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ENERGY CROPS: THE LINK BETWEEN EDUCATION AND SCIENCE

UPRAWY ENERGETYCZNE: WSPÓŁPRACA NAUKI I EDUKACJI

Summary: Involving in energy balance of agriculture industry biological kinds of fuel as renewable resources of accumulated solar energy is one of the critical tasks at present. But, use of energy biomass potential is restricted by agro-industrial technologies to obtain energy and appropriate equipment and technical means absence that would be adapted to functioning conditions and the lack of specialists in this field.

Within 10 years of fruitful scientific work we a great deal of information has been compiled, theoretical material and results of researches of energy crops have been summarized and trained students.

The basis of theoretical researches was detailed and substantial review of literature references, materials of domestic and foreign scientific publications as well as corresponding practical recommendations and methods. We applied both general scientific methods (dialectics, analysis and synthesis) and special ones for analytical review of literature.

It is determined that energy crops are adapted to growing conditions throughout the territory of Ukraine. Also it has been established that management of cultivation, harvesting and storage of energy crop biomass requires improvement and scientific substantiation in the conditions of our country. Environmental issues of energy plantations and carbon circulation require further more complicated study. These problems solving will allow obtaining plant raw material to produce biofuel annually for a long period of time which requires the work of the relevant specialists.

That is why, the problem of professional training of the future specialists, forming of social and labour potentiality is paid considerable attention at present. It has been established that education is a branch of social sphere in which stable development of modern activity should be considered as a process of human potential reproduction on the broadened and innovative basis. A poor teachers' motivation for doing innovative activity results in insufficient application of innovation technologies in the teaching process at higher educational establishment. Furthermore, innovative activity involves stable development of teacher's creativity as well as changes of activity methods, styles of thinking and information competency formation.

Application of the proposed model in the teaching process enables to optimize mastering of theoretical and practical components of the disciplines of natural sciences on the basis of innovative component. Besides, this increases effectiveness of students' independent work while doing research work together with postgraduates and teachers. It's help students of agronomic profile to gain new, modern knowledge and become more competitive at the employment market.

Key words: education, teaching process, science, energy crops, energy potential

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Problem statement and motivation

Search for new ways of cheapen the variety of bioraw material, development of new technical and economic decisions and training of highly qualified specialists are the main priorities of the new industry - bioenergetics. The problem of necessary infrastructure creation aimed at effective use of plant energy resources and their phytomass processing to produce liquid (bioethanol, biobutanol), gas and solid biofuel (pellets, briquettes) is very important and urgent at present.

Bioenergetics (bioenergy) is a science studying general regularities of energy transformations in the living systems (cells, organisms, ecosystem).

Technical bioenergetics (technical bioenergy) is a science of general regularities of energy production and use (solid, liquid and gas biofuel) from the sources of biological origin.

Technical bioenergetics is one of the approaches of environmental biotechnology connected with efficient use of photosynthesis energy.

Bioenergetics of agricultural production (bioenergy of agricultural production) is a branch of energetics based on production and use of fuel out of biomass of agricultural origin.

There are all necessary backgrounds in order to implement the program of bioenergetics development in Ukraine. They are the following:

1. soil and climatic conditions which are favorable for providing high yield of power - intensive phytomass of energy crops;
2. human scientific potential that require proper education and training of specialists in the field of bioenergetics;
3. application of adaptive and improvement of existing technologies bioenergy crops cultivation on marginal lands.

Appropriate processing of phytoraw material and use of fuel in the fuel and energy complex will result in growth of bioenergy part in the total structure of Ukrainian energetic and decrease of our country energy dependence. As a result, reduction of using non - renewable energy resources with increase of demand in alternative energy sources that in future will favour development of national economics and betterment of population welfare. Energy strategy of Ukraine till 2030 [1] expects dynamic growth of energy biomass use in 2015 to 5 million tons of equivalent fuel or 2.5 percent of total energy consumption and in 2030 - to 20 million tons of equivalent fuel or up to 10 percent.

Besides, Law of Ukraine “On Alternative Energy Sources” with introduced amendments [2] determines the main fundamentals of the state policy in the field of alternative energy sources. Increase of production and consumption of energy generated from the alternative sources with the aim of saving spending of traditional fuel and energy resources is the main issue in the law. This will result in decrease of Ukraine dependence on import of energy resources by production restructuring and rational energy consumption due to growth of energy part generated from renewable sources.

In the field of electrical energy production from biomass the situation has been changing because of new procedure of calculation of electrical energy produced from renewable energy sources according to “Green” Tariff. This procedure of calculation is explained in the Law of Ukraine “On Amendments to the Law of Ukraine “On Electrical

Power Engineering" to Stimulate Use of Alternative Sources of Energy [3], and NEURC's Resolution "On Approval of Changes to the Procedure for the Establishment, Revision and Termination of the "Green" Tariff for Business Entities" [4].

Taking into account importance of securing of Ukraine energy safety and transfer to energy efficient and energy saving consumption of energy resources introducing innovative technologies, researches of this direction are very important at present.

S. Yermak and O. Buhaienko (2016) [5] have analyzed world - wide experience of using alternative energy sources such as energy of the sun, wind, waves and heat of the Earth as well as peculiarities of energy obtaining from residues and various crops. Also they have investigated perspectives of introducing renewable energy sources into the energy market of Ukraine concerning its energy potential in order to be an energy independent country. The projects of heat energy generation from biomass namely poplar and willow, silver grass (Miscanthus), switchgrass and wood residues implemented in Ukraine have been considered as well.

I. Dumanska (2015) [6] studies theoretical and methodological problems and develops practical recommendations concerning economic - organizing fundamentals of innovation activity and shows the ways of their introducing in fuel and energy complex of Ukraine. The place and role of innovations in "Energy strategy of Ukraine for the period till 2030" have been defined. Structure of the strategies of innovation activity in fuel and energy complex has been substantiated.

Also, the scientists [7] pay much attention to analysis of the existing evaluation methods of the components of territory energy potential by nature - resourse complex. The necessity of natural resource use in order to increase energy component through identification of environmental conflicts has been determined. It has been proved that evaluation of energy potential increases controllability of economics of complex as a whole and energy component in particular.

The main scenarios of development of the world energy market and strategies of the countries implementing them are studied on the basis of the complicated reserches [8]. The authors summarized energy priorities and tendencies. As a result they defined problems and ways of formation of energy strategy of Ukraine in accordance with the world guidelines.

Kaletnik GM. (2008) in his monograph [9] has systematized scientific and methodical economic - organizing fundamentals of biofuel market formation as well as formation and development of energy crop market. The author has defined technical - technological characteristics of biofuel production from plant raw material and has presented economical evaluation of their application in the agroindustrial complex of Ukraine. Author's systematization of the world trends of development of market of biofuel from plant raw material enabled to work out economic substantiation of perspectives of future biofuel market development in Ukraine.

Analysis of world - wide experience of renewable energy sources use and perspectives of their introduction in energy market of the certain country in order to decrease its energy dependence is studied by many research, scientifical and educational institutions. Higher educational establishments of Europe and Ukraine in particular Poltava State Agrarian Academy (PSAA) are a great example of such institution.

PSAA is a higher educational establishment that successfully combines educational process with scientific work. Some academy structural units namely research department, international relations department, scientific subdivisions (laboratories, centers), languge center, scientific research farm, the centre of pre - entering training, educational departments of information technologies and others [10] successfully offer educational services.

Due to broad and strong international relations of our academy students are able to have practice and training in many foreign countries. The students also may receive Ukrainian diploma in parallel with Europen diplomas of state pattern.

Teaching process is held by highly qualified lecturers who actively work at renewal of methodological support of disciplines and introduce the latest techniques of study. Teaching staff and students of the academy often participate in various seminars, workshops, conferences, research projects and introduce innovations.

Nowadays, innovation development of our country demands renovation of agroindustrial complex as well as engagement of new specialists with innovation knowledge and easily adaptable to complicated situations in modern life. This problem is extraordinary important in the new field of alternative energy source use in agriculture that is in bioenergetics.

One of bioenergetics component involves growing crops to meet food requirements as well as growing energy crop for biofuel production [11].

That is why training of highly qualified specialists in the field of bioenergetics is necessary and important at present. The students of PSAA study available agrarian resources, energy crops, cultivation technologies for further energy conversion, ecological aspects of biofuel and others. New discipline “Energy crops” that is taught at Agrotechnology and Ecology department helps students to gain knowledge and skills of high level.

