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THE EFFECT OF GREEN MANURE AND SOIL LIMING ON THE YIELDING OF ROOTED CELERY, 'EDWARD' CV.

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ABSTRACT

The studies concerned the effect of green manure and soil liming on the yielding of rooted celery, 'Edward' cv. Celeries were cultivated directly after organic fertilization. The plants intended for green manure were sown in July and they were ploughed over in October. The yielding of celery was related to the weather conditions in particular years of the experiment. The highest yields of celery were obtained in 2002. A significant influence on the yield of storage roots and the leaves of rooted celery was exerted by soil liming and the kind of applied organic fertilizer. A higher yield of callosities - both total and commercial – was obtained on the soil where the carbonate lime fertilizer was used. The best yields were obtained of celeries cultivated after ploughing in faba bean and manure. Green manure in the form of phacelia, rye and winter vetch had a similar or greater yield-forming effect than rye straw in the quantity of 6 t·ha^{-1}. Joint application of soil liming and organic fertilization in the form of green manure of faba bean made it possible to obtain the highest total yield of the storage roots of rooted celery. The highest yield of leaves and the total yield of rooted celery, 'Edward' cv., was obtained in the cultivation in the limed soil with ploughed in manure.

Key words: organic fertilization, green manure, soil liming, rooted celery, yield

INTRODUCTION

Interest in rooted celery and its cultivation have increased in recent years. Nowadays, it is treated not only as a spice but also as a valuable raw material processed into dried material, tinned food, juices and frozen food.

Celery has very high soil requirements. It requires medium-heavy soils that are rich in humus, abundant with nutritious elements that keep water, but the ones that are not wet and have the reaction close to neutral. The increasing processes of mineralization cause a permanent decrease of the humus content in the soil. In order to prevent it and keep the soil in proper culture, it is necessary to introduce organic matter into it systematically. Green manure is an easily accessible source of the organic matter [3, 5]. According to Debruck [4], fertilization with straw and green manure can maintain the present level of humus in the soil. The effect of green manure is largely dependent on the weight of the ploughed in plants, the rate of their mineralization as well as on the climatic conditions – mainly on the size and distribution of atmospheric falls [1, 2]. The advantages of using green manure include a considerable reduction of the production costs [7] and saturation of the rotations with catchcrops, which is so important in ecological agriculture [11].

METHODS

A field experiment was conducted at the Experimental Station of the Podlasie University in Zawady near Siedlce in the years 2000-2003. The experiment was set on a site after winter barley on brown soil proper formed from light loamy sand. The humus content in the soil reached the depth of 30-40 cm. The content of organic carbon was 0.9%, on average. The soil had acid reaction with pH 5.6 in H_2O. The experiment was set in a split-plot scheme in three repetitions. The following factors were considered:

A. soil liming:

- soil limed with carbonate lime fertilizer in the quantity of 2.0 t $CaO \cdot ha^{-1}$,
- soil not limed.

B. Organic fertilization:

- control without organic fertilization,
- manure in the quantity of 60 $t \cdot ha^{-1}$,
- rye straw in the quantity of 6 $t \cdot ha^{-1}$,
- phacelia (the sowing norm of 15 $kg \cdot ha^{-1}$),
- rye (220 $kg \cdot ha^{-1}$),
- winter vetch (70 $kg \cdot kg^{-1}$),
- faba bean (250 $kg \cdot ha^{-1}$).

The harvest area of the plots was 12.5 m^2.

Catchcrops for green manure (phacelia, rye, winter vetch, faba bean) were cultivated in the years 2000-2002. In the second 10-days' period of July a field for plants intended for green manure was prepared and soil liming was performed. In the third 10-days' period of July mineral ferlilization was applied. The quantities of phosphorus and potassium under all catchcrop plants were 40 kg $P_2O_5 \cdot ha^{-1}$ and 80 kg $K_2O \cdot ha^{-1}$. Nitrogen fertilization was differentiated. For faba bean and vetch it was 20 kg $N \cdot ha^{-1}$, while for phacelia and rye it was 60 kg $N \cdot ha^{-1}$. The seeds of plants prepared for ploughing in were sown in the third 10-days' period of July. In the third 10-days' period of October samples of organic fertilizers were taken (manure, rye straw and green manure) in order to determine the fertilizer value of:

- the fresh and dry weight yields of catchcrop plants marked by means of a table method from the area of 1 m^2,
- the quantity of the organic matter and macro-elements in organic fertilizers applied per an area of 1 ha.

