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INFLUENCE OF INTERCROP PLANTS AND VARIED TILLAGE ON YIELDS AND NUTRITIONAL VALUE OF SALSIFY (*Tragopogon porrifolius* L.) ROOTS

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Abstract. The field experiment was carried out in 2006–2008 on lessive soil developed from medium dusty loams. Salsify (*Tragopogon porrifolius* L.) of 'Mamut' cv. was the experimental species. The experimental design included three intercrop plants: common vetch, lace phacelia, and oats; two soil tillage ways: a) set of pre-sowing tillage operations, sowing the intercrop plants (mid of August), pre-winter ploughing, mixing the green matter with soil, b) set of pre-sowing tillage operations, sowing the intercrop plants (mid of August), spring ploughing, mixing the plant matter with soil; as well as two plant cultivation manners: on ridges and on flat soil. It was found that spring ploughing made to mix the intercrop biomass with the soil as well as cultivation of plants on ridges significantly increased the total salsify root yields. Significantly positive influence of intercrop plants on salsify root yields, inulin content, inulin yield, and dry matter content was also recorded. Considering the roots yield and their nutritional value, plants cultivated on ridges after spring ploughing and mulching with lace phacelia appeared to be the most beneficial salsify cultivation combination.

Key words: salsify, inulin, conservation tillage, ridges, intercrop plants

INTRODUCTION

Salsify (*Tragopogon porrifolius* L.) is a root plant of great nutritional and dietetic features. It is rarely cultivated, although deserves larger popularization and utilization in human's diet. Storage roots and young leaves are suitable for consumption. Salsify roots contain carbohydrates, proteins, fats, minerals: calcium, phosphorus, iron, and small amounts of vitamins: A, B_1, B_2, C, and PP [Wierzbicka 2002]. However, the most valuable component is inulin – fructane with pre-biotic properties that has a positive influence on digestive tract functions [Kolida et al. 2002]. The plant yielding and their nutritional value are determined by many factors, among which pre-sowing tillage and plant

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cultivation manner dominate. Tillage under root crops has to be scrupulous and deep, but also should take into account the elements of conservation tillage. The plant cultivation in ridges, which makes them good conditions for growth and development, has been recently revived in root crops cultivation [Babik 2000, Konopiński 2003]. Climatic changes, intensifying the cultivations, chemization and mechanization in crop production lead to a gradual soils degradation, hence the decrease of their productivity. In order to compensate the negative phenomena occurring in the nature and neighborhood of crops, the systems of conservation tillage that use intercrop plants for soil mulching and its protection, are introduced. Properly selected mulches can inhibit processes that degrade the soil environment and even make better yielding of crops. They have also an essential influence on microorganisms composition in soil [Pięta and Kęsik 2008].

The present study aimed at evaluating the yielding abilities of salsify grown on ridges and on flat soil using intercrop plants (common vetch, lacy phacelia, oats) for soil conservation.

MATERIAL AND METHODS

The field experiment was carried out in 2006–2008 on lessive soil developed from medium dusty loams. Salsify of 'Mamut' cv. was the experimental species. Completely randomized blocks method at four replications was used during the experiment. The experimental design included three intercrop plants: common vetch, lace phacelia, and oats; two soil tillage ways: a) set of pre-sowing tillage operations, sowing the intercrop plants (mid of August), pre-winter ploughing, mixing the green matter with soil, b) set of pre-sowing tillage operations, sowing the intercrop plants (mid of August), spring ploughing, mixing the plant matter with soil; as well as two plant cultivation manners: on ridges and on flat soil. The seeds were sown at the beginning of May at the amount of 20 kg·ha^{-1} and at 50 cm spacing 1.5 cm deep. Plant fertilization was following: 100 kg N·ha^{-1}, 100 kg P_2O_5·ha^{-1}, and 200 kg K_2O·ha^{-1}. Phosphorus-potassium nutrition was applied once before sowing, while nitrogen was applied at two doses: ½ before sowing and ½ post-crop. After seed sowing, salsify plantation was sprayed against weeds with herbicide Kerb 50WP. Fungicidal agents Bravo and Nimrod 25 were used to protect plants against fungal diseases.

