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CONSIDERATIONS ON THE IMPORTANCE OF CULTIVATING SORGHUM TO THE BIOFUEL INDUSTRY FOR PRODUCING BIOETHANOL

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ABSTRACT

Energy crops are crops suitable for the production of products such as biofuels (biodiesel, ecological diesel) and electric or thermal energy. Plants suitable for such energy crops are: woody (energy willow, poplar, paulownia) and grasses (annual crops such as corn, wheat, rapeseed, soybeans, sweet sorghum or perennials: pampas grass, elephant grass). The article presents a series of arguments for growing sugar sorghum on large areas in order to obtain the bioethanol used in the biofuel industry.

INTRODUCTION

Domain of energy crops is relatively new for agriculture. Therefore, at world level, many energetic crops are experimental and some of them are considered as commercial crops. Energy crops are mostly, high density cultures, being established with high yield species, used for burning in order to generate thermal energy. Predominantly, woody crops, such as energy willow, poplar or paulownia crops, but also grasses, are used. Grasses divide in annual crops, such as: corn, wheat, rapeseed, soybeans, sweet sorghum, but also perennial crops, namely pampas grass, elephant herb). [1].

Sorghum *(Sorghum* sp) is a perennial herbaceous plant, that can reach an external height of 4.5m similar to corn. It is named the „camel plant", because it grows in areas where other plant could not resist. It is cultivated in areas with lack of rains or with irregular precipitations.

Sorghum is a productive plant, irrespective of soil fertility and draught and involves minimum expenses for cultivation and processing, without losses, even the sorghum waste being capitalized. It is successfully used for obtaining bioethanol.

Sorghum belongs to Plantae kingdom, Magnoliophyta division, class Liliopsida, Poales order, Poaceae family, genus-Sorghum [8].

Sweet sorghum (*Sorghum saccharatum*) is a variety belonging to Poaceae family, the main variety with high sugar content.

The main species, *Sorghum bicolour*, is The main cereal designed to Be grown in Southern Europe, Central America and Southern Asia. Sorghum takes its origins in East Africa, being a cereal adapted to a hot and dry climate. A species of sorghum used as energy plant is Sudangrass (*S. sudanense*) [8].

In figure 8 is shown a sorghum crop, at 40-50 days after sowing, established at INMA Bucharest.

Fig. 1- Sorghum crop at 40-50 days after sowing

MATERIAL AND METHOD

Sorghum (*Sorghum bicolor L.* Moench) is species endowed with a great genetic variability, that makes difficult to frame it within a certain category. Importance of sorghum is explained in studies on its structure, content of phenols and antifungal proteins coming from its caryopsis (Ralph D Waniska, 2000).

In USA, sorghum is used as green fertilizer or for covering the crops in order to remove the weeds by the allelochemical action of its roots exudates, which was described as mixture of biologically active hydrophobic substances, named „sorgoleone” [8].

<u>Temperature requirements</u>

Sorghum is a thermophile species, highly demanding in terms of temperature. Thus, the minimum temperature of germination is of 10-12° C, and that enables the plants growing is of 25-27° C. Sum of temperature degrees necessary for the entire vegetation period is of 25-35° C. At temperatures below 10-12° C, sorghum growing stops. Among annual foddering plants cultivated in Romania, sorghum has the highest resistance to draught, due to its roots, that are well developed and reduction of growing in case of lack of water. This explains the reduced transpiration coefficient of sorghum (140-170). Sorghum is a highly productive plant, irrespective of soil fertility and draught and involves minimum expenses for cultivation and processing, without losses, even sorghum waste being profitable. Sorghum requirements in terms of soil are minimum, therefore, it can be cultivated in fields which soil pH has wide values, between 4.5-8.5.

<u>Humidity requirements</u>

Sorghum is not very demanding in terms of humidity, the transpiration coefficient being 150 - 290. High humidity during the vegetation period determines a bigger quantity of juice in which the sugar content diminishes.

