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DEPENDENCE OF RED CLOVER PRODUCTION PROCESSES ON TECHNOLOGICAL ELEMENTS

One of the most promising agricultural crops is red clover, which can be used as forage for farm animals and for energy purposes. In addition, this crop plays an important agri-environmental role as it helps to improve soil fertility. The aim of this work is to establish the dependence of the production processes of red clover, as the main component of legume-grass agrophytocoenosis, on the use of lime, inoculant, growth enhancers, and phosphorus-potassium fertilizer. The study was conducted in the conditions of a stationary field experiment in the Western Forest-Steppe of Ukraine. Determination of the main parameters of red clover crop formation was carried out by theoretical calculations, which are based on the share of red clover in legume-grass, which originated in 2011.

The highest share of red clover in legume-grass was noted in the second and third years of use. The multiplicity of use had the greatest influence on the formation of the assimilation surface of red clover. Three times cutting of grasses stipulated the formation of up to 61 % of leaves. The highest percentage of leaves was recorded when composite organo-mineral fertilizer on the background of phosphorus-potassium fertilizer and liming was used. Liming also had a noticeable effect on the increase in the proportion of red clover leaves. The usage of limestone fertilizers on legume-grass increased the proportion of red clover leaves by 3–4 % in the first cut, 18–22 % in the second, and 5 % in the third, and increased the net productivity photosynthesis of red clover by 33 %. Inoculation of seeds with rhizobophyte on the background of phosphorus-potassium fertilizer and double mowing of grasslands provided the highest indicators of photosynthetic potential (31.8–34.1 million m^2/day/ha) of red clover. The reduction of the periods between cuts due to three-time use reduced the photosynthetic potential of each cut, however, as a whole during the growing season, this indicator slightly increased.

Therefore, to make fuller use of the potential of red clover when growing it in a mixture in the meadow agrophytocoenosis, it is advisable to conduct liming of the soil, apply phosphorus-potassium fertilizer and inoculation of seeds with rhizobophyte, and cut the grass twice during the growing season.

Keywords: red clover, leaf mass, net productivity of photosynthesis, photosynthetic potential.

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Залежність продуційних процесів конюшини лучної від технологічних елементів

Однією із перспективних сільськогосподарських культур є конюшина лучна, яку можна використовувати як корм для тварин, так і на енергетичні цілі. Водночас ця культура відіграє важливу агроекологічну роль, оскільки сприяє покращанню родючості ґрунту. Метою цієї роботи є встановити залежність продуційних процесів конюшини лучної як основного компонента бобово-злакового агрофітоценозу від застосування вапна, інокулянта, стимуляторів росту та фосфорно-калійного удобрення. Експериментальну роботу виконували в умовах стаціонарного польового досліду в зоні Західного Лісостепу України. Визначення основних параметрів формування врожаю конюшини лучної проведено шляхом теоретичних розрахунків, які базуються на її частці у бобово-злаковому травостої, залуженому в 2011 р.

Найвищий відсоток конюшини лучної у досліджуваному агрофітоценозі відзначено у другому та третьому роках використання, а найбільший вплив на формування асиміляційної поверхні цієї культури мала кратність використання. Триразове скошування трав обумовлювало формування до 61 % листя. Найвищий відсоток листя зафіксовано за використання композиційного органо-мінерального добрива добродій на фоні фосфорно-калійного удобрення та вапнування. На збільшення частки листя конюшини лучної помітний вплив мало також вапнування. Застосування вапнякових добрив на бобово-злаковому травостої сприяло зростанню цього показника на 3–4 % в першому укосі, 18–22 % у другому і на 5 % у третьому та підвищувало чисту продуктивність фотосинтезу конюшини лучної на 33 %. Проведення інокуляції насіння ризобофітом на фоні фосфорно-калійного удобрення та дворазового скошування травостою забезпечувало найвищі показники фотосинтетичного потенціалу (31,8–34,1 млн м^2/добу/га) цієї культури. Зменшення періодів між укосами, обумовлене триразовим використанням, зменшувало фотосинтетичний потенціал кожного укосу, проте в цілому за вегетаційний період цей показник незначно зріс.

