Scientific quarterly journal ISNN 1429-7264

Agricultural Engineering

2014: 4(152):135-142

Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2014.152.088

RESPONSE OF THE SELECTED VARIETIES OF COMMON OSIER (*SALIX VIMINALS*) TO ORGANIC AND MINERAL FERTILIZATION IN LIGHT SOIL

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ARTICLE INFO

Article history:
Received: September 2014
Received in the revised form: September 2014
Accepted: November 2014

Keywords:
willow tree
variety
mineral fertilization
compost
yield
biometric measurements

ABSTRACT

Research was carried out on light soil in 2010-2012 on plantations of a willow tree (*Salix viminalis* founded in Spring 2010. The objective of the paper was to assess a response of two cultivars – Sprint and Boks of common osier on organic and mineral fertilization in light soil. The experiment included two varieties - Sprint and Boks and three fertilization combinations: without compost 0, 10 and 20 t·ha^{-1} of dry matter of compost produced from urban greenery waste. In facilities under experiment the following were used every year in the form of mineral fertilizers: 100 kg N, 80 kg P_2O_5 and 100 kg·ha^{-1} K_2O. Detailed research included: the number of shoots on the plant, thickness of shoots on 10 cm height from the surface of soil and length of shoots and the yield of fresh and dry matter. Boks variety in all fertilization combinations formed less shoots on a plant but with a greater thickness and length in comparison to Sprint variety. Boks variety also characterized with greater production potential, reacted with higher increase of fresh and dry matter yield after the use of compost in 10 and 20 t·ha^{-1} doses compared to mineral fertilization.

Introduction

Biomass constitutes the source of renewable energy and may play a significant role in the energy balance of our country. Biomass for production of renewable energy may come from purposefully set permanent plantations of the selected species of native grasses, e.g. reed canary-grass, couch grass as well as introduced species e.g. maiden grass, prairie cordgrass and others (Golińska et al., 2012). Many authors (Dubas, 2003; Gradziuk, 2003; Szczukowski et al., 2004a) pay attention to favourable economic and ecological effects obtained at the cultivation of a willow tree for energy purposes. Kozak et al. (2004) think that a common osier may be cultivated in the entire country and factors restricting its cultivation are mainly water and nutrients deficiencies. The positive reaction of a common osier to mineral and organic fertilization, e.g. in the form of sewage sludge is proved by the research carried out by Nowak et al. (2011), Szczukowskiego et al. (2004a), MacPherson (1995), Szwedziak (2006). At the cultivation of a willow tree for enriching soil in nutrients,

by-products or waste, which are formed in various production processes, may be used. Composts produced from waste from greenery treatment and sewage sludge may be used for plant production (Styszko et. al., 2009; 2010; 2012), or waste which come from plant production (Denisiuk, 2006).

Material and methods

Experiment was set out in the Agricultural Experimental Station in Lipki near Stargard Szczeciński on mineral soil, of good rye complex, IV valuation class. Schematic representation of an experiment, which included two factors – various cloned varieties of a common osier (*Salix viminalis*) (Sprint, Boks) – (factor I) and compost doses – 0, 10 and 20 t·ha^{-1} of dry matter (factor II), was planned in the split-plot system in four repeats. In early spring 2010 after first spring cultivations, organic fertilization in the form of compost, which was mixed with soil in the depth of approx. 15 cm was applied. Compost was composed of: tree leaves, conifer needles, moss and cones. Chemical analysis of compost proved that it characterizes with the following content of macro-elements (g·kg^{-1}s·m): N - 9.54, P – 194.8, K – 354.0, Ca – 3497, M*g* – 291.2. pH in KCl was 6.78. Directly before planting of willow stem cuttings, uniform mineral fertilization was used for experimental purposes. Phosphorus dose was 80 kg·ha^{-1} P_2O_5 potassium – 120 kg·ha^{-1} K_2O_5, and nitrogen – 50 kg·ha^{-1}N. Fertilization with nitrogen in the dose of 50 kg·ha^{-1} was repeated when young plants achieved the height of approx. 10 cm after mechanical treatment. Mineral fertilization in provided doses was also used in the following years of research. Stem cuttings with length of approx. 20 cm was planted on 8th April 2010 in the distance between rows 70 cm and in the distance of 35 cm in a row. It was planted to a depth in which 2-3 buds were over the surface of soil. A favourable system of meteorological conditions after planting caused that stem cuttings have taken root in 100%. No diseases or pests were reported and in protection against damages by animals, experiment was fenced with a forest wire. In the year when the experiment was set out, shoots were not mowed after vegetation. Plantation was run in a three-year cycle. In each year after the vegetation was finished, biometric measurements were carried out and they covered: number of stems in a plant, thickness of stems at the height of 10 cm from the soil surface and the length of shoots. Yield of fresh and dry matter and content of dry matter was determined after three years of research. Willow was harvested in March 2013.

