The Influence of Forecrops, Tillage Techniques and Chemicalization Levels on Soil Moisture, Spring Wheat Grain Dockage and Yield in the Forest-Steppe conditions of Irkutsk Region

A M Zaitsev¹², V I Solodun¹² and M N Orobej³
¹Irkutsk State Agrarian University named after A.A. Ezhevsky, Molodezhny Settlement, Irkutsk district, Irkutsk region, Russian Federation
²Irkutsk Scientific Research Institute of Agriculture, 14, Dachnaya St., Pivovarikha, Irkutsk district, Irkutsk region, Russian Federation
³Irkutsk National Research Technical University, Irkutsk, Russian Federation

E-mail: zaycev38@mail.ru

Abstract. The aim of the studies was to assess the influence of forecrops, tillage techniques and chemicalization levels on soil moisture, spring wheat grain dockage and yield. The studies were carried out in 2019–2020 in the forest-steppe zone of Irkutsk region. The three-factor experiment scheme included the forecrops: annual grasses (pea-oat mixture) and corn; the basic tillage methods: PLN-4-35 ploughing by 18–20 cm and BDT-3 disk plowing by 8–10 cm; chemicalization level: no fertilizers, mineral fertilizer N₄₅P₄₅K₄₅ (diammofoska and ammonium nitrate) and mineral fertilizer N₄₅P₄₅K₄₅ and herbicides. Differences in the moisture accumulation efficiency between corn and annual grasses, as well as in tillage techniques, have not been established. Decrease in wheat plantings dockage for annual grasses in relation to corn is from 6.2 to 10 pcs/m². The use of disk plowing leads to an increase in wheat plantings dockage for corn by 23.7–24.3 pcs/m², for annual grasses by 19.9–27.4 pcs/m². The use of the herbicide has significantly reduced the number of weed plants for all forecrops, both in terms of ploughing and disk plowing. The wheat yield for corn has ranged from 2.15 to 2.67 t/ha, depending on the tillage and fertilization techniques. The yield after annual grasses has been significantly lower and ranged from 1.62 to 2.26 t/ha. The use of disk plowing has led to a significant decrease in wheat yield for annual grasses by 0.18–0.29 t/ha, and for corn by 0.21-0.23 t/ha. The application of mineral fertilizers has increased the yield for corn by 0.28–0.29 t/ha, for annual grasses by 0.35–0.37 t/ha. The forecrop has had the greatest influence on the yield – 45.8%, the share of the chemicalization level influence has been 30.4%.

1. Introduction
In the conditions of Cisbaikalia, the spring wheat grain production remains the predominant direction in the most farms’ activities. An important element of the wheat cultivation technology in the region conditions is a forecrop. The forecrop determines the level of soil moisture supply and its role increases even more in arid conditions. The role of forecrops in accumulating mineral nutrition elements, regulating the species composition and the number of weeds, pests and causative agents is well known. The influence of the forecrop on the yield can reach from 15 to 35% [1]. In areas with insufficient moisture, incl. in the forest-steppe conditions of Irkutsk region, the most effective forecrop of spring
wheat, which guarantees stable grain yields, is considered to be complete fallow. More than 50% of the crop plantings in the region is located for complete fallow [2].

However, in many region farms, a significant part of wheat plantings is placed on non-fallow forecrops – perennial and annual grasses, tilled crops, rapeseed, cereal crops, etc. In this case, in addition to moisture accumulation, the challenge is to ensure plant nutrition and control weeds.

When introducing the resource-saving tillage systems in field crop rotations, even short-rotation ones, there is a steady tendency to an increase in the agrophytocenosis dockage [3, 4].

Tillage is the most important agricultural method when cultivating agricultural plants. The yield of agricultural crops can depend on the tillage method and quality by 25%. The tillage techniques are influenced by many factors, but they are always aimed at increasing the cultivated crops productivity [5, 6]. Therefore, studies aimed at finding optimal tillage methods and systems aimed at improving soil fertility, phytosanitary crops state and, as a result, at obtaining high stable yields of agricultural crops are always relevant [7].

