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PLANT SPECIES FOR RENEWABLE ENERGY PRODUCTION IN THE REPUBLIC OF MOLDOVA

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Abstract

In the context of the current sharp rise in energy prices and climate changes, humankind faces two major problems: food provision and energy shortages. The Republic of Moldova possess few energy resources, so being forced to import near 95%, energy crops cultivation seems to offer an ideal solution to the problem of alternative energy sources.
The investigation of introduced tall perennial grasses for biofuel production is an important object in Botanical Garden (Institute) of ASM. Agro biological peculiarities introduced plant species provide perspectives for cultivation in the Republic of Moldova: Macleaya cordata, Sorghum almum, Sida hermaphrodita, Helianthus tuberosus, Miscanthus x giganteus, Symphyotrichum novi-belgii with 10-20 years longevity. Cultivation and harvesting of these species do not need sophisticated mechanisms and specific equipment as in forest exploitations, ensuring a high quantity of dry biomass: 11.0-27.2 t / year / ha with gross calorific value – 18.5 to 20.0 MJ / kg. Biomass potential of these species can be developed in three main directions for biofuel production briquettes or pellets, bio-ethanol, biogas being transformed into energy.

***Key words**: agro biological peculiarities, energy characteristics of biomass, Macleaya cordata, Sorghum almum, Sida hermaphrodita, Helianthus tuberosus, Symphyotrichum novi-belgii.*

INTRODUCTION

In the context of the current sharp rise in energy prices and climate changes humankind faces two major problems: food provision and energy shortages. Energy is the dominant factor that determines the welfare of the country and people, influences the level of development of all spheres of activity in society. The sources of renewable energy acquire considerable interest, if accompanied by a more rational use of energy, to facilitate the transaction by a high use of fossil fuels to a sustainable use of renewable energy. There are many alternative energy sources such as wind, solar, geothermal and biomass that fulfill the criteria of sustainability and economic feasibility. The complex problems of the development of renewable energy have become a global political dimension. The European Commission approved the Energy Policy for Europe which envisages the following objectives for 2020: a 20% increase in energy efficiency, a 20% reduction in emissions of greenhouse gases, achieving a 20% share of renewable energy. For this reason it is estimated that as a consequence it will be biomass which will constitute the most important source of energy, particularly essential in comparison to conventional sources, since it is renewable. Plant species are efficient users of solar energy for converting CO_2 into biomass. Biomass currently accounts for 2/3 of renewable energy in Europe and bioenergy will play a key role in achieving the ambitious targets approved by the renewable energy directive. 20 % of the final energy consumption has to be provided using renewable sources by 2020. Pahkala et al. (2009) estimated that energy crop potential would be about 3 EJ by 2050 in EU-27.

The Republic of Moldova has few fossil energy resources, so being forced to import near 95%, depending entirely on the supplying countries. Therefore, the issue of renewable energy sources has been and remains actuality. Moldova has taken the first steps in this field in 2007 when it was approved the Renewable Energy Law, in 2013 – the Energy Strategy by 2030, implemented the project “Moldova: Energy and Biomass”, financed by the European Union and UNDP Moldova. Solving the problem concerning the creation of secure alternative sources of energy requires, first of all, the production of volumes of renewable biomass at industrial scale, the processing of which allows obtaining the necessary quantity of fuel. The structure expected by 2020 of the total production and consumption of energy obtained from renewable sources based on biomass will constitute approximately 70.0%. The climatic conditions from the years 2011 - 2012, which had serious consequences on the development of agriculture, revealed that only on the basis of agricultural remains - straw, sunflower stalks and corn, the problem of biomass supply cannot be solved, which determined the orientation of the research and innovation policy towards identifying new plant species by analyzing their productivity, environmental impact, economic efficiency and ensuring that they didn't affect the food supply of the population. For biomass production on industrial scale, the most efficient crops that use to a great extent the photosynthetically active solar energy during the vegetation period, accumulate a considerable amount of dry matter and demand optimal expenses for establishment and low expenses for maintenance, harvesting and processing should be selected and implemented (Wróblewska et al., 2009; El Bassam, 2010; Kalensky et al., 2010; Rakhmetov, 2011). Over more than half a century, as a result of the introduction and acclimatization researches done in the Botanical Garden (Institute) of the ASM, collections and exhibitions of plants with multiple use, necessary for the development of the national economy, were founded. The investigation of local as well as introduced tall perennial species for biofuel production is an important object. Currently, about 100 species of plants from the Botanical Garden can be used to produce different types of biofuels.

