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# Vegetable structure balance in agrochernozems and the quality of seed production in the field crops cultivation with elements of soil protective technologies

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# Vegetable structure balance in agrochernozems and the quality of seed production in the field crops cultivation with elements of soil protective technologies

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**Abstract.**The combination of elements of soil-protective technologies in crop rotation, such as minimizing the main tillage for grain crops, plowing up wheat residues after soybean cultivation, desiccation and scattering potato tops, along with the classical cultivation of fallow fields contributes 6.8 t/ha, remaining the same the quality of seed products of soybeans, potatoes and wheat.

## 1. Introduction

Plant residues in soil perform a lot of functions. They are the main source of organic substance and nutrients during decomposition [1-4]. They stimulate biological activity [5, 6], contribute to the stabilization of soil, improve physical and water-physical properties [7], as well as increase the soil erosion resistance [8].However, the reduction of cultivation requires the obligatoryapplication of plant protection substance, contributes to soil compaction and littering [9, 10]. It breaks their aeration and nitrification capacity [11]. The presence of stubble and crop residues contributes to an increase in pathogenic organisms that negatively affect the production of high-quality products, especially in seed production [12, 13].In this regard, it is proposed to combine elements of soil-protective technologies and classic technologies of cultivation of agricultural crops in crop rotations to develop optimal conditions for the functioning of an agro ecosystem for obtaining high-quality products.

The goal of the research is to study the balance of plant substance in farming black soils and the quality of seed products using elements of soil-protective technologies in the structure of grain-crop cultivation in the Krasnoyarsk forest-steppe.

## 2. Objects of research

The studies were conducted in 2017-2018 in the training farm “Minderlinskoye” of the Krasnoyarsk State Agrarian University in the Krasnoyarsk forest-steppe (56.427638$^0$N, 92.917071$^0$ E). The objects of the research are the links of grain-and-crop rotation. Theyarefallow - potatoes - soy - spring wheat.

The crop rotation was established in 2017 on a complex of typical clay-illuvial farming black soils and cryogenic-mycelial farming black soils. The granulometric structure of the complex of farming black soils is represented by medium and heavy loamy varieties, the sum of exchange bases in the humus horizon ranges from 35 to 56 mg-equ.·100 g$^1$, the pH varies from close to neutral and neutral in the upper rock. The structure of the exchange cations is dominated by calcium. The humus content varies from medium to high (5.8 - 6.9%), the thickness of the humus horizon varies from 32 on mounds to 68 cm in micro dishes. The micro relief of the studied area is well defined.It is typical in general for the Krasnoyarsk forest-steppe. The availability of mobile potassium in the soil is very high, mobile phosphorus is medium and low, mobile forms of nitrogen are low and very low. Fertilizers were not applied; plant protection products were used.The elements of soil-protective technologies were flat-cutting cultivation in the tillage of soybeans and wheat, stubble leaving, grinding and scattering of all plant residues of cultivated crops.

The preparation of the pure fallow was carried out according to the classical technology and consisted of autumn plowing, carried out to a depth of 25–27 cm and four cultivations during the growing season to a depth of 8–10 cm. The predecessor was spring wheat.

The soy of the Zaryanitsa variety of the super elite category belongs to varieties of early ripening; this variety is included in the State Register for the East Siberian region, recommended for cultivation in the Krasnoyarsk Territory. The main tillage is flat-cutting, loosening to a depth of 15-17 cm in the autumn after harvesting the predecessor (potatoes), the early spring harrowing is necessary in the year of sowing.The sowing was carried out in the second decade of May with the help of the seeder Agrator 5800 to a depth of 5 cm, with a norm of 0.8 million viable seeds per 1 ha. At the beginning of June, the soil herbicide Zontran was applied with a dosage of 0.6 $l \cdot ha^{-1}$. In the phase of the second trifoliate leaf (the second decade of June), the herbicide Paradoks with a dose of 0.2 $l \cdot ha^{-1}$was applied. It was harvested with the help of the combine Palessein the second decade of September. The seed yield was 1.8 $t \cdot ha^{-1}$, with an average seed yield in the region of 2.0 $t \cdot ha^{-1}$. Soybean crop residues were left in the field.