Overview of publications

Observation of the problem in education. The problem of teaching process optimization in order to improve education quality is devoted a great number of scientific publications by the following authors: VI. Andreiev, YuK. Babansky, VP. Bezbalko, MV. Bulanova-Toporkova, OO. Glushenko, NV. Kuzmina, G. Melkhorn, NYe. Moiseiuk, OV. Morozov, IM. Nizamov, VM. Oleksenko, VN. Pidlasyi, MM. Potashnyk, ZI. Sliepkan, DV. Chernilevsky and many others. These scientific works describe problems of searching favourable conditions to obtain the expected results with minimum efforts and time taking into consideration regularities of education, concepts, forms and methods, internal and external conditions in order to achieve teaching efficiency. That is why, the problem of professional training of the future specialists, forming of social and labour potentiality is paid considerable attention at present. It has been established that education is a branch of social sphere in which stable development of modern activity should be considered as a process of human potential reproduction on the broadened and innovative basis and according to G.I. Lukin [12] provides higher profit than material capital does.

In the procedure of selection and implementation of traditional and introduction of innovative technologies in education process there are contradictions between:

- modern education purposes and old methods of presenting and acquiring knowledge,
- increasing information content and limited educational time,
- necessity of introducing teaching innovations in the educational process and insufficient development of methodology of applying new pedagogical technologies in education.

Modern innovative pedagogical technologies are characterized by the following:

- enrich teaching process due to introduction of active, analytical and communicative training methods;
- ensure high level of teaching and educational process;
- form competency of future specialists;
- ensure gaining of necessary knowledge and skills;
- develop abilities of making right decisions in non - typical situations;
- form teachers' skills to create own educational programs;
- is a resource of change of education essence and structure of teaching process according to the international requirements;
- increase indices of achievements of the components of education technologization process;
- aimed at creativity development stimulation [13].

Personal ethics, adequate self - evaluation, positive development of abilities, readiness to self - determination and self - realization are the efficiency indicators of socially - pedagogical support of a teacher [14].

A poor teachers' motivation for doing innovative activity results in insufficient application of innovation technologies in the teaching process at higher educational establishment. Furthermore, innovative activity involves stable development of teacher's creativity as well as changes of activity methods, styles of thinking and information competency formation.

A higher educational establishment needs a teacher of more advanced typological structure of personality. The teacher must be labile, capable to self - development and self - determination in changing situations, ready to constant self - perfection, renovation of knowledge, skills and abilities of teaching activity organization [15].

Thus, while training specialists in higher school it is necessary to combine application of innovative forms and methods with understanding of purposes and tasks of education and training of future specialists for the particular field [16].

Introduction of innovative teaching methods at the chairs of Agrotechnology and Ecology department of Poltava State Agrarian Academy anticipates:

- improvement of teaching staff activity that involves organization of interdepartment meetings, consultations, holding methodical seminars and conferences, sharing pedagogical experience with other higher educational establishments during practical study and advanced training courses;
- improvement of teaching process - application of modern educational technologies and forms, testing intermediary and final knowledge, using videos, presentations and modern technical tools etc.

Such modern teaching components as situational tasks, brainstormings, business and role playings, express monitoring of knowledge, computer programs, multimedia techniques and others have been increasingly applying. Professional situations are modeled both in the field and classroom conditions by the teachers of the department. For instance: modeling of specific technological operations; group exercises; field experiments, excursions to the laboratories and farms etc.

Thus, the fundamentals for achieving innovative teaching goals are the following students' active methods:

- creative, scientifically - innovative approach to understanding of future profession;
- mentality independence, ability to make optimal decisions in particular situations;
- ability to master and apply new knowledge.

As our own experience show using active, the latest methods in higher school is a necessary condition in order to train qualified specialists.

But, nowadays interconnection of theoretical and scientifically - practical approaches involving innovative component of training students of the specialty 201 - "Agronomy" (by the example of new discipline "Energy crops") has not been found out to the full extent yet.

Observation of the problem in science. Biofuel production may increase energy safety of the country by supplanting import fuel, assist in development of domestic farm markets and decrease effect on environment due to reduction greenhouse gases emissions. Various plant raw materials - wood residues and energy crops can be used for production of biofuel of the second generation [17-20].

A great number of scientific works by MV. Roik, VL. Kurylo, MYa. Humentuk [21], OM. Hanzhenko [22], DB. Rakhmetov, OM. Vergun [23], GG. Geletukha, TA. Zhelezna [24], GS. Goncharuk, SM. Mandrovska [25], MI. Kulyk [26] and others are devoted to study ing energy crops in the conditions of Ukraine.

Among the most widespread energy crops in Ukraine are: switchgrass, willow, silver grass (Miscanthus) and poplar (likely live between 10 to 15 years, sometimes till 30 years). Agrotechnological techniques for growing these crops do not need much costs, harvest is gathered in winter or in spring using ordinary farm machines [27-29]. Such crops as giant bulrush (Arundo donax) [30-32], sugar sorghum and perennial sorghum cause a great scientific interest too [33].

Cultivation of energy crops in Ukraine is a perspective way of producing solid biofuels for further use, namely heating energy production. Country has up to 4 million vacant farm land by the data provided by Bioenergy Association of Ukraine, half of this land may be used for energy crop growing [34]. Ecology, economical and social efficiency of growing energy crops may be obtained if criteria of sustainability developed by Global bioenergy partnership taken into account [35]. Right choice of plot of land and energy crop has a significant influence on further effectiveness of energy plants plantations.

According to the requirements of IPCC (*Intergovernmental Panel on Climate Change*) aiming at preventing food competition while growing food products at the time of establishing energy crop plantations non - agriculture lands should be used because reverse tendency will provoke competition with food products. In turn, growing energy crops on land with high carbon content for example forests, peatbogs and meadows will lead to

indirect change of land use effect (ILUC - *Indirect Land Use Change*) that contradict to European concept of sustainable development.

In view of that as much in Ukraine as in the world tendency of using non-agricultural lands is seen (low productive soil, degraded, polluted lands) for creating an exploiting of energy plantations.

For the last 20 years for EU countries there had been performed a series of experiments of planting various crops as energy ones and most perspective crops for various climatic zones had been defined. Such perennial energy crops as willow, poplar, silver grass, sorghum are the most reasonable for the continental zones, poplar, silver grass are the best for Mediterranean north and giant bulrush, eucalyptus - for Mediterranean south [36]. Data provided by European biomass association AEBIOM, show that overall energy crop area in 2017 year is 50764 hectares [37].

In Ukraine energy crops are grown mostly on the experimental plots of educational and scientific establishments, in particular National Science Academy of Ukraine and National Academy of Agrarian Sciences of Ukraine and Forest Academy of Sciences of Ukraine. One of the greatest collection of energy crops in Europe has been formed at M.M. Gryshko National botanical garden NAS of Ukraine. This collection numbers 457 taxons, out of which 180 are promising for solid biofuel production [38].

Starting since 2010 there had been establishing industrial plantations of energy crops, willow, poplar and silver grass in particular that had total plantation area of 4000 hectares by 2016 year [39]. At Poltava State Agrarian Academy in particular the potential of plant residues of agriculture and phytomass of energy crops have been studying for more than 10 years [40].

Studying of energy crops excepting some publications, mainly concerns yield and energy potential, biofuel obtaining possibilities out of its biomass. These works do not take into consideration botanical - biological peculiarities of the given crops and possibilities of its zoning by soil - climatic zones of Ukraine in order to much greater potential realization of crops aiming at obtaining maximum output of biofuel out of plant biomass.

On account of that the chosen vector of researches that connects education and science of studying energy crops is crucial and requires deeper, complicated studying and more concrete conclusions.

Research methods and matetials

The publication purpose is to clear up the peculiarities of teaching process optimization and its connection with research work of agrarian direction of students, postgraduates and teachers.

In educational process the model of teaching and scientific process optimization (by the example of discipline "*Energy crops*") has been worked out in order to apply it studying other disciplines of specialty "Agronomy". The program of researches implied complicated study of energy crops in the central forest - steppe of Ukraine (Poltava region). The framework of the experiments was international scientific program (P4P, 2010 - 2013), state scientific themes (Agroecological fundamentals of energy crop cultivation in Ukraine, 2014 - 2016), the project of applied research (Development of optimal energy

system taking into account available potential of renewable energy sources in forest - steppe of Ukraine, 2017 - 2019).

