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The collective monograph describes the integration of traditional and innovation processes of development of modern science. The general issues of the biological sciences, engineering and technical support and AIC management, information, computing, and automation, etc. are considered. The publication is intended for scholars, teachers, postgraduate students, and students, as well as a wide readership.

Contents

AGROECOLOGICAL POTENTIAL OF LEGUMES IN CONDITIONS OF INTENSIVE AGRICULTURE OF UKRAINE

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Abstract. The ecological significance of leguminous crops grown in modern intensive crop rotation in Ukraine is considered. In particular, the sown areas of common leguminous crops in Ukraine and the level of their productivity have been analyzed. A comparison is made with the acreage of common field crops in Ukraine. The volume of accumulation of by-products in the form of their straw and stubble is calculated. A comparison is made for these indicators with the most widespread grain crops grown in Ukraine. The data on the content of the main nutrients in the by-products of leguminous crops – nitrogen, phosphorus, potassium are given. On the basis of these indicators, a calculation was made of the accumulation of the main nutrients in the soil, which can come with by-products of leguminous crops at their average yield. We also compared the obtained indicators with the input of nitrogen, phosphorus and potassium into the soil with by-products of the most common grain crops. Calculated symbiotic nitrogen fixation by leguminous crops. Based on this, a conclusion was made about the most effective leguminous crops, the cultivation of which in the modern intensive crop rotation of Ukraine will more contribute to the stabilization of the agroecological state of the soil.

It is proved that an increase in the areas of leguminous crops in the intensive crop rotation of Ukraine will have a positive effect on the agroecological state of the soil. In particular, growing beans allows you to get the highest mass of by-products, which can be buried in the soil – 3.5 t/ha. Also, the by-products of beans provide the input into the soil of all mineral

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phosphorus – 12.6 kg/ha of all leguminous crops, as well as potassium – 16.5 kg/ha. By-products allow to accumulate more mineral nitrogen in the soil with by-products – 38.4 kg/ha. Also, soybeans are characterized by a high symbiotic nitrogen-fixing ability among all leguminous crops – 120 kg/ha.

1. Introduction

Modern field crop rotations of Ukraine, involved in commercial cultivation of agricultural crops, occupy an area of about 1994–1900 hectares. Of these, about 70% of the specified arable land area is occupied by intensive farming technologies used in agricultural enterprises processing leased land.

In Ukraine, such technologies are characterized by the cultivation of a limited number of crops in the rotation, among which winter wheat prevails, which occupies 31% in the structure of sown areas, sunflower – 30%, corn – 23% in the structure; intensive use of mineral fertilizers, the volumes of which for the cultivation of these crops reach 200–300 kg/ha in the active substance of the main nutrients of nitrogen, phosphorus and potassium, in the physical mass of mineral fertilizers reaches 1000 kg/ha; repeated use of synthetic pesticides, the amount of which during one growing season can be up to 10 times when growing one crop; frequent return to the same field of the cultivated crop can be in one to two years, and for corn – growing in a row for two to three years by a non-optimal alternation of crops in the crop rotation, when for corn and winter wheat, sunflower is the main precursor, and for sunflower – corn. With such high-tech conditions for growing crops in Ukraine, unfavorable conditions are formed for the growth and development of plants, which requires a further increase in the use of chemicals – mineral fertilizers and synthetic pesticides.

Considering the lack of organic fertilizers in the modern crop rotation of Ukrainian agriculture, when in 2019 the fertilized area of soil with manure was only 503 600 hectares, which is only 2.7% of the arable land area with an estimated application of organic fertilizers for the entire arable land area of Ukraine 0.5 t/ha at a scientifically grounded rate of 18.3 t/ha, which could partially stabilize the stability of such agroecosystems, an important problem arises of finding alternative ways to replenish the stock of organic matter in the soil, which will not only improve the agroecological state of

soils, but will also lead to an increase in the stability of such monotonous agroecosystems to the impact of harmful organisms – pests, diseases and weeds, the number of which has increased dramatically.

