MOLDBOARD SMOOTH PLOUGHING FOR CONSERVATION OF SOIL FERTILITY IN ARID REGIONS

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ABSTRACT

In the paper, the results of theoretical studies on the effect of soil fertility on the yield of agricultural crops and the structure of the soil fertility management system are presented. The causes of loss of humus in arable soils are the imbalance in the structure of crop areas by the mass of plant residues entering the soil; increase in mineralization of organic matter because of intensive cultivation and increasing the degree of aeration of soils; soil deflation and erosion. In arid conditions, the development of root systems largely determines the formation of the aboveground biomass. Creation of conditions for a powerful development of the root system of plants is one of the important methods of combating drought, a mean of increasing the yield of crops and the reproduction of organic matter in the soil. In solving the problem of a deficit-free humus balance in the arid steppe region of Western Kazakhstan, it is crucial to leave the straw of cereal crops on the field, which is introduced as a mulching material that reduces evaporation, improves moisture absorption and soil moisture; improves the water and temperature conditions of the soil, reduces leaching of nitrate N; replenishes the organic matter of the soil and increases the yield from 10 to 40%. The proposed moisture regulating system with a surface mulching layer, an intra-soil structural layer and a system of vertical and horizontal bond channels provides a lesser degree soil frosting than that treated with large lumps (more than 5 cm) or untreated; prevents volatilization of inter-soil and subsoil moisture. Mouldboardless ploughing of soil to different-depth with the developed ripper creates conditions for the prevalence of humification processes over the mineralization of humus; regulates the content and reserves of humus and productive moisture in the soil; controls soil fertility and soil moisture, and increase the productivity of the unit up to 30%, reducing the fuel consumption by 20% due to the reduction of the length of idle moves and decreasing of the of traction resistance. Accumulation of moisture in the arable horizon of 0-30cm is 7-8% more than when for mouldboard ploughing, surface and flat cutting, while the yield of crops is higher for 0.76-1.37 t/ha as compared to the existing technology.

Keywords: soil fertility; soil moisture; organic matter; mulching; mouldboard ploughing.

INTRODUCTION

The competitiveness of Kazakhstan wheat and its export potential depends on the quality, and the efficiency of its production from the level of profitability. Since the beginning of the 1990s, during the reform of the region's agriculture, the volume of grain production and grain yields fell below the potentially possible for 2.5-4 times and for 1.5-2 times, respectively, and the quality of grain produced deteriorated (Agriculture, 2004).

Yield of agricultural crops depends on many factors, among which the soil is given a special place, since all other factors are realized in the crop through the soil. Soil is an instrument of production; its productivity is directly related to its fertility and crop yield (Konstantinov et al., 2011).

Intensification of agricultural production contributes to fundamental changes in the natural fertility of soils. There are two oppositely directed trends in soil fertility changes:

a) a systematic decrease in the humus content, deterioration of physical properties of the soil, and the processes of technogenic soil degradation are intensively developing, such as erosion and compaction of soils;

b) on the other hand, the rational use of soils, the use of appropriate cultivation systems and fertilization of crops, contribute to the processes of increasing soil effective fertility - the content and degree of mobility of nutrients increases, the rate of humus mineralization are slowed down.

The transformation of the fertility level is reflected in the form of dynamic models for a given crop yield. Component parts of the models are soil regimes, which are estimated by the main elements of fertility: the content of mobile forms of nutrients, reserves of productive moisture, air capacity, aeration level and seasonal dynamics of soil temperature.

Management of changes in elements of soil fertility should include the use of methods that eliminate completely the processes of soil degradation and accelerate the stabilization processes of soil properties and regimes that determine a high level of effective fertility.

The general structure of the soil fertility management system is shown in Figure 1. All the components of the functional and structural parts of the soil are closely interrelated. However, in the practical agriculture, the main attention is paid to the optimization of the functional part, and, to a lesser extent, to the preservation and directional transformation of the soil system. At the same time, applied fertilizers and agrotechnical methods are evaluated from the point of view of obtaining a high yield, which can lead to spontaneous formation of the soil “body”, with eventual degradation.

Among the indicators of the structural part of the soil model, most attention is paid to humus. In conditions of inadequate supply of soils with nutrients, the correlation coefficients of the yield of cereal crops and the humus content in the steppe are 0.76-0.84. The main criterion for regulating the humus condition of soils is the determination of its lower boundary, below which the optimization of soil regimes and the stability of yields are difficult to achieve.

