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*ORIGINAL ARTICLE*

# Effect of the cultivation of legumes on the dynamics of sod-podzolic soil fertility rate

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The effect of cultivation of legumes on the fertility rate of sod-podzolic surface-gleyed soil has been investigated. Based on the obtained results it has been found that on average, during the years of cultivation, the fertilizer factor with a percentage of 62% turns out to be more influential in terms of yield obtained from 1 ha of dry mass. The highest nutrient content is observed on the alfalfa variant: alkaline hydrolyzed nitrogen-80.4 mg/kg of soil, mobile phosphorus-81.5 mg/kg of soil and exchangeable potassium-77.3 mg/kg of soil.

**Keywords:** Legumes; sod-podzolic soil; nutrients; soil fertility

## Introduction

In order to preserve and increase soil fertility, as well as to increase agroecological resistance to adverse anthropogenic factors, it is essential to accumulate organic matter in the soil. Due to the sharp decrease in the number of livestock in the farms of Ukraine, it is almost impossible to address this problem only by introducing manure. Therefore, it is necessary to find ways to restore and maintain the optimal level of soil fertility by means of the application of alternative methods of accumulation in the soil. One of the main resources and promising direction in solving this problem can be the cultivation of perennial legumes (Balayev, 2011).

Perennial legumes are one of the factors, which enable to stabilize the processes occurring in the soil-plant-animal-human system. A large phytomeliorative role of perennial legumes on the arable land, the optimal ratio of plowed land, hayfields and pastures will contribute to the elimination of destructive processes that occur in agricultural landscapes, reduce erosion and increase soil fertility and crop yields (Petrichenko, 2010; Didur, 2019).

It should be noted that perennial legumes improve the fertility of soil, protect it from wind and water erosion, leave dry roots and nutrient residues in the soil (from 40 to 100-120 kg/ha). Their root system contains between 2.5-3 and 4% nitrogen (per dry substance). After its dying and decomposition, nitrogen stocks in the soil increase by 150-200, sometimes 300 kg/ha. Accumulated in the root system and crop residues of leguminous crops, nitrogen in the soil is well absorbed by other crops involved in rotation (Sobko, 2012; Butenko, 2019).

The scientists claim that the use of leguminous crops, perennial grasses that can improve soil fertility and form high yields in crop rotations facilitate a solution to the issue of providing livestock feed and organic fertilizers-crop production. Therefore, most farms develop these important agricultural sectors from a comprehensive perspective.

At the same time, perennial grasses enrich the soil with organic matter and biological nitrogen, which stabilizes its fertility. The manufacture of their products is economically justified (Tsimbalyuk, 2000).

Nitrogen is an important element for plant growth and development. Perennial grasses, especially legumes, in terms of nitrogen accumulation in the soil, are a very good precursor to many major cultivated plants (Vasileva, 2012; Kolisnyk, 2019).

According to the calculation of scientists (Kvitko, 2003), in the conditions of the Central Forest-Steppe of Ukraine alfalfa for three years of life is able to absorb from the air 735 kg/ha of nitrogen, enriching the soil in the amount of 598 kg per 1 hectare (Tsyhanskyi, 2019).

