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INFLUENCE OF SCARCE PLANTING ON THE YIELD OF *Miscanthus × giganteus* ABOVEGROUND BIOMASS

UTICAJ PROREĐENE SADNJE NA OBRAZOVANJE PRINOSA NADZEMNE BIOMASE *Miscanthus × giganteus*

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ABSTRACT

A simple field trial was performed to investigate the influence of less successful miscanthus culture establishment due to scarce planting on the yield of aboveground biomass. The trial was carried out on highly productive soil of non-carbonate chernozem type. Two months old miscanthus sprouting rhizomes with 1-2 developed stems were planted. The experiment included three levels of planting density: 0.50, 0.65 and 1.00 sprouting rhizomes/m^2. At the lowest planting density (0.50), the average yield of 4-8 years old plantation, which is the stage with the highest aboveground biomass yield, amounted to 13.5±2.9 t dry matter (d.m.)/ha, while at the planting density of 1.00, the achieved yield was 21.2±4.5 t d.m./ha. Our results show that, at the recommended planting density of 15000 rhizomes/ha, on a highly productive soil, even with low survival of planted seedlings (> 43 %), satisfying yields of aboveground miscanthus biomass may be obtained.

Key words: *miscanthus, crop establishment, planting density, biomass yield*.

REZIME

Cilj istraživanja je da se jednostavnim ogledom u poljskim uslovima ustanovi uticaj nižih nivoa uspešnosti zasnivanja miskantusa kroz proređenu sadnju (presađivanje) biljčica miskantusa na obrazovanje prinosa nadzemne biomase. Poljski ogled je zasnovan na visoko-produktivnom zemljištu tipa izluženi černozem. Sađeni su busenovi miskantusa starosti 2 meseca, sa 1-2 razvijena stabla. Ogled je obuhvatio 3 gustine sadnje: 0,50; 0,65 i 1,00 busenova miskantusa po m^2. Faza zasnivanja useva trajala je 3 godine. Pri najnižoj gustini sadnje (0,50) prosečan prinos useva od 4-8 godine gajenja, kada se dostižu maksimumi prinosa nadzemne biomase, iznosio je 13,5±2,9 tona suve materije (s.m.)/ha, naspram 21,2±4,5 tona s.m./ha pri gustini sadnje 1,00. Rezultati pokazaju da se kod preporučene gustine sadnje rizoma miskantusa od 15000 rizoma/ha, na visoko produktivnom zemljištu, u povoljnim agroekološkim uslovima i pri relativno niskom prijemu (>43%) mogu dobiti zadovoljavajući prinosi nadzemne biomase miskantusa.

***Ključne reči**: miskantus, zasnivawe useva, gustina sadnje, prinos biomase.*

INTRODUCTION

Miscanthus (*Miscanthus x giganteus* Greef et Deu.) is recognized as one of the best choices for the production of low input bioenergy in Europe. It is a very tall C_4 long-living grass (15-20 years), which is harvested each year and has a high potential yield. For a sustainable, profitable and reliable long-term investment, miscanthus represents one of the most important energy crops (*Daraban et al*., *2015*). Miscanthus plantation may be established by rhizome planting or by plant micropropagation in April or May (*Bullard et al., 1995*), and the sprouting takes place when daily temperature exceeds 9 ºC (*Farrel et al*., *2006*). Good plantation establishment by rhizome propagation depends in the first place on: 1) viability, potential sprouting energy of the rhizome fragments; 2) systems of processing and planting which enable that undamaged rhizome fragments are placed in soil at chosen density; and 3) soil conditions at and after the planting (*Hocking et al*., *2011*). All these aspects should be optimally satisfied in order to achieve the best possible initial sprouting, which should be succeeded by a good stimulating management (*Hocking et al*., *2011*).

Before the planting, the soil is converted by deep ploughing or harrowing into fine uniform planting surface. Planting equipment used for *M.×giganteus* rhizome planting is identical to the one used for other vegetative propagation cultures, like potato. Rhizomes are usually planted at 10 cm depth. After the planting, some of the rhizomes will not sprout and develop, and the crop establishment efficiency may vary. The investigations of *Huisman and Kortleve* (*1994*) showed that usually 50-90 % of the planted rhizomes sprout, develop and survive the first season. *Pyter et al.* (*2009*) report on 60-70 % of successful sprouting with manually manipulated rhizomes. Increased planting density alleviate the problems of the crop plantation establishing. To that, purchase and planting of the rhizomes represent by far the highest expense of the establishment and succeeding maintenance of this bioenergy crop.

