

INFLUENCE OF INTERCROP PLANTS AND VARIED TILLAGE ON YIELDS AND NUTRITIONAL VALUE OF SCORZONERA (*Scorzonera hispanica* L.) ROOTS

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Abstract. Intensification in plant growing is a direct reason for deteriorating soil properties, as well as conditions of plant growth and development. Aiming at improvement of soil fertility and structure, conservation tillage, limiting the processes of soil environment degradation, is introduced into garden crop production techniques. Field experiments were conducted in the years 2006–2008, on grey brown podzolic soil of impermanent structure. The experimental plant was scorzonera (*Scorzonera hispanica* L.) of ‘Duplex’ cultivar. Three intercrop plants were considered in the studies: common vetch (*Vicia sativa* L.), phacelia (*Phacelia tanacetifolia* B.) and oats (*Avena sativa* L.). There were also two ways of pre-sowing soil tillage: a) complex of pre-sowing practices, sowing of intercrop plant (2nd decade of August), pre-winter ploughing and putting green matter into soil, b) complex of pre-sowing practices, sowing of intercrop plant (2nd decade of August), spring ploughing and putting plant matter into soil, as well as two plant growing methods: on ridges and on flat soil. Significantly advantageous effects of spring putting intercrops into soil, growing of scorzonera on ridges and ploughing the soil with oats upon the total root yield were demonstrated. The examined experiment factors, however, did not significantly affect inulin, protein and dry matter contents in scorzonera roots. The most favorable tillage combination, as to inulin productivity was growing of scorzonera on ridges after spring ploughing oats with soil.

Key words: scorzonera, intercrop plants, term of ploughing, ridges, inulin, protein

INTRODUCTION

Among numerous vegetable species, plants containing nutrients and therapeutic components enjoy special consumers’ interest. Often these are not very well known and rarely grown plants. One of them is scorzonera – a root plant abounding in carbohydrates of prebiotic properties. One of more valuable components of scorzonera root is

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inulin polysaccharide [Wierzbicka 2000, 2002, Kolida et al. 2002, Skowronek and Fiedurek 2003]. Inulin is a fructan, which, included in diet, favorably affects the functioning of human and animal digestive system. It contributes to the increased population of beneficial bifidobacteria and limited occurrence of harmful putrefactive bacteria [Cieślik et al. 2001]. Inulin also binds cholesterol and bile acids, decreases triglyceride levels in blood serum, prevents atherosclerosis and is safe for diabetics [Delzenne et al. 2002, Gałązka 2002, Monti et al. 2005]. It stimulates assimilation of such mineral components as: calcium, magnesium, iron and phosphorus [Labell 1999, Ninness 1999, Tunland 2000], and prevents osteoporosis [Skowronek and Fiedurek 2003].

The growing conditions and vegetable cropping to a substantial extent depend upon appropriate and careful pre-sowing soil tillage. It is especially important in the situation, when, as a result of intensified plant production, unfavorable changes take place in the soil environment, manifested by deterioration of soil quality, and sometimes by its strong degradation. A large number of agrotechnical treatments, strongly interfering into the natural state of soil enhances its excessive pulverization, compaction and crusting. It also leads to losses of organic substance and decreased biological activeness. These processes should be prevented. One of the methods is applying conservation tillage, using intercrop plants. Growing them, and then ploughing, allows for limiting soil degradation processes and improve the growing conditions of cultivated plants. As a result of such tillage the physical and chemical properties of soil are improved, together with its resistance to erosions caused by wind and water [Hargrove 1990, Dzieńka et al. 1995, Konopiński et al. 2001, Pięta and Kęsik 2007].

The aim of conducted studies was to determine the influence of intercrop plants: common vetch, phacelia and oats, differentiated methods of pre-sowing tillage (pre-winter ploughing, spring ploughing), as well as plant growing (on ridges and on flat soil) upon the quantity and biological value of scorzonera root yield.