The experiment has been done by laying out field trials and performing laboratory trials with energy crops: species and varieties of miscanthus (giganteus Chinese and sugar flower), varieties of foreign and domestic selection of switchgrass, annual sorghum and perennial sorghum, hollyhock, sida, rumex, paulownia, and others.

In the research we have used both general scientific methods (dialectics, experiment, analysis and synthesis) and special methods such as field one - determination of interaction between subject and object of the research; laboratory one - study of productivity elements; weight - calculated one - establishment of productivity and yield; observation - defining dynamics of plant gain; mathematical statistics method - dispersion and correlated - regression analyses and graphic representation of data in the trial.

Planning and laying out of the experiments have been performed according to methods of scientific investigation in agronomy [41,42] and methodical recommendations [43-45], observation of plant growth and development has been done by the methods of the state variety testing of crops [46], plant quantitative indices have been determined by the corresponding methods [47,48], yield has been recorded by land weighing of plant material with further calculation to standard moisture [49,50], statistical processing of the research results has been done by dispersion and correlated - regression analyses.

Teaching proces optymization

At present in view of urgent issues of energy independence of Ukraine the technologies of energy production out of biomass have been implementing with great intensity and taking into account stable growing demand for biofuel - agriculture biofuel market development are being stimulated. That, in turn requires new specialists training.

Taking into consideration that PSAA annually increases license number of students at new specialties and introduce new disciplines there is an increasing need in competent teachers and students with modern knowledge, special abilities and non - standard ways of thinking.

That is why, our publication has made an attempt to find out methods of teaching process optimization involving students in scientific work (by the example of discipline “Energy crops” of the specialty “Agronomy”) at PSAA. In future this will help to improve quality of education and train highly qualified professionals.

At the first stage educators have to work out the following documents: teaching and methodological complex comprising textbooks, lecture notes, reference books, dictionaries, methodical recommendations, workbooks and others.

Developed research and methodological complex of the discipline “Energy crops” is fully compiled with teaching and methodical material including innovative and international components. Students have an opportunity to master theoretical and practical material of the course, do an independent work and gain new, innovative knowledge based on the experience of European scientists and experts.

Theoretical material is delivered as multimedia lectures with various video components. Foreign experts are often engaged in delivering lectures. Thus, every year

scientists, businessmen and farmers deliver lectures to the students of Agrotechnology and Ecology department on the themes related to bioenergetics branch and belong to teaching and methodological complex (fig. 1). These themes are: “Peculiarities of plant resource use”, “Energy crops: botanical and biological peculiarities, cultivation technology, harvesting and using of biomass”, “Potential of genetic material and selection of energy crops” and others. The material delivered by foreign colleagues is valuable, informative, rich in content and based on the latest achievements of the world science because “energy crops” are new crops for Ukraine and growing them in our conditions we have to take into consideration existing experience, territories and possibilities of different farms.

Fig. 1. Andreas Schweizer (in the center), lecturer Maksym Kulyk and students after lecture on energy crops at PSAA

The lectures of foreign experts always cause enthusiasm, discussions and lots of questions and their style is quite interesting and necessary to follow and approve at higher educational establishments of Ukraine. Our students are interested in groundwork and the best practices in the countries of EU and the world.

At laboratory courses of the discipline “Energy crops” students work in mini groups (three persons in the group), do practical research tasks according to the themes, learn morphological and biological characteristics of the following crops: switchgrass (*Panicum virgatum L.*), miscanthus giganteus, (*Miscanthus giganteus*), sugar flower miscanthus (*Miscanthus sacchariflorus*), Chinese miscanthus (*Miscanthus sinensis*), perennial sorghum (*Sorghum almum Parodi.*), sugar sorghum (*Sorghum saccuratum Pers.*), perennial sida (*Sida hermaphrodita Rusby*), rumex (*Rumex pateientia L x Rumex tianschanicus L.*), energy willow (*Salix*) and poplar (*Populus*), paulownia (*Paulownia tomentosa*), and other energy crops (fig. 2).

Students write down the results of each laboratory work into specially dezigned workbooks [52], analyze obtained data by computer programs and make conclusions at the end of class. So, students do not copy material but reproduct it gaining skills of creative and research work.

Confirming this idea NYe. Shylina [53] says that at laboratory courses theoretical and methodological knowledge integrate with students' practical skills and abilities in the conditions close to the real professional activity. The author pays special attention to the group work and thinks that maximum degree of approaching to future profession is reached during training practice at real working places.

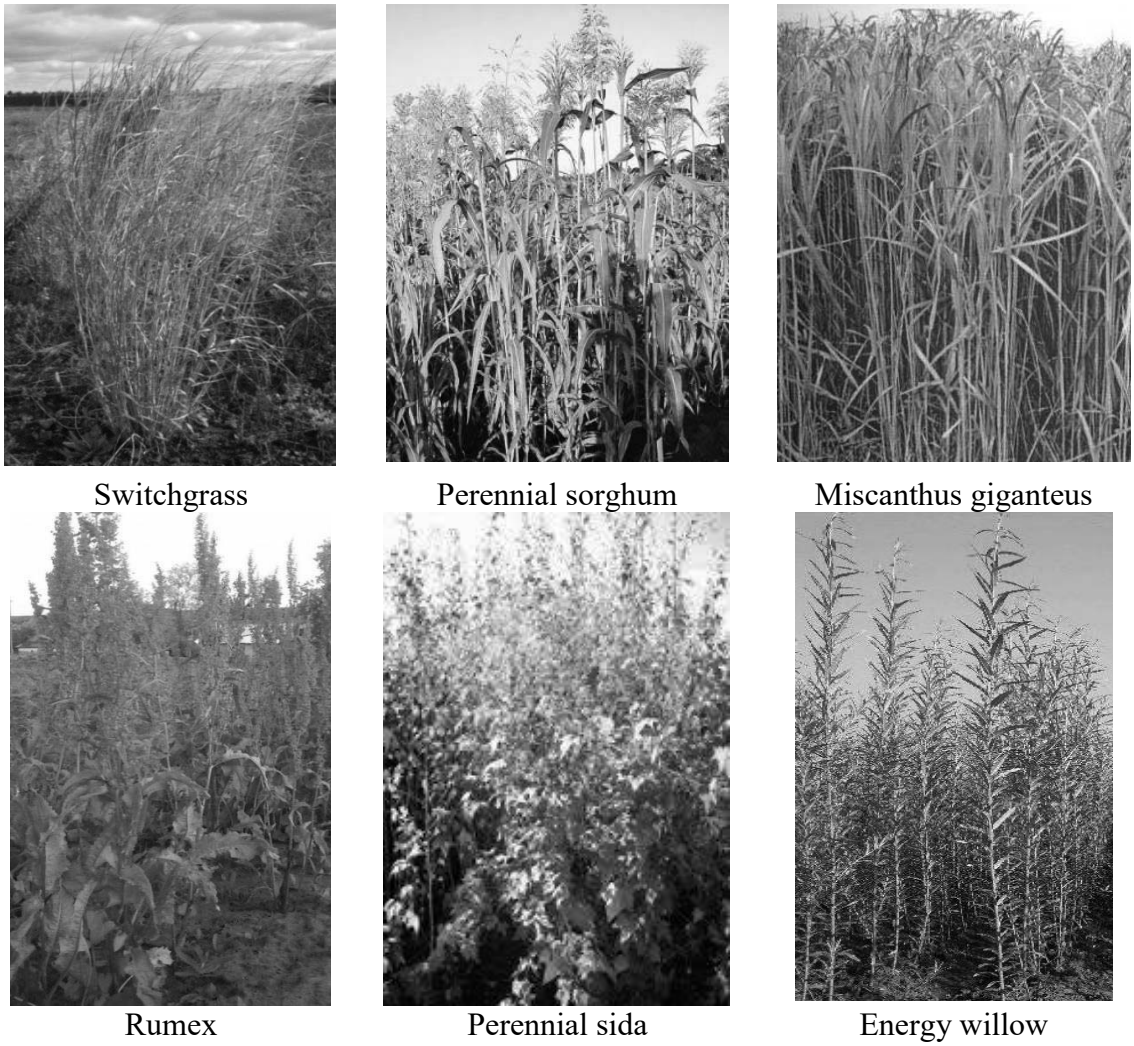


Fig. 2. Example of delivering phytomaterials of visual demonstration "Album: energy crops" [51]

Sheaf samples, herbarium, planting material, collection of energy crop seeds, albums, reference books [54], textbooks [55] and methods of foreign and Ukrainian specialists are used at laboratory course. Furthermore, students have opportunity to carry out experiments on the plots of land "Collections of energy crops" (fig. 3) on the territory of our academy. And this activity allows them to gain skills and abilities of the scientifically practical aspects.

