Effect of resource-saving systems of basic tillage on the efficiency of crop rotation link and dynamics of organic matter in ordinary black soil

V S Polous¹, S N Osaulenko², L O Prokopova³, S P Stepanov⁴ and A I Belyy³

¹ Agro-industrial complex Kuban Agro, Bryukhovetsky district, Krasnodar Krai, Russia
² Stavropol State Agrarian University, Stavropol, Russia
³ Kuban State Agrarian University, Krasnodar, Russia
⁴ Krasnodar State Agrarian University, Krasnodar, Russia

E-mail: s.polous@list.ru

Abstract. In recent years, periodic droughts in various regions set limits to the production of field crops, negatively affect the economy of land users and the condition of soil. In this regard, the relevance of research on the development of options for energy-saving technologies that contribute to the preservation of productive moisture, yield of field crops and the return on production costs and maintaining soil fertility is increasing. The research on this issue had been carried out in the central zone of the Krasnodar Territory in 2013-2018. The researchers studied the effect of 22-24cm plowing (the control); surface 6-8 cm and zero direct sowing technology for oil flax, winter wheat, stubble sowing without irrigation and sowing peas, as well as their combined effect on the economic efficiency of production and the dynamics of organic matter in ordinary black soil. It was found that the cultivation of 4 crops for 3 agricultural years for basic surface tillage exceeded the control for the conditional net income and the formation of organic matter - humus over its consumption. The technology of direct sowing of crops provides a conditional net profit and dominates over moldboard plowing and even surface tillage in terms of the accumulation of organic matter in the soil. The studied combination of crops, with different biological characteristics, and energy-saving technologies for their cultivation allows maintaining profitable agricultural production and soil organic matter in the present period and in the future.

1. Introduction

In recent years, profitable agricultural production is possible in case when crop rotations or their links are adapted to soil and climatic conditions, methods and techniques of basic tillage, as well as modern technical means, achievements of breeding and new types of mineral fertilizers and pesticides. Over time, the underestimation and simplification of this system contribute to a number of problems. Thus, the annual decrease in soil fertility has already been noted [5, 7, 15, 17], due to their intensified compaction, increased acidity [1, 3]; destruction of structure [8], biological activity [2, 6, 10, 12, 14, 16], and climate change [9], which sometimes does not economically justify significant material investments in the cultivation of field crops [11, 13].

In order to obtain new information on the stated problem, the research was carried out in the central zone of the Krasnodar Krai for the first time. Scientific publications and production data on the
efficiency of cultivation of individual crops differ significantly. In general, there were no such information on the grain-row link of the crop rotation, with the sowing of a stubble crop on dry land with various methods and techniques of the main processing of ordinary black soil. In the present and in the future, resource conservation, the reduction of production and labor costs, as well as maintenance of ecological balance will remain relevant for farmers in the south and other regions of Russia.

2. Materials and methods

The research had been carried out in 2013-2018 in a stationary crop rotation located in the eastern part of the central zone of the Krasnodar Krai.

The average annual air temperature in the region was + 12.1°C. Annual precipitation was 614 mm. The frost-free period lasted up to 235 days. The sum of temperatures above 5°C was 2990-3000 °C. The soils were ordinary black soil, super deep and medium loamy. The humus content in the arable layer was 3.8%.

In the experiments, the crop rotation links had the following alternation in time: oil flax-2014, 2015, 2016; winter wheat and stubble crops - 2015, 2016, 2017; sowing peas-2016, 2017, 2018.

The crops were cultivated by 22-24 cm plowing (control); surface 6-8 cm and zero direct sowing technology. The fertilization and maintenance system was common for the central zone. In the experiments, the yield, humus balance, economic efficiency and mathematical data processing were determined according to existing methods.

3. Results

According to weather conditions, the options for basic tillage and other factors, the crop yield of the crop rotation link was formed (Table 1).

| Crop                  | Plowing | Surface | Direct sowing | LSD 0.5 |
|-----------------------|---------|---------|---------------|---------|
| Oil flax              | 1.84    | 1.75    | 1.70          | 0.08    |
| Winter wheat          | 6.23    | 6.48    | 6.05          | 0.11    |
| Stubble crop          | 0.49    | 0.50    | 0.51          | 0.05    |
| Sowing peas           | 3.79    | 3.71    | 3.62          | 0.10    |

The analysis of the presented data indicates an important role of basic tillage in the formation of the yield of the studied crops. Oil flax provided a higher threshing rate of 1.84 t/ha according to the option of the experiment with moldboard plowing and exceeded the other options by 5% and 8%. The winter wheat yield of 6.48 t/ha significantly exceeded by surface tillage: control by 0.25 t/ha and zero tillage by 0.43 t/ha. The yield of millet grain in the stubble sowing did not have significant differences in the aftereffect of treatments and amounted to 0.49-0.51 t / ha. Sowing peas provided a similar yield in plowing and surface tillage - 3.79-3.71 t/ha, but with the technology with direct sowing it was significantly lower than 3.62 t/ha. The data on the production costs and the cost of the grown products allowed calculating the conditional net income and profitability of the cultivation of crops by various methods and methods of basic tillage (Table 2).

The cost of gross production for the option with plowing and only surface tillage for all crops of the crop rotation link was close to 157 thousand rubles/ha. However, lower production costs were formed on plots with resource-saving tillage - 92.7-92.1 thousand rubles/ha, which provided a conditional net income of 64.1 thousand rubles/ha, or 5% higher than on control and 9% option with direct sowing technology.

