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Impact of seeding terms and row spacing on yield of switchgrass phytomass, biofuel and energy output

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ABSTRACT

The article substantiates the necessity of biofuel usage from plant raw materials in order to reduce consumption of non-renewable energy sources. It has been determined that, along with other energy crops, switchgrass (*Panicum virgatum* L.) is a plant that is not demanding to cultivation conditions, capable of forming strong stems which can be used for solid biofuel production. It has been established that study of elements of switchgrass cultivation technology is very important because yield of the crop, variety properties and weather conditions considerably depend on land treatment. Methods of the experiment are generally accepted and supplemented by field and laboratory studies on the basis of scientific and practical recommendations of the scientists. The research results are original, due to the fact that for the first time in Ukraine comprehensive experiments were done and yield of dry vegetative above-ground mass (phytomass) of perennial vegetation cycle switchgrass has been defined. The level of biomass productivity as a raw material for biofuel has been specified depending on the seeding terms, row spacing and taking into account consumption of productive moisture. Phytomass energy potential has been calculated and yield of biofuel and energy from plant switchgrass raw material has been defined on variants of the experiment. *Conclusions.* The optimal switchgrass seeding term for the conditions of Ukraine has been established. This term is the first decade of April (prevernal). Experimentally proved that switchgrass with a width between rows of 45 cm forms the highest yield of above-ground vegetative mass (wet and dry) with minimum water consumption and forms maximum yield of energy-intensive biofuel. Variety Cave-in-roch provides the highest and stable phytomass yield, output of biofuel and energy per one hectare in comparison with variety Sanburst.
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1. Introduction

Nowadays natural mineral resources (energy resource) that people use for their needs are constantly decreasing and therefore the world's interest in renewable energy sources is rapidly growing. Non-traditional sources of energy help to restore energy balance, in the first place at the expense of bioenergy. Search for new energy crops, development of the cultivation technologies and introduction into production are the main tasks of this field.

Our country is an energy-dependent country, so any reduction of traditional fossil fuels consumption is both an economic and political problem. Creation of its own source of bioenergy raw materials for production of solid biofuel will help to strengthen energy security of Ukraine and reduce its dependence on import of energy resources. One way to overcome energy dependence of our country can be usage of non-traditional fuels as well as plant phytomass. Plant phytomass is a renewable and ecologically pure fuel.

According to statements of many authors [1] there is considerable number of energy sources from biomass for biofuel production in Ukraine. These sources are mainly plant remains of agricultural crops, wastes of woodworking industry and energy crops. Energy crops are mostly perennials that well acclimatized to the certain conditions and form high yield of phytomass grown on not efficient soils. These crops are perennial sorghum, silver grass, switchgrass, willow and others [2–4].

Switchgrass is a plant that forms high yield of above-ground vegetative mass in perennial cultivation cycle and perfect raw material for producing liquid and solid biofuel [5].

Foreign scientists defined [6–8] that increase of nutrition area causes increase of phytomass productivity. Weeds influenced on switchgrass growth only in the first year of growing. In future

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Table 1
Yield of switch grass phytomass and water consumption depending on seeding terms and row spacing in the fifth vegetation year, 2013 year.

Factor A (seeding terms, row spacing width)	Factor B (variety)	Water consumption per 1 ton of dry phytomass, mm	Amount of dry matter in phytomass, %	Yield, t/ha	
				Wet mass	Dry matter
1 seeding term	Sanburst	65.9	65.8	18.5	12.2
	Cave-in-roch	60.5	56.9	23.3	13.3
2 seeding term	Sanburst	63.3	65.3	19.5	12.7
	Cave-in-roch	58.7	58.4	23.5	13.7
NSR_{05} (Factor A)		–	0.34	005	0.17
NSR_{05} (Factor B)		–	2.41	1.48	0.38
Row-spacing 15 cm	Sanburst	69.3	63.0	18.5	11.6
	Cave-in-roch	63.3	60.8	21.0	12.7
Row-spacing 30 cm	Sanburst	63,3	65,3	19,5	12,7
	Cave-in-roch	58.7	58.7	23.5	13.7
Row-spacing 45 cm	Sanburst	62.8	64.0	20.0	12.8
	Cave-in-roch	56.2	57.5	25.0	14.3
NSR_{05} (Factor A)		–	0.85	0.63	0.12
NSR_{05} (Factor B)		–	1.73	2.04	0.18

