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DEVELOPMENT OF AN ELECTRIC-DRIVEN MINI-CULTIVATOR FOR SOIL TILLAGE BEFORE PLANTING SEASONAL FLOWER SEEDLINGS IN GREENHOUSES

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Abstract. This article examines the mechanization of soil preparation before planting seasonal flower seedlings in greenhouses. The main requirements for technical equipment used under greenhouse conditions—compactness, low weight, maneuverability, low noise, environmental safety, and the ability to provide high-quality soil tillage—are analyzed. Recommendations are developed for selecting the main parameters of an electric-driven mini-cultivator, including the diameter of the working body, working width, tillage depth, rotor rotational speed, and travel speed. Based on calculations, the feasibility of using a low-power electric drive for loosening and fine crumbling the soil to a depth of 50–120 mm before planting flower seedlings under greenhouse conditions is demonstrated.

Keywords: greenhouse, flower seedling, soil tillage, mini-cultivator, electric drive, rotary working body, working width, tillage depth, energy consumption.

1. Introduction. In greenhouse cultivation of seasonal flowers, the physical condition of the soil directly affects the development of the plant root system. Before planting seedlings, the soil must be loosened, clods must be broken down, weed residues removed, and the soil surface leveled. In particular, seasonal flower crops such as petunia, salvia, Tagetes, begonia, and others require a non-compacted soil layer with a favorable air–water regime for proper root-system development.

The use of large tractors and implements in greenhouses is often difficult because of their dimensions, turning radius, and limited working space. Therefore, the use of small electric cultivators is particularly relevant. Studies have shown that electric mini-cultivators designed specifically for greenhouse use are characterized by a narrow working width and compact construction. For example, some electric cultivators are reported to have a power rating of 300–800 W, a working width of 150–360 mm, and a tillage depth of approximately 100–220 mm.

Another important advantage of an electric drive under greenhouse conditions is the absence of exhaust gases from internal-combustion engines in the enclosed environment. Technical solutions for greenhouse electric micro-cultivators have also been developed using an electric motor, gearbox, working rotor, and control elements.

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Figure 1. Soil tillage in a greenhouse using an electric mini-cultivator

2. Research Objective. The main objective of the study is to substantiate the structural and technological parameters of an electric-driven mini-cultivator capable of ensuring high-quality soil preparation before planting seasonal flower seedlings in greenhouses.

To achieve this objective, the following tasks were defined:

- analyze greenhouse soil-tillage conditions;
- develop the structural layout of the mini-cultivator;
- substantiate the working width and tillage depth;
- determine the required electric motor power;
- select the rotational speed of the working rotor;
- determine the travel speed of the unit;
- calculate field capacity;
- evaluate electrical energy consumption.

3. Specific Features of Soil Tillage under Greenhouse Conditions. Technological rows in greenhouses may be narrower than those in open-field conditions. Therefore, the overall width of the cultivator should be kept as small as possible, while ensuring convenient control and a minimal turning radius.

Before planting flower seedlings, the main technological operations may be performed in the following sequence:

Initial soil cleaning → loosening → clod crushing → leveling → seedling planting.

Well-prepared soil promotes rapid root development in ornamental plants. Some agronomic recommendations emphasize the importance of deep loosening and good drainage when preparing beds for flower crops.

However, the purpose of a mini-cultivator is not complete deep plowing, but rather loosening and crumbling the upper soil layer in which seedlings will be planted. Studies on the use of compact electric drives for shallow greenhouse tillage also indicate a secondary tillage depth of about 50 mm as a practical option.

4. Structural Layout of the Mini-Cultivator. The proposed mini-cultivator consists of the following main components:

1. electric motor;

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2. battery or power-supply unit;
3. gearbox;
4. chain or belt transmission;
5. working rotor;
6. cultivator blades;
7. protective cover;
8. support wheel;
9. control handle;
10. speed-control device;
11. safety switch.

