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BIOENERGY POTENTIAL OF PERENNIAL HERBOSA OF UKRAINE

The research represents bioenergy potential of natural grasslands and perennial herbosa. The research establishes the effect of species and varietal composition on energy productivity of seeded meadow grass stands, as well as the productivity of various species of perennial energy crops.

Keywords: *perennial herbosa, bioenergy, biomass energy potential, natural grasslands, productivity.*

Introduction. It is important to develop and use renewable energy sources, including biomass for biofuels to reduce Ukraine's energy dependence. Due to rising costs of energy reserves, usage of renewable energy, including biomass, is successful all over the world. Today production volume of the biomass as fuel is the fourth largest in the world. Its share in the total production of primary energy reaches 10%. In the European Union the share of biomass in total energy consumption is 7% [1]. Latvia is the leader of the biomass usage in the total country energy consumption, its share is 28, in Finland - 21%, Sweden - 22%, in Denmark - 17%, Austria - 16%, in Poland and in Germany - 8% in Ukraine - 1.24%. Total in EU from the biomass was obtained 68.7 million tons of fuel energy. Amongst all types of biomass the share of solid biomass is the largest, it is 80% and, depending on the country varies between 0 and 94%. The largest is in Finland.

Ukraine has great biomass potential, available for energy production, has good conditions for increasing biomass usage for the fuel. Energy Strategy of Ukraine till 2030 [3] provides for the dynamic growth of the biomass energy usage in 2015 to 5 million tons of fuel, which is 2.5% of total energy consumption and up to 20 million tons of fuel or 10% in 2030.

According to the Institute of Thermophysics of the National Academy of Sciences of Ukraine growing energy crops on an area of 5 million hectares for the biomass fuel will increase production of the energy from biomass to 18% of total energy consumption. Estimations showed that the economically expedient potential of biomass (excluding peat) is estimated at 33.92 million tons of fuel per year [2].

Analysis of the literature showed that researches on the energy potential of perennial herbosa of Ukraine and development of measures to improve their energy performance haven't been conducted until now. Therefore, the study of these issues is the goal of our research which actuality increases due to the significant price increase for the non-renewable primary energy sources, together with a significant decrease in demand for herbal feed due to the reduction of livestock number.

Research was conducted by the generally accepted field and laboratory methods using measurement and weight, calculated-comparative, chemical and mathematical-static methods. Gross energy content was calculated according to the chemical composition of the dry biomass.

The use of perennial herbosa plant biomass for the biofuels is an alternative usage of it. Our analysis of the biofuel resources in Ukraine (Table 1) showed that energy economically viable potential of perennial herbosa is 7.05 million tons of fuel per year, which is 20% of the total biomass and peat in Ukraine. Including natural grasslands accounted for 12%, quicksand and swamps - 7%, alternative energy crops - 1%.

Among energy perennial herbosa, special attention in Ukraine deserve natural grasslands which have an area of about 6.6 million hectares. Because of the catastrophic reduction in livestock number their biomass is hardly ever used for feed producing. Calculations showed that 50% of the perennial herbosa biomass can be

used for the production of solid biofuel. Economically viable energy potential of the natural grasslands of Ukraine is 4.22 million tons of fuel.

Table 1

Biomass and peat potential in Ukraine

Type of biomass	Energy potential, mln t of standard fuel		
	theoretical	technical	economic
Straw of crops	10,39	5,21	1,34
Straw of rape	1,07	0,75	0,75
Pre-consumer waste of corn to grain (stems, leaves, ears)	5,7	3,99	2,79
Pre-consumer waste of sunflower (stems, leaves, ears)	4,27	2,86	2,86
Woody biomass	2,13	1,66	1,48
Biomass of the natural forage lands and reserves	11,40	8,42	4,22
Biomass of marsh soil and bat lags and aquatic vegetation	7,44	4,96	2,48
Biodiesel	0,50	0,50	0,25
Bioethanol	2,33	2,33	0,86
Biogas from manure	3,27	2,45	0,76
Biogas from solid waste landfills	0,77	0,46	0,26
Biogas from sewage	0,21	0,13	0,09
Energy crops			
- poplar, acacia, alder, willow	14,58	12,39	12,39
- non-traditional herbal perennial energy crops (sylfiya, artichoke, miscanthus, etc.)	0,60	0,38	0,35
- rape (straw)	1,65	1,15	1,15
- rapeseed (biodiesel)	0,78	0,78	0,78
- corn (biogas)	1,59	1,11	1,11
Peat	0,77	0,46	0,40
Total	**69,45**	**49,99**	**34,32**