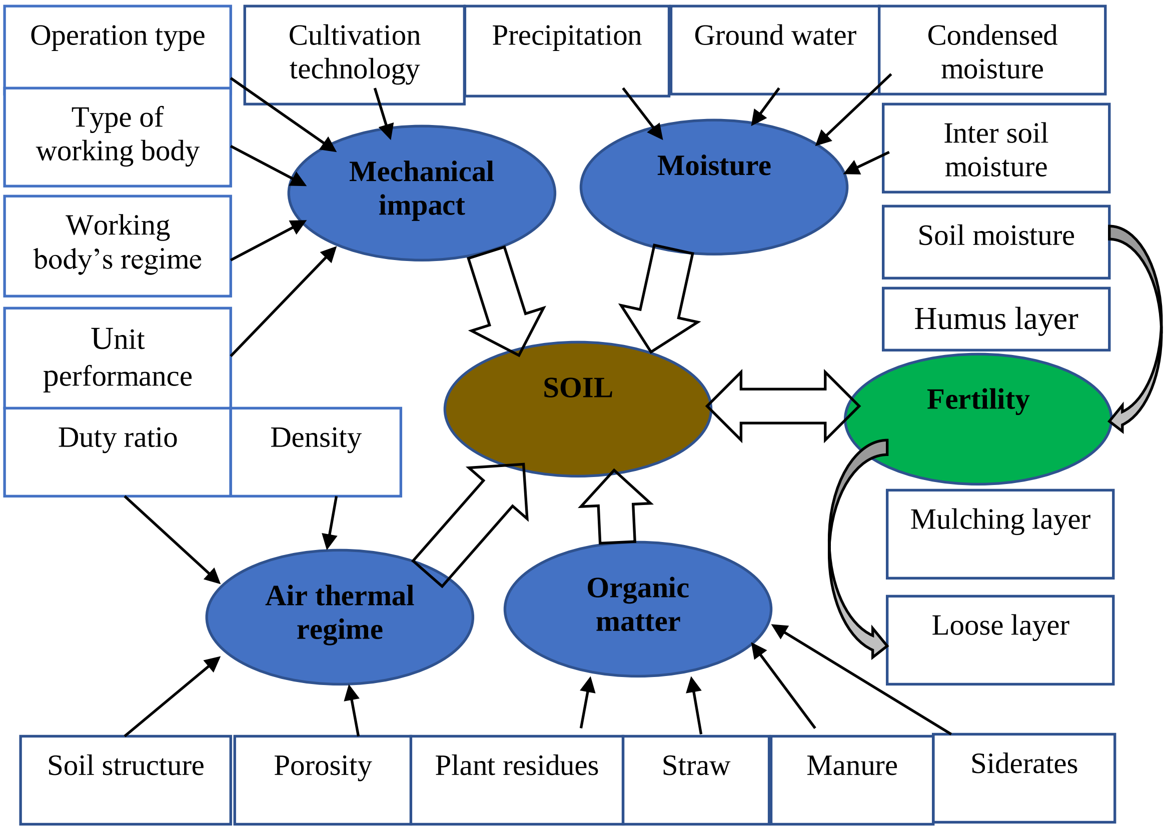


Figure 1. Functional scheme of the system "Soil - Soil-Processing unit - Effective fertility"

The main causes of loss of humus by arable soils are:

- Imbalance in the structure of arable areas by the mass of plant residues entering the soil;
- Increased mineralization of organic matter because of intensive processing and increasing the degree of aeration of soils;
- deflation and erosion of soils.

Orlov (1998) emphasizes that the losses of humus content are, most likely, a consequence of not generally economic activity, but theoretically poorly designed human activity. To increase humus and improve the water-physical properties of soil, it is preferable to prolong the processes of decomposition of soil organic matter.

One of the main sources of organic matter in agriculture are the root and stubble plant residues of crops. They fertilize the soil every year after harvesting crops, their nutrients are in the form of organic compounds and easily mineralized, which contributes to effective soil fertility. Addition of stubble-root residues of cultivated plants does not require additional costs and they are distributed evenly in the soil.

In arid conditions, the development of root systems largely determines the nature of the formation of the aboveground mass of plants. Creation of conditions for a powerful development of root system of plants is one of the important methods of combating drought, a mean to increase the yield of crops and the replenishment of soil organic matter (Table 1).

Table 1. Balance of energy potential of soil in agrolandscapes of Western Kazakhstan, thousand MJ per 1 ha of arable land

Periods, years	Loss of soil energy in the form of mineralized soil organic matter	The input of energy into the soil in the form		Balance (-; +)	Required amount of straw, tons
		Plant residue	Organic fertilizer		
1960-1969	20.3	5.1	0.1	-15.1	0.81
1970-1979	20.2	5.8	0.2	-14.2	0.76
1980-1989	20.5	6.2	0.3	-14.0	0.74
1990-1999	20.0	5.9	0.3	-13.8	0.73
2000-2009	18.9	4.8	0.1	-14.0	0.74

In solving the problem of a deficit-free balance of humus in the arid steppe region of Western Kazakhstan, the leaving the straw of cereal crops on the field is crucial. Organic matter of straw is evaluated as a source of nitrogen and ash elements for plant nutrition, as an energy source for microorganisms, a source material for the formation of humus. According to Viurkov (2006), 0.4 t/ ha of straw of grain crops returns to soil: 3200 kg/ha of organic matter; 14-22 kg/ha of N; 3-7 kg/ha P; 22-35 kg/ha K; 9-37 kg/ha Ca; 2-7 kg/ha Mg. In addition, grain straw contains trace elements: S, B, Cu, Mn, Zn and others. Leaving of straw on the field is a resource-saving technology in growing of cereals, which reduces the costs of collecting and transporting the non-grain part of the crop from the field (65% of the total cleaning costs).

The straw added as a mulching material reduces evaporation, increases the rate of moisture absorption and soil moisture, improves water and temperature conditions of the soil, reduces by 10-14 kg/ha leaching of nitrate N, replenishes the organic matter of the soil and increases the yield from 10 to 40%. Such straw decomposes faster without significant accumulation of products harmful to plants and without adverse effect.

Thus, in the natural conditions of the dry steppe zone of Western Kazakhstan, the maximum use of straw for the cultivation of grain crops, along with traditional organic fertilizers: manure and siderates - should be considered as a promising measure for the reproduction of soil fertility that fully meets the principles of biological and resource-saving agriculture.

An important factor in obtaining high and stable yields on the soils of Western Kazakhstan is the optimization of the water regime. This is achieved by a complex of technological methods of accumulation and preservation of soil moisture. It is necessary to develop technological methods for moisture-saving soil cultivation based on analysis of input and output components of the water balance, as well as information data. The water balance of the actual moisture reserve in the soil is a part of the atmospheric precipitation entering the soil, and the rest is expended on runoff, evaporation and seepage.