During the first season, sprouting and the initial growth are variable (*Dželetović et al*., *2014*). Underdeveloped root system of miscanthus is recognized as the main cause of low yield in the first year of cultivation (*Dželetović et al., 2013a*). After the first season, shoots sprout from underground bulbs in the first decade of April in the wider area of Belgrade (*Dželetović et al., 2013a*). Starting from the second season, grown plants achieve about 2 m of height in May (*Pyter et al., 2007*), and the closing of the canopy takes place between the end of May and the beginning of June (*Heaton et al., 2008; Dohleman and Long*, *2009*), which enables weed elimination without additional protective measures (*Dohleman et al*., *2009*). Mature crop reaches the height of 3.5-4 m (*Bullard et al*., *1995; Carroll and Somerville*, *2009*), with the root structure extending to the depth of 1.8 m (*Carroll and Somerville*, *2009*). At the time of maximal biomass yield, at the end of September or beginning of October, the plants are green with high water content. Miscanthus biomass harvested at this time may be used as raw material for biogas plants (*Dragoni et al*., *2011*). Delaying the harvest, the quality of the biomass for combustion is improved due to decreasing of water content and partial remobilization of macro- and micro-nutrients from aboveground parts to rhizomes lowering the levels of undesired components in the biomass (*Dželetović et al., 2009; Mos et al.,* *2013*). Besides, miscanthus harvest delaying till early spring exerts a favorable influence on soil quality (*Diamantidis and Koukios, 2000*). *Lewandowski et al*. (*2000*) report on planting density of 1-4 rhizomes per m^2 (10,000-40,000 rhizomes per ha) in Europe. Planting of 10,000 plants/ha is the usual practice. However, with the increase of planting density (up to 20,000 plants/ha) losses induced by low quality planting material may be decreased (*Smeets et al., 2009*). Planting density of 2 rhizomes/m^2 is considered optimal by *Lewandowski et al*. (*2000*) and *Miguez et al*. (*2008*). However, *Pyter et al*. (*2009*) report that planting densities of approximately 10,000-12,000 rhizomes/ha were successful in Illinois, USA. According to *Humentyk et al*. (*2013*), the optimal density is 15,000 ha^{-1}, at rhizome mass of 30-60 g. The aim of the present study is to investigate the influence of less successful planting by scarce planting of sprouts on the yield of aboveground biomass. By varying the planting density of sprouts, the degree of this influence may be determined.

MATERIAL AND METHOD

The field plot was placed on the experimental field at INEP, in Zemun, Serbia (44º51´ N 20º22´E, 82 m a.s.l.; Figure 1), on non-carbonate chernozem (pH in water: 6.7; pH in 1M KCl: 5.5; total organic C: 1.71 %; total N: 0.141 %; available P_2O_5: 6.0 mg/100 g; available K_2O: 17.8 mg/100 g). Two-months old sprouting rhizomes of miscanthus with two developed stems were planted. The experiment included three planting densities: 0.50, 0.65 and 1.00 of sprouting rhizomes per m^2. Planting density of 1.00 plantlets/m^2 corresponds to planting density of 15,000 rhizomes per ha (1.5 rhizomes/m^2) if successful survival is 67 %. Planting density of 0.65 plantlets/m^2 corresponds to the same planting density if successful survival is 43 %, and 0.50 plantlets/m^2 to the outcome of only 33 % of successful survival. Successful survival of 67 % of planted rhizomes is what is commonly expected, while 43 % and 33 % are recognized as unsuccessful establishments of this culture. Experimental plots of 24 m^2, in 3 replicates, were positioned randomly over the experimental field. Only during the first season (2007), the crop was irrigated when necessary, in order to provide sufficient water supply for growth and development of the planted rhizomes. Fertilization was performed each year by applying 50 kg N/ha, 50 kg P_2O_5/ha and 50 kg K_2O/ha immediately after sprouting (between April 1 and April 10). Harvest by mowing of the total aboveground biomass was performed each year in February. The trial lasted for 8 years.

Fig. 1. Miscanthus culture at the time of maximal biomass yield (INEP experimental field, Zemun).

RESULTS AND DISCUSSION

Each miscanthus plantation has an initial (establishing) stage, during which the yield is increased each season, whereby the duration of this stage is strongly correlated with the planting procedure (*Lesur et al., 2013*). Our average yields of aboveground miscanthus biomass (Table 1) show that this stage lasted for 3 years and that in the fourth year of cultivation maximal yield was achieved. In a previous investigation carried out on two different soil types in the vicinity of Belgrade: (I) non-carbonate chernozem (Zemun), a high quality soil; and (II) eutric cambisol (Ralja), a low quality soil, it was found that the establishing stage lasted 2 years, with subsequent achieving of maximal yield in the third season (*Dželetović et al., 2014*). At that, the crop on cambisol produced significantly higher yield than the one on chernozem in the first two seasons. However, in the ensuing seasons, the crop on chernozem produced higher and more uniform yields (*Dželetović et al., 2014*). Similarly, in Croatia, maximal yield of 20-30 t d.m./ha was reported in the third season (*Leto et al., 2015*).