## Materials and Methods

The field studies were conducted in the stationary testing range of the Department of Agrochemistry and Soil Science, which was established in 2011. The soil samples had been chosen prior to the experience and three years after the growing of herbs.
The soil cover of the experimental field is represented by sod-podzolic surface-gleyed soil on the slope of the north-western exposure with steepness of 1-3°. Prior to the sowing of legumes, the research plot was characterized by the following indicators: humus content-2.4% (low), alkaline hydrolyzed nitrogen-67.1 mg/kg of soil (very low), mobile phosphorus-75.6 mg/kg of soil (medium), exchangeable potassium-66.0 mg/kg of soil (low). The soil reaction was very acidic and acidic (pH of the salt extract is 4.4-4.8), hydrolytic acidity-5.8-6.0 mg-EQ per 100 g of soil. The amount of calcium absorbed in the soils was 6.3 mg-EQ, magnesium 2.5 mg-EQ per 100 g of soil, indicating low base saturation.
The assessment of weather conditions during the years of research was carried out on the basis of meteorological data obtained in Ivano-Frankivsk Regional Hydrometeorological Center.
The weather conditions in 2011 were different from long-term indicators, but favorable for the formation of agrophytocoenosis of legumes. The precipitation, which was 13.1 mm less than the mean annual precipitation, fell during the growing season, while there was a decrease in the average daily air temperature in relation to the average long-term indicators by 4.5°C.
The year of 2012 was characterized by an increased temperature regime, with an average daily temperature of +1.5°C, exceeding the long-term norm and insufficient precipitation, when precipitation, which was 23.7% mm less than the mean annual precipitation, fell.
Analyzing the weather conditions of 2013, we should focus on their difference from the average long-term data, but positive effect of such conditions on the formation of agrophytocenosis of legumes. The plant growth and development were satisfactory.
The scheme of two-factor experiment provides for the three levels of fertilizing (Table 1). Mineral fertilizers were applied at-ground in the form of ammonium nitrate, granulated superphosphate and double manure salt in early spring. The size of seedling plots was 15 $m^2$, accounting plots-10 $m^2$. In addition, perspective varieties of legumes such as cow clover-Darunok, alsike clover-Rozheva 27, birdsfoot deer vetch-Aiaks, alfalfa-Andi, were sown and released.

**Table 1.** Field experiment scheme.

| Factor A-herb species | Factor B-fertilizers |
|---|---|
| 1. Cow clover | Without fertilizers |
| 2. Alsike clover | $Ph_{60}P_{60}$ |
| 3. Birdsfoot deer vetch | $Ph_{90}P_{90}$ |
| 4. Alfalfa | |

During the studies we used the conventional techniques (Dospekhov, 1985), “Methods of Conducting Experiments on Forage Production” (Babych, 1998), the content of total humus by Tiurin (DSTU 4289:2004), pH of salt extract-potentiometrically in pH-meter (GOST ISO 10390-2001), alki-hydrolyzable nitrogen-by Cornfield (DSTU 7863:2015), mobile phosphorus and exchangeable potassium by Chyrikov (DSTU 4115-2002).
A positive effect of the cultivation of legumes on the rate of fertility of sod-podzolic soil has been established on the basis of the conducted research. The results of experiments have shown that the long-term cultivation of perennial legumes on nutrient-poor soils results in the development of a highly branched root system. As a result, the weight of the root and stubble residues exceeds the weight of the above-ground mass or approaches it. Thus, the yield of the above-ground herb mass for two years of use has amounted to 14.6 c/ha of air dry matter, and the yield of legumes-14.2 t/ha. The root and stubble residues are amounted to 165.3 and 132 c/ha, respectively. With a well-developed root mass, a large amount of nitrogen remains in the soil (231.4 and 145.2 kg/ha, respectively), which largely (about 50-70%) compensates for the expenditure of soil nitrogen to form a yield of herbs.
The productivity of perennial legumes in single-species crops, depending on fertilizers in the experiment conducted during 2011-2013, is shown in Table 2. On average, over the years of use, Factor A with the percentage of 62% has turned out to be a more influential factor by output from 1 ha of dry weight. The percentage of Factor B accounts for 37%. It should be noted that in the first year of use of herbs, the percentage of influence of Factor A was the greatest and equal to 61%. Later, due to a decrease in the amount of the bean component and a certain decrease in the action of symbiotic nitrogen, it decreased, reaching the level of 54% in the third year and vice versa, the influence of Factor B has increased from 39 to 46% over the years.
It has been established that the productivity of perennial legumes on average during the years of research with the two-haying use on the variants without fertilizers and with the application of $Ph_{60}P_{60}$ is in the range of 5.03-of 6.47 t/ha of dry weight, 3.62-4.98 t/ha of fodder units, 0.79-1.08 t/ha of crude protein, 43.3-58.2 GJ/ha of exchange energy.
Among the studied species of perennial legumes, the highest productivity was provided by cow clover and birdsfoot deer vetch, which dominate alfalfa and alsike clover by 19-31%.
The highest content of alki-hydrolyzable nitrogen is observed in the soil when growing alfalfa-80.4 mg/kg of soil, due to the productive activity of symbiotic nitrogen-fixing bacteria of this species of herbs. The nitrogen content in the soil under cow clover was 4.8% lower and amounted to 77.0 mg/kg of soil. The other experimental plots had almost the same nitrogen content-77.5-77.8 mg/kg of soil that was 3% less compared to the variant under alfalfa. When applying phosphorus-potassium

fertilizers on the variants of alfalfa+$Ph_{60}P_{60}$ and alfalfa+$Ph_{90}P_{90}$, the nitrogen index increased by 10.6 mg/kg of soil. On all variants of the experiment the content of alkaline hydrolyzed nitrogen was very low.

