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INTRODUCTION OF TALL GRASSES IN SERBIAN AGRICULTURAL PRODUCTION AND USING BIOMASS AS AN ALTERNATIVE FUEL

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Abstract

This research involved four perennial species belonging to the family of grasses (fam. Poaceae) characterized by intensive annual vegetative biomass growth and stalk height of above two meters. These are rush wheatgrass (Thinopyrum ponticum), switch grass (Panicum virgatum), elephant grass (Arundo donax) and miscanthus (Miscanthus × giganteus). These species originate from a large geographical area and are well adapted to various agro-ecological conditions. They are suitable for growing on soils with low natural fertility, on which most cultivated plants fail. The produced biomass (fresh or dry) is used to obtain gaseous, liquid and solid biofuels. Owing to their high tolerance to soil conditions, they are increasingly used for phytoremediation of devastated surfaces in the process of recultivation. During the vegetation season, these species incorporate significant quantities of carbon dioxide and other gases from the atmosphere. Production technology for these plants is simple and can be implemented using standard agricultural mechanization. Highest investments are required in the first year, when crops are established, with production costs significantly dropping in subsequent years. According to data from our own investigations, as well as results of other authors, costs for establishing crops amount to 4,000-4,500 EUR/ha, depending on the species. Biomass yields in the year of establishing are relatively low and do not cover production costs, but from the second or third year, high yields that justify the investment in growing these energy crops are realized. Depending on the

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species, as well as the maintaining of crops, established plants can be used for up to twenty years, which in the end fully justifies growing tall grasses for producing biofuels, but also for phytoremediation of devastated soils.

Key words: *tall grasses, agricultural production, biomass yield, alternative fuel, production costs.*

Introduction

The family of grasses (*Fam. Poaceae Barnhart*) encompasses annual and perennial species of natural and seeded lawns, forests (bamboo) and arable land. Today, grasses grow among spontaneous flora and on arable surfaces on all five continents, including the Antarctica (*Reynolds*, 2016). From the dawn of civilization, they played an important role for the human community, and for thousands of years they are grown and used for food for humans and domesticated animals.

The future significant growth of the human population will present a huge problem to discover and apply new technological solutions to produce food and energy, as well as protect the environment. Scientists predict that in 2050 utilization of food and energy will double (*Oljača et al.,* 2007). Global quantities of fossil fuels, the main source of energy, are limited. On the other hand, the constantly growing utilization of fossil fuels significantly increases quantities of harmful gasses in the atmosphere. There is a growing global interest in obtaining fuel from alternative sources. One of the directions is the use of plant mass as a renewable source of clean energy.

The global problem of availability of energy sources and concern about inevitable climate changes occurring as a result of the emission of greenhouse gases have imposed the need for more environmentally-friendly energy sources. Moreover, conventional energy sources have difficulties to match increasing demands of energy consumption (*Hashem et al*., 2013). One of the forms of renewable energy sources is biomass of energy crops. This group of field crops comprises species whose annual production of biomass per unit area can provide sufficient quantities of raw materials for obtaining biofuels.

Research to date has shown that perennial grasses are a very good raw material for obtaining bio fuels. These species have high photosynthesis activity and produce high yields of maximum efficiency biomass. Due to high annual stalk growth (over two meters), they are frequently referred to as tall grasses.

Owing to a series of positive production traits in recent decades tall grasses are becoming increasingly interesting as energy crops. Their fresh biomass serves for obtaining gaseous and liquid bio fuels, and when dry, for producing pellets and briquettes. Investigations by *Dickeduisberg et al*. (2017) have shown that by annual above ground biomass yield and obtained methane, these species can compare to maize. Investigating the application of various agro-technical measures for biomass growth, these authors conclude that in their years of full production these species are crops very good for commercial production of bio fuels. As fuels, they fully exclude the use of maize for these purposes, emphasizing that they are better adapted to unfavorable agro-ecological conditions.

While researching biological characteristics and the relationship between species and agro-ecological conditions, scientists have singled out several species of perrenial grasses as the best energy species. Following species should be emphasized: rush wheat grass (*Thinopyrum ponticum*), switch grass (*Panicum virgatum*), reed canary grass (*Phalaris arundinacea*), common reed (*Pharagimites communis*), elephant grass (*Arundo donax*) and miscanthus (*Miscanthus ×giganteus*). Work on the breeding of various wild forms of these species, has created varieties with following favorable characteristics: intensive annual above ground biomass growth, upright stalks over two meters tall that regenerate well after mowing and can be grown under different climate and soil conditions. Mentioned species develop a strong root system and perennial rhizomes deep underground that are protected against freezing and can be grown also in areas with cold winter sand longer periods of frost.

