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USING OF MILLET STRAW FOR ENERGY PURPOSES

Abstract

The article considers the issue of using plant waste from agriculture for energy production in Ukraine. The following aspects are analyzed: the formation of straw and sifted grains of cereals, in particular, millet (P. miliaceum L.), available directions of their utilization, as well as the prerequisites for the possibility of application in energy purposes.

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A positive correlation was noted between the parameters of the structure of millet plants and investigated elements of cultivation technology. When applied to the studied species of millet, both the grain yield of plants and biomass, which after harvesting forms waste, increases as well, and it is expedient to use it as a source of biofuel. The use of agricultural techniques in research has had a positive effect on both the increase in biomass and grain productivity of energy millet. The highest yield was recorded in the variants when applying $N_{60}P_{60}K_{60}$: in the variety Jubilee – 5.31 t/ha, Zolushka – 5,00 t/ha (50–55% to control), which provided the amount of waste mass – 5,0–5,3 t/ha, respectively, and increased potential resource of raw materials for the production of various types of biofuels for millet by 50%.

Key words: *Energy security, Plant remains, Millet straw, Disposal Bioenergy.*

Introduction

Nowadays energy safety is one of the most important parts of the national economy since only reliable use of fuel energy sources allows for the relevant operation of all economic (and on basis thereof – public) institutions. Without any doubt, it can be stated that the energy sector is a groundwork for almost every activity in the modern world and plays a crucial role in the economic progress of a country. Moreover, it provides foundation for sustainable development of a society as a whole.

Nonetheless, considering the energy safety of a country (society) to be completely reliable in every socio-political situation is a great mistake. In the context of globalization (first of all in the competitive development of a polycentric world), the positions of states donating the energy are characterized by increased instability, unpredictability, and political selfishness.

Consequently, the countries which have been and are the energy recipients have to build their own systems of energy safety which become effective enough to balance dysfunctional influences (challenges, threats, and dangers) created by the international environment [1].

The task of reducing energy dependence can be partially solved by developing effective energy safety programmes and the alternative energy sector in Ukraine. According to Energy Strategy for 2030, the alternative energy share should reach 20%. The main directions of alternative energy in Ukraine are wind power, solar power, bioenergy, and hydroelectric power [1].

High and unstable oil and gas prices, the necessity for more economical consumption of fuel reserves, environmental protection, and dealing with the problems of climate change cause the need to find alternative energy sources, in particular, expand the energetic use of biomass. Its main components are straw and other agricultural waste (stems, pots, husk, etc.), as well as wood waste, liquid fuels from biomass, different types of biogas and energy crops [2].

It is projected that by 2023 the EU land available for cultivating energy crops will grow to 20.5 million ha, and by 2030 – to 26.2 million ha.

Energy crops are great significance for the bioenergy sector of the European Union. European Biomass Association (AEBIOM) estimates the current potential of energy crops in the EU as 44–47 Mtoe/y. One of the EU 2020 targets is to reach 138 Mtoe of biomass in the gross final energy consumption, which corresponds to 14% of GFC. The available potential of energy crops allows covering about 1/3 of the target [3].

In Ukraine, only 2.5% of the energy consumed from its total volume comes from biomass, while in Western Europe – about 12%, and in some Scandinavian countries – from 17 to 40% [4].

Currently, the world has accumulated enough extensive experience in using vegetable waste agricultural production, primarily straw, for energy purposes. When burning 1 ton of straw, about 3 MW of thermal energy is produced, which means replacing 333 cubic meters of gas. The recognized leader in the bioenergy sector is Denmark, where nearly 1.5 million t of 6 million t of annually produced straw are burned for energy production (~ 17 PJ / year) [5].

In the UK (Ely) there is one of the most powerful straw power plants in the world – 38 MW. The straw of grain crops, the volume of about 200 thousand t/year, is the main fuel of this TPP. Straw-fired power plants are also available in Spain [6].

In Poland, there are about 100 small-capacity straw boilers (~ 100 kW) and more than 40 small- and medium-sized boilers in the district heating system (0,5–7 MW) [7–8].

In Sweden, the straw market as fuel is in the process of development. Currently, the country has a relatively small number of straw boilers and boilers in the district heating system [9].