Отже, для повнішого використання потенціалу конюшини лучної при вирощуванні її у сумішці в лучному агрофітоценозі доцільно проводити вапнування ґрунту, застосовувати фосфорно-калійне удобрення, інокуляцію насіння ризобофітом та скошувати травостій двічі за вегетаційний період.

Ключові слова: конюшина лучна, листова маса, чиста продуктивність фотосинтезу, фотосинтетичний потенціал.

Introduction. The sown area of red clover in Ukraine is more than 25 % of the total sown area of perennial grasses, or more than 300,000 ha [7]. In order to sustainable agricultural management, thanks to the recognition of the usefulness of legumes and red clover, in particular, an increase in the area of its use is encouraged [24]. This culture is considered one of the best predecessors of many agricultural crops regardless of the method of its use [23, 28]. Red clover is mainly used for livestock feed (and it is fed to almost all types of animals and poultry in a wide variety of forms: hay, haylage, hay straw, loose and granulated grass flour, etc.). Its productivity can be 9–15 t/ha of dry matter [16], and a sufficient amount of nitrogen accumulates in the soil to grow the following crop rotations with reduced rates of nitrogen fertilizers by 10–12 % and without reducing economic efficiency [17]. Red clover ensures 12–13 t/ha of fodder units and 1.7 t/ha of digestible protein with a feed unit content of up to 142 g of digestible protein [6, 12].

In recent years, the attention of scientists to the use of perennial grass, and in particular red clover, for bioenergy purposes has increased [22, 19, 26]. The use of grass biomass, especially if it is in excess for use in animal husbandry, as an energy source it is an alternative way of using this agricultural crop [30]. Many studies have been conducted to determine the bioenergetic potential of grass plants from semi-natural and sown grass stands [18, 21, 20, 24, 29]. Biomass, which is cultivated regularly, and its use as an energy source is not accompanied by a decrease in the number of green spaces in the region, is recognized as a renewable resource and is considered ecologically neutral because it has a zero balance of carbon dioxide emissions.

The intensity of the growth of the above-ground mass, and therefore the productivity of agrophytoceonoses, has a direct dependence on the rates of production processes in plants [4, 13, 27], which are a total of processes of formation, accumulation, and transformation of organic matter, absorption and passage of energy through the biota of the ecosystem at different levels of organization [14].

The main factor in plant development and yield formation is photosynthesis, which is the basis of production processes and significantly depends on many landscape and ecological factors (light, temperature, water, and nutrients in the soil). Photosynthesis and growth are considered as interrelated processes. The energy supply of the growth function by photosynthesis is an indispensable condition for growth [9]. The productivity of plant photosynthesis is determined by two main indicators – the total leaf area (assimilation surface) and the intensity of dry matter growth per unit of leaf area per day. The net productivity of photosynthesis makes it possible to determine the limiting indicators of increasing the productivity of the grass stand and to establish the biological potential of plants. A leaf surface index (LSI) has been developed for counting the number of leaves in a certain area, which is an important indicator for studies of the condition of agricultural crops since leaves are an important part of plants and occupy up to 90 % of their biomass. In it, the process of photosynthesis takes place, as a result of which the nutrients necessary for the healthy development of plants are produced. LSI is used as an input parameter for the productivity forecasting model. In today's high-precision technologies, the LSI was introduced for the NASA MODIS sensor to refine the Normalized Differentiated Vegetation Index data. Unlike the latter, it takes into account topographic features and the spectral zones used for its calculations undergo atmospheric correction [2].

The increase in the area of the leaf apparatus of the herbage of sown hayfields is closely related to the level of its mineral nutrition and the species composition of agrophytoceonoses [3, 15]. Due to the fertilization of meadow clover plants in the phase of the beginning of flowering, high intensity of the process of biosynthesis of pigments (chlorophyll and carotenoids) occurs, the presence of which in plants is a determining factor in the formation of productivity and is considered as a factor of crop productivity [11]. According to the research conducted in the Forest-Steppe zone [7, 8], it was established that the growth of leaf-stem mass of meadow clover depends on fertilization by 44 % and by 18 % on the period of regrowth (cut).

