Soil Tillage as a Factor of Soil Conservation

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Abstract. The work describes the question of the soil treatment system influence on agrophysical and microbiological properties of gray forest soils, and yield of barley in Western Siberia. Research works were carried out in 2013-2014 in Yaya region of the Kemerovo region. Tillage affects soil structure. The water stability in zero tillage conditions was poor (15.7%). Soil density corresponding to the optimum rate for barley is formed by the zonal processing system, while at the zero tillage soil remains solid. The best indicators of phosphataze, catalysis and amylase activity are formed with minimum processing system. In the experiment the highest yield of barley was obtained with minimum tillage - 12.1 c/ha.

1. Introduction
At present, all over the world for the purpose of energy and resource saving is very relevant to develop the so-called saving (preservative) agriculture, and the priority is given to the replacement of the traditional intensive technologies of grain and other crops cultivation on saving soil protection ones. The technologies of minimum and zero tillage for soil protection are among the specific and important ways to the economy of resource and energy saving in agriculture. [1,2,3,4].

In connection with the massive development of energy saving in the cultivation of crops in South-West Siberia, based on minimizing tillage, economical usage of fertilizers and plant protection products, there was a need for research to determine the reproduction of soil fertility with non-traditional technologies implementation.

The research task was to study the effect of the minimum (Mini-Till) and zero soil tillage (No-Till), and comparison of their agrophysical properties, soil biological activity and the formation of spring barley yields to the results of zonal tillage implementation.

2. Equipment and devices used in studies
The testing site: an experimental plot in the forest-steppe zone of the Kemerovo region in 2013-2014. The plot’s soil - gray forest podzolized, medium heavy loam soil. The humus content in the soil is low - 4.3%, that is typical for the gray forest soils. The labile phosphorus and potassium concentration is average. While the nitrate nitrogen presence at the sowing time is very low - 2.4 mg / kg. The degree of base saturation is low - 70%. The reaction of the soil solution is medium acid - 4.6 pH.

The experiment repetition was conducted four times; plot allocation was stepped and systematical. The total area of the experiment site was 59 hectares. Forecrop was annual grasses. Optimal sowing
time for barley in the natural climatic zone was May 21-22\textsuperscript{nd}, 2013-2014. The seeding rate was 4.5 million germinating seeds per hectare.

During the growing season the following surveys and observations were made:
- The yield components (number of germinating and surviving plant, weight of 1000 grains, number of grains per ear, grain weight from 1 m\textsuperscript{2}) were estimated by the procedure of the State Agricultural Crop Variety Testing of crops [5];
- The mass of 1000 grains - according to State All-Union standard 12042-80;
- Soil density by cutting ring method [6];
- An enzymatic activity in the field and laboratory conditions [7].

Meteorological conditions during the growing season are varying from year to year. The hydrothermal index was 1.34 in 2013 and 1.78 in 2014, that shows a sufficient moisture proportion for the crop sector.

Thus, this year, weather conditions were quite favorable according to the moisture availability and the effective heat sum (Figure 1 and 2). There were some unfavorable factors such as protracted rainfall showers that led to the soil overcrust and crust formation on the soil surface at the beginning of the growing season.

![Climatograph of the growing season 2013](image)
Objects of the study.
1. Zonal tillage (controlled experimental plot)
   a) cultivation (autumn cultivation, rotary cultivator RUBIN) 13-15 sm;
   b) dragging BZTS -1
   c) preplanting cultivation SMARAGD 9/400 and fertilization (8-10 sm);
   d) sowing SZP – 3.6;
   e) post-emergence dragging
2. Minimal tillage
   a) Air Drill John Deere 1820, sowing + fertilization + seed rolling (depth 5-6 sm);
   b) post-emergence dragging
3. Zero tillage
   a) drill-machine Primera 602, sowing + fertilization (depth 5-6 sm);
   b) post-emergence dragging
4. Spring barley “Odessa 100” (is middle, large-kerneled barley, 1000 grains weight – 50-53 g.;
   yield production 44.4 c / ha, resistant to lodging).

3. Results and discussion
Decision of use of the soil tillage or rejection of it depends on many factors, including soil and climatic conditions as well as technological level of production. The most costly element of the farming system is different tillage systems. To improve the competitiveness of agricultural sector it is necessary to introduce high technologies with low energy costs that can maintain soil fertility parameters [8,9].