Ukraine has some experience in energy and biofuel production from straw. About 100 boilers and heat generators for straw bales are in operation in rural areas of the country. About 45 of them are boilers manufactured by UTEM (Ukraine), 10 units are boilers by Faust and Passat Energy (Denmark), the others are heat generators by Brig (Ukraine). The total installed capacity of the equipment is 70 MWth. The sector of solid biofuel production from straw is also in progress: in 2012, 21.700 t of pellets and 2.000 t of briquettes were produced in the country. The first part of Vin-Pelleta, a new factory, started its operation in Vinnytsa oblast (Ukraine) in the autumn of 2012. Its productivity is 75.000 t/yr of straw pellets. In 2014 the factory reached its design productivity of 150.000 t/yr. Smart Energy, the owner of Vin-Pelleta, is planning to build 20 factories for the production of straw pellets in all Ukraine's regions. Total productivity of the factories is supposed to be 2.5–3 Mt [17]. In addition, KSG Agro (a Ukrainian agricultural holding) started the operation of a factory for straw pellets production in Dnipropetrovska oblast (Ukraine) in 2014. The agricultural holding is going to use its own feedstock for the pellets production. Further actions include the construction of another two factories in the Dnipropetrovsk oblast.

Straw is a waste product of cereal crops production. The ratio between the grain part and straw is about 1:1 (except for corn, for which the ratio is 1:1.3), therefore the annual amount of straw is close to the production volume of cereal crops in Ukraine. During harvesting, the grain part of a crop is detached from the stalk, and the way of collecting straw depends on the technology applied. Some straw is left in the field as stubble remains to be later plowed back into the soil.

The following technologies for collecting straw of spiked grains are applied in Ukraine:

– "Streaming" technology. Straw is shredded by a combine harvester, collected in replaceable trailers and transported to a storage place. If the trailer is not available, the straw is scattered over the field;

– Stacking technology. Harvester-stacker makes stacks of 150–300 kg, and they are discharged onto the field on the stubble remains. The stacks are collected from the field by rope sweeps or by push sweeps. If stacks are formed (shaped) as blocks, they are taken out of the field by stack-movers;

– Swathing technology. Straw is swathed by a combine swathe. There are different ways for collecting swaths, one of which is baling;

– "Spreading" technology. During cereal crops harvesting, straw is shredded and spread (scattered) over the field.

The swathing technology of straw collection provides for further baling. It is important for transporting straw at middle or relatively long distance and the use as fuel. Baled straw can be stored under a shed or indoors that protects it from moistening and contaminating. Baling considerably reduces the volume of straw and allows mechanizing some operations during straw handling and transportation.

For the wider introduction of straw energy equipment in Ukraine, it is necessary to switch from streaming technology of the straw harvesting to swathing technology with its further baling.

The collected cereal straw is utilized in different ways: as litter and fodder for cattle, as organic fertilizer, for growing mushrooms in hothouses, and also for energy purposes (direct combustion in boilers, production of pellets/briquettes). The unutilized remains, which altogether make up quite big volume all over the country, are often burnt on the field that is legally prohibited in Ukraine and harmful for the environment and soil [10].

Just after harvesting, the moisture of cereal straw is 15–20% (heating value Q = 12–15 MJ/kg). If straw is left on the field for some (rather long) period of time, its moisture drops to 14–17% (Q = 14–15 MJ/kg); content of chlorine and potassium decreases due to washing-out that improves the quality of straw as fuel [55]. For combustion in boilers, straw moisture content must be below 20%, and for pellets production it should be below 12–14% [10].

The fuel characteristics of biomass of agricultural origin are specific and different from wood biomass (which is worse), which requires a more thorough approach to the choice of energy equipment and the organization of the combustion process. For example, straw contains chlorine and alkali metals, which means that some chemical compounds, such as sodium chloride and potassium chloride, are formed during its combustion. These compounds cause the corrosion of steel elements of energy equipment, especially at high temperatures. Another feature of straw as fuel is the relatively low melting point of ash (900–1 000 °C), which can lead to the slugging of elements of energy equipment. Fortunately, constructive and other technological solutions, which minimize the negative impacts and allow using straws as fuel, are available around the globe. Examples of such solutions are co-combustion of straw with coal, wood and other fuels, or the use of "grey" straw (kept in the open air for a long time) instead of "yellow" (fresh) straw. As a result of flushing with rain falls, "grey" straw contains much less chlorine and potassium compared to the "yellow" straw. It is worthwhile to note that content of chlorine and alkali metals in the straw of Ukrainian origin is significantly less than in the straw of other countries. This is due to an essential reduction in the introduction of mineral fertilizers under crops over the past 25 years [11].

There are 32 million hectares of cultivated land in Ukraine. Grain crops are grown in 58% of the area [12].