MATERIAL AND METHODS

Field experiments were conducted in the years 2006–2008, on grey brown podzolic soil, formed of medium silty loam. The experiment plant was scorzonera (*Scorzonera hispanica* L.) of 'Duplex' cultivar. The scheme of experiment included: three intercrop plants – common vetch (*Vicia sativa* L.), phacelia (*Phacelia tanacetifolia* B.) and oats (*Avena sativa* L.); two methods of pre-sowing tillage: a) complex of pre-sowing cultivations, intercrop plant sowing (2nd decade of August), pre-winter ploughing (depth 25 cm) and mixing green matter with soil, b) complex of pre-sowing cultivations, intercrop plant sowing (2nd decade of August), spring ploughing (depth 15 cm) and mixing plant matter with soil, as well as two methods of plant growing: on ridges and on flat soil. Plant fertilization was applied in the amount of 100 kg N·ha⁻¹, 44 kg P·ha⁻¹ and 166 kg K·ha⁻¹. Nitrogen fertilizer (ammonium saltpetre) was applied in two doses: ½ before sowing and ½ as topdressing, phosphorus fertilizer (superphosphate) and potassium (potassium salt) – once, before sowing. The scorzonera seeds were sown in the first decade of May, in the amount of 18 kg·ha⁻¹, in rows 50 cm apart, at a depth of

1.5 cm. After the seeds had been sown, the scorzonera plantation was sprayed against weeds with Kerb 50 WP herbicide.

In the conducted studies the total scorzonera root yield was determined, as well as their nutritional value, considering the following factors: inulin contents (determined with the use of HPLC – High Pressure Liquid Chromatography Technique), protein (by Kjeldahl's method) and dry matter, as well as inulin yield from one hectare of plantation.

The obtained results were statistically elaborated by means of variance analysis method. The significance of differences was determined using Tukey's test, for the significance level $\alpha = 0.05$.

STUDY RESULTS

Total scorzonera root yield. Irrespective of the examined experiment factors, the total scorzonera root yield was on average $19.5 \text{ t}\cdot\text{ha}^{-1}$ (tab. 1). Spring ploughing and using of intercrop plants, significantly affected the increase of scorzonera root yield, compared to pre-winter ploughing by 23.1%.

Table 1. Total scorzonera root yield, mean from years 2006–2008 ($\text{t}\cdot\text{ha}^{-1}$)
Tabela 1. Plon korzeni skorzonery ogółem, średnio z lat 2006–2008 ($\text{t}\cdot\text{ha}^{-1}$)

Ploughing Orka	Plant growing Uprawa roślin	Intercrop plants Rośliny międzyplonowe				Mean Średnio
		control kontrola	vetch wyka	phacelia facelia	oats owies	
Pre-winter ploughing Orka przedzimowa	on ridges na redlinach	14.9	19.9	18.5	19.4	18.2
	on flat soil na płask	12.6	16.8	17.4	20.5	16.8
	mean – średnio	13.8	18.4	17.9	19.9	17.5
	Spring ploughing Orka wiosenna	on ridges na redlinach	19.0	26.5	19.0	27.3
	on flat soil na płask	17.0	20.2	18.2	25.0	20.1
	mean – średnio	18.0	23.3	18.6	26.2	21.5
Mean Średnio	on ridges na redlinach	17.0	23.2	18.7	23.3	20.6
	on flat soil na płask	14.8	18.5	17.8	22.8	18.5
	mean – średnio	15.9	20.9	18.3	23.0	19.5
	LSD _(0.05) for:	ploughing – orka				1.64
	plant growing – uprawa roślin				1.65	
	intercrop plants – rośliny międzyplonowe				3.52	

An important role in scorzonera yielding was played by plant growing on ridges. Irrespective of the term of ploughing, in the plots with growing of scorzonera on ridges, a significantly higher root yield was collected ($20.6 \text{ t}\cdot\text{ha}^{-1}$) than in growing on flat soil ($18.5 \text{ t}\cdot\text{ha}^{-1}$).

