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ENERGY CROPS AS ALTERNATIVE AGRICULTURE CROPS FOR BIOMASS PRODUCTION IN MACEDONIA AND BULGARIA

Zoran Dimov[1], Tatjana Prentovic[1], Milena Moteva[2], Antoaneta Gigova[3]

[1]University St. Cyril and Methodius, Faculty of Agricultural Sciences and Food, Skopje, R. Macedonia
[2]University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria
[3]Institute of Soil Science, Agro-Technology and Plant Protection "N. Pushkarov", Sofia, Bulgaria

Corresponding author: dimov632002@yahoo.co.uk

Abstract
In this review the focus is on few agricultural energy crops, which means crops that are grown exclusively or primarily for the purpose of producing biomass for energy purposes in an agricultural rather than a forestry context. However, cultivation of most of these crops is restricted to certain regions, e.g. by requirements for a certain climate zones. Having in mind the similar agro ecological conditions in R. Macedonia and Bulgaria, but also needs of the crops for successful growth and development, species as *miscanthus*, *switch grass* and *sweet sorghum* are introduced as a potentially used energetic plant species for this part of the Balkan region.

Keywords: Miscanthus, switch grass, sweet sorghum, production, yield.

Introduction
Energy crops can be classified into those providing solid fuels for direct combustion, thermal processing and electricity generation, and liquid fuels, notably bioethanol and bioediesel. Solid fuel crops include energy coppice, *Miscanthus* and whole-crop cereals. Bioethanol is derived from the fermentation of sugar, starch or, potentially, cellulosic crops. Biodiesel refers commonly to transesterified vegetable oil, derived from oilseed rape or sunflower. So far, energy cropping with ligno-cellulosic crops is not wide spread in most EU countries. From the data published by Panuotsou et al. (2011) there are only some larger cropping areas in Sweden, Poland and the UK. In total the present EU wide perennial cropping area is estimated to be at around 93000 hectares with a total energy potential of 440 KTOE/year. Most of the previous research on energy crops were focused on cost of production for these crops (Khanna et al., 2008; Hallam et al., 2001; McLaughlin & Kszos 2005). Measuring the cost of production is required, but not sufficient to promote adoption of energy crops by farmers to achieve the target levels of cellulosic ethanol production. For many farmers growing of energy crops for bioenergy production is new and analysis should be conducted within the context of technology adoption. The aim of this review is to evaluate species as *miscanthus*, *switch grass* and *sweet sorghum* as a potentially used energetic plant species for this part of the Balkan region.

Status of bioenergy production/energy crops in R. Macedonia and Bulgaria
R. Macedonia. Republic of Macedonia has large amount of biomass from agriculture available to be used as an energy source. The quantity is really large and it could bring to the theoretical generation of 1 500 GWh of electricity (R. Macedonia – IPA Rural Development Program 2014-2020 (2015)). In 2007 Macedonia's petrol company Makpetrol opened the first (and so far the only) biodiesel plant in the country with an annual capacity of 30.000 t. The raw material for the production of biodiesel is oil from oilseed rape exclusively provided by imports. In October 2014 the Macedonian Government joined a Memorandum of Understanding (MOU), to facilitate development of the cellulosic ethanol market in the Pelagonia region between Ethanol Europe and DuPont. According to the terms of the MOU, the Government had to facilitate the project in establishing a viable supply chain using energy crops, increasing local production of cereals and oilseeds, and offering incentives for renewable

biomass electricity for the nation's power grid. So far, with the exception of the one-year field trials with sorghum and switch grass in sub-region of Prilepsko Mariovo (as part of project activities), nothing has been realized.
R. Bulgaria. As a member-state of EU, Bulgaria harmonizes its policies and legislation with the European: 1) to increase the share of renewable energy in overall energy by up to 20% EU consumption and 2) for all Member States of 10% minimum share of biofuels in the overall consumption of petrol and diesel fuel for the transport in the EU. Up to now, Bulgaria has followed two main ways for pushing ahead the activities for implementing the EU energy policy: 1) by implementing measures and stimuluses' for increasing the consumption of biofuels and 2) by implementing measures and stimuluses' for increasing the production of raw materials and their processing for producing energy products. Bulgaria has enough land to ensure the production of biofuels with the raw materials required for this purpose, without the food industry being adversely affected. The necessary areas to achieve the mandatory target of 10% biofuels in 2020 amount will be totally 509,001 ha, representing 14.6% of the arable land in 2016. At present, the sawn area with industrial oil crops is around 200.000 ha (196,958 ha).

