młyniec [15] emphasises a particularly positive effect of winter vetch. Its fertilizing value is confirmed by Jabłońska-Ceglarek and Zaniewicz [9].

The over-drying effect of the big amount of biomass introduced into the soil could have been the cause of lower cabbage yields in the first year after ploughing the intercrop of faba bean as compared to the intercrop of winter vetch. Wadas [22] points out that ploughing winter vetch in the earlier developmental stages than faba bean causes its earlier decomposition, owing to which the nutritive elements are used by the successive plants earlier. In the second and third years after ploughing, the intercrop of faba bean was characterized by a better effect than the intercrop of winter vetch.

Estimating the effect of the ploughed biomass of the intercrop on the yielding of vegetables, it was found out that ploughing the whole biomass contributed to higher yields. Jabłońska-Ceglarek and Zaniewicz [9] showed a better effect of the ploughed biomass of the aftercrop plants as compared to the aftercrop residue. This confirms the thesis by Batalin [1] according to which there is a simple relation between the amount of the ploughed green mass of plants and the increase of the yield, i.e. increase of this mass caused a parallel increase of the yield of the successive plant. The yield-forming effect of straw fertilization was observed in the first and second years after ploughing in. Kuduk [12] emphasises that the positive effect of straw fertilization results from the increase of the total quantity of the organic matter, which is so important in vegetable cultivation. The most productive dose of straw in vegetable cultivation was 4 $t \cdot ha^{-1}$ as compared to the objects that were not fertilized with straw, and 6 $t \cdot ha^{-1}$ in comparison to those that were fertilized. Straw applied jointly with winter vetch contributed to higher yields of cabbage in the first year after ploughing in, while straw applied with faba bean contributed to higher yields of onion in the second year after ploughing in. Nowak [17] emphasises that straw addition to the ploughed green fertilizers can extend their effect.

CONCLUSIONS

1. The yield-forming effect of green fertilizers from papilionaceous plants was more positive than the effect of manure fertilization.
2. In a three-year-long rotation, the intercrop of winter vetch had the most positive effect on the yielding of vegetables in the first year, while in the case of faba bean in the second and third years after ploughing in.
3. Ploughing the whole biomass of intercrop contributed to significantly higher yields of vegetables in the first and second years of cultivation as compared to ploughing in the aftercrop residue.
4. Rye straw in the dose of 4 $t \cdot ha^{-1}$ had a better yield-forming effect than in the dose of 6 $t \cdot ha^{-1}$. Applied jointly with vetch it contributed to the highest yields of cabbage, and with faba bean – to the highest yields of onion.

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