The actual reserves of soil moisture throughout the year:

$$W_{д.з.в.} = W^{ло}_{д.з.в.} + W^{о.i}_{д.з.в.} + W^{з.i}_{д.з.в.} + W^{в.i}_{д.з.в.} + W^{л.i}_{д.з.в.}, \quad (1)$$

were, $W^{ло}_{д.з.в.}$ - initial actual moisture after harvesting; $W^{о.i}_{д.з.в.}, W^{з.i}_{д.з.в.}, W^{в.i}_{д.з.в.}, W^{л.i}_{д.з.в.}$ - the actual moisture reserves, respectively, in the autumn, winter, spring and summer periods.

The moisture available to plants:

$$W_{д.р.в.} = W_{д.з.в.} - W_{пр.св.}, \quad (2)$$

where $W_{пр.св.}$ - firmly bound moisture.

In general, firmly bound moisture for the year seasons is a constant value.

Analysis of equation (2), taking into account the statistical estimates of the distribution of precipitation over time and year cycles, allows in this model to predict the runoff, evaporation and percolation of moisture, and also its retention in the soil in the form available and unavailable to plants.

Considering the above arguments, equation (2) takes the form:

$$\begin{aligned} W^{о.i}_{д.р.в} &= W^{ло}_{д.з.в.} + W^{о.i}_{а.о.} - W_{пр.св.} \\ W^{з.i}_{д.р.в.} &= W^{о.i}_{д.з.в.} + W^{з.i}_{а.о.} - W^{з.i}_{сток} - W^{з.i}_{исп} \\ W^{в.i}_{д.р.в.} &= W^{з.i}_{д.з.в.} + W^{в.i}_{а.о.} - W^{в.i}_{сток} - W^{в.i}_{исп} - W^{в.i}_{прос} \\ W^{л.i}_{д.р.в.} &= W^{в.i}_{д.з.в.} + W^{л.i}_{а.о.} - W^{л.i}_{исп} \end{aligned} \quad (3)$$

Based on the above, the coefficient of use of atmospheric precipitation is determined as:

$$\eta_{иао} = \frac{\sum W^{ni}_{а.о.} + W^{ло}_{д.з.в.} - W_{пр.св.} - W^{з.i}_{сток} - W^{з.i}_{исп} - W^{в.i}_{прос} - W^{в.i}_{сток} - W^{в.i}_{исп} - W^{лi}_{исп}}{\sum W^{ni}_{а.о.}}, \quad (4)$$

where $\sum W^{ni}_{а.о.}$ is total amount of precipitation for the periods of the year.

The autumn basic tillage should include all the necessary elements: the surface layers must be treated with the creation of a mulching layer. Additional mulching is provided by spreading straw chaff, manure or other mulch on the surface of the field (Yesenzhanov, 1998; Sdobnikov, 1973; Olson 1977). The subsoil tillage layer is treated to obtain the soil clots of 1-3 cm in size to increase its moisture retention properties. With such a macrostructure, the interaggregate pores are maximally filled with moisture, and the moisture does not flow down with gravitational forces, but is retained by the capillary and sorption forces of interaggregate pores and microaggregate capillaries. The macroaggregate moisture under the capillary forces penetrates soil lumps, fills capillaries and weakens the connection between soil microaggregates. Soil lumps are "restructured" and the distribution of soil moisture becomes more uniform, i.e. there is a structure-forming effect. When the moisture is excessive the small soil microaggregates, the most valuable agronomic, are washed into the subsoil under the effect of vertical water runoff.

To increase the accumulation of moisture in the soil, it is proposed to create a horizontal interlayer of straw of 2-3 mm length and 3-5 cm thick in the root layer. Degradation of water in the soil is better in horizontal intrasoil cracks. Absorption of water in soil goes better in horizontal intrasoil crevices. Therefore, to create conditions for intrasoil capillary humidification, it is necessary to have a network of vertical and horizontal channels - links along layers. In the subsoil, this system is necessary to have in conditions of excess surface precipitation and they must be stored in the subsoil, at the right time (growth, flowering, earing) and fed via the channels up to the crop roots. In conditions of drought at lack of moisture in the soil layers, in the subsoil humidity increases with increasing the depth. Creating in the soil layers of horizontal channels, filled with special storage, you can accumulate moisture. Creating horizontal channels, filled with special moisture accumulators allows to accumulate moisture in soil. Lifting the accumulated moisture upward along vertical communication channels is carried out under the influence of a natural thermocapillary effect. The main goal is to ensure the construction of vertical slots, i.e. connections in the form of cellular capillaries, and the horizontal slots - accumulators should provide maximum water retention as intermediate moisture accumulators. The proposed moisture-accumulating, moisture-regulating system increases the absorption of surface moisture into the soil and subsoil, reducing the surface runoff.

This system connects the soil and subsoil with the atmosphere, activates the vital activity of living microorganisms' due to the improvement of the water and air regime of the soil and subsoil.

In the presence of the proposed moisture regulating system with a surface mulching layer, an intrasoil structural layer and a system of vertical and horizontal bond channels, the soil freezes to a lesser degree than the soil with coarse lumps (greater than 5 cm) or non-tilled. The transfer of moisture to the surfaces of evaporation that meets the atmosphere, under the influence of the gradient, occurs mostly in the compacted soil along the capillaries. With a significant loss of moisture, cracks are formed, like the formation of cracks in drought. The presence of cracks or large inter-aggregate pores increases the contact surfaces with the atmosphere, and the freezing out due to moisture gradient (from the soil to the atmosphere) increases. The presence of interaggregate pores between soil particles of 1-3 cm disrupts capillary bonds, the moisture and air are trapped in them, and a type of capillary connection occurs.

The surface mulching layer also creates an air layer, which reduces the movement of moisture. Vertical slits move moisture towards a decrease in moisture gradient, that is, from the subsoil to the soil layer. Vertical cracks in the soil should be closed to cover the connection with the atmosphere and to prevent volatilization of subsoil and subsoil moisture Yesenzhanov, 1998; Salnikov 1973).