Next, manure fertilization as well as rye straw fertilization were applied onto the proper combination and the whole experimental area was ploughed over in pre-winter deep plough. The soil was kept as black fallow until the planting of celery seedlings took place. Mineral fertilizers under celery were used in the following quantities: N – 171 $kg \cdot ha^{-1}$, P_2O_5 – 171 $kg \cdot ha^{-1}$, K_2O – 257 $kg \cdot ha^{-1}$. Mineral fertilizers were all used before the seedling planting.

The seedlings of 'Edward' cv. celery were prepared in a glasshouse. They were planted onto the permanent place in the second 10-days' period of May in the spacing of 40×30 cm. The treatments during the growth of celery included systematic weeding, both manual and mechanical, and protection from diseases and pests. The harvest took place in the second 10-days' period of October, when the total and commercial yields of storage roots and the weight of the above ground parts were established. The results were statistically analyzed by means of variance analysis. The significance of differences of the mean values was estimated using Tukey's test with the level of significance at $p = 0.05$.

RESULTS AND DISCUSSION

Weather conditions during the studies

The cultivation of plants intended for green manure and a field cultivation of vegetables depend on the atmospheric conditions during their growth.

According to the Meteorological Station at Zawady, the mean annual air temperatures in the years 2000, 2002, 2002 and 2003 were higher than the mean value of many years for 1951-1990 (tab. 1). The temperatures during the vegetation of plants intended to be ploughed in and the vegetation of celeries were also higher than the many-years' mean value.

Table 1. Mean monthly air temperatures (°C) during the studies according to the Meteorological Station at Zawady

Years	Mean annual temperature	Mean temperatures during the vegetation of	
		Sumer aftercrops	celeries
2000	10.3	15.4	-
2001	8.6	16.8	17.2
2002	8.9	15.3	16.1
2003	8.0	-	16.1
Many years' mean 1951-1990	7.5	13.8	14.1

Despite the sums of rainfalls that were lower than many-years' mean in particular years of studies, the humidity conditions during the vegetation of summer aftercrops were positive for their growth (tab. 2). The sums of rainfalls during their growth in the field were higher than many-years' mean values for that period, from 5 mm in 2001 to 53.2 mm in 2000.

Table 2. Mean monthly atmospheric falls (mm) during the studies according to the Meteorological Station at Zawady

Years	Yearly sum of rainfalls	Sum of rainfalls during the vegetation of	
		sumer aftercrops	celeries
2000	457.0	263.8	-
2001	423.5	215.4	256.4
2002	437.8	233.7	307.8
2003	221.6	-	129.5
Many-years' mean 1951-1990	514.9	210.6	334.2

Humidity conditions were the best for the growth of rooted celery in 2002 and the worst in 2003. Celery as an uliginose plant has high requirements as to the water content in the soil. When the water supply is insufficient, granary roots of worse quality are formed, with strongly developed lateral roots. The highest demand for water is shown by celery in the period of root thickening and growing – between the middle of July and October [9].

Fertilizer value of organic fertilizers

The greatest amount of fresh weight was introduced into the soil together with manure, while the smallest with rye straw (tab. 3). Among the catchcrops, phacelia formed the greatest amount of fresh weight (47.0 kg·ha^{-1} on average). Faba bean was also characterized by a high yield of fresh weight (39.7 kg·ha^{-1}). Rye and winter vetch formed twice and three times as little fresh weight as phacelia and faba bean.

Table 3. The amount of fresh and dry weight (t·ha^{-1}) introduced into the soil with organic fertilizers – mean values from the years 2000-2002

Kind of organic fertilizer	Fresh weight			Dry weight		
Manure	60.0			16.1		
Rye straw	6.0			5.2		
	soil liming		mean	soil liming		mean
	W*	NW**		W*	NW*	
Phacelia	46.2	47.8	47.0	8.5	8.9	8.7
Rye	22.2	23.0	22.6	6.3	6.3	6.3
Winter vetach	13.6	14.2	13.9	3.1	3.1	3.1
Faba bean	39.9	39.5	39.7	8.4	8.2	8.3
$NIR_{0.05}$ for						
– soil liming			n.i.			n.i.
– organic fertilization			2.1			0.5

W* – limed soil, NW** – not limed soil

Dry weight of manure in the quantity of 60.0 kg·ha^{-1} was 16.1 kg·ha^{-1} and it was significantly greater than the dry weight of the remaining organic fertilizers studied in the experiment. A significant effect on the quantity of dry weight supplied to the soil with catchcrop plants was exerted by the plant species, whereas no significant effect of soil liming was proved. The dry weight yield of phacelia (8.70 kg·ha^{-1}) and faba bean (8.30 kg·ha^{-1}) significantly exceeded the yields of dry weight of the other catchcrop plants.

