The influence of the sowing coulters type on the seeding quality and the spring wheat yield

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Abstract. The paper presents data on the influence of the sowing coulters type on the seeding quality and the spring wheat yield in the conditions of the steppe part of Altai Krai. For the grain sowing, seeders are used with the most common types of the sowing coulters such as V-shaped, chisel and disk openers. The wheat was sown after the fallows, the peas and the wheat forecrops. The chisel openers provided the highest sowing quality of wheat seeds. Also the maximum efficiency of the spring wheat cultivation in the extra dry steppe conditions (2012) was achieved by the chisel sowing coulters. In the years with the moderately dry conditions (2006–2011) in the steppe the seeders with the various types of the sowing coulters do not significantly affect the yield structure constituent elements; to a greater extent it depended on the forecrops, the maximal wheat yield was obtained after the fallow.

1. Introduction

The problem of rational use of agricultural land is currently acute [1-4]. In the future, obtaining the maximum possible yield of grain crops per unit of sown area allows to optimize the agriculture in the climate change conditions. In Altai Krai, the problem of getting the full value seedlings of the grain crops is directly related to the instability of the climatic conditions, pests and diseases, but to a greater extent with the failure of the agrotechnical requirements for the sowing. For the grain sowing, seeders are used with the most common types of the sowing coulters such as V-shaped, chisel and disk openers. Despite the fact that these sowing machines have been used in the Altai steppe for many years, the question of their influence on the soil moisture reserves, the soil nitrogen content, the weed infestation, the realisation of the agrotechnical requirements, the seed germination and the elements of the yield structure in the system plan are insufficiently studied [5].

The aim of the study is to investigate the influence of the sowing coulters type on the seeding quality and the spring wheat yield in the conditions of the steppe part of Altai Krai.

2. Materials and methods

In order to determine the most effective type of sowing coulter in 26 farms of the steppe part of Altai Krai, from 2005 to 2012, the studies were conducted with the double-disc coulters (SZP – 3.6A, John Deere 730), the V-shaped coulters (SZS-2.1, Agromaster and Morris) and the chisel coulters (Amazone Condor and DMC).

Assessment of the work of the seed openers was carried out in the field experiments by the main forecrops of the spring wheat (fallow, peas, wheat) in three repetitions according to the scheme (Table...
Table 1. The scheme of the experiments on the assessment of the sowing coulters, 2006-2012

| Variant | Tillage, depth | Type of sowing machine, Russian or foreign-made | Sowing method | Type of sowing coulter |
|---------|----------------|---------------------------------|---------------|-----------------------|
| 1       | Autumn, 14-16 cm + presowing, 10-12 cm | single-function, Russian-made | row | double-disk |
| 2       | Autumn, 14-16 cm | combined, Russian-made | strip | V-shaped |
| 3       | No-tillage | direct seeder, foreign-made | row | chisel |
| 4       | No-tillage | combined, foreign-made | strip | V-shaped |

The main concomitant observations were carried out in accordance with standard methods: moisture reserves before sowing in the meter soil layer; the content of the nitrate nitrogen in 0-40 cm of soil before sowing; the weed infestation of crops; the seeding depth; the field germination of seeds; the wheat yield structure.

Technological operations were carried out by the experimental scheme, the sowing of spring wheat in the third part of May, taking into account generally accepted recommendations with the sowing rate of 3.0–4.0 million germinating grains per 1 ha, depending on the moisture content of the territories. The herbicidal treatment of wheat plants, seeded with the seeders with the double-disc sowing coulters, and with the V-shaped coulters was carried out 1 time against dicotyledonous weeds. In the variant of sowing wheat, seeded with the seeders with the chisel openers it had to be treated 5-10 days before seeding with the nonselective herbicides. The experiments were carried out without the use of the mineral fertilizers.

3. Results and Discussion

3.1. Soil moisture reserves

The main reason for the low and unstable productivity of spring wheat in the steppe part of the Altai Kray is the aridity of the climate. Crops lack moisture throughout the growing season. The intense water regime is exacerbated by the uneven precipitation and their low intensity. The amount of vegetation period’ rainfall over the 6 year in the studied area amounted to the average of 168 mm (80% of the norm) with the fluctuations from 80 mm (2010) to 208 mm (2006). The year 2012 was exceptional in terms of aridity. So, in many areas of the Altai steppe there were in April only 2-6 mm of rainfall, in May 8-14 mm, in June 12-38 m, in July 9-18 mm and in August 21-27 mm. In general, in the all research area there was on average 83 mm (40% of the norm) precipitation during the vegetation period, which affected the soil moisture (Table 2, Figure 1a).

