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ASSESSMENT OF THE PARTICIPATION OF PLANT RESIDUES FROM DIFFERENT CROPS IN THE SOIL NUTRIENT BALANCE

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Abstract
The balance of soil nutrients affects not only the productivity of crops grown, but also the fertility of the soil. The search for the possibility of maintaining a positive balance in crop rotation is very important. Returning plant residues of cultivated crops allows farmers to return NPK-nutrients that are removed with the harvest. Each crop has variable NPK-content. The main objectives of this study were to assess from which field crop farmers can get the greatest amount of plant residues; and which plant residues are richest in nitrogen, phosphorus, potassium. The following field crops were studied: winter wheat, maize for grain, sunflower, peas for grain. The maximum plant residues were found to remain after maize, the minimum after peas. The maximum nitrogen remains after plant residues from maize and winter wheat, then sunflower, while the maximum phosphorus was found with the plant remains of maize and sunflower; for potassium, sunflower residues were found to provide the maximum.

Keywords: crop productivity, fertilizers, N-P-K soil nutrient balance, plant residues

1. INTRODUCTION

Modern agriculture is faced with the task of obtaining profitable, highly productive and qualitative crops, but also maintaining fertility of one of the main means of production - the soil. Using soils in agricultural production causes an intervention in the relatively closed cycle of biogenic elements existing in natural biocenoses. The removal of nutrients from the economic harvest requires their return to the soil, to avoid a decrease in potential fertility and depletion of soils. The harvest always depends on very many factors: on the crop, on the meteorological conditions of the year, on the amount of nutrients in the soil, on the genetic potential of the variety and so on. Optimization of plant nutrition is possible through the use of fertilizers, but an excessive use is undesirable, as it leads to environmental pollution. It is important to remember that the absorption of one element depends on the content of other nutrients. The balance of agricultural nutrients was studied in the seminal work of D.N. Pryanishnikov in 1937 and nitrogen reimbursement of 80% was recommended. Phosphorus reimbursement was recommended at 100-110% (Pryanishnikov, 1965). The widespread use of high doses of fertilizer in the 1980s left the balance of assimilable nutrients in the chernozems of Moldova positive +16 to +35 kg ha^{-1}. As the use of fertilizer declined the balance fell and by the year 2000 was recorded as -36 to -150 kg ha^{-1} (Andries and Zagorcea, 2002; Andries, 2007; Krupenikov, 2008). Therefore, the study of the balance of nutrients and the ways of its regulation is highly important in the struggle for obtaining high yields and preserving the soil fertility.

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Two of the main crops grown in the world are wheat and corn (FAO, 2019). In the past five years, wheat occupies in Moldova on average 23.3% of the total sown area, maize - 31.6%, sunflower - 23.2%. About 1,146.2 thousand tons of wheat grain, 1574.4 thousand tons of maize grain, 660.6 thousand tons of sunflower seeds are produced annually in Moldova on average last five years (National Bureau of Statistics of the Republic of Moldova, 2019).

Depleting natural resources leads to higher prices for mineral fertilizers. Some scientists already predict in the near future a shortage of phosphate fertilizers, which will make their use too expensive and impossible (Krupenikov and Boincean, 2004).

The widespread use of organic fertilizer such as manure is not always possible due to insufficient livestock farms and their remote location. In Moldova, there has been a large reduction in the number of farmed animals. In 2018, this number decreased by 12.4% compared with 2015 (Moldova in number, 2018). According to statistics in Moldova, on average 0.05 t ha^{-1} of organic fertilizers were applied in 2017 compared to 0.08 t ha^{-1} in 2016. As a result of the reduced access to fertilizers, alternative sources are needed to balance the soil nutrients. Plant residues provide one of the most affordable, and environmentally friendly ways to replenish the soil. Plant residues contain a significant amount of ash elements and other nutrients. Crop residues have a short-term and long-term effect on the basic properties of the soil and are very important for maintaining soil fertility (Matyuk et al., 2011). A number of studies have concluded that each culture has variable residue quantity and content, C/N ratio, rate of decomposition (mineralization) of plant residues, which depends on very many factors: biological characteristics, growing conditions, cultivation technology, etc. (Zagorcea, 1990; Abiven et al., 2005; Chen, 2014).