In modern conditions of intensive agriculture in Ukraine, an alternative way of replenishing the stock of nutrients and organic matter in the soil is plowing by-products of common crops grown in crop rotation: straw, stalks and stubble of winter wheat, winter rape, corn, sunflower and others. In Ukraine, such an agro-ecological measure has not been used for a long time, since during the existence of the Soviet Union, grain straw, corn and sunflower stalks were used for animal husbandry as feed and bedding. Since the 2000s, a sharp decline in the livestock sector of Ukrainian agriculture has led to the abandonment of crop by-products in the field, followed by their burning. Only since the 2010s, agricultural enterprises began to grind plant residues and plow them as organic fertilizer. And in such conditions, a part of the by-products of winter wheat, corn, sunflower, winter rape is withdrawn from fields for biofuel production.

However, a more significant factor in increasing the accumulation of nutrients in the soils of agricultural land in Ukraine is the plowing of by-products of leguminous crops, which is characterized by a significantly higher content of nutrients in its chemical composition, symbiotic nitrogen fixation of leguminous crops during their cultivation, however, the agroecological significance of leguminous crops in modern intensive crop rotation in Ukraine is underestimated .

2. Analysis of recent research and publications

The use of by-products of legumes, cereals and cereals to increase the yield of subsequent crops in the crop rotation was studied at the National Scientific Center, Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine V.F. Kaminskiy (2014).

The study of the properties of straw as an organic fertilizer and the peculiarities of its use for fertilizing the soil and increasing the yield of subsequent crops in the crop rotation are covered in the works of the Sumy National Agrarian University and the Scientific Research Institute of Agriculture of the North-East of the National Academy of Agrarian Sciences of Ukraine (Butenko, A.A., 2020), National Research Center Institute of Agrarian Economics (Korchinsky, A.A., 2015).

The effect of plowing pea straw together with mineral fertilizers on the indicators of the agrochemical composition of gray forest soil, yield and grain quality of winter wheat were studied at the Institute of Agriculture of the Carpathian Region of the National Academy of Agrarian Sciences of Ukraine by scientists Sedilo, G.M., Dubitsky, A.A., Kachmar, O.I., Vavrinovich, A.V., (2018).

The study of the joint use of by-products of plants and green manure was studied at the Research Institute of Agriculture of Polissia of the National Academy of Agrarian Sciences of Ukraine Bovsunovskiy, A.M., 2009. Fertilization of field crops based on the maximum use of local organic resources, in particular, by-products of plant growing of common agricultural crops are covered in the works Kabanchik, V.M., Sobko, M.I. and Radchenko, A.V. in Institute of Agriculture of the North-East of the National Academy of Agrarian Sciences of Ukraine, 2015. All these scientists note the positive effect of the use of by-products of grain and leguminous crops on the indicators of soil fertility and increasing the yield of subsequent crops in the crop rotation.

3. Literature review

Traditional leguminous crops of agricultural land in Ukraine during the second half of the twentieth century was sown peas, which occupied at least 10% of the sown area of each farm. In those days, its straw was used for animal feed, so it was not scattered over the fields. The removal of nutrients from the soil by cultivated crops was compensated by significant amounts of organic fertilizers. The agroecological significance of peas at that time was determined by its symbiotic nitrogen fixation and the optimal characteristics of this crop as a steam predecessor of winter wheat.

At the same time, it is not uncommon for straw to be burned in the fields after harvest. At the same time, 1.5–2 tons of organic matter is irretrievably lost from one hectare, and the soil microflora is also disturbed. This leads to a decrease in soil fertility, which also affects the yield of agricultural crops. And although in Ukraine at the legislative level there is a ban on such burning of plant residues, it is still ignored by many enterprises from year to year.

In the 21st century, the acreage of peas in Ukraine has sharply decreased, and its agroecological significance has increased significantly. The decrease in the acreage of peas is due to economic and business factors and not too

high intensification of the technology of its cultivation. At the same time, the sown areas of other, often rare leguminous crops, in particular soybeans, began to grow.

The straw of leguminous crops contains more organic matter than other organic fertilizers, and very valuable components for increasing soil fertility: cellulose, pentose, hemicellulose and lignin, which are carbon energy substrates for soil microorganisms. It is the main building material for soil humus.

Smelling of one ton of straw is equivalent to 3.5–4.0 t/ha of straw manure in its effect. This indicates that when 0.2–0.4 tons of legume straw are left in the soil, 0.3–2.6 tons of humus per hectare is formed. In the research of the Institute of Agriculture of the North-East, it was established that the use of straw as fertilizer during the rotation of a 4-field crop rotation contributed to an increase in the humus content by 0.13–0.17%. The calculations show that with its systematic plowing, it is possible to achieve a deficit-free humus balance in soils without additional costs.

