

Energy Value, Economic and Ecological Meaning of Perennial Leguminous and Legume-cereal Agrocoenoses in the Central Non-Black Soil Area of Russia

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Abstract

The research is important because it is necessary to get the perennial leguminous grasses and the legume-cereal grass mixtures involved in the wide production.

In this connection, this paper is aimed at discussing evident advantages of growing the perennial leguminous grasses and the legume-cereal grass mixtures in terms of energy, protein and economic efficiency, their use as the main link during the agriculture biologization an ecologization in the Central Non-black soil area of Russia.

The major method of researching this problem was the field experiments carried out using the facilities of Kaluga Agriculture Research Institute, which allowed implementing the comprehensive comparison of the annual and perennial fodder crops and their mixtures.

The paper covers comparative data on energy and monetary expenditures on growing the annual and perennial fodder crops and their mixtures, recoupage of them by harvesting the gross and exchange energy. The energy and economic efficiency of producing the exchange energy and crude protein during growing the various fodder crops and mixtures was calculated. Advantages of growing the perennial leguminous grasses and the legume-cereal grass mixtures in the Central Non-black soil area of Russia were substantiated experimentally.

The paper materials are of practical value to the plant growing branch in selecting the crops to be grown and forming the crop rotations in Russia's Central part.

Key-words: Perennial Leguminous Grasses, Legume-cereal Grass Mixtures, Exchange Energy, Digestible Protein, Energy Efficiency.

1. Introduction

Rational nature management cannot be formed without creating such agro-ecosystems that have a multi-year stability with observing optimal correlation in agrarian landscapes of the natural objects and agrocoenoses. The fodder agro-ecosystems must be multifunctional. They must produce the animal fodder, favor the increase in soil fertility, enrich the soils with humus and nitrogen, favor the acidity decrease, improve their structure and prevent the soil erosion. Only if to observe the said conditions, it is possible to speak about the rational nature management.

A lot of research proved an environment-forming role of perennial grasses that are indispensable in increasing the stability and in preserving the productive longevity of agrarian landscapes.

When studying the productivity, longevity and adaptational features of the perennial rootstock cereal of the reed canary grass, A.I. Golovnya and V.A. Lesina note its special meliorative features, which determines its use range [1].

V.V. Diachenko, A.V. Dronov and O.V. Diachenko, in their research carried out on the derno-podzolic soils of Russia's South-West, emphasize their particular significance for maintaining the soil fertility and receiving the high-quality fodder of the double legume-cereal grass mixtures with the participation of variegated alfalfa, awnless brome and timothy grass [3].

On the basis of multi-year field research, the scientists prove that it is necessary to select species composition of fodder crops on the basis of biological features of crops, their complementarity and a place of intended use [5-7].

V.N. Lukashov and A.N. Isakov repeatedly noted a positive effect of long-time growing of the single-crop perennial grasses and in the composition of legume-cereal grass mixtures for productivity, fodder quality and soil fertility state in the conditions of Russia's central part in their research [11-13, 15-16].

A.S. Shpakov believes that Russia's fodder production systems must include the broad use of perennial grasses that allow obtaining a high productivity of the animal husbandry as well as implement an environment-forming function in the Non-black soil area, which underwent the degradation processes to a superfluous extent [22, 23].

S.T. Esedullaev, in his research, speaks about a negative influence on the soil fertility of superfluous inclusion of annual crops in the crop production areas structure in the Upper-Volga region and that it is necessary to include the single-crop and mixed perennial grasses on the basis of variegated alfalfa and the Eastern galega [25].

Volumes of applying the organic and mineral fertilizers, which were reduced dramatically in the last years, make us look for alternatives of solving the problems of preserving and recovering the soil fertility. A critical role in that must be played by the perennial grasses that are virtually the only accessible means of increasing the annual crop yield, protecting the soil against erosion and degradation, creating the conditions for the stable ecosystem formation [4, 5, 7, 8].

As a solution to the ecological and economical problems of increasing the protein adequate of fodder in the field fodder production in Russia's central region, many researchers offer, along with the use of the grain legume crops and the legume-cereal grain mixtures, a broad inclusion of the perennial grasses and grass mixtures in the fodder conveyor [15, 17, 18, 21].

Some scientists believe that the leguminous and legume-cereal grass mixtures must occupy the largest areas in a structure of the fodder crop areas, which will make it possible, without decreasing the total harvest of necessary fodder products, to significantly improve the fodder protein value and the environment-forming situation in the agrocoenosis [7, 9, 13, 15].

According to the modern agriculture requirements, the technologists must take care not only of production of specific species of the plant products, but also use the whole natural resource rationally.