Table 4. The amount of mineral elements (kg·ha^{-1}) in the examined organic fertilizers – mean values from the years 2000-2002

Kind of organic fertilizer	N	P	K	Ca	Mg
Manure	205.1	104.0	308.4	136.8	82.1
Rye straw	40.5	3.6	62.9	12.7	15.3
Phacelia	151.6	71.2	161.5	102.4	42.5
Rye	97.1	44.9	88.3	18.2	18.4
Winter vetch	87.9	14.9	44.9	7.4	8.6
Faba bean	223.6	39.7	143.9	29.8	29.9
$NIR_{0.05}$	11.2	5.5	12.6	6.3	3.6

The amount of mineral elements in the examined organic fertilizers was differentiated (tab. 4). Manure in the quantity of 60.0 kg·ha^{-1} introduced more phosphorus, potassium, calcium and magnesium, while faba bean introduced more nitrogen than the other organic fertilizers. Considering the organic fertilizers studied in the experiment as the source of nutritious elements, however, it should be emphasized that it was only manure and rye straw that introduced nitrogen, phosphorus, potassium, calcium and magnesium into the soil. Among the inter-crop plants, papilionaceous plants, namely vetch and faba bean, were also the source of nitrogen for the soil. The other plants took the nutritious elements from the soil where they grew and, after being ploughed in, they returned them. Their positive effect above all consisted of temporary immobilization of mineral elements in the tissues and protecting them from being washed away into the soil in the period when celeries were not cultivated.

The yielding of rooted celery

Analyzing the yields of rooted celery obtained in the years 2001-2002 it was found out that they were differentiated depending on weather conditions in the successive years of studies (tab. 5, 6, 7). The highest total and commercial yields of storage roots (53.4 kg·ha^{-1} and 48.5 kg·ha^{-1}) as well as the yield of leaves (49.7 kg·ha^{-1}) were obtained in 2002. That year was characterized by the amount of atmospheric falls close to the mean of many years during the vegetation of celeries. The lowest harvest was obtained in 2003, when a considerable humidity deficit was marked in the soil. In that year 2.5 times as much rain fell during the growth of celeries as in the mean of many years. Brzeski et al. [2] and Szymankiewicz [12] consider the yield-forming effect of green manure as dependent on weather conditions in the period of their decomposition as well as during the vegetation

of a consecutive plant. The total yield of storage roots of celeries on limed soil was by 2.8 t·ha^{-1} higher than the yield obtained without liming. The difference was statistically significant (tab. 5). Rooted celery is a vegetable of considerable requirements as to the reaction of the soil, and it reacts positively to its liming [9].

A significant effect on the yielding of rooted celery 'Edward' cv. was exerted by organic fertilization. The total yield of the callosities of the celeries cultivated without organic fertilization was the lowest. All organic fertilizers applied in the experiment contributed to the growth of celery by 5.4% to 24.0% as compared to the control. The highest yields of storage roots were obtained after faba bean (53.1 t·ha^{-1}) and after manure (51.7 t·ha^{-1}). The other green manures used in the experiment, except winter vetch, were characterized by the direct yield-forming effect similar to that of manure in the quantity of 60 t·ha^{-1} and a higher one than rye straw in the quantity of 6 t·ha^{-1}.

Joint application of liming and faba bean fertilization had the best effect on the total yield of celery callosities (54.6 t·ha^{-1}). Also, joint application of soil liming and organic fertilization in the form of manure and rye caused a significant increase of celery yields as compared to the cultivation without organic fertilization and after the other organic fertilizers (tab. 5).

Table 5. The yield of storage roots of rooted celery, 'Edward' cv.

