# Study on the development of a rotary soil softener

*Botirjon* Nishonov[1], *Abdukayum* Normirzaev[1], and *Mirzokhid* Tukhtabayev[1*]

[1]Namangan Engineering-Construction Institute, Islam Karimov avenue-12, Namangan 160103, Uzbekistan

**Abstract.** This article presents the technological working process of the rotary softener developed for the chisel-cultivator; results of experimental studies carried out to justify its parameters. The type of soil and its physic-mechanical properties are the main factors in the selection of the working bodies of the soil tillage machine and assessment of aggregate performance. The researches are carried out mainly in grassy, pale gray and barren soils, and the physic-mechanical properties of the soil in irrigated fields of the Republic of Uzbekistan have been sufficiently studied. However, in a short period of time, machines that can treat a large area with high quality and at the level of demand have not been created. In order to choose the optimal type of rotary softener, based on the physical and mechanical properties of the soil, rotors equipped with different types of blades were prepared and tested. A rotary tiller for a chisel cultivator was compared with a chisel tiller and leveler, and cost effectiveness, labor and operating costs were calculated.

## 1. Introduction

In Uzbekistan, consistent measures are being taken to develop the production of agricultural machinery, to increase the volume and variety of finished products for export, as well as to supply the agricultural sector with domestically produced machinery. However, the machines and devices created on the basis of these studies have achieved certain results [1,2] in agricultural production, there have not been enough scientific research works on the creation of combined technical tools for soil surface treatment [3,4], substantiating the parameters of their working bodies, and they have shortcomings from a technological and constructive point of view that are not widely used in production, and studies on their development and parameter justification have not been conducted enough.

Field relief, soil type and physic-mechanical properties are the main factors in the selection of working bodies of soil-cultivating machines and in evaluating performance of aggregates that process it [5,6,7].

Grassy, pale gray and barren soils are widespread in our republic. The total land fund is 39,807 thousand hectares. 2/3 of the total field area, i.e. 27,004 thousand hectares, corresponds to desert soils. The remaining part forms the eastern mountain and mountain slopes of the republic. 16.6 mln hectares of fields suitable for irrigation, currently 4.2 mln hectares of land are irrigated [4]. A number of scientists studied the physic-mechanical properties of the soil in irrigated fields and cotton-growing areas of our republic before planting [2,8].

One of the important problems in implementation of these tasks, including technical and technological modernization of high-quality tillage machines for planting, is to obtain high yields and reduce their cost [9,10,11,12]. Depending on the conditions of arable lands preparation for planting, it is necessary to carry out various technological operations, for which the entry of different techniques into the field, excessive compaction of tractors and machine wheels to the soil is harmful, dusty part increases, soil water permeability changes [2,7,13].

Repeated entry of the machine into the field causes great damage to the soil, especially in dry climates, in soils with low humus content [7,13]. Under the mechanical action of the aggregates, the organic matter decomposes and evaporates with moisture or is washed away by water. Therefore, the minimum processing method is widespread and is rapidly spreading around the world [3,14]. It is convenient to use combined machines that perform multiple operations on the same road to reduce machine crossing in the field [3,7,14]. With this in mind, the use of a rotary crusher-leveler in conjunction with this combined unit chizel-cultivator is effective, aimed at the theoretical substantiation of their working bodies [4,15,16].

During interaction of working bodies with soil, various stresses appear in it [17,18,19,20]. If these voltages reach a critical value, decomposition will occur in soil. As a result of soil decomposition, lumps of different sizes are formed.

*Corresponding author: mirzoxidt_2011@mail.ru

As a result of our research, we have come to the conclusion that combined forms of working bodies should be used in heavy and medium soils. They have a gradual effect on the lumps. First the lead and at the same time soil is subjected to additional processing blade, in the next process main processing blade is pierced into hard and large lumps and grinds them into pieces. After the leading and rear blades, the blades are further processed by attached disc [4,21].

## 2. Materials and Methods

In order to grow repeated crops on farms and peasant farms, the land cleared of autumn spike crops is mainly cultivated with a chisel-cultivator. Taking this into account, we studied the physic-mechanical properties of the soil before planting repeated crops [7,8].