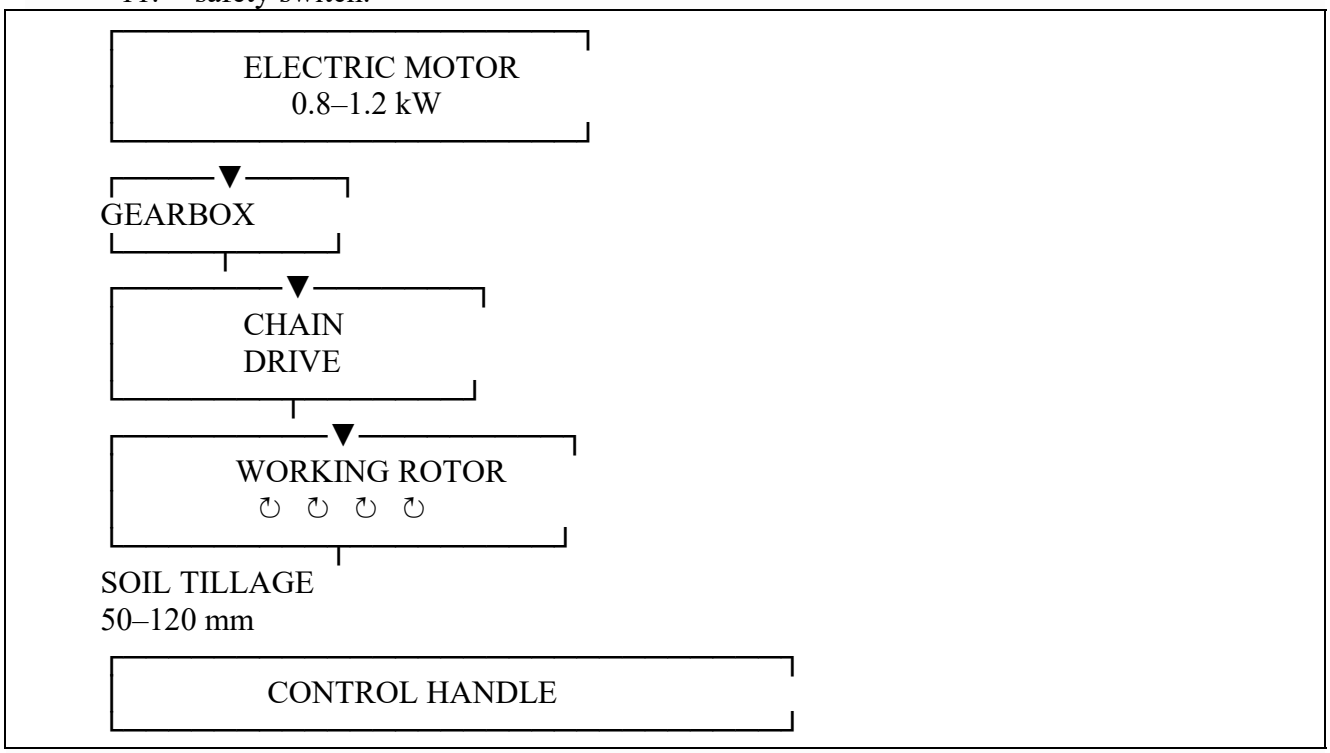


Figure 2. Recommended structural layout of the electric mini-cultivator

Electric cultivators developed for greenhouse use commonly employ components such as an electric motor, gearbox, rotor, wheel, and control handle as practical structural solutions.

5. Selection of the Main Structural Parameters. When determining the working width of the mini-cultivator, the spacing between greenhouse rows and the width of the planting bed should be taken into account.

Recommended parameters:

Parameter	**Recommended value**
Electric motor power	0.8–1.2 kW
Working width	250–350 mm
Tillage depth	50–120 mm
Rotor rotational speed	250–450 rev/min

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Operating speed	0.3–0.8 m/s
Mass	10–20 kg
Rotor diameter	180–240 mm
Number of blades	4–8
Control-handle height	800–1100 mm

These values are also consistent with the technical specifications of existing small electric cultivators. For example, a 750 W electric cultivator may have a working width of 320 mm and a tillage depth of up to 220 mm, while other models with a 300 W motor have a working width of 150 mm and a depth of 100 mm.