The choice of scientifically based fertilizers doses to ensure optimal conditions for plant nutrition remains relevant in the context of modern technologies. In a market economy, it is necessary to study and establish an acceptable level of mineral nutrition for each wheat variety [8]. The importance of choosing the optimal doses of mineral fertilizers when cultivating spring wheat, including due to the high cost of mineral fertilizers, is indicated in the studies of Eastern Siberia scientists [9, 10, 11, 12, 13].

The objective of the work is to assess the effect of non-fallow forecrops, tillage techniques and chemicalization levels on soil moisture, dockage and yield of spring wheat.

2. Conditions, materials and methods
The studies were carried out in 2019–2020 on the experimental field of the Irkutsk Scientific Research Institute of Agriculture. The soil of the area is gray forest heavy clayloam with the following parameters: humus level – 5%; N – 0.22%; P₂O₅ – 0.23%; pH₅ – 5.5; base saturation 73–83%; provided with available forms of phosphorus and potassium at an average level. The area of the experimental plot is seventy square meters. The experience is based on three times repetition. Variety – Buryat awned.

Experiment scheme. Factor A – forecrops: annual grasses (pea-oat mixture) and corn in a four-course rotation pea-oat mixture – wheat – corn – wheat. Factor B – tillage: PLN-4-35 ploughing by 18–20 cm; BDT-3 disk plowing by 8–10 cm. Factor C – chemicalization level: no fertilizers; mineral fertilizer N₄₆P₂₅K₄₅ (diammofoska and ammonium nitrate); mineral fertilizer N₄₆P₂₅K₄₅ and herbicides.

Corn and annual grasses were harvested for forage in the second decade of August. After they had been harvested, the basic tillage was carried out. In the third decade of April, early spring harrowing with spike-tooth harrows was carried out on the experimental plot; before sowing, pre-sowing cultivation was carried out to a depth of 6–8 cm with a PAV-4 cultivator. Spring wheat sowing was carried out in the second decade of May with a Kverneland seeder with a seeding rate of 7 million. The method of sowing is a row-type with 15 cm row-spacing. Then the field was rolled with star-wheeled rollers. Harvesting was carried out with a “Terrion” combine harvester. In variants with herbicides, crops were cultivated during the tillering phase with Puma plus at a dose of 1.5 l/ha. The moisture content was determined by the thermostat-weight method. Crops dockage – by the quantitative-weight method.

The weather conditions over the years of the study differed both in air temperature and in the amount of precipitation. From May to August in 2019, 227.6 mm of precipitation fell. This is 46 mm less than in 2020 and 23.8% less than the mean annual value. The precipitation distribution by months and decades in 2019, as well as in 2020, is uneven. In May, 30% of precipitation fell of normal, and the average monthly temperature was 1.7 °C lower than the mean annual values. In the first and second decades of June, there was a precipitation deficit (77 and 35% of normal, respectively). In the third decade of June, an increase in average daily temperatures and precipitation was observed (52.9 mm in the third decade). In July, 99.3 mm fell, or 90% of the mean annual norm. In August, the amount of precipitation was 48.5 mm, or 51% of normal. The average daily air temperature during the vegetation period was 2.4 °C higher than the mean annual values. High air temperature values were observed from the second decade of June to the second decade of August, 19.0 °C on average, which is 18% higher
than the mean annual data. In 2019, the sum of active temperatures was 2048°C. In 2020, from May to August, 273.6 mm of precipitation fell, which is 25.2 mm less than the mean annual values. At the same time, 1.5 monthly precipitation norm fell in May – 45.6 mm. A precipitation deficit was observed in June, the precipitation amount was 28 mm, or 44.8% of the mean annual value. The deficit occurred during the important for plants tillering-earling period and had a significant impact on the yield. The average daily temperatures of the vegetation period were 3.7°C higher than the mean annual values. The large precipitation amount in September 2020 made harvesting difficult and had an impact on the decline in grain quality. The sum of active air temperatures above 10°C was 2276 °C, which is 228 °C more than in 2019. Therefore, it can be noted that the meteorological conditions in 2019 were more favourable.