The collection of energy crops on the territory of PSAA includes following crops: species and varieties of miscanthus (giganteus, Chinese and sugar flower), varieties of foreign and domestic selection of switchgrass, annual sorghum and perennial sorghum, hollyhock, sida, rumex, paulownia and others.

The collection of energy crops has not only familiarization function but educational and scientific ones:

- investigation of varieties of foreign and domestic selection,
- studying measures of pre - sowing preparation of seed and planting material,
- determination of dynamics of plant growth and development throughout the vegetation period in connection with weather conditions,
- finding out influence of biometric plant indices on phytomaass yield,
- studying influence of mutual cultivation of energy crops with legumes,
- determination of influence of biopreparations and mineral fertilizers on phytomass yield,
- studying phytoremediation characteristics of energy crops and other ecological issues.

a)

b)

c)

Rys. 3. Collection of energy crops on the territory of PSAA:
a) overview, b) switchgrass, c) silvergrass

Scientific material from the collection worked up by the students will be used in different research works and graduation research papers on the topics: “Agroecological fundamentals of energy crop cultivation”, “Effect of growing conditions on switchgrass yield”, “Formation of energy crop yield depending on a variety”, “Productivity of miscanthus giganteus depending on genotype origin” and others.

Students’ independent work comprises the following themes: less common energy crops, bioenergetic evaluation of technologies of energy crops cultivation, production and processing of raw material for the field of bioenergetics. The students are offered “Tasks for an independent work” [56] that contain recommendations, annotations as well as reference of new methods, textbooks, reference - books and Internet sources with the latest information.

It is highly important to engage students as well as postgraduates in scientific activity such as performing laboratory analyses and doing field experiments according to the experiment tasks. Modern devices namely pads, mobile analyzers and mini express-laboratories are used to achieve this purpose. Collected material is thoroughly detailed by the computer programs. It is interpreted and given in the objective form - in the form of correlative - regression equations, dependences between indices, graphs, diagrams and tables. A basis of fruitful cooperation student → postgraduate → teacher is results of researches performed by a teacher.

Research results

Within 10 years of fruitful scientific work a great deal of information has been compiled, theoretical material and results of researches of energy crops have been summarized. Preparatory stage (2008 - 2010) implied determination of the experiment places for studying agrobiomass potential (straw of grain crops), possibility of energy crop cultivation (switchgrass, silver grass), variety and genotype selection and the peculiarities of using resource of reed from swamped territories.

At the first stage of research within the framework of international scientific project “P4P” (2010 - 2013) it has been established that using straw of grain crops as a raw material for biofuel is not reasonable and use of reed is limited because of its fluency on biovariety (fig. 4). Also, it has been determined that switchgrass and silver grass are well adapted to cultivation conditions in Ukraine, able to provide high yield and have biomass energy capacity of 17 - 18 MJ/kg.

The most productive switchgrass varieties have been singled out. Some elements of cultivation technology and production chain (from field to energy) have been developed too.

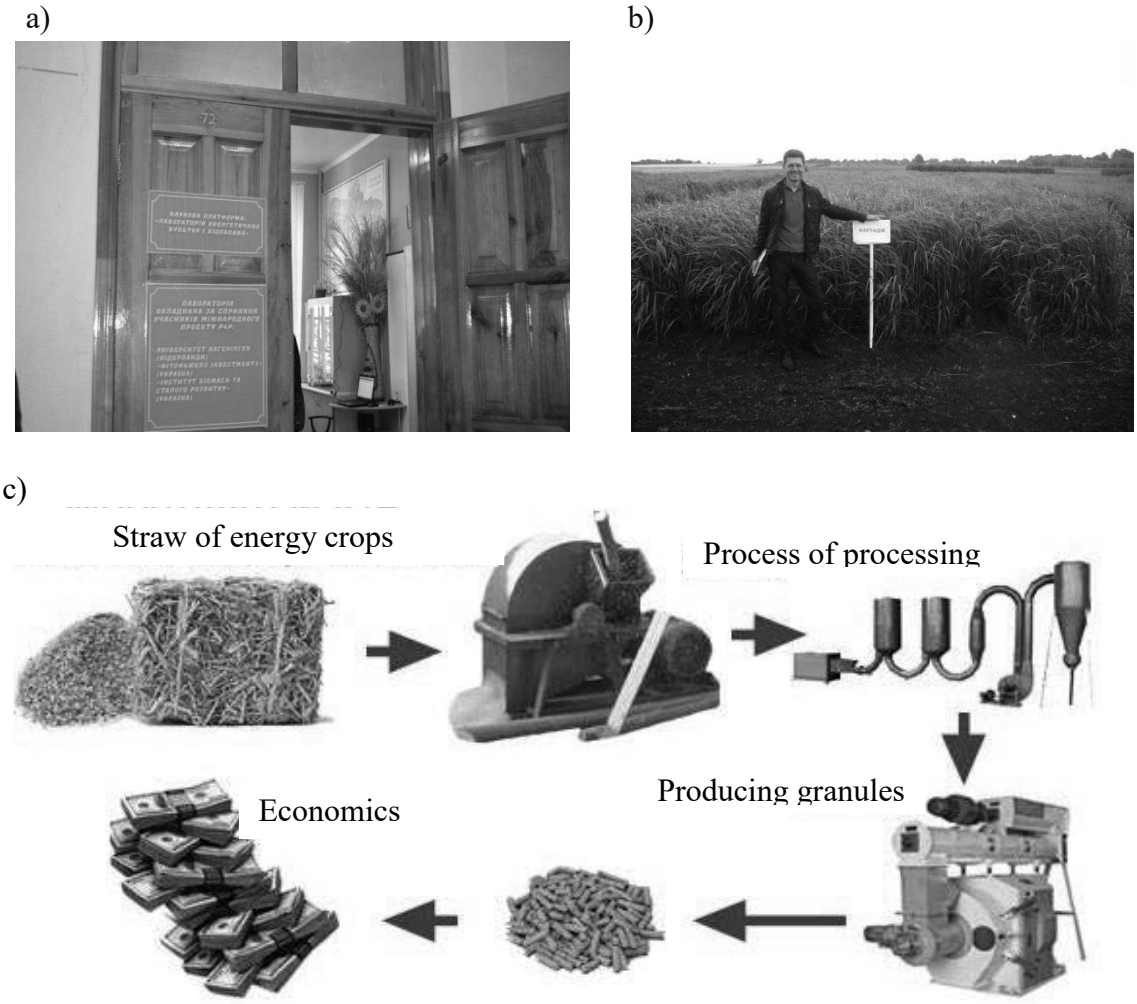


Fig. 4. Investigation of energy crops according to international scientific project „P4P"
a) laboratory, b) experimental fields, c) Scheme of biofuel production

Preliminary management of switchgrass seedings has been developed as well. Greenhouse gas emission under direct and indirect use of land resources for growing energy crops and biofuel production has been calculated.

Laboratory of Energy crops and Biofuel was founded on the territory of academy due to the project. The main task of the laboratory is a complicated study of energy crops as a raw material for biofuel production (Head - dr Maksym Kulyk).

Activity directions:

- research work of studying energy crops as a raw material for biofuel production,
- introducing experience of advanced international research institutions and organization in Ukraine,
- organization of teaching classes, trainings, workshops, webinars and seminars.

At the second stage of completion of the state scientific themes “Agroecological fundamentals of energy crop cultivation” (2014 - 2017) the following actions have been made (fig. 5):

- collection for complicated study of energy crops on the territory of PSAA has been founded (fig. 3),

- potential of energy crop yield while growing on soils with different degree of fertility has been determined,
- possibility of switchgrass and silver grass cultivation together with legumes has been found out (mixed and stripe crops),
- peculiarities of additional fertilizing of energy crops (mineral and organic substances) have been defined,
- dynamic of organic substance in soil under perennial use of energy plantation has been established.