On average, 4.2 kg of nitrogen, 1.7 kg of phosphorus, 8.3 kg of potassium, 4.2 kg of calcium, 0.7 kg of magnesium, and a number of trace elements are returned to the soil from one ton of straw of grain and leguminous crops. Fertilization with straw increases the availability of phosphorus and potassium in the soil, due to the dissolving action of acidic substances formed during its decomposition. When plowing straw in an amount of 5 t/ha, up to 40 kg/ha of potassium and up to 66 kg/ha of nitrogen, as the most essential components of mineral nutrition, are returned to the soil annually. Of course, the nutrients bound in the organic matter of the straw will be available to plants only 3–5 years after the decomposition of the straw. But with the systematic introduction of straw, this problem will disappear by itself.

The straw contains all the nutrients necessary for plants, which are easily available to plants after mineralization.

The wide C: N ratio in grain straw (70–80: 1) affects its decomposition in the soil. Cellulose-freezing microorganisms need nitrogen. When it is deficient in straw, microorganisms consume mineral nitrogen from the soil, that is, the process of nitrogen immobilization is in progress. It has been established that for the normal course of straw decomposition processes, the C: N ratio should be 20–30: 1. Therefore, the efficiency of straw fertilization of grain crops increases significantly when combined with

additional sources of mineral nitrogen. Depending on the crop, which acted as a predecessor, the dose of mineral nitrogen can vary from 3 to 11 kg requires additional application of mineral nitrogen.

The annual application of straw improves the agrophysical properties of the soil. In particular, for 3–4 years, the number of valuable water-resistant aggregates larger than 0.25 mm in size increases and the permeability of soil increases.

Straw has a positive effect on the microbiological activity of the soil. The introduction of straw approximately doubles the amount of cellulolytic microflora in comparison with the control, and also leads to an increase in the activity of nitrogen fixation in the soil. The introduction of straw causes an increase in the «breathing» of the soil – the release of carbon dioxide, which is necessary for plants in the process of photosynthesis.

In the process of straw destruction, physiologically active substances are formed, which in low concentrations can positively affect the growth and development of plants.

The straw yield depends on the crop and its yield. The ratio between the main product and straw ranges from 1:0.8 to 1:2.0. Calculations show that the average annual output of straw for grain and leguminous crops in Ukraine's agriculture over the past five years is 56 million tons. Plowing this volume of straw can provide the return to the soil of about 280 thousand tons of nitrogen, 140 thousand tons of phosphorus and 448 thousand tons of potassium. This amount of nutrients is sufficient to obtain an increase in the grain yield of winter wheat in the amount of 3-3.5 million tons.

The largest sources of supply of plant residues in Ukraine in terms of their volumes, based on the sown area, are wheat straw – 30.3%, corn stalks for grain – 17.9%, barley straw – 12.0%, sunflower stalks – 23.8% and rapeseed – 12.6%. Making the most of plant residues for fertilizing agricultural crops, one can count on their annual application in favorable years of about 5 t/ha, in unfavorable years – up to 3.5 t/ha.

The decomposition of plant residues in the soil is slow and depends on the quality of plowing and weather conditions. It has been established that up to 46% of straw decomposes in 2.5–4 months, and up to 80% in one and a half to two years. For the decomposition of 1 ton of straw in the soil, after 3 months, about 50 kg of humus is formed, and after 2 years – about 90–100 kg.

Along with the specified properties of grain by-products, leguminous plants have a number of advantages, which can significantly increase their positive agroecological effect at lower economic costs. The growth of the agroecological value of leguminous crops in crop rotation is determined not only by their accumulation of organic matter with by-products for a more favorable ratio between nitrogen and carbon, but also by symbiotic nitrogen fixation, a taproot system, loosens the soil well, a variety of crops in crop rotation and an improvement in their rotation, after a short the growing season of leguminous crops – additional accumulation of moisture in the soil, cleaning the agroecosystem from pests, diseases and weeds. At the same time, the sown area of leguminous crops in Ukraine was unjustified and did not allow them to fully realize their agroecological potential.