Natural grasslands of Ukraine in their present state are low-yielding due to their irrational use and shortfall for years with recommended technology of improvements. Unlike previous years when grasslands degradation took place due to the large load of cattle and excessive use of meadow herbages, now the degradation is due to lack of use. Meadows are overgrown with rough grasses, large areas are covered with tussocks. A lot of meadows that border upon the forest are unsuitable for mowing because of their non-use and overgrowing with undergrowth and shrubs. Among the undergrowth and shrubs most common are willows trees. According to our data overgrowing starts in 6-8 years after the last mowing and annually increases by 6-12 meters from the forest. As a result of these phenomena

feed attraction of natural grasslands reduces, but the energy value increases by the spread of rough grasses (thistles, sorrel, goldenrod, etc.) as well as undergrowth and shrubs which are good power plants.

To evaluate the current state of natural grasslands during 2011-2013, we have conducted their field geo-botanical examination in Borodyanskyy, Ivankov and Vyshgorodskiy areas of Kyiv region and Malyn, Luhyny, Korosten, Ovruchskiy and Olevsk areas of Zhytomyr region. Analysis of the examination results showed that the performance of different types of land was very contrasting and varied over a wide range: upland meadows – from 0.9 to 1.5 tons of the dry biomass and from 17.0 to 27.3 GJ of the total energy, lowland meadows – 1.1 - 2.4 tons and 20.0 - 31.0 GJ, flood plain meadows – 1.3 - 4.4 tons and 22.5 - 78.3 GJ per hectare. The most valuable for the accumulation of biomass were motley-grass herbages in wet lowland and floodplain meadows. Productivity of natural meadow coens vary widely from year to year and is determined by their species composition, weather conditions and soil fertility.

Analysis of the statistical data over Ukraine showed that the average performance of not improved natural grasslands is 1.4-2.2 tons per hectare of dry biomass or 22.2-38.7 GJ per hectare of the total energy [4]. These data suggest that natural grasslands and lealands without even flood plains and improvements accumulate on the average about 12 million tons of dry biomass or 200 million GJ of total energy over Ukraine. Adding mineral amendments can increase their productivity by 2-3 times [5].

The scientific researches and manufacturing practice indicate that the establishment of sown meadow herbages on most low-productive natural grasslands improves their performance by several times. To evaluate the effects of species and varietal composition of sown coens we have conducted experiments on drained flood plain meadows since 2011 (s. Lytvynivka, Vyshgorodska area, Kyiv region). Soil of the research areas is sod-gley, sandy loam, in layer 0-15 cm which contains moving potassium - 7.3 mg and Phosphorus - 3.1 mg per 100 g of soil, pH = 4.8. In experiments used a new zoned varieties of perennial herbs which were bred by Kiev

experimental station of NSC “Institute of Agriculture of NAASU” and NSC “Institute of Agriculture of NAASU”. Efficiency of varieties was studied on the background of $R_{60}K_{90}$ in standard cereals or horse-cereals mixtures in which are included one or two varieties of the same species of herbs.

Weather conditions during the study were very contrasting and in the summer they were very dry and hot. The most favorable year by humidification for meadow coens was 2012.

Analysis of the researches shows that herbage yield depends on the species and varietal composition of cereals and for the last three years was in the range from 4.6 to 11.7 tons of dry biomass and from 81.7 to 213.1 GJ of total energy per hectare. The most productive are herbages with varieties of Gryaznitsi Collectible Early of Kiev and Natalka, meadow chaff Rosunka and Siveryanka and Rump Beardless Arcen and Helius, which provides 9.45-11.22 tons per hectare of the dry biomass and 170.5-199.1 GJ per hectare of the total energy by 1,3-2,4 times more than other mixtures. Adding to sown cereal herbage N120 increase the land productivity by 5.16-5.73 tons per hectare of dry biomass or 90.0-102.7 GJ per hectare of the total energy. Natural herbages on the same background of $R_{60}K_{90}$ were in 1.7-3.4 times less productive than sown herbages.

