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Department of Horticultural Nursery and Seed Production
University of Life Sciences in Lublin,
S. Leszczyńskiego 58, 20-068 Lublin
e-mail: andrzej.borowy@up.lublin.pl

ANDRZEJ BOROWY, MONIKA PODOLSKA, SALWINA PALONKA

Effect of green manures on the growth and yield of celeriac

Wpływ nawozów zielonych na wzrost i plonowanie selera korzeniowego

Summary. Blue lupine 200 kg · ha^{-1}, and hairy vetch (80 kg · ha^{-1})-rye (120 kg · ha^{-1}) mixture seeded at the beginning of August and cut and ploughed in the middle of November did not affect the yield of celeriac 'Mentor'. The yield of celeriac plants with leaves and roots as well total and marketable yield of roots 'Albin' harvested on plots fertilized with a vetch-rye mixture was significantly higher than on plots fertilized with lupine and control plots. Green manures did not affect the content of nitrogen, phosphorus, calcium and magnesium in celeriac leaves. The effect of green manure on potassium content was dependent on cultivar and interaction between green manure and the cultivar. Roots developed by plants of both cultivars fertilized with green manures contained more dry matter than control ones. The content of crude fiber, L-ascorbic acid, monosaccharides and total sugars was independent on the cultivar and green manure fertilization. In July the growth of plants of both cultivars grown on plots fertilized with a vetch-rye mixture was more rapid than on other plots; however, at the end of the vegetation period the leaves of plants 'Albin' fertilized with a vetch-rye mixture were the shortest and the leaves of control plants 'Mentor' were the longest.

Key words: blue lupine, hairy vetch, rye, dry matter, macroelements, sugars, L-ascorbic acid

INTRODUCTION

Celeriac is cultivated as a spice vegetable since many years. It's importance as a material used in processing industry for production of juices and of tinned, chilled and dry food increased in last years. In Poland, the consumption of celeriac is about 2 kg per person and year [Kołota 2007]. The area of celeriac cultivation was 6100 ha in 2006 and had an increasing tendency [Świetlik 2007]. Celeriac contains considerable amounts of

mineral salts and especially of potassium, sodium and phosphorus: 320 mg K, 86 mg Na and 80 mg P in 100 g of edible parts. It contains also essential oils and a small amount of vitamin C: 8,2 mg in 100 g of edible parts [Kunachowicz *et al*. 2005]. Celeriac's root system is rather small and therefore it requires fertile soils and organic fertilization [Kołota 2007]. In experiment carried out by Christiansen *et al*. [2006], the final depth of roots developed by celeriac plants 'Mentor' ranged from 45 to 60 cm. Among organic fertilizers, importance of green manures increased considerably in sustainable agriculture and horticulture management during last years [Christiansen *et al*. 2006, Księżak 2000, Lal 2008]. In the midst of plants cultivated as green manures, papilionaceous and their mixtures with grasses are especially valuable and their beneficial effect on crop yield remains for a few years [Borna 1959, 1960, Jabłońska-Ceglarek *et al*. 2007, Księżak 2000, Songin 1998, Wadas 1997]. Several authors proved that green manures influence significantly on the growth and the yield of vegetables [Borna 1959, 1960, Buczak 1959, 1967, Jabłońska-Ceglarek 1981a, Jabłońska-Ceglarek and Rosa 2002, Jabłońska-Ceglarek *et al*. 2002, 2007, Wadas 1997] however there is less information on this subject referring to celeriac [Buczak 1960, 1969, Jabłońska-Ceglarek 1981b, Jabłońska-Ceglarek and Kowalski 1985, Jabłońska-Ceglarek *et al*. 2004a, b]. Sometimes the effect of green manures fertilization on the yield of vegetables is little or unfavourable and especially in the periods of drought [Borna 1960, Buczak 1960, 1964, 1967]. Celeriac is cultivated in Lublin region [Markowski 2012] but until now there is no information on utilization of green manures for its fertilization in this area. The aim of this study was evaluation of the effect of blue lupine and hairy vetch-rye mixture cultivated as green manures on growth and yield of two celeriac cultivars grown in the Lublin region.