The intercrop plants applied for soil conservation affected scorzonera root yield very favorably. Irrespectively of ploughing term and plant growing method, all the examined intercrop plants stimulated scorzonera yielding, compared to control treatments. Two plant species affected the significantly increase of scorzonera yield the most: oats ($23.0 \text{ t}\cdot\text{ha}^{-1}$) and common vetch ($20.9 \text{ t}\cdot\text{ha}^{-1}$). The lowest total root yield ($15.9 \text{ t}\cdot\text{ha}^{-1}$) was harvested from control treatments, without intercrop plants. The most advantageous growing combination for scorzonera turned out to be plant growing on ridges, after spring mixing with soil (spring ploughing) of mulch made of oats.

Inulin content in scorzonera roots. Inulin content in fresh scorzonera root weight was on average 16.5% (tab. 2). The examined experiment factors did not significantly affect the content of this component.

Table 2. The inulin content in scorzonera root, mean from years 2006–2008 (%)

Tabela 2. Zawartość inuliny w korzeniu skorzonery, średnio z lat 2006–2008 (%)

Ploughing Orka	Plant growing Uprawa roślin	Intercrop plants Rośliny międzyplonowe				Mean Średnio
		control kontrola	vetch wyka	phacelia facelia	oats owies	
Pre-winter ploughing Orka przedzimowa	on ridges na redlinach	16.2	16.5	16.2	16.3	16.3
	on flat soil na płask	15.7	16.4	15.8	17.8	16.4
	mean – średnio	16.0	16.5	16.0	17.1	16.4
	Spring ploughing Orka wiosenna	on ridges na redlinach	17.4	16.4	16.8	17.3
	on flat soil na płask	18.4	15.9	15.7	15.6	16.4
	mean – średnio	17.9	16.2	16.3	16.5	16.7
Mean Średnio	on ridges na redlinach	16.8	16.5	16.5	16.8	16.6
	on flat soil na płask	17.1	16.2	15.8	16.7	16.4
	mean – średnio	16.9	16.3	16.1	16.8	16.5
	LSD _(0.05) for:	ploughing – orka				i.d.*
	plant growing – uprawa roślin				i.d.	
	intercrop plants – rośliny międzyplonowe				i.d.	

i.d.* – insignificant differences

Irrespectively of scorzonera growing method and intercrop plants, in the roots collected from plots with spring ploughing the content of inulin was on average 16.7%, whereas the roots from cultivation after pre-winter ploughing contained less inulin by 0.3%.

Growing scorzonera on ridges and on flat soil did not differentiate the contents of this component in fresh root weight. Inulin content here, respectively amounted to 16.6% and 16.4%. Slightly more differentiated inulin content in roots, although statistically insignificant, occurred as a result of intercrops effect upon scorzonera. In roots from non-mulched objects was found 16.9% of inulin, from mulched with oats 16.8%

and from mulched with phacelia 16.1%. Irrespective of scorzonera growing method, inulin content (18.4%) was in roots from the control plots with spring ploughing and cultivation of plants on the flat soil. From among the examined growing combinations, considering aspect of intercrops, the most advantageous growing combination for scorzonera, as to inulin content (on average: 17.8%) was plant growing on flat soil, after pre-winter ploughing and mulching the soil with oats.

Protein content in scorzonera roots. The content of protein in scorzonera root was on average: 3.28% (tab. 3). The term of mixing bio-matter with soil and method of scorzonera growing, as well as the applied intercrops did not significantly affect the protein synthesis in roots. Slightly more protein was found in roots collected from plots with spring ploughing (3.34 %) than with pre-winter ploughing (3.21%).