The field research was aimed at developing efficient methods and technologies in order to make the multi-year agrosystems more productive, at assessing the gross energy storage in the agrosystem that is being formed.

The research tasks are as follows:

To assess a productional process of an aboveground part of the main kinds of the fodder agrocoenoses; to determine the total energy expenditure on producing certain kinds of the fodder; to calculate the exchange energy output in the harvest produced; to calculate the fodder protein availability and the energy expenditure on producing the protein; to study the productional and environment-forming potential of the single-crop and mixed crops of the perennial grasses.

2. Materials and Methods

In order to implement the set goal, it is necessary to carry out the long-time field research with the participation of various species and varieties of annual and perennial single-crop and mixed fodder crops. The research venue was an experimental ground of Kaluga agriculture research institute, which fully meets the requirements for starting and carrying out the field experiments – a levelled land plot, homogeneous soil type and grain-size composition, uniformed soil fertility.

The experimental ground is located in the North-West of the Middle-Russian Elevation, in the area of temperate continental climate with strongly-marked seasons, cold winter and temperate warm summer. During a year, continental air masses of middle latitudes prevail, which give rise to clear and warm weather in summer and temperate cold weather in winter. The mid-seasons are characterized by the atmospheric circulation accompanied by cyclonic activity and cloudy weather with participation. A frequent change of air masses makes the weather unstable, especially in Autumn and in Winter. The average yearly air temperature in the experimental ground area is 3.8 °C. The average temperature of the coldest month in a year (January) is equal to -10 °C, and the average temperature of the warmest month in a year (July) is +17.6 °C. The minimum air temperature is -39.3 °C, and the maximum air temperature is +35.9 °C.

This territory is in the sufficient moistening area. 720 mm of precipitation fall for a year, out of which 458 mm fall in a warm year period, and 262 mm fall in a cold year period. The rainiest month is July, when, in average, 95 mm of participation fall, while the “driest” month is March (44 mm of precipitation). The average date of forming the seasonal snow cover is November 29, and the average date of destructing the seasonal snow cover is April 6. The average number of days with the snow cover is 139. On average, the snow cover depth is 47 cm, in some years the snow cover depth reaches up to 70 cm.

The experiment agrotechnology is traditional for the Central district of the Non-black soil area. The soil treatment system was built depending on the previous crop. If a predecessor was the tilled crops, then in the autumn they carried out the disk plowing, the early-spring harrowing, the presowing cultivation, the packing of soil and the coverless sowing of perennial grasses. If a predecessor was the grain crops, they implemented the primary tillage, the autumn plowing, the early-spring harrowing, the presowing cultivation, the packing of soil and the coverless sowing of perennial grasses. The soil had a high content of humus – 2.4-2.6%. That's why the fertilizers were not applied.

The field experiments for studying the raised issues were carried out from 1993 to 2016.

Experiment 1, which was carried out in 2008-2011, studied an energy efficiency of growing the annual and perennial fodder crops. The experimental area soil is gray forest, middle loamy, the humus content is 2.4%, pH is 5.9, the gross nitrogen content is 0.13%, the labile phosphorus content is 205 mg, the exchange potassium content is 140 mg/kg of the soil. The experiment used the following varieties of crops: red clover (*Trifolium pratense* L.) - Orlovsky, variegated alfalfa (*Medicago varia*) - Sarga, Eastern galega (*Galéga orientális* L.) - Gale, awnless brome (*Brōmus inērmis*) - Morshansky 760, winter triticale (*Triticosecale*) - Viktor, winter vetch (*Vicia vilosa*)-Lugovskaya 2, common oats (*Avena sativa* L.) - Yakov, spring vetch (*Vicia sativa*) - Assortment.

Experiment 2, which was carried out in 2015-2018, studied the agro-energy efficiency of the leguminous-festulolium agrocoenoses. The experimental area soil is gray forest, middle loamy, the humus content is 2.8%, pH is 5.8, the gross nitrogen content is 0.12%, the labile phosphorus content is 135 mg/kg, the exchange potassium content is 100 mg/kg of the soil. The experiment used the following varieties of crops: festulolium (*Festulolium*) –Fest, red clover- Orlovsky, variegated alfalfa - Sarga, Eastern galega - Gale.

Experiment 3, which was carried out in 2006-2009, studied the productivity and agro-energy efficiency of growing the annual grain-legume crops and their mixtures. The experimental area soil is gray forest, middle loamy, the humus content is 2.8%, pH is 5.9, the gross nitrogen content is 0.12%, the labile phosphorus content is 130 mg/kg, the exchange potassium content is 110 mg/kg of the soil. The experiment used the following crops and mixtures: broad beans, common vetch, field pea, garden pea, broad beams with field pea, broad beams with vetch, broad beams with peas, vetch with oats, peas with oats, field pea with oats, spring vetch with spring triticale.