The total yield of salsify roots and root nutritional value including inulin (indicated by High Pressure Liquid Chromatography – HPLC techniques), proteins, dry matter and inulin yield per a hectare, were determined in performed study.

Achieved results were statistically processed by means of variance analysis. The difference significance was estimated using Tukey's test for significance level $\alpha = 0.05$.

RESULTS

Total root yield. The total salsify root yield, regardless of experimental factors, amounted to 23.46 t·ha^{-1} (tab. 1). Ploughing had significant influence on salsify's yielding. The spring ploughing under salsify caused significant increase of root yield as

compared to pre-winter ploughing. In objects with spring ploughing, the mean total root yield was 25.12 t·ha^{-1}, while in objects with pre-winter ploughing 21.80 t·ha^{-1}. Plants cultivated on ridges also exerted significant influence on root yield size. The root yields harvested from that cultivation were higher by 1.76 t·ha^{-1} than those from cultivation on flat soil. The intercrop plants that were used for soil conservation, appeared to be very significant yield-forming factor.

Table 1. Total yield of salsify roots, mean from years 2006–2008 (in t·ha^{-1})
Tabela 1. Plon korzeni ogółem salsefii, średnio z lat 2006–2008 (w t·ha^{-1})

Soil tillage Uprawa roli	Cultivation of plants 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	18.41	24.72	24.45	20.05	21.91
	on flat soil na płask	15.37	25.86	20.25	25.29	21.69
	mean średnio	16.89	25.29	22.35	22.67	21.80
Spring ploughing Orka wiosenna	on ridges na redlinach	19.89	28.02	30.65	28.53	26.77
	on flat soil na płask	16.18	26.02	25.63	26.00	23.46
	mean średnio	18.04	27.02	28.14	27.27	25.12
Mean Średnio	on ridges na redlinach	19.15	26.37	27.55	24.29	24.34
	on flat soil na płask	15.78	25.94	22.94	25.65	22.58
	mean średnio	17.46	26.15	25.25	24.97	23.46

$LSD_{(0.05)}$ for: – $NIR_{(0,05)}$ dla:	
soil tillage – uprawy roli	1.33
cultivation of plants – uprawy roślin	1.33
intercrop plants – roślin międzyplonowych	2.66

When comparing to cultivation with no intercrops, all applied intercrop plants considerably affected the increase of salsify root yields. Among studied plant species, common vetch exerted the most positive influence on salsify yielding. In that case, the total root yield amounted to 26.15 t·ha^{-1}, while in cultivation with no intercrops – only 17.46 t·ha^{-1}.

Content of inulin in salsify roots. The average content of inulin in fresh matter of salsify roots was 15.17% (tab. 2). Varied soil tillage and plant cultivation did not any significant influence on that component content in experimental plants. The inulin concentrations were similar both in roots harvested from objects with pre-winter (15.15%), and spring ploughing (15.19%). Similarly, salsify cultivated on ridges and on flat soil contained almost the same levels of the fructane in roots. However, significant differences in the component concentration in roots were found due to intercrop plants applied. The highest quantities of inulin were recorded in plants cultivated on objects with

mulched lace phacelia – 15.72%, whereas considerably less – those from objects mulched with oats – 14.38%. Salsify cultivating with no plant mulches did not cause the decrease of inulin content in its roots (15.47%).

Table 2. The inulin content in salsify root, mean from years 2006–2008 (in %)
Tabela 2. Zawartość inuliny w korzeniu salsefii, średnio z lat 2006–2008 (w %)

Soil tillage Uprawa roli	Cultivation of plants 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	15.43	14.97	14.98	14.87	15.06
	on flat soil na płask	15.57	15.34	15.63	14.43	15.24
	mean średnio	15.50	15.16	15.31	14.65	15.15
Spring ploughing Orka wiosenna	on ridges na redlinach	15.39	15.42	16.03	14.37	15.30
	on flat soil na płask	15.50	14.69	16.24	13.86	15.07
	mean średnio	15.45	15.05	16.14	14.12	15.19
Mean Średnio	on ridges na redlinach	15.41	15.19	15.51	14.62	15.18
	on flat soil na płask	15.53	15.02	15.94	14.15	15.16
	mean średnio	15.47	15.10	15.72	14.38	15.17

$LSD_{(0.05)}$ for: – $NIR_{(0,05)}$ dla:		
	soil tillage – uprawy roli	n.s. – r.n.*
	cultivation of plants – uprawy roślin	n.s. – r.n.*
	intercrop plants – roślin międzyplonowych	0.76

n.s. – r.n.* – differences not significant – różnice nieistotne

Referring to inulin concentration in salsify roots, cultivation on flat soil after spring ploughing and mulching with lace phacelia, was the most favorable (16.24%).