Table 3. Content of protein in scorzonera root, mean from years 2006–2008 (%)

Tabela 3. Zawartość białka w korzeniu skorzonery, średnio z lat 2006–2008 (%)

Ploughing Orka	Plant growing Uprawa roślin	Intercrop plants Rośliny międzyplonowe				Mean Średnio
		control kontrola	vetch wyka	phacelia facelia	oats owies	
Pre-winter ploughing Orka przedzimowa	on ridges na redlinach	2.82	3.04	3.16	3.40	3.11
	on flat soil na płask	3.24	3.38	3.25	3.41	3.32
	mean – średnio	3.03	3.21	3.21	3.41	3.21
Spring ploughing Orka wiosenna	on ridges na redlinach	3.13	3.41	3.15	3.58	3.32
	on flat soil na płask	3.28	3.48	3.34	3.33	3.36
	mean – średnio	3.21	3.45	3.25	3.46	3.34
Mean Średnio	on ridges na redlinach	2.98	3.23	3.16	3.49	3.21
	on flat soil na płask	3.26	3.43	3.30	3.37	3.34
	mean – średnio	3.12	3.33	3.23	3.43	3.28
LSD _(0.05) for:	ploughing – orka					i.d.*
	plant growing – uprawa roślin					i.d.
	intercrop plants – rośliny międzyplonowe					i.d.

i.d.* – insignificant differences

Slightly more advantageous effect upon the content of this component was that of plant growing on flat soil (3.34%), as compared to planting on ridges (3.21%). Small differentiation of protein content occurred in roots, under the influence of the applied intercrops. It was found that using examined intercrop plants favorably affected its amount in scorzonera root. In roots coming from cultivation without intercrop plants was found 3.12% of protein, from growing with oats 3.43% and with common vetch 3.33%. The most favorable growing combination as to the effect upon protein content in scorzonera root was growing it on ridges, after spring ploughing and mulching the soil with oats (3.58%).

Dry matter of scorzonera root. Irrespectively of the examined experiment factors, the dry matter of scorzonera root constituted on average 24.2% (tab. 4). The factors applied in the experiment did not significantly influence on the quantity of examined feature. The roots collected from plots with spring ploughing were distinguished by 24.3% of dry matter on average, whereas those from objects with pre-winter ploughing – 24.1%.

Table 4. Dry matter of scorzonera roots, mean from years 2006–2008 (%)
Tabela 4. Sucha masa korzeni skorzonery, średnio z lat 2006–2008 (%)

Ploughing Orka	Plant growing Uprawa roślin	Intercrop plants Rośliny międzyplonowe				Mean Średnio
		control kontrola	vetch wyka	phacelia facelia	oats owies	
Pre-winter ploughing Orka przedzimowa	on ridges na redlinach	23.5	24.1	23.8	24.6	24.0
	on flat soil na płask	23.4	24.3	23.7	25.4	24.2
	mean – średnio	23.5	24.2	23.8	25.0	24.1
	Spring ploughing Orka wiosenna	on ridges na redlinach	24.7	24.0	24.8	24.9
	on flat soil na płask	24.9	23.3	23.9	23.6	23.9
	mean – średnio	24.8	23.7	24.4	24.3	24.3
Mean Średnio	on ridges na redlinach	24.1	24.1	24.3	24.8	24.3
	on flat soil na płask	24.2	23.8	23.8	24.5	24.1
	mean – średnio	24.2	23.9	24.1	24.6	24.2
	LSD _(0.05) for:	ploughing – orka				i. d.*
	plant growing – uprawa roślin				i. d.	
	intercrop plants – rośliny międzyplonowe				i. d.	

i. d.* – insignificant differences

Similar values were found in roots coming from plants grown on ridges and on flat soil, respectively: 24.3% and 24.1%. The applied intercrop plants did not significantly affect the share of dry matter in the root. However, in roots collected from objects mulched with oats was found 24.6% of dry matter and in roots grown in plots with common vetch 23.9%. As to the dry matter of scorzonera root, the most favorable growing combination was growing plants on flat soil, after pre-winter ploughing and mulching the soil with oats (25.4%).

Inulin productivity from acreage unit. Inulin yield, converted into one hectare of scorzonera cultivation was on average 3.22 t·ha⁻¹ (tab. 5). The term of mixing bio-matter with soil significantly affected the quantity of inulin yield. It was found that the ploughing in the organic substance in spring favorably influenced the quantity of inulin obtained with root yield. The average yield of this component, for 1 hectare here amounted to 3.58 t·ha⁻¹, whereas, as a result of putting intercrop bio-matter into soil after winter, the inulin yield from these treatment was only 2.87 t·ha⁻¹. The differentiated ways of

scorzonera cultivation did not significantly affect inulin yield. From growing of scorzonera on ridges received $3.42 \text{ t}\cdot\text{ha}^{-1}$ of inulin and from growing it on flat soil $3.03 \text{ t}\cdot\text{ha}^{-1}$.

