# Comparative tests of ridging cultivators with active and passive working tools

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**Abstract.** Two types of ridging cultivators for growing potatoes and other vegetables were designed and tested. The first machine GPK-2 has active working tools – rotary drum with straight cutters, passive sweeps on rigid tines, and plates forming ridges. The second machine GD-2 has only passive drought working tools: spring S-shaped tines with sweeps of two forms, disks, and plates forming ridges. Field tests were carried out to determine soil preparation quality and energy consumption indicators of both machines on loamy soils typical for the non-chernozem zone of the Russian Federation. It is advisable to use the indicator of the specific power consumption related to the average diameter of loosened soil clods. Measured specific power per average clod diameter was in range 3.3…4.3 kW×mm$^{-1}$ for the active rotary ridging cultivator, and 2.6…3.2 kW×mm$^{-1}$ for the cultivator with passive working tools. The required power for the machine with passive working tools at the maximum possible forward speed is 25…35% lowers than for a rotary machine. Though cutting ridges on the post-planting treatment of loamy soil, rotary tiller supplies better soil crumbling. On inter-row cultivation of light loamy soils, the machine with passive working tools is a preferable solution due to less energy consumption relative to the machine with an active rotary drive.

## 1 Introduction

Farmers mainly use technologies for growing potatoes on ridges with 75 cm row spacing. These technologies usually use pre-planting and post-planting tillage [1], including upper soil layer loosening, weed control, and the formation of ridges [2]. Cultivators, forming ridges, carry out at the same time continuous loosening of the upper soil layer [4], strip tillage of the underlying soil layers along the axis of the rows. Pre-planting soil tillage should ensure its high-quality soil preparation for the development of seedlings [5]. In conditions of insufficient moisture and low humidity, recommended additionally to roll the soil surface.

Optimal design parameters of rotary tilling machines substantiated in researches [6, 7]. Theoretical methods for calculating energy consumption during the operation of combined machines are devoted to works [8, 9]. One of the main indicators of soil preparation quality

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for vegetable crops, especially on irrigated lands, is the degree of soil pulverization. Also, reducing energy and fuel consumption is very important to increase design tillage machines [3].
The purpose of this study was to select the best types of working bodies of cultivators for ridge-forming cultivators for soil conditions typical for the central region of the European part of the Russian Federation.

## 2 Methods

Timiryazev State Agrarian University, jointly with Federal Scientific Agro-engineering Center VIM, developed experimental samples of bed-forming cultivators for pre-plant forming seedbeds and ridges when growing potatoes, Jerusalem artichoke, and other vegetables (figures 1 and 2).

It is advisable to compare soil preparation quality and energy consumption indicators of tillage machines by experimental methods [10, 11].

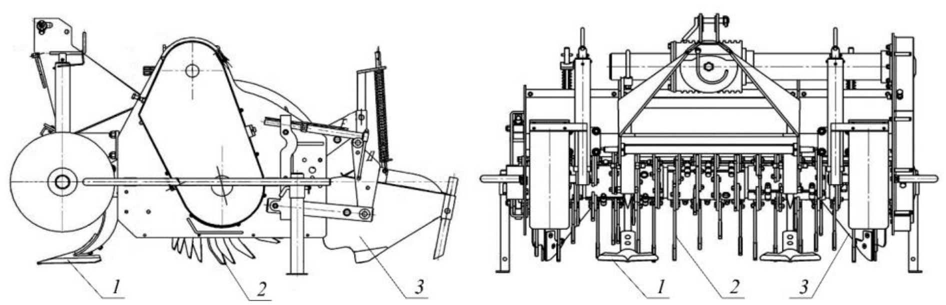


**Fig. 1.** Rotary cultivator GPK-2 for ridging: 1 are sweeps 150 mm wide cut; 2 is rotary drum with straight cutters; 3 are ridge forming plates

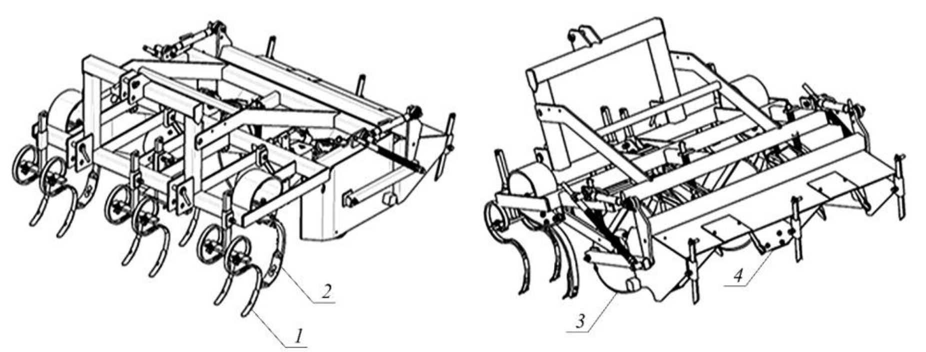


**Fig. 2.** Tine sweeps - disc cultivator GD-2 for ridging:

1 and 2 are loosening spring tines; 3 and 4 are discs and plates for ridge formation