The straw of winter crops is rich in carbon in the form of cellulose and hemicellulose, but contain little nitrogen and phosphorus. Winter crops have a wide ratio of carbon to nitrogen (80:1). In the process of decomposition of straw in the soil, intensive consumption of available nitrogen by microorganisms occurs. The biological fixation of soil nitrogen impairs the nitrogen nutrition of plants. To improve nitrogen nutrition, it is necessary to add an additional 8-10 kg of nitrogen to 1 ton of straw. It is advisable to apply with straw phosphate and potash fertilizers on nutrient-poor soils (Matyuk et al., 2011). The addition of 3-4 t ha^{-1} of straw is equivalent to 10.5 t ha^{-1} of carbon in manure (Titova, 2000). The stubbles and roots of crops that have remained in the soil mineralize by 70–80% for two years, and only 20–30% humifie. Humus also mineralizes, but only significantly slower (Sheudzhen et al., 2011).

It was calculated that on average 258 M t $year^{-1}$ dry plant residues are produced within the European Union. The contribution of wheat to the straw production (dry matter) is the highest – 42.2%, then maize and barley – 18.8%, rapeseed – 6.9% and sunflower – 5.2% (Scarlat et al., 2010).

2. MATERIALS AND METHODS

The main objective of these studies was: to calculate the balance of nitrogen, phosphorus and potassium for basic crops cultivated with and without the use of mineral fertilizers and with the introduction of all plant residues in the soil; to evaluate the participation of plant residues in the nutrient balance and determine the possibility of obtaining a positive balance with this fertilizer system.

This research was conducted on the Ketrosy (Chetrosu) Experimental Station of the State Agrarian University of Moldova. This is a long-term field experiment with fertilizers that began in 1950 based in the Central Zone of Moldova (Anenii Noi) that has a continental climate and rainfall

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varying between 246 and 550 mm (annual mean of 449 mm) with drought occurring once in three or four years.
The soil is Calcareous chernozem (Calcic chernozem in the World reference base for soil resources 2014): light loam with 2.5-3.0% humus (Tyurin), 0.8-1.5 mg 100 g^{-1} mobile phosphate (Machigin), 18-22 mg 100 g^{-1} exchangeable potassium and 1.8-2.2% carbonates in the 0-20 cm layer.
The following crops were studied: winter wheat (Triticum aestivum L.), maize (Zea mays L.), sunflower (Helianthus annuus L.), peas (Pisum sativum L.). Winter wheat had two predecessors: winter wheat and peas for grain. The crop rotation is eight-field: maize for grain – peas – winter wheat – winter wheat – maize for grain – peas – winter wheat – sunflower.
The crop rotation is set up in three 2 ha fields, the area of each experimental plot is 200 m^2 (20 × 10 m), there are 3 replications.
An eight-field experimental rotation was applied after two complete cycles of ten-field crop rotation with low doses of fertilizer in the period of 1950 to 1970. Since 1971, a system of fertilization for the planned yield was used in the eight-field crop rotation: annual applications of 300 kg NPK ha^{-1} of mineral fertilizers – $N_{120}P_{90}K_{90}$ ($N_{90}P_{60}K_{60}$ since 1999). Since 2005, the after effects of fertilizers have been studied. Since 2008, the minimum dose required of mineral fertilizers $N_{47}P_{46}$ have been introduced.
In the crop rotation all plant residues were introduced (stalks, stubble, roots). The vegetable residues were crushed during harvesting by the combine harvester and embedded in the soil: for winter wheat, during surface primary processing with disk implements; for corn, sunflower by plowing to a depth of 25-27 cm.
The nutrient balance was examined in the 2001-2018 period on experimental plots: without fertilization from 1950 – natural fertility, with influence of mineral fertilizers – on average $N_{47}P_{46}$ per year on variants with previous long-term application of minerals – $N_{90}P_{60}K_{60}$, organic – manure 18 t ha^{-1} and organomineral – manure 9 t ha^{-1} + $N_{45}P_{45}K_{30}$ fertilizers.
Doses of mineral fertilizers: for winter wheat and maize during pre-sowing 100 kg ammophos and as an additional fertilizer N_{50} ammonium nitrate (total $N_{62}P_{52}$), for sunflower 100 kg ammophos and N_{34} ammonium nitrate (total $N_{46}P_{52}$), for peas 50 kg ammophos (total N_6P_{26}).
The average crop yield was calculated in the 2001-2018 period first on average for three fields, then on average for the studied period.
The mass balance for nitrogen, phosphorus and potassium of the crop rotation comprised of inputs with mineral fertilizers, crop residues and outputs with grain yield (equation 1).