MATERIAL AND METHODS

The experiment was carried out on a farm placed in Wilczopole, 10 km south from Lublin, in the years 2009–2010. The experimental field was located on loess-like soil of 6,7 pH, containing 1,63% of organic matter, and of IIIa evaluation class. The forecrop was winter wheat harvested in the second decade of July 2009. Then the field was skimmed and on August 5th it was cultivated and harrowed and blue lupine (*Lupinus angustifolius* L.) seeds 200 kg · ha^{-1} and mixture of hairy vetch (*Vicia villosa* L.) 80 kg · ha^{-1} and rye (*Secale cereale* L.) seeds 120 kg · ha^{-1} were sown. On September 3rd soil samples were taken and then the content of macroelements (mg · dm^{-3}) in the soil was determined in the Regional Chemical-Agricultural Station in Lublin: N-NO_3^- – 13.4; P – 103.7; K – 151.4; Ca – 1562.3 and Mg – 44.7. On November 16th the green manures were cut with hummer crusher and ploughed in.

Next year at the end of April, the field was cultivated and harrowed. On May 13th it was fertilized with 220 kg N ha^{-1} ammonium nitrate, 65.2 kg P · ha^{-1} super-phosphate and 100 kg K · ha^{-1} potassium salt and then cultivated. On May 19th the field was harrowed and next day 8 weeks old celeriac – *Apium graveolens* L. var. *rapaceum* (Mill.) Gaud. – transplants 'Albin' (Moravoseed Spol. s.r.o., CZ) and 'Mentor' (Royal Sluis,

NL) were planted by hand with 50 cm distance between rows and 40 cm distance between plants in the row. On one 8.0 m^{-2} plot 40 transplants were planted. The experiment was established in randomized block design with four replications. 5 weeks later celeriac plants were top dressed with 50 kg N · ha^{-1} ammonium nitrate. Weeds were controlled by hand soon after emergence during whole vegetation period. In the middle of June celeriac plants were sprayed with dimethoate against celery fly (*Euleia heraclei*) and at the end of July with azoxystrobin and in August twice with Grevit 200 SL against leaf spot (*Septoria apii*).

Starting on June 5th, the length of the longest leaf of every celeriac plant was measured every 10 days. One week before harvest, 10 well developed and healthy leaves were collected from each plot, then they were dried and then the content of total nitrogen (distillation method), phosphorus (colorimetric method), potassium (flame photometry), calcium (flame photometry) and magnesium (atomic absorption spectrometry) in the leaves was determined in the Regional Chemical-Agricultural Station in Lublin. Celeriac was harvested by hand on October 10th. During harvest the weight of whole plants with leaves and roots was measured first and then the leaves and the roots were removed and total and marketable yields of celeriac were determined. Then 10 marketable celeriac roots were chosen randomly from each plot and their fresh weight was measured. On October 10th the content of dry matter (oven dry method [Chmielewska 1955]), crude fiber (Hennenberg and Stockman's method, modified by Hennenberg [Charłampowicz 1966]), total sugars (Luff-Schoorl's method [Charłampowicz 1966]) and L-ascorbic acid (refractometric method [Korenman 1973]) in celeriac samples was determined in the Laboratory of the Department of Vegetable Crops and Medicinal Plants.

