The productivity of five-field crop rotations and their influence on humus content in southern Russia

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Abstract. It is proved that the productivity of all crops is higher when growing them in crop rotation, and not permanently. According to a significant number of scientists, crop rotation is the only agricultural element in the system of agriculture, the action of which is based on natural foundations. Proper crop rotation, with an appropriate set of crops, helps stabilize the presence of humus in the soil. If the structure contains 20-25% of legumes, the amount of humus in the soil will not only stabilize but will increase. The purpose of these studies is to study the productivity of short-rotational crop rotations and to establish their effect on soil fertility, in particular on the presence of humus after two rotations. The experimental component of the study consists of three repetitions with a randomized placement of crop rotations. Soil cultivation, norms and terms of fertilizer application, sowing, and crop care are generally accepted. All studied crop rotations are recommended to farm enterprises, depending on the specialization of the farm. Crop rotations with clean steam should be in farms engaged in the production of a marketable grain of valuable and robust wheat and seed production. Crop rotations with busy couples should be in enterprises that specialize in raising dairy cattle. Crop rotation is an economically viable, real way to increase the productivity of each crop and the entire crop rotation as a whole, as well as restoration of soil fertility. Compliance with crop rotation stabilizes or increases the presence of humus from 1.70 to 2% in a layer of 0-40 cm.

1. Introduction
Farming in our country is an entirely new type of enterprise. Developing and studying short-rotation crop rotation, we focused on farms with a small amount of arable land, while studying a significant range of issues. In this paper, we dwell on equivalent and significant issues, such as crop rotation productivity and their impact on the conservation of soil fertility. At the beginning of their activity, farmers were mainly interested in the yield of crops and the economy. However, very soon, many concluded that the conservation and stabilization of soil fertility are no less important [1].

Humus, in its essence, is the reversed kinetic energy of sunlight. Caring for its preservation, simple, and even better-expanded reproduction, is not only the concern of farmers, but it is also the care and support of each and everyone, and, of course, the state. A healthy, in all respects, soil condition should be protected by law [2–5].

All agrarians, both practitioners and scientists, are interested not only in the presence of humus in the soil but in its quantitative and qualitative changes. It is known for sure that there is close
interdependence between the quantity, quality of humus in the soil and the productivity of agricultural plants [6–8].

Humus has created over hundreds of thousands of years as a result of complex biological, physical and chemical processes in the soil, depending on environmental conditions. And then a reasonable person invaded this process. The natural process of creating humus has become more complicated [9–11].

The main goal of the farmer has always been to obtain the maximum yield at the lowest cost [12, 13]. History knows many cases when human intervention ended in the loss of soil fertility, simply desertification [14–16].

Today, the growth rate of humus is not comparable to its losses [17, 18]. In the immediate vicinity of the stationary experiment site (the exact distance on the map is 1.06 km), there is a reserved steppe – it is a nature reserve of high priority (Klepininsky steppe), where it was possible to preserve the real steppe with rich steppe flora and fauna, as well as natural soil fertility. A detailed study of the soil condition of the protected steppe was carried out by teachers and students of the faculty of soil science of Moscow State University in 1952. According to them, the presence of humus in the 0-30cm layer was 3.34%, repeated studies - 2011, 2019, conducted by the Institute's laboratory, confirm the humus composition at almost the same level, i.e. 3.64, 3.46%, respectively. When laying experiments on the field of the hospital, the amount of humus was only 1.79%, which is 1.7–1.8 times less than in the virgin area [19, 20].

In our stationary experiment on the study of short-rotation crop rotations, we determined the presence of humus during the laying of the experiment and at the end of the experiment for single crop rotations. It has been proved that the effect of scientifically based crop rotation is not only an increase in the productivity of all crops of fruit rotation but also stabilization of soil fertility, in particular, the reproduction of the presence of humus. Thus, our research aimed to study the productivity of short-rotation crop rotations in order to establish their effect on soil fertility, in particular for the presence of humus after two rotations.

2. Research methods and conditions

The climate of the steppe Crimea is arid continental, with mild winters and hot summers. Snow cover is short, unstable. Spring and autumn are unpredictable: in recent decades, spring comes in February, April-May is characterized by high-temperature conditions. The temperature drop begins in October, judging by the temperature of the air and soil, in December, the negative air temperature begins. The average annual air temperature during the study ranged from 11.1 to 11.9 °C, with an average annual temperature of 10.4 °C. Strong winds occur at any time of the year, causing wind erosion of the soil of varying intensity. They are especially dangerous in the early spring, when significant areas of arable land, chilly, are not covered by vegetation, and winter grains are not sufficiently strengthened. There are dry winds, in some years the number of days with hot winds reaches 59-70. Annual precipitation ranges from 280 to 560 mm, with an average annual rate of 428 mm. Periods without economically useful precipitation during plant vegetation sometimes reach three to four or more months. Global climate changes on the planet influenced weather conditions, including that of our peninsula [21].