The Balance of Nutrients (N/P/K) = $\sum$ Input (N/P/K) - $\sum$ Output (N/P/K), kg ha^{-1} yr^{-1} (1)

The calculation of nitrogen balance did not take into account the receipt of seeds, sediments and losses due to denitrification, considering them to be approximately equal and compensating each other.

3. RESULTS AND DISCUSSIONS

Crop productivity
The productivity of the studied crops was influenced foremost by meteorological conditions, then by fertilizers, predecessor crops and other factors. So for winter wheat 2003 was extremely dry: the grain yield on plot with natural fertility was 0.16 t ha^{-1} after winter wheat and 0.17 t ha^{-1} after peas, on plots with fertilizers – 0.16-0.33 t ha^{-1} (figure 1). The highest grain yield of winter wheat was

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obtained on fertilized variants in 2018 – 6.16 t ha^{-1}. The use of fertilizers made it possible to obtain yield increase up to 2.99 t ha^{-1} in years with favorable weather conditions (2018).

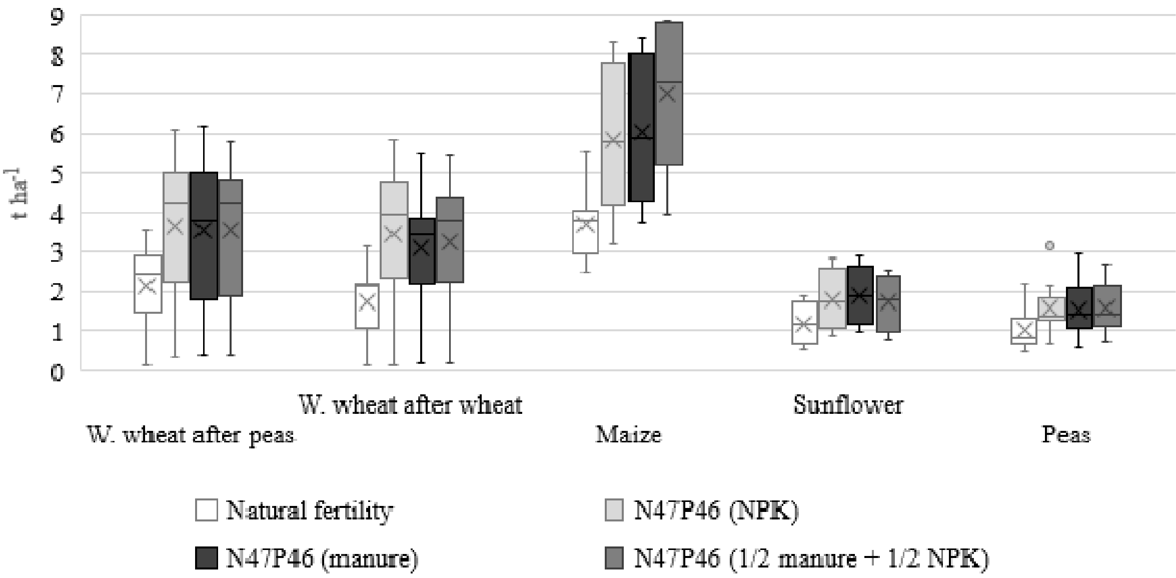

Figure 1. Grain yield in the 2001-2018 period

The grain yield of maize varied from 2.46 on the control group (natural fertility) in unfavorable years to 8.88 t ha^{-1} on fertilized variants in favorable years. The grain yield of sunflower varied from 0.52 to 2.88 t ha^{-1}. The lowest peas grain yield was 0.45, the highest – 3.14 t ha^{-1} in favorable conditions (2006) as shown in figure 1.