The obtained results were subjected to analysis of variance at the level of significance 0.05 and uniform groups were created with the use of Tuckey's test.

Discussion on results

The research which was carried out proved that plants of a willow tree form a small number of shoots if in the year when the plantation was set, their cutting is performed in order to initiate tillering in the following year. Bury and Czyć (2006) obtained similar results on plantations of a willow set out on organic and mineral soil.

In the first year of research, in relation to the facility, plants formed from 1.8 to 3 shoots. Average value in case of Sprint variety was 2.6 and in case of plants from Boks variety – 2.1 shoots for one rootstock. This difference was statistically significant (table 1).

Small number of shoots on a plant indicated high domination of first shoots, which form on planted stem cuttings. Confirmed values in the first year were not subject to explicit change in the following years. Statistical analysis proved that fertilization with compost had not essential impact on the number of shoots in a plant (table 1). Boks variety, which formed lower number of shoots, distinguished with their bigger thickness (table 2). In the year, when plantation was set, differences between varieties were not big, but they were statistically significant. In the following years differences increased in favour of Bok variety. Significant interaction between varieties and fertilization combinations were reported. In the first year of research on fertilized facilities, additionally treated with compost in doses 10 and 20 t·ha^{-1} the increase of shoots thickness was 42.0% and 65.9% for Sprint variety and 53.8 and 72.1 % for Boks variety. In the second year (2011) increases were respectively: 14.3% and 17.0% – for Sprint variety and for Boks variety only after using 20 t of compost – 8.4%. In the last year of research (2012) in which average thickness of shoots was 26.5 mm (Sprint variety) and 40.4 mm (Boks variety) fertilization favourably influenced the shoots thickness but interaction between doses and fertilization combinations were determined. For Sprint variety in the facility treated with mineral fertilizers, average thickness of shoots was 24.5 mm, whereas for Boks variety – 35.3 mm. In combinations with additional compost in doses 10 and 20 t·ha^{-1}, increase of average thickness of a shoot was: 8.5 and 15.3% for Sprint variety and 22.7 and 21.0% – for Boks variety (table 2). Average results from three years of research prove that additional fertilization with compost favourably influenced the shoots thickness and shoots in relative numbers were similar in case of both varieties, although shoots of Boks variety were thicker.

Table 1
The structure of a number of shoots per plant (pc)

Variety	Doses of compost	Years			Mean
		2010	2011	2012	
	(t·ha^{-1})		(item)		
Sprint	0	2.0	2.6	3.0	2.5
	10	3.0	2.6	2.0	2.5
	20	2.8	1.8	2.2	2.3
	Mean	2.6	2.3	2.4	2.4
Boks	0	1.8	1.8	1.6	1.7
	10	2.2	2.2	1.6	2.0
	20	2.2	1.8	1.4	1.8
	Mean	2.1	1.9	1.5	1.8
Mean for doses of compost	0	1.9	2.2	2.3	2.1
	10	2.6	2.4	1.8	2.3
	20	2.5	1.8	1.8	2.1
$NIR_{0.05}$ – $LSD_{0.05}$					
Varieties	(I)	0.3	0.4	0.5	0.2
Doses of compost	(II)	n.i	n.i	n.i	n.i
Interaction	IxII	n.i	n.i	n.i	n.i
	II x I	n.i	n.i	n.i	n.i

Table 2
The structure of shoots thickness (mm)

Variety	Doses of compost	Years			Mean
		2010	2011	2012	
	(t·ha^{-1})		(mm)		
Sprint	0	13.5	22.3	24.5	20.1
	10	19.2	25.5	26.6	23.7
	20	22.4	26.1	28.3	25.6
	Mean	18.4	24.6	26.5	23.1
Boks	0	14.0	29.7	35.3	26.3
	10	21.5	28.1	43.3	30.9
	20	24.1	32.2	42.7	33.0
	Mean	19.9	30.0	40.4	30.1
Mean for doses of compost	0	13.8	26.0	29.9	23.2
	10	20.4	26.8	35.0	27.3
	20	23.3	29.2	35.0	29.3
$NIR_{0.05}$ - $LSD_{0.05}$					
Varieties	(I)	1.3	0.8	1.9	1.9
Doses of compost	(II)	n.i	n.i	n.i	n.i
Interaction	IxII	1.8	2.7	2.9	3.9
	IIx I	2.6	6.5	5.6	5.1