In order to find ways to increase the productivity of agricultural crops and to develop methods of managing the production process, knowledge about it is important both at the level of natural ecosystems and agrophytoceonoses, as well as individual plant species. Therefore, the aim of this work is to establish the dependence of the production processes of red clover, as the main component of legume-grass, on the use of lime, inoculant, growth enhancers, and phosphorus-potassium fertilizer.

The obtained results will contribute to more complete use of the potential of red clover when growing it for fodder or energy purposes or for increasing soil fertility.

Materials and methods. The study was carried out at the legume-grass grasslands created in 2011 within the framework of a stationary long-term field experiment of the Institute of Agriculture of the Carpathian Region of the National Academy of Agrarian Sciences of Ukraine (Stavchany 49°41' N 23°50' E longitude, altitude 320 m) on drained pottery drain in low meadows with dark gray podzolized surface-gleyed soil with a humus content of 3.20–3.94 % in a layer of 0–20 cm, $pH_{salt.}$ – 4.2–5.1, the content of alkaline hydrolyzed nitrogen (by Kornfield) – 142–187 mg/kg of soil, exchangeable potassium and mobile phosphorus (by Kirsanov) 62–97 and 70–164 mg/kg of soil, respectively. The grassland was grown by sowing a mixture of red clover cultivar ‘Peredkarpatska 6’ (4 kg/ha), goat's rue cultivar ‘Kavkazkyi branets’ (4 kg/ha), meadow fescue cultivar ‘Dibrova’ (8 kg/ha), timothy cultivar Pidhirianka (6 kg/ha). ha) and awnless bromus cultivar ‘Topaz’ (10 kg/ha). Determination of the production processes of red clover was carried out by theoretical calculations, which are based on the share of field clover in legume-grass planted in 2011.

The experiment included the unfertilized plots, the plots with phosphorous-potassium fertilizer ($P_{60}K_{90}$), and plots where in the background ($P_{60}K_{90}$) the effect of a composite organo-mineral fertilizer (dobrodii), an inoculant (rhizobophyte based on *Rhizobium trifolii*) and growth enhancer (ecostym) and limestone materials by two and three-time studying was studied. The size of the experimental plots was 15 m^2 with four repetitions.

The climate is semi-continental (a lot of precipitation with rapid temperature changes), which was formed under the influence of Atlantic and continental atmospheric masses. In terms of temperature, the weather conditions during the years of research were favorable for the growth and development of perennial grasses and differed in the amount of precipitation, which in 2011–2015 was 2–20 % lower than the average perennial values. 2012 and 2015 were characterized by insufficient moisture supply.

Determination of the phytoceonotic, botanical composition, and structure of the crop of agrophytoceonosis was carried out according to the methodology of the Institute of Fodder of the National Academy of Sciences [1]. Determination of the area of the leaf was carried out by a calculation method, while the area of each individual leaf was determined by measuring the length and width using conversion coefficients, the net productivity of photosynthesis was determined periodically by sampling plants, in which the total mass, the mass of individual organs and the area of the leaves were determined [5]; the photosynthetic potential of grass stands was calculated according to M. M. Makrushyn [14], taking into account the duration of inter-mowing periods and the area of the leaf.

Theoretical calculations were carried out using the Microsoft Excel program. The obtained data were processed by the method of dispersion and correlation analysis according to V. O. Ushkarenko et al. [10].

Results and discussion. The percentage of red clover in the sown agrophytoceonosis depended on the kind of fertilizers, and the number of cuts, and changed by the years of use. The highest share of red clover was noted in the second (38–49 %) and third (30–59 %) years of use (Table 1).