Multi-year field experiment 4 in 2006-2011 studied the productivity and dynamics of accumulating the biological nitrogen by the single-crop perennial leguminous grasses and the legume-brome grass mixtures. The experimental area soil is gray forest, middle loamy, the humus content is 2.7%, pH is 5.8, the gross nitrogen content is 0.12%, the labile phosphorus content is 135

mg/kg, the exchange potassium content is 120 mg/kg of the soil. The experiment used the following crops and grass mixtures: variegated alfalfa, variegated alfalfa with awnless brome, red clover, red clover with awnless brome, Eastern galega, Eastern galega with awnless brome, birdsfoot deer vetch (*Lotus corniculatus* L.), birdsfoot deer vetch with awnless brome.

Multi-year experiment 5, which was carried out in 1993-2016, studied the productive longevity of single-crop Eastern galega, peculiarities of forming the legume-cereal grass mixtures with its participation, determination of influence of long-time growing of the single-crop legume grasses and legume-cereal grass mixtures upon soil fertility, accumulation of organic substance in the soil. The experimental ground soil is gray forest, middle loamy, the humus content is 2.85%, 301 and 166 mg/kg are the labile phosphorus content and the exchange potassium content, respectively, pH is 5.3. The experiment used the following varieties of crops: Eastern galega - Gale, variegated alfalfa Sarga, red clover - VIK-7, birdsfoot deer vetch - Solnyshko, awnless brome - Morshansky-312.

All the experiments has three replications, randomized options location, the total plot area is 56 m², the total registration plot area is 20 m². The experiments were carried out against a natural agricultural background without applying the mineral fertilizers.

In terms of water availability, vegetation periods in the years of carrying out the experiments were distributed in the following way: 1995, 1996, 2002, 2005, 2007, 2009, 2010, 2011, 2014, 2015 had a hydrothermal index of less than 1.6; 1997, 1998, 1999, 2000, 2001, 2003, 2004, 2006, 2008, 2012, 2013, 2016 had a hydrothermal index of more than 1.6.

Registrations and observations in the field experiments were carried out according to the methodology instructions on carrying out the field experiments with fodder crops [19] and the field experiment methods with the basis of statistical processing of the research results [2]. The gross energy production was determined according to methods developed by All-Russian Fodder Institute with account taken of crop capacity and the gross energy concentration in the fodder [20].

3. Results

The fodder productivity results and the fodder chemical analysis allowed the authors to calculate the energy efficiency of growing of major species of the food products in the region: perennial leguminous grasses, legume-cereal grass mixture, and winter and spring grains mixture (Table 1).

Table 1 – Energy Efficiency of Growing the Annual and Perennial Fodder Crops in Kaluga Region

Crop	Total energy expenditures, gigajoule/hectare	Exchange energy output with harvest, gigajoule/hectare	Energy efficiency ratio
Red clover	16.4	83.9	5.1
Variegated alfalfa	16.8	104.1	6.2
Eastern galega	14.2	106.9	7.5
Clover + alfalfa + galega + awnless brome	16.5	118.2	7.2
Winter triticale + winter vetch	26.2	72.3	2.8
Common oats+ spring vetch	23.8	36.8	1.5

Total energy expenditures depending on an experiment option made up 14.2- 26.2 gigajoule/hectare, and the perennial agrocoenoses formation required lower expenditures.

Exchange energy output with the studied crops harvest made up 36.8-118.2 gigajoule/hectare, the perennial agrocoenoses had the highest output.

The best energy efficiency figures were obtained in crops of Eastern galega and the legume-cereal grass mixture.

The digestible protein yield among the studied fodder crops and mixtures made up 490-1670 kg/hectare. The single-crop perennial grass had the highest yield (Table 2). The digestible protein content of the studied crops and mixtures exceeded the zootechnic standards by 15-77%.

Table 2 - Digestible Protein Content and Energy Efficiency of its Production in the Case of Perennial Crops and Annual Mixtures

<i>Crop</i>	Digestible protein yield, kg/hectare	Digestible protein content, g/1 fodder unit	Total energy expenditures on producing the digestible protein, megajoule/kg
Red clover	960	149	16.1
Variegated alfalfa	1670	186	10.8
Eastern galega	1610	182	11.5
Clover + alfalfa + galega + awnless brome	1320	129	12.4
Winter triticale + winter vetch	820	128	35.9
Common oats+ spring vetch	490	121	64.5

The total energy expenditures on producing the digestible protein on the experiment options made up 10.8- 64.5 megajoule/kg and were determined by a species composition of the agrocoenosis. The perennial crops had the lowest expenditures.