Soil cultivation in modern agriculture is a universal means of impact on soil, plants and the environment.

A frequent phenomenon is degradation of soil, that is, the destruction of its structure, expressed in a decrease or loss of the ability to perform the functions of the reproduction of resources and socio-economic functions. A special role in the physical degradation of soils plays mechanical tillage, wheeled vehicles, harvesters. Kant (1980) notes that "mouldboard ploughing is one of the most difficult interventions in the natural structure of the soil, whose negative consequences are difficult to foresee for a long time". Therefore, mouldboard ploughing should be replaced by other means of soil cultivation.

Rejection mouldboard ploughing and deep intensive tillage, preservation and creation a mulching layer on the surface, are elements of soil cultivation technologies that provide conditions for expanded reproduction of soil fertility and yield growth.

The different-depth mouldboardless cultivation promotes a more balanced process of decomposition and synthesis of humus on all soil horizons and a reduced losses of nitrate N. The mouldboardless cultivation together with organic fertilizers promotes humification process versus mineralization of soil humus.

Thus, in the new economic conditions, successful farming is possible only with the extensive use of biological methods for improving arable land. This will reduce the losses of soil fertility and yield caused by limited application of manure and mineral fertilizers, eliminate the migration of mobile elements into deep soil layers and reduce soil degradation.

Therefore, the development of a set of techniques and means of mechanization to optimize the elements of soil fertility requires a systematic approach that combines both tactical and strategic targets for obtaining high yields, and a targeted reduction in the intensity of humus mineralization, preservation and restoration of soil fertility.

As a result of the synthesis of the optimal structure of soil-protective, water-saving and energy-saving technological methods and the mechanization of soil cultivation, the synthesis of layout structures of parameters of soil processing units to provide the technological and energy stability, the following developments were proposed and partially tested Yesenzhanov, 1998; Konstantinov et al., 2009; Konstantinov et al., 2009b; Nuralin and Yesenzhanov 2010; Nuralin et al., 2010):

1. Setting up the vertical slots-channels and the horizontal interlayers to increase the accumulating capacity of soils.
2. Application of hydrophilic and hydrophobic ameliorants for regulating the water-air regime of soils
3. Creation of a water-saving mulching layer by loosening the field surface and applying mulch materials (manure, strawchip, etc.)
4. Creation of a uniform agronomic valuable macrostructure in the root zone with the sizes of soil lumps 1-3 cm, and optimal density for the growth of crops.
5. Technological methods and technical means of cultivation of soils with insufficient moisture by reducing moisture loss via evaporation and condensation of vaporous moisture in compacted soil layers.

The results of the experimental evaluation of the tested designs with the synthesized structures and parameters are given in the sequence indicated above:

1. Experimental evaluation of the vertical slots-canals was carried out by plows with soil-tillers, flat-cutters and scrapers. During the development of the constructive scheme of flat-cutters-scrapers, the synthesized structures of technological methods and technical means of mechanization of soil cultivation were used, ensuring the preservation of fertility, the maximum accumulation of moisture in the soil and its effective use by agricultural crops.

The creasing, carried out simultaneously with the soil cultivation, increases the accumulation of moisture in the soil, improves the moisture absorption, reduces the surface runoff of meltwater and rainfall. The experimental evaluation was made by the moisture absorption coefficient of $К_{вп}$* $К_{mc}$

The influence of soil tillage types on the value of Kmc was observed:

- $K_{mc} = 0{,}38 \div 0{,}45$, at mouldboard plough;
- $K_{вп}^{бо} = 0{,}38 \div 0{,}52$, at mouldboardless plough;

- $K_{вп}^{но}=0,35$ on the plots non-tilled in autumn.

The effect of slotting on the value of Kvp at a depth of the main till of 20 cm is observed:

- $K_{вп}^{о+щ}= 0,47 \div 0,66$, - at mouldboard plough;
- $K_{вп}^{бо+щ}=0,51 + 0,69$, at mouldboardless plough;
- $K_{вп}^{но+щ}=0,52$ on the non-tilled plots only slotting was done

Slotting gives an increase in the value of Kvp:

- On non-tilled plots $\Delta K_{вп}^{но}=0,17$;
- at mouldboard plough $\Delta K_{вп}^{о} =0,115$;
- at mouldboardless plough $\Delta K_{вп}^{бо} =0,25$.

The obtained data indicate that the deep sub-soil cut and non-tilled plots showed increased absorption of melt water into the soil and have a high Kvp value. While, the main mouldboardless plough with slotting increases the absorption coefficient by $\Delta K_{вп}^{бо+щ} = K_{вп}^{компл} + K_{вп}^{но}= 0,69$.

Comparing the coefficients $K_{вп}^{но} =0,35$, $K_{вп}^{компл} =0,34$, we can note an increase in moisture reserves in the soil for two times due to a reduction in the outflow of melt water and better absorption into the soil.

2. An experimental assessment of the straw chaff application 2-3 mm to create a horizontal layer was carried out on a portable soil channel. A straw layer 3-5 cm thick with a straw particle size of 2-3 mm was set up in a soil channel at a depth of 20 cm. Above that layer the soil, both mouldboard and mouldboardless treated was placed. The control treatment of the experiment was without setting up a horizontal layer. Then the soil was wetted to the value of the lowest field moisture capacity (LWC) and exposed to the summer environment due to the lack of an artificial climate chamber.

Experimental characteristics:

The soil was light-chestnut calcareous. Daily temperatures 34-35°C, night temperatures 20-24°C.