As shown in figure 1, the incorporation into the soil of all plant residues in crop rotation made it possible to obtain yields with the natural fertility of Calcareous chernozem in years with favorable weather conditions up to 3.55 t ha^{-1} winter wheat grain (2016, the predecessor crop was peas), up to 5.50 t ha^{-1} grain of maize (2013), up to 1.88 t ha^{-1} seeds of sunflower (2006) and up to 2.17 t ha^{-1} grain of peas (2006). On average the winter wheat grain yield in the studied period was 2.09 t ha^{-1} without fertilizers and 3.56-3.78 t ha^{-1} with fertilizers; maize – 3.66 and 6.16-7.09 t ha^{-1}; sunflower – 1.36 and 1.92-2.15 t ha^{-1} peas – 1.04 and 1.64-1.68 t ha^{-1}.

With an increase in crop productivity, not only the grain harvest increases, but also the crop of by-products and amount of residue grows. If we evaluate the studied culture by crop yield of by-products (straw, stalks) then maize is in first place – on average 5.39 t ha^{-1} on plot with natural fertility and 9.41 t ha^{-1} on variants with fertilizers, then winter wheat – on average 3.95 and 6.85 t ha^{-1}, respectively as shown in figure 2. The least amount of by-products is seen after peas – on average 1.78 and 2.92 t ha^{-1}. If we evaluate crops by the amount of stubble and root remains, then sunflower will be the highest - on average 4.34 t ha^{-1} on plot with natural fertility and 4.62 t ha^{-1} on variants with fertilizers, then maize – on average 3.12 and 4.49 t ha^{-1}, respectively. The least amount of stubble and root remains leaves behind again peas – on average 1.20 and 1.38 t ha^{-1}. In general, the most plant residues (including by-products, stubble and root remains) are left behind maize – on average 8.51-13.90 t ha^{-1}.

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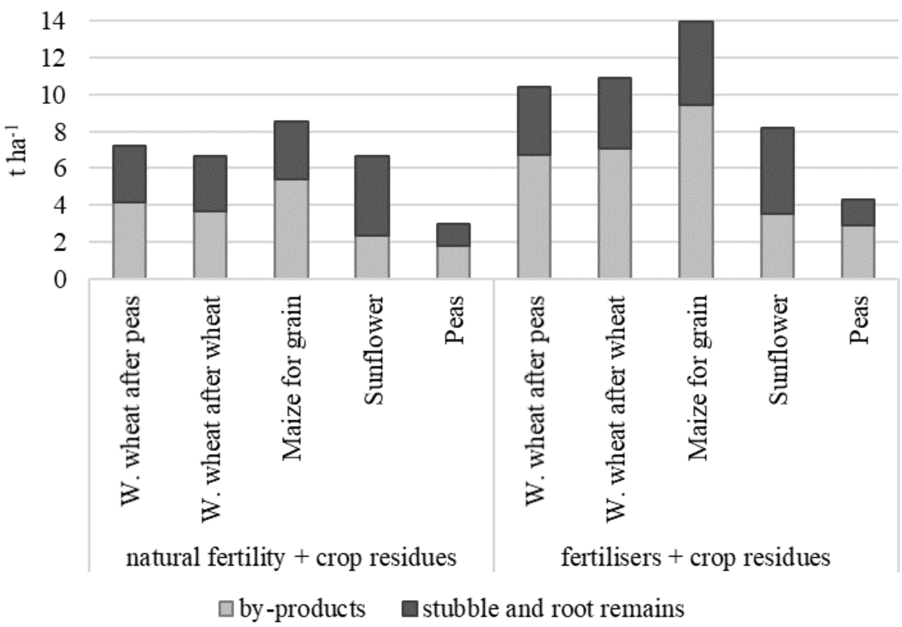

Figure 2. Average crop residues yield in the 2001-2018 period

N-P-K output

Removal of nutrients from soil in the N-P-K balance occurs with the grain harvest. If the cultures are evaluated by the content of nitrogen in the grain, then the highest are peas – on average 3.07-3.45%, followed by sunflower – 2.60-3.10%; most of all phosphorus is found in the grain of winter wheat – 0.88-0.99%, peas – 0.80-1.25% and sunflower – 0.81-1.11%; most potassium in grain of peas – 1.30-1.45% (table 1).