The aim of the present study was to evaluate some agro biological peculiarities and energy characteristics of biomass of the species: *Macleaya cordata, Sorghum almum, Sida hermaphrodita, Helianthus tuberosus, Symphyotrichum novi-belgii.*

MATERIALS AND METHODS

The introduced plant species from the collections of the Botanical Garden (Institute) of the ASM were used as material for research: *Macleaya cordata* (Willd.) R. Br., *Sorghum almum* (Piper) Parodi, *Sida hermaphrodita* Rusby, *Helianthus tuberosus* L., *Miscanthus x giganteus*, *Symphyotrichum novi-belgii* (L.) G.L. Nesom. The experiments were performed on non-irrigated experimental land. The plant growth and development, their productivity were done according to methodical indications (Ivanov, 1985). The moisture content of biomass (chopped material) was determined by CEN/TS 15414 in an automatic hot air oven MEMMERT100-800. Content of ash was determined at 550°C in a muffle furnace HT40AL according to CEN/TS 15403. Automatic calorimeter LAGET MS-10A with accessories was used for the calorific value determination, according to CEN/TS 15400. The cylindrical containers were used for determination of bulk density, calculated by dividing the mass over the container volume. The briquetting was carried out by hydraulic piston briquetting press BrikStar model 50-12 (Briklis). The mean compressed (specific) density of the briquettes was determined immediately after removal from the mould as a ratio of measured mass over calculated volume.

The scientific researchers were performed during the 2010-2014 years.

RESULTS AND DISCUSSIONS

The introduced non-food herbaceous perennial plant species with intensive growth is Plume poppy, *Macleaya cordata* (Willd.) R. Br., family *Papaveraceae*, natives of eastern Asia (China, Japan). Is cultivated as a garden plant, the aerial parts have long been used as a medicine (Xinrong, 2003, Kosina et al. 2010). As a result of the study of the biological peculiarities in the first year of vegetation, we can mention that in April, from the rhizomes of the species *Macleaya cordata* at the soil surface appears the bud which develops erect, glaucous, basally lignified, yellow lactiferous stems; the leaves are light green to olive green, simple lobed, alternate arrangement; the flower is radially symmetrical, panicles of creamy white flowers. At the end of vegetation the plant height reaches 168 cm. The productivity of biomass constitutes 0.47-0.51 kg/m^2 dry matter.

In the second year and the following years of vegetation, in spring, when the air temperature exceeds 8°C, starts plant development from generative buds formed on the rhizomes, which go through all stages of ontogenetic development finishing with seed formation, the plant height reaches 318-343 cm (Figure1).

At the end of the period of vegetation and with the establishment of negative temperatures the stems are completely defoliated, the humidity of the stems – about 33-35%, in January - below 23%, and in early March 10-13%.

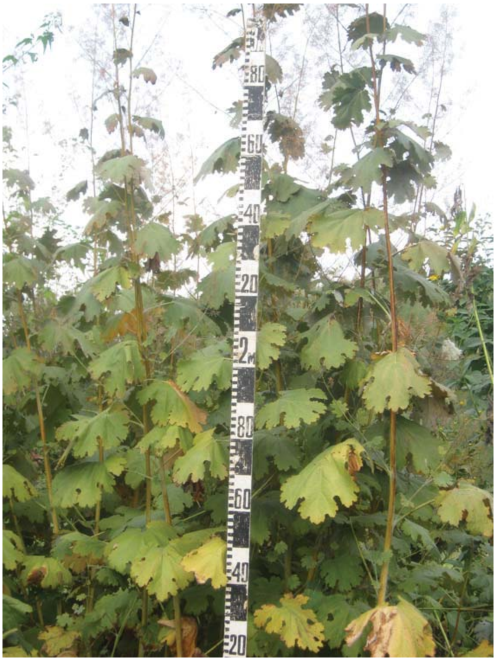

Figure 1. *Macleaya cordata*(Willd.) R. Br.

The productivity of the harvested biomass constitutes 16.7-20.1 kg/m^2 dry matter. The bulk density of the chopped stems is 146-185 kg/m^3. The gross calorific value absolutely dry mass reaches 19.12 MJ / kg. The density of the briquettes made from biomass is 860 kg/m^3. The ash content absolutely dry mass is 1.7%.