The least moisture capacity (LMC) in the experimental plots was: $LMC_{0\text{-}50}^{on} =158$ *mm* in 0-50 cm; $LMC_{50\text{-}100}^{on} =290$ *mm* in 50-100 cm; and in the control plot: $LMCB_{0\text{-}50}^{к}= 150$ *m* in 0-50 cm; $LMCB_{50\text{-}100}^{к}=280$ *mm* in 50-100 cm.

The productive moisture (PM) in the experimental plots was $PM_{0\text{-}50}^{on} =105$ *mm* in 0-50 cm; $PM_{50\text{-}100}^{on} =172$ *mm* in 50-100 cm; and in the control plot: $PM_{0\text{-}50}^{к}=87$ *mm* in 0-50 cm; $PM_{50\text{-}100}^{к} = 170$ *mm* in 50-100 cm.

The creation of a horizontal layer 3-5cm thick from a straw stripe with a size 2-3 mm at a depth of 20 cm increases the LWC value in a meter layer by 18 mm, that is, $\Delta LMC_{0-100}^{on} = 18\ mm$ and the productive moisture in a meter layer by 20 mm, that is $\Delta PM_{0-100}^{on} = 20\ mm$.

The change in the amount of evaporated moisture in time is shown in Figure 2. The horizontal 3-5 cm straw interlayers with straw sized to 2-3 mm reduce the loss of soil moisture via evaporation. The length of the straw particle is taken in proportion to the diameter of the cut that is 2-3 mm. This allows the largest wetting surface, a greater accumulation of moisture and a minimum loss of moisture by physical evaporation.

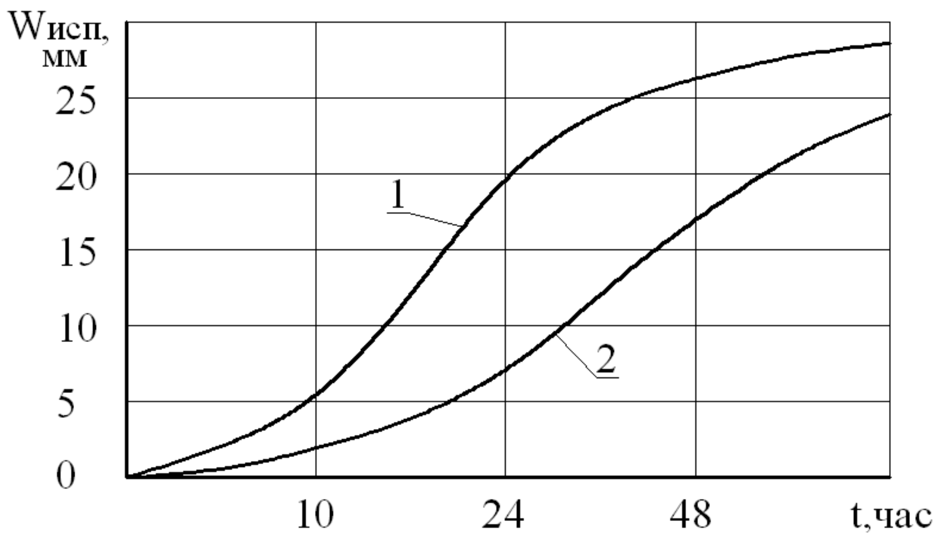


Figure 2. Dependence of evaporated moisture on evaporation time

1.Control without horizontal straw layer;
2. The plot with straw layer

3. An experimental evaluation of technological methods for creating a water-saving mulching layer by loosening the surface of the soil and mulching the surface of the field with a straw chuff was carried out in a series of laboratory experiments as described earlier. An estimation of soil crumbling was carried out with different options of arrangement of the working body. To automate the process of crumbling, to reduce metal consumption, it is recommended to use a rotary type working body. Admissible indicators for the crumbling of dry soil were obtained with the soil moisture, close to the wilting point W = 15-17%. Fractions of silty and a particle size > 10 cm were negligible, fraction of 5-10 cm was less than 20%. The results show that the treatment of dry soils by

active working bodies is equivalent to one pass of two double-row batteries of needle discs. The loss of soil moisture by physical evaporation in time is shown in Figure 3.

Treatment 1: With an optimal treatment of the soil surface, h=8 cm (crumbling - 75% size particles of 1-5 mm, curve 2; less than 20% of 5-10 cm, curve 3; and untreated control soil, curve 1).

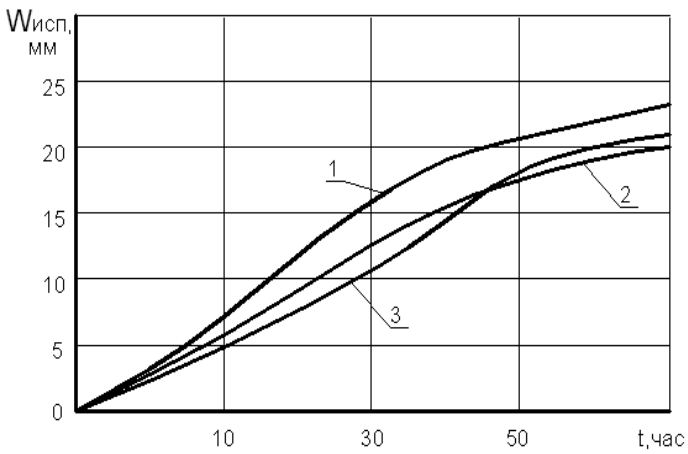


Figure 3. Dependency graph $W_{ucn}=f(t)$

1 - control
2 - treatment 2
3 - treatment 1

Treatment 2: Without mulching (curve 1) and with surface mulching with a straw chuff of h = 3 cm (curve 2).

The experiments showed:

- surface loosening to a depth of 8-10 cm effectively reduces the loss of soil moisture by physical evaporation, especially at the initial stages of the process;
- mulching with straw is effective for a longer period, because it reduces the soil temperature.