The obtained results concerning the length of shoots (table 3), in relation to the research combination indicate that this property, similarly to the shoots thickness depended on the properties of a variety and the applied fertilization. In the year of planting stem cuttings, plants developed shoots with average length of 229.9 cm (Sprint variety) and 242.7 cm (Boks variety). In case of plants of both varieties completing the mineral fertilization with doses 10 and 20 t·ha^{-1} of compost favourably influenced the increase of shoots (table 3). Doubling the length of shoots was reported in the second year of vegetation (2011) since their average length was 472.8 cm in the facility with a maple of Sprint variety and 495.6 cm – in the facility with Boks variety maple. Fertilization with compost, similarly to the previous year (2010) caused obtaining considerably longer shoots. In the facility with a dose 10 t·ha^{-1} of compost shoots were longer by 45.2 cm for Sprint variety and by 48.6 cm for Boks variety. Increasing a dose of compost by further 10 t·ha^{-1} caused obtaining longer shoots by 5 cm and 14 cm (respectively Sprint and Boks variety). In the third year (2012) the increase was lower and the obtained lengths of shoots were at the average – 562.5 cm (Sprint variety and 650.0 cm – (Boks variety). In this year, efficiency of fertilization with compost was considerably lower, but statistically significant. Mean results from three years of research prove that the additionally used fertilization with compost favoured formation of shoots for the investigated varieties, which is confirmed by statistical analysis (table 3). Styszko, Fijałkowska and Sztyma (2009) using in their research 15 t·ha^{-1} of fresh mass of compost and hydrofoska 15 fertilizer which provides 90 kg·ha^{-1} N, 90 kg K_2O and 90 kg·ha^{-1} P_2O_5 and double dose, reported a positive reaction of a willow tree, expressed with greater lengths and thickness of shoots, but a significant interaction between varieties and fertilizer combination was reported.

Table 3
The structure of shoots length (cm)

Variety	Doses of compost	Years			Mean
		2010	2011	2012	
	($t \cdot ha^{-1}$)		(cm)		
Sprint	0	228.6	441.4	542.6	404.2
	10	217.2	486.2	568.6	424.0
	20	244.0	491.2	576.4	437.2
	Mean	229.9	472.9	562.5	421.8
Boks	0	232.2	458.4	633.8	441.5
	10	241.2	507.0	673.6	473.9
	20	254.8	521.4	642.6	472.9
	Mean	247.2	495.6	50.0	462.8
Mean for doses of compost	0	230.4	449.9	588.2	422.9
	10	229.2	496.6	621.1	449.0
	20	249.4	506.3	609.5	455.1
$NIR_{0.05}$ - $LSD_{0.05}$					
Varieties	(I)	18.4	14.6	11.6	9.2
Doses of compost	(II)	n.i	n.i	n.i	n.i
Interaction	IxII	22.7	27.8	19.3	19.5
	IIxI	24.5	30.4	21.6	22.6

Energy willow characterizes with high production potential (Dubas, 2003; Szczukowski et al., 2004b). According to many authors (Szczukowski et al., 2004a; Ignatowicz and Styszko 2012; Styszko et al., 2012) willow shows extensive reaction to habitat conditions, especially to water conditions and fertilization with organic and mineral substances. Ignatowicz and Styszko (2012) confirmed that there is a varied reaction of willow varieties to fertilization, in particular to nitrogen. Based on the obtained results they selected a group of varieties which has the highest yield in case of a dose of 180 $kg \cdot ha^{-1}$ of nitrogen and a group of varieties which has the highest yield in case of 55 $kg \cdot ha^{-1}$. In the authors' own research the obtained yield was – 118.0 $t \cdot ha^{-1}$ of fresh matter and 70.7 $t \cdot ha^{-1}$ – of dry matter for Sprint variety and respectively – 156.5 and 97.5 $t \cdot ha^{-1}$ – for Boks variety (tab. 4). This set proves that Boks variety in comparison to of Sprint variety, forming less shoots on a plant, but thicker and longer, it characterized with higher production potential. Plants of a willow tree showed a positive reaction to fertilization with compost used in the experiment. Using 10 tonnes of dry matter of compost per 1 ha, mean increase of fresh matter yield by 31.1% and dry matter by 26.7% was obtained in comparison to the facility with only mineral fertilization. In facilities treated with a dose of compost of 20 $t \cdot ha^{-1}$ the increase of the yield was respectively – 39.1% and 33.5%. Statistical analyses which were carried out confirmed significance of interaction between varieties and the applied fertilization combinations. In the facility with only mineral fertilization (100 kg N, 80 kg P_2O_5 and 120 $kg \cdot ha^{-1}$ K_2O) cloned plants of Sprint variety had yield at the level of 102.6 $t \cdot ha^{-1}$ of fresh matter and 65.0 $t \cdot ha^{-1}$ – of dry matter, and Boks variety – 156.5 $t \cdot ha^{-1}$ and 75.2 $t \cdot ha^{-1}$. Using additionally 10 $t \cdot ha^{-1}$ of the compost the increase of fresh matter yield by 17.2% and dry matter by 6.5% – (Sprint variety) and respectively – 43.1% and 44.0% – (Boks variety). For facilities, where 20 $t \cdot ha^{-1}$ of compost was applied, the increase was: for Sprint variety – 27.9% and 20.0%, and for Boks variety – 48.8% and 45.1%. The content of dry matter was within