Fig. 5. Investigation of energy crops according to the state scientific themes "Agroecological fundamentals of energy crop cultivation"

The third stage of the scientific project of the Ministry of Education and Science allowed to monitor and find out available potential of renewable energy sources in the conditions of forest - steppe of Ukraine (fig. 6).

For present time:

- theoretical researches have been performed and available renewable energy sources on the area of the forest - steppe of Ukraine (paying attention to plant biomass for energy use) have been defined;
- analytical researches concerning interconnected agrarian enterprises, product - oriented suppriers and institutions functioning in the field of renewable energy sources have been performed;
- scientifically - practical recommendations for farm have been developed.

In future these accomplishments will allow to develop optimal energy systems with renewable energy sources in separate regions taking into account available potential.

It has been established that for the development of biofuel production and use, increasing energy independence and farm production efficiency it is necessary to work out the following approaches (fig. 7):

- production and use of diesel biofuel and biooil,
- production of bioethanol,
- production and use of biogas and pyrolysis gas,
- use of energy crops and wood residues in order to meet heat demands,
- production of briquettes from agricultural waste and sawdust.

Involving in energy balance of agriculture industry biological kinds of fuel as renewable resources of accumulated solar energy is one of the critical tasks at present. But a wide spread of using biological energy resources is a complicated process that requires

additional costs in order to give them consumable qualities. Fuel consumers are technologically and technically ready to use concentrated non - renewable energy sources during the last century. Huge capital spending required for transitioning to use renewable biological energy resources, but annual deficit of fuel to be used for performing the main field work and necessity of environmental preservation require efforts consolidation at developing methods and technical means for providing energy - autonomous of agriculture business.

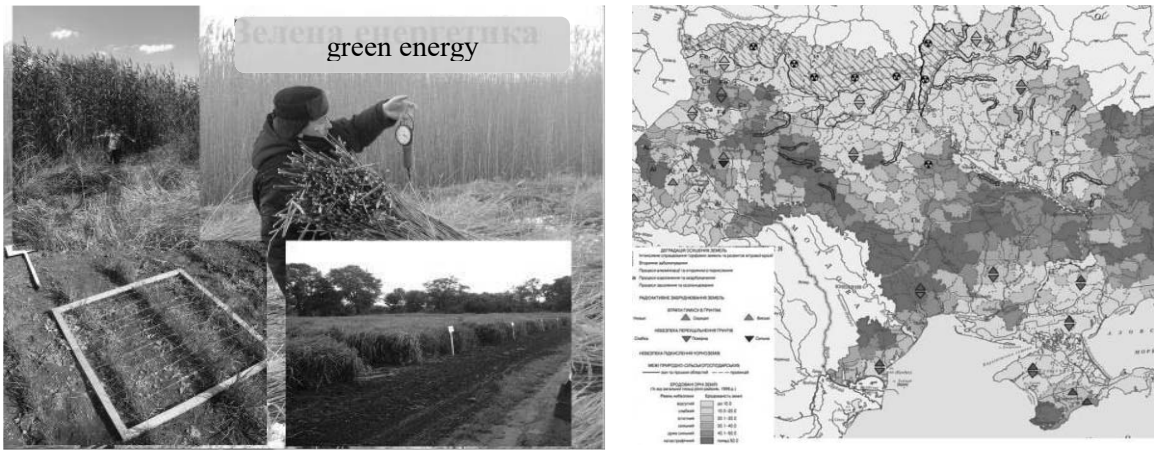


Fig. 6. Investigation of energy crops according to the project of applied research "Development of optimal energy systems taking into consideration available potential of renewable energy sources in the conditions of forest - steppe of Ukraine"

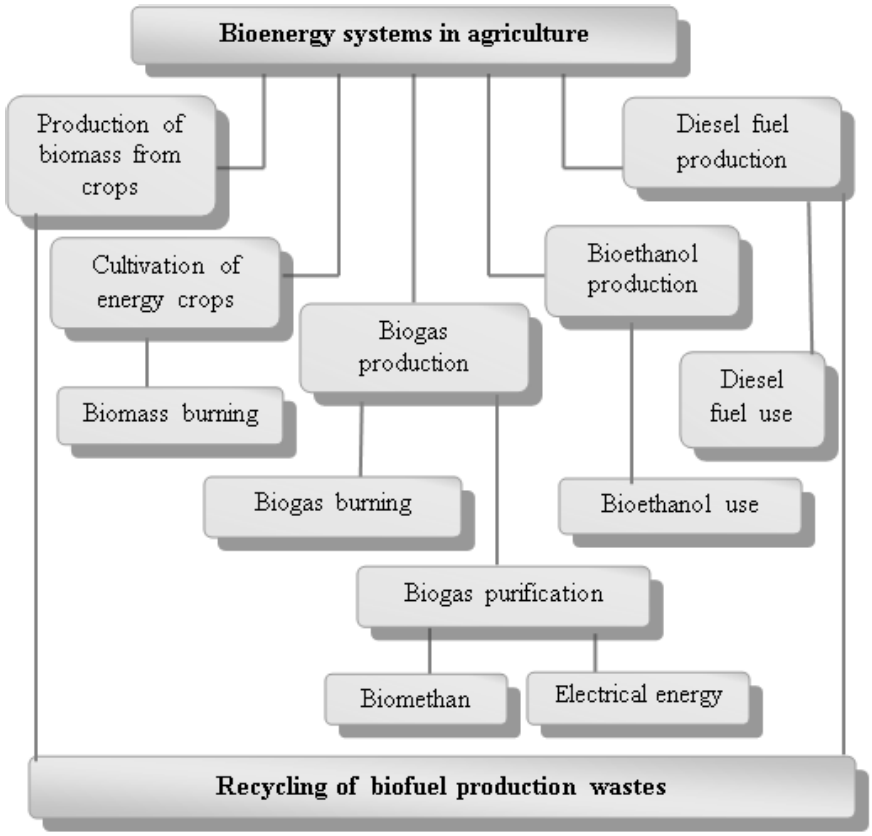


Fig. 7. Objects of bioenergy systems in agriculture

But, use of energy biomass potential is restricted by agro - industrial technologies to obtain energy and appropriate equipment and technical means absence that would be adapted to functioning conditions (tab. 1).

It is necessary to point out that energy consumption reducing, increasing productivity of machinery and equipment, their indices of reliability and accordance to agro - technological requirements are the main ways of improvement of the means of mechanization and equipment in technological process of agriculture business.

Table 1. Advantages and disadvantages of biofuel production and obtaining of energy in agroecosystems

Advantages	Disadvantages
Heat energy obtainment	
- renewable energy production - availability of huge resource potential of raw material for conversion into heat energy	- absence of the structure of conversion technological process (burning or processing) of non - grain harvest - absence of technical means for small - scale straw burning - unsolved problems of straw burning in boiler furnace
Diesel biofuel production	
- production of pollution - free fuel for diesel engines - availability of huge resource potential for diesel biofuel production	- complication of technologies of diesel fuel obtaining - existing equipment do not provide necessary efficiency of methanolysis reaction flowing - high energy expenditures for emulsion mixing
Biogas production	
- production of renewable energy - production of ecologically clean organic fertilizers - improvement of sanitary and epidemiological environment - great variety of raw materials that can be used for biogas - fired plant operation	- stratification of substrate that decreases efficiency of methan release - high energy expenditures for mixing of substrate

Processes, machines and equipment for energy production out of agricultural raw material should be based on waste-free production cycles that is based on complex use of natural and raw material resources. Furthermore, it is important to evaluate influence of raw material, in particular energy crops on agroecosystem efficiency. Energy crops are grasses or woody crops grown on marginal lands as a raw material to produce different biofuels [57].

Energy crops are differentiated by vegetation period duration, growth and development intensity, forms, colouring and structure of productive organs, responses to environment, cultivation technology and peculiarities of biomass harvesting.

Energy crops can be both monocotyledonous plants and dicotyledonous plants.

Energy crops are classified by general characteristic of vegetative and generative organs as well as the peculiarities of growth, development and yield formation in order to describe a wide variety of energy crops more reliably (tab. 2).

