The advanced rational process flowsheets for cropping spiked cereals

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Abstract. The highly-effective process flowsheets for cropping spiked cereals have been proposed, representing the operation sequence and cycle performed, interconnected with the effective operations technical support, supported by highly productive technical-economic indicators. Cultivation sheets are based on many years of research in machine technologies for grain crop cultivation, a scientifically grounded farming system, working knowledge of serial equipment design features produced by the machine-building industry in Russia and the Republic of Belarus, as well as the climatic conditions of the Krasnodar Krai. The proposed process flowsheets consider a new scientific direction for the creation of multifunctional machine units that perform several types of farming operations in one pass through the field, due to which high efficiency is ensured. A labor productivity doubles in field husbandry, a metal consumption in production process performance is reduced 1.3 times, an energy consumption – 1.6 times compared to the basic process flowsheets for grain farming, contributing to the growth of the product competitiveness.

1. Introduction
Successful grain production depends on the technologies for cropping spiked cereals\([1, 2]\) and the innovative equipment in use\([3]\). Krasnodar Krai is the main grain supplier to the granary of the country. The average annual grain production of spiked cereals in the region over the past five years amounted to 9.4 mln tons from an area of 1.9 million hectares\([4]\). Favorable natural and climatic conditions in the region and adherence to cultivation technologies make it possible to obtain high grain yields with a good profitability. However, as noted in some scientific works\([5-7]\), the in-use technologies for grain crop cultivation are already outdated and fail to provide the required rate of increase in gross grain harvest and its quality. The analysis of the scientifically grounded farming system for the Krasnodar Krai\([8]\) and the actual technologies for grain crop cultivation allowed one to conclude that not all of the farming system requirements are met to obtain high yields. The applied technologies are labor-intensive, energy-intensive, they are 4 ... 5 times inferior to foreign ones in these indicators\([9]\), are related to a great number of machine passes through the field, to soil compaction and its structure destruction, the combination of technological operations is poorly used in performing agricultural field works. The use of diskers in soil cultivation increases the number of dust particles and negatively affects soil fertility. In practice, the useful recommendations of the farming system for the rational distribution of certain types of solid mineral fertilizers in the soil layers are not applied. For example, phosphorus fertilizers should be deposited during the basic tillage to the bottom...
of the furrow, and nitrogen and potassium fertilizers are evenly distributed throughout the arable layer [8]. Non-fulfillment of such requirements in practice reduces the effect of their application. In practice, the press work of soil and grain crops is inefficient. The recommended star-wheeled rollers leave unpressed up to 60...70 percent of the cultivated arable land [10]. As a result, optimal soil density in the sowing layer and moisture conservation are not ensured, especially in arid conditions.

The purpose of the article is to develop advanced rational process flowsheets for cropping spiked cereals, ensuring their efficiency increase. The proposed advanced cultivation process flowsheets are based on domestic series-produced machines, except for the Canadian trailed grain harvesters MH130 and MH230, with their completing into multifunctional machine units [3].

2. Materials and methods
The proposed technological systems for grain crop cultivation have been taken as the object of research. The main research method is the analysis and synthesis of technological processes for the grain crops cultivation according to the basic and the proposed variants of the technology. To determine the effectiveness of rational process cultivation flowsheets, the following specific technical-economic indicators for the technological operations performed have been taken: farm labor input, man-h./ha; metal consumption, kg/ha; energy intensity, MJ/ha. The advantage of these indicators values shows the preference of the flowsheets proposed. The changeover to rational process cultivation flowsheets will ensure an increase in the competitiveness of the produced grain and its quality.