In another experiment, the mixed varieties with new sorts of new permanent legumes grasses in legume-grass mixes at the same planned dried meadow at applying $P_{60}K_{90}$ on the average in two years are provided of getting from one hectare 8,32-12,07 t of dry weight or 145,8-213,1 GJ of gross energy (tab.2), that in 1,3-1,9 times more in comparison with grass sward and in 2,4-3,5 times in comparison with natural. The most productive seeded legume-grass herbage were included in the mixes of cow clover Polyanka or Polisyanka and the chalk ground of Onobrychis viciifolia Olga or Intensyvna1 74. At soil liming the productivity of herbage is increasing on 0,08-2,57 t/ha of dry weight. A better reaction on a soil liming was in herbage with participation of Onobrychis viciifolia and worse - the mixes with bird's-foot Ukrainian.

Table 2

Impact of the species composition and variety assortment of legume components on the sown cenosis productivity (2012-2013)

Composition of grass- and mixed varieties and та seeds seeding rate , kg/ha	Without chalking						Chalking ground					
	Dry weight , g/ha			Grey protein (medium)		Gross energy (middle), GJ/ha	Dry weight , g/ha			Grey protein (medium)		Gross energy (middle), GJ/ha
	2012	2013	middle	%	gathering, t/ha		2012	2013	middle	%	gathering, t/ha	
Cow clover Polyanka, 9 + grain varieties *	13,19	8,08	10,63	13,2	1,40	186,3	14,95	8,62	11,78	13,9	1,63	200,3
Cow clover Polisyanka, 9 + grain varieties*	13,18	8,09	10,60	13,6	1,44	177,0	15,18	8,13	11,65	13,8	1,60	206,2
Cow clover Polyanka, 4,5 + Polisyanka, 4,5 + grain varieties *	14,22	8,42	11,32	13,6	1,53	199,6	15,68	8,47	12,07	13,9	1,67	213,1
Onobrychis viciifolia Olga, 10 + grain varieties *	9,75	6,98	8,36	12,2	1,02	147,7	12,77	9,18	10,97	13,5	1,48	192,5
Onobrychis viciifolia Intensyvna 174, 10 + grain varieties *	9,93	6,96	8,44	12,1	1,02	150,5	12,66	9,36	11,01	13,6	1,49	195,4
Onobrychis viciifolia Olga, 5 and Intensyvna 174, 5 + grain varieties *	10,35	7,10	8,72	12,0	1,04	155,5	12,87	9,42	11,14	13,7	1,52	197,1
Bird's-foot Ukrainian local , 5 + grain varieties *	9,81	7,38	8,60	12,3	1,06	150,1	10,84	7,56	9,20	12,8	1,17	163,3
Bird's-foot Ukrainian local, 2,5 + Cow clover Polyanka , 4,5 + grain varieties *	13,96	8,06	11,01	12,5	1,37	192,4	14,14	8,04	11,09	13,8	1,53	196,0
Iamb suckling Sprint, 5 + grain varieties	9,78	6,85	8,32	12,1	1,01	145,8	10,28	6,95	8,11	12,6	1,02	142,7
Grain varieties *	6,15	6,22	6,18	12,0	0,74	109,5	7,40	6,31	6,85	12,5	0,85	120,5
Grain varieties * + N_{120}	13,30	8,65	10,97	12,8	1,40	192,2	14,74	8,45	11,59	12,8	1,48	196,6
Natural herbage	3,30	3,52	3,41	12,0	0,41	56,5	3,66	3,48	3,57	12,6	0,45	62,1
$HIP_{0,5,}$t/ha	0,76	0,86	0,82				0,76	0,86	0,82			

** Grain varieties– awnless bromegrass,10 + meadow fescue grass, 8 + timothy grass, 6 kg/ha*

Depending on grasses sorts a dry matter yield from 1 ha of the incidental outputs (straw), which is the remainder after thrashing of herbal's testess ranges within 1,5 to 4,2 t, and gross energy – from 26,8 to 73,0 GJ. The maximum dry matter yield and gross energy per hectare of by-products are provided by testess of intermediate wheatgrass, sedge usual, awnless brome and cock's-foot.