Table 1. Nutrients content, %

#	In grain			In plant residues		
	N	P	K	N	P	K
I	Peas 3.07-3.45	Wheat 0.88-0.99	Peas 1.30-1.45	Peas 0.85-1.05	Sunflower 0.43-0.51	Sunflower 3.11-3.35
II	Sunflower 2.60-3.10	Peas 0.80-1.25	Sunflower 0.91-1.05	Sunflower 0.80-0.92	Maize 0.25-0.40	Peas 1.10-1.40
III	Wheat 1.88-2.25	Sunflowers 0.81-1.11	Wheat 0.53-0.59	Maize 0.53-0.70	Peas 0.20-0.28	Maize 0.60-0.75
IV	Maize 1.65-1.75	Maize 0.55-0.87	Maize 0.45-0.60	Wheat 0.47-0.55	Wheat 0.10-0.17	Wheat 0.47-0.55

With each 1 t of wheat grain farmers take out from the soil about 18.8-22.5 kg N, 8.8-9.9 kg P and 5.0-5.9 kg K; with maize grain – 16.5-17.5 kg N, 5.5-8.7 kg P and 4.5-6.0 kg K; with sunflower grain – 26.0-31.0 kg N, 8.1-11.1 kg P and 9.2-10.5 kg K; with peas grain – 30.7-34.5 kg N, 8.0-12.5 kg P and 13.0-14.5 kg K. A higher grain yield results in more nutrients being removed from the soil. The highest content of nitrogen in the studied period was harvested by the grain of maize – on average 60.5 kg ha^{-1} without fertilizers and 107.9-124.1 kg ha^{-1} shown in figure 3 with fertilizers,

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then winter wheat – 39.3 and 55.7-80.5 kg ha^{-1} due to the high productivity of these crops Although peas have the highest nitrogen content, because of its low productivity, the removal of nitrogen is 30.3 and 55.7-56.9 kg ha^{-1}.

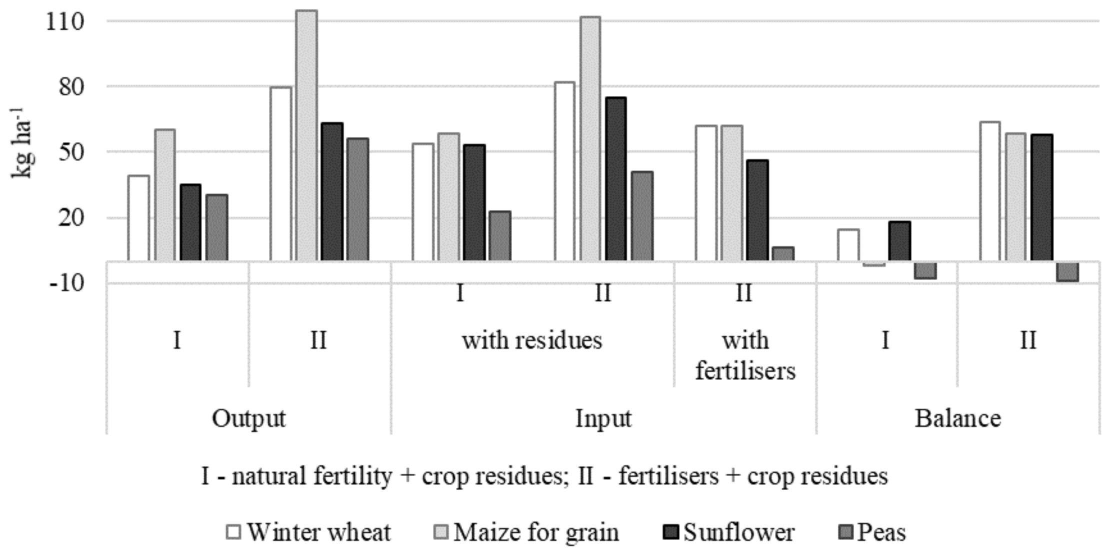

Figure 3. The nitrogen balance

According to the removal of phosphorus with grain, the highest was maize – on average 20.2 shown in figure 4 with natural fertility of calcareous chernozem and 53.6-61.7 kg ha^{-1} with fertilizers, then winter wheat – 20.7 and 31.5-35.9 kg ha^{-1}, respectively, then sunflower – from 11.0 to 21.3-23.8 kg ha^{-1}.