3. The study of the structure of the modified lead-tin-base bronze
The advantages and high efficiency of the developed process flowsheets for grain crop cultivation are explained by the layout of the proposed multifunctional machine-tractor units for the technology implementation. Usually, a new machine is designed for an already proven crop cultivation technology. In our case, some proposed multifunctional units fundamentally change the process crop cultivation flowsheet, the list, and the sequence of farm operations. In developing process flowsheets, the strict fulfillment of the farming system requirements [8], the parameters and operating modes of machines as part of multifunctional machine units for combining technological operations in one pass through the field, have been considered. Let us consider the basic and the proposed process flowsheets for grain crop cultivation. According to the current farming system in our region [8], spiked cereals are cropped after perennial grasses, tilled crops, as well as after spiked cereal and grain legume crops. But each type of these forecrops should have its technological system. This has already been proven by numerous scientific studies, confirmed by industrial practice.

The set rules in our region are such that when in cropping spiked cereals, after perennial grasses and spiked cereal crops, the flat plowing is required, as well as the surface tillage with plowing outfits is required after tilled forecrops. Substitution of moldboard plowing after spiked cereals by the surface tillage led to an increase in weediness, diseases, an increase in the number of farm pests in the fields, and, as a consequence, to a sharp decrease in grain yield.

Tables 1 and 2 show the proposed and the basic process flowsheets for cropping spiked cereals after perennial grasses, which is the best forecrop.

The obvious advantage of cropping spiked cereals after perennial grasses according to the proposed flowsheet is twice preferable for farm labor input, metal consumption, and energy intensity – 1.8 times. The new complex of machines has the SZ-3.6 seeding-machine modernized into a multi-functional unit for sowing, rolling, and applying basic fertilizer.
Table 1. The proposed process flowsheet for cropping spiked cereals after perennial grasses

| No. | Farm operation name title | MTA consist | Technical-economic indicators |
|-----|---------------------------|-------------|-------------------------------|
|     |                           |             | farm labor input, man-h./ha   | metal consumption, kg/ha | energy intensity, MJ/ha |
| 1   | Sod layer cutting of 8…10 cm | U-450+OPT-5 | 0.25                          | 10.14                       | 198.9                     |
| 2   | Flat moldboard plowing of 20…22 cm | U-450+PShKO-(6+2)+AIR | 0.20                          | 5.85                        | 317.0                     |
| 3   | Harrowing                  | U-450+BZP-27 | 0.07                          | 1.53                        | 53.0                      |
| 4   | Full cultivation (3…4 fold) of 4…6 cm | U-450+KBM-14,4+KVS | 0.11                          | 9.63                        | 85.6                      |
| 5   | Seeds and mineral fertilizers supplying to the units | Belarus 1523 +Reboke | 0.12                          | 3.4                         | 57.3                      |
| 6   | Seeding grains with basic fertilization and rolling | Belarus 892+ MPA-3,6 | 0.33                          | 8.56                        | 11.2                      |
|     | Total                      |             | 1.08                          | 39.1                        | 723.0                     |

Table 2. The basic process flowsheet for cropping spiked cereals after perennial grasses

| No. | Farm operation name title | MTA consist | Technical-economic indicators |
|-----|---------------------------|-------------|-------------------------------|
|     |                           |             | farm labor input, man-h./ha   | metal consumption, kg/ha | energy intensity, MJ/ha |
| 1   | Two-fold disking of crop remains of 8…10 cm | K-744+BDT-7 | 0.52                          | 17.9                        | 408                      |
| 2   | Mineral fertilization     | MTZ-80+MVU-6 | 0.22                          | 4.2                         | 47.2                     |
| 3   | Plowing of 20…22 cm      | K-744+1HY-8-40 | 0.18                          | 11.0                        | 378.9                   |
| 4   | Soil layer stripping     | K-744+ BDT-7 | 0.26                          | 8.7                         | 204.0                   |
| 5   | Full cultivation (3…4 fold) of 4…6 cm | K-744+KShU-9 | 0.48                          | 10.8                        | 85.6                    |
| 6   | Seeds and mineral fertilizers supplying to the units | MTZ -80+ 2PTS-4 | 0.16                          | 1.0                         | 57.3                    |
| 7   | Seeding spiked cereals of 4…6 cm | T-150K+ 3SZ-3,6 | 1.0                           | 16.3                        | 92.1                    |
| 8   | Seed rolling             | T-150K+3KSh-6A | 0.13                          | 8.15                        | 43.1                    |
|     | Total                    |             | 2.7                           | 78.1                        | 1316.2                  |