At the same time, the main agroecological emphasis today is made on the traditional during the last years leguminous crops – peas and soybeans, but the sown areas of other leguminous crops, in particular chickpeas, lentils, beans, beans, are beginning to grow on farms. Very little is known about their agroecological significance in crop rotation.

4. Conditions, objective and methods of research

The research was carried out on the basis of processing the materials of the State Statistics Service of Ukraine concerning the sown areas and yield levels of leguminous crops in the farms of Ukraine, in particular soybeans, peas, chickpeas, lentils, beans, beans. On the basis of reference data, an assessment was made of the nitrogen-fixing ability of leguminous crops and the volume of accumulation of by-products in the form of their straw. We also used reference data on the content of nutrients in the straw of the studied leguminous crops: nitrogen, phosphorus, potassium. We used calculation methods for calculating the intake of nutrients into the soil. All these indicators were compared with traditional crops grown in intensive crop rotation.

The main objectives of the research were:

1. To analyze the sown area of leguminous crops in Ukraine and their structure;

2. Provide the actual level of productivity of the main leguminous crops grown in Ukraine;

3. Calculate the volume of possible formation of by-products of leguminous crops, which can be buried in the soil;

4. Give the chemical composition of the by-products of leguminous plants in terms of the content of the main inorganic substances necessary for plants: nitrogen, phosphorus and potassium;

5. Calculate the volume of input into the soil of the main elements of plant nutrition: nitrogen, phosphorus and potassium when plowing plant residues of leguminous crops;

6. To analyze the volumes of symbiotic nitrogen fixation of leguminous crops grown by intensive technologies in Ukraine;

7. Make a conclusion about leguminous crops that have the most positive agroecological impact on the supply of nutrients to the soil.

5. Research results

According to the State Statistics Service in Ukraine, in 2019 the sown area for leguminous crops was 566.0 thousand hectares, which is about 2.8% of the total sown area in Ukraine and a very low indicator (Figure 1).

According to scientifically grounded calculations, the minimum required sown area of leguminous crops in the structure of sown areas of field plants in Ukraine to stabilize the agroecological state of agroecosystems should be at least 10% of the arable land. For this, the sowing of leguminous crops

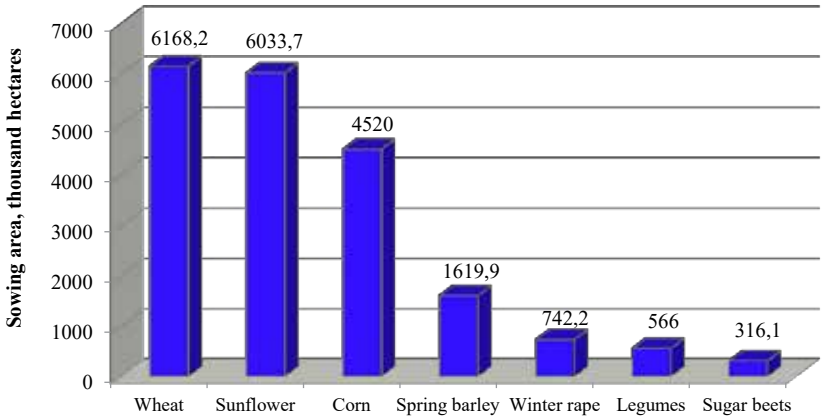

Figure 1. Sown areas of major crops in field crop rotations of Ukraine in 2019

in Ukraine must be brought to a total area of 1994,190 hectares that is, increased by 3.5 times from existing in 2019.

By the way, in 2015 in Ukraine, according to the State Statistics Service, the sown area of soybeans alone, excluding other leguminous crops, amounted to 1999.8 thousand hectares, which corresponded to the minimum agro-ecological requirements for stabilizing the state of agroecosystems. However, due to the change in climatic conditions, which is due to global warming, there was a significant decrease in the yield of soybeans and since then the sown areas of this crop began to decrease sharply.

The largest sown area among leguminous crops, according to the State Statistics Service in Ukraine in 2019, belonged to peas – 347.0 thousand hectares. The sown area of soybeans was 129.8 thousand hectares. The rest of leguminous crops have an insignificant sown area from 42.0 thousand hectares – in beans, up to 3.2 thousand hectares – in legumes (Table 1).