Miscanthus. *Miscanthus* is a perennial rhizomatous grass with the C4 photosynthetic pathway. Giant miscanthus - *Miscanthus* x *giganteus* is a natural hybrid, formed by crossing *Miscanthus sinensis* (diploid 2n=2x=38) and *Miscanthus sacchariflorus* (tetraploid 2n=4x=76) (Greef and Deuter, 1993). As a result of his triploidness, *Miscanthus* x *giganteus* is sterile, so it cannot produce fertile seed (Linde-Laursen, 1993).
Growth and development. In practice exists two methods of propagation that are currently used for *Miscanthus* plants – rhizome division and micropropagation. Rhizome division is more used method because it is less expensive and generally produces more vigorous plants. Plants starts to grow from dormant winter rhizomes, when the soil temperatures reach 10-12 °C, and the temperature threshold for leaf expansion of the plants that start to grow is in the range of 5-10 °C (Clifton- Brown and Jones, 1997). From the rhizomes during of April overhead stems appear characterized by a rapid increase, reaching height of about 2.0 m. During the winter they are dried where the water content is around 30%. The harvest is carried out during February by cutting the entire stems. New plants evolve from rhizomes next spring when favorable temperature conditions are created.
Fertilization. The cultivation cycle of *Miscanthus* x *giganteus* is characterized by less demand of mineral fertilizers and pesticides. An amount of 60 kg ha^{-1} N was found optimal to support the development of the rhizome system from the second or third year onwards (Greef, 1995). Overall nutrient requirements for N, P and Ca are about 2-5, 0.3-1.1 and 0.8-1.0 kg t^{-1} of dry matter respectively (Lewandovski and Kicherer, 1997). The potassium fertilization did not improve the yield of M. x giganteus which may be an efect of indifference of the crop for this element or the good potassium supply level in the soil .
Irrigation. To obtain high yields of *Miskanthus* in temperate climates, the optimum amount of precipitation is around 800 mm (Schwarz, 1993). Hovewer, from the second year onwards, plants develop a more powerful root system and more robust rhizomes, so crops are more tolerant to drought, but also to freezing. In absence of N fertilization, irrigation did not modify biomass yield and the effect of irrigation increased with the increase in N level (Ercolia et al. 1999).
Weed, pest and diseases. Weed control in the establishment phase of the crop is essential. Once the crop is mature, weed interference is effectively suppressed (Planting and growing miscanthus). Miscanthus species are susceptible to diseases and pests in the areas to which they are native (Asia). To date, there are no reports of plant diseases signifcantly limiting production, but the crop is known to be susceptible to *Fusarium* (Thinggaard, 1997), to Barley Yellow Dwarf Luteovirus (Christian et al., 1994) and to miscanthus blight (*Leptosphaeria* sp.). There are no reported insect pests in Europe that have significantly affected the production of miscanthus. However, two 'ley pests', the common rustic moth – *Mesapamea secalis* and ghost moth larvae – *Hepialus humuli*, have been reported feeding on miscanthus and may cause problems in the future (Planting and growing miscanthus).

Harvest and biomass yield. Harvest is usually carried out in spring (February to April), in order to collect well-dried material. The optimal time for harvesting may be quite short, since the crop will be about to re-start growth in April, and this can add to the costs of harvest. Yields of up to 25 t ha^{-1} $year^{-1}$ (dry matter) have been obtained from the third year onwards in the spring harvest, even there have been huge diferences in biomass yields from 2 t ha^{-1} (Hotz et al.), to 44 t ha^{-1} (Danalotos et al).

Switchgrass – *Panicum virgatum,* is a C_4 perennial grass native to North America (Moser and Vogel, 1995). The species is polymorphic with two distinct ecotypes: lowland, mostly tetraploid with 2n = 4x = 36 chromosomes, and upland, which are tetraploid and octaploid with 2n = 8x = 72 chromosomes (Brunken and Estes, 1975; Sanderson et al., 1996). (

Growth and development. Switchgrass reproduces through seeds and spreads vegetatively as well. The base temperature for germination and growth is between 8 and 10 ^{0}C, optimum temperature is around 30 ^{0}C (Hsu et al. 1985), and maximum temperature can be around 40 ^{0}C, but all of these conditions appear to be cultivar dependent. Upland cultivars have been selected from higher latitudes, are thin-stemmed and found in drier conditions, and have greater winter survival potential than the lowland cultivars when grown at the same latitude. Regrowth of bought genotypes begins each spring, and its primary growth period follows through the warm months of June, July, and August. Frost in the autumn stops its annual growth.

Fertilization. For maximizing biomass production the optimum N rates for switchgrass varied, from 50 – 110 kg ha^{-1} $year^{-1}$ (Planting and Managing Switchgrass as a Biomass Energy Crop) up to 160 – 220 kg ha-^{1} $year^{-1}$ (Is switchgrass a low nutrient input crop or not?). Split applications are more suitable for rates greater than 100 kg ha^{-1} or for a two-cut harvest system. Investigations from Muir et al., (2001) and Parrish and Fike (2005), reported little or no yield response of switchgrass to phosphorus fertilization. Hovewer in soils with low plant available P, application of 45 kg P ha^{-1} increases biomass yield by up to 17% (Kering et al., 2012). The single use of potassium (68 kg ha^{-1}) did not affect the yield level. Applied together with N (135 kg ha^{-1}) has positive influence of increasing yield, indicating that for maximum biomass production, proper nutrient management (N, P, and K) is required (Maru et al., 2013).