A biomass chemical constitution depends on the species structure and harvest phase. The crude protein contents in a dry basis of different herbage ranged from 11.2 to 13.7%, crude fat - from 1.8 to 2.1%, crude fiber - from 32.4 to 36.1% from 40.1 MAR to 43.4% and crude ash from 8.9 to 11.9%. The greatest influence on energy-output ratio has the total amount of organic matter in the dry weight. As a rule, an amount of biomass determines by the ash content in it [5]According to our sources the energy value of 1 kg of dry weight of different herbage is 17,51-18,16 MJ, in other words, was at the level of value of wheat straw. Such small variations due to low biomass content in such crude ash.

However, dry content in the meadow grass s raw material for the production of solid biofuels for traditional harvesting, that practices at procurement of fodder is much lower than the straw ranges from 20 to 30%, which of course requires additional costs for drying, cutting and picking biomass.

New recognized variety of permanent grasses on the inundation drained lands provides high performance and is instantiated by different terms of pickling ripeness that gives a possibility to organize biomass conveying receipting for solid biofuel production

Study of the comparative power output of different perennial energy crops we performed dark grey soil with content in it 0-20-cm layer of humus 2.4%, easy hydrolysable nitrogen- 13.1 mg per 100 g soil, labile phosphorus 17,1 and exchange potassium 12.9 mg per 100 g soil, pH 5.2. Analysis of rare plurannual energy crops as on an annual basis as in the average in two years is shown that the advanced from a growing management and productivity were Sylphid, Sakhalin bluet, Veirih buckwheat, Helianthus tuberosus L. X H. annus L. and juncaceous scurvy grass (Tab.3). On average in two years juncaceous scurvy grass gives 14.6 t/ha of dry basis

and 230 GJ/ha of gross energy, sylph pronyzanolystyy respectively 13.5 t / ha and 234 GJ / ha Highlander Sakhalin - 12.8 t / ha and 220 GJ / ha Highlander Veyriha - 12.5 t / ha and 217 GJ / ha and Highlander Baikal - 11.0 t / ha and 191 GJ/ha. Sylphium perfoliatum respectively13.5 t / ha and 234 GJ/ha, Sakhalin bluet - 12.8 t/ha and 220 GJ/ha, Veirih buckwheat - 12.5 t/ha and 217 GJ/ha and transbaikalian bluet - 11,0 t/ha and 191 GJ/ha. Less productive were permanent crops which provided obtain 10.9 t/ha of dry basis190 GJ/ha gross energy Helianthus tuberosus L. with capacity of according - 10.8 t/ha and 185 GJ/ha and girasole topinambur - 9.8 t/ha and 172 GJ/ha.

Table 3

Comparative evaluation of rare perennial energy crops,

the average of the years 2011-2012

Crop	Dry basis, t/ha	Gross energy outlet, GJ/ha	Dry basis, %	High, cm	Density of sward, running metre/м^2	Leaf, %
Veirih buckwheat	12,5	217	39,0	195	45	31,2
Baikal buckwheat	11,0	191	37,0	185	46	32,8
Sakhalin buckwheat	12,8	220	36,4	266	25	35,5
Sida plurannual	10,9	190	41,4	247	29	30,0
Sylphium perfoliatum	13,5	234	39,2	274	57	41,8
Girasole topinambur	9,8	172	30,5	157	72	30,0
Helianthus tuberosus L.	10,8	185	32,6	162	78	31,4
Miscanthus juncaceous	14,6	230	56,4	218	85	58,6
Feeding sorrel	10,0	154	78,4	220	76	28,2
Canadian goldenrod	9,2	163	31,8	130	67	35
$НИР_{0,5}$, т/га	0,8					