The second type of cereal forecrops – tilled crops – includes corn, sunflower, and sugar beet. It also provides high efficiency in all technical-economic indicators (Tables 3 and 4). Farm labor input in the process flowsheet proposed in comparison with the basic one is reduced 2, 3 times, metal consumption – 1,7 times, energy intensity – 1,5 times. The AKP-8 modernized machines in the proposed process flowsheet make it possible to apply the basic fertilizer simultaneously with soil cultivation, abolishing the series-produced MVU-6 fertilizer spreader (Table 4). 3KKSh-6 rollers, which are non-compliant in meeting agricultural requirements for the soil rolling quality, have been replaced by spiral-screw KShV-15 machines (Table 3).
### Table 3. The proposed process flowsheet for cropping spiked cereals after tilled forecrops

| No. | Farm operation name title | MTA consist of | Technical-economic indicators |
|-----|---------------------------|----------------|--------------------------------|
|     |                           |                | farm labor input, man-h./ha | metal consumption, kg/ha | energy intensity, MJ/ha |
| 1   | Mineral fertilizer loading, 0.5 t/ha | Manitou | 0.03 | 0.04 | 3.1 |
| 2   | Transporting fertilizers to the units, 0.5 t/ha | Belarus 1523 + Reboke | 0.12 | 3.4 | 57.3 |
| 3   | Soil cultivation by multi-functional unit with basic fertilization | U-450+AKP-8 | 0.20 | 6.86 | 156.0 |
| 4   | Presowing cultivation of 4…6 cm | U-450+KBM-14,4 | 0.11 | 9.63 | 51.8 |
| 5   | Loading of seeds and mineral fertilizers and their transport to the units | Belarus 1523 + Reboke | 0.12 | 3.4 | 57.3 |
| 6   | Seeding spiked cereals with rolling | Belarus 892+ SZ-3,6+KShV-5,4 | 0.32 | 5.85 | 76.9 |
|     | Total                      |                | 0.90 | 29.16 | 402.4 |

### Table 4. The basic process flowsheet for cropping spiked cereals after tilled forecrops

| No. | Farm operation name title | MTA consist of | Technical-economic indicators |
|-----|---------------------------|----------------|--------------------------------|
|     |                           |                | farm labor input, man-h./ha | metal consumption, kg/ha | energy intensity, MJ/ha |
| 1   | Mineral fertilizer loading 0.5 t/ha | MTZ-80+ PKU-0,5 | 0.09 | 0.83 | 19.1 |
| 2   | Mineral fertilization | MTZ-80+MVU-6 | 0.22 | 4.2 | 47.2 |
| 3   | Soil cultivation by tillage rig | K-744+AKP-5 | 0.31 | 8.74 | 248.6 |
| 4   | Presowing cultivation | K-744+KShU-9 | 0.16 | 10.8 | 85.6 |
| 5   | Transporting seeds and fertilizers to the units | MTZ-80+ 2PTS-4 | 0.12 | 1.0 | 57.3 |
| 6   | Seeding spiked cereals | T-150K+SZ-3,6+SP-11 | 1.0 | 16.3 | 92.1 |
| 7   | Seed rolling | T-150K+3KKShV-6A | 0.13 | 8.15 | 43.1 |
|     | Total |                | 2.03 | 50.0 | 592.6 |