Moisture, density and hardness of the soil are considered to be its main physic-mechanical properties and have a significant impact on quality and productivity of the aggregate in soil cultivation and energy consumption. Studies to determine these parameters were carried out in gray soil experimental fields of Uychi district, which were freed from autumn grain crops., Soil moisture, density and hardness were determined for several consecutive days as soon as, the wheat was harvested [4].

The dynamics of changes in soil moisture after plowing, the working conditions of the driving unit are extremely complex and diverse. It depends on the field relief of the plowed field and the density of soil [22-25].

As a result of the influence of hot summer light and hot wind, a sharp decrease in soil moisture in the upper horizon was observed. We witnessed that the hardness of the soil increased from 0.54-0.76 MPa to 0.98-1.01 MPa during the observation days.

## 3. Results and discussion

According to the results of the conducted research, the soil moisture in the empty fields of autumn grain crops changes with passing of days. Before processing, the field was irrigated due to the hardness of soil. For example, during 4 days in the 0-10 cm layer, the humidity decreases from 18.47% to 4.11%, that is, 16.93% less than the initial humidity. In the 10-20 cm layer, this decrease was 8.28 percent [4]. Therefore, under the influence of hot weather, the upper layers of soil lose moisture faster, and the lower layers, because they are below the upper layer, the reduction of moisture in them slows down.

In order to choose optimal type of rotary softener based on physic-mechanical properties of soil, rotors equipped with curved-shaped blades were first prepared and compared and tested. The rotary softener is equipped with discs fixed (welded) to it and curved-shaped blades bolted to the discs. The blades of both rotary softeners move due to the reaction forces generated as a result of contact with the soil.

As a second variant of rotary softener, rotors equipped with paddle blades were prepared and tested with comparing. The rotary softener is equipped with discs fixed (welded) to it, and equipped with paddle blades bolted to discs. The rotary softener consists of a square shaft and blades fixed to it at different angles. The blades and shovels of both rotary softeners are driven by the reaction forces generated by the contact with soil.

A special suspended experimental device (chisel-cultivator) assembled with the MTZ-80 tractor was designed and built for testing developed and prepared rotary softeners.

The soil of the experimented fields is gray soil of medium-heavy mechanical composition, which has been irrigated for a long time, and its moisture and hardness at the time of the experiment were 11.4-14.2% and 1.64-1.93 MPa in the 0-10 cm layer, respectively, and 12.7- 14.8% and was in the range of 1.56-1.87 MPa.

Straight-flat and spade blades were selected for further studies (Figures 1). Tests of rotary cultivators equipped with selected straight-flat and shovel blades a special suspended experimental device (rotary cultivator) was designed and manufactured to be aggregated with a New Holland T 6070 tractor.

**Fig. 1.** Rotary softener equipped with shovel and straight flat blades.

During contact of the working bodies with soil, various stresses appear in it. If these stresses reach a critical value, the soil will crack. As a result of soil decomposition, lumps of different sizes are formed. As a result of the conducted research, we came to the conclusion that it is necessary to use combined forms of working bodies in heavy and medium soils. They have a gradual effect on the cuts. First, the soil is affected by the straight-flat blade of additional cultivator, and in the next process, the main cultivator blade stabs into hard and large lumps and grinds them into pieces. After the working bodies of the chisel-cultivator, disk with fixed blades is processed additionally [4].

According to the substantiated parameters based on the theoretical and experimental studies, a rotary softener was prepared and field tests were carried out by installing it on chisel cultivator developed at Scientific-Research Institute for Agricultural Mechanization (SRIAM). Figure 1 shows overall view of the unit, and Figure 2 shows working process view.

**Fig. 2.** A view of the working process of chisel-cultivator equipped with a rotary softener

In the test, the following were determined: the quality of soil compaction, density of soil in the 0-10 cm layer, the degree of leveling of the treated field surface.

The conditions and results of comparative tests were carried out. The tests were carried out in 2021 during preparation for planting fields of “Abrorbek Iftikhor Fayz” and “Kamron Sof Tolasi” farms, which were freed from wheat planted in the fall.