Phosphorus, which is found mainly in organic and mineral compounds and resistant to leaching, occurs very often in a form inaccessible to plants. This macroelement is heavily used by plants in the process of ontogenesis. On the basis of the analysis conducted it has been determined that the phosphorus content in the soil before the experiment was: in the arable layer (0-20 cm)-75.6 mg/kg of soil; in the eluvial horizon (20-30 cm)-37.0 mg/kg of soil; in the iluvial horizon (30-50 cm)-26.0 mg/kg of soil.

**Table 2.** Productivity of perennial legumes, t/ha, 2011-2013.

| **Species of herbs** | **Fertilizers** | **Dry weight by years** | | | **Average values for 2011-2013** | | | |
|---|---|---|---|---|---|---|---|---|
| | | **2011** | **2012** | **2013** | **dry weight** | **fodder units** | **crude protein** | **exchange energy, GJ/ha** |
| Cow clover | Without fertilizers | 7.85 | 7.1 | 3.65 | 6.23 | 4.55 | 1.01 | 54.2 |
| | $Ph_{60}P_{60}$ | 8.02 | 7.11 | 3.71 | 6.31 | 4.61 | 1.03 | 55.5 |
| | $Ph_{90}P_{90}$ | 8.14 | 7.22 | 3.86 | 6.44 | 4.77 | 1.07 | 57.3 |
| Alfalfa | Without fertilizers | 6.33 | 5.53 | 3.13 | 5.03 | 3.62 | 0.79 | 43.3 |
| | $Ph_{60}P_{60}$ | 6.43 | 5.62 | 3.27 | 5.14 | 3.7 | 0.82 | 44.7 |
| | $Ph_{90}P_{90}$ | 6.43 | 5.54 | 3.35 | 5.14 | 3.8 | 0.82 | 44.7 |
| Alsike clover | Without fertilizers | 7.38 | 5.57 | 2.68 | 5.18 | 3.78 | 0.8 | 45.1 |
| | $Ph_{60}P_{60}$ | 7.59 | 5.68 | 2.79 | 5.39 | 3.99 | 0.84 | 47.4 |
| | $Ph_{90}P_{90}$ | 7.44 | 5.64 | 2.84 | 5.34 | 4.01 | 0.83 | 47.5 |
| Birdsfoot deer vetch | Without fertilizers | 7.91 | 6.41 | 5.07 | 6.43 | 4.89 | 1.07 | 57.2 |
| | $Ph_{60}P_{60}$ | 7.97 | 6.37 | 5.18 | 6.47 | 4.98 | 1.08 | 58.2 |
| | $Ph_{90}P_{90}$ | 8.06 | 6.46 | 5.15 | 6.56 | 5.12 | 1.1 | 58.2 |
| $HIP_{05}$, t/ha by factors: | | | | | | | | |
| plant stand | | 0.38 | 0.35 | 0.32 | 0.35 | | | |
| fertilizing | | 0.31 | 0.29 | 0.3 | 0.3 | | | |
| Percentage of factors,%: | | | | | | | | |
| plant stand | | 61 | 63 | 64 | 62 | | | |
| fertilizing | | 39 | 37 | 36 | 37 | | | |

The content of mobile phosphorus on the experiment variants ranged from 80.9 to 83.2 mg/kg of soil (average level) depending on the crop (Figure 1). It has been established that the cultivation of cow clover, alsike clover, birdsfoot deer vetch, alfalfa against $Ph_{90}$ during the study period contributed to the growth of mobile phosphorus in comparison with its content in the soil prior to the sowing of herbs by 4.2-5.9%, in particular, in the variant with alfalfa it was amounted to 5.0 mg/kg of soil. This is due to the fact that the stockpile of phosphorus in the soil is the most stable among other indicators of fertility, and the creation of cover with perennial herbs with a developed root system contributes to the suspension of erosion processes, the content of mobile phosphorus in the soil increases.