Protein content in salsify roots. Regardless of studied experimental factors, protein content in salsify roots was 3.39%, on average (tab. 3). Applied varied tillage and plant cultivation methods, as well as intercrops had not any significant influence on the components in roots. Protein content in plants from objects with pre-winter ploughing amounted to 3.41%, while with spring ploughing 3.35%. Slightly higher protein quantity was found in roots harvested from plots with cultivation on a flat soil (3.43%) than on ridges (3.34%). Intercrops, as an element of conservation tillage, did not differentiate the protein content in salsify roots.

Considering the interaction of applied experimental factors, salsify cultivated on ridges after pre-winter ploughing and soil mulching with oats, appeared to be the most advantageous combination in a view of protein content that amounted to 3.64%, on average.

Table 3. Content of proteins in salsify root, mean from years 2006–2008 (in %)
Tabela 3. Zawartość białka w korzeniu salsefii, średnio z lat 2006–2008 (w %)

Soil tillage Uprawa roli	Cultivation of plants 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	3.37	3.42	3.30	3.64	3.43
	on flat soil na płask	3.36	3.49	3.47	3.25	3.39
	mean średnio	3.37	3.46	3.39	3.45	3.41
Spring ploughing Orka wiosenna	on ridges na redlinach	3.22	3.24	3.38	3.13	3.24
	on flat soil na płask	3.59	3.38	3.37	3.47	3.45
	mean średnio	3.41	3.31	3.38	3.30	3.35
Mean Średnio	on ridges na redlinach	3.30	3.33	3.34	3.39	3.34
	on flat soil na płask	3.48	3.44	3.42	3.36	3.43
	mean średnio	3.39	3.39	3.38	3.38	3.39

$LSD_{(0.05)}$ for: – $NIR_{(0,05)}$ dla:

soil tillage – uprawy roli	n.s. – r.n.*
cultivation of plants – uprawy roślin	n.s. – r.n.
intercrop plants – roślin międzyplonowych	n.s. – r.n.

n.s. – r.n.* – differences not significant – różnice nieistotne

Dry matter content in roots. The mean dry matter content in salsify roots was 22.3% (tab. 4). Different dates of mixing the intercrop biomass with the soil had not considerable impact on that feature. However, roots harvested from objects with pre-winter ploughing contained little more dry matter (22.4%) as compared to those with spring ploughing (22.2%). Similar situation was observed in the case of plant cultivation manners. Plants grown on ridges were characterized by slightly higher dry matter content (22.4%) than those cultivated on a flat soil (22.2%). Instead, a significant influence of intercrop plants on that trait was found. Among studied intercrops, the soil mulching using lace phacelia had the greatest influence on dry matter increase in salsify roots (up to 22.9%). Introducing the oats organic matter into the soil had much less effects on that parameter (21.5%).

Productivity of inulin. The yield of inulin from 1-ha-area salsify plantation amounted to – regardless of studied experimental factors – about 3.56 $t \cdot ha^{-1}$, on average (tab. 5). Applied various ploughing tillage and intercrops used for mulching exerted significant influence on inulin yields from the plantation. It was found that remaining the intercrop biomass for winter on a field and ploughing it in spring, had positive effects on yields size of inulin contained in harvested salsify roots. In that tillage combination, the in ulin yield was 3.81 $t \cdot ha^{-1}$, while after managing the intercrops before win-

Table 4. Content of dry mass in salsify roots, mean from years 2006–2008 (in %)
Tabela 4. Zawartość suchej masy w korzeniu salsefii, średnio z lat 2006–2008, (w %)

