Scientific quarterly journal ISNN 2083-1587; e-ISNN 2449-5999

Agricultural Engineering

2015: 4(156):43-49

Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2015.156.150

ROOT BIOMASS DISTRIBUTION IN AN ENERGY WILLOW PLANTATION[1]

Tadeusz Juliszewski[a], Dariusz Kwaśniewski[b*], Marcin Pietrzykowski[c], Paweł Tylek[d], Józef Walczyk[d], Bartłomiej Woś[c], Justyna Likus[c]

[a] Institute of Machinery Management, Ergonomics and Production Processes
[b] Institute of Agricultural Engineering and Informatics
[c]Institute of Forest Ecology and Silviculture, Department of Forest Ecology and Reclamation, Faculty of Forestry
[d] Institute of Forest Utilization and Forest Technology
University of Agriculture in Krakow
[*]*Contact details:ul. Balicka 116B, 30-149 Kraków, e-mail: dariusz.kwasniewski@ur.krakow.pl*

ARTICLEINFO

Article history:
Received: September 2015
Received in the revised form: October 2015
Accepted: November 2015

Keywords:
energy willow
rootstock
willow root

ABSTRACT

The objective of the paper was to determine the distribution of energy willow roots biomass, which is significant for developing a structure of a machine for reclamation of fields after their cultivation. The scope of work covered the research studies carried out on 30 roots-tocks of energy willow, which come from a plantation set up in 2003 in the Department of Production Engineering and Power Energy of the University of Agriculture in Krakow. A vertical scope of thick roots with a diameter above 30 mm was at the average 42.3 cm and the horizontal one was – 51.6 cm. Total fresh mass of rootstock (roots + butt log) was 18.61 kg at the average, and the mass of thick roots was – 7.75 kg.

Introduction

An interest in energy cultivations has been observed in Poland for a few years and production and collection of biomass of fast-growing species has been shaped as a new trend in agricultural production. Energy willow is the most popular energy plant cultivated in Poland.

In 2009, the area of willow cultivation in Poland was 6,160.4 ha (Gajewski, 2010).Biomass willow plantations are cultivated for 20-25 years (Szczukowski et al., 2004; Dubas and Tomczyk, 2005; Stolarski, 2009). When the production is completed, a plantation should be properly eliminated. During the elimination process the following operations are indispensable: removal (uprooting) of roots from soil and fragmentation of roots into pieces which will not grow again. Fragmentation of roots and leaving them in soil is a more

[1] The paper was written as a part of the scientific project no. PBS2/A8/26/2014 funded by the State Research and Development Centre as a part of the Applied Research Program path A

beneficial solution because a poor range of nutrients resulting from biomass collection may be thus compensated (Kowalkowski and Olejarski, 2013).

Willow roots grow from the so called rootstocks, which can be used on mother and annual plantations in the number of 40 thousand pieces per hectare (32 thousand without technological routes) in the space of 0.75×0.33 m each. In case of longer production cycles (3 and 4-year long) sprout cuttings should be planted in two rows (0.5×0.75 m) in lanes spaced 1.25-1.5 m or 2.8 m (technological routes) which gives 18-20 thousand of pieces of sprout cuttings per hectare (Dubas, 2003; Szczukowski et al., 2004; Dawson, 2007). Mechanical unrooting of rootstocks as a method of elimination of a plantation is a labour and energy consuming operation. The research show that unrooting rootstocks in a 15-year old plantation (ploughing with a tractor with a plough of own construction and manual removal) requires approx. 213 man-hour for plantation elimination on the area of 1 ha (Stolarski et al., 2008).