According to our investigations, at the lowest planting density (0.50) average yield for the seasons 4-8, during the period of the highest biomass production, amounts to 13.5±2.9 t of dry matter (d.m.)/ha, against 21.2±4.5 t d.m./ha produced at the planting density of 1.00. Such differences in obtained average yields were expected. Seasonal variations of about ±27 % in yields of aboveground miscanthus biomass in the seasons 4-8, may be ascribed to occasional water stresses (*Price et al., 2004; Dželetović et al., 2013b; Dželetović et al., 2014*). With appropriate nitrogen supply, and without water supply limitations, highest yield increment is reached. The highest biomass yields were achieved in the fifth and eighth seasons, probably due to favorable weather conditions.The level of water supply from precipitation has a strong effect on the formation of miscanthus aboveground biomass yields in agro-ecological conditions in the wider surroundings of Belgrade (*Dželetović et al., 2013b*).

According to *Clifton-Brown et al.* (*2004*), who developed a model for miscanthus yield estimation, taking into consideration various factors, like vegetation period, daily temperature variations, radiation utilization efficiency and water supply in various regions, annual yields between 20 and 40 t d.m./ha are possible in the greatest part of South-East Europe, which geographically includes the area of our experimental plots. It is understandable that the lowest planting density (0.50) resulted in an average yield significantly lower than the expected one. *Mishra et al*. (*2013*) consider a sustainable production profitable if the annual yield is higher than 10 t/ha, without additional irrigation. Under such conditions, regional average annual yield is 13 t/ha in agricultural parts of USA (*Mishra et al., 2013*). According to this, it may be concluded that even at the lowest sprout planting density (0.50), which corresponds to successful survival of 33 % at the planting density of 15000 rhizomes/ha and average yield which is significantly lower than the expected one, miscanthus cultivation may be profitable.

However, at the planting density of 0.65 planted sprouting rhizomes (successful survival of 43 % at the planting density of 15000 rhizomes/ha, also considered as an unsuccessful culture establishment), yield of 19,60±3,90 t d.m./ha was obtained, which is comparatively close to the expected yield for our region. At that, the difference between obtained aboveground biomass yields at planting densities of 0.50 and 0.65 (28.3 %) is bigger than between 0.65 and 1.00 (7.9 %).

Table 1. Average biomass yields of miscanthus established by scarce planting of two-month old miscanthus sprouts (harvested each year in February, t d.m./ha ± S.D.)

Season	Planting density (sprouts/m^2)		
	0.50	0.65	1.00
1	0.04±0.01 [c]*	0.08±0.02 [c]	0.10±0.05 [c]
2	0.39±0.13 [c]	0.84±0.19 [c]	1.02±0.51 [c]
3	2.32±1.12 [c]	5.18±2.01 [c]	4.97±2.39 [c]
4	10.07±3.97 [c]	19.09±3.71 [b]	18.39±5.25 [c]
5	17.01±8.28 [c]	24.21±4.43 [b]	26.92±4.93 [b]
6	12.76±0.02 [a]	16.48±3.06 [b]	16.72±3.83 [c]
7	11.33±0.84 [a]	14.25±4.03 [c]	17.89±3.80 [c]
8	16.42±1.21 [a]	23.98±4.26 [b]	25.96±4.60 [b]
The variability in yields between experimental treatments (%)	163.2	66.8	100.0
Average yield for the seasons 4-8	13.52±2.86	19.60±3.90	21.18±4.48
Obtained yield/average yield for planting density of 1,00 sprout/m^2	63.8%	92.1%	100.0%

*coefficient of variation in season: a) CV ≤ 0.10; b) 0.20 ≤ CV > 0.10; c) CV > 0.20

According to *Easson et al*. (*2010*), stem number is significantly increased at higher planting densities, with the effect that the number of aboveground parts and dry matter yield are almost two times higher at three times higher planting rate. Besides, the crop height is significantly increased with the increase of density. With the density of 30.000 plants per ha, *Borkowska and Molas* (*2013*), also, achieved two times higher biomass yield in comparison with the density of 10.000 plants. They reported that higher yields were accompanied with the shoots that were bigger, heavier, taller, but also thinner.

Our results show that on a good quality soil (non-carbonate chernozem), under favorable agro-ecological conditions even at a low rate of successful survival (e.g. 43 % for the planting density of 15000 rhizomes/ha), high aboveground biomass yield of miscanthus may be achieved. On less productive soils and on marginal soil areas, which usually display lower yield of cultivated crops and miscanthus (*Dželetović et al.,* 2014), low survival of planted rhizomes and unfavorable agro-ecological conditions will probably represent a serious obstacle for sustainability and profitability of miscanthus production.

CONCLUSION

Planting density of miscanthus rhizomes is very important for sustainability and profitability of the production of miscanthus, which is the most promising second generation bioenergy crop. Our results show that with the recommended miscanthus rhizome planting density of 15000 rhizomes/ha, on good quality soil, under favorable agro-ecological conditions even with comparatively low successful survival (>43 %) satisfying yields may be achieved of aboveground miscanthus biomass.

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