Table 2. Botanical classification of energy crops

Family		Crops
Ukrainian name	**Latin name**	
Grain crops	*Gramineae*	switchgrass, perennial sorghum, brome grass, sugar sorghum, miscanthus giganteus, miscanthus sugar flower, Chinese miscanthus, giant bulrush
Cole crops	*Brassicaceae*	rape (spring, winter)
Legumes	*Fabaceae*	galega orientalis
Asteraceae	*Asteraceae*	topinambour, silphium
Buckwheat	*Polygonaceae*	rumex, poligonum wyrichii
Hollyhock	*Malvaceae*	perennial sida
Willow	*Salicaceae*	willow, poplar
Paulownia	*Paulówniaceae*	paulownia

The greatest quantity of energy crops belongs to grain crops which have their own morthological characteristics - fibrous root system, linear leaves and have some adaptable responses to environment.

Energy crops are classified according to the following categories:

- growing cycle - annual (rape, sunflower) and perennial (willow, poplar);
- type - trees (poplar, paulownia), bushes (willow, sida) and grasses (silver grass, switchgrass);
- characteristics of final product: oil plants (rape/sunflower - for biodiesel), starch and sugar plants (sugar beet/corn - for bioethanol), lignocellulosic (switchgrass, silver grass, willow, poplar and others - to produce heat and electrical energy, solid biofuels and liquid biofuels of the second generation);
- "Origin" - classical crops, used only for energy purposes (switchgrass, silver grass, painted grass), less common (sida, rumex) and usual crops grown both for food purposes and for biofuel production (rape for biodiesel, sugar beet for bioethanol, corn for biogas), (fig. 8).

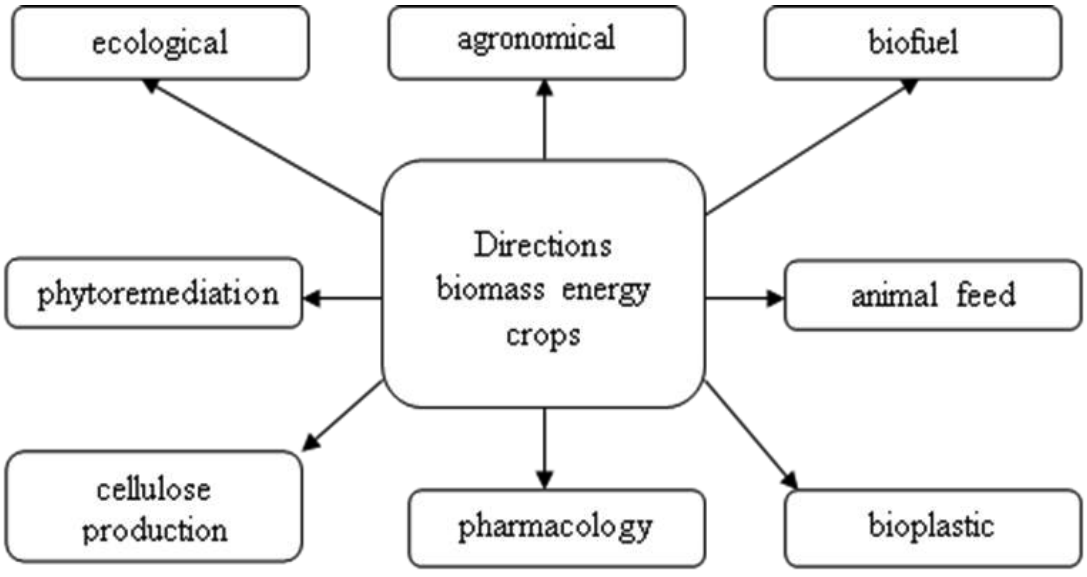


Fig. 7. Directions biomass energy crops

Dry phytomass of energy crops is used to produce biofuel of different types. That is why energy crops are divided by the method of biomass using (fig. 9).

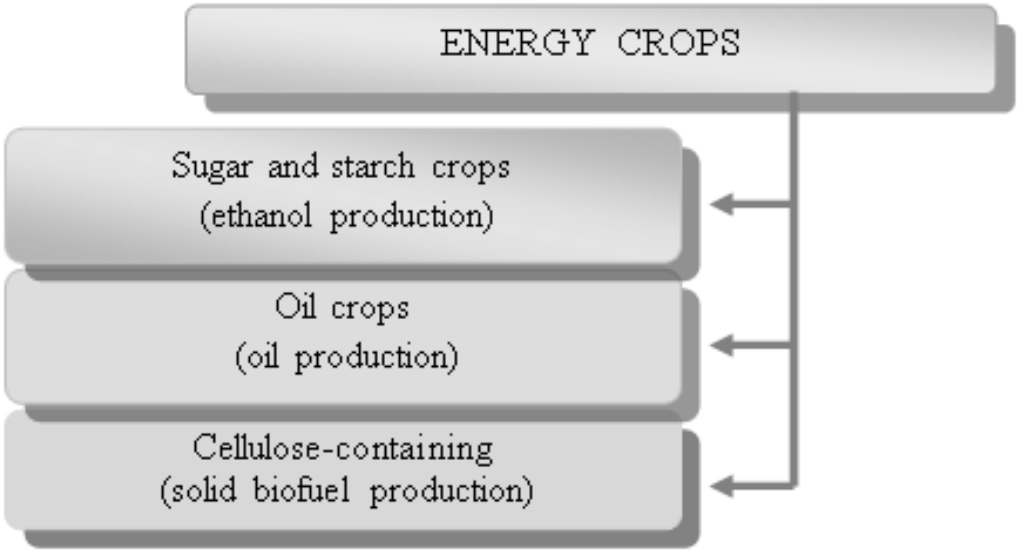


Fig. 9. Classification of energy crops by method of use

According to the type of above - ground part energy crops are divided into:

- trees - trunk , one stem where top of the tree is placed;
- bushes - root system is perennial, above - ground part is biennial or perennial and forms bush, plants have several stems;
- grasses - plants have annual or perennial root system with herbaceous above - groung part.

According to lifecycle (from seed to seed) we offer to divide energy crops into: annual, biennial and perennial crops.

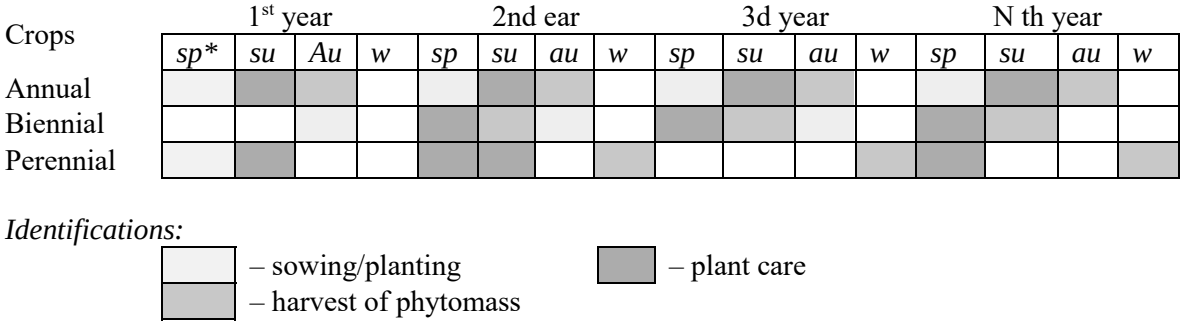
1. Annual - monocarpic crops which complete their development from germination to the production of seeds within one vegetation period, and then dies.
2. Biennial - monocarpic crops that take two years (two vegetation periods including winter) to complete its lifecycle.
3. Perennial - polycarpic crops that can form above-ground vegetative mass and produce seeds several times within their lifecycle. They can live 5 - 20 years and even longer depending on cultivation conditions. These plants begin to fruit mainly from the second vegetation year and continue for several years.

Classification of energy crops according to life cycle is given in table 3.

Table 3. Classification of energy crops according to life cycle

Life cycle	Representatives
Annual	spring rape, sugar sorghum
Biennial	winter rape
Perennial	switchgrass, perennial sorghum, brome, miscanthus giganteus, sugar flower miscanthus, Chinese miscanthus, perennial sida, topinambour, rumex, smartweed, poplar, willow, giant bulrush, galega orientalis, silphium, paulownia

Summarizing of scientific works studying energy crops in Ukraine and our own investigations allowed us to compare energy crops according to dry phytomass harvesting, productivity and output of equivalent fuel (fig. 10).