57.5-63.2%. Fertilization with compost influenced insignificant decrease of its content of dry matter (table 4).

Table 4
The yields of raw and dry matter (t·ha^{-1}) and the content of dry matter (%)

Variety	Doses of compost	Fresh matter	Dry matter	Content of dry matter
		(t·ha^{-1})		(%)
Sprint	0	102.6	65.0	63.0
	10	120.2	69.2	57.5
	20	131.2	78.0	59.4
	X	118.0	70.7	60.1
Boks	0	119.8	75.2	62.8
	10	171.4	108.3	63.2
	20	178.3	109.1	61.2
	X	156.5	97.5	62.4
Mean for doses of compost	0	111.2	70.1	63.1
	10	145.8	88.8	60.4
	20	154.6	93.6	60.3
$NIR_{0,05}$ - $LSD_{0,05}$				
Varieties	(I)	3.0	1.4	
Doses of compost	(II)	4.7	2.9	
Interaction	IxII	4.8	3.0	
	IIxI	6.7	4.2	

In the research, which was carried out, Styszko et al. (2009, 2010) confirmed a positive effect of the compost itself and compost used in combination with mineral fertilizers on the obtained yields of willow biomass. According to Gostomczyk (2014) organic products may constitute alternative for artificial fertilizers in the energy willow cultivation. Philip (1997) says that a willow tree of *Salix viminalis* type characterizes with strong increase of biomass. According to this author, biomass of one hectare of two-year willow collects 350 kg of nitrogen and 80 kg of phosphorus each year.

Conclusions

1. Boks willow variety compared to Sprint variety forms less shoots but with greater thickness and length.
2. Fertilization with compost of 10 and 20 t·ha^{-1} doses of dry matter will favourable influence the thickness and length of shoots and the obtained increases are not significantly equal in case of investigated varieties.
3. Boks variety compared to Sprint variety characterizes with higher production potential and shows more extensive reaction to additional fertilization with compost from urban greenery waste, used on the background of mineral fertilization (100 kg N, 80 kg P_2O_5 and 120 kg K_2O per 1 ha).

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REAKCJA WYBRANYCH ODMIAN WIERZBY KRZEWIASEJ (*SALIX VIMINALIS*) NA NAWOŻENIE ORGANICZNO-MINERALNE W WARUNKACH GLEBY LEKKIEJ

Streszczenie. Badania przeprowadzono na glebie lekkiej w latach 2010-2012 na plantacji wierzby (*Salix viminalis*) założonej wiosną 2010 roku. Celem badań była ocena reakcji dwóch odmian – Sprint i Boks wierzby krzewiastej na nawożenie organiczno-mineralne w warunkach gleby lekkiej. W doświadczeniu uwzględniono dwie odmiany – Sprint i Boks oraz trzy kombinacje nawozowe: bez kompostu 0, 10 i 20 t·ha^{-1} suchej masy kompostu wyprodukowanego z odpadów zieleni miejskiej. Na obiektach doświadczenia corocznie stosowano w formie nawozów mineralnych: 100 kg N, 80 kg P_2O_5 i 100 kg·ha^{-1} K_2O. Badania szczegółowe obejmowały: ilość pędów na roślinie, grubość pędów na wysokości 10 cm od powierzchni gleby i długości pędów oraz plonu świeżej i suchej masy. Odmiana Boks na wszystkich kombinacjach nawozowych wykształciła mniej pędów na roślinie, ale o większej grubości i długości w porównaniu do odmiany Sprint. Odmiana Boks, także charakteryzowała się większym potencjałem produkcyjnym, reagowała większym przyrostem plonu świeżej i suchej masy, po zastosowaniu kompostu w dawkach 10 i 20 t·ha^{-1}, na tle nawożenia mineralnego.

Słowa kluczowe: wierzba, odmiany, nawożenie mineralne, kompost, plony, pomiary biometryczne