Soil tillage Uprawa roli	Cultivation of plants 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	23.1	22.8	22.7	21.7	22.6
	on flat soil na płask	22.5	21.8	23.0	21.2	22.1
	mean – średnio	22.8	22.3	22.8	21.4	22.4
Spring ploughing Orka wiosenna	on ridges na redlinach	22.4	22.2	22.8	21.6	22.3
	on flat soil na płask	22.6	21.9	23.0	21.3	22.2
	mean – średnio	22.5	22.0	22.9	21.5	22.2
Mean Średnio	on ridges na redlinach	22.8	22.5	22.8	21.7	22.4
	on flat soil na płask	22.5	21.8	23.0	21.3	22.2
	mean – średnio	22.7	22.2	22.9	21.5	22.3

$LSD_{(0.05)}$ for: – $NIR_{(0,05)}$ dla:

soil tillage – uprawy roli	n.s. – r.n.*
cultivation of plants – uprawy roślin	n.s. – r.n.
intercrop plants – roślin międzyplonowych	0.72

n.s. – r.n.* – differences not significant – różnice nieistotne

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

Soil tillage Uprawa roli	Cultivation of plants 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	2.83	3.70	3.67	2.99	3.30
	on flat soil na płask	2.39	3.96	3.16	3.64	3.29
	mean – średnio	2.61	3.83	3.42	3.32	3.30
Spring ploughing Orka wiosenna	on ridges na redlinach	3.06	4.31	4.90	4.11	4.10
	on flat soil na płask	2.50	3.82	4.15	3.61	3.52
	mean – średnio	2.78	4.07	4.53	3.86	3.81
Mean Średnio	on ridges na redlinach	2.95	4.00	4.29	3.55	3.70
	on flat soil na płask	2.45	3.89	3.66	3.63	3.41
	mean – średnio	2.70	3.95	3.98	3.59	3.56

$LSD_{(0.05)}$ for: – $NIR_{(0,05)}$ dla:

soil tillage – uprawy roli	0.37
cultivation of plants – uprawy roślin	n.s. – r.n.*
intercrop plants – roślin międzyplonowych	0.81

n.s. – r.n.* – differences not significant – różnice nieistotne

ter – 3.30 t·ha^{-1}. The tillage methods did not considerably differentiate that trait; however, higher yields were recorded when salsify was grown on ridges (3.70 t·ha^{-1}) rather than on flat soil (3.41 t·ha^{-1}).

Intercrops applied for soil mulching had significantly positive influence on inulin yield per area unit. All examined plant species, regardless of the date of mixing with the soil, invoked a significant increase of inulin yield. Among studied mulches, that made of lace phacelia revealed the greatest impact (3.98 t·ha^{-1}), then common vetch (3.95 t·ha^{-1}), and the least – the oats (3.59 t·ha^{-1}). The lowest inulin yield was recorded in salsify cultivation with no mulching (2.70 t·ha^{-1}).

Considering the interaction of all experimental factors, salsify cultivation on ridges after spring mulching with lace phacelia appeared to be the most advantageous tillage combination, in which inulin yield amounted to 4.90 t·ha^{-1}, on average.

DISCUSSION

The three-year studies upon the influence of varied tillage and plant cultivation as well as conserving tillage using mulches made of common vetch, lace phacelia, and oats revealed that these factors had significant effect on phacelia yielding as well as its nutritional value. It was found that spring ploughing to cover and mix the intercrop biomass with the soil positively affected the on the total salsify roots yield. Root yields from objects ploughed in spring amounted to 25.12 t·ha^{-1}, which was significantly higher than after pre-winter ploughing (21.80 t·ha^{-1}). Salsify is recommended to grow on ridges. The yield of roots from plants cultivated using that method was considerably higher (24.34 t·ha^{-1}) than that from flat soil (22.58 t·ha^{-1}). Significantly the highest inulin yields were also recorded in salsify cultivated on ridges; however, the component content in the plant roots did not considerably depend on the plant cultivation method. The ridge and flat growing had not significant effects on inulin and protein contents in scorzonera roots [Konopiński 2003]. The plant cultivation on ridges makes very good conditions for root growth and development as a result of lower soil density and increase of its porosity. It is particularly advantageous cultivation method for root crops. Many authors [Saiful-Islam et al. 1998, Sady and Cebulak 2000, Konopiński 2003, Wierzbicka et al. 2004, Konopiński and Błażewicz-Woźniak 2008] confirmed that in their earlier studies.