The soil of the experimental bookmark is the southern carbonate, low-humus carbonate, low loamy clay on diluvial loams, underlain by eluvium of limestone. The thickness of the humus horizon (A) is 40-50 cm, the total humus layer is (A + B) within 60-70 cm. The humus amount (according to Tyurin) varies from 2.0 to 2.3%, mobile phosphorus (according to Machigin) ranges from 3.0 to 3.9 and exchange potassium is contained in a volume of 30–40 mg per 100 g of soil [22].

The stationary experience was laid in 2004-2005 on the experimental field in the village of Klepinino, the introduction and technology department in field husbandry and livestock farming at the Research Institute of Agriculture. It consisted of four five-field crops and crop rotation: Crop rotation I. 1. Clean steam; 2. Winter wheat; 3. Mustard; 4. Winter wheat; 5. 0.5 Spring barley + 0.5 sunflower. Crop rotation II. 1. The steam is clean; 2. Winter wheat; 3. legumes; 4. Winter wheat; 5. 0.5 spring barley + 0.5 sunflower. Crop rotation III. 1. The steam is clean; 2. Winter wheat; 3. legumes; 4. Winter
wheat; 5. Spring barley. Crop rotation IV. 1. The steam is clean; 2. Winter wheat; 3. Mustard; 4. Winter wheat; 5. Sunflower.

The experience was laid out in triplicate with a randomized placement of crop rotation. Soil cultivation, norms and terms of fertilizer application, sowing, crop care are generally accepted [23]. Ploughing to a depth of 20-22 cm was carried out once per rotation in steam fields. For winter crops, according to non-steam predecessors, surface treatment of soil with a depth of 6-8 cm was used, under shallow spring tillage with a depth of 12-14 cm. Organic fertilizers (cattle manure) were applied in steam fields with a dose of 25-30 t / ha; mineral fertilizers were applied necessary tillage, recommended doses for each specific crop [24]. Mathematical processing was carried out according to B.A. Dospehov [25].

3. Research results

Let us dwell on the leading indicators obtained in the study of short-rotation crop rotations after two rotations, namely, their productivity depending on the set of crops and the change in soil fertility according to one of the main components, i.e. humus. The classic crop rotation with the title field of pure steam and 20% mustard was taken as control (in the first rotation it was Sarepta mustard, in the second rotation it was white mustard).

In the second and third crop rotations, instead of mustard, legumes were included (in the first rotation, chickpeas, in the second rotation, sowing peas). Mustard in our crop rotation is acceptable as a drought-tolerant crop, and legumes are refreshing in symbiosis with nitrogen-fixing nodule bacteria. Thanks to the biological fixation of air nitrogen, leguminous crops significantly affect soil fertility.

The crop yield, on average, for two rotations, for a complete assessment of crop rotation was converted to grain, feed units. At the same time, the presence of digestible protein per hectare of crop rotation area was calculated. The data are presented in Table 1.

The yield of cereals, feed units and digestible protein crop rotations with clean steam No. 1 and No. 2 are almost at the same level. In crop rotation No. 3 with steam occupied by spring legumes (oats + peas), the number of legumes and the final field of spring barley by 20%, the number of grain units significantly increased by 0.32t / ha, feed units by 0.95t / ha and digestible protein by 0.10 t / ha. Crop rotation No. 4 with steam occupied by winter legumes (triticale + Vika pano kaya) with fields of mustard and sunflower has the above indicators also at a rather high level: the excess is 0.52 t / ha, 0.71 and 0.07 t / ha, respectively.

Consider crop rotation as a factor in the reproduction of soil fertility. The presence of humus was determined under winter wheat crops in each of the five-field crop rotations at the end of the experiment. The data on the humus content in crop rotation are presented in Table 2.

It is not easy to talk about an increase in humus after ten years. It can be stated that the following results are observed. In the number 1 crop rotation taken for control, its quantity remained almost at the same level as the initial indicators, in the three subsequent crop rotations, its growth trend was observed.