A broad use of annual fodder crops and mixtures in the fodder production makes it necessary to determine the agro-energy efficiency of their growing (Table 3). Output of the exchange energy of the studied crops and mixtures, in average for 3 years, made up 57.9- 98.4 gigajoule/hectare, with a

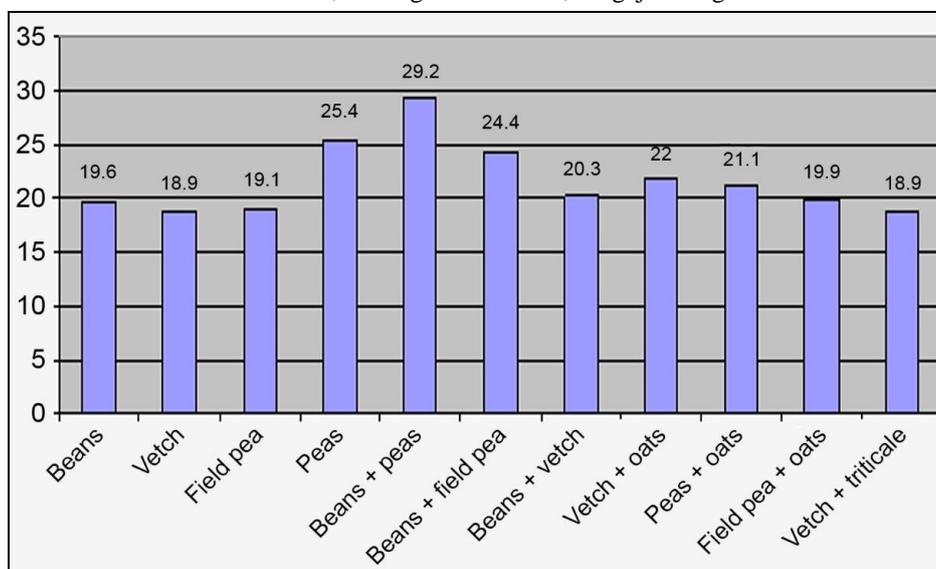
level of the energy expenditures of 24.0- 32.5 gigajoule/hectare, which allows receiving the energy income depending on the experiment option of from 27.8 to 68.3 gigajoule/hectare. The legume-cereal fodder mixtures had the highest energy efficiency of growing.

Table 3 – Agro-energy Efficiency of Growing of the Single-crop Grain-legume Crops and their Mixtures, Average for three Years

Option	Exchange energy output, gigajoule/ hectare	Total energy expenditure, gigajoule/ hectare	Net energy income, gigajoule/ hectare	Energy efficiency ratio	Bioenergetic ratio
Beans	57.9	24.9	33.0	1.3	2.3
Vetch	58.9	24.0	34.9	1.5	2.5
Field pea	72.1	24.1	48.0	2.0	3.0
Peas	57.7	24.2	33.5	1.4	2.4
Beans+peas	59.6	31.8	27.8	0.9	1.9
Beans+field pea	67.0	31.9	35.1	1.1	2.1
Beans+vetch	81.7	32.5	49.2	1.5	2.5
Vetch+oats	95.3	30.4	64.9	2.1	3.1
Peas+oats	93.4	29.5	63.9	2.2	3.2
Field pea+oats	98.4	30.1	68.3	2.3	3.3
Vetch+triticale	72.3	26.2	46.1	1.8	2.8

In terms of a qualitative assessment of the fodder and its energy availability, determination of the energy expenditures on producing the crude protein is of interest. These kinds of expenditures, when growing the annual agrocoenoses, made up 18.9- 29.2 megajoule/kg of crude protein depending on a species composition of the coenosis (Figure 1).

Figure 1 – Total Energy Expenditures on Producing the Crude Protein of the Single-crop Grain-legume Plants and their Mixtures, Average for 3 Years, Megajoule/kg



Expansion of range of crops, which have the high fodder advantages, served as the basis for assessing the leguminous-festulolium agrocoenoses.

On the basis of process charts, the total expenditures and energy efficiency of growing the leguminous-festulolium mixtures were calculated and assessed (Table 4).