The soil protection against erosion and natural environment degradation are particularly important elements of crop production. These negative processes intensify due to crop production and mechanization intensification. The soil conserving cultivation using plant mulches is one of method for preventing these effects. Plant mulches cover the soil in winter and early spring against negative outer conditions, as well as moisture losses [Nyakatawa et al. 2001, Resende et al., 2005, Kęsik et al., 2006]. In the case of salsify, plant mulches made of common vetch, lace phacelia, and oats played an important role in increasing the root and inulin yields per area unit. Konopiński [2003] also recorded positive effects of common vetch and oats mulches on protein content in scorzonera cultivation. Many other authors confirmed positive influence of plant mulches on crop yielding and their quality. Mulching caused the increase of bean [Skarphol et al. 1987], tomato [Masiunas et al. 1995], pea [Knott 1996], onion [Kęsik et al. 2000,

Błażewicz-Woźniak et al. 2008], carrot [Khatun and Farooque 2004), chicory, and scorzonera yields [Konopiński and Błażewicz-Woźniak 2008]. The action of plant mulches is prolonged, as similar as that of manure [Jabłońska-Ceglarek and Zaniewicz 1994]. According to many authors [Dzienia et al. 1998, Błażewicz-Woźniak et al. 2001, Epperlein and Martinez-Vilela 2001, Konopiński et al. 2001, Pięta and Kęsik 2007], the intercrop biomass mixed with the soil contributes to the improvement of water-air balance, as well as it has a positive influence of the soil aggregation, its structure, and biological activity. However, intercrop plants introduced into the soil may also negatively affect the crops [Oleszek 1995].

Performed experiments revealed significant increase of total salsify root yield resulting from cultivation of plants on ridges after spring ploughing and soil mulching with lace phacelia.

CONCLUSIONS

1. The spring ploughing to cover and mix the intercrop biomass with the soil caused significant increase of total salsify root yield as well as inulin yield.
2. Plant cultivation on ridges considerably affected the increase of total salsify root yields as well as slight increase of inulin yield as compared to the cultivation on flat soil.
3. The intercrop plants exerted significant positive influence of salsify yielding, inulin content in roots, inulin yields, and dry matter content.
4. Considering the roots yield and their nutritional value, plants cultivated on ridges after spring ploughing and mulching with lace phacelia made up the most beneficial salsify cultivation combination.

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WPŁYW ROŚLIN MIĘDZYPLONOWYCH I ZRÓŻNICOWANEJ UPRAWY ROLI NA PLON I WARTOŚĆ ODŻYWCZĄ KORZENI SALSEFII (*Tragopogon porrifolius* L.)

Streszczenie. Doświadczenie polowe przeprowadzono w latach 2006–2008, na glebie płowej wytworzonej z gliny średniej pylastej. Rośliną doświadczalną była salsefia (*Tragopogon porrifolius* L.) odmiany 'Mamut'. W schemacie doświadczenia uwzględniono trzy rośliny międzyplonowe: wykę siewną, facelię błękitną i owies; dwa sposoby uprawy roli: a) zespół uprawek przedsiewnych, siew roślin międzyplonowych (II dekada sierpnia), orka przedzimowa, wymieszanie zielonej masy z glebą, b) zespół uprawek przedsiewnych, siew roślin międzyplonowych (II dekada sierpnia), orka wiosenna, wymieszanie masy roślinnej z glebą; dwie metody uprawy roślin: na redlinach i na płask. Stwierdzono, że orka wiosenna wykonana w celu wymieszania biomasy międzyplonów z glebą oraz uprawa roślin na redlinach istotnie zwiększały plon korzeni ogółem salsefii. Wykazano również istotnie korzystny wpływ roślin międzyplonowych na plon korzeni, zawartość inuliny oraz jej produktywność z jednostki powierzchni, a także na zawartość suchej masy w korzeniu. Najkorzystniejszą kombinacją uprawową pod względem plonowania i wartości odżywczej roślin była uprawa salsefii na redlinach, po orce wiosennej i ściółkowaniu gleby facelią błękitną.

Słowa kluczowe: salsefia, inulina, uprawa konserwująca, redliny, rośliny międzyplonowe

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