Technology of the main tillage of the abandoned fields

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Abstract. The lands that turned out to be unclaimed for agrarian production pass into the category of waste, due to the spread of weeds on them. At the first stage, such lands pass through a wild grass stage with typical weed-field vegetation, where annual dicotyledons predominate, subsequently these plants are supplanted by perennial grasses, overgrown with shrubs and tree growth, and waste lands become uncultivated deposits. The presence of vegetation cover with a height of 1-1.7 m not only complicates the conduct of mechanical tillage, but also requires large amounts of energy. On lands left out of agricultural use, there is a noticeable change in soil properties. All agrochemical parameters of deposits have a lower value than arable land. On abandoned fields, along with a decrease in nutrients in the soil, there is a change in water and air conditions, which complicates the process of tilling. Entering abandoned fields in crop rotation for the production of agricultural products is an important economic problem of the day. The aim of the work is to develop the technology of the main tillage and dump plow for its implementation, ensuring the incorporation of tall plants in abandoned fields at low energy costs and high agrotechnical indicators.

1. Introduction
The analysis showed that the lands, which turned out to be unclaimed for agricultural production, go into the category of waste and are determined by the dynamics and processes of weed vegetation spreading on them. At the first stage, such lands pass through a wild grass stage with typical weed-field vegetation, where one-year dicotyledonous plants prevail. The natural tendency is the increase of the proportion of dangerous perennial weeds (field sow thistle, field thistle, field bindweed, Lactuca tatarica), rhizomatous (Elymus repens, wild rye), as well as quarantine species (Rhaponticum repens, ambrosia, dodders and broomrapes). Subsequently, dicotyledonous plants are supplanted by perennial grasses, and abandoned lands turn into uncultivated deposits [1-3]. On lands left out of agricultural use, there is a noticeable change in soil properties [4-6]. All agrochemical parameters of deposits have a lower value than arable land. On abandoned fields, along with a decrease in nutrients in the soil, there is a change in the water and air regime [8], which makes it difficult to process the soil [8-10].

Thus, when studying the agro-ecological state of the lands of the Russian Federation left out of agricultural use, it was found that in almost all soil-climatic zones of the country, weedy land for 10-15 years is overgrown with wild, weed-field vegetation with an increase in the proportion of dangerous perennial weeds and shrubs and woody shoots up to 1-1.7 m high [2, 3]. The presence of tall vegetation cover not only complicates the conduct of mechanical tillage, but also requires large amounts of energy [11, 12]. Obviously, the introduction of abandoned fields for the production of agricultural products is an urgent national economic problem.
Mechanical treatment of abandoned fields includes the initial shredding of vegetation with disc harrows [16-18], and then plowing with general-purpose plows or special plows. But according to agrotechnical requirements, disc harrows work effectively with a height of vegetation and crop residues of no more than 25 cm. With a considerable height of vegetation reaching 1-1.7 m, disc harrows are not operational. Also known plows provide high quality tillage only at a height of stubble and herbage of no more than 25 cm. With a height of grass over 25 cm, the plow bodies are clogged with vegetation located on an abandoned field. Thus, the process of main tillage stops.

It follows from the energy intensity indicators that the energy intensity of tillage with plows is almost two times higher than the energy intensity of tillage with disc harrows, and the technological processes they perform do not differ in principle, but only in the depth of tilling.

The technological process of the main tillage with known plowshare plows is presented in the following diagram (Figure 1).

Figure 1. Process flow diagram of the main tillage with known plows: a – tillage depth; b – the width of the plow body; c – thickness of the plow sole.

On the one hand, the technology of tillage with plows includes cutting, crumbling, circulation of crushed soil and embedding stubble and plant residues not more than 25 cm high into the treated soil layer [18]. On the other hand, when processing abandoned fields with a height of vegetation of more than 25 cm, the technologically known main tillage process will be disturbed. This raises a scientific problem to develop a technological process for the treatment of abandoned fields and a working body for its implementation, which performs processing with minimal energy costs, high agrotechnical indicators and eliminates the technological operation of disking soil.

2. The object and method of research
The technological process of main tillage of abandoned fields, performed by plows with new working bodies, is taken for the object of the research. The technical characteristics of plows for soil tillage PBC-3 and PBC-5 are presented in table 1.

| Indicator                                      | PBC-3  | PBC-5  |
|------------------------------------------------|--------|--------|
| Aggregated with tractors of a traction class   | 3–4    | 5      |
| Operating speeds, km / h                       | up to 15 | up to 15 |
| Working width, m                              | 2.4    | 4.0    |
| Overall dimensions, mm                         |        |        |
| length                                         | 3100   | 4100   |
| width                                          | 2800   | 3800   |
| height                                         | 1800   | 2000   |
| Weight kg                                      | 845    | 1440   |
| Number of working bodies, pcs                  | 3      | 5      |
| Width of the working body, mm                  | 800    | 800    |
| The distance between the working bodies on the timber, mm | 970    | 970    |
| The distance between the toes of the workers along the plow, mm | 670    | 670    |
| Height from the reference plane of the working bodies to the frame, mm | 720    | 720    |
The depth of tillage was determined by the method of transverse profiling. The quality of embedment of vegetation located on the surface of the field was determined by its mass.