In a market economy, the important indicator of the economic efficiency of methods and techniques for basic tillage and other technological operations is the consumption of fuel, labor and costs (Table 3).
### Table 2. Economic efficiency of crop cultivation in the crop rotation link with various methods and techniques of basic tillage

| Crops         | Yield, t/ha | Gross product value, rub/ha | Production costs, rub/ha | Cost price, rub / c | Conditional net income, rub / ha |
|---------------|-------------|-----------------------------|--------------------------|---------------------|----------------------------------|
| Plowing and surface tillage for millet |             |                             |                          |                     |                                  |
| linen         | 1.84        | 42320                       | 23112                    | 1256                | 19208                            |
| wheat         | 6.23        | 56070                       | 30664                    | 492                 | 25406                            |
| millet        | 0.49/1.74   | 14760                       | 10801                    | -                   | 3959                             |
| peas          | 4.01        | 44110                       | 31184                    | 778                 | 12926                            |
| total for option |           | 157260                     | 95761                    | -                   | 61499                            |
| Surface tillage for all crops |         |                             |                          |                     |                                  |
| linen         | 1.75        | 40250                       | 22014                    | 1258                | 18236                            |
| wheat         | 6.48        | 58320                       | 29569                    | 456                 | 28751                            |
| millet        | 0.50/1.78   | 15120                       | 11750                    | -                   | 3370                             |
| peas          | 3.92        | 43120                       | 29380                    | 748                 | 13740                            |
| total for option |           | 156810                     | 92713                    | -                   | 64097                            |
| Direct sowing technology and surface tillage for millet |             |                             |                          |                     |                                  |
| linen         | 1.62        | 37260                       | 22902                    | 1414                | 14358                            |
| wheat         | 6.05        | 54450                       | 30445                    | 503                 | 24005                            |
| millet        | 0.51/1.73   | 16590                       | 10340                    | -                   | 6250                             |
| peas          | 3.86        | 42460                       | 28435                    | 737                 | 14025                            |
| total for option |           | 150760                     | 92122                    | -                   | 58638                            |

*millet grain / hay yields

### Table 3. Fuel consumption and labor costs for various methods and techniques of basic tillage for crops of crop rotation link (average value for 2013-2018)

| Basic tillage          | Total | Including | Basic treatment | Autumn herbicides |
|------------------------|-------|-----------|-----------------|-------------------|
|                        | fuel, kg / ha | person hour / ha | fuel, kg / ha | person hour / ha |
| plowing                | 221.7 | 19.11     | 113.3          | 3.98              | 2.2 | 0.20 |
| surface                | 154.9 | 17.66     | 46.1           | 2.12              | 6.6 | 0.60 |
| direct sowing          | 127.0 | 16.99     | 12.3           | 0.60              | 8.8 | 0.80 |

In the experiments, the most significant fuel consumption was accumulated in the summer-autumn period during technological operations.

The fuel consumption and labor costs amounted to 8.8 kg / ha and 0.80 person hour / ha for the crop rotation link on plots without mechanical treatment during weed destruction in the summer-autumn period, respectively, exceeding the control many times. At the same time, this option did not consume diesel fuel (except the costs of basic tillage for millet). The total fuel consumption here was 127.0 kg / ha with labor costs of 16.99 person h / ha, which was 11% lower than the control and 4% lower than the surface tillage.

The total fuel consumption exceeded the option with direct sowing by 18%, and in terms of labor costs by 0.67 person hour / ha in the option of the experiment with the surface tillage for all crops of the crop rotation.

The crops of the crop rotation link annually provided the soil with stubble-root residues (SRR), which underwent mineralization and subsequent transformation into humus. At the same time, the methods and techniques for the basic tillage of ordinary black soil are important (Table 4).
Table 4. Mineralization, accumulation and balance of organic matter - humus in the link of crop rotation with different methods and techniques of basic tillage, t / ha. Average value for 2013-2018

| Basic tillage | Mineralization of humus in soil of pko of humus | Accumulation of humus | Balance of humus |
|---------------|-----------------------------------------------|----------------------|-----------------|
| plowing       | 3.14                                          | 31.14                | 4.63            | +1.49           |
| surface       | 3.20                                          | 31.55                | 5.04            | +1.84           |
| Direct sowing | 2.95                                          | 30.25                | 5.14            | +2.19           |

*During the calculation of humus balance, the recommendations were used [4]

The use of fertilizers and biological characteristics of crops in the crop rotation link and millet contributed to the decrease in soil humus mineralization to 3.0-3.2 t/ha. The amount (PKO) was 31.55 t/ha for surface tillage. The accumulation of humus depended on the depth of basic tillage. The highest values of this indicator were provided by the technology of direct sowing of crops - 5.14t/ha, which exceeded the control by 10%. In the plots without mechanical tillage or only with surface loosening of the soil, favorable conditions also developed for the accumulation of organic matter-humus and amounted to 2.19 t/ha and 1.84 t/ha, respectively, which was 1.5-1.2 times more than in control.

The formation of a positive balance of organic matter-humus was provided by: winter wheat - 49-50%, peas - 32-35%, millet in crop sowing 20-24%.

4. Discussion

In the present and future period effective agricultural production should be carried out taking into account the market demand for the crops of crop rotation link and ensure their high cost and conditional net income. Biological characteristics of cultivated crops should provide the soil with the maximum amount of crop and root residues. Reasonable use of energy-saving tillage, including direct sowing, can create the conditions to preserve the soil fertility of ordinary black soil and to reduce the production and labor costs.

5. Conclusion

Oil flax, winter wheat, millet stubble sowing on dry land and sowing peas provided stable indicators of conditional net income during their growth using resource-saving systems of basic tillage. During the rotation of the grain-tilled link of the crop rotation, crop and root residues also entered the soil and contributed to the excess of the formation of organic matter - humus over its consumption.

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