Millet is one of the crops grown in Ukraine, and its area is increasing (P. miliaceum L.). Some amount of waste is also formed while cultivating this crop for grain. Various techniques and coefficients are proposed for calculating the amount of waste. The ratio of 1:1 is most often used for cereal crops, i.e., the waste coefficient is taken per unit as already mentioned above, the coefficient of 1.6 is proposed for wheat under other recommendations. It is difficult enough to estimate the amount of straw collected in each region following the application of various technologies for cultivating culture. In the present researcher, we have analyzed the ratio of different elements of the millet plant structure depending on the elements of the cultivation technology [13].

Material and Methodology of Research

Indicators that regulate the productivity of millet plants include architectonics, especially those that are elements of the product structure and determine competitiveness. The height of millet plants, which considerably depends on the soil fertility, moisture content and other factors, still remains a stable, high-grade feature. The length and shape of the panicle, the height of the plant – varietal signs, vary considerably from the conditions of cultivation and especially from the area of the plant nutrition [14].

Experiments were carried out in the field crop rotation of the experimental field of the State Agrarian and Engineering University in Podilia, which, under the conditions of heat supply and humidification, belongs to the southern moist agroclimatic region.

The field soils of the State Agrarian and Engineering University in Podilia are typical black currant with little humus, heavy loamy on the loess. The experimental area was characterized by the following agrophysical and agrochemical properties of the soil: the content of humus (by Tyurin) – 3.8–4.4%, alkaline hydrolyzed nitrogen (by Cornfield) – 122–126, the content of mobile phosphorus by Chirikov – 90–120, exchangeable potassium – 190–230 mg per kg of soil, the capacity of absorption and the number of absorbed elements, respectively, 32–34 and 30–33 mg/eq. per 100 g of soil. Hydrolytic acidity is 2.3–2.8 mg/eq. per 100 g of soil, and the degree of saturation with the elements – is close to absolute – 94.7–99.0%.

The sown area of the unitary field was 45.0, and the accounting – 25.2 m^2 in four-time repetition. In the experiment, Yuvileine and Zolushka varieties were sown. The sowing date is early May. The before sown is buckwheat for grain.

Millet needs and reacts well to nutrition. The experimental scheme included five backgrounds of the power supply – control (without fertilizers), $N_{40}P_{40}K_{40}$, $N_{40}P_{40}$, $N_{60}P_{60}K_{60}$, $N_{60}P_{60}$. Ammonium nitrate was used as fertilizer – 34.6% active substance (DSTU 7370:2013), granular superphosphate – 20% active substance (GOST 5956-78), potassium chloride – 60% active substance (GOST 4568-83).

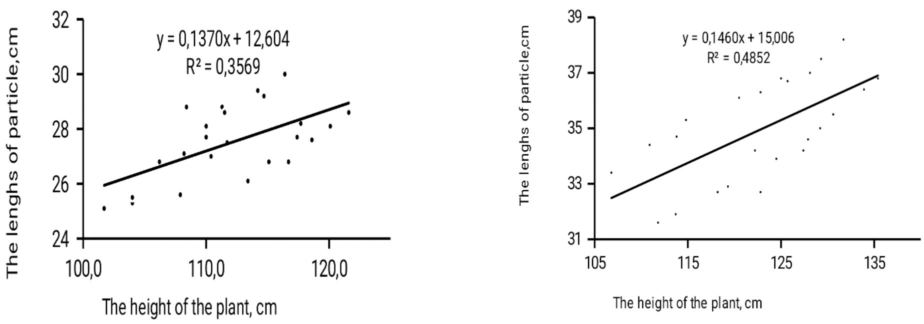
Herbicides were used in experiments for avoiding couch grasses: Agritox, 2.4-D, Lontrel 300. Control is an option without using herbicides. Systemic herbicides used at optimal standards demonstrate high selectivity: they suppress cotyledon and do not influence cereal plants. Common couch grasses on crops of millet were: Convolvulus arvensis L., Amaranthus retroflexus L., Cirsium arvense (L.) Scop., Chenopodium album L., Polygonum aviculare L. Herbicides were brought into the phase of blooming of millet plants with norms recommended by the “List of pesticides and agrochemicals authorized for use in Ukraine”.

Result and Discussion

The research findings indicate that studied agro-devices have somehow affected the morphological structure of the millet plants: the height and length of the panicle and the branching of stems.

The results of studies confirm that fertilizers, methods of sowing and, partly, herbicides, which reduced the level of couch grassed crops and facilitated the better development of cultivated plants, have a significant influence on the elements of the structure of millet plants. This has affected the following basic parameters of the architectonic of the millet plants, such as the height of plants, the length of the panicle, and the branching of the stem.