Table 4 – Energy Efficiency of Growing the Leguminous-Festulolium Agrocoenoses (Average for 3 Years)

Option	Total energy expenditures, gigajoule/hectare	Exchange energy output with harvest, gigajoule/hectare	Energy efficiency ratio
Skip-row sowing			
Festulolium + variegated alfalfa	17.7	89.4	5.1
Festulolium + red clover	17.4	76.4	4.4
Festulolium + Eastern galega	17.2	66.3	3.8
Mixed sowing			
Festulolium + variegated alfalfa	17.7	90.0	5.1
Festulolium + red clover	17.4	75.3	4.3
Festulolium + eastern galega	17.4	70.3	4.0

Ways of sowing the grass mixtures were not of great importance to the energy efficiency of growing the grass mixtures studied. The total energy expenditures in the studied grass mixtures made up 17.2-17.7 gigajoule/hectare. A mixture of fistulolium with variegated alfalfa had the highest values. It also ensured the highest exchange energy output – 90.0 gigajoule/hectare. The energy efficiency ratio was varied depending on the experiment option from 3.8 to 5.1.

The energy and economic efficiency of growing the grass mixtures is determined by a level of expenditures on producing a unit of the exchange energy and the crude protein (Table 5).

Table 5 – Energy and Economic Efficiency of Growing the Leguminous-Festulolium Grass Mixtures (Average for 3 Years)

Option	Expenditures on 1 gigajoule of exchange energy		Expenditures for 1 centner of crude protein	
	Total energy, gigajoule	rubles	Total energy, gigajoule	rubles
Skip-row sowing				
Festulolium + alfalfa	0.20	165	1.04	863
Festulolium + clever	0.23	172	1.44	1086
Festulolium+ galega	0.26	181	1.55	1081
Mixed sowing				
Festulolium + alfalfa	0.20	168	1.06	888
Festulolium + clever	0.23	172	1.44	1063
Festulolium + galega	0.25	178	1.49	1058

When growing the leguminous-festulolium grass mixtures on the gray forest soils in Kaluga region, 0.20-0.26 gigajoules of total energy (depending the experiment option) were expended on producing 1 gigajoule of the exchange energy, which, in monetary terms, made up 165-181 Russian rubles (in the prices of 2018). Expenses for producing 1 centner of crude protein made up 1.04-1.55 gigajoule of the total energy or 863- 1081 rubles.

The perennial grasses and grass mixtures are of importance as a factor of biologization and ecologization of the agriculture. They play an especially great role for soils of the Central Non-black soil area, where about 40-60% of a territory are occupied by soils of low natural fertility.

Along with improvement of the soil structure, the leguminous grasses are able to enrich the soil with the fixed atmospheric nitrogen. The received data show that, depending on a species composition of the grass, and a year of its living, 40.3 – 198.6 kg/hectare of atmospheric nitrogen were fixed (Table 6). This is a substantial biological additive to the nitrogenous nutrition availability for plants and a possibility to do without expensive mineral nitrogen.

Table 6 – Accumulation of Biological Nitrogen by the above Ground Organs of the Leguminous and Leguminous-brome Grass, kg/hectare

Experiment option	Year of grass living				
	2nd	3rd	4th	5th	6th
variegated alfalfa	72.5	186.4	186.8	68.4	75.2
Alfalfa + brome	54.3/ 57.2	164.0/ 187.4	153.2/ 160.2	55.4/ 55.5	48.9/ 52.4
Red clover	123.4	109.6	-	-	-
Clover + brome	114.4/ 123.1	86.3/ 90.2	-	-	-
Eastern galega	44.1	98.9	185.3	189.9	198.6
galega + brome	38.4/ 40.3	78.6/ 82.4	178.3/ 180.6	175.1/ 174.9	180.0/ 174.3
Birdsfoot deer vetch	134.5	140.1	89.6	44.8	-
Birdsfoot deer vetch + brome	120.5/ 122.4	128.4/ 128.2	60.8/ 64.9	27.2/ 29.7	-

Note – above the line the mixed sowing is described, under the line skip-row sowing is described

For perennial crops of galega-cereal coenoses, a positive tendency was revealed on changing the soil fertility (Table 7).

Table 7 - Agrochemical Characteristics of Soil for Legume-cereal Grass with the Participation of Eastern Galega

Year of using the grass	pH	humus, %	P ₂ O ₅ , mg/kg	K ₂ O, mg/kg
Year of sowing (1993)	5.3	2.85	301	166
3rd year of use (1996)	5.5	2.87	340	168
7th year of use (2000)	5.5	2.90	362	168
16th year of use (2009)	5.7	2.92	367	208
21st year of use (2014)	5.8	2.96	368	208

After the 21st year of the grass use, increase in the humus content by 3.8% was noted, the labile phosphorus and exchange potassium content increased. The soil acidity decrease was noted.

4. Discussion

Traditionally, the field and meadow fodder production are the major fodder sources. The major measures on increasing the production volumes and improving the vegetable fodder quality are the areas expansion, the sowing structure optimization, the fodder crops capacity enhancement. The arable lands are used more intensively, preference is given to the energy- and resource-saving technologies of growing and laying-in of fodder, the use of the most productive species and varieties of fodder crops for specific soil and climatic conditions.