The crumbling of the soil was determined by samples taken at four points of the site (two in the direction of travel of the unit, two - in the opposite direction).

Soil hardness was determined using a Revyakin hardness tester. To determine the energy indicators, the IP-238 small-sized portable information and measuring system was used, intended for measuring, analyzing, storing and displaying the parameters that determine the operational and technological indicators of tractors and agricultural machinery. Resistance strain gauges installed on the leading axes of the T-150K tractor were used as sensors of power parameters.

3. Results and discussion
To solve the scientific problem, a technological process for the main tillage of abandoned fields was developed (Figure 2).

![Figure 2. Flowchart of the main tillage of abandoned fields: a) loosening the soil layer F to a depth a; b) movement 0.5F from position 1 to position 2; c) movement of high stem plant residues 4 to furrow 3 and cross sections 0.5F₁ and 0.5F₂ to furrow 3; d) movement of part of the section 0.5F₁ to position 5 and section 0.5F₂ to position 6; e) movement of plant residues of reservoir sections 0.5F₃ and 0.5F₄ to position 8.](image)

At the first stage (Figure 2a), the soil layer F is loosened with section a×b. At the second stage (Figure 2b), the loosened layer is divided in half, that is, 0.5F₁ and part of the layer with 0.5F₂ section moves from position 1 to position 2. Then half of the sections of F₂ and F₁ layers are simultaneously moved to the resulting furrow 3 and tall stem plant residues 4 of these sections, in the sequence: - first 0.5F₁ to position 5, then 0.5F₂ to position 6 (Figure 2d).

Further process repeats. In contrast to the known technology [16] (Figure 1), dividing the initially loosened volume into two parts and the presence of ridges 7 (Figure 2e) located at the bottom of the arable layer under cultivation will ensure the best turn of the arable layer being treated and the vegetation embedded cultivated arable layer, as well as will increase the width of the plow.

It is known [11] that due to the implementation of the stress-strain state of the arable layer, which is formed as a result of pure shear, the traction resistance of the working body can be reduced. This condition...
of the arable layer arises when the conical working surface interacts with the arable layer, that is, the working surface of the plow body, which interacts with the arable layer, must have the shape of a conical surface.

Using the scheme (Figure 2) of the technological process of the abandoned field and the conditions for the realization of the net shift, a new working body was developed, the scheme of which is shown in Figure 3

![Figure 3](image)

**Figure 3.** Scheme of the new working body for processing abandoned fields: 1 – cultivator point; 2 – shellboard; 3 – stilt.

As a result of theoretical studies, the main parameters of the new working body were determined: $a_{\text{max}}$ – maximum depth of tillage, $a_{\text{max}} = 35$ cm; $b$ – the width of the grip on the neck, $b = 0.5$ m; $l$-length of the neck, $l = 0.5b$. At the same time, to study the degree of embedding of tall plants of an abandoned field, two types of shellboards were installed on the working body. Conditional mark of the hull with an extended blade is KBK-80, and of the hull with a modified configuration of the crop edge blade is KBK-80-01.

On the basis of the scheme of the new working body, the PBC-3 and PBC-5 plows were developed for coupling with tractors of class 3 and 5 with a working width of 2.4 and 4.0 m.

Studies of the technology and plow for processing abandoned fields were carried out on homogeneous sites according to the type and mechanical composition of the soil - ordinary medium loamy chernozem with the microrelief of a weak and moderate character. The relief of the abandoned field was flat, with a slope of up to 4°. The height of vegetation varied by agrofone from 9.5 to 83.8 cm. The weight of vegetation on one square meter ranged from 439 to 780 g. In summer, the units worked on the soil with a hardness of 2.7-3.8 MPa and humidity of 14.9-19.1%. In autumn period, all the arable layers: 0-10, 10-20, 20-30 cm had high humidity from 31.5 to 32.5%, and hardness 0.7; 1.0; 1.5 MPa respectively.

Agrotechnical evaluation of the efficiency of use of the arable unit T-150K+PBC-3 and K-701+PBC-5 was carried out at depths of 23.2-28.7 cm. The standard deviation of the depth from the established one was ± 1.3-6 cm, and did not exceed permissible requirements (± 2 cm). The deviation of the working width from the constructive width of the aggregates did not exceed ± 10%, even when tilling the soil with high humidity. Based on the analysis of waste treatment of soil with low humidity in terms of the quality of crumbling, it was established that the fractional composition with a size of less than 50 mm has a range from 40.0 to 85.6%.