In the third group of forecrops (Tables 5 and 6) – the spiked cereal crops, the process flowsheet for its cultivation includes flat moldboard plowing with the simultaneous application of the basic fertilizer, where the MVU-6 fertilizer spreader is also abolished. Disc implements for stubble plowing, causing soil erosion, have been replaced by KSU-6 stubble cultivators (Table 5).
Table 5. The proposed process flowsheet for cropping spiked cereals after spiked cereal crops and grain legume crops

| No. | Farm operation name title                        | MTA consist                      | Technical-economic indicators |
|-----|-------------------------------------------------|---------------------------------|-------------------------------|
|     |                                                 | farm labor input, man-h./ha     | metal consumption, kg/ha      | energy intensity, MJ/ha |
| 1   | Soil treatment by stubble cultivators of 5…6 cm | U-450+KSU-6                    | 0.17                          | 2.17                     | 33.7                   |
| 2   | Mineral fertilizer loading, 0.5 t/ha             | Manitou                         | 0.03                          | 0.04                     | 3.1                    |
| 3   | Transporting fertilizers to the units, 0.5 t/ha  | Belarus 1523 +Reboke            | 0.12                          | 3.4                      | 57.3                   |
| 4   | Flat moldboard plowing of 20…22 cm with basic  | U-450+PShKO(6+2+2)+             | 0.20                          | 5.85                     | 317.0                  |
|     | fertilization, soil layer stripping and smoothing| PVR-2,3+AIR                     |                               |                          |                        |
| 5   | Full cultivation of semifallow land of 6…8 cm   | U-450+KBM-14,4+KShV-15         | 0.11                          | 9.63                     | 51.8                   |
| 6   | Seeding cereals with rolling                     | Belarus 892+SZ-5,4              | 0.32                          | 5.85                     | 76.9                   |
|     | Total                                           |                                 | 0.95                          | 26.9                     | 539.8                  |

Table 6. The basic process flowsheet for cropping spiked cereals after spiked cereal crops and grain legume crops

| No. | Farm operation name title                        | MTA consist                      | Technical-economic indicators |
|-----|-------------------------------------------------|---------------------------------|-------------------------------|
|     |                                                 | farm labor input, man-h./ha     | metal consumption, kg/ha      | energy intensity, MJ/ha |
| 1   | Disking stubble remains 6…8 cm                   | K-744+BDT-7                    | 0.26                          | 8.9                      | 204                    |
| 2   | Mineral fertilizer loading, 0.5 t/ha             | MTZ-80+PKU-0,5                 | 0.09                          | 0.83                     | 19.1                   |
| 3   | Transporting and mineral fertilization, 0.5 t/ha | MTZ-80+MVU-6                   | 0.22                          | 4.2                      | 47.2                   |
| 4   | Plowing of semifallow land to a depth of 20…22 cm| K-744+PNU-8-40                 | 0.18                          | 11.0                     | 378.9                  |
| 5   | Plowed soil layer stripping                       | K-744+ BDT-7                   | 0.26                          | 8.7                      | 204.0                  |
| 6   | Full cultivation of semifallow land, 6…8 cm      | K-744+KShU-9                   | 0.16                          | 10.8                     | 85.6                   |
|     | Total                                           |                                 | 1.47                          | 44.63                    | 938.8                  |

4. Conclusion
The advanced rational process flowsheets for cropping spiked cereals have been developed, considering the natural and climatic conditions of the Krasnodar Krai. The proposed process flowsheets include all types of spiked cereal forecrops, a set of technological operations for cultivating, their effective technical support, and a technical-economic substantiation in comparison with the basic ones. The process flowsheets are based on the use of multifunctional machine units that combine several types of farm operations in one pass through the field: the basic fertilizer application
and the basic cultivation, the basic fertilization, sowing and rolling, etc. The distinctive features of the advanced process flowsheets for the cultivation, according to the recommendations of the authors, ensure their high economic efficiency. Farm labor input for mechanized operating process implementation in field cultivation is reduced by half, metal consumption – 1.3, energy intensity – 1.6 times compared to the basic flowsheets and contribute to the growth of the competitiveness of the products.

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