Table 1

Sown areas and yield level of legumes in Ukraine in 2019 (according to the State Statistics Service)

Culture	Sowing area, thousand hectares	Yield, t/ha
Soybeans	129.8	2.29
Peas	347.0	2.28
Chickpeas	36.0	1.40
Lentils	8.0	1.39
Beans	42.0	1.59
Fodder beans	3.2	2.32
Total	566.0	-

Structurally, the share of peas of all leguminous crops grown in Ukraine is 61.3%, the share of soybeans is 22.9%. Lentils and beans in the structure of sown areas among leguminous crops in Ukraine occupy the smallest share – 1.4% and 0.6%, respectively (Figure 2).

The average yield of leguminous crops, according to the State Statistics Service in Ukraine in 2019, varied within 1.39–2.32 t/ha. It was most found in beans, soybeans, and peas, while the lowest was found in lentils,

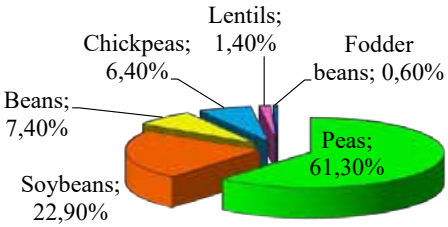

Figure 2. The structure of sown areas of leguminous crops in Ukraine in 2019

chickpeas, and beans. If we take barley, a grain ravine as a reference, the yield of leguminous crops was 0.7–2.4 times less than it.

The ratio of grain to by-products of all leguminous crops is similar and is in the range of 1:(1.2-1.5). Most of the by-products from the mass of seeds are formed by beans, and the least – by lentils (Table 2). In terms of the ratio of grain to by-products, legumes form more by-products than grain crops, and by this indicator they are close to winter rapeseed.

Table 2

Volumes of formation of by-products of legumes in intensive crop rotation

Culture	The ratio of grain to by-products	The average volume of by-products, t/ha
Soybeans	1 : 1.4	3.2
Peas	1 : 1.4	3.2
Chickpeas	1 : 1.3	1.8
Lentils	1 : 1.2	1.7
Beans	1 : 1.4	2.2
Fodder beans	1 : 1.5	3.5

Taking into account the average level of productivity of leguminous crops in Ukraine, we calculated the formation of vegetative mass of by-products (straw, stems) by them. Most of the by-products can be returned to the soil by beans – 3.5 t/ha, soybeans and peas – by 8.6% less, beans – by 37.1%, and least of all – chickpeas and lentils – 1.7–1.8 t/ha. In comparison with other field crops of intensive crop rotation, the return

to the soil of by-products of leguminous crops is lower than from such crops as winter wheat, corn, sunflower, but the same as when forming by-products from spring barley.

The content of the main nutrients in the by-products of all leguminous crops is similar and is: nitrogen – 10.0–12.0 kg/t, phosphorus – 3.4–3.6 kg/t, potassium – 4.6–5.0 kg/t (Table 3).

Table 3

The content of basic elements in by-products of legumes, kg/t

Culture	N	P	K
Soybeans	12.0	3.6	5.0
Peas	10.0	3.5	4.6
Chickpeas	10.6	3.5	4.7
Lentils	10.8	3.4	4.6
Beans	10.6	3.5	4.7
Fodder beans	10.6	3.6	4.7

Soybeans have a somewhat high content of nutrients in by-products, while other crops have approximately the same indicators. In terms of nitrogen content, leguminous crops are dominated by cereals by 2.3–2.7 times, phosphorus by 1.5–1.6 times and are inferior in terms of potassium content.

With the vegetative mass of by-products of leguminous crops, 19.1–38.4 kg/ha of mineral nitrogen will come from it. Most of it will be accumulated for growing soybeans and beans, and least of all – for growing chickpeas and lentils. Smelling of soybean by-products ensures that the soil is supplied with almost twice as much mineral nitrogen as it will be supplied by prioritizing plant residues of winter wheat.

Most of the mineral phosphorus will enter the soil when growing beans – 12.6 kg/ha, as well as soybeans and peas – 11.2–11.5 kg/ha, which is 1.1–1.3 times more than it will receive into the ground with winter wheat straw. Less mineral phosphorus will enter the soil with lentil by-products – 5.8 kg/ha.