A standard is generally accepted in Russia, according to which it is necessary to lay in the fodder with the average protein content of 13- 16% and 9.2-10.1 megajoule of exchange energy in 1 kg of dry substance [24].

At present, availability of digestible protein in a fodder unit in Russia makes up 80- 90 g, and the fodder expenditure on the livestock products exceeds the standards in 1.3-1.4 times. In the dry substance of herbage for producing the voluminous fodder, the crude protein content does not exceed 10- 12% with the standard of 13- 16% [23].

The standard indicators can be performed when the mineral fertilizers are used. But taking into account the resources limitedness, the major area of stabilizing and developing the fodder production is expected to be a decrease in the use of material and energy resources and the agriculture biologization. It is necessary to reduce the amounts of anthropogenic grants of energy and substance, and to ensure the highest possible storage of solar energy in the form of the cash crop.

For fodder crops, solution to this task is simplified by the fact that in most cases they do not grow one species (variety) of plants, but the fodder mixtures consisting of plants of various species. The plants have peculiarities of positional application of aboveground and underground organs, have

various rates of growth and development. Therefore, the multi-crop agricultural ecosystems are more viable and functional [4].

At present, the perennial grasses are uppermost in the fodder production of Russia's Non-black soil area. They are traditionally grown in the form of grass mixtures. According to many researchers, the perennial legume-cereal grass mixtures in various soil and climatic conditions continue to play a key role in receiving the high-protein, energy-packed and cheaper fodder [3, 5, 6].

The market relations, which are formed in the country, allow considering fodder products as the goods. In addition, first of all, it is necessary to be guided by their energy and protein nutritiousness. Determination of the animals demand in dry substance of the fodder and concentration of the exchange energy and crude protein in the dry substance must be the basis.

In the period of shortage of material-financial and labor resources in the agriculture, introduction of energy-saving technologies in the production guarantees the survival of the fodder production branch, stabilizes the production of cheap and full-fledged fodder and protects the fertile soils against degradation [4].

When comparing the total energy expenditures on producing various agrocoenoses, it was found out that, depending on a species, 14.2- 16.8 gigajoule/hectare of the total energy were required for growing the single-crop perennial grasses, 16.5 gigajoule/hectare were expended on growing the perennial multicomponent grass mixture, and the highest expenditures were born by the annual grains mixtures of 23.8-26.2 gigajoule/hectare (Table 1). The highest exchange energy output with harvest was possessed by the perennial agrocoenoses - from 83.9 to 118.2 gigajoule/hectare depending on the mixture specimen composition. The multicomponent grass mixture had the highest figures. The crops of Eastern galega and the multicomponent grass mixtures had the best energy efficiency, while the spring grains mixtures were less efficient.

It should be noted that the perennial agrocoenoses, which were represented by variegated alfalfa and Eastern galega, had the energy efficiency advantage over the few-year coenoses formed by red clever.

Growing the perennial legume-cereal agrocoenoses is cheaper economically than the fodder production from the annual spring and winter fodder mixtures, since the expenditures are cut on preparing the soil for sowing and its proper maintenance in the plant vegetation period.

The experimental data analysis indicates that growing the perennial agrocoenoses allowed receiving the digestible protein of from 960 kg/hectare from the red clover crops to 1670 kg/hectare from the variegated alfalfa crops (Table 2). The perennial grass mixture was insignificantly inferior to variegated alfalfa and produced 1320 kg/hectare of digestible protein, which is explained by

availability in its composition of cereal components, which, depending on a year of the use in the botanic composition, had from 40 to 62% of cereal species in the harvest. The digestible protein yield from the annual agrocoenoses crops was in the range of from 490 kg/hectare in the case of vetch-oats mixture to 820 kg/hectare in the case of winter fodder mixtures. The total energy expenditures on producing the digestible protein depended on species composition of the agrocoenosis and duration of its use. If the perennial coenoses expended from 10.8 to 16.1 megajoule/kg on its production, then the annual coenoses expended 35.9- 64.5 megajoule/kg of the total energy.

The studied fodder crops exceeded the zootechnic standard (105-110 g/1 fodder unit) in terms of the digestible protein content in the fodder unit. The perennial agrocoenoses had a higher digestible protein content in the fodder unit in comparison with the annual agrocoenoses, exceeding the zootechnic requirements on this figure considerably. Especially, this dealt with the single-crop perennial crops - variegated alfalfa and Eastern galega – 186 and 182 g / 1 fodder unit, respectively.