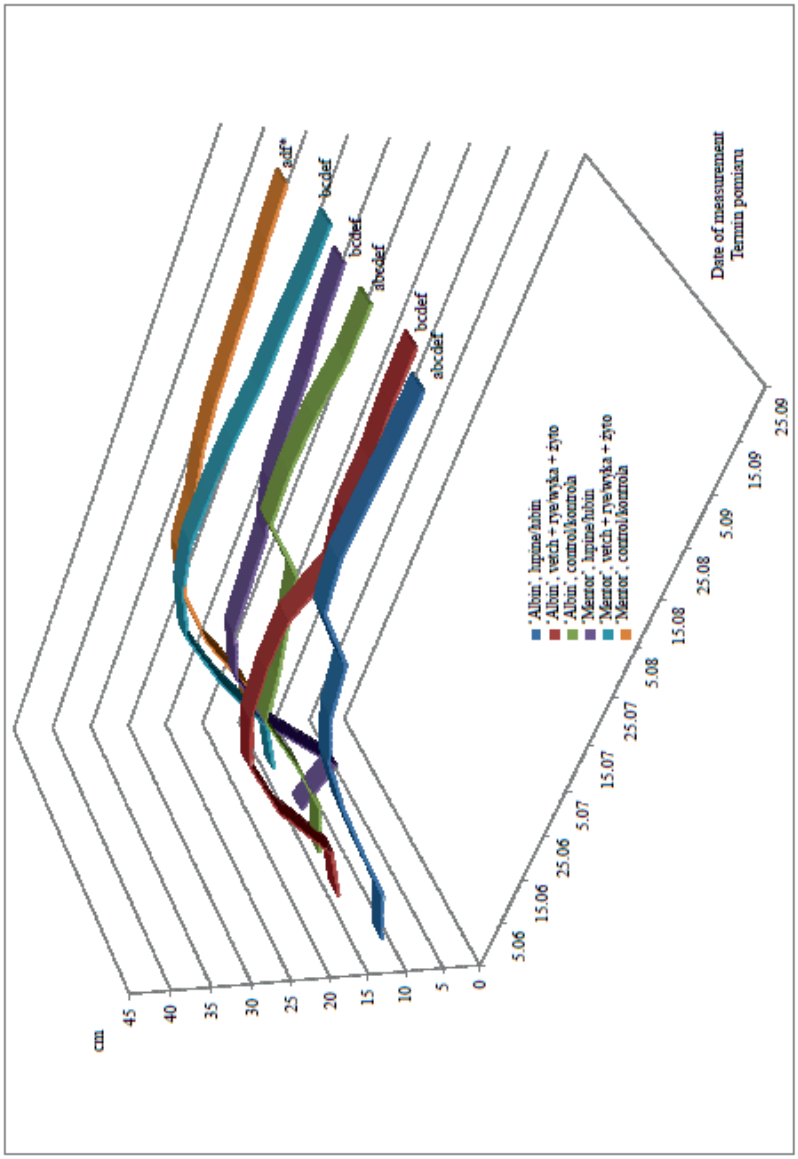
Weather conditions were favourable for celeriac cultivation. An average monthly air temperature was 18.0°C in June, 21.6°C in July, 20.2°C in August and 12.5°C in September. Monthly sum of rainfall in June was 65.6 mm, in July – 101.0 mm, in August – 132.8 mm and in September – 119.0 mm.

The results were studied by analysis of variance and the significance of differences was determined using Tukey's test at 0.05 probability level.

RESULTS

Celeriac plants of both cultivars grew rapidly up to beginning of July and there was no effect of green manures on this process (fig. 1). Then the plants 'Albin' and 'Mentor' fertilized with vetch-rye mixture continued rapid growth while the other plants grew slower. In the beginning of August, in all treatments the leaves attained the length which did not change much till harvest. On September 25th the longest were the leaves of plants 'Mentor' grown on control plots (40.1 cm) and the shortest – 'Albin' grown on plots fertilized with vetch-rye mixture (36.7 cm) and this was a significant difference. An average length of leaves of both celeriac cultivars was similar.

Content of total nitrogen in air dry celeriac leaves determined one week before harvest ranged from 2.49% ('Mentor', control) to 2.70% ('Albin', lupine). Generally, a ten-



* Means of September 25th marked with the same letter do not differ significantly
* Średnie z 25 września oznaczone tą samą literą nie różnią się istotnie

Fig. 1. Growth of celeriac leaves in dependence on cultivar and green manure fertilization
Rys. 1. Wzrost liści selera w zależności od odmiany i nawożenia nawozem zielonym

dency of increased nitrogen content in the leaves of plants fertilized with green manures was observed however this effect was not significant. The green manures did not affect the content of phosphorus, calcium and magnesium. Leaves of plants fertilized with blue lupine contained potassium significantly more and leaves of plants fertilized with vetch-rye mixture contained potassium significantly less then leaves of control plants. Content of potassium was dependent also on cultivar and interaction between green manure and cultivar. The content of nitrogen, phosphorus, calcium and magnesium did not depend on cultivar (tab. 1).