Taking into account the expansion of areas of soils with a high salt content and the frequency of droughts in our country, an introduced plant that can help solve the above mentioned problems is Columbus grass, *Sorghum almum* Parodi, family *Poaceae*, plant group C_4, native to South America (Argentina, Paraguay, Uruguay) is a robust, tussocky perennial with numerous tillers and thick short rhizomes which curve upwards to produce new shoots near the parental stool. Culms are solid and pithy, about 1 cm thick, sometimes reaching a height of 3-3.6 m. The leaves are 2.5-4.0 cm wide and waxy. The inflorescence is a large pyramidal panicle (25-33 cm) with secondary and tertiary branches, generally drooping as seed ripens. 2n = 40. It reproduces by seeds (Uteush, 1990; Heuzé et al., 2015).

We have established that seedlings of *Sorghum almum* appear on the soil surface after 5-7 days from sowing and growth and development are intensive in the first year, the plant goes through all phenological phases till full ripening of seeds, it develops a strong root system and its aerial part is a bush of 2-4 branches, about 2.0 m tall, it forms 8-12 leaves with a length of 82-124 cm and a width of 1.2-3.0 cm (Figure 2).

In the following years, the resumption of vegetation starts in April and a bush can develop up to 20 shoots which attain a height of 3.0 m and a diameter of 0.8-1.3 cm. Its seed productivity reaches 1.5-2.4 t/ha.

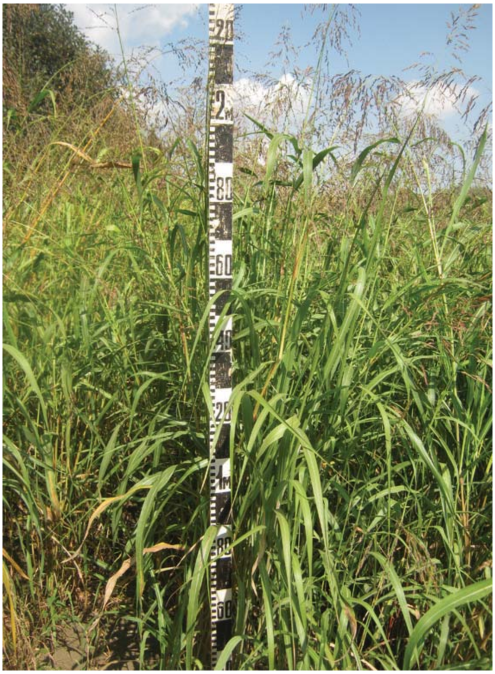

Figure 2. *Sorghum almum* Parodi

To produce solid biofuel, the *Sorghum almum* plants can be harvested in August-September by mowing and drying in swaths or by grinding in November-December when the temperatures are below 0ºC and when the humidity is reduced to 10%. The yield, depending on age and manner of exploitation of the plantation, is about 11-15 t/ha. The bulk density of the biomass is of 118-133 kg/m^3, the gross calorific value reaches 18.6 MJ/kg.

The density of the briquettes is 700 kg/ m^3. The ash content absolutely dry mass is 3.7%. Columbus grass has anti-erosion properties, it is pest and disease tolerant, highly resistant to drought, heat and salty soil and averagely resistant to frost.

Virginia mallow, *Sida hermaphrodita* Rusby, family *Malvaceae*, is a perennial herbaceous native to North America with tubular, erect stem, smooth surface coated with a waxy layer, solid, with high lodging resistance. It reproduces by seeds and vegetatively (cutting, root pieces). It is sown in late autumn or early spring with layered seeds at a depth of 2-3 cm with a norm of 2-3 kg/ha, the distance between rows – of 45 cm or 70 cm, with soil compaction before and after sowing.

Figure 3. *Sida hermaphrodita* Rusby, variety Energo

The vegetative propagation is done by planting cuttings in the middle of May (25-30 thousand/ha), in the first 45 days, the plants have a slow rate of growth and development of aerial parts, the stem formation begins, in the next period, the growth rate is accelerating and, in the middle of September, flower bud formation begins and shoots reach a height of 171 cm. When propagation by seed is used, seedlings grow slowly, forming a strong, erect, branched stem, which is up to 1.4 m tall and 1.7-2.1 cm thick at the base. Virginia mallow plants develop maple-like leaves; the leaf blade has double-serrated, light green edge. In the first year of vegetation, it develops a strong, pivoting, extended root system. Fresh mass productivity reaches 24-28 t/ha at the end of September.