Being highly productive plants with a perennial life cycle, certain species are introduced into production in areas with a continental climate, from northern Europe and American the northern hemisphere, to Australia in the southern hemisphere. In the mentioned climate belt most species are grown on various types of soils, from sandy, loamy, to heavy clayey. They also thrive on dry as well as wet and occasionally flooded soils. They are very tolerant to the reaction of the soil solution. It is possible to grow them on acid (pH 5.5) and very alkaline soils (pH 8.5). These plants have very high photosynthetic activity and sunny positions suit them best. Water requirements are relatively low (except for reeds) and they thrive in areas with 300-750 mm of annual rainfall. During the growing season, they absorb a lot of heat and tolerate very high air temperatures (+40^{o} C), as well as frosts down to -40 ^{o}C.

There are various compression technologies to process it to solid bio fuels (bales, briquettes, pellets) for more efficient use in the production of electricity and heat (*de Vries et al.*, 2010). Apart from energy purposes, the biomass of tall grasses is being increasingly used as a raw material for making cardboard and some biodegradable products for everyday use, for building materials, as an ornamental plant, for amelioration of various areas (*Dželetović and Glamočlija*, 2011), for obtaining high-quality organic fertilizer and for biochar, which is used for repairing the physical and chemical properties and increasing the soil fertility (*Melligan et al.*, 2012).

From the group of tall grasses, four species have been singled out as the most suitable for growing under agriecological conditions in Serbia, in low lands and hilly regions. These are rush wheat grass, switch grass, elephant grass and miscanthus. According to our own research results (*Dželetovićand Glamočlija*, 2011; *Glamočlija et al.* 2012; *Djuric and Glamoclija*, 2017; *Maksimović et al*. 2019; *Mladenović, Glamočlija et al*. 2020), as well as conclusions of other authors (*Rowe et al*. 2009; *Hoque et al*. 2015), these species offer high yields of raw materials for further processing. Low investments in production and several years of utilization secure a cheap source of energy that justifies commercial production and can compete with fossil fuel prices. They have no major significance as food for humans and domesticated animals; therefore their use for obtaining bio fuels does not threaten global food quantities. It should be emphasized that agritechnics are simple, and investments in productionare minimal. Simultaneously, the growing of these plants has a favorable influence on the environment.

Results and Discussion

Based on the analysis of the most important climate data (amounts and distribution of precipitation during the vegetation period and thermal regime) and the requirements of these tall grasses it can be emphasized that environmental conditions in our most important lowland and hilly regions are very favorable (Tables 1 and 2).

Table 1. Monthly precipitation amounts in vegetative period, perennial average, (mm).

Month/Locality	Srem	Mačva	Podrinje	Šumadija	Optimum*
IV	49	55	55	48	50-70
V	66	56	68	56	70-85
VI	89	82	102	85	80-95
VII	67	63	88	63	80-90
VIII	58	55	75	57	70-80
IX	45	53	68	52	50-65
IV-IX	358	364	456	361	400-485

1. Locality –Srem (Stara Pazova), 2. Locality – Mačva (Šabac), 3. Locality – Podrinje (Loznica), 4. Locality – Šumadija (Mladenovac), * Clifton-Brown (1997)

Table 2. Temperature regime in vegetative period,perennial average, (^{o}C)

Month/Locality	Srem	Mačva	Podrinje	Šumadija	Optimum*
IV	13.6	15.2	11.1	12.1	10-15
V	18.5	18.2	16.2	17.2	15-17
VI	21.1	20.3	19.1	20.1	18-20
VII	22.8	22.2	21.4	22.4	20-24
VIII	22.7	21.1	20.2	21.2	19-23
IX	18.2	17.2	17.0	17.0	16-19
IV-IX	19.5	19.0	17.5	18.3	16.3-19.6

1. Locality –Srem (Stara Pazova), 2. Locality – Mačva (Šabac), 3. Locality – Podrinje (Loznica), 4. Locality – Šumadija (Mladenovac), * Clifton-Brown (1997)

Annual climate condition variations, especially of precipitation quantities and distribution have no effect on yields of biomass of miscanthus, a plant species subject to several years of investigations under various agro-ecological conditions (*Djuric and Glamoclija*, 2017; *Maksimović et al*., 2019; *Mladenović Glamočlija et al*., 2020). Rush wheat grass originates from semiarid areas of Eastern Europe so agro-ecological conditions of temperate continental climate are optimal for growing this species (*Dickeduisberg et al*., 2017). Switch grass grows wild in the steppes of North America. It is very tolerant of drought and to both high summer air temperatures and cold winters. Newly created varieties have these characteristics, especially forms of mountain switch grass, which allows the cultivation of these plants in a wide area of temperate to harsh continental climate (*Dale and Kim*, 2004). Giant elephant grass originates from the region from the Mediterranean to South Asia. It thrives best under conditions of warm and humid climate, but there are ecotypes that can also be grown outside these areas, because they tolerate winter frosts well (*Hardion et al*., 2014), as was also shown by our initial investigations in experiments established in Eastern Srem.

