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Willow clones with high biomass yield in short rotation coppice in the southern region of Tohoku district (Japan)

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ABSTRACT

The present study was conducted to select willow (*Salix* spp.) clones with a high potential for use as biomass energy crops in the southern region of Tohoku district in Japan. Cuttings of 8 willow clones were planted on an abandoned farmland near Sendai (av. annual temp., 10.9 °C) in March 2006, grown throughout the year and cut back in late December 2006 to resprout from the remaining stools in March 2007. The biomass yield in December 2007, after the first growing season, was highest in *Salix pet-susu* clone KKD, followed by *Salix pseudolinearis* clone FXM and *Salix sachalinensis* clone SEN. The biomass yield on December 2008, after the second growing season, was again highest in clone KKD followed by clone FXM, *S. pet-susu* clone HB471 and *S. sachalinensis* clone SEN; the average annual yield of dry mass after the second growing season being 3.09, 2.58, 2.17 and 1.85 kgDM plant^{-1} for the clones in this order. Plant growth form differed among the clones. Clones FXM and SEN had several shoots of almost uniform base diameter, whereas clones KKD and HB471 showed plagiotropic growth with one thick and several thin shoots. The calorific values of dried stem segments were similar among clones, ranging from 18.7 to 19.1 kJ g^{-1}. The dried stem segments contained 78.9–81.2 wt.% hollocellulose, 27.2–32.3 wt.% lignin and 2.1–4.0 wt.% extractives with ethanol-benzene, depending on clones. Based on these results, we could select four clones (KKD, FXM, HB471 and SEN) suitable for biomass production by SRWC in this area.

1. Introduction

Woody crop biomass is gaining popularity worldwide as an energy resource. It can be used to provide energy by regional demand, for local heat generation and electricity [for reviews [1,2,3]], although in most cases it is still not economically vital without direct governmental support. A woody crop plantation can contribute in reducing the rate of CO_2 build-up by sequestering carbon and by displacing fossil fuels. There have been many research and industrial activities on the production of fast growing woody species such as willows, popular and eucalyptus trees for the purpose of energy, wood products and wood pulp [3]. In Europe and North America, a willow species, *Salix viminalis*, has been used for biomass production in the short-rotation willow coppice (SRWC). Studies have been made to search for willow species and clones with the

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highest biomass productivity in SRWC [4,5], since multiple species or clones of a willow plantation should be grown to minimize the risk of pest and disease infection.

In Japan, however, there have been few trials on the production of fast growing woody species. The abundance of abandoned farmlands by a Japanese acreage-reduction policy offers great opportunities for the production of woody biomass as an energy resource in Japan. Since many willow species grow indigenously in Japan, native willow populations would be good resources for selection of species or clones with good performance (high biomass productivity, easy management, tolerance against infection and insect attack).

We plan to establish SRWC in the southern region of Tohoku district (the northern part of Honshu Island), Japan. For this purpose, we need to use willow species or clones that are well adapted to the climactic conditions in this region. In the present study, we collected 8 clones of willows mainly from Tohoku and Hokkaido districts, Japan, cultivated them for three years and determined their biomass productivity. Four clones were selected as suitable for biomass production in SRWC from the results of their growth, calorific values and chemical compositions.

2. Materials and methods

2.1. Site characteristic

Willow trees grown as shrubs were cultivated for two growing seasons (2007 and 2008) after one establishment season (2006) on an abandoned farmland at Miyagi Prefectural Forestry Technology Institute (38°28.4′N, 140°52.7′E) located 25 km north of Sendai, Japan. The site was 20 × 10 m^2 and gently sloping and open to the west. Soil of the site was Andosol (fine volcanic ash soil), a predominant soil type in Japanese upland fields, which is low in available P but rich in K and Ca. This site had been previously used for the nursery of Japanese cedar, and then left as a grassland for several years until the start of this study.

The area had an average annual temperature of 10.9 °C and an annual average precipitation of 1293 mm [6]. The mean total precipitation during the growing season (March to November), which was calculated from the regional data over a period of 22 years from 1979 to 2000 was 1011 mm.

2.2. Willow clones and cultivation

The willow clones used in the present study were obtained in 2005 from the Botanical Gardens of Tohoku University (Sendai, Miyagi Prefecture, Japan), Fukushima Agricultural Technology Center (formerly, Fukushima Agricultural Experimental Station, Yanagawa Branch, Yanagawa-cho, Fukushima Prefecture, Japan) and Oji Paper Forest Museum (Kuriyama-cho, Yubari-gun, Hokkaido, Japan), excepting one clone (*S. sachalinensis* clone SEN) which was obtained from a natural stand grown in Sendai area, Japan. The majority of the clones were native to Tohoku and Hokkaido districts, Japan, but one clone (*S. viminalis* clone Rs82) originated in Hungary. Details of the clones are summarized in Table 1.

Since the cuttings were supplied as genetic resources, the number of cuttings was limited to less than ten cuttings. They were planted and grown as nursery stands designed for the propagation of willows until the spring of next year (2006).

Cultivation started on March 16, 2006. Soils were rototilled one week before plantation. Willow cuttings 30 cm in length and 0.7–2 cm in diameter were prepared from the nursery stands. The number of planted cuttings was varied for each clone depending limited numbers of cutting available from the nursery stands. The exact numbers of cuttings were 24 for HB471, 26 for KKD, 36 for I-82, 38 for Y-118, 48 for FXM, 36 for SEN, 10 for HB831 and 18 for Rs82. Plots were 2 m in width and 10 m in length, and they were closely-lined. Cuttings were planted in double rows for each clone by placing the cuttings at 0.5 m on the row and leaving 1 m between the rows with 0.5 m margins in each plot. When the number of cuttings for one clone was insufficient to fill the plot, cuttings of another clone were planted to avoid empty spaces in each plot. Therefore, the calculated density was 20,000 plants per ha. The experiment was conducted with only one trial without repetition, because the number of cuttings available for respective clones was limited. The cuttings were planted by hand at a depth of about 15 cm.

The plot was not fertilized at the start of cultivation, since its soil was rank, allowing vigorous growth of weeds soon after planting willow cuttings. The plot was weeded with a power weeder every month from May to September. Fertilization was applied when necessary so as not to cause yellowing of leaves. This was conducted by applying two briquettes (ca. 32 g in total) of fertilizer (Maruyama No.1, N6:P4:K3, Nihon Ringyo Hiryo Co., Ltd, Tokyo Japan) per plant every three months in the growing season starting at June 2006.

Table 1 – List of willow clones used in this study.

Salix spp.	Clone	Institute which supplied the clone	Origin of the clone
S. pet-susu	HB831	Tohoku University, Botanical Gardens	Gunma Prefecture, Japan (JP)
	HB471	Tohoku University, Botanical Gardens	Akita Prefecture, JP
	KKD	Tohoku University, Botanical Gardens	Miyagi Prefecture, JP
	I-82	Oji Paper Forest Museum	Hokkaido, JP
	Y-118	Oji Paper Forest Museum	Oji Paper Forest Museum
S. pseudolinearis	FXM	Fukushima Agricultural Technology Center	Unknown
S. sachalinensis	SEN	–	Sendai, Miyagi Prefecture, JP
S. viminalis	Rs82	Tohoku University, Botanical Gardens	Hungary