In the next years, plant growth and development starts in spring, when temperatures are above 0ºC, the shoots appear in the middle of April, they are vigorous and numerous (8-17 shoots on a bush). Due to the pivoting and highly branched root system, which reaches to a depth of 2.5-3.0 m, Virginia mallow plants efficiently use soil moisture accumulated in autumn and winter, the shoots grow and branch intensely and at the end of growing season attain a height of 3-4 m and a diameter of 3-7 cm at the base. It blooms from the middle of July to August, and in some years – until the end of growing season, providing a late pollen collection for bees (that produce about 60 kg/ha of honey) and serves as a source of food for other pollinating insects. When the frosts begin, all the leaves fall from the stems and their dehydration increases so that the dry biomass can be harvested in December-January. It has been found that the bulk density of the collected material is 268 kg/m^3. The gross calorific value of the dry matter reaches 18.7 MJ/kg. The ash content is 1.5%.

The fresh aerial biomass is used as substrate for obtaining biogas - 395 m^3/t dry matters (Oleszek et al., 2013).

By individual selection of the introduced population, the local variety Energo of Virginia mallow (Figure 3) was created and registered in the Catalogue of plant varieties of the Republic of Moldova in 2014. The fresh mass productivity in the 3rd-4th years reaches 96-112 t/ha, the potential of obtaining biogas is 11-12 thousand m^3, equivalent to 5.0-5.5 thousand m^3 of natural gas, and the dry biomass productivity reaches 22 t/ha with an energy potential of 380 GJ/ha.

Jerusalem artichoke, *Helianthus tuberosus* L., family *Asteraceae*, plant group C_4 native to North America, it has a coefficient of utilization of photosynthetically active solar energy of over 3.5% exceeding 3 times the maize (Kays and Nottingham, 2008)

In the Botanical Garden (Institute) of the ASM, over the years, a collection of over 60 different taxa of Jerusalem artichoke with different growing season, plant habitus, shape and color of tubers was created, being selected promising forms to create new varieties.

Figure 4. *Helianthus tuberosus L.,* variety Solar

The variety Solar of Jerusalem artichoke (Figure 4) was created in the Botanical Garden (Institute) of the ASM by clonal selection from large populations and was mainly intended for animal feeding. It was registered in the Catalogue of plant varieties of the Republic of Moldova in 2014. It propagates vegetatively, is planted in April at a depth of 7-10 cm (1.5-2.3 t/ha tubers).

It was found that from the buds on the tubers, during 13-18 days after planting, 2-3 seedlings develop and appear on the soil surface. During the growing season they develop erect stems of green color with shades of anthocyanin, covered with a film of bluish-gray wax, 300-450 cm tall and with a diameter of 2-5 cm at the base, rough, porous, branched in upper part, with 50-70 leaves. The leaves are dark green, on the lower part of the stem they are opposite and on the upper part - alternate, petiolate, the leaf blades are ovate, medium sized with coarse toothed edge. Inflorescence is a solitary calathidium situated at the ends of branches, with a diameter of 4-6 cm at flowering. The root system develops rapidly and during the first month the fibrous roots can grow as long as 30 cm. On the underground part of the stem, at the end of May, stolons start forming, the stolons of the Solar variety are 10-23 cm long and by thickening of the terminal part thereof, during July, first tubers are formed, the period of tuber formation and growth lasts until the end of September. The tubers are placed in the hole in a scattered way. The medium-sized tubers weigh 43-65 grams, are oval-oblong, with a thin peel of cherry color with a strong anthocyanin intensity and white core (Teleuță and Țîței, 2013)

In several countries, the tubers of Jerusalem artichoke are used in food, pharmaceutical industry, as well as to obtain bioethanol, and the fresh aerial biomass is used to obtain biogas and liquid biofuels (Kays and Nottingham, 2008; El Bassam, 2010; Halford and Karp, 2011; Micu, 2011)

At the end of growing season and after frost, over 15-35 days, depending on weather conditions, *Helianthus tuberosus* stems are completely defoliated, they dehydrate faster than those of *Macleaya cordata*, the bulk density of the harvested biomass is 268-288 kg/m^3. The gross calorific value of the dry matter of *Helianthus tuberosus* reaches 18.5-18.7 MJ/kg. The ash content is 2.2 %. Specific density of the briquettes is 720-760 kg/m^3

In 2013, at the variety Solar, the yield of tubers reached 44.0 t/ha which allowed to obtain 3850 l/ha bioethanol and the yield of dry aerial biomass – 27.2 t/ha with an energy potential of 470 GJ/ha.