Critical stages of sorghum humidity are characteristic to intense growing period of stem, apparition of panicle, blossoming, formation of grains. In draught areas, the irrigation applied during these stages determines an increased production of green matter, juice in stems and grains.

<u>Light requirements</u>

Comparing to sugar beet, sweet sorghum has higher requirements in terms of light. Shadowing during the first vegetation stages and the stem intense growing negatively impacts on production of stems, juice and grains. In conditions of shadow or low intensity of light the plants grow in length, the resistance to leaves fall decreases and vegetation period extends.

A sufficient quantity of light correlated to other factors during the vegetation period determines to collect a big quantity of high sugar content juice in the stem and an increased resistance to fall. Both sorghum populations and hybrids behave as plants of short day.

<u>Soil requirements</u>

The sorghum is moderately demanding in terms of soil. It valorise very well the less fertile soil, acid, salty or sandy and eroded, where it ensures in normal conditions, greater yields than other plants growing in this type of soils. Sorghum may be cultivated in soil which pH limits range between 4.5 and 8.5. These reduced requirements in terms of soil (in correlation with other biotic factors) explains why the sorghum crop has been extending in many world areas with salty or sandy soil (Northern, East and West Africa, West Asia, Mexico, Southern USA and South-_West part of Romania).

Sweet sorghum should not be cultivated in compact, acid, cold soils with groundwater close to surface or in soils prone to stagnant water coming from groundwater or rain.

Productivity of sweet sorghum depends on many parameters: climate conditions, (temperature, precipitations), soil quality, varieties of sweet sorghum, agricultural practices.

As a general rule, all the components of sorghum can be used: grains, husks and flour, that keeps its taste and rice quality that will be several times cheaper; also, the juice (syrup) obtained from stems with qualities similar to those of honey. At the same time, the sugar from sorghum is much more healthy, cheaper and obtained in bigger quantity than the sugar beet; also, we can obtain the world-wide searched starch, excellent beer, alcohol (by 20 - 40 litres more out of ton of seeds comparing to wheat), fodder, combined livestock and birds mixed fodder, liquid fuel (bio-ethanol) and solid fuel (briquettes that may replace wood and coal). Also, the sorghum roots have an extraordinary role. Starting from 1 ha of sweet sorghum, a quantity of up to18 t. of dry matter coming from roots remains in soil. If, at the quantity of carbon in roots we add phosphorus and potassium and other elements, after rot processing, annually can be reached 3-4 t of humus per 1 ha. Comparing to other crops, the most of them do not own the appropriate balance of humus, and orchards and vines, on the contrary, they destroy every year approximately 2 t of humus.

The most important arguments in favour to sorghum cultivation are:

<u>Scientific argument</u> – existence of a great number of varieties and especially hybrids, as well as, the appropriate cultivation framework both for producing bio-fuel (bio-ethanol, solid fuel, etc) and obtaining the products designed to food industry and livestock.

Sorghum (Sorghum bicolour) is a species endowed with a remarkable genetic variability, that makes it difficult to frame. Sorghum importance is presented in studies on its structure, phenol and antifungal protein content.

<u>Economic argument</u> – sorghum is a productive plant, unpretentious to soil fertility, draught, involves minimum expenses of cultivation and processing, being a plant without losses (even wastes are capitalized). Therefore, sorghum was studied in terms of its performance by land valorisation, production profitability, possibility of obtaining food and non-food products, livestock products and not less important for obtaining and using the bio-ethanol.

<u>Ecologic argument</u> – sweet sorghum, cultivated on large surfaces could substantially solve the air pollution issue. 1 ha of sweet sorghum annually absorbs from the atmosphere up to 50-55 t of carbon dioxide while the hardwoods absorb 16 t/ha/year, and cereals3-10 t/ha/year. According to Kyoto Protocol, Romania and Bulgaria have the opportunity of earning important amounts of money only by cultivating the sweet sorghum on large surfaces, considering that one ha of sweet sorghum annually absorbs 50-55 t of carbon dioxide, removing big quantities of oxygen.