The potato variety Aramis of the super super-elite (SSE) category is also included in the State Register for the East-Siberian region. It is mid-season, of table purpose. Potatoes were grown in order to obtain seed fraction by seed technology. A clean fallow was the predecessor for potatoes. For two weeks before planting potatoes, early spring harrowing was done, then, just before planting, the soil was loosened to a depth of 18-20 cm. Planting was carried out in the combs of the potato planter AVR, the consumption of planting material was 2.9 $t \cdot ha^{-1}$. The planting density was 53 thousand tubers $\cdot ha^{-1}$, the inter-row spacing is 90 cm. When planting, the potato tubers were treated with Prestige. Before sprouting the soil was treated against annual dicotyledonous and cereal weeds with Zenkor ultra, and during the growing season of potato they were treated against late blight, alternaria, aphids and leaf-eating pests with Consento, Biscay, Infinito. In early August, mechanical grinding and scattering of tops were made, and in the second decade of August, they began harvesting potatoes for seed purposes. All crop residues of potatoes were also left in the field. The average seed yield was 15 tons $\cdot ha^{-1}$.

Soy was a predecessor of the wheat Novosibirskaya elite of the 15th categories. Since autumn, flat cut cultivation was carried out to a depth of 5-6 cm; in the year of sowing, in early May, early spring harrowing was carried out. The sowing was carried out in the second decade of May by the seeder Agrator with a seeding rate of 4.5 million viable seeds $\cdot ha^{-1}$. In middle of June, the antiserum herbicide Puma Plus was treated at a dose of 1.25 l $\cdot ha^{-1}$ at the tillage stage. The harvest was carried out in the second decade of September with the help of the combine Palesse; the plant residues were not removed from the field. Wheat yield was 2.6 t $\cdot ha^{-1}$.

## 3. Research methods

The aboveground plant substance was taken into account for 4 terms during the growing season by the method of cuttings in 6 times repetition at the same time in all links of crop rotation. The aboveground vegetable substancewas disassembled into fractions, i.e., phytomass and aboveground substance. Along with the aboveground, underground plant substance was taken into account by the method of monoliths to a depth of 20 cm. The underground plant substance, washed from the soil, was fractionated into roots, a large mortmassis > 0.5 mm and a small mortmass is <0.5 mm. All fractions of plant substancewere brought to the air-dry state and determined their reserves. Further, on the basis of the balance equations [14], the intensity of the transition of phytomass and roots to the mortmass and the intensity of decomposition of the mortmass were calculated. Carbon in plants was estimated by the method of Anstet in the modification of V.V. Ponomareva and T. Nikolaeva.

The structure of potato yield was determined immediately before harvesting. Taking into account the level of contamination of the studied cultures in the presence of phytopathogens in the fields of crop rotation is performed applying the route survey method according to the CINAO methodology.

## 4. Results and discussion

The constant increase in stocks of phytomass and roots during the growing season reflects the biological characteristics of the cultivated crops. The dynamics of the formation of the aboveground mortmass, in addition to the biological and physiological characteristics of plants, are significantly influenced by the technology of their cultivation. Thus, in the cultivation of potatoes for seed purposes andtop desiccation were produced in early August. It entails a significant increase in the stocks of the aboveground mortmass up to 3 t $\cdot$ha$^{-1}$in the form of crushed leaves and stems of potatoes. In other links of the crop rotation, the maximum stocks of the aboveground mortmass were formed by September (Figure 1).

The formation of underground plant substance has more complex mechanisms, associated with the necrosis of the plant's aboveground parts and their entry into the underground unit, the stock of plant residues of the precursor, the intensity of decomposition of plant residues, as well as the applied agricultural technology. Thus, in the cultivation of potatoes for seed purposes, the tops desiccation are produced in early August, which entails a significant increase in the stocks of the aboveground mortmass up to 3 t $\cdot$ha$^{-1}$ in the form of crushed leaves and stems of potatoes. In other parts of the crop rotation, the maximum stocks of the aboveground mortmass were formed by September (Figure 1).In the soil of the studied crop rotation units, the average stocks of the mortmass have no significant differences, with the exception of the potato field where the stock of the large mortmass increases significantly in August and September due to the receipt of aboveground residues. Another feature noted by many authors is the predominance of large mortmass in the structure of the underground plant substance. It was also noted that during the cultivation of soybean, the underground mortmass is formed mainly due to the withering away of the roots of a given culture [15]. In the cultivation of wheat and potatoes, a significant proportion of plant residues in the soil is represented by the crushed aboveground plant parts (straw, tops).

A model was developed for the formation and transformation of stocks of plant substance in the links of crop rotation based on the previous studies [14, 16] and on the basis of our data. The model takes into account the blocks of plant substance and the substance flows between them for the discrete periods of time, i.e., one can characterize the intensive parameters of the agro ecosystem functioning using this model.