The mounted rotary cultivator ridge-former GPK-2 can form seedbed in two ridges with tractors with an engine power of more than 60 kW at a PTO speed of 540 or 1000 min$^{-1}$. Pre- and post-planting ridging can produce on fields of various configurations with a slope of up to 3°, soil hardness up to 3.0 MPa, and absolute soil humidity up to 25%. The cultivator can be equipped with additional working bodies in the form of cultivator paws, rollers, plates for the formation of ridges [12].

Continuous soil cultivation with an active rotary drum carried out to a depth of 12 cm. On medium and heavy soils along the axis of the planting crops rows, strip loosening with cultivator tines produced to a depth of 18 cm [13] within permissible deviation from the set depth for tilling ±1.5 cm [14].

The mounted cultivator GD-2 has only passive working tools [11] designed for pre-planting and post-planting processing of light and medium soils by strip loosening up to 20...25 cm or chisel to a depth of 35 cm with two rows of tiny sweeps with a row spacing of 75 cm with furrow discs and plates forming ridges or ridges.

Field tests were carried out in the fields of the Russian Potato Research Center (Moscow region) and the experimental station of the Timiryazev State Agrarian University on medium and light loamy soils with the following characteristics: even relief and micro-relief, soil layer 0...15 cm hardness 0.2...0.34 MPa, absolute humidity 19...22%, post-harvest residues – stubble of grain crops.

# 3 Results and Discussion

Agrotechnical and energy indicators of two types of cultivators were evaluated during the formation of ridges after spring planting potatoes with a planter. The cultivators aggregated with MTZ-82 tractor with engine tested preliminarily. According to the certification test, the tractor engine had an operating power of 61.0 kW and specific fuel consumption of 0.24 kg((kW(h)-1.

The following parameters were measured and calculated during the field tests: torques on the tractor engine shaft and on the power take-off shaft PTO (N×m); cultivator traction resistance (kN); the rotational speed of the engine shaft, tractor driving wheels, and the PTO rotational speed ($s^{-1}$); the path traversed by the unit during the experiment (m) and experience time (s). Relative errors of energy indicators obtained less than 2-3% according to the standard methods [15].

The quality of soil cultivation and the energy performance of the machines [16] were determined in series of experiments at four forward speeds from 5.1 to 7.2 km×$h^{-1}$. Our test shows that the tractor MTZ-82 engine overloaded at a speed of more than 6.1 km×$h^{-1}$ working with the GPK-2 rotary ridge cultivator.

Both machines satisfied quality requirements adopted in Russia [17]. The presence of clods up to 20 mm was more than 90%, and there were no clods with a diameter over 50 mm. The height of the formed ridges was 28.5…28.6 cm. The width of the ridges was 21...22 cm. There was no increase in the content of erosion-hazardous particles with a diameter less than 1 mm in the 0...5 cm soil layer. The topsoil density in the ridges was 0.85...1.1 g×$cm^{-3}$.

The diagram of soil crumbling (distribution of clod sizes in mm by fractions), obtained during the agrotechnical assessment of the compared cultivators GPK-2 and GD-2, is shown in figure 3.

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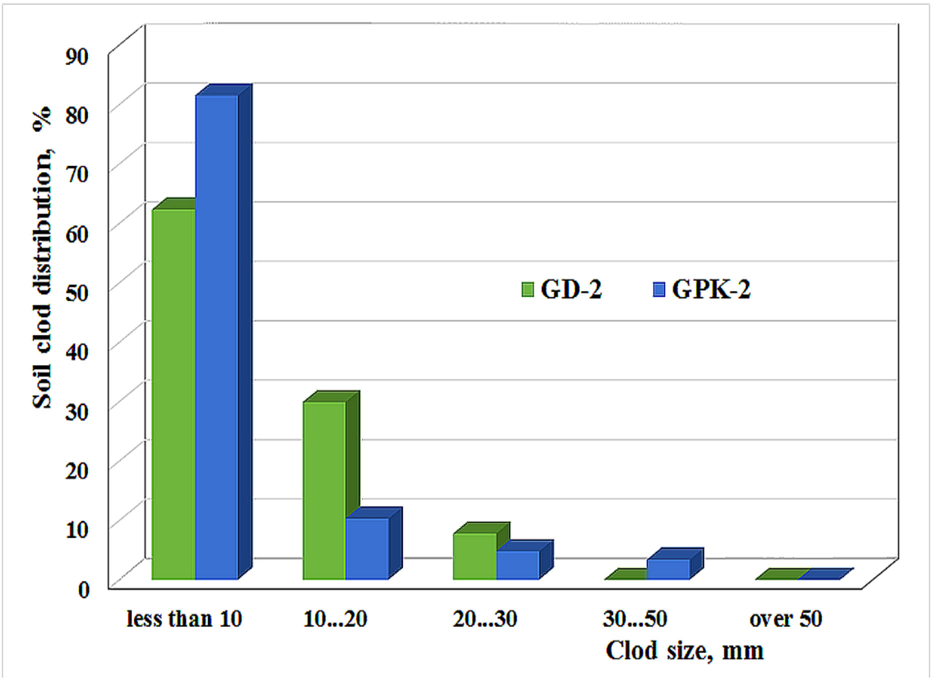