4. For the development of technological methods and technical means for processing "unripe" dry soils with insufficient moisture the theory of the condensation of vapor moisture - the inflow from deep moist soil layers into a compacted soil layer at a depth of 10-15 cm and a decrease of moisture evaporation by creating a loosened fine-lumpy surface structure on 8-10 cm depth due to rupture of capillary bonds between soil particles was applied.

Surface loosening was carried out by an aggregate to a depth of 8-10 cm with a disc machine. If the soil is excessively dry, then second, and sometimes third surface loosening is carried out. At the same time, the moisture state of the treated soil layer is constantly checked. With the relative "ripeness" of the soil after its "sweating", the main soil treatment with a deeper sclerosis - a soil dredger, was carried out with simultaneous rolling it up with rollers and loosening the surface of the field to a depth of 8 cm with needle discs. The loss of moisture from the soil by physical evaporation were:

• when ploughing immediately after harvesting of dry soil with insufficient humidity the losses were 50-70 mm;

• when applied the proposed technology the moisture losses were 22-55 mm.

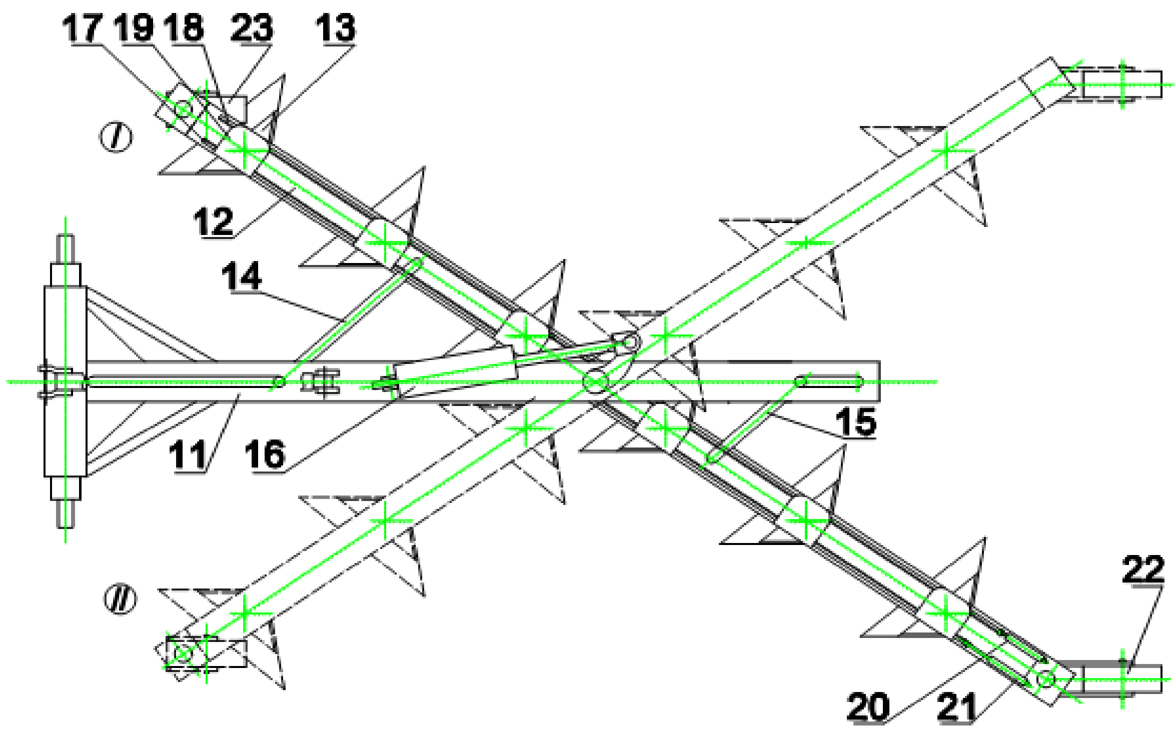
It was established that, in comparison with the control, the application of the proposed technology provides an average saving of 20 mm or more than 1/3 of the moisture, a reduction of traction resistance by 15-20%, a 10% reduction in fuel consumption, and a 12% increase in productivity.

6.The structures of water-saving, energy-saving and soil-protective technological methods and technical means of mechanization of soil cultivation, developed theoretically and experimentally, allow to propose a layout of a tillage unit consisting of a ripper for the basic tillage with replaceable working elements (for smooth ploughing).

The general arrangement of the six-hull plough ripper with the placement of the working bodies and the mechanism of their rotation, and the construction of the working body are shown in Fig. 4. (Innovative patent KZ 26192, 2012; Konstantinov et al., 2011; Patent for invention KZ B 22323).

The plough ripper works as follows. When the arable unit moves “forward”, the ploughed field is on the right as the machine moves, the working beam of the frame 12 is set to the right-turning position as shown in Fig. 4 by solid lines (position I). In the same position, the working elements are transferred by means of hydraulic cylinders 20 and 21. After the arable unit has reached the end of the field, the ripper is recessed and the unit rotates 180° along the loop circuit. At the same time, the working beam of the frame and the working elements are transferred by the hydraulic cylinders 16, 20 and 21 to the left-turning position, as shown in Fig. 2 with a dotted line (position II). When moving “reverse” the ploughed field is on the left during the movement.