RESULTS AND DISCUSSIONS

The main biofuels that are used nowadays are:

- crude oil (for diesel non-perfected engines for trucks and tractors);

- biodiesel (for diesel engines with joint ramp or nozzle pump);
- bioethanol (for Otto engines or for diesel oil mixture as E-diesel);
- bio-methanol (for Otto engines and for producing biodiesel) [9].

In figure 9 is presented the diagram of obtaining these bio-fuels.

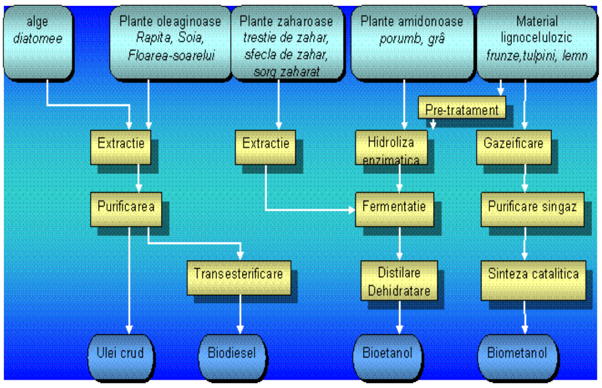

Fig. 2 - Diagram of obtaining the main bio-fuels [9]

Bioethanol is obtained by distilling the fermented simple sugar (glucose maltose, raffinose). This simple sugar is obtained from:
- saccharate plants (sugar cane, sugar beet, sweet sorghum);
- starch plants (corn, wheat, potatoes);
- lignocellulosic material (waste biomass).

Starch and lignocellulosic material (actually, hemicelluloses and celluloses) turns to simple sugar through methods of degradation (enzymatic hydrolysis (figure 3).

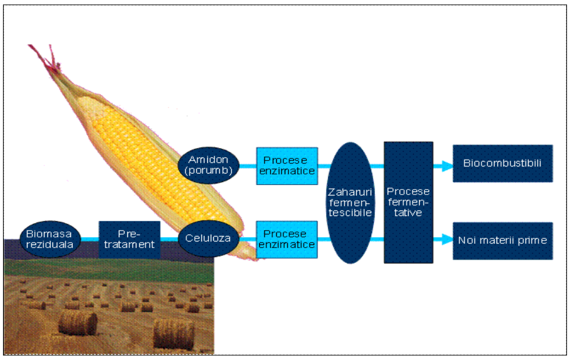

Fig.3. Producing fermentable sugars and their fermentation through enzymatic hydrolysis [9]

Solution of fermentable sugars is treated with yeast (or, in state-of-the art technologies, with Zygomonas mobilis bacteria) and is left to ferment. Alcoholic fermentation lasts 2-3 days in case of yeasts and several hours in case of bacteria. Recipients where fermentation takes place should be cooled, because by fermentation of each kilo of fermentable, sugar133 kcal are generated. Carbon dioxide formed can be collected in gasholders (and should be collected because otherwise it negatively contributes to greenhouse effect).

By alcoholic fermentation, a liquid named leaven that contains up to 18 % alcohol, the rest being water, small quantity of glycerine, propyl, butyl, amyl alcohols etc. This liquid is submitted to a first distillation, after which the raw ethanol of 90% concentration, results. Distillation residue is named marc and is used in foddering, as it contains proteins, fats etc. Raw alcohol is subjected to rectification in rectifying column, the distillate being an alcohol of 95.6 %, and the distillation residue the glycerine and fusel – oil liquid, made of superior alcohols (propyl, butyl and amyl alcohols).