**Fig. 3.** Soil crumbling diagram for two tested cultivator types

The depth of cultivation with loosening tines for both ridge-formers (with active rotary and with passive disc-tine working bodies) in a series of experiments varied from 8 cm to 16 cm within a step of 2 cm.

An example of the experimental determination, how the power $N$ (kW) required for the unit operation dependent on two main parameters: the sweeps depth $h$ (cm) and the machine forward speed $v$ (m×s$^{-1}$), is shown in figure 4.

To establish a functional connection $N = f(v, h)$ the linear regression equation was used in the form $N=b_0+b_1 \times v+b_2 \times h$. The following regression equations were obtained for the power required for the tested cultivators after processing the results of 16 observations of experiments (table).

**Table.** Dependencies of required energy $N$ (kW) on forward velocity $v$ (m×s$^{-1}$) and sweeps working depth $h$ (cm)

| Machine type | Regression equation | Multiple $R$ | $R^2$ |
|---|---|---|---|
| GPK-2 rotary cultivator | $N = 29.44 + 6.35 \times v + 1.0 \times h$ | 0.70 | 0.58 |
| GD-2 sweeps-disks cultivator | $N = 21.27 + 4.83 \times v + 0.95 \times h$ | 0.71 | 0.63 |

The regression coefficients $b_0$, $b_1$, and $b_2$ for the certain field conditions are determined through the least squares method. The dispersion values for all coefficients were calculated, and the trustful interval through the Student's criterion was estimated. Coefficients not meeting the 0.95 value level excluded from the equation. The adequacy of the regression was tested by the Fisher's criterion.

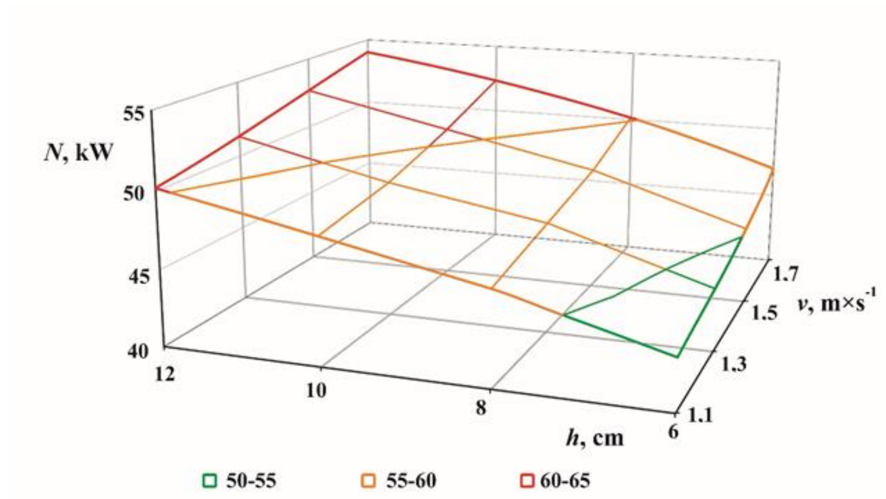


**Fig. 4.** Dependence of power consumption (*N*, kW) on sweeps depth (*h*, cm) and forward speed (*v*, m×s$^{-1}$) for rotary ridging cultivator GPK-2