Table 2. The soil meter layer productive moisture reserves before sowing depending on the forecrop and the tillage, mm (2006-2012)

| Variant | Moderately dry 2006-2011 | Extra dry 2012 |
|---------|----------------|---------------|
|         | Forecrop | | Forecrop |
|         | fallow | peas | wheat | fallow | peas | wheat |
| 1       | 123 | 118 | 76 | 42 | 44 | 28 |
| 2       | 126 | 116 | 72 | 44 | 46 | 32 |
| 3       | 111 | 102 | 61 | 71 | 61 | 57 |
| 4       | 108 | 101 | 59 | 70 | 60 | 51 |
|          | 117 | 109 | 67 | 57 | 53 | 42 |
|          | 9 | 9 | 8 | 16 | 9 | 14 |
| SEM     | 4 | 4 | 4 | 8 | 4 | 7 |
| Cv, %   | 8 | 8 | 12 | 28 | 17 | 34 |
The soil water regime in the years with the average moisture supply developed more favorably in the variants with the autumn tillage (1 and 2 variants) after the fallow and peas forecrops. Productive soil moisture reserves were 14-17 mm higher than for backgrounds with no-tillage (3 and 4 variants). In the extra dry year 2012, the direct sowing with the chisel openers with the backgrounds of no-tillage (3 and 4 variants) contributed to an increase in the soil moisture reserves of 15-28 mm relative to another due to the better water preservation in the spring time.

3.2. Nitrogen supply and weed control

The plants supply with the nitrate nitrogen in the soil was the most dependent on the forecrops. Before sowing the content of the nitrate nitrogen in 0-40 cm of soil depending on the weather conditions of the particular year after the fallow ranged from 11.0 to 43.2 mg/kg, after the peas forecrops – 6.7-35.8 mg/kg, after the wheat it was 6.2-18.3 mg/kg. With the background of no-tillage the accumulation of the nitrate nitrogen in the soil did not differ in the experimental variants.

It is known that herbicides are an integral element of weed control in the cultivation of wheat using direct sowing technology. The use of herbicides in the experiments allowed to reduce the weed infestations of crops to a low level (up to 10% of the mass of weeds in the total plant mass from 1 m²), but there is still a tendency to increase the weed infestations of crops on the variant sown by the seeder with the chisel seed openers, where nonselective herbicides were only used in time of 5-7 days before the sowing. Seeders with the V-shaped coulters had the advantage of weed control. They destroyed weeds during the sowing and the herbicidal treatment of crops in the period of seedling stage to tillering stage increased the efficiency of combating the weeds. The weed infestations of crops decreased in these variants to 3.8-6.0%.

3.3. Seeding depth

Among the agrotechnical methods (forecrops, tillage, etc.), the sowing is of no small importance in obtaining the full-fledged seedlings of grain. The task of sowing is to obtain the even sprouts through the optimal use of the method, the sowing time, the seeding rate, the seeding depth and the distribution of seeds, the row spacing. The field germination index is significantly affected by the sowing depth. When it smaller than 4 cm, the death of the sprouts in dry years reaches 27.7%, and when the place of seeds is in the soil layer of 8-10 cm, the number of sprouts is reduced by 5-10%, so they need to be sown to a depth of 5-7 cm [6]. In our experiments, seeders with the disk coulters did not withstand the specified parameters of the seeding depth and sowed them at a smaller depth (Table 3).

In our experiments, seeders with the disk coulters did not withstand the specified parameters of the seeding depth and sowed them at a smaller depth (Table 3).

| Variant | Type of sowing coulter | Forecrop | Forecrop | Forecrop |
|---------|------------------------|----------|----------|----------|
|         |                        | fallow   | peas     | wheat    |
| 1       | double-disk            | 47.6     | 48.1     | 46.9     |
| 2       | V-shaped               | 69.4     | 62.3     | 61.8     |
| 3       | chisel                 | 55.6     | 53.0     | 55.5     |
| 4       | V-shaped               | 65.0     | 66.5     | 57.1     |
| x       |                        | 59.4     | 57.5     | 55.3     |
| σ       |                        | 9.7      | 8.4      | 6.2      |
| SEM     |                        | 4.9      | 4.2      | 3.1      |
| Cv, %   |                        | 16.4     | 14.6     | 11.2     |