Table 5. Productivity of inulin from acreage unit, mean from years 2006–2008 ($\text{t}\cdot\text{ha}^{-1}$)
Tabela 5. Produktywność inuliny z jednostki powierzchni, średnio z lat 2006–2008 ($\text{t}\cdot\text{ha}^{-1}$)

Ploughing Orka	Plant growing Uprawa roślin	Intercrop plants Rośliny międzyplonowe				Mean Średnio
		control kontrola	vetch wyka	phacelia facelia	oats owies	
Pre-winter ploughing Orka przedzimowa	on ridges na redlinach	2.40	3.28	2.99	3.15	2.96
	on flat soil na płask	1.98	2.76	2.75	3.64	2.78
	mean – średnio	2.19	3.02	2.87	3.40	2.87
Spring ploughing Orka wiosenna	on ridges na redlinach	3.31	4.36	3.20	4.70	3.89
	on flat soil na płask	3.12	3.20	2.85	3.90	3.27
	mean – średnio	3.22	3.78	3.03	4.30	3.58
Mean Średnio	on ridges na redlinach	2.86	3.82	3.10	3.93	3.42
	on flat soil na płask	2.55	2.98	2.80	3.77	3.03
	mean – średnio	2.70	3.40	2.95	3.85	3.22
LSD _(0.05) for:	ploughing – orka					0.52
	plant growing – uprawa roślin					i. d.*
	intercrop plants – rośliny międzyplonowe					1.13

i. d. * – insignificant differences

The application of intercrop plants for soil fertility also favorably influenced the inulin yield from an acreage unit. Irrespectively of the term of mixing intercrops with soil and scorzonera cultivation method, the highest inulin yield ($3.85 \text{ t}\cdot\text{ha}^{-1}$) was obtained in the case of ploughing the oats. The lowest inulin yield was obtained with the root yield without intercrop plants ($2.70 \text{ t}\cdot\text{ha}^{-1}$).

Considering all the examined experiment factors, the best growing combination, as to the inulin yield from an acreage unit ($4.70 \text{ t}\cdot\text{ha}^{-1}$), was growing of scorzonera on ridges, after spring ploughing the oats.

DISCUSSION

Results of the three-year studies on the effect of varying pre-sowing soil tillage and fertilization with the use of common vetch, phacelia and oats demonstrated that these factors in general significantly affect scorzonera yielding and its nutritional value. Ploughing the intercrop bio-matter in spring (spring ploughing), as well as plant growing on ridges favorably affected the total root yield. The root yield from plots ploughed in spring was significantly higher than the yield from plots ploughed before winter. The root yield of plants grown on ridges was significantly higher than the yield collected

from plants grown on flat soil. In scorzonera growing on ridges higher inulin yield was also reported for acreage unit.

Favorable effect on root plants growing on ridges upon their yielding is confirmed by the results of studies conducted by numerous authors [Saiful-Islam et al. 1998, Sady and Cebulak 2000, Wierzbicka et al. 2004, Konopiński 2008, Konopiński and Błazewicz-Woźniak 2008]. The well-formed ridges, providing less dense and more porous soil create good conditions for root growth and development. They also play the important role in protecting the soil from erosion phenomena, which increase as an effect of frequent cultivation treatments and crop chemicalization. The effect of increased cultivation frequency is also fast decomposition of organic substance and its decreased contents in the soil. Taking care of maintaining the high level of soil fertility, conservation tillage is introduced into vegetable plant agrotechnology, using intercrop plants for soil mulching. Plant mulches protect the soil from the activity of unfavorable external factors, as well as from moisture loss [Nyakatawa et al. 2001, Resende et al. 2005, Kęsik et al. 2006]. In scorzonera growing, intercrop plants: common vetch, phacelia and oats significantly increased the root yield and inulin yield from an acreage unit. Positive effect of intercrop plants upon plant yielding is confirmed by the results of studies conducted by many authors. Soil mulching increased the yield of beans [Skarphol et al. 1987], tomatoes [Masiunas et al. 1995], peas [Knott 1996], onions [Kęsik et al. 2000], carrots [Khatun and Farooque 2005], as well as chicory, scorzonera and salsify [Konopiński and Błazewicz-Woźniak 2008, Konopiński 2009]. The effect of intercrop plants putting into the soil is long-lasting, like that of organic manure [Jabłońska-Ceglarek and Zaniewicz 1994]. According to many authors [Błazewicz-Woźniak et al. 2001, Konopiński et al. 2001, Pięta and Kęsik 2007] the bio-matter putting into the soil, enhances the improvement of water-air relations, and it favorably affects the state of soil aggregation, its structure and biological activity.