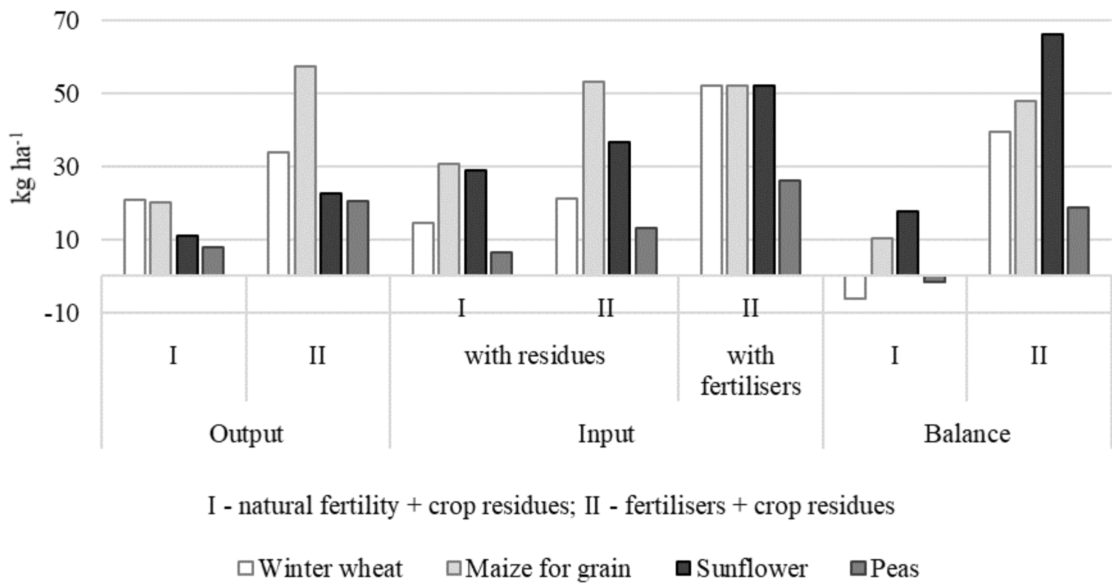

Figure 4. The phosphorus balance

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The highest potassium removal was made by maize – on average from 16.5 to 37.0-42.5 kg ha^{-1}, then peas – from 12.8 to 23.6-23.9 kg ha^{-1} and sunflower – from 12.5 to 20.2-22.5 kg ha^{-1} (figure 5).

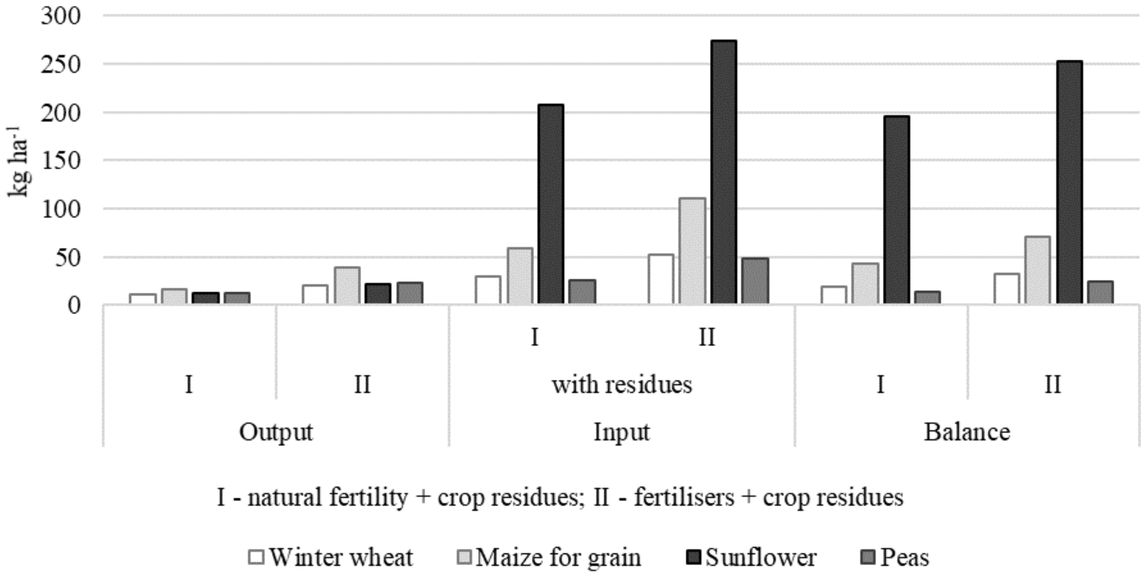

Figure 5. The potassium balance

N-P-K input

The input in the studied balance includes nutrients delivered to the soil through fertilizers and plant residues.