The increase in the number of fertilizers resulted in an increase of vegetative mass: the height of the plant, the length of the panicle, and the number of branches of the stem. A positive correlation was noted between the height of plants and the length of the panicle of millet (r = 0,7 – Yuvileine variety, r = 0,6 – Zolushka variety) (Fig. 1).

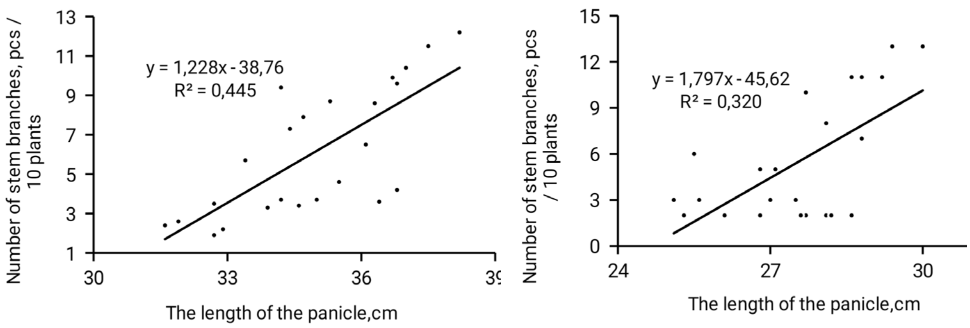


Yuvileine variety Zolushka variety

Fig. 1. Correlation of the length of the panicle from the height of the millet plants

Millet is a grass plant whose stem can form branches. They affect in two ways at the level of plant productivity. Firstly, under favorable weather conditions and sufficient mineral nutrition, these branches produce panicles in which the grains are bound and matured that advances the fertility of the plant, especially in lean crops under wide-ranging sowing methods, and also improves the vegetative mass of the plant. Secondly, when some of the factors are not available or inadequate, then branches can be formed on the plant, but they often do not form panicles, or if they form, then they are either empty-headed or empty-grained. Consequently, the fertility of the central panicle is reduced. Based on the above-mentioned, the plants of the investigated millet varieties were shaping from 1 to 13 branches per ten plants.

The positive correlation is marked between the increase in the length of the central panicle stem and the number of branches formed by the stem, that is, the larger the plant is, the longer the panicle, the more branches were formed on the stem (r = 0,7 – Yuvileine variety, r = 0,6 – Zolushka variety) (Fig. 2).

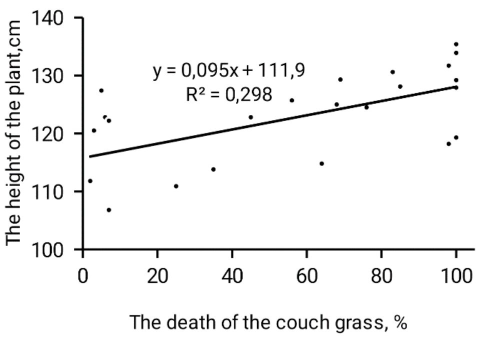


Yuvileine variety Zolushka variety

Fig. 2. Correlation dependence of the number of branches of the stem on the panicle length

The peculiarity of the millet plants branching is that on wide-ranging sowing with increased fertilizer use, the number of branches on plants, as well as vegetative mass, increases, and decreases on the row sowing.

The use of herbicides affected the number and size of the main structural elements of millet plants. Herbicides, acting on dicotyledonous couch-grass, reduce their number and make it possible for cultivated plants to grow better and develop. However, using herbicides should be considered as an effect on cultivated plants. The herbicides used in the experiment influenced the reduction of the number of dicotyledonous couch-grass to varying degrees in comparison with control and, accordingly, changes in the architectonics of millet plants occurred. The height of plants positively correlated with the influence of herbicides, aimed at reducing the couch-grass of the millet sowing (r = 0,5 – Yuvileine variety, r = 0,7 – Zolushka variety) (Fig. 3).



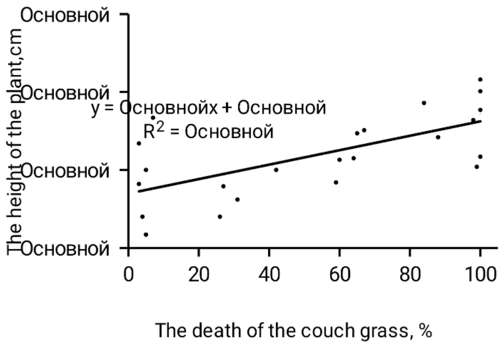


Fig. 3. Correlation of the height of millet plants from couch-grass reduction

Conclusions

Correlation analysis of the research results shows that the elements of cultivation technology affect the fertility of cultivated plants, as well as the elements of architectonics, which are directly involved in its formation and stipulate vegetative wastes.