For the universalization of the developed ripper, a tool combining deep loosening of the arable layer with cutting of the cracks in the bottom of the furrow and simultaneous insertion of a straw chuff into the gap is proposed (Fig. 5a). This operation improves the soil porosity at a depth of 30-35 cm, which contributes to a greater accumulation of moisture in the autumn-spring period. The technological scheme of the ejector type apparatus for applying the straw chuff is shown in Fig. 5б. The directional airflow created by the fan is fed through the nozzle into the mixing chamber, creating a certain discharge near the side walls. The crushed straw mass stored in the bunker, through the lateral channel enters the mixing chamber, then captured by the air flow and in the form of air-straw mass is fed along the flexible arm and along the channel into the slot formed by the knife-sclerosis (Fig. 5в). In the sole of the furrow of the working part of the ripper, a channel is formed behind the knife-slither, that conditionally divided into three horizons: 1-the horizon with the domination of loosened soil; 2-the horizon with loose soil with the maximum content of crushed straw mass; 3-the horizon of loose soil formed by the "restoring" sole of the slit after deformation by the toe of the knife.



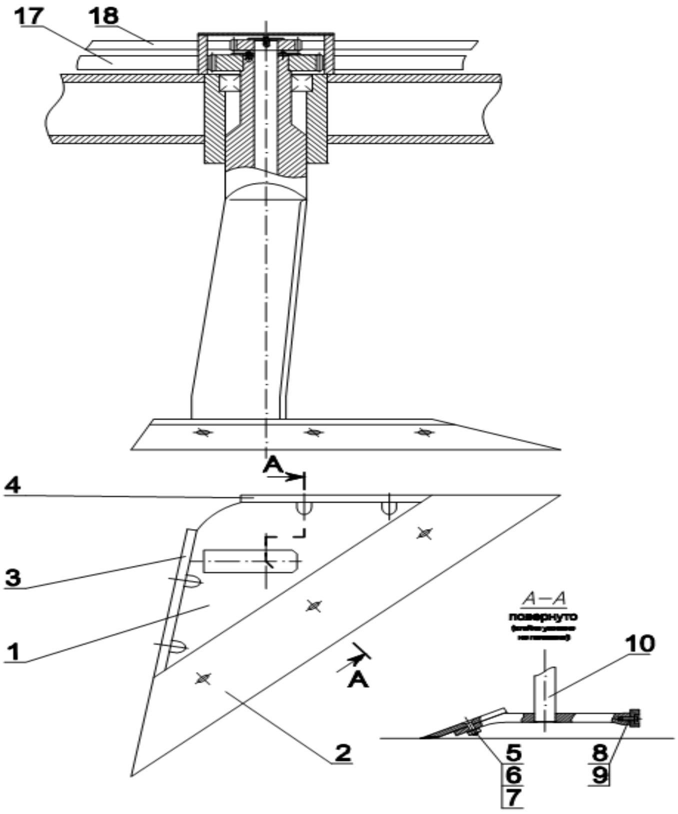


Figure 4. General arrangement of the six-hull plough ripper with swivel hulls for smooth ploughing

1. shoe; 2. blade; 3,4. field boards; 5,6,7. ploughshare bolts; 8,9. bolts with recessed heads; 10. axis; 11. horizontal frame beam; 12. working beam; 13. stand of working body; 14,15. streamers; 16, 20,21. hydraulic cylinders; 17,18. racks; 19. reducer; 22,23. support wheels.

The construction of the combined working tool, which performs deep loosening of the soil along the shuttle scheme with simultaneous splitting of the bottom of the furrow and subsoil application of the crushed straw mass (chuffs) into the cut slit, is shown in Fig. 6. The working tool, in addition to the usual rack and ripping body with two shovels, has a knife - a ripper, rigidly fixed on the rack and ensuring the cutting of the slot in the bottom of the furrow, a hollow duct for supplying airy straw to the formed gap. The chuff is fed by special flexible links due to the airflow created by the fan. The stock of the chuff is determined by its consumption (rate of application) and the length of the drive. There is a special bunker for loading the chuff. Feeding of a chuff in a certain amount to the working elements is carried out with the ejector type devices.