The depth of seeding with the V-shaped sowing coulters fits into the set parameters (50.0-70.0 mm), regardless of which seeders they were sown - Russian or foreign production. When sowing on plowed backgrounds (fallow, peas), the depth of seeding was higher by 9-7.3 mm than sowing on untreated
stubble backgrounds. At the same time, a high uneven distribution of seeds was observed along the depth of their placement. The best indicators for the listed values were observed with sowing seeders with chisel-type sowing coulters. The depth of seeding in this case by the different forecrops ranged from 51.0 to 55.6 mm.

### 3.4. Field germination

In the normal humidification years (2006–2011), the type of the sowing coulters did not have a significant effect on the differences in field germination index of the wheat seeds. Only in the extra dry year 2012 it was higher on the variants with the Condor and DMC seeders with the chisel openers. The difference in the field germination index relative to the other variants reached 4.8% after the fallow, and amounted to 7.4 and 12.0 % after the wheat and the peas (Table 4). The low level of the field germination index is explained by the influence of the hydrothermal regime of dry conditions during the sowing–sprouting period, as well as by the root rot damage, especially by the falls (Figure 1b).

| Variant | Type of sowing coulter | Moderately dry 2006-2011 | Extra dry 2012 |
|---------|-----------------------|--------------------------|---------------|
|         | Forecrop              |                          | Forecrop      |
|         | fallow                | peas                     | wheat         |
|         |                       |                          | fallow        |
|         |                       |                          | peas          |
|         |                       |                          | wheat         |
| 1       | double-disk           | 67.6                     | 70.8          |
|         |                       |                          | 69.1          |
|         |                       |                          | 57.2          |
|         |                       |                          | 55.9          |
|         |                       |                          | 53.3          |
| 2       | V-shaped              | 62.6                     | 69.3          |
|         |                       |                          | 62.1          |
|         |                       |                          | 58.0          |
|         |                       |                          | 53.2          |
|         |                       |                          | 52.1          |
| 3       | chisel                | 68.1                     | 75.0          |
|         |                       |                          | 70.5          |
|         |                       |                          | 62.0          |
|         |                       |                          | 65.2          |
|         |                       |                          | 59.5          |
| 4       | V-shaped              | 66.2                     | 74.4          |
|         |                       |                          | 68.8          |
|         |                       |                          | 57.4          |
|         |                       |                          | 55.2          |
|         |                       |                          | 53.3          |
| x       |                       | 66.1                     | 72.4          |
|         |                       |                          | 67.6          |
|         |                       |                          | 58.7          |
|         |                       |                          | 57.4          |
|         |                       |                          | 54.6          |
| σ       |                       | 2.5                      | 2.8           |
|         |                       |                          | 3.8           |
|         |                       |                          | 2.3           |
|         |                       |                          | 5.3           |
|         |                       |                          | 3.3           |
| SEM     |                       | 1.2                      | 1.4           |
|         |                       |                          | 1.9           |
|         |                       |                          | 1.1           |
|         |                       |                          | 2.7           |
|         |                       |                          | 1.7           |
| Cv, %   |                       | 3.8                      | 3.8           |
|         |                       |                          | 5.6           |
|         |                       |                          | 3.9           |
|         |                       |                          | 9.3           |
|         |                       |                          | 6.1           |

### 3.5. Wheat yield

The potential yield of grain crops depends on the tilling capacity, the number of productive stems per 1 m², the number of the grains in the ear, and the mass of the 1000 grains. An analysis showed that in normal humidification years (2006–2011) in the dry steppe the seeders with the various types of the sowing coulters do not significantly affect the yield structure constituent elements, only the number of productive stems shows the advantage of the chisel openers. In this variant the number of productive wheat stems in the fields after the fallow was higher by 9.5%, after the peas by 10.8% and after the wheat 8.4% then in the other variants. In the extra dry year 2012 the positive influence of the chisel coulters affected all the elements of the yield structure after all forecrops. Thus, the number of productive stems in the variant 3 was 55 pcs./m² higher than on the variant 1 with the double-disk coulters (188 and 242 pcs./m², respectively), the number of the grains in the ear was higher by 7.5 pcs. (10.4 and 17.9 pcs., respectively), and the weight of 1000 grains was higher by 4.0 g. The V-shaped openers occupied the intermediate position and did not have the large differences between the Russian-made sowing machines in the frames of the yield structure constituent elements.