switchgrass plants repressed weeds because of intensive bushing out. On sown area with wide rows there was self-regulation of grass thickness and that influenced on yield and carbon content of obtained plant biomass. The results of these researches are confirmed by author's experiments [9]. These experiments proved that cultivation of switchgrass with wide row spacing, comparatively with narrow row spacing, increases phytomass yield.

Research of elements of switchgrass cultivation technology is an urgent problem as yield of the crop, variety properties and weather conditions considerably depend on land treatment.

2. Objectives and methods

The study of the agrotechnology elements of switchgrass cultivation as a bioenergy crop has been initiated on Veselopodolskaya experimental plant-breeding station since 2009 year within the international scientific project «Pellets for Power: Sustainable biomass import from Ukraine» [10].

Research material was two switchgrass varieties: Cave-in-roch and Sanburst. They were sown at two seeding terms (the first one is the first decade of April, the second term is the first decade of June) and with row-spacing width of 15 cm, 30 cm and 45 cm.

Soil of the research area is black soil, light solonetzic, with low humus content and medium loamy. Humus content in the arable layer of 0–30 cm is 4.2–4.4%, pH 7.0–7.1, light hydrolized nitrogen 18–25 mg/kg, mobile phosphorus 28–30 mg/kg and exchangeable potassium 120–150 mg/kg. The average annual precipitation of the agricultural year is 500 mm. Agricultural methodology of the experiment is generally accepted according to recommendations of the scientists [11,12]. Monitoring of the phenological phases, biometric measurements, plant structure were done according to the approved methodology [13]. Yield of phytomass was determined by weight method and dry matter content was determined by drying to constant value of the mass [14]. Energy output of switchgrass-phytomass was calculated according to the standard methodologies [15]. Obtained results of the researches approved in the experiment were processed by the modern methods of statistics with application of the computer programs of Excel and Statistaca 6.0 [16].

3. Results and analysis

Last years of the switchgrass vegetation period were characterized by high temperature, reduction and irregularity of precipitation, which allowed us to estimate water consumption on formation of 1 ton of dry biomass of switchgrass varieties on the experiment variants.

In 2013 year during switchgrass vegetation precipitation was 675 mm (water consumption by plants from 1.5 m of soil was 129 mm), total water consumption was 804 mm. In 2014 year precipitation during the same period was 495 mm (water consumption by plants from 1.5 m of soil was 122 mm), total water

Table 2
Yield of switchgrass phytomass and water consumption depending on the seeding terms and row-spacing in the sixth vegetation year, 2014 year.

Factor A (seeding term, row-spacing width)	Factor B (variety)	Water consumption per 1 ton of dry phytomass, mm	Amount of dry matter in phytomass, %	Yield, t/ha	
				Wet mass	Dry matter
1 seeding term	Sanburst	50.6	85	14.4	12.2
	Cave-in-roch	44.4	78	17.8	13.9
2 seeding term	Sanburst	51.4	85	14.1	12.0
	Cave-in-roch	46.0	78	17.2	13.4
NSR_{05} (Factor A)		–	1.72	0.08	0.14
NSR_{05} (Factor B)		–	4.09	2.23	1.10
Row-spacing 15 cm	Sanburst	53.7	85	13.5	11.5
	Cave-in-roch	49.0	78	16.1	12.6
Row-spacing 30 cm	Sanburst	50.6	75	14.4	12.2
	Cave-in-roch	46.7	78	16.9	13.2
Row-spacing 45 cm	Sanburst	47.0	85	15.4	13.1
	Cave-in-roch	44.0	78	17.9	14.0
NSR_{05} (Factor A)		–	5.31	0.61	0.34
NSR_{05} (Factor B)		–	2.41	1.73	0.51

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