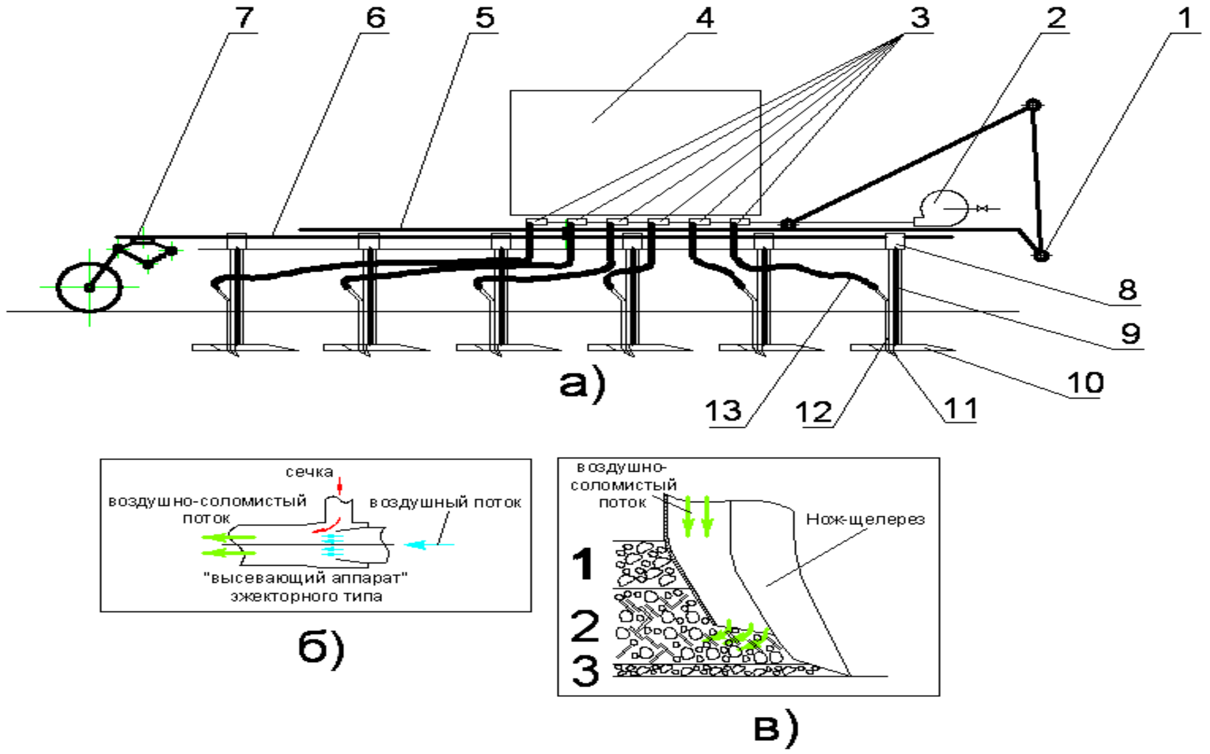


Figure 5. Schematic diagram of the tool

1. the system of hitching the body; 2. fan of "pneumatic sowing machines"; 3. ejector sowing apparatus; 4. hopper for cutting; 5. horizontal bar of tool; 6. working bar of tools; 7. rear support wheel with depth adjustment mechanism; 8. rack reduction gear for control of working organs into left and right regimes; 9. working tool stand; 10. working part of the ripper; 11. knife - slitter; 12. channel of supply of air-straw mass into the cut slot; 13. flexible hose for supplying air-straw mass

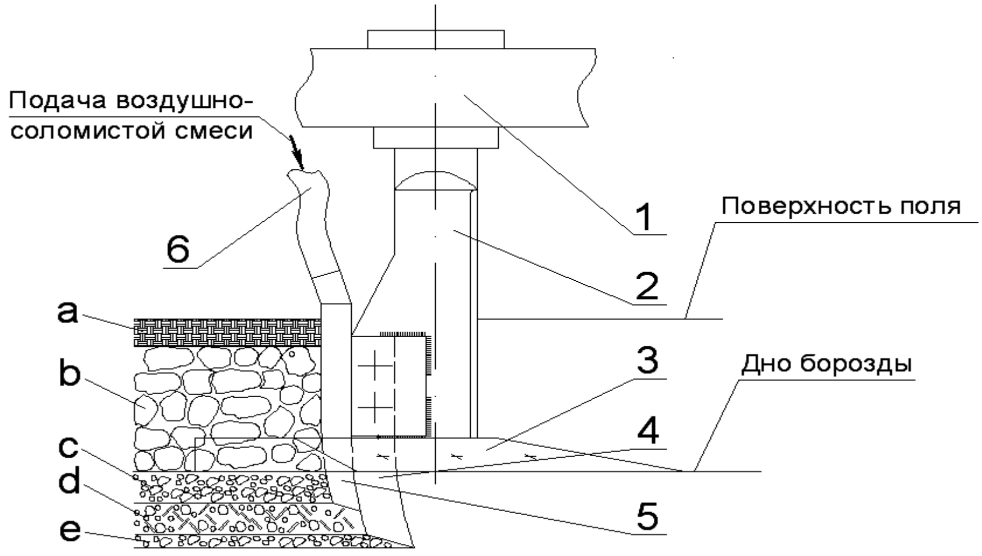


Figure 6. Schematic diagram of combined working tools.

1. working bar of the tool; 2. stand of the working body; 3. shovel of the working part of the ripper; 4. knife - a slitter; 5. channel of supply of air-straw mass into the gap; 6. flexible hose for supplying air-straw mass.

After the passage of the working body, the soil has a different degree of crumbling and condition. The horizon a - the top layer with stubble remains practically unaffected, except for the track of the passage of the stand. The horizon b - the main plough layer is crumbled due to deformation by the working body - the shovel. The degree of crumbling depends on the moisture content of the soil horizon. On the width of the working element, the ratio of the sizes of the cracks in the horizons c, d and e is an order of magnitude smaller than the total width of the working body.

CONCLUSIONS

1. Theoretical and experimental studies have established:

a). The development of a horizontal 3-5 cm interlayer of straw 2 to 3 mm size in root layer, with the size of macro- and micro-soil aggregates of 2-3 cm, ensures the condensation of vaporous moisture coming from deep layers of soil and increases the amount of productive moisture in a meter layer for 20 mm;

b). The provided loosened fine-clad surface structure by the proposed tools at a depth of 8-10 cm reduces evaporation of moisture due to rupture of capillary bonds between soil particles and retains soil moisture by an average for 22 mm;

2. The developed ripper for smooth ploughing in the arid zone of Western Kazakhstan provides options for the installation of adaptive working bodies (rhomboid, disc, bottomless) with a vertical knife for cutting slits and channels and provides an increase in the aggregate productivity up to 30%, reducing fuel consumption by up to 20% due to reduction of idle moves and the traction resistance. Loosening with experimental bottomless stands provides accumulation of moisture in the arable horizon 0-30cm for 7-8% more than with mouldboard ploughing, surface and flat cutting, while the yield of crops is higher for 0.76- 1.37 t/ha compared to the existing technology.

3. The developed combined working tool for mouldboardless loosening allows efficient use of atmospheric precipitation and reduces surface run-off. During autumn soil cultivation in conditions of arid region provides:

- creation of a system of channels-links along the layers that connect the soil and subsoil with the atmosphere at a depth of 35 cm and horizontal at 20 cm;

- mulching the surface of the field and filling vertical slots with a straw chuff with a size of 2-3mm.

These measures reduce the evaporation of moisture, soil freezing, increases the absorbing capacity of soil and provides additional moisture accumulation in the soil up to 30-50 mm and yield increase up to 20%.

- different depth soil processing by mouldboardless way with preservation of plant residues ensures the reproduction of soil energy up to 12% per year, reducing to 10-13% the total technological energy costs.

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