The spring wheat productivity in the favorable moisture years did not differ significantly depending on the type of opener and ranged within the standard error of the mean for all forecrops. To a greater extent, it depended on the forecrop than on the type of sowing coulter (Table 5, Figure 1c). In the extra dry year 2012, the yield of the spring wheat in the variant 1 (double-disc coulter) was the lowest and consisted after the fallow 6.4 c/ha; after the peas 5.9 c/ha and after the wheat 2.5 c/ha. In this severe weather conditions high efficiency in the spring wheat cultivation was obtained on the fields sowing with the chisel openers (variant 3). Relative to the variant 1, the yield increase here after the fallow was 7.0 c/ha, after the peas 3.0 c/ha and after the wheat 4.5 c/ha. Seeders of Russian and foreign production with the V-shaped sowing coulters did not have the significant differences in the wheat yield (variants...
2 and 4), but they exceeded the double-disc coulter seeders by 5.9 c/ha and 2.1 c/ha respectively for the best forecrops (fallow, peas). At the same time, the yield of wheat sown after the wheat with the double-disc coulters was lower than in the variant with the chisel openers.

Table 5. The wheat yield depending on the type of sowing coulter and the forecrop, c/ha (2006-2012)

| Variant | Type of sowing coulter | Moderately dry 2006-2011 | Extra dry 2012 |
|---------|------------------------|--------------------------|---------------|
|         | Forecrop               | fallow | peas | wheat | fallow | peas | wheat |
| 1       | double-disk            | 24.2  | 17.2 | 15.8  | 6.4   | 5.9  | 2.5   |
| 2       | V-shaped               | 24.6  | 16.9 | 16.2  | 12.6  | 8.1  | 4.6   |
| 3       | chisel                 | 24.4  | 17.5 | 16.2  | 13.4  | 8.9  | 7.0   |
| 4       | V-shaped               | 25.0  | 18.0 | 16.0  | 12.0  | 7.9  | 4.0   |
| \(\bar{x}\) | -                      | 24.6  | 17.4 | 16.1  | 11.1  | 7.7  | 4.5   |
| \(\sigma\) | -                      | 0.3   | 0.5  | 0.2   | 3.2   | 1.3  | 1.9   |
| SEM     | -                      | 0.2   | 0.2  | 0.1   | 1.6   | 0.6  | 0.9   |
| Cv, %   | -                      | 1.4   | 2.7  | 1.2   | 28.7  | 16.6 | 41.4  |

Figure 1. Comparison of the average soil productive moisture (a), the average field germination index (b) and the average wheat yield (c) in 2006-2011 and in extra-dry 2012.

4. Conclusion
The water regime of the soil in the moderately dry years was more dependent on the forecrops (fallow, peas) than on the type of the sowing coulters of the seeders. In an extremely dry year direct sowing with the seeders with the chisel openers contributed to the safety of the soil moisture reserves to the seeders with the double-disk openers of 17–28 mm. Provision of wheat plants with soil nitrogen between the experimental variants was almost the same and differed only in their forecrops. On the background of the use of herbicides, the weed infestation of wheat crops was low (up to 10%), although it increased on the variant with chisel openers to 8.0–9.1% with a contamination level of 3.8–6.0% on the variant with the V-shaped openers. The chisel openers provided the highest sowing quality of wheat seeds.

The maximum efficiency of the spring wheat cultivation in extra dry conditions (2012) was achieved by the sowing it with the seeders with the chisel sowing coulters. Due to the increase in the field
germination index (by 4.8–12%) and other indicators of the crop structure, the yield of the spring wheat in the extra dry year was after the fallow 13.4 c/ha, after the peas 8.9 c/ha and after the wheat 7.0 c/ha with the yield in the variant with the double-disk openers 6.4, 5.9 and 2.5 c/ha, respectively by the forecrops. The seeders with the V-shaped openers held an intermediate position with the average wheat yield of 12.3, 8.0 and 4.3 c/ha, respectively by the forecrops. In the years with the moderately dry conditions (2006–2011) in the steppe the seeders with the various types of the sowing coulters do not significantly affect the yield structure constituent elements; to a greater extent it depended on the forecrops, the maximal wheat yield was obtained after the fallow.

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