Irrigation. Even though irrigation has potential to increase yield, the feasibility of switchgrass production is based primarily on the use of otherwise unproductive and unprofitable agricultural lands, which likely do not have access to cost-effective irrigation. Example of weekly application of 2.54 cm of irrigation delivered by overhead sprinklers during the growing season over a three-year period (2009-2012) did not significantly increase annual biomass yield of switchgrass (Jacobs and King, 2012).

Weed, pest and diseases. Weed competition is a major reason for switchgrass stand failure during establishment. In already established stands, weed pressure during the second growing season could be worse than in subsequent years if there was poor site occupancy by switchgrass seedlings during the seeding year. With adequate weed control during the first two years of a stand, subsequent problems can be limited. The two main pests that are of concern in the U.S. are the switchgrass moth and the switchgrass gall midge (Samson et al., 2016). Outbreaks of rust and smut can occur during the establishment year but are generally more likely to occur post-establishment (Sanderson et al., 2012).

Harvest and biomass yield. An established stand of switchgrass can be maintained for more than 10 years (Fike et al. 2006), obtain yield from 8–15 t ha^{-1} (Monti et al. 2008). Lowland cultivars are recommended to be harvested once per year after the first frost. Upland cultivars may be harvested under a two-cut system, with the first cut in June or July and the second cut after the first frost (Bransby et al. 1999; Cassida et al. 2002).

Sweet sorghum. Sweet sorghum – *Sorghum bicolor* (L) Moench is similar to grain sorghum but features more rapid growth, higher biomass production, and wider adaptation. As a C4 species is more wateruse efficient and can be successfully grown in semiarid tropics, where other crops such as maize fail to thrive (Hlophe, 2014).

Growth and development. Sorghum comes in many forms. All are canelike grasses some 50 cm to 6.0 m tall. The plants have a fibrous root system that may penetrate 150 to 250 cm into the soil unless a hard pan is present in the soil. The leaves look very much like those of maize and number 14 to 18, growing on alternate sides of the stem. During a drought, the leaves will curl inward, thus conserving moisture loss through transpiration. The plant is self-pollinated. The crop is grown from seed (Smith and Frederiksen, 2000).

Fertilization. Different authors recommend different requirement of nitrogen, from 112, 150, 224 even to 269 kg N ha^{-1} depends from many factors (Maughan et al., 2012; Wortmann et al., 2010; Powell and Hons, 1992; Marsalis and Bean, 2001). For phosphorus, according Roy and Khandaker (2010) who evaluate the effect of various levels of phosphorus fertilizer on the yield of sorghum fodder at three cuttings, it may be suggested that sorghum fodder can be cultivated through the application of 80 kg P/ha^{-1} and harvested at the age of 66 days at first cutting for maximum production. In combination of N and P an increase yield has been observed with fertilizer application up to 100 kg N + 50 kg P_20_5 ha^{-1} whereas, the quality parameters such as protein content, crude fiber and ash percent had significantly higher with NP application of 100 + 100 kg ha^{-1} (Ayub et al., 1999).

Irrigation. In its growing period of about 4.5 months, the crop water requirement is 800 mm for two crop cycles. The crop may deplete less water from the soil than maize, and that in general confirms sweet sorghum's 25% less water requirement compared to maize (Hanson, 2014)

Weed, pest and diseases. The lack of weed control of sweet sorghum can result in yield losses, emphasizing the need of a good weed management (Leandro et al., 2016). At least 150 insect species have been reported as pests for sorghum worldwide. Many of the sorghum pests can damage crops other than sorghum, such as corn, cotton, and millet. (Chunshan et al., 2011). Like with pests, any disease prone to infecting grain sorghum may also influence sweet sorghum. Diseases that affect sweet sorghum include leaf anthracnose, red stalk rot and maize dwarf mosaic virus.

Harvest and biomass yield. Early maturing sweet sorghums, typically mature in approximately 90 days. Certain full-season varieties or hybrids can take more than 150 days to mature (Sweet sorghum production guide). The yield of fresh mass could be from 36 to 45 t ha^{-1}, even up to 100 t ha^{-1}.

Conclusions

As biofuels are produced from biomass of crop plants, as indicated earlier, they offer enormous opportunities to improve the income levels of smallholder farmers in bought countries – R. Macedonia and Bulgaria. At community level, farmers can cultivate energy crops that fetch more income while meeting their food needs. Local production of biofuels is projected to have a broad range of positive economic, social and environmental implications. At a national level, producing more biofuels will generate new technologies, new industries, new jobs and new markets assisting economic growth in rural areas besides reducing environmental pollution.

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