One of the most commonly used herbaceous energy crops is *Miscanthus x giganteus*, a sterile tetraploid hybrid, parental forms: *Miskanthus sinensis* Andersson and *Miscanthus sacchariflorus* (Maxim.) Franch., family *Poaceae*, plant group C_4, native to tropical and subtropical regions of Africa, Southeast Asia, is characterized by a rapid growth and development, is tolerant to soil and environmental conditions being widely used for fuel production in North and Central Europe since the 80s of the last century. It propagates vegetatively through rhizomes or plantlets obtained from tissue culture. *Miscanthus* rhizomes are planted at a depth of 8-10 cm in early spring when temperatures are above 8ºC. The plantlets of *Miscanthus* are planted during May-June with the equipment used for planting vegetables. Planting scheme: 1.0m x 0.7m or 1.0m x 1.0 m, about 10-14 thousand bushes per hectare (Lewandowski et al., 2000). In the first year of vegetation, in the conditions of the Republic of Moldova, *Miscanthus x giganteus* develop, in the underground part, the root system and new rhizomes, and the shoots can reach 1.2-1.8 m tall, with high leaf content. In the following year, vegetation starts in April and, from rhizomes, grow shoots which by the end of vegetation reach 3.0 m tall (Figure 5), the leaf content is below 20%, the root system reaches 2 m depth, the number of rhizomes increases considerably.

Figure 5. *Miscanthus giganteus*

The biomass yield from the plantation founded by rhizomes reaches 7-8 t/ha in the second year. In the following years, plant growth is more intensive, the number of shoots on a bush increases significantly influencing positively the crop. The dry biomass productivity of a 3-4 year old plantation reaches 14.2-16.3 t/ha and, in 2013, due to the high amount of rainfall – 20 t/ha. We can mention that when temperatures below 0ºC are established, dehydration and defoliation of shoots accelerate so that in December biomass harvesting can be started. Forage harvesters are used to harvest Miscanthus plants by chopping directly the stems or by mowing and baling them. The bulk density of the chopped biomass is of 138-153 kg/m^3. The gross calorific value of the dry matter reaches 18.7-20.0 MJ/kg. The ash content is 1.9-2.2%. Specific density of the briquettes is 760-800 kg/m^3.

Longleaf Aster, *Symphyotrichum novi-belgii* (L.) G.L.Nesom, family *Asteraceae,* is an ornamental perennial plant native to North America (Canada and the United States). It is a branching, multi-stemmed plant that grows up to 100–140 cm. It has narrow, green, oblong or lance-shaped leaves. It is a prolific bloomer. Large flower heads are arranged in showy panicles. The heads consist of a ring of 20 or more purple or pink or occasionally white ray florets that surround a central cluster of yellow disc florets. Flowers are frequented by monarchs and other butterflies, skippers and bees. Rhizomatous roots make it a good soil stabilizer. Propagate from seed, clump division and cuttings (Brouillet et al., 2006).

Figure 6. *Symphyotrichum novi-belgii*

We have found that *Symphyotrichum novi-belgii* plants are characterized by a fast growth of the aerial part and of the root system. So, in the 3rd-4th years of vegetation, 8-10 erect shoots up to 120-140 cm tall grow on a bush (Figure 6). Dehydration of shoots during 20-30 days after the beginning of frosts is very severe, reaching values of 85-90%. The aerial biomass productivity is of 11.7-12.5 t/ha, with a leaf content of 10-18%. After harvesting the plants using a forage harvester, the bulk density of biomass is of 248-256 kg/m^3. The biomass can be easily processed into briquettes. The specific density of the briquettes is 843-913 kg/m^3. The gross calorific value is 18.6-18.7 MJ/kg of dry matter. The ash content is 1.8-3.2%. *Symphyotrichum novi-belgii* can be used for the exploitation of eroded and polluted soils.

CONCLUSIONS

Agro biological peculiarities and energy characteristics of biomass provide perspectives for implementation in the Republic of Moldova the species: *Macleaya cordata*, *Sorghum almum*, *Sida hermaphrodita*, *Helianthus tuberosus*, *Miscanthus x giganteus* and *Symphyotrichum novi-belgi*i with 10-20 years longevity. Cultivation and harvesting of these species do not need sophisticated mechanisms and specific equipment as in forest exploitations, ensuring a high quantity of dry biomass: 11.0-27.2 t/year/ha, gross calorific value – 18.5 to 20.0 MJ/kg. Biomass potential of these species can be developed in three main directions for biofuel production briquettes or pellets, bio-ethanol, biogas being transformed into energy.

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