A relevant evaluation of the scope and distribution of roots and the size of rootstock biomass size is a significant element in developing effective economic and technological methods of elimination of a plantation. Determination of root biomass is difficult from the point of view of methodology and it is also labour consuming. The spread of roots of a single tree may be very extensive. Thus, the applied methods of indirect research and direct methods based on evaluation with the use of empirical formulas give most frequently similar effects (Böhm, 1985). Methods of research may be divided generally into indirect and direct, field and laboratory (Böhm, 1985). Indirect manners use relations between the biomass of the above ground and underground part of a tree. These relations are presented with the use of allometric equations and a R/S ratio (root to shoot ratio) and require measurements of only the above ground part of a tree (Bijak and Zasada, 2007). However, for a proper evaluation of the biomass size and distribution on account of developing a technology of plantation elimination in specific conditions of habitat and land, a method based on the measurement of roots taken out straight from soil seems to be the most appropriate one.

Objective, scope and methods

The objective of the paper was to determine the distribution of energy willow roots biomass, which is vital on account of developing a structure of a machine for reclamation of a plantation.

The scope of work covered the research studies carried out on 30 rootstocks of energy willow, which come from a plantation set up in the Department of Production Engineering and Power Energy of the University of Agriculture in Krakow.

An experimental area of an energy willow plantation is in total 0.36 ha and is divided into plots. The plantation is 12 years old (set up in 2003).

Characteristics of the set up plantation:

- the plantation was set up on the soil: loamy sand (fractions: 75% of sand, 15% of silt, 10% clay particles),
- the field, which for the last few years has been set aside, was sprayed with Roundup herbicide in a dose of 6 $l \cdot ha^{-1}$ and then in October 2003 a disc ploughing was carried out, in November the field was ploughed on the depth of 35 cm,

– fall planting of sprout cutting was performed in December 2003 (2nd December 2003) and spring planting in April 2004 (22nd April 2004),
– sprout cuttings 25 cm long and with average thickness of 8 mm were planted manually - two energy willow clones were planted and marked with numbers 1052 and 1059,
– sprout cuttings were planted every 50 cm and interrows were 70 cm wide, planting of approx. 28, 400 pcs·ha^{-1},
– treatment of a plantation in the first year was performed with a mechanical and chemical method (sprayer and chemical product Bladex in a dose of 4 l·ha^{-1} and a hoe); during vegetation double manual weeding was necessary,
– the plantation was cultivated extensively (without mineral fertilization),
– in the following years, no treatments related to treatment and fertilization were performed, only a manual harvesting every 3 years.

In order to realize the objective of the study, a hydraulic head for replanting of big trees by OPTIMAL company aggregated with a front loader was used to collect willow root balls (fig. 1). Four blades of a replanter move on the curvilinear trajectory and enable complete loosening of a root ball and departing from the undisturbed root (Tylek, 2008). A volume of a single ball root was 0.34 m^3 and the width of the upper part was 1.14 m and the depth of 0.75 m. After the root balls were wrapped in a jute matt and steel net, they were transported to the storage and then soil was removed by a pressure washer – acquiring root systems thereby.

Figure 1. Excavation of a rootstock of energy willow with a head for replanting of big trees

After the root system was washed by the water stream, the following parameters of the root system (fig. 2) were determined: diameter of the rootstock in the rootstock at the soil height (D0), diameter of the main root in the thickest place (Dg), the biggest measured vertical range (ZGkr) and the horizontal one (ZPkr) of roots, the highest vertical range (ZGkrg) and the horizontal one (ZPkr) of roots, the biggest vertical range (ZGkrg) and a horizontal one (ZPkrg) of the main coarse roots) (diameter > 30 mm) (fig. 2). The total

mass of roots in fresh state (Mkc) and mass of the main coarse roots (> 30 mm) was determined with the use of an electronic hook scale MENSOR WM150P2.