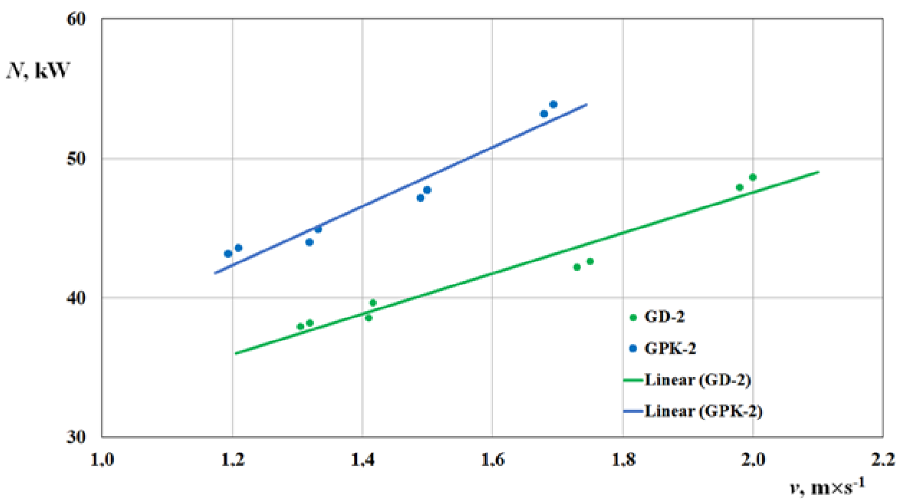


**Fig. 5.** Power requirements for compared ridging cultivators

It was found that the maximum power consumption *N* (kW) unit with sweeps and disks passive tools cultivator, when performing a technological process at speed 1.3…2.0 m×s$^{-1}$ was 38…49 kW (figure 5). Maximum power consumption of unit with active rotary cultivator GPK-2 in the forward speed range 1.2…1.7 m×s$^{-1}$ was 43…54 kW [14-24].

Power consumption measurements shown in figures 5 и 6 correspond to the working depth of the loosening cultivator tines in the range from 11.9 to 12.7 cm. The maximal forward speed of tractor MTZ-82 with cultivator GPK-2 was 5.4 km×h$^{-1}$, with cultivator GD-2 – 7.2 km×h$^{-1}$.

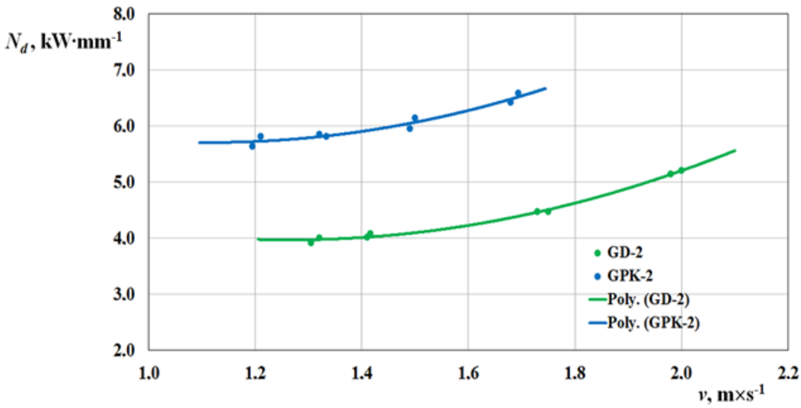


**Fig. 6.** Specific power consumption per average clod diameter for compared cultivators

We have a significant increase of tillage energy requirements with forward speed raising for a rotary cultivator with active working tools we explained by an increase in cutting forces, and for a cultivator with passive sweeps and disk working tools an increase in traction resistance [9, 10].

## 4 Conclusions

Studies of 2-row ridge-forming cultivators with active and passive working tools, carried out on typical soils of Russia Central European part, allow us to conclude that their quality indicators fully meet the agrotechnical requirements.

Cultivator with active working tools demonstrated higher soil preparation quality because the design of the active rotary ridge-former allows controlling the soil crumbling degree by changing the machine forward speed. Though on post-planting treatment of loamy soil, rotary tiller supplies better soil crumbling.

The required powers for the cultivator with passive working tools at the maximum possible forward speed is 25…35% lower than for rotary machine. Measured indicator of specific power per average clod diameter was obtained in range 3.3…4.3 kW×mm$^{-1}$ – for the active rotary ridging cultivator, and 2.6…3.2 kW×mm$^{-1}$ – for the ridging cultivator with passive sweeps and discs working tools. On inter-row cultivation of loamy soils, the machine with passive working tools is a preferable solution due to less energy consumption relative to the machine with an active rotary drive.

One of the directions for further research is to determine the possibility of using the rotary cultivator on continuous pre-planting soil cultivation for potatoes on heavy loamy soils to replace the chisel cultivator and a 2-row disc harrow, aggregated with tractors with engine power over 110 kW. Preliminary calculations show that at the same time, due to the combination of deep loosening and rotary tilling can increase productivity.

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