1. The percentage of red clover in the legume-grass depending on fertilization, inoculation, growth enhancers, and liming, the average for two (three*) cuts, % of the total yield

Fertilizers	2011	2012	2013	2014	2015
Without fertilizers (control)	26	38	30	11	0
$P_{60}K_{90}$ – background (B)	23	43	35	16	0
B + ecostym	21	38	39	10	0
B + ecostym + lime	17	49	42	20	2
B + rhizobophyte	20	46	42	20	3
B* + ecostym	10	44	38	19	0
B* + dobrodii	11	45	36	18	1
B* + dobrodii + lime	11	49	59	21	3
LSD_{05}	1,0	3,3	2,9	1,1	0,1

* Three cuts.

The percentage of leaves was quite high and amounted to 37–39 % in the structure of red clover in unfertilized grass and with background fertilization ($P_{60}K_{90}$), (Table 2).

2. The structure of the red clover yield in the newly created legume-grass depending on different types of fertilization and the use, the average for 2011–2015, % of the total yield

Fertilizers	Leaves			Stems			Inflorescence		
	Cuts								
	I	II	III	I	II	III	I	II	III
Without fertilizers (control)	38	39	0	60	59	0	2	2	0
$P_{60}K_{90}$ – background (B)	39	37	0	58	54	0	4	9	0
B + ecostym	33	32	0	61	56	0	6	12	0
B + ecostym + lime	34	39	0	60	53	0	6	7	0
B + rhizobophyte	38	49	0	58	47	0	4	4	0
B* + ecostym	37	42	45	55	42	52	7	16	4
B* + dobrodii	51	51	58	38	42	42	11	8	1
B* + dobrodii + lime	53	60	61	36	35	30	11	5	10
LSD_{05}	3,1	2,9	4,0	3,2	3,0	3,0	0,2	0,3	1,0

* Three cuts.

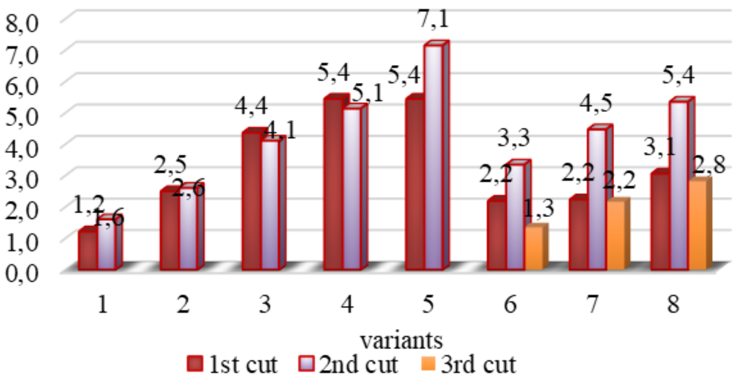
The use of bacterial preparations, growth enhancers, and liming contributed to better growth and development of red clover, as a result of which the plants formed powerful shoots – the number of stems in the yield was 36–61 %, depending on the type of fertilizer. The smallest proportion of shoots (35 % in the first cut, 30 % in the second, and 11 % in the third) and the highest percentage of leaves (53 %, 60 %, and 61%, respectively) was recorded with the use of a composite organic-mineral fertilizer dobrodii on the background of phosphorus-potassium fertilizer and liming. With the same fertilization, but excluding liming, the proportion of leaves was 2–9 % lower.

Liming has a noticeable effect on the increase in the proportion of red clover leaves. When it was used twice in combination with ecostym (growth enhancer), the increase of leaves was 1 % in the first cut and 7 % in the second. When mowing three times by the combination of liming with organo-mineral fertilizer, the percentage of legume leaves increased by 2 % in the first cut, and by 9 % in the second and third cut. In the case of double mowing, the highest proportion of leaves (38 % in the first cut and 49 % in the second cut) was provided by inoculation of leguminous grass seeds with rhizobophyte.

In the first cut, the index of the leaf surface of meadow clover ranged from 1.2 to 5.4. With two cutting of grasses and the use of a growth enhancer, it decreased by 6–7 % in the second cut, which is explained by the positive effect of ecostym on the growth of other components of the mixture, in particular grass species. With triple cutting, the leaf surface index increased in the second cut compared to the first (2.2–3.1 vs. 3.3–5.4) and due to the influence of dry July-August conditions observed in the second and third years of research, sharply decreased in the third cut (1.3–2.8). (Fig.).