We believe that in the rotation No. 2, the increase in humus occurred in a layer of 0-40 cm due to the presence of leguminous crops such as chickpeas in the first rotation and peas in the second by 0.28%. In rotations 3 and 4, the amount of humus increased when replacing pure steam with occupied winter and summer grain legumes by 0.53 and 0.59%. The growth trend of humus was preserved in subsequent horizons: in the 0-40 cm layer, we have 1.98 and 2.00%, compared with 1.7% in control.
| The culture | Crop rotation number | Productivity, t / ha | The output of grain units, t / ha | The output of feed units, t / ha | Digestible protein, t / ha |
|-------------|----------------------|----------------------|----------------------------------|---------------------------------|--------------------------|
| Clean steam | 1                    | -                    | -                                | -                               | -                        |
| Winter wheat|                      | 3.84                 | 3.84                             | 4.55                            | 0.50                     |
| Mustard     |                      | 1.13                 | 2.83                             | 1.98                            | 0.19                     |
| Winter wheat|                      | 3.31                 | 3.31                             | 3.91                            | 0.40                     |
| 0.5 sunflower + 0.5 spring barley | 1 | 2.24                 | 2.45                             | 2.62                            | 0.22                     |
| On 1 ha of crop rotation | | 2.48                 | 2.61                             | 0.26                            |                          |
| Clean steam | 2                    | -                    | -                                | -                               | -                        |
| Winter wheat|                      | 4.07                 | 4.07                             | 4.84                            | 0.50                     |
| Legumes     |                      | 1.23                 | 2.23                             | 1.44                            | 0.21                     |
| Winter wheat|                      | 3.30                 | 3.30                             | 3.90                            | 0.40                     |
| 0.5 spring barley + 0.5 sunflower | 2 | 2.86                 | 2.64                             | 2.70                            | 0.23                     |
| On 1 ha of crop rotation | | 2.44                 | 2.57                             | 0.27                            |                          |
| Busy steam (spring s / b) | 3 | 23.83                | 2.87                             | 4.73                            | 0.59                     |
| Winter wheat|                      | 3.62                 | 3.62                             | 4.19                            | 0.43                     |
| Legumes     |                      | 1.20                 | 1.73                             | 1.44                            | 0.22                     |
| Winter barley|                     | 3.78                 | 3.38                             | 4.27                            | 0.34                     |
| Spring barley|                    | 2.76                 | 2.49                             | 3.11                            | 0.24                     |
| On 1 ha of crop rotation | | 2.80                 | 3.56                             | 0.36                            |                          |
| Busy steam (winter s / b) | 4 | 21.96                | 2.64                             | 4.38                            | 0.50                     |
| Winter wheat|                      | 3.40                 | 3.40                             | 4.06                            | 0.41                     |
| Mustard     |                      | 1.10                 | 2.75                             | 1.92                            | 0.19                     |
| Winter barley|                     | 3.69                 | 3.30                             | 4.17                            | 0.33                     |
| Sunflower   |                      | 1.42                 | 2.87                             | 2.11                            | 0.19                     |
| On 1 ha of crop rotation | | 3.00                 | 3.32                             | 0.33                            |                          |
| LSD$_{05}$, t / ha | | 0.19                 | 0.26                             | 0.03                            |                          |
Table 2. Humus content as a function of crop rotation at the end of two rotations

| Horizons, cm | Humus, % ± | ± |
|--------------|------------|---|
| **Crop rotation 1. Field of winter wheat in pure steam (control)** | | |
| 0-10 | 1.86 | |
| 10-20 | 1.82 | |
| 20-30 | 1.75 | |
| 30-40 | 1.35 | |
| 0-40 | 1.70 | |
| **Crop rotation 2. Field of winter wheat in pure steam** | | |
| 0-10 | 2.28 +0.42 | |
| 10-20 | 2.05 +0.23 | |
| 20-30 | 1.95 +0.20 | |
| 30-40 | 1.62 +0.27 | |
| 0-40 | 1.98 +0.28 | |
| **Crop rotation 3. Field of winter wheat for occupied steam** | | |
| 0-10 | 2.45 +0.59 | |
| 10-20 | 2.10 +0.28 | |
| 20-30 | 1.72 -0.03 | |
| 30-40 | 1.64 +0.29 | |
| 0-40 | 1.98 +0.28 | |
| **Crop rotation 4. Field of winter wheat for occupied steam** | | |
| 0-10 | 2.39 +0.53 | |
| 10-20 | 2.00 +0.18 | |
| 20-30 | 1.95 +0.20 | |
| 30-40 | 1.64 +0.29 | |
| 0-40 | 2.00 +0.30 | |

4. Conclusion
All studied crop rotations are recommended to farm enterprises, depending on the specialization of the economy. Crop rotations with clean steam should be in farms engaged in the production of commercial grain and high-value wheat and seed production. Crop rotations with busy couples should be in enterprises that specialize in raising dairy cattle. Crop rotation is an economically viable, real way to increase the productivity of each crop and the entire crop rotation as a whole, as well as restoration of soil fertility. Compliance with crop rotation stabilizes or increases the presence of humus from 1.70 to 2% in a layer of 0-40 cm.

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