However, the use of maximum tillage depth is not always necessary when preparing soil before planting seasonal flower seedlings. Therefore, from a design standpoint, an adjustable tillage depth in the range of 50–120 mm is considered appropriate.

6. Substantiation of Electric Motor Power. The required motor power of the cultivator can be approximately determined using the following expression:

$$P = \frac{F \cdot v}{\eta}$$

where:

- P — motor power, W;
- F — soil resistance force acting on the working body, N;
- v — forward travel speed of the unit, m/s;
- η — transmission efficiency.

Studies have also tested electric-driven units with a power of 350–450 W in greenhouses for light operations such as secondary tillage and weed control. Therefore, the final motor power should be determined experimentally according to soil density, moisture content, and the required tillage depth.

7. Determination of Field Capacity. The theoretical field capacity of the mini-cultivator is:

$$W_t = \frac{B \cdot v}{10}$$

where:

- Wt — theoretical field capacity, ha/h;
- B — working width, m;
- *v — operating speed, km/h.*

8. Selection of the Working-Body Design. Rotating rotor blades are proposed as the main working body of the mini-cultivator.

The blades perform the following functions:

- cutting the soil;
- crumbling the soil;
- loosening the soil;
- mixing plant residues;
- improving soil aeration.

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The rotor blades may be designed in an L-shaped or curved configuration. The sharper and stronger the working part of the blade, the more efficiently the energy required for cutting the soil is utilized.

Existing electric cultivators include designs using working bodies with 4–6 steel tines. Some models have a working width of 360–400 mm and a rotor speed of 390–400 rev/min.

9. Optimization of Technological Parameters. The operating quality of the electric cultivator is affected by the following factors:

$Y = f(v, n, h, B, \theta, W)$

where:

- *v — travel speed;*
- n — rotor rotational speed;
- h — tillage depth;
- B — working width;
- θ — blade installation angle;
- *W — soil moisture content.*

Recent studies on electric horticultural machinery have investigated the effects of travel speed, tillage depth, and rotor speed on soil crumbling quality, stability of tillage depth, and energy consumption. Researchers have shown that these parameters should be optimized jointly.

On this basis, the following preliminary experimental regime can be proposed for seasonal flower seedlings:

Experiment	Speed, m/s	Depth, mm	Rotor speed, rev/min
1	0.3	50	250
2	0.4	70	300
3	0.5	90	350
4	0.6	100	400
5	0.8	120	450

During the experiment, the following indicators are measured:

1. degree of soil crumbling;
2. actual tillage depth;
3. energy consumption;
4. field capacity;
5. vibration affecting the operator;
6. frequency of clogging of the working body.

10. Electrical Energy Consumption. The hourly energy consumption of the electric cultivator can be approximately expressed as:

$E = P \cdot t$

where:

P — motor power, kW;

t — operating time, h.

For the battery-powered version, the battery capacity is:

$$C = \frac{P \cdot t}{U \cdot \eta_b}$$

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where:
U — nominal battery voltage, V;
η — battery efficiency.

11. Advantages of the Proposed Design. The proposed mini-cultivator should preferably have the following characteristics:

- compact design;
- small turning radius;
- 250–350 mm working width;
- adjustable tillage depth;
- 0.8–1.2 kW electric motor;
- battery or mains power supply;
- adjustable working-rotor speed;
- protective cover;
- emergency stop switch;
- adjustable handle for the operator.

Electric-drive designs can eliminate the problem of exhaust gases associated with internal-combustion-engine machinery in greenhouses. At the same time, particular attention must be paid to humid operating conditions, cable safety, and battery protection in the electrical system.

12. Conclusion. Based on the analysis, the use of a compact electric-driven mini-cultivator for preparing soil before planting seasonal flower seedlings in greenhouses is considered one of the technically justified approaches. The main performance criteria for an electric mini-cultivator should include soil crumbling quality, stability of tillage depth, field capacity, and electrical energy consumption per unit area. Contemporary studies use the combined evaluation of these indicators to optimize the operating modes of electric cultivators.

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