Thus, the field research results confirm the lower total energy expenditures per 1 hectare, the higher exchange energy harvesting and the digestible protein yield with harvest of perennial agrocoenoses. This indicates a high energy and protein saturation of the grass perennial legume-cereal agrocoenoses.

Modern fodder production cannot be implemented with using the annual fodder plants in the single-crop and mixed crops.

A.S. Shpakov said that at present, for the fodder production, $\frac{3}{4}$ of the plant products are also used including 70% of the gross yield of grain, 90% of all the corn and grain-legume crops [22]. The annual crops are able to form the economically full-fledged harvests of qualitative green fodder during a short period of time.

The research, which was conducted to determine the agro-energy efficiency of growing the grain-legume crops and their mixtures on gray forest soils of the Central Non-black soil area, allow noting higher figures of the mixed grain-legume crops in comparison with the single-crop agrocoenoses (Table 3).

Among the single-crop grain-legume plants, growing the field pea required the lowest total energy expenditures of 24.2 gigajoule/hectare and ensured the highest exchange energy output of 72.1 gigajoule/hectare and the net energy income of 48.0 gigajoule/hectare. The highest coefficients of the energy and bioenergy efficiency of 2.0 and 3.0, respectively, were obtained. The lowest figures of the agro-energy efficiency were obtained during growing the peas.

The mixed legume-cereal agrocoenoses were characterized by a relative uniformity of the agro-energy efficiency figures. The highest exchange energy output and the net energy income were

possessed by the fodder mixture of field pea with oats of 98.4 and 68.3 gigajoule/hectare, respectively. The vetch and oats fodder mixture was inferior to the above-mentioned mixture in terms of the said figures insignificantly.

According to the researchers, in the condition of gray forest soils of the Kaluga region, the grass crop capacity in the single-crop grain-legume plants was in the range of 262 - 407 centner/hectare in average for 5 years. Blue lupine and broad beans had the best crop capacity. As regards the two-component mixtures, mixtures of broad beans with common vetch had the best and most stable harvest, depending on a year, the harvest made up 301 – 594 centner/hectare, while blue lupine with field pea harvest made up 313 – 554 centner/hectare. The exchange energy content, depending on the mixture components composition, changed from 7.3 to 9.1 megajoule per 1 kg of the dry substance. The digestible protein availability was in the range of 93-135 gram per 1 fodder unit [14].

The total energy expenditures on producing the crude protein were determined by species composition of the annual agrocoenosis (Figure 1). They were in the range of 18.9-25.4 megajoule /kg in the single-crop grain-legume plants, 20.3-29.2 megajoule /kg in the double leguminous mixtures and 18.9 – 22.0 megajoule /kg in the grain-legume mixtures. Common vetch, the mixture of broad beans with common vetch and the mixture of spring vetch with spring triticale had the lowest expenditures.

One of the components of intensification of Russia's modern fodder production is selection and broad introduction of species and varieties of the fodder crops that are the most productive and adapted to places of their use. As regards the perennial crops, these species may include festulolium- a hybrid of ryegrass with fescue, which has high productivity, fodder quality and good adaptational features.

According to the originator, festulolium borrowed from ryegrass such properties as high content of sugars and exchange energy in the dry substance, good palatability and digestibility. It grows quickly after mowing or browsing, bears repeated alienation of the aboveground mass during a vegetation period, reacts to the nitrogen fertilizers and irrigation efficiently. The festulolium adopted from fescues the longevity, the high winter resistance, the vitality, the good bearableness to poaching damage and the drought resistance.

The leguminous-festulolium mixtures are the best for the use.

The conducted research revealed the best way of sowing the leguminous-festulolium agrocoenoses and the most acceptable, in terms of the energy efficiency, leguminous component to be grown in mixtures with festulolium (Table 4).

The studied energy efficiency figures did not reveal significant differences between the skip-row and mixed sowings of the leguminous-festulolium grass mixtures. Variegated alfalfa, as a component for the grass mixture with festulolium, had certain advantages. Options with the said components, with the skip-row and mixed sowings, had the highest total energy expenditures during growing- 17.7 gigajoule/hectare for each, respectively, but because of the best grass productivity, these options gave the highest exchange energy output – 89.4 and 90.0 gigajoule/hectare, with the skip-row and mixed sowings, respectively, and the highest energy efficiency ratio of 5.1. The grass mixture of festulolium with red clover was the worst in terms of the energy efficiency.

A comparative assessment of total expenditures, during producing a unit of the exchange energy and the crude protein, determines in many respects the economic efficiency of growing various leguminous-festulolium grass mixtures (Table 5).