Soil structure resistant to mechanical stress and its ability to maintain the structure in soil moistening conditions (water resistance) define its conservation of favorable soil consistency in the context of repetitive tillage and moisturizing [10]. The experience results (table 1) show that water stability of aggregates is very low and does not reach 20%, which characterizes the soil state as unsatisfactory and liable to soil overcrust and crust formation on the soil surface, which indirectly affects the crop productivity.
Table 1 – Influence of processing systems on the structural aggregate composition of 0-30 cm soil layer

| tillage | aggregate composition, % |  |
|---------|--------------------------|---|
|         | blocky | macrostructure | microstructure | water resistance |
| Zonal   | 14.7   | 83.66          | 1.98            | 18.86            |
| Minimal | 7.54   | 89.36          | 3.09            | 17.36            |
| Zero    | 18.58  | 79.11          | 2.31            | 15.68            |

The received data on the content of more than 10 mm fractions differed significantly. The maximum content of blocky fraction observed in the soil with zero tillage (18.58%). The same trend in heterogeneity of soil aggregates, depending on the processing methods was observed in the work by G. Lili, E. Becker, 2017 [11]. The content of agronomically valuable aggregates in all experimental soil plots was optimal. The unsatisfactory water resistance index can not be stabilized in 2 years. To implement the methods of the minimum conservation tillage requires a special transition period. Tillage on the same depth requires use of variable-depth equipment (subsurface plow and chisel tools). To increase water resistance it is necessary to enrich the crop rotation with perennial grasses, green manure crops and to leave stubble and straw, etc. [12].

Soil density was determined before sowing and before harvesting in the layer of 0-60 cm. The received data characterizing the soil condition by using various processing techniques are shown in Table 2.

Table 2 – Soil density depending on soil tillage system, g/sm³

| Soil layer, cm | Zonal | Minimal | Zero |
|---------------|-------|---------|------|
|                | beginning of the vegetation period | end of the vegetation period | beginning of the vegetation period | end of the vegetation period | beginning of the vegetation period | end of the vegetation period |
| 0-10          | 1.21  | 1.19    | 1.24 | 1.23 | 1.22 | 1.36 |
| 10-20         | 1.39  | 1.35    | 1.20 | 1.29 | 1.24 | 1.46 |
| 20-30         | 1.39  | 1.34    | 1.07 | 1.39 | 1.20 | 1.36 |
| 30-40         | 1.31  | 1.30    | 1.17 | 1.38 | 1.28 | 1.41 |
| 40-60         | 1.28  | 1.45    | 1.19 | 1.41 | 1.36 | 1.49 |

The data of the studies show that the soil is characterized as dense and very dense, both for the whole vegetative period and for the soil crossover. The autumn tillage of the soil did not help to reduce the soil density at the beginning of vegetation. Summer precipitation did not affect the decrease in density to the harvest period. Minimal tillage did not affect the density during the years of research. While zero tillage, despite a significant amount of summer precipitation, contributed to an increase in density at the end of the vegetation period by 1.36 in 0-10 cm of the upper layer. Thus, the gray forest soil optimal density for barley is provided by the zonal tillage system.

We believe that at the current stage of agricultural management, the technology of cultivating agricultural crops should be adaptive, contain a selection option for choosing a variant from a bank of technologies meeting requirements of being the most adaptable to natural, soil and production conditions. And it is not always necessary to refuse from deep soil treatment [13].

The process of mineralization of organic substances predominates over their renewal. In the gray forest soil, as a result there is a strong depletion of soil humus. Soil treatment affects the microbiological processes taking place in it. In our studies soil biological activity is represented through the enzymatic soil activity.
Enzymatic activity, especially the activity of a large range of enzymes of different classes (oxidoreductase, hydrolases, etc.), gives valuable characteristics of soils and the ability to comprehend some specific soil features, which is successfully used in the diagnosis of soil fertility.

In soils there is a large amount of phosphorus in the form of organic compounds that are introduced with the dying remnants of plants, animals and microorganisms. The release of phosphoric acid from these compounds is carried out by a comparatively narrow group of microorganisms having specific phosphatase enzymes (Table 3).

**Table 3** – Phosphatase activity of soil plough-layer depending on the type of soil tillage

| Sample Collection Session | Type of soil tillage | Diameter of the decomposition zone, mm | Color density of the decomposition zone |
|---------------------------|----------------------|----------------------------------------|----------------------------------------|
| May                       | Whole field          | 25.0                                   | +++                                    |
| July                      | Zonal                | 27.0                                   | ++++                                   |
|                           | Minimal              | 27.0                                   | +++                                    |
|                           | Zero                 | 26.9                                   | +++                                    |
| September                 | Zonal                | 26.3                                   | +++                                    |
|                           | Minimal              | 26.3                                   | ++                                     |
|                           | Zero                 | 23.7                                   | +                                      |

+  very weak
++ weak
+++ saturated
++++ very saturated

Analyzing the obtained data it can be said that the activity of phosphatase was dynamic during the vegetative period. The phosphatase activity of soils was maximal in active phases of plant growth at high soil temperature and sufficient humidity in July. The diameter of the decomposition zone was 26.9-27.0 mm. There was a significant decrease in phosphatase activity in the variant with zero tillage.

Catalase activity largely depends on agronomic techniques.

The catalase activity was determined by a gasometric method based on a change in the decomposition rate of hydrogen peroxide in its interaction with the soil (Table 4).