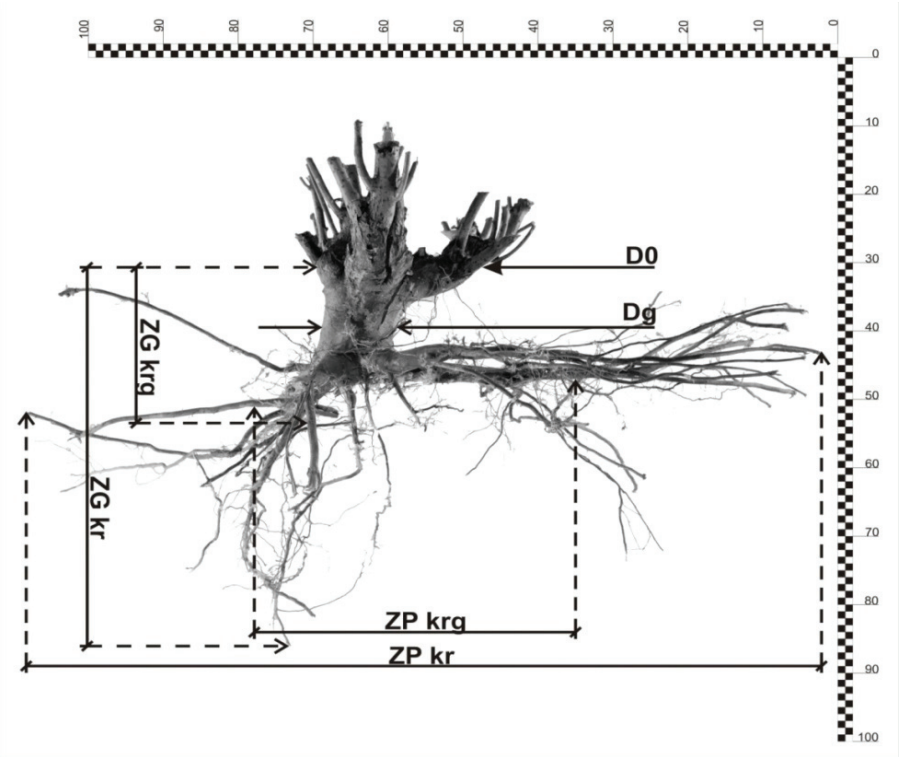

Figure 2. Parameters which characterize distribution of roots in soil

The paper was written as a part of the scientific projectno PBS2/A8/26/2014 "Development of new technology and a functional model of a machine for reclamation of fields after cultivation of energy willow". Project is carried out by a scientific and industrial consortium:

1. University of Agriculture in Krakow – a project leader:
– Faculty of Forestry (Department of Forest Work Mechanization, Department of Forest Ecology and Reclamation),
– Faculty of Production Engineering and Power Energy (Institute of Machinery Management, Ergonomics and Production Processes, Institute of Agricultural Engineering and Informatics),
2. Industrial Institute of Agricultural Machines in Poznań
– Scientific Laboratory of Agricultural Machines,
– A Team for Research and Development of Machines for Obtaining Renewable Energy of Farm and Storage Work.
3. PROMAR Spółka z o.o [Promarlmitedliabilitycompany] in Poznań.

Researchresults

Parameters that characterize distribution of energy willow roots in soil were presented in table 1. Diameter of a rootstock of a willow in the root neck (D0) was at the average of 20.9 cm and the diameter of the main root in the thickest place was (Dg) – 11.2 cm.

Table 1
Parameters concerning distribution of energy willow root

Parameter	Symbol	Average	Min.	Max.	Standard deviation
		(cm)			
Diameter of a rootstock in the root neck at the height of soil	D0	20.9	11.7	36.7	5.8
Diameter of the main root in the thickest place	Dg	11.2	6.3	16.5	2.6
The biggest measured vertical range of coarse roots	ZGkr	58.3	27.5	87.5	12.8
Measured vertical range of the main coarse roots	ZGkrg	42.3	18.5	69.5	17.1
The biggest measured horizontal range of roots	ZP kr	75.2	53.5	96.0	11.6
Measured horizontal range of thick roots	ZPkrg	51.6	31.0	80.5	11.7

Average vertical range of roots (ZGkr) was 58.3 cm and the horizontal range (ZPkr) – 75.2 cm. And the average, the vertical range of thick roots (ZGkrg), significant for developing a structure of a machine for reclamation of fields after cultivation of energy willow, it was 42.3 cm and the horizontal range was (ZPkrg) – 51.6 cm. The maximum verticalrange of roots (ZGkr) was 58.3 cm and the horizontal range (ZPkr) – 75.2 cm.