Taking into account the fact that in the structure of the red clover yield, a significant share is occupied by stems, the net productivity of photosynthesis in this grass is quite relative. Plants grown with the use of phosphorus and potassium fertilizers were characterized by the highest rates of net photosynthesis productivity (2.0–3.0 g of dry matter per m^2 per day) (Table 3).

With the use of the ecostym growth enhancer, the net productivity of photosynthesis, both with two and three cuttings, was the lowest and amounted to 1.0–1.1 g of dry matter/m^2 per day in the first cutting. An increase in the level of the net productivity of photosynthesis was noted with the additional application of lime – with double cutting, the net productivity of photosynthesis increased in the first cut, and with triple cutting – in all three cuts.



Note: 1 – control (without fertilizers), 2 – B – $P_{60}K_{90}$, 3 – B + ecostym, 4 – B + ecostym C + lime, 5 – B + rhizobophyte, 6 – B + ecostym, 7 – B + dobrodii, 8 – B + dobrodii + lime; 6, 7, 8 – variants of triple use.

Fig. Leaf surface index of red clover depending on the types of fertilization and use, the average for 2011–2013

3. Photosynthetic potential and net photosynthetic productivity of meadow clover depending on types of fertilization and use, the average for 2011–2015

Fertilizers	Photosynthetic potential, million m²/day/ha			Net productivity of photosynthesis, g dry weight/m² per day		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Without fertilizers (control)	8,1	12,5		1,9	1,6	
$P_{60}K_{90}$ – background (B)	11,5	9,1		2,0	3,0	
B + ecostym	31,2	20,8		1,1	1,8	
B + ecostym + lime	30,9	25,4		1,2	1,7	
B + rhizobophyte	31,8	34,1		1,4	1,3	
B* + ecostym	16,1	15,6	5,9	1,0	1,2	1,2
B* + dobrodii	11,9	21,1	9,0	1,3	1,1	0,9
B* + dobrodii + lime	13,6	18,6	6,0	1,5	1,3	1,2

* Tree cuts.

The reduction of the periods between cutting, due to the three-time use of grass, reduced the photosynthetic potential of each cut, however, in general, during the growing season, this indicator is higher. During the three-times use, the highest photosynthetic potential in the first cut (16.1 million m^2/ha per day) was characterized by the grassland, where fertilization was carried out with organic-mineral fertilizer on the background of liming and phosphorus-potassium fertilization. In the second and third cuts, the highest indicators were noted for the same fertilization, but excluding liming – 21.1 million m^2/ha per day and 9 million m^2/ha per day, respectively.

The photosynthetic potential of red clover had a significant influence on the modes of use – with two times of use, this indicator was higher in the first cut, and with three times of cutting – in the second cut.

Conclusions

1. The formation of the assimilation surface of red clover which is grown in a legume-grass agrophytoceonosis is strongly influenced by the multiplicity of use. Three-time cutting of grass causes the formation of 60 % of leaves in the yield of the second and third cuts, and the indices of the leaf surface are 3.3–5.4 and 1.3–2.8 %, respectively.

2. The use of limestone fertilizers on legume-grass makes for an increase in the proportion of red clover leaves by 3–4 % in the first cut, by 18–22 % in the second cut, and by 5 % in the third cut, and increases the net photosynthetic productivity of red clover by 9–33 %.

3. The highest indicators of photosynthetic potential (31.8–34.1 million m^2/day/ha) are provided by red clover after seed inoculation with rhizobophyte against the background of phosphorus-potassium fertilization and two cutting of the grass.

4. In order to fully utilize the potential of res clover when growing it in a mixture in a meadow agrophytocoenosis is advisable to lime the soil, apply phosphorus-potassium fertilizer, and seed inoculation with rhizobophyte, and cut the grass twice during the growing season.

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