Table 1. Content of total nitrogen, phosphorus, potassium, calcium and magnesium in air dry leaves (%) in dependence on celeriac cultivar and green manure
Tabela 1. Zawartość azotu ogólnego, fosforu, potasu, wapnia i magnezu w powietrznie suchych liściach (%) w zależności od odmiany selera i nawozu zielonego

Treatments Kombinacje		N	P	K	Ca	Mg
Lupine Łubin	'Albin' 'Mentor'	2.70 2.57	0.42 0.38	2.64 3.25	2.98 3.56	0.20 0.22
Vetch + rye Wyka + żyto	'Albin' 'Mentor'	2.68 2.56	0.40 0.35	2.27 2.69	2.75 2.38	0.24 0.24
Control Kontrola	'Albin' 'Mentor'	2.60 2.49	0.41 0.42	3.40 4.44	3.32 2.47	0.22 0.18
Lupine/Łubin		2.64	0.40	2.95	3.27	0.21
Vetch + rye/Wyka + żyto		2.62	0.38	2.48	2.57	0.24
Control/Kontrola		2.55	0.42	3.92	2.90	0.20
'Albin'		2.66	0.41	2.77	3.02	0.22
'Mentor'		2.54	0.38	3.46	2.80	0.21
$LSD_{0.05}/NIR_{0,05}$:						
Cultivar (A)/Odmiana (A)		n.s./n.i.	n.s./n.i.	0.093	n.s./n.i.	n.s./n.i.
Green manure (B) Zielony nawóz (B)		n.s./n.i.	n.s./n.i.	0.124	n.s./n.i.	n.s./n.i.
A × B		n.s./n.i.	n.s./n.i.	0.238	n.s./n.i.	n.s./n.i.

The yields of celeriac were dependent on green manure, cultivar and their interaction (tab. 2). Blue lupine used as a green manure did not affect the yield of plants with leaves and roots as well as total and marketable yields of celeriac roots of both cultivars. Using vetch and rye mixture as a green manure caused a significant increase of all mentioned above yields of 'Albin' and did not affect yields of 'Mentor' The effect of green manures on weight of celeriac roots was similar. Plants 'Albin' produced significantly higher yield of whole plants with leaves and roots and significantly higher total and marketable yield of roots than plants 'Mentor'. An average weight of one marketable root 'Albin' (349.5 g) was also significantly higher in comparison to that of 'Mentor' (281.3 g).

Celeriac bulbous parts developed by plants of both cultivars fertilized with green manures contained dry matter more than control ones. Content of crude fiber, L-ascorbic acid, monosaccharides and total sugars was independent of cultivar and green manure fertilization (tab. 3).

Table 2. Yield of celeriac plants with leaves and roots (kg 100 m^{-2}), total and marketable root yield (kg 100 m^{-2}) and mean weight of root (g) in dependence on cultivar and green manure

Tabela 2. Plon roślin selera z liśćmi i korzeniami (kg 100 m^{-2}), plon zgrubień ogółem (kg 100 m^{-2}), plon handlowy zgrubień (kg 100 m^{-2}) oraz średnia masa zgrubienia (g) w zależności od odmiany i nawozu zielonego