Note. The study was conducted on a background introduction in early spring $N_{60}P_{60}K_{60}$. Lots of energy crops was formed in the 2000-2011

The least productive were feeding sorrel and Canadian goldenrod. It should be noted that on the basis of the noted energy crops is able to create energy flow conveyor of biomass into biofuel. The earliest biomass reception provides a horse sorrel, pickling ripeness, which is determined by the phase of seed maturation and occurs in June. Next for early maturation is a permanent crop Veirih buckwheat, Canadian goldenrod, pickling ripeness in August and September. Other crops are late ripening, pickling ripeness in late autumn (October -November), and even in inter.

Studies have shown that perennial energy crops respond have well reaction to fertilizer, including Sylphium perfoliatum. The nitrogen was most active among mineral amendment on this culture.

Compared to the version without fertilizers a picking of dry basis per 1 hectare in the different backgrounds of phosphate and potash fertilizers from making an average of N_{60} for two years increased by 3,3-5,6 1,7-2,2 tons or times , N_{120} - on 5,8-7,9 m or 2,1-2,6 times , N180 - on 7,8-8,0 tons or 2.7 times . However, the payback on 1 kg of nitrogen increase crop dry weight was greatest when making N_{60} (52-71 kg) return when making N_{120} and N_{180} respectively - 37-58 and 39-46 kg.

Conclusions. Agrophytocenosis longstanding (natural forage lands and energy crops) is an important reserve of biomass to biofuels. Economically viable potential of the natural forage lands is 4.22 million tons of fuel and 12% of total energy consumption. Productivity of unimproved natural forage lands is 1,4-2,2 t/ha of dry matter. Their productivity is increasing in 1,5-4,0 times if includes the leguminose grasses into grass mixture and fertilizer dressing.

Best perennial energy crops productivity dry matter is 9,0-12,5 t/ha. The most productive among them are Sylphium perfoliatum, Veirih buckwheat and Sakhalin buckwheat, and Miscanthus juncaceous. Energy value of 1 kg of dry matter of different grassland swards and energy crops is equivalent 16,9-18,12 MJ and straw of winter crops.

Bibliography

1. Титко Р. Відновлювальні джерела Енергії (Досвід Польщі для України) / Р.Титко, В.Калініченко. – Варшава: QWG, 2010. – 15 с.

2. Г.Г.Гелетуха, Т.А.Железна, Е.М.Олійник Перспективи виробництва теплової енергії з біомаси в Україні / Промислова теплотехніка, – 2013. – № 4 (т. 35). – С. 5-15

3. Енергетична стратегія України на період до 2030 р. Директива Кабінету Міністрів № 145 від 15 березня 2006. – hnnh;//mpe.kmu.gov/ua/fue/control/uk/doccatalog/list?currDir=50358

4. Кургак В.Г. Лучні агрофітоценози. – К.: ДІА, 2010. – 374 с.

5. Методи визначення енергоємності і поживності, К.: Держспоживстандарт України, 2009. – 15 с.

Анотація

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Біоенергетичний потенціал багаторічних трав'янистих фітоценозів України

Представлено біоенергетичний потенціал природних кормових угідь і багаторічних трав'янистих культур. Встановлено вплив видового і сортового складу на енергетичну продуктивність сіяних лучних травостоїв, а також продуктивність різних видів багаторічних енергетичних культур.

Ключові слова: *багаторічні трав'янисті фітоценози, біоенергетика, біомаса, енергетичний потенціал, природні кормові угіддя, продуктивність*

Аннотация

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Биоэнергетический потенциал многолетних травянистых фитоценозов Украины

Представлено биоэнергетический потенциал природных кормовых угодий и многолетних травянистых культур. Установлено влияние видового и

сортового состава на энергетическую продуктивность сеяных луговых травостоев, а также продуктивность различных видов многолетних энергетических культур.

Ключевые слова: *многолетние травянистые фитоценозы, биоэнергетика, биомасса, энергетический потенциал, природные кормовые угодья, продуктивность.*