The doses of mineral fertilizers ($N_{62}P_{52}$ for winter wheat and maize, $N_{46}P_{52}$ for sunflower and N_6P_{26} for peas) compensated for the removal of nitrogen with grain yield for winter wheat by 73-80%, for maize by 50-57.5%, for sunflower by 69-77%, and for peas by 9-11%. Phosphorus removal was replenished with fertilizers only for maize not by 100% (by 84-97%), for other crops by more than 100%: for peas by 126-129%, for winter wheat by 138-166%, for sunflower by 218-244%. Potash fertilizers were not applied, as carbonate chernozem is able to provide plants with potassium (Krupenikov, 2008).

Let us now estimate the studied cultures on the return of nutrients to the soil due to plant residues. According to the content of nutrients in plant residues, the cultures are distributed as follows: most of the nitrogen is contained in the straw of peas – on average 0.85-1.05%, then sunflower – 0.80-0.92%, the lowest in winter wheat – 0.47-0.55%; on phosphorus and potassium in the first place sunflower – 0.43-0.51% and 3.11-3.35%, respectively, least in winter wheat – 0.10-0.17% and 0.47-0.55% (table 1). This means that with 1 t winter wheat straw farmers return in soil about 4.7-5.5 kg N, 1.0-1.7 kg P and 4.7-5.5 kg K; with maize stover – 5.3-7.0 kg N, 2.5-4.0 kg P and 6.0-7.5 kg K; with sunflower – 8.0-9.2 kg N, 4.3-5.1 kg P and 31.1-33.5 kg K; with peas straw – 8.5-10.5 kg N, 2.0-2.8 kg P and 11.0-14.0 kg K.

If we estimate the amount of nutrients introduced into the soil due to all plant residues (by-products, roots, stubbles) then the highest for nitrogen is maize – on average 58.6 kg ha^{-1} without fertilizers and 111.9 kg ha^{-1} on variants with fertilization, next is winter wheat – 54.0 and 81.8 kg ha^{-1} followed by sunflower – 53.4 and 75.0 kg ha^{-1} (figure 3).

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In terms of amount of phosphorus that is introduced, maize is also in the first place – on average 30.5 and 53.1 kg ha^{-1}, and then sunflower – 28.8 and 36.7 kg ha^{-1}, winter wheat – on average 14.4 and 21.1 kg ha^{-1}, least is peas at – 6.4 and 13.1 kg ha^{-1} (figure 4).
For potassium, sunflower is in the lead at – 207.9 and 273.3 kg ha^{-1}, thanks to high productivity of by-products, then followed by maize – 59.3 and 110.1 kg ha^{-1}, then winter wheat and peas – on average 29.5-52.2 and 25.9-48.6 kg ha^{-1}, respectively (figure 5). Such a high demand for potassium and phosphorus plants is replenished by reserves of these elements in calcareous chernozem.

N-P-K balance

In the N-P-K balance, the amount of nutrients removal from soil depends on crop yields. The increase in yield leads to an increase in the removal of nutrients from the soil. But with an increase in crop yields, the mass of plant residues increases, and, accordingly, it becomes possible to return more nutrients to the soil. Of course, this increase is limited by the genetic potential of not only culture, but also of variety. But increasing the productivity of field crops is impossible without providing plants with available nutrients, especially during critical growth phases, and this is possible through the use of even small doses of mineral fertilizers.
As shown in figure 3, the calculated nitrogen balance was negative on plots with natural fertility of carbonate chernozem (without the use of fertilizers) for peas – -7.7 and maize – -1.9 kg ha^{-1}, with fertilizers this balance was negative only for peas – on average -9.3 kg ha^{-1}, since the crop increased and, accordingly, nitrogen removal increased, and the dose N_6 replenished this removal only by 9-11%.
The balance of phosphorus was negative for winter wheat – on average -6.3 and peas – -1.5 kg ha^{-1} on the plot with natural fertility (figure 4). The use of fertilizers not only increased the yield, but also sufficiently compensated for the removal of nutrients from soil.
As shown in figure 5, potassium balance was positive in all variants and for all cultures. The plant remains of sunflower are so rich in potassium that the P-input of the balance was about 12-15 times more than the removal.
The balance of nutrients in the soil was positive even with a high yield of the studied field crops due to incorporation of all plant residues and using small doses of mineral fertilizers.