Green manure Nawóz zielony	Yield of plants with leaves and roots Plon roślin z liśćmi i korzeniami			Total root yield Plon zgrubień ogółem			Marketable root yield Plon handlowy			Average weight of root Średnia masa korzenia		
	'Albin'	'Mentor'	mean średnio	'Albin'	'Mentor'	mean średnio	'Albin'	'Mentor'	mean średnio	'Albin'	'Mentor'	mean średnio
Lupine/Łubin	179.0	166.8	172.9	132.0	124.1	128.1	130.2	116.1	123.2	325.5	290.3	307.9
Vetch + rye Wyka + żyto	208.9	165.2	187.1	167.4	121.2	144.3	159.7	112.1	135.9	399.3	281.2	340.3
Control Kontrola	178.1	164.0	171.1	130.9	119.0	125.0	129.5	108.5	119.0	323.8	272.4	298.1
Mean Średnio	188.7	165.3	177.0	143.4	121.4	132.5	139.8	112.2	126.0	349.5	281.3	315.4
$NIR_{0,05}/LSD_{0.05}$:												
Manure (A)/Nawóz (A)		6.13			9.71			5.59			13.43	
Cultivar (B)/Odmiana (B)		4.11			6.52			3.75			10.23	
A × B		10.78			17.08			9.83			23.74	

Table 3. Effect of green manure and cultivar on content of several components in celeriac root
Tabela 3. Wpływ nawozu zielonego i odmiany na zawartość kilku składników w zgrubieniach selera

Treatments Kombinacje		Dry matter Sucha masa (%)	Fiber Włókno (%)	L-ascorbic acid (mg · 100 g^{-1} f.m.) Kwas L-askorbinowy (mg · 100 g^{-1} św.m.)	Total sugars (% f.m.) Cukry ogółem (% św.m.)	Monosaccharides (% f.m.) Cukry proste (% św.m.)
Lupine	'Albin'	11.15	16.00	3.32	0.220	0.099
Łubin	'Mentor'	10.84	16.69	3.60	0.228	0.152
Vetch + rye	'Albin'	11.87	16.23	3.31	0.221	0.122
Wyka + żyto	'Mentor'	11.18	16.32	3.30	0.159	0.065
Control	'Albin'	10.07	16.55	4.01	0.228	0.151
Kontrola	'Mentor'	10.06	16.44	2.38	0.289	0.152
Lupine/Łubin		11.00	16.43	3.46	0.224	0.124
Vetch + rye/Wyka + żyto		11.53	16.28	3.31	0.187	0.094
Control/Kontrola		10.07	16.49	3.20	0.259	0.151
'Albin'		11.03	16.26	3.55	0.223	0.124
'Mentor'		10.69	16.48	3.09	0.225	0.123
$LSD_{0.05}/NIR_{0,05}$:						
Manure (A)/Nawóz (A)		0.641	n.s./n.i.	n.s./n.i.	n.s./n.i.	n.s./n.i.
Cultivar (B)/Odmiana (B)		n.s./n.i.	n.s./n.i.	n.s./n.i.	n.s./n.i.	n.s./n.i.
A × B		n.s./n.i.	n.s./n.i.	n.s./n.i.	n.s./n.i.	n.s./n.i.

DISCUSSION

The effect of blue lupine and vetch-rye mixture used as green manures on growth and yield of two celeriac cultivars was rather little. In the literature there is no information about influence of green manures fertilization on growth of celeriac plants, most of this information is related to the yield of celeriac. In the experiment, vetch-rye mixture caused a significant increase of yield of one celeriac cultivar only and blue lupine did not influence the growth and the yield of both cultivars. These results differ from those obtained by Buczak [1960], Jabłońska-Ceglarek [1981b], Jabłońska-Ceglarek and Kowalski [1985], and Jabłońska-Ceglarek *et al*. [2004a, b] who stated a significantly favourable effect of several green manures on yield of celeriac. However, Christiansen *et al*. [2006] found no effects of differences in soil N mineral distribution after incorporation of mixture of three papilionaceous and three grass plant species on growth of roots of celeriac 'Mentor'. In the studies of Jabłońska-Ceglarek *et al*. [2004a], the effect of hairy vetch and rye used separately as green manures on yield of celeriac 'Odrzański' was little. Similarly hairy vetch used as a green manure in cultivation of celeriac 'Edward' did not affect its marketable yield [Jabłońska-Ceglarek *et al.* 2004b]. According to Borna [1960], beneficial effect on yield of vegetables appears mostly in the second year after green manures cultivation and lasts for a few years [Borna 1959, Księżak 2000, Songin 1998, Wadas 1997], but it was not studied in the experiment. Unfavourable effect of green manure fertilization is seen usually in the dry years [Borna 1960, Buczak 1960] however this was not the case in the discussed experiment. Vetch-rye mixture caused a significant increase of the yield of celeriac 'Albin' and therefore it should be evaluated as a better green manure than blue lupine. This agrees with the opinion of several authors

[Borna 1959, 1960; Jabłońska-Ceglarek *et al*. 2007, Wadas 1997] that papilionaceous plants and their mixtures with grasses are especially valuable green manures in vegetable cultivation.