The proposed model can be described with the help of the system of balance equations, these equations are developed taking into account the scientific paradigm on the substance and energy save in nature, so it is assumed that all net primary production either is accumulated in the mortmass blocks, or spent on alienation with the crop or decomposition.

$$ANP=\Delta G+J3 \qquad BNP=\Delta R+J7$$
$$J3=\Delta D+J4+J6 \qquad J5+J6+J7=\Delta Rem+J8$$
$$J4=\Delta St+J5 \qquad NNP=ANP+BNP$$

ANP is aboveground Products; BNP is underground products; NNP is pure primary production; J3 is necrosis of phytomass, transition to the aboveground mortmass; J4 is transition of the aboveground mortmass to a large underground mortmass; J5 is transition of a large underground mortmass to a small underground; J6 is transition of the aboveground mortmass to a small underground; J7 is root necrosis, J8 is decomposition; ΔG, ΔD, ΔSt, ΔR, ΔRem is the difference in reserves of the previous and subsequent accounting periods in blocks of phytomass, elevated mortmass, large underground mortmass, roots and small underground mortmass, respectively

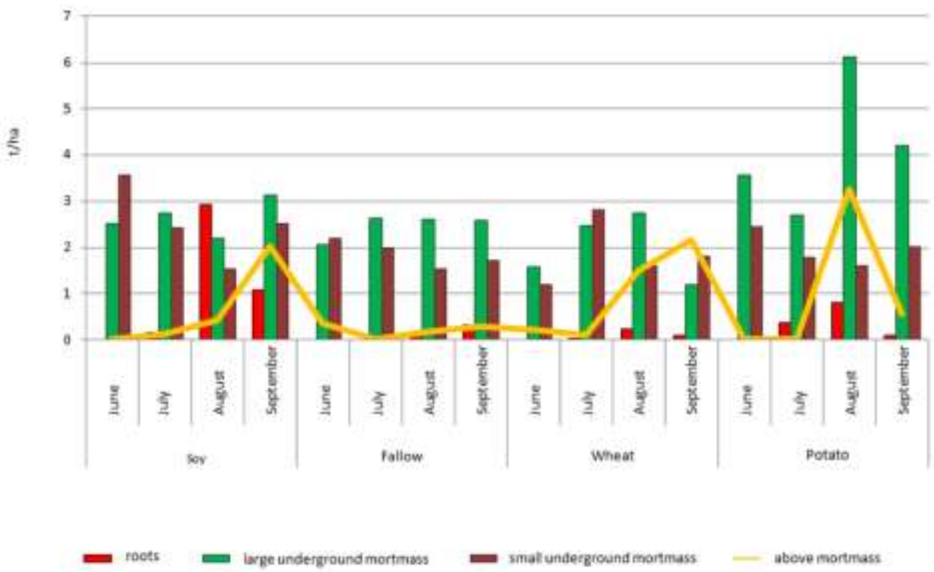


**Figure 1.** Dynamics of mortmass reserves, t ·ha$^{-1}$.

In the potatoes cultivation, the intensity of the production process, the intake and decomposition of plant substance turned out to be greatest compared to other links of crop rotation. New portions of fresh and shredded plant substance that entered the soil in early August caused a slow “seed effect” [5] and significantly increased the intensity of decomposition. The correlation coefficient in this case was 0.97. It indicates a direct positive relationship.

In the wheat and soybean cultivation, the decomposition rate of plant residues increased from the middle of July to September and reached 1.4 and 1.9 t ·ha$^{-1}$ over this period. Such a low rate of decomposition is associated with a low flow of plant residues into the soil; in addition, the residues entered the soil during extremely unfavorable periods and they were already withered and yellowed by the time they arrived. Thus, in the cultivation of wheat and soybeans, the maximum amount of residues entered the soil either during the June drought, when the hydrothermal coefficient (HTC) dropped to 0.1, or in September, when average daily temperatures dropped, and the amount of precipitation increased sharply, while HTC was 2.8. Under such extreme conditions, the biological activity of the soil decreased and the intensity of the residues was higher than the intensity of their decomposition. However, it is worth noting that when the soybean residues entered the soil, the decomposition intensity increased, the correlation relationship between these processes was direct and very close (correlation coefficient was 0.99). When wheat residues entered the soil, the decomposition intensity did not increase immediately, but with some delay, therefore, the correlation was close, but inverse (correlation coefficient was 0.81).

In addition to the amount of fresh vegetable substance and terms of its entry into the soil, the chemical structure of residues, i.e., the ratio of carbon to nitrogen (C/N), affects the intensity of the decomposition. Soybean residues have a rather narrow C/N ratio (28) and they are favorable for decomposition. However, most of them entered the soil in the second decade of September and did not have time to decompose.Wheat residues entered the soil evenly throughout the growing season, but they had a very wide C/N ratio (58). It was unfavorable for decomposition and also led to accumulation of straw, leaves, roots and other wheat residues in the soil.The tops of potatoes and weeds had an average C/N ratio (38–40), their residues still green entered the soil after grinding in the process of cultivation and desiccation. Itgreatly accelerated the processes of decomposition. In general, the nitrogen level was significantly reduced during the transition from the living organs of plants to the mortmass, and the nitrogen content in soybean residues was particularly intense.