A positive correlation was noted between the parameters of the structure of millet plants (plant height, panicle length, number of stem branches) and investigated elements of cultivation technology [15]. When applied to the studied species of millet, both the grain yield of plants and biomass, which after harvesting forms waste, increases as well; it is expedient to use it as a source of biofuel given the agrarian development of Ukraine and the need for energy efficiency in settlements.

The energy sector is one of the most important and integral components of the economic complex of Ukraine. At the same time, energy security is one of the weakest components of the national security of our state.

The most urgent tasks faced by the state are to reduce the consumption of expensive imported fuels - natural gas and oil – and find own alternative renewable energy sources while solving environmental problems and developing energy-saving technologies. According to leading experts in bioenergy, the economic potential of biomass is about 21 million toe / year, which can meet up to 14% of Ukraine's primary energy needs, of which 12 million toe / year available today [1].

The use of agricultural techniques in research has had a positive effect on both the increase in biomass and grain productivity of energy millet. The highest yield was recorded on the variants when applying $N_{60}P_{60}K_{60}$: in the variety Yuvileyne – 5.31 t/ha, Zolushka – 5,00 t/ha (50–55% to control), which provided the amount of waste mass – 5,0–5,3 t / ha. Thus, potential resource of raw materials for the production of various types of biofuels for millet boosted by 50%.

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ВИКОРИСТАННЯ СОЛОМИ ПРОСА В ЕНЕРГЕТИЧНИХ ЦІЛЯХ

Анотація

Розглянуто питання використання рослинних відходів сільського господарства для виробництва енергії в Україні. Проаналізовано такі аспекти, як утворення зерна та соломи зернових культур, зокрема проса (P. miliaceum L.), наявні напрями їх використання, а також передумови можливості використання в енергетичних цілях. Відзначено позитивний кореляційний зв'язок між параметрами структури рослин проса та досліджуваними елементами технології вирощування. У разі застосування досліджуваних сортів проса підвищується як урожайність зерна рослин, так і біомаса, яка після збирання утворює відходи, і її доцільно використовувати як джерело біопалива.

Використання агротехніки в дослідженнях позитивно вплинуло як на збільшення біомаси, так і на зернову продуктивність проса. Найвища врожайність зафіксована на варіантах із внесенням $N_{60}P_{60}K_{60}$: у сорту Ювілейний – 5,31 т/га, Золушка – 5,00 т/га (50–55% до контролю), що забезпечило кількість відходів – 5,0–5,3 т/га. га, відповідно, збільшився і потенційний ресурс сировини для виробництва різних видів біопалива для проса на 50%.

Розглянуто питання використання рослинних відходів сільського господарства для виробництва енергії в Україні. Найактуальнішими завданнями, які стоять перед державою, є скорочення споживання дорогих імпортних видів палива – природного газу та нафти, і пошук власних альтернативних відновлюваних джерел енергії під час вирішення екологічних проблем та розвитку енергозбережувальних технологій. За оцінками провідних фахівців у галузі біоенергетики, економічний потенціал біомаси становить приблизно 21 млн тне/рік, що може забезпечити до 14% потреб України в первинній енергії, із яких натепер доступно 12 млн тне/рік.

Проаналізовано такі аспекти, як утворення соломи та просіяного зерна зернових культур, зокрема проса (P. miliaceum L.), наявні напрями їх використання, а також передумови можливості використання в енергетичних цілях.

Зазначено позитивний кореляційний зв'язок між параметрами будови рослин проса (висота рослини, довжина волоті, кількість гілок стебла) і досліджуваними елементами технології вирощування. У разі застосування до досліджуваних видів проса підвищується як урожай зерна рослин, так і біомаса, яка після збирання утворює відходи, що є доцільним з огляду на аграрний розвиток України й актуальність використання його як джерела біопалива, енергоефективності в населених пунктах.

Використання агротехніки в дослідженнях позитивно вплинуло як на збільшення біомаси, так і на зернову продуктивність енергетичного проса. Найвища врожайність зафіксована на варіантах за внесення $N_{60}P_{60}K_{60}$: у сорту Ювілейний – 5,31 т/га, Золушка – 5,00 т/га (50–55% до контролю), що забезпечило кількість відходів – 5,0–5,3 т/га, відповідно збільшився потенційний ресурс сировини для виробництва різних видів біопалива для проса на 50%.

Ключові слова: *енергетична безпека, рослинні залишки, солома проса, утилізація біоенергетики.*

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