Content of all elements determined in roots of both celeriac cultivars was independent (except of dry matter) on green manure fertilization (tab. 3). Similarly Jabłońska-Ceglarek [1981a]) did not stated any effect of hairy vetch, broad bean and tansy phacelia used as green manures on content of L-ascorbic acid and total sugars in celeriac (except of tendency for higher L-ascorbic acid content after fertilization with tansy phacelia). Green manures fertilization did not affect also the content of macroelements (except of potassium) in the leaves of celeriac (tab. 1). No information on this subject was found in the literature.

In the experiment, celeriac transplants were planted in a relatively big distance and therefore the total and marketable yields were lower than those obtained by Jabłońska-Ceglarek *et al*. [2004a, b] and similar to the yields in the studies carried out by Buczak [1960] in Lower Silesia natural conditions.

CONCLUSIONS

1. Blue lupine and hairy vetch-rye mixture used as green manures did not affect the growth and the yield of celeriac ‘Albin’ and ‘Mentor’.

2. Content of nitrogen, phosphorus, calcium and magnesium in the leaves of celeriac did not depend on green manure fertilization. Content of potassium was dependent on green manure, cultivar and interaction between them.

3. Fertilization with green manures did not affect the content of crude fiber, L-ascorbic acid, monosaccharides and total sugars and caused a significant increase of dry matter content in roots of both celeriac cultivars.

4. Among two celeriac cultivars compared in the experiment, Czech cultivar ‘Albin’ proved to be more suitable than Duch cultivar ‘Mentor’ for cultivation in the Lublin region.

The results presented in this paper were obtained in one-year experiment and they should be confirmed in further studies.

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Streszczenie. Łubin wąskolistny (200 kg nasion na ha) oraz mieszanka wyki kosmatej (80 kg · · ha^{-1}) i żyta (120 kg · ha^{-1}), posiane na początku sierpnia, a następnie rozdrobnione i przyorane w połowie listopada, nie miały wpływu na plonowanie selera korzeniowego odmiany 'Mentor'. Natomiast plon całych roślin selera z liśćmi i korzeniami, jak również plon ogółem i plon handlowy zgrubień użytkowych selera odmiany 'Albin' były istotnie wyższe w uprawie po przyoraniu mieszanki żyta z wyką, w porównaniu z plonem zebranym z poletek nawiezionych łubinem i kontrolnych. Nawozy zielone nie miały wpływu na zawartość azotu, fosforu, wapnia i magnezu w liściach selera, natomiast wpływ tych nawozów na zawartość potasu był zależny od odmiany oraz jej współdziałania z nawozem zielonym. Zgrubienia użytkowe obu odmian wytworzone przez rośliny nawożone nawozami zielonymi zawierały więcej suchej masy niż zgrubienia roślin kontrolnych. Zawartość włókna, kwasu L-askorbinowego oraz cukrów prostych i cukrów ogółem była niezależna od odmiany i od nawożenia nawozami zielonymi. W lipcu wzrost roślin obu odmian rosnących na poletkach nawiezionych mieszanką żyta i wyki był szybszy niż na poletkach z pozostałymi kombinacjami; pod koniec okresu wegetacji liście roślin odmiany 'Mentor' nawiezione mieszanką wyki i żyta były najdłuższe, a liście roślin odmiany 'Albin' – najkrótsze.

Słowa kluczowe: łubin wąskolistny, wyka kosmata, żyto, sucha masa, makroelementy, cukry, kwas L-askorbinowy