4. CONCLUSIONS

These studies, carried out in a long-term field experiment, demonstrated that plant residues can contribute substantially to the N-P-K soil nutrient balance and may provide valuable assistance in sustaning good yields as the cost of fertilizers rise.
Most of the nitrogen and phosphorus was removed from the soil with grain of maize, then with winter wheat, sunflower. From the studied cultures, maize and winter wheat had the highest input of nitrogen into the soil through its plant residues, then sunflower, while phosphorus come with the plant remains of maize, then sunflower, most of potassium – with sunflower. The nitrogen balance of the peas was negative on all variants, but the phosphorus balance only in the soil with natural fertility (without fertilizers).
Plant residues offer an excellent source of low cost improvement to the nutritious balance of soils but they cannot compensate for all N-P-K removed after the harvest of crops, such as phosphorus after a winter wheat crop has been harvested.

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6. REFERENCES

Abiven, S., Recous, S., Reyes, V., Oliver, R. (2005). Mineralisation of C and N from root, stem and leaf residues in soil and role of their biochemical quality. *Biol fert soils, 42*, 119–128.

Andries, S., Zagorcea, C. (2002). Soil fertility and agrochemical servicing of agriculture. *Bulletin of ASM. Biological, chemical and agricultural sciences, 2,* 42–44.

Andries, S. (2007). Optimization of nutritive regimes and cultural plant productivity. Chisinau: Pontos.

Chen, B., Liu, E., Tian, Q., Yan, C., Yanqing Zhang, Y. (2014). Soil nitrogen dynamics and crop residues. *Agronomy for Sustainable Development, 34 (2),* 429–442.

Donos, A. (2008). Accumulation and transformation of nitrogen in the soils. Chisinau: Pontos.

FAO (2019). Faostat-agriculture, food and agriculture organisation of the united nations, FAO, 2019. Http://www.fao.org/faostat (accessed on: May 2019).

Krupenikov, I.A. Chernozems. (2008). Appearance, improvement, tragedy of degradation, ways of protection and rebirth. Chisinau: Pontos.

Krupenikov, I.A., Boincean, B.P. (2004). Chernozioms and ecological agriculture. Balti: B.

Matyuk, N. S., Belenkov, A.I., Mazirov, M.A. and alt. (2011). Ecological farming with bases of soil survey and agrochemistry. Moscow: RSAU-MTAA.

Moldova in number. (2018). National Bureau of Statistics of the Republic of Moldova. Statistical overview. Chisinau.

National Bureau of Statistics of the Republic of Moldova. (2019). Http://statistica.gov.md (accessed May 2019).

Pryanishnikov, D. N. (1965). Selected works. Agrochemistry. Moscow: Kolos, 63–96.

Scarlat, N., Martinov, M., Dallemand, J. (2010). Assessment of the availability of agricultural crop residues in the European Union: potential and limitations for bioenergy use. *Waste management, 30,* 1889–1897.

Sheudzhen, A.Kh., Neshchadim, N. N., Onishchenko L. M. (2011). Organic soil matter and its ecological functions. Krasnodar: KubGAU.

The World reference base for soil resources 2014. (2015). Food And Agriculture Organization Of The United Nations, Rome:FAO.

Titova, E.V. (2000). Agrochemical bases of effective application of fertilizers in zonal soils of the Tomsk region. PhD thesis. Barnaul: Altai State Agrarian University.

Zagorcea, C. (1990). Optimization of the fertilizer system in field crop rotations. Chisinau: Stiinta.

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