In natural forest ecosystems, root biomass constitutes usually approx. 20% of the total biomass of trees (Lieth and Whittaker, 1975). In willow plantations, which are subject to short cutting cycles, it may be considerably higher. In case of a *Salix viminalis*plantation set up in Great Britain, the roots biomass constitutes from 35 to 60% of the total biomass (Martin and Stephens, 2006). The mass of roots of energy willow determined based on the research was presented in table 2.

Table 2
Mass of energy willow roots in soil

Parameter	Symbol	Average	Min.	Max.	Standard deviation
			(kg)		
total mass of fresh roots (root +butt log)	Mkc	18.61	5.70	51.43	12.12
Mass of fresh main coarse roots (diameter > 30 mm)	Mkrg	7.75	1.18	20.62	5.63

Fresh mass of the root system of a willow was at the average of 18.61 kg, including the mass of main coarse roots (diameter above 30 mm) – 7.75 kg. The obtained results may be recognized as high. In comparison to those values, obtained fresh biomass of the root system of single pine trees aged 12 to 23 years on the KWB "Bełchatów" dumps and the sand excavation site 'Szczakowa" was from 0.43 to 43.45 kg (Pietrzykowski et al., 2010). In conditions of North America (USA, state of New York) an evaluated underground biomass of a willow plantation *Salix dasyclados*(dry mass) in chronological sequence from 5 to 19 years was within 2.9 to 5.7 $t \cdot ha^{-1}$ for coarse roots (> 2 mm), from 3.1 to 10.2 $t \cdot ha^{-1}$ for the main root and from 5.6 to 9.9 $t \cdot ha^{-1}$ for fine roots (< 2 mm) (Pacaldo et al., 2012).

Statements and conclusions

1. Distribution of willow roots biomass in a plantation is significant from the point of view of theneeds for developing new technology and a functional model of a machine for reclamation of the plantation. In this case distribution of roots is of cognitive nature and the obtained results constitute precious information for constructors.
2. A vertical range of the main coarse roots with a diameter above 30 mm was at the average 42.3 cm and the horizontal one of thick roots was – 51.6 cm.
3. Total fresh mass of a rootstock (roots + sprout cuttings) was within 5.70 to 51.43 kg and at the average it was 18.61 kg, and the average mass ofcoarse roots was 7.75 kg (from 1.18 to 20.62 kg).
4. The obtained results concerning parameters of distribution of energy willow roots in soil and their mass constitute a basis for further research within this scope.

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ALOKACJA BIOMASY KORZENI WIERZBY ENERGETYCZNEJ

Streszczenie. Celem pracy było określenie rozmieszczenia biomasy korzeni wierzby energetycznej, które jest istotne ze względu na opracowanie, w ramach projektu badawczego, konstrukcji maszyny do rekultywacji pól po jej uprawie. Zakresem pracy objęto badania przeprowadzane na 30 karpach wierzby energetycznej, pochodzących z plantacji założonej w 2003 roku na Wydziale Inżynierii Produkcji i Energetyki Uniwersytetu Rolniczego w Krakowie. Zasięg pionowy korzeni grubych o średnicy powyżej 30 mm wynosił średnio 42,3 cm, a zasięg poziomy korzeni grubych – 51,6 cm. Całkowita świeża masa karpy (korzenie + odziomek) wynosiła średnio 18,61 kg, natomiast masa korzeni grubych – 7,75 kg.

Słowa kluczowe: wierzba energetyczna, karpy, korzenie wierzby