* *Note: sp* - spring period, *su* - summer period, *au* - autumn period, *w* - winter period.

Fig. 10. Logistic chain of cultivation, plant care and energy crop harvesting.
[Source: author's development]

The sowing of energy crops is carried out in the spring, harvesting - in autumn and winter. Biomass of energy crops for biofuel production can reach the consumer for a long time. Basing on agro - technical factors, the features of forming the yield of rod - shaped millet (switch grass) within the forest - steppe of Ukraine.

According to many years' researches it has been established that energy crops are differentiated by vegetation period duration, growth and development intensity, forms, colouring and structure of productive organs, responses to environment, cultivation technology and peculiarities of biomass harvesting.

Also according to many years' researches it has been established that potential of energy crop as well as their species peculiarities, responses to soil and climatic conditions depend upon agrochemical soil properties, tillage methods, application of fertilizers, biopreparations, methods and terms of planting, specifics of harvesting and other factors.

Comparative description of energy crops by the period of biomass harvesting and yield is given in table 4. Comparative description of energy crops according to the period of biomass harvesting confirmed that due to proper management dry biomass yield (raw material for biofuel: solid, liquid and gas) in the range 9 to 28 tons per hectare may be provided within the long period - June of the previous year till March of the next year.

Description of energy crops according to yield potential depending on temperature regime and precipitation by the agroclimatic zones is given below (tab. 5, fig. 9).

Table 4. Comparative description of energy crops according to the period of biomass harvesting and yield

Energy crops according to life cycle	Period of biomass harvesting	Biomass yield, [t/ha]		Output of equivalent fuel, [t/ha]
		Conditionally humid	Conditionally dry	
Annual	June – July	70 - 100	9 - 10	10 - 20
Biennial	July – September	80 - 120	14 - 20	15 - 21
Perennial	February – March	80 - 130	15 - 28	17 - 25

Table 5. Comparative description of energy crops according to yield potential

Energy crops	Temperature, [°C]	Precipitation, [mm]	Agroclimatic zone	Yield of above - ground mass, [t/ha]	
				phytomass	dry biomass
Giant bulrush	20 - 30	> 500	P	80 - 120	-
Miscanthus giganteus	20 - 30	> 500	P, F	70 - 100	20 - 30
Swithgrass	20 - 30	400 - 500	P, F, S	40 - 60	15 - 25
Perennial sorghum	20 - 30	400 -500	F, S	40-65	15 - 25
Sugar sorghum	> 30	< 400	F, S	30 - 50	-
Big-bluestem	20 - 30	400 - 500	P, F, S	10 - 15	10 - 13
Energy willow	20 - 30	> 500	P	25 - 50	15 - 20
Rumex	20 - 30	400 - 500	P, F, S	25 - 35	-

Note: P - Polissya, F - Forest-steppe, S - Steppe

Due to proper management dry biomass yield (raw material for biofuel: solid, liquid and gas) in the range 10 to 50 tons per hectare may be provided within the long period - August - September of the previous year till February - March of the next year.

In accordance with agroclimatic zoning there are zonal peculiarities of selection of varieties and species as well as special features of cultivation technology of crops and energy crops in Ukraine (fig. 11).

Taking into consideration morphological and biological characteristics, plant responses to temperature regime and precipitation within the vegetation period it is reasonably to allocate the most widespread energy crops in the following way: miscanthus giganteus and switchgrass - Polissya zone, miscanthus giganteus, switchgrass, perennial sorghum and sugar sorghum - Forest - Steppe zone, switchgrass, perennial sorghum and sugar sorghum - zone of Ukraine Steppe. Different crops of miscanthus species are possible to be grown in the zone of Ukraine Steppe under the condition of irrigation providing.

Efficient energy crop growing on industrial scale will enable to get biofuel (solid biofuel is the most exploited one) and burning it in boiler houses to produce cheap heat (fig. 12).

Science and education connection

Unsolved problems concerning agrotechnological techniques of growing, harvesting and processing of energy crops in Ukraine have been determined according to the results of scientific works and own experience (tab. 6).

Beside that, issues of phytoremediation are studied insuffiently - soil purification from heavy metals, polluters and oil contamination by plants of energy crops. Also, further investigation is required concerning organic matter content in soil while perennial growing of energy crops. Problem of applying mineral and organic fertilizers for enriching energy plantations needs to be studied further. Reaction of energy crops to the registered insecticides using (before and after sowing) is not found out yet. Elaborations of calculations of carbon circulation in the system of energy plantations required.

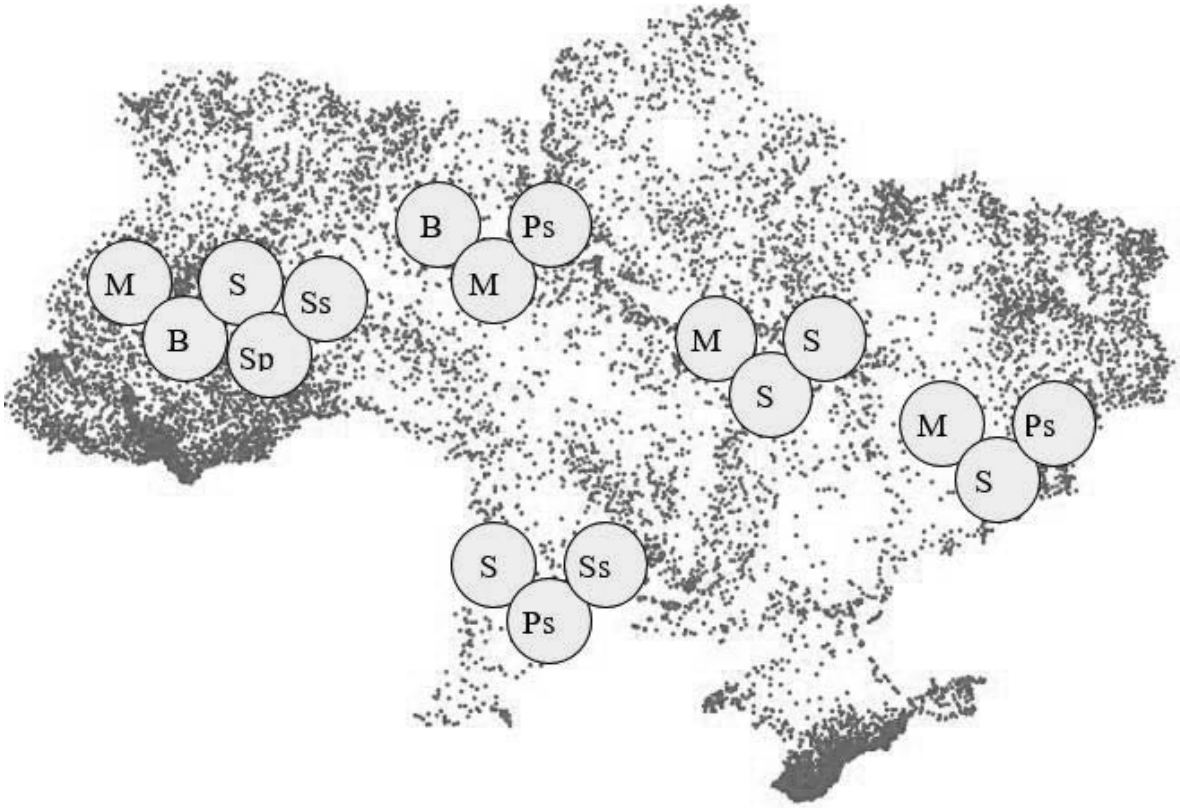


Fig. 11. Allocation of energy crops across the territory of Ukraine:
M - miscanthus giganteus, S - switchgrass, Ss - sugar sorghum,
Sp - perennial sorghum, B - energy willow

a)

b)

Fig. 12. Practical use of energy crops:
a) biofuel from various kinds of raw material, b) biofuel boiler house

Table 6. Technical provision state of production cycles in the chain of growing - harvesting of energy crops

Energy crops	**Preparation**		**Sowing or planting**	**Seeds care**	**Harvesting**	**Processing**
	Plantations	**Seed and planting material**				
Woody	Main and spring land tillage	New machinery and equipment invention requirements	New machinery and equipment invention requirements	Measures development to fight against weeds, pests and diseases. Fertilizers using is to be grounded for soil material nutrition	New machinery invention requirement	Drying and storage process, logistics
Grasses					Corn combines, haymaking machines	

All of that proves that there is a need to perform a much deeper and broader researches in the chosen vector to develop recommendations and incorporate results in production. These issues are being concerned by postgraduates and competitors for PhD degree who has been working at the department of Agrotechnology and Ecology according to initiative, self - financing and state scientific themes and are being engaged to perform some issues of the project of applied research of the Ministry of Education and Science.