Kind of organic fertilizer	Years									Mean for soil liming		Mean for organic fertilization
	2001			2002			2003					
	W*	NW**	Mean	W*	NW**	Mean	W*	NW**	Mean	W*	NW**	
Total yield												
Control	42.4	36.7	39.6	49.6	54.4	52.0	34.8	36.8	35.8	42.3	42.6	42.5
Manure	52.2	53.7	53.0	61.7	55.1	58.4	44.9	42.5	43.7	52.9	50.4	51.7
Rye straw	46.3	43.9	45.1	50.2	51.7	51.0	46.1	42.1	44.1	47.5	45.9	46.7
Phacelia	47.8	50.1	49.0	54.8	47.4	51.1	42.8	39.1	41.0	48.5	45.5	47.0
Rye	52.6	44.8	48.7	57.4	47.9	52.7	47.3	43.0	45.2	52.4	45.2	48.8
Winter vetach	45.9	42.2	44.1	50.3	49.1	49.7	41.7	39.3	40.5	46.0	43.5	44.8
Faba bean	51.0	51.4	51.2	61.0	57.4	59.2	51.9	46.1	49.0	54.6	51.6	53.1
Mean	48.3	46.1	47.2	55.0	51.9	53.4	44.2	41.3	42.7	49.2	46.4	47.8
NIR (p=0.05)	for: years = 1.8, soil liming = 1.2, organic fertilzation =3.6; joint applicattion: soil liming × organic fertilization = 3.6											
Commercial yield												
Control	37.8	33.0	35.4	46.0	41.7	43.9	31.5	33.1	32.3	38.4	35.9	37.2
Manure	47.0	50.1	48.6	57.1	51.0	54.1	40.6	38.8	39.7	48.2	46.6	47.4
Rye straw	41.9	39.0	40.5	46.0	46.8	46.4	42.1	37.4	39.8	43.3	41.1	42.2
Phacelia	43.5	46.5	45.0	50.1	42.8	46.5	38.6	35.5	37.1	44.1	41.6	42.9
Rye	48.5	40.5	44.5	52.8	43.6	48.2	42.5	38.6	40.6	47.9	40.9	44.4
Winter vetach	41.8	38.4	40.1	45.7	44.7	45.2	37.1	35.5	36.3	41.5	39.5	40.5
Faba bean	45.7	47.3	46.5	57.3	53.7	55.5	47.8	42.0	44.9	50.3	47.7	49.0
Mean	43.7	42.1	42.9	50.7	46.3	48.5	40.0	37.3	38.7	44.8	41.9	43.4
NIR (p=0.05)	for: years = 1.6, soil liming = 1.0, organic fertilizer = 3.5											

W* – limed soil, NW** – not limed soil

Table 6. The leaves yield of rooted celery, 'Edward' cv., t·ha^{-1}

Kind of organic fertilization	Years									Mean for soil liming		Mean for organic fertilization
	2001			2002			2003					
	W*	NW**	mean	W*	NW**	mean	W*	NW**	mean	W*	NW**	
Control	36.5	33.2	34.9	47.6	42.9	45.3	34.3	24.4	29.4	39.5	33.5	36.5
Manure	46.8	36.0	41.4	60.4	46.8	53.6	42.0	36.3	39.2	49.7	39.7	44.7
Rye straw	34.4	34.8	34.6	37.8	44.9	41.4	25.0	27.4	26.2	32.4	35.7	34.1
Phacelia	34.9	29.5	32.2	48.5	56.4	52.5	26.2	30.4	28.3	36.5	38.8	37.7
Rye	35.6	40.7	38.2	48.4	48.7	48.6	30.6	30.7	30.7	38.2	40.0	39.1
Winter vetach	51.0	44.0	47.5	47.6	55.3	51.5	43.0	36.2	39.6	47.2	45.2	46.2
Faba bean	42.8	44.8	43.8	58.0	51.8	54.9	30.1	38.4	34.3	43.6	45.0	44.3
Mean	40.3	37.6	39.0	49.8	49.5	49.7	33.0	32.0	32.5	41.0	39.7	40.4
$NIR_{(p = 0.05)}$	for: years = 3.4, organic fertilization = 7.9; joint application: soil liming × xorganic fertilization = 8.2											

W* – limed soil, NW** – not limed soil

Table 7. The total yield (storage roots + leaves) of rooted celery, 'Edward' cv., t·ha^{-1}