We found that the accumulation of plant residues occurs during the cultivation of soybean using flat-cut tillage, as well as in the cultivation of wheat according to the classical technology with the obligatory sealing of crop residues analyzing the balance of plant substance in the links of crop rotation, taking into account the spring stocks of precursor residues, autumn stocks after harvest, and the intensity of receipt and decomposition of the mortmass during the growing season. In pure fallows, the plant substance was equal to its decomposition and the reserves of the mortmass did not change in the autumn compared with the spring stocks. When growing potatoes using seed technology with desiccation, grinding and scattering the potato tops on the soil surface, the stock of plant residues decreased slightly by autumn. In general, for the entire crop rotation, the stock of plant residues in the soil is positive and the accumulation of mortmass was 6.8 t $\cdot ha^{-1}$.

The main element of the crop productivity structure of potato variety Aramiswas the number of commercial tubers, which amounted up to 11.5 pieces$\cdot bush^{-1}$. It determined its high productivity. Cultivation on a clean fallow, the absence of the aboveground mortmass during flowering and tuberization, the timely use of protective equipment and the conduct of variety and phytocleaning contributed to obtaining high-quality seed products of potatoes. It was established that the defeat of tubers with common scab was 2.0%, with brown patch was1.0% according to the results of the tuberous analysis.Thus, the quality of tubers meets the requirements of the interstate standard.

The productivity of soybean depended on the number of seeds per legume, the number of beans per plant, and the mass of seeds per plant. The variety Zaryanitsa is characterized by high resistance to fusarium and peronosporosis, moderate susceptibility to bacteriosis and churciasis, surpassing the standard variety of SibNIIK 315 in resistance. During route examinations, leaf-stem diseases were not found on soybean crops, due to dry conditions in the beginning and middle of the growing season. The weed component is represented by Chenopodium album and by Chenopodiumaristatum, Amaranthusblitoides and amarsnt-Amaranthusretroflexus, Cannabis ruderalis, Echinochro syrup, Setariaglauca, viridis. The use of herbicide led to the destruction of a significant part of the weeds (90%), however, the low efficacy of the drug was established for Chenopodium album.

The wheat productivity in the study year was largely dependent on the weight of 1000 seeds and the number of grains per ear. Since the conditions for the beginning of the growing season were arid, the productive tillage had a slight effect on wheat productivity. The mass of 1000 seeds was 38 g., the average number of grains per ear was 30 pieces. An annual phytoexamination of seeds shows that in the Krasnoyarsk Territory a high prevalence of seeds is observed in diseases, the most common and harmful of which are root rot. Lack of moisture and placement of soybeans contributed to reducing the spread of root and leafy diseases in wheat crops.However, rainfall character of the second half of July-August affected the distribution of wheat the Septoria leaf spot in crops. According to the results of field surveys, it was established that the spread of Septoria leaf spot is 61%, the spread index is 18%, that generally did not affect the productivity and quality of wheat seeds.The weed vegetation in wheat is represented by the following species: Fagópyrumesculéntum L., Cannabis ruderalis L., Panicummiliaceumsubsp.ruderale L, Echinochloacrus-galli L., Setariaglauca L. Beauv. Amarantusretroflexus L., Amaranthusblitoides, Linariavulgaris Mill, Cirsiumarvense L., Gal iiuririus, Cirsiumarvense L., Gal-iurimanse L., Cirsiumarvense L., Galiuririus M. The use of protective equipment on wheat led to the destruction of 86% of weeds.

## 5. Conclusion

In the of soy cultivation, a significant contribution to the formation of the mortmass is made by its roots, in the cultivation of wheat it is made by the aboveground parts of plants (straw). In the crop-rotational fallow-potato link the majority of the mortmass is done by the residues of the potato tops. The intensity of production and decomposition of plant substance decreases in the series: potato-soy-wheat-fallow. The intensity of decomposition of plant residues is directly related to the intensity of their release into the mortmass. The balance of plant substance in the soy-wheat link is positive, and in the link potato-pair it is negative. In general, for this crop rotation, the accumulation of plant residues in the soil was 6.8 t $\cdot ha^{-1}$. The applied soil-protection agro technology (scattering and plowing up of stubble, minimizing the main processing for grain crops) against the background of the protective equipment did not lead to an increase in pathogenicity of pathogens and deterioration of the quality of seed products.

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