Potassium input into the soil with the by-product of beans and soybeans will be the largest and will amount to 16.0–16.5 kg/ha. At the same time, less will be received when growing lentils – 7.8 kg/ha.

Unlike other agricultural plants, leguminous crops fix symbiotic nitrogen with the help of nodule bacteria and additionally enrich the soil

with it. Most of all, it is fixed by soybeans – 120 kg/ha, beans – by 10 kg/ha less, peas – by 20 kg/ha, beans – by 50 kg/ha, chickpeas – by 40 kg/ha and lentils – by 35 kg/ha less.

Taking into account the complex effect of growing leguminous crops on the optimization of the agroecological state of the soil, including the conversion of a part of the organic mass of by-products into humus, the accumulation of nutrients nitrogen, phosphorus and potassium from it, as well as the production of biological nitrogen by leguminous crops in symbiosis with nodule bacteria, we calculated the total the positive impact of all leguminous crops on the state of the soil, taking into account all the above factors and is presented in relative units in Figure 3.

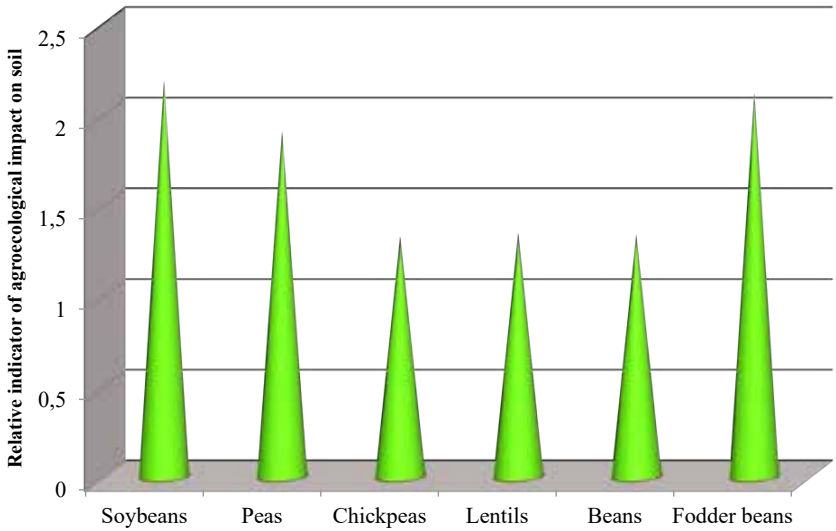

Figure 3. Relative agroecological effect of impact on the soil of growing leguminous crops

The greatest positive impact on the agro-ecological state of the soil is carried out by the cultivation of soybeans with a relative indicator of 2.18, as well as beans – 2.11. Pea cultivation has a slightly lower rate – 1.90. The rest of leguminous crops – chickpeas, lentils and beans have the lowest relative impact on the soil – 1.32–1.34.

6. Conclusions

It has been proven that an increase in the area of leguminous crops in an intensive crop rotation will have a positive effect on the agroecological state of the soil. In particular, growing beans allows you to get the highest mass of by-products, which can be buried in the soil – 3.5 t/ha. Also, by-products of beans are characterized by a high content of mineral phosphorus – 3.6 kg/t, which ensures the supply of all mineral phosphorus to the soil – 12.6 kg/ha of all leguminous crops, as well as potassium – 16.5 kg/ha.

Soybean by-products are characterized by high nitrogen content – 12.0 kg/t, phosphorus – 3.6 kg/t and potassium – 5.0 kg/t. This makes it possible to accumulate more mineral nitrogen in the soil with by-products after growing soybeans – 38.4 kg/ha. Also, soybeans are characterized by a high symbiotic nitrogen-fixing ability among all leguminous crops – 120 kg/ha.

The by-product of leguminous crops has a high nitrogen content by 2.3–2.7 times, phosphorus – 1.5–1.6 times compared to the by-product of grain crops. Also, when plowing soybean by-products into the soil, there will be 2 times more mineral nitrogen and 1.1–1.3 times more phosphorus than when plowing winter wheat by-products.

Among all leguminous crops grown in Ukraine, the greatest positive complex agroecological impact on the soil, taking into account the input of organic matter from by-products, mineral nitrogen, phosphorus and potassium with it and symbiotic nitrogen fixation, will be carried out by the cultivation of soybeans and beans.

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