The examined experiment factors, however, did not significantly influence the contents of inulin, protein and the dry matter share in scorzonera roots. These results are confirmed by earlier studies conducted by Konopiński [2008] on scorzonera.

CONCLUSIONS

1. Intercrop plants positively affected scorzonera yielding. Significant increase of root yield was obtained especially with oats.
2. Spring ploughing the intercrop bio-matter with soil significantly increased of total scorzonera root yield in comparison with pre-winter ploughing.
3. Growing of scorzonera on ridges significantly affected the increase of total root yield, as compared to growing on flat soil.
4. The examined experiment factors did not significantly affect inulin and protein contents, as well as dry matter share in the root.
5. The most advantageous growing combination of 'Duplex' scorzonera cultivar, as to the yield and nutritional value of roots was growing the plants on ridges, after spring ploughing the oats.

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WPLYW ROŚLIN MIĘDZYPLONOWYCH I ZRÓŻNICOWANEJ UPRAWY ROLI NA PŁON I WARTOŚĆ ODŻYWCZĄ KORZENI SKORZONERY (*Scorzonera hispanica* L.)

Streszczenie. Intensyfikacja upraw roślinnych jest bezpośrednim powodem pogorszenia właściwości gleb oraz warunków wzrostu i rozwoju roślin. W trosce o poprawę żyzności i struktury gleby do agrotechniki roślin ogrodniczych wprowadza się uprawę konserwującą, która ogranicza procesy degradacji środowiska glebowego. Doświadczenia polowe przeprowadzono w latach 2006–2008, na glebie płowej o nietrwalej strukturze. Rośliną doświadczalną była skorzonera (*Scorzonera hispanica* L.) odmiany 'Duplex'. W badaniach uwzględniono trzy rośliny międzyplonowe: wykę siewną, facelię błękitną i owies; dwa sposoby przedsięwziętej uprawy roli: a) zespół uprawek przedsięwziętych, siew roślin międzyplonowych (II dekada sierpnia), orka przedzimowa i wymieszanie zielonej masy z glebą, b) zespół uprawek przedsięwziętych, siew roślin międzyplonowych (II dekada sierpnia), orka wiosenna i wymieszanie masy roślinnej z glebą oraz dwie metody uprawy roślin: na redlinach i na płask. Wykazano istotnie korzystny wpływ wiosennego wymie-

szania międzyplonów z glebą, uprawy skorzonery na redlinach i mulczowania gleby owsem na plon korzeni ogółem. Badane czynniki doświadczenia nie miały natomiast istotnego wpływu na zawartość inuliny, białka i suchej masy w korzeniu skorzonery. Najkorzystniejszą kombinacją uprawową pod względem produktywności inuliny była uprawa skorzonery na redlinach po wiosennym wymieszaniu z glebą mulczu z owsa.

Słowa kluczowe: skorzonera, rośliny międzyplonowe, termin orki, redliny, inulina, białko

ACKNOWLEDGEMENTS

Research financed by Ministry of Science and Higher Education within the framework of project No 2P06R 014 29

Accepted for print – Zaakceptowano do druku: 28.06.2005