Kind of organic fertilization	Years									Mean for soil liming		Mean for organic fertilization
	2001			2002			2003					
	W*	NW**	mean	W*	NW**	mean	W*	NW**	mean	W*	NW**	
Control	78.9	69.9	74.4	97.2	88.4	92.8	69.0	61.2	65.1	81.7	73.2	77.4
Manure	98.9	89.7	94.3	122.1	101.8	112.0	86.9	78.8	82.9	102.6	90.1	96.4
Rye straw	80.7	78.7	79.7	87.9	96.6	92.3	71.1	69.4	70.3	79.9	81.6	80.7
Phacelia	82.7	79.6	81.2	103.4	103.8	103.6	69.0	69.5	69.3	85.0	84.3	84.7
Rye	88.2	85.5	86.9	105.7	96.6	101.2	77.9	73.7	75.8	90.6	85.3	87.9
Winter vetach	96.8	86.2	91.5	97.9	104.4	101.2	84.7	75.5	80.1	93.1	88.7	90.9
Faba bean	93.8	96.2	95.0	119.0	109.2	114.1	82.9	84.5	83.7	98.6	96.6	97.6
Mean	88.6	83.7	86.1	104.7	100.1	102.4	77.4	73.2	75.3	90.2	85.7	88.0
$NIR_{(p=0.05)}$	for: years = 2.2, soil liming = 1.4, organic fertilization = 7.2; joint application: soil liming × organic fertilization = 8.2											

W* – limed soil, NW** – not limed soil

Like in the case of the total yield, soil liming also significantly affected the commercial yield of storage roots of celery (tab. 5). This yield was higher on limed soil by 2.9 t·ha^{-1} as compared to the commercial yield obtained on the soil that was not limed. A significant effect on the commercial yield of celery was exerted by the kind of the applied organic fertilization. The highest commercial yield of granary callosities was obtained in the cultivation of celeries after faba bean (49.0 t·ha^{-1}) and after manure (47.4 t·ha^{-1}). The positive yield-forming effect probably resulted from the big quantity of dry weight and nitrogen introduced into the soil by them. As stated by Wadas [13], the highest content of nitrogen in those fertilizers is conducive to faster mineralization of the organic substance and, consequently, to faster availability of the nutritious elements contained in them for the plants cultivated in the main crop.

The lowest commercial yield of callosities was provided by rooted celery on the soil that was not organically fertilized.

Considering the effect of organic fertilization on the green weight formed by celeries it was found out that the highest yield of leaves (46.2 t·ha^{-1}) was obtained cultivating them after the introduction of the winter vetch biomass into the soil (tab. 6). The high yield of leaves was also obtained in the cultivation on manure and after faba bean (44.7 t·ha^{-1} and 44.3 t·ha^{-1}, respectively). The studies also observed a positive effect of simultaneous liming and organic fertilization of the soil on the yield of leaves. The highest aboveground weight was formed by celeries cultivated on limed soil, where manure was ploughed in.

The total yield (storage roots + leaves) of rooted celery on limed soil was by 4.5 t·ha^{-1} higher as compared to the soil that was not limed, the difference being significant (tab. 7). Also, a positive effect of organic fertilization on

the total yield of rooted celery was noticed. The highest was found out on the soil fertilized with green manure of faba bean (97.6 $t \cdot ha^{-1}$), while the lowest on the control without organic fertilization (77.4 $t \cdot ha^{-1}$) and after ploughing in the rye straw (80.7 $t \cdot ha^{-1}$). The total yield was also significantly affected by joint application of soil liming and organic fertilization. The highest total yield of storage celeries and leaves was provided by celeries cultivated on limed soil, where manure was ploughed in (102.6 $t \cdot ha^{-1}$), while the smallest in the soil without liming and without organic fertilization (73.2 $t \cdot ha^{-1}$). Among the green fertilizers, faba bean ploughed in on the soil where the lime fertilizer had been sown turned out to be the most yield-forming.

Comparing different kinds of green manure used in the experiment it was found out that phacelia was characterized by a value similar to faba bean. It formed more fresh and dry weight and contained a similar amount of mineral elements (tab. 3, 4). Nevertheless, it was faba bean, which is a papilionaceous plant that was characterized by a much better yield-forming effect. Skrzyczyński et al. [10], Hruszka [8], Wadas [13] and Franczuk et al. [6] point to a positive effect of papilionaceous plants, which are a valuable source of nitrogen, on the yielding of plants.

CONCLUSIONS

1. Rooted celeries as plants that do not like the acid reaction of the soil yielded better on the limed soil as compared to the yielding on the soil without liming.
2. Faba bean and manure were characterized by the best yield-forming effect. The highest total and commercial yields of storage roots as well the best total yield (storage roots + leaves) were obtained after those organic fertilizers.
3. The highest yield of leaves was obtained in the cultivation of celeries after ploughing in winter vetch.
4. The studies observed joint effect of soil liming and organic fertilization. Celeries yielded the best on the limed soil with simultaneously ploughed in faba bean and manure.

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