Alcohol of 95.6 % is an azeotrope mixture with 78.15^{o}C boiling moment; therefore, for obtaining a pure alcohol

(alcohol absolutely necessary to be used as bio-ethanol) another distillation is not advised (because azeotrope distills like a pure substance), but special dehydrating methods should be applied (e.g. treating with substances that easily combine with water, such as calcium oxide, calcium sulphate burnt etc.) followed by distillation. Producing bio-fuels involves a whole chain starting from the farmer who cultivates the energy plant and ends at the fuel pump level. In the whole world, the main countries producing bio-fuels are:

- Brazil (bio-ethanol from sugar cane);
- SUA (bio-ethanol from corn);
- China (bioethanol from sorghum);
- European Union (biodiesel from rapeseeds).

In figure 4 are shown the main areas where bio-fuel is produced.

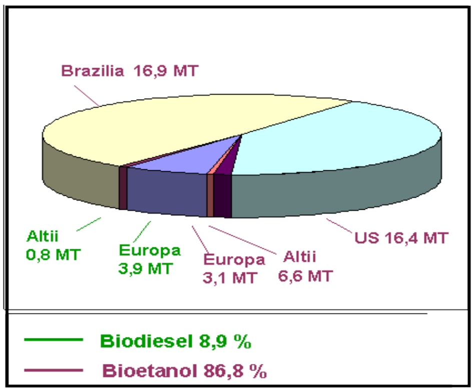

Fig.4. Main countries producing biofuels [9]

Imbalances determined by by-products resulted after bio-fuel obtaining. The following by-products result after the bio-fuel production:

- Rapeseed biodiesel;
  - glycerine;
  - rape husks.
- Bio-ethanol from sweet sorghum – sorghum bagasse (stems squeezed sugar);

- fermenting yeast / marc

Bio-ethanol from corn – corn marc

- fermenting yeast [9].

The main energy crops for Romania are rapeseeds, sunflower (with high content of oleic acid), sweet sorghum and corn. In Romania, among the plants above, sunflower (Helianthus annuus L.) and corn (Zea mays L.) dispose of most appropriate conditions. Sunflower produces an edible oil well accepted by people and the seed surplus is capitalized abroad. Corn has also multiple uses and the fuel producers and farmers are less interested in producing bioethanol. That is explained by fiscal reasons (high level of excise taxes for alcohol, lack of efficient structure of collecting the State incomes) that make the bioethanol unable to benefit yet of any fiscal facilities, fhat is why the interest in this type of fuel is low [9].

CONCLUSIONS

In favour of the extent of the cultivation and whole industrialization of sweet sorghum in Romania, the most important arguments are:

1. large surfaces of unexploited or inefficient agricultural field can be capitalized by massive sorghum crops, thus creating new employments.
2. Cultivation of sorghum can produce great quantities of biomass (80-120 t/ha) with 15-30% sugar content, (5-7 t sugar/ha), renewable raw matter for chemical, petrochemical industry, agriculture, food industry and pharmaceutical industry.
3. By entire industrialization of sorghum, can be obtained the following: bio-ethanol (bio-fuel for transport means, agricultural

fixed and mobile equipment), edible alcohol, vinegar, syrup, paper, cellulose, natural fibres, vegetal proteins, livestock fodder, etc.

4. Bio-fuel resulted from sorghum is ecological and diminishes the carbon dioxide emissions, which are the main responsible factor for greenhouse effect in terrestrial atmosphere nowadays.

5. Residue or pulp (bagasse) remained after extracting the sweet juice from stems contain cellulose of approximately 31-35 % and a series of other carbohydrates convertible in bio-ethanol after the enzyme hydrolysis (figure 10).

6. Sorghum bagasse is successfully used for obtaining cellulose. The cellulose quality obtained is similar to hardwood cellulose (designed to produce cellulose) quality. Production of bleached cellulose per hectare of sweet sorghum is cheaper and 2.5- 3 times bigger than the common production per hectare of forest .

In Romania, bio-ethanol obtained from sweet sorghum could be produced by means of conventional technologies, at a total price below 200 euro per ton, including the duties, transport costs, commissions, etc., being a competitive price on European market, unless the production obtained is of approx. 5 tons ethanol per hectare.

ACKNOWLEDGEMENT

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