According to results of investigations related to establishing perennial high grasses, overall production technology can be implemented using standard agricultural mechanization (*Dželetović and Glamočlija*, 2011; *Maksimović et al*., 2016). Under our agriecological conditions, rush wheat grass is established in the fall (October), while elephant grass and miscanthus are planted in the spring (April). In the following year the first two species have a yield that to a large extent covers production costs, while commercial yields of elephant grass are not obtained until the third year. Total costs of establishing crops depend on the species. The average price for establishing tall wheat grasses seeds (rush wheat grass and switch grass) is715.5 to 774.5 Euro (Tables 3 and 4). Elephant grass and miscanthus are propagated exclusively from rhizomes so the average price for establishing these plants is higher, because considerable quantities of rhizomes are needed for planting (Tables 5 and 6).

Table 3. Analytical calculation for establishment a tall wheatgrass plantation

Elements	Quantity	Price, (Euro)	Value, (RSD)
Production costs			
1. Material costs			
- NPKmineral fertilizer - KAN (AN)	300 kg ha^{-1} 150 kg ha^{-1}	0.30 0.25	90 37.5
- seeds - herbicides (*Glyphosate*) - herbicides (*Florasulam*)	25 kg ha^{-1} 4 l ha^{-1} 0,5 l ha^{-1}	6.00 3.50 18	150 14 9
2. Machines			
- plowing	95		95
- disking	34		34
- soil preparation	12		12
- sowing	30		30
- top dressing - herbicide spraying	32 20 x 2		22 40
- irrigation	182		182
Total costs			**715.5**

Source: * Tall Wheatgrass (2020).

Table 4. Analytical calculation for establishment a switch grass plantation

Elements	Quantity	Price (Euro)	Value (Euro)
Production costs			
1. Material costs			
- NPK mineral fertilizer - KAN (AN)	300 kg ha^{-1} 150 kg ha^{-1}	0.30 0.25	90 37.5
- seeds - herbicides (Glyphosate)	18 kg ha^{-1} 4 l ha^{-1}	12.2 3.5	220 14
2. Machines			
- herbicide spraying - plowing	20 95		20 95
- disking	34		34
- soil preparation	20		20
- sowing	30		30
- top dressing	32		22
- irrigation	182		182
Total costs			**774.5**

Source: * Tall Wheatgrass (2020).

Table 5. Analytical calculation for forming a giant reed plantation

Elements	Quantity	Price (Euro)	Value (Euro)
Production costs			
1. Material costs			
- NPKmineral fertilizer	300 kg ha^{-1}		170
- rhizomes - herbicides (*Glyphosate*)	20,000 ha^{-1} 4 l ha^{-1}		1,250 45
2. Machines			
- tillage and planting	720		720
- irrigation	335		335
- hilling	120		120
Total costs			**2,640**

Source: Pilu et al. (2013).

Table 6. Analytical calculation for establishment a miscanthus plantation.

Elements	Quantity	Price (Euro)	Value (Euro)
Production costs			
1. Material costs			
- NPK mineral fertilizer	300 kg ha^{-1}	0.30	90
- rhizomes - herbicides (Glyphosate)	22,000 ha^{-1} 4 l ha^{-1}	0.18 3.5	3,960 14
2. Machines			
- plowing	90		90
- soil preparation	20		20
- planting	45		45
- cultivation between rows	22		22
- hilling	80		80
Total costs			**4,336**

Source: Own research (Djuric i Glamočlija, 2017).

As a raw material for obtaining fuel, produced biomass can compete with prices of fossil fuels if we opt for a technology of production that will maximally use the potential fertility of the genotype and upgrade the process for obtaining bio fuel. In addition, it should be emphasized that the production of these fuels significantly contributes to maintaining a healthy ecosystem and rural development, especially in areas with dominantly elderly households, and with increasing areas of uncultivated agricultural land, as pointed put by *Janić et al*., (2009).

Conclusions

Based on own research results and comparisons with results of other authors, following conclusions can be drawn:

- The studied four species belonging to the group of tall grasses are economically very important plants the biomass of which can be used in multiple ways;
- The best way to use produced plant biomass, but also seeds is to produce gaseous, liquid and solid bio fuels;
- To date, all four species, growing wild in a large geographical area and under various agro-ecological conditions, have been the subject of numerous investigations, so that numerous varieties have been created and the technology of production perfected;

- This research has shown that the establishing of plants and their maintaining in subsequent years can be achieved with standard agricultural mechanization;
- The perennial life cycle, as well as the possibility of growing on marginal soil sand the relatively simple technology of production, enable better utilization of overall agricultural resources;
- The produced raw material can be processed on own small homesteads in various ways, including to obtain bio fuels, because today the market offers small processing facilities;
- Large agricultural producers can more efficiently recultivate certain areas of land and secure larger quantities of raw materials for fuel that could be used in small facilities for producing electricity;
- The burning of bio fuels obtained by processing these raw materials does not increase quantities of carbon dioxide, or of other harmful gases in the atmosphere;
- Tall grasses are also very significant from the point of ecology, because these crops can be established in areas exposed to high environmental pollution (industrial plants, livestock farms, roads, cities). Simultaneously, reliance on fossil fuel imports would decrease;
- Finally, it should be emphasized that the high initial investments to establish plants, especially elephant grass and miscanthus, should be mitigated via adequate subsidies, until plants reach full yield and provides a continuous market supply of cheap and quality raw material for bio fuel production.

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