3. Results and discussion

From the data in table 1, it can be concluded that there were no differences in the efficiency of moisture accumulation for sowing spring wheat between the forecrops.

| Forecrop            | Tillage technique | Soil layer, cm | Determination period |
|---------------------|-------------------|----------------|----------------------|
|                     |                   |                | 10/V                 | 15/VI | 20/VII | 15/VII | 13/IX | 15/X |
| Corn                | ploughing 18–20 cm (control) | 0–50 | 41.5 | 35.5 | 35.8 | 37.2 | 41.9 | 49.1 |
|                     |                   | 0–100 | 128.6 | 35.5 | 35.8 | 37.2 | 41.9 | 130.2 |
|                     | disk plowing 8–10 cm | 0–50 | 44.3 | 39.6 | 37.4 | 39.2 | 43.5 | 52.1 |
|                     |                   | 0–100 | 129.5 | 39.6 | 37.4 | 39.2 | 43.5 | 134.2 |
| Annual grasses (pea+oat) | ploughing 18–20 cm | 0–50 | 40.9 | 35.8 | 37.6 | 35.5 | 40.2 | 46.2 |
|                     |                   | 0–100 | 127.7 | 35.8 | 37.6 | 35.5 | 40.2 | 132.6 |
|                     | disk plowing 8–10 cm | 0–50 | 45.9 | 40.8 | 38.1 | 37.4 | 42.1 | 49.9 |
|                     |                   | 0–100 | 129.9 | 40.8 | 38.1 | 37.4 | 42.1 | 135.5 |
| HCP05               | 0–50              | 4.9  | 5.2  | 5.8  | 3.8  | 3.7  | 6.1  |         |
|                     | 0–100             | 8.5  | 5.2  | 5.8  | 3.8  | 3.7  | 6.1  | 9.9   |

So, before the soil freezing, the amount of productive moisture in the 0–50 cm layer was 49.1 mm after corn and 46.2 mm after annual grasses. No differences were found in the meter-deep soil layer either. The moisture content in the 0–100 cm layer before soil freezing was 130.2–132.6 mm. There is a tendency to an increase in the moisture content in the variant with disk plowing as compared with moldboard plowing both in the half-meter and in the meter-deep soil layer.

Crops dockage. Quantitative assessment of wheat crops dockage has shown that all factors have influenced the number of weeds in wheat crops table 2.

The wheat crops dockage for annual grasses is significantly lower than after corn. The decrease is from 6.2 to 10 pcs/m². The use of disk plowing as the main tillage technique leads to an increase in wheat crops dockage for the forecrop corn by 23.7–24.3 pcs/m², for the forecrop annual grasses by 19.9–27.4 pcs/m². No reliable change in the number of weeds after fertilization has been established, and the use of the herbicide significantly reduces the number of weeds for all predecessors, both amid the moldboard plowing and disking. The greatest influence on the number of weeds in wheat crops during the years of study was exerted by the chemicalization level – 45.2%, the tillage technique rate was 24.5%, and the forecrop accounted for by 15.6%.

Table 3 shows that the wheat yield for corn ranged from 2.15 to 2.67 t/ha, depending on the tillage technique and fertilization. The yield after annual grasses was significantly lower and averaged from 1.62 to 2.26 t/ha over the years of study.
Table 2. Wheat crops dockage before harvesting, depending on the forecrop, the tillage technique and the chemicalization level on average for 2019–2020, mm.

| Forecrop            | Tillage technique | Chemicalization level                  | Number of weeds, pcs/m² |
|---------------------|-------------------|----------------------------------------|--------------------------|
|                     |                   |                                        | total | incl. |
|                     |                   |                                        |       | perennial |
| Corn                | ploughing         | without fertilizers (control)          | 42.4  | 2.4    |
|                     | 18–20 cm          | N₄₅P₄₃K₄₅                            | 44.6  | 2.6    |
|                     | (control)         | N₄₅P₄₃K₄₅ and herbicides              | 21.2  | 0.9    |
|                     | disk plowing      | without fertilizers                   | 66.1  | 4.8    |
|                     | 8–10 cm           | N₄₅P₄₃K₄₅                           | 68.9  | 5.3    |
|                     |                  | N₄₅P₄₃K₄₅ and herbicides              | 24.3  | 1.2    |
| Annual grasses      | ploughing         | without fertilizers                   | 36.2  | 1.9    |
| (pea+oat)           | 18–20 cm          | N₄₅P₄₃K₄₅                           | 41.5  | 2.1    |
|                     |                  | N₄₅P₄₃K₄₅ and herbicides              | 21.2  | 0.8    |
|                     | disk plowing      | without fertilizers                   | 56.1  | 5.1    |
|                     | 8–10 cm           | N₄₅P₄₃K₄₅                           | 58.9  | 4.9    |
|                     |                  | N₄₅P₄₃K₄₅ and herbicides              | 21.4  | 1.1    |
| HCP₉₅ forecrop       |                   |                                        | 5.6   |        |
| HCP₉₅ tillage technique |               |                                        | 4.5   |        |
| HCP₉₅ chemicalization level |         |                                        | 5.7   |        |