**Table 4** – Catalase soil activity depending on the type of soil tillage (ml O₂/g of soil in 3 min)

| Sample Collection Session | Type of soil tillage | ml O₂/g of soil in 3 min |
|---------------------------|----------------------|--------------------------|
| May                       | Whole field          | 2.8                      |
| July                      | Zonal                | 2.9                      |
|                           | Minimal              | 3.6                      |
|                           | Zero                 | 3.2                      |
| September                 | Zonal                | 3.7                      |
|                           | Minimal              | 3.7                      |
|                           | Zero                 | 3.5                      |

Data on the catalase soil activity indicate a uniform distribution of the enzyme in the arable layer of the soil processed with the zonal tillage. The minimal tillaged soil showed an increase in the activity of enzymes in the plow layer. The decrease in catalase activity by the end of vegetation period was not revealed. The enzyme amylase carries out the hydrolysis of starch, which is a part of the organic
remains into the soil; therefore, the higher the amylase activity is (Table 5), the higher the rate of decomposition of organic matter and the higher the fertility of the soil are.

**Table 5** – Amylase activity depending on the type of soil tillage (diameter of the decomposition zone/1 g of soil / day)

| Sample Collection Session | Type of soil tillage | Diameter of the decomposition zone (1 g of soil /day), mm |
|---------------------------|----------------------|--------------------------------------------------------|
| May                       | Whole field          | 18.3                                                   |
|                           | Zonal                | 17.6                                                   |
|                           | Minimal              | 18.3                                                   |
|                           | Zero                 | 16.5                                                   |
| July                      | Zonal                | 17.8                                                   |
|                           | Minimal              | 18.5                                                   |
|                           | Zero                 | 17.8                                                   |
| September                 | Zonal                | 17.8                                                   |
|                           | Minimal              | 18.5                                                   |
|                           | Zero                 | 17.8                                                   |

Under the conditions of the experiment, the stable amylase activity was characterized by the minimal tillage.

Enzyme urease is involved in the regulation of nitrogen exchange in the soil. This enzyme catalyzes the hydrolysis of urea to ammonia and carbon dioxide, and its activity directly depends on the meteorological conditions of the year (Manoshkina NV, 2009).

The determination of urease activity was carried out under laboratory conditions (Table 6).

**Table 6** – Urease activity depending on the type of soil tillage

| Sample Collection Session | Type of soil tillage | Maximal pH | Time, hours |
|---------------------------|----------------------|------------|-------------|
| May                       | Whole field          | 9.0        | 65          |
|                           | Zonal                | 9.5        | 68          |
|                           | Minimal              | 10.0       | 91          |
|                           | Zero                 | 9.4        | 69          |
| July                      | Zonal                | 9.5        | 72          |
|                           | Minimal              | 10.0       | 78          |
|                           | Zero                 | 9.5        | 73          |

The maximum pH value 10.0 was noted in the variants with minimal soil tillage. Thus, the urease activity of the soil in the arable layer was positively affected by the lack of mechanical treatment, despite the fact that the plant remains in this case are concentrated on the soil surface.

The yield of barley is largely determined by a combination of factors: the genetic peculiarity of the variety, the elements of technology, and the indices of fertility. In our studies, the yield indicator in the experiment varied from 5.9 to 12.1 centners per hectare (Table 7). A variant with minimal soil tillage was highlighted. Such a low yield of barley is explained with the high density and low acidity index of the soil-absorbing complex of gray forest soil.

This fact has affected the number of risen plants, preserved to harvest, to form a spike. Despite the sufficient amount of precipitation in the tillering phase, productive bushiness is generally very low; the plants did not form a spike.
Table 7 – Yield formula of barley

| Tillage  | Plants, pcs./m² | Stems with a spike, pcs./m² | Tilling capacity | Grains per a spike, pcs. | Mass of 1000 grains, g | Biological productivity, c / ha |
|----------|-----------------|----------------------------|------------------|-------------------------|------------------------|-------------------------------|
| Zonal    | 311             | 312                        | 1.01             | 15.8                    | 34.3                   | 11.4                          |
| Minimal  | 241             | 240                        | 1.0              | 15.8                    | 36.0                   | 12.1                          |
| Zero     | 157             | 152                        | 0.97             | 13.7                    | 31.6                   | 5.9                           |

HCP 0.05 = 0.71 c / ha

4. Conclusions

The maximum content of particles of the aggregate fraction - 18.58% was noted in the soil with zero tillage. The water resistance of aggregates is very low, does not reach 20%, which characterizes the state of the soil as unsatisfactory and capable of soil overcrust and crust formation on the soil surface.

The use of zero tillage promotes an increase in soil density by the end of vegetation period to 1.36 in the upper 0-10 cm of the soil layer. The optimum density of gray forest soils for barley was provided by the zonal processing system.

Minimization of tillage had a positive effect on the enzymatic activity of the soil in the experimental sites. The decrease in the thickness of the biologically active soil layer during zonal processing is associated with the redistribution of plant remains.

Soil with a minimum tillage showed high yield productivity of barley - 12.1 c / ha.

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