**Table 1.** Test conditions

| № | Indicator name | Indicator value |
|---|---|---|
| 1 | Exam date | June, 2021 |
| 2 | Place of the test | “Abrorbek-Iftikhor-Fayz” and “Kamron SofTolasi” farms |
| 3 | Type of work | Preparation of fields free from winter wheat for planting |
| 4 | Background | The field is empty of the wheat |
| 5 | Macrorelief | Plain |
| 6 | Microrelief | Wavy |
| 7 | Soil type | A typical gray soil irrigated previously |
| 8 | Mechanical composition | Medium-heavy sand |
| | Soil moisture in the following layers (cm), %: | |
| | 0-10 | 18.1 |
| 9 | 10-20 | 19.9 |
| | 20-30 | 19.3 |
| | 0-30 | 19.1 |
| | The hardness of the soil in the following layers (cm), MPa: | |
| 10 | 0-10 | 1.7 |
| | 10-20 | 2.2 |
| | 20-30 | 2.8 |
| | 0-30 | 2.2 |

The chisel cultivator was combined with New Holland T 6070 tractor. Table 1 shows the test conditions, and Table 2

shows their results.
Before the tests, the area freed from winter wheat was irrigated and treated with rotary softener after tilling.
In tests, processing depth of the rotary softener was determined to be 25 cm.

**Table 2.** Results of comparative tests

| № | The designation of indicators | Agrotechnics | Accordingto the test results | |
|---|---|---|---|---|
| 1 | Working speed, km/h | 6-8 | 6.12 | 7.76 |
| 2 | Number of fractions with the following size (mm), (%): greater than 50 mm | No more than 10 percent | 7.1 | 6.2 |
| 3 | less than 25 mm | Not less than 80 percent | 84.9 | 86.8 |
| 4 | The degree of the field leveling surface, % | should not be less than 90 percent | 91.5 | 93.8 |
| 5 | Fuel consumption, kg/ha | – | 17.2 | 18.7 |

From the data presented in Table 2, it can be seen that the operating parameters of chisel cultivator equipped with rotary softener with based parameters meet the requirements of agrotechnics. The fractions of soil size larger than 50 mm and smaller than 25 mm after treatment with this device were 7.1 and 84.9 percent, respectively, at a speed of 6.12 km/h, 6.2 and 86.8 percent at a speed of 7.76 km/h (according to agrotechnical requirements, amount of these fractions should be at most 10 percent and at least 80 percent, respectively), the degree of leveling off the field surface and density of soil in 0-10 cm layer at the indicated speeds are 93.5 and 95.8 percent respectively, 1.19 and 1.18 g/cm$^3$ (according to agrotechnical requirements, these indicators should be at least 90 percent and 1.1-1.2 g/cm$^3$, respectively). It should also be noted that the chisel-cultivator equipped with the recommended rotor softener reliably performed the specified technological process at both speeds.
The economic efficiency of the chisel-cultivator equipped with recommended rotary softener was calculated based on the existing regulatory documents. In this case, a chiselcultivator equipped with a rotary softener was compared with a chisel softener and leveler.

## 4. Conclusions

Soil moisture decreased faster during 3 days after harvest of autumn cereals. This decrease was 10% compared to the initial humidity in 0-10 cm layer, and 6.1% in 10-20 cm layer. During the next 1 day, the decrease of soil moisture in these layers is 6.93%, respectively; It was 2.18 percent. It can be observed that the soil hardness increased from 0.54-0.76 MPa to 0.98-1.01 MPa during the days of observation, in 0-10 cm layer, the soil hardness increased by 19.8% compared to the initial hardness in 4 days, in 10-20 cm layer and it increased by 12.1% and 8.6% in 20-30 cm layer. Therefore, the hardness of the surface part of soil increases rapidly, and it changes slowly in the lower layers.
Calculations show that when a chiselcultivator equipped with a rotary softener is used in soil cultivation, labor costs are reduced by 33.1% and operational costs per hectare of land are reduced by 12.75%. In this case, the annual economic efficiency is 33,220,180.53 sums according to the estimates of January 2021.

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