Factor influence rate, %:
- forecrop: 15.6
- tillage technique: 24.5
- chemicalization level: 45.2

The use of disk plowing instead of ploughing as the main tillage in autumn led to a significant decrease in wheat yield for annual grasses by 0.18–0.29 t/ha, and for corn by 0.21–0.23 t/ha.

Mineral fertilizers at a dose of N₄₅P₄₃K₄₅ kg r.a./ha increased wheat productivity both for forecrops and for tillages. Growth for corn was 0.28–0.29 t/ha, for annual grasses 0.35–0.37 t/ha.

The results of the statistical analysis of the yield results showed that the forecrop had the greatest influence on the yield – 45.8%, the chemicalization level was in second place – 30.4%. The tillage technique rate is much less and was 10.8%.

Table 3. Average yield of spring wheat for 2019-2020, t/ha.

| Forecrop            | Tillage technique | Chemicalization level                  | Yield, t/ha |
|---------------------|-------------------|----------------------------------------|-------------|
|                     |                   |                                        | year 2019 | year 2020 | average in 2 years | Increase (decrease) |
| Corn                | ploughing         | without fertilizers (control)          | 2.47       | 2.25      | 2.36              | -             |
|                     | 18–20 cm          | N₄₅P₄₃K₄₅                            | 2.62       | 2.68      | 2.65              | 0.29          |
|                     | (control)         | N₄₅P₄₃K₄₅ and herbicides              | 2.62       | 2.72      | 2.67              | 0.31          |
|                     | disk plowing      | without fertilizers                   | 2.24       | 2.05      | 2.15              | -0.21         |
|                     | 8–10 cm           | N₄₅P₄₃K₄₅                           | 2.41       | 2.45      | 2.43              | 0.07          |
|                     |                  | N₄₅P₄₃K₄₅ and herbicides              | 2.43       | 2.44      | 2.44              | 0.08          |
| Annual              | ploughing         | without fertilizers                   | 1.87       | 1.90      | 1.89              | -             |
|                     | 18–20 cm          | N₄₅P₄₃K₄₅                           | 2.27       | 2.25      | 2.26              | 0.37          |
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influence on the yield for corn by 0.29 t/ha, and for annual grasses by 0.35 t/ha. The use of disk fertilization. The yield after annual grasses and 27.4 pcs/m leads to an increase in tillage technique. Differences in the efficiency of moisture accumulation between corn and annual grasses, as well as 4.

Factor influence

HCP05

Factor A 0.08 0.06 0.07
Factor B 0.10 0.07 0.08
Factor C 0.12 0.11 0.10

Factor influence rate, %

Factor A 50.9 40.4 45.8
Factor B 7.8 15.9 10.8
Factor C 32.8 31.4 30.4

4. Conclusion

Differences in the efficiency of moisture accumulation between corn and annual grasses, as well as tillage techniques, have not been established.

Reducing wheat crops dockage for annual grasses is from 6.2 to 10 pcs/m². The use of disk plowing leads to an increase in wheat crops dockage for corn by 23.7–24.3 pcs/m², for annual grasses by 19.9–27.4 pcs/m². The use of the herbicide has significantly reduced the number of weeds both for forecrops and for tillage techniques.

The wheat yield for corn has ranged from 2.15 to 2.67 t/ha, depending on the tillage technique and fertilization. The yield after annual grasses has been significantly lower and ranged from 1.62 to 2.26 t/ha. The use of disk plowing has led to a significant decrease in wheat yield for annual grasses by 0.18–0.29 t/ha, and for corn by 0.21–0.23 t/ha. The application of mineral fertilizers has increased the yield for corn by 0.28–0.29 t/ha, for annual grasses by 0.35–0.37 t/ha. The forecrop has had the greatest influence on the yield – 45.8%, the chemicalization level influence rate has been 30.4%.

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