So, fruitful cooperation and intercomplementary nature of gainings of all participants of scientific process allow to obtain objective results of scientific work that will be used for writing degree projects and dissertations. Along with that a direct involvement of scientific adviser is also very important. He separates the objective, define the task, help with planning the research, coordinates the work and experiment performing - so by doing that thoroughly supports both student and postgraduate to fruitful scientific cooperation. And as an in - between result is mutual publications of conference theses, articles and etc., as a result defending of degree projects and dissertations.

Hence, overall model of educational process and scientific innovative work optimization(by the example of studying the discipline “Energy crops” of the sceciality 201 “Agronomy”) contains the following interconnected and intercomplementary components that will encompass theoretical and practical material with involvement of innovative component taking into account students’ independent work (fig. 13).

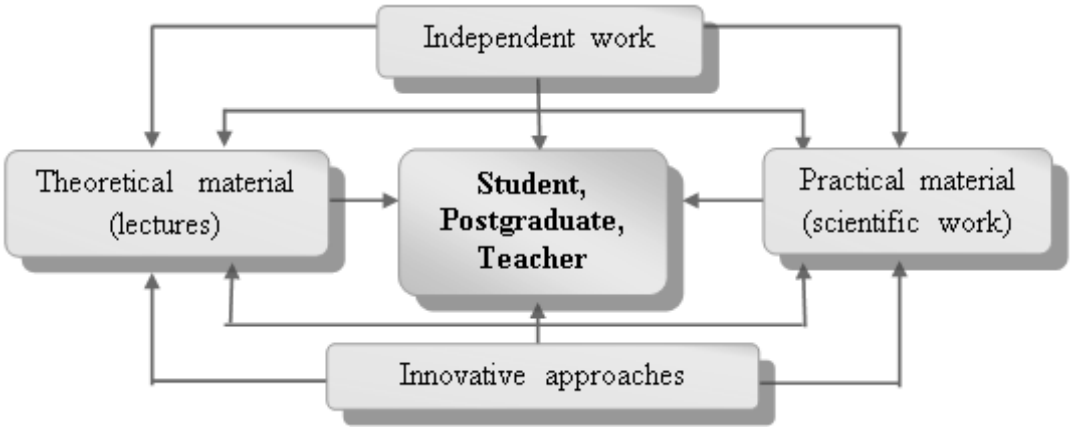


Fig. 13. Model of teaching process optimization of speciality 201 «Agronomy» (by the example of discipline “Energy crops”)

In accordance with the model of teaching process optimization we offer to deliver theoretical and practical material involving foreign and domestic innovations. An independent work should be combined with the elements of research work such as additional information to lectures and laboratory work with application of the latest methods and techniques. During laboratory classes where students learn to work in a team it is reasonably to interpret obtained results by computer programs. Evaluation of accomplished tasks is more reliable and unprejudiced due to computer programs. Applying this model studying other subjects of the specialty “Agronomy” various innovative approaches and modern methods should be taken into account.

Mutual publications in Ukrainian and foreign collective monographs, articles of foreign abstract and citation databases, professional articles of DAK of Ukraine, scientifical and practical recommendations to farms, dictionaries, textbooks, reference books, participation in international and Ukrainian conferences are the results of fruitful research cooperation of teaching staff, postgraduates and students. Participation of students, postgraduates and teachers in various scientific international and domestic projects is of highly importance as well.

Conclusion

1. Application of the proposed model in the teaching process enables to optimize mastering of theoretical and practical components of the disciplines of natural sciences on the basis of innovative component. Besides, this increases effectiveness of students' independent work while doing research work together with postgraduates and teachers.
2. Using scientifically - methodological and innovative components as well as international one (by the example of discipline "Energy crops") will enable to improve higher education quality, help students of Agrotechnology and Ecology department to gain new, modern knowledge and become more competitive at the employment market.
3. Energy crops are greatly differentiated according to soil and climatic conditions of Ukraine. This relates to crops' origin, biological peculiarities, adaptable reactions during plant introducing period and agrotechnological cultivation demands. Polissya soil and climatic conditions are the most favourable for miscanthus giganteus and giant bulrush cultivation. Conditions of Forest - Steppe and Steppe zones are more favorable for switchgrass, perennial sorghum and sugar sorghum cultivation.
4. Miscanthus giganteus has the highest potential of dry mass yield among the grain energy crops. Perennial sorghum and switchgrass provide less yield while perennial growing in soil and climatic conditions that correspond to their biological peculiarities. The problem of using less common energy crops such as giant bulrush, rumex and paulownia for bioenergetics purposes requires further more complicated researches.
5. It has been established that management of cultivation, harvesting and storage of energy crop biomass requires improvement and scientific substantiation in the conditions of Ukraine. Besides, it is necessary to develop new machines in the chain of ensuring production cycles of energy crop cultivation-harvesting. Environmental issues of energy plantations and carbon circulation require further more complicated study. These problems solving will allow obtaining plant raw material to produce biofuel annually for a long period of time.

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UPRAWY ENERGETYCZNE: WSPÓŁPRACA NAUKI I EDUKACJI

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Streszczenie: Włączenie do bilansu energetycznego przemysłu rolno - spożywczego paliw biologicznych jako odnawialnych zasobów gromadzenia energii słonecznej jest obecnie jednym z najważniejszych zadań rozwojowych. Jednak korzystanie z energii biomasy jest ograniczone technologicznie, brakiem odpowiedniego sprzętu i specjalistów.

W ciągu 10 lat pracy badawczej prowadzono badania teoretyczno - praktyczne poświęcone możliwościom upraw roślin energetycznych. Podstawą badań teoretycznych był znaczący przegląd literatury i materiałów z publikacji naukowych krajowych i zagranicznych, technik przetwarzania i odpowiedniego doradztwa naukowego. Do przeglądu analitycznego literatury wykorzystaliśmy ogólne naukowe metody badań (dialektyka, analiza i synteza), a także metody specjalistyczne.

Stwierdzono, że rośliny energetyczne są przystosowane do warunków klimatycznych na całym terytorium Ukrainy. Ustalono również, że zarządzanie uprawą, gromadzeniem i przechowywaniem roślin energetycznych wymaga w kraju poprawy i naukowego uzasadnienia. Problemy środowiskowe plantacji energetycznych i emisji dwutlenku węgla wymagają dalszych, bardziej złożonych badań. Rozwiązanie tych problemów pozwoli na coroczne uzyskiwanie materiału roślinnego do produkcji biopaliw co wymaga pracy odpowiednich specjalistów.

Dlatego w istniejących warunkach wiele uwagi poświęca się problemom odpowiedniego kształcenia przyszłych specjalistów, kształtowaniu potencjału społecznego i pracowniczego. Ustalono, że edukacja jest sektorem społecznym, gdzie działalność w kierunku zrównoważonego rozwoju obecnie powinna być postrzegana jako reprodukcja ludzkiego potencjału oraz innowacyjności. Słaba motywacja do działalności innowacyjnej prowadzi do niewystarczającego zastosowania innowacyjnych technologii w procesie nauczania na uczelni wyższej. Ponadto innowacja zapewnia stabilny rozwój kreatywności nauczycieli i zmiany w metodach pracy, stylu myślenia i tworzenia kompetencji informatycznych.

Zastosowanie proponowanego modelu w procesie kształcenia w celu optymalizacji rozwoju teoretycznych i praktycznych elementów dyscyplin jest elementem innowacji opartym na nauce. Ponadto zwiększa efektywność samodzielnej pracy studentów w prowadzeniu prac badawczych z absolwentami i nauczycielami. Pozwoli to studentom kierunku agronomicznego w pełni opanować temat, otrzymać nowoczesną, aktualną wiedzę i stać się bardziej konkurencyjnymi na rynku pracy.

Słowa kluczowe: edukacja, proces kształcenia, nauka, rośliny energetyczne, potencjał energetyczny