A way of sowing the grass mixtures did not exert a significant influence upon these figures. A species of the leguminous component within the mixture determined the total expenditures and the economy of growing the agrocoenosis.

Among the grass mixtures studied, the lowest total energy and financial expenditures per unit of the exchange energy were born by the alfalfa-festulolium agrocoenosis, which had 0.20 gigajoule/hectare and 165 rubles with the skip-row sowing, 0.20 gigajoule/hectare and 168 rubles with mixed sowings, respectively.

The said agrocoenosis was also the most preferable in terms of the energy and financial expenditures on producing a unit of the crude protein. They made up 1.04 gigajoule/hectare and 864 rubles with the skip-row sowing, 1.06 gigajoule/hectare and 888 rubles with the mixed sowings, respectively.

According to the scientists of All-Russian Fodder Institute, the lowest total energy expenditures on producing 1 centner of the crude protein were borne by the legume-cereal grass mixtures-1.4-1.65 gigajoule or 1193-1220 rubles (in the prices of 2018), and 0,17-0,23 gigajoule of the total energy or 171-183 rubles were expended on receiving 1 gigajoule of the exchange energy. At the same time, the expenditures, during growing the annual spring grain mixtures, were, respectively, 2.6 and 4 times higher, and during growing the winter grains mixtures, they were 4.0 and 3.3 times higher [8].

Apart from the direct fodder meaning, the perennial grasses and their mixtures are the main link of the agriculture biologization and ecologization. This is of great importance to the Central Non-black soil are of Russia, where about 40-60% of the plowed field areas are occupied by the soils of low natural fertility.

The main distinctive sign of the leguminous crops is their ability to fix the atmosphere nitrogen, accumulating it in the radical layer, thus removing the need to apply the expensive mineral fertilizers. When studying the dynamics of accumulating the biological nitrogen by the aboveground organs of perennial leguminous grasses and the leguminous-brome agrocoenoses on gray forest soils of the Non-black soil area with various ways of sowing the grass mixture components, certain regularities were revealed (Table 6).

The skip-row sowing of the grass mixtures components favored the highest accumulation of fixed nitrogen by the plants organs, which is explained by a more rational plant spacing in the sowing, during which, their suppression and worsening of growth processes take place in a lesser degree.

In the grass mixtures, the most of fixed nitrogen, 187.4 kg/hectare, was noted on the 3rd year of living of variegated alfalfa, with the skip-row sowing. In grass mixtures of Eastern galega, this figure had the maximum value of 180.6 kg/hectare on the 4th year of living of the grass. In the case of birds foot deer vetch - 128,4 kg/hectare - on the 3rd year, in the case of red clover - 123.1 kg/hectare - on the 2nd year of living of the grass.

In the single-crop perennial leguminous grasses, variegated alfalfa accumulated the maximum quantity of the atmospheric nitrogen of 186.8 kg/hectare on the 4th year, eastern galega accumulated 198.6 kg/hectare on the 6th year of living. Red clover was a few-year plant and could accumulate 123.4 kg/hectare of nitrogen on the 2nd year of living.

Considering a role of perennial agrocoenoses for the soil restoration, it is important to trace a change of the most significant figures of the soil fertility after long-time growing of single-crop leguminous grasses and grass mixtures.

The long-time field experiment studied a dynamics of the soil fertility for the galega-cereal agrocoenoses (Table 7). A positive tendency was revealed on changing the soil fertility. Thus, with the humus content in the soil of 2.85 % before starting the experiment, after 7-year growing of Eastern galega and the legume-cereal grass mixtures, this figure made up 2.90%, and on the 21st year of the grass use, the humus content was equal to 2.96%. The labile phosphorus and exchange potassium content increased significantly. At the same time, the soil acidity decreased - by 0.5 units pH on the 21st year of the grass use.

Therefore, the long-time use of perennial agrocoenoses with the participation of the leguminous crops has a beneficial effect on the soil fertility indicators, enriches the soil with humus, labile forms of phosphorus and exchange potassium, favors the decrease in the soil acidity.

5. Conclusion

Growing of the perennial leguminous grasses and the legume-cereal grass mixtures in Russia's Central region allows forming the agrocoenoses with the lowest total energy expenditures on producing a unit of the crude protein and the exchange energy in comparison with growing the annual winter and spring grains mixtures. They ensure the most rational use of the nonrenewable energy, serve the most important means of preserving and improving the soil fertility, of ensuring stability of agroecosystems and agrarian landscapes.

The perennial leguminous grasses and the legume-cereal grass mixtures must become the basis of fodder and field crop rotations, they must be used more widely in creating the green fodder chain, in improving the natural fodder lands and in creating the cultural hayfields and pastures.

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