The distinctive quality of the T-150K+PBC-3, K-701+PBC-5 units is a high degree of embedding of the plant mass. The vegetation was buried to a depth of 12.7-19.0 cm at 95.1-97.6%.

The ridge surface of arable land was 6.8-10.1 cm, which does not meet agrotechnical requirements of no more than 5 cm. The plugging of the working bodies of the plows with vegetation during plowing was not observed.
Figure 4 shows the tillage of a field overgrown with single and perennial tall weeds up to 1.2 m in height with T-150K+PBC-3.

In general, the tested PBC-3 and PBC-5 plows steadily performed the technological process of tillage of abandoned fields according to the main agrotechnical indicators, with the exception of the clumpiness of the arable land surface.

![Figure 4. Dump processing of an abandoned field with a T-150K+PBC-3 unit: (a) view of the unit from the side of the field; (b) view of the unit from the furrow side.](image)

Figure 5 shows the dependence of the specific traction resistance of the investigated KBK-80 and KBK-80-01 buildings on the speed of movement.

![Figure 5. Dependence of the specific tractive resistance $K_{sp}$ of the investigated bodies on the speed of movement $v$: 1 - KBK-80; 2 - KBK-80-01.](image)

Analyzing the specific tractive resistance of bodies, it can be concluded that the pattern of change in specific tractive resistance has the same character.

The energy assessment showed that the technological process of dumping the soil of an abandoned field with the T-150K+PBC-3 unit equipped with the KBK-80-01 body is less energy-intensive, the specific energy consumption was 33.7 - 40.5 kW·h/ha.

The distinctive quality of the unit with the PBC-3 and PBC-5 plows is a high degree of embedding plant mass and crop residues, the ability to embed tall, double-stalked plant residues obtained during operation of the K-701 + PBC-5. With a height of crop residues of 47.6 to 100.4 cm and high soil moisture, the new unit plows them under by 98%.

A comparative operational assessment of the units consisting of a T-150K tractor with a PLN-5-35 serial plow and a T-150K tractor with a developed PBC-3 plow are presented in Table 2.

Analysis of the table shows that the reduction in the specific energy consumption of the arable unit equipped with a PBC-3 plow compared to PLN-5-35 was 21.7%, hectare fuel consumption by 10.0%, while the hourly productivity of the arable unit increased by 11.1%, and the quality of stubble seeding increased by 14.0%.
Table 2. Operational and technological indicators of plows PBC-3 and PLN-5-35.

| Indicator                          | PBC-3            | PBC-5            |
|-----------------------------------|------------------|------------------|
| Soil moisture,%                   | 32.3-35.9        | 32.3-35.9        |
| Soil hardness, MPa                 | 0.7-1.3          | 0.7-1.3          |
| Height of crop residue, cm        | 27.0             | 27.0             |
| Depth of processing, cm           | 26.6             | 25.5             |
| Coverage,  m                      | 3.2              | 1.9              |
| Driving speed, km/h               | 8.2              | 7.8              |
| Standard deviation of depth, ± cm | 1.2              | 1.8              |
| Soil crumbling,% fractions up to 50 mm | 85.6          | 89.6             |
| The degree of stubble termination,% | 98.9          | 85.0             |
| Stubble embedment depth, cm       | 7.4              | 12.6             |
| Traction resistance, kN           | 21.4             | 20.6             |
| Specific traction resistance, N/cm² | 4.15            | 4.19             |
| Specific energy consumption, kW•h/ha | 33.7          | 43.0             |
| Productivity per 1 h, ha          | 1.8              | 1.6              |
| Per hectare fuel consumption, kg/ha | 13.5          | 15.0             |

4. Conclusion

The problem of restoring abandoned fields can be solved through the use of new tillage technology, which is carried out by the developed working body and differs from the known dump processing by a rotary dump plow. Developed working body consists of a rack, on which a cultivator point and a shellboard are installed. To reduce the energy intensity of tillage, the cultivator point is made of a convex shape, which ensures the stress-strain state of the arable layer due to shear displacement. On the basis of this working body, PBC-3 and PBC-5 plows were created, providing 98% vegetation incorporation with a height of more than 25 cm located in an abandoned field to a depth of 7-10 cm, which eliminates the use of disk vectors in the technological plan. Also, according to the operational and technological indicators, the proposed plows, as compared to the serial plows PNL-5-35, PNL-8-40, PNI-8-40, provide improved performance and reduced fuel consumption. At the same time, new plows are not clogged with vegetation and reduce the cost of arable work by 10.7%. The developed technology of restoring abandoned fields in comparison with the proposed method allows reducing the energy consumption of soil tillage by 50%, while, according to research, the depth of vegetation incorporation by 7.0-8.0 cm ensures effective decomposition of plowed plants.

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