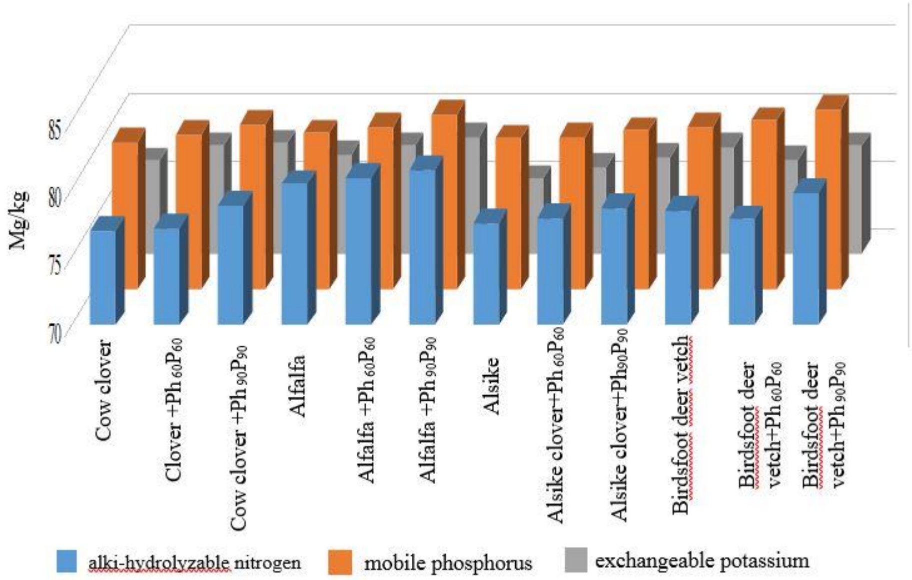


**Figure 1.** Indicators of fertility of sod-podzolic soil obtained when growing legumes.

The content of exchangeable potassium in three years was 76.8-78.6 mg/kg of soil and remained at a low level in the soil. The highest rates are recorded in the variants with alfalfa and birdsfoot deer vetch. All herbs with the application of $P_{90}$ have contributed to an increase in the content of exchangeable potassium in the soil during the years of their cultivation by 13.4-14.8%.

Characterizing the balance of nutrients of sod-podzolic soil subject to the cultivation of legumes, the analysis of nitrogen expenditure has shown that this element of nutrition is most heavily used by birdsfoot deer vetch and cow clover-the yield is 105.4 and 100.3 kg/ha, respectively. This is due to the high productivity of these crops. The lowest nitrogen losses are found in alfalfa-98.6 kg/ha that correlate with the lowest productivity of that variant. The rate of biological nitrogen entering the soil is largely dependent on the efficiency of nitrogen fixation. The highest nitrogen intake from nitrogen fixation is recorded on the variant with birdsfoot deer vetch-140.8 kg/ha, and the lowest-on the variant with alsike clover-91.8 kg/ha, which is 34.8% lower compared to the previous variant. The total balance is negative in the variants with alsike clover and amounted to 8.2 kg/ha.

It has been established that phosphorus is the most intensely removed by birdsfoot deer vetch-320 kg/ha and cow clover-31.0 kg/ha. Its smallest loss is observed in the variant with alfalfa (25.5 kg/ha). Relative to the potassium regime, this food element is the most heavily used by birdsfoot deer vetch-91.4 kg/ha. The lowest potassium expenditure is observed in the variant with alfalfa-71.4 kg/ha, which, in our opinion, is connected with the yield of the crop grown. The balance of potassium in the soil in the variants with legumes when applying potash fertilizers at the rate of 60 kg/ha is negative.

## Conclusion

In the conditions of Subcarpathia, the cultivation of legumes in the sod-podzolic soil using the method of coverless sowing with the application of phosphorus-potassium fertilizers on average for the three years provided an improvement in fertility, in particular the growth of the content of alkaline hydrolyzed nitrogen (3.9%), mobile phosphorus (5%) and exchangeable potassium (14%).

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