Comparative tests of mechanization means for digging seedlings of fruit crops

A A Drobyshev, V Yu Lantsev, A V Alyokhin, A A Zavrazhnov, A I Zavrazhnov
Michurinsk State Agrarian University, 101, International st., Michurinsk, 393760, Russia
E-mail: drobyshev1968@bk.ru

Abstract. The increase in the area of orchards of intensive fruit crops in the Russian Federation is one of the priority tasks of horticulture. This requires a huge amount of quality planting material. Digging remains one of the laborious and responsible operations in the production of seedlings of fruit crops. Grubbers and diggers of various producers are used for continuous digging of seedlings. After this, the dug-in seedlings are manually removed from the soil and row and only after that the next run of the unit is possible. The authors proposed a means of mechanization, selective digging of individual varieties or rows of plants, with a winch traction using a cable. The paper provides a comparative analysis of mechanization means for selective digging of seedlings and presents a diagram and results of field tests of two types of devices to perform this operation.

1. Introduction
Since the dawn of time, a person has been eating fruits and berries that have a kind of unique aroma and taste. They are rich in vitamins and many other useful nutrients.

The priority task of horticulture is the annual receipt of a stable and high-quality harvest with low operating and labor costs [1-3].

A promising direction in the development of industrial horticulture is the transition to intensive technologies using low-growing rootstocks.

The increase in the area of orchards of fruit crops of an intensive type requires a huge amount of high-quality planting material. Therefore, much attention is paid to the issue of its cultivation in the required volume [4-6].

Digging remains one of the most laborious and responsible operations in the production of seedlings of fruit crops.

Grubbers and diggers of various producers are used for continuous digging of seedlings [7, 8]. After the run of the unit, the dug-in seedlings are manually removed from the soil and row and only after that the next run of the unit is possible.

The disadvantage of this method is the impossibility to perform selective digging of individual varieties or rows, since a tractor can not pass in the aisles not damaging the plants. Another problem is that when digging pome crops or pear seedlings on heavy soils, the grubber is aggregated with a caterpillar tractor with a thrust class of at least 3 tons and not every orchard is able to purchase and maintain it. Therefore, the improvement of the means of mechanization for selective digging of seedlings in orchards is an urgent task.
2. Materials and methods
The problem of mechanization of selective digging of seedlings can be solved using a device for digging with a winch traction using a cable. Such a device can be a cutting plow produced by DAMCON.

At the Department of Transport Technological Machines and the Basics of Design, two devices for digging in seedlings have been developed.

Figure 1 shows a device for digging in seedlings, similar to a cutting plow from DAMCON, with a side cutting knife.

The digging process is as follows. A tractor with a winch stands at the edge of the plot, opposite the row to be dug. Pulling down the tractor hitch, the unit is fixed in the working position with the winch lugs. The unwound cable clings to the frame of the device installed in the place of the row from which it is necessary to start digging the seedlings. The winch turns on and, under the action of the cable, the device moves along the row and the knife cuts the soil layer and long roots of the seedlings at the required depth. In order to compensate for lateral forces, a supporting wheel with a flange and a control mechanism is used. Since the roots of the plants remain in the soil, the dug-in seedlings can remain in this state for a long time.

After the run of the unit, the dug-in seedlings are manually removed by workers from the soil, the necessary varieties of seedlings in the required quantity are packed for sale and the rest of the plants wait in the wings.

The big advantage of such a device is that a wheeled tractor of a traction class of 0.9 tons is enough in order to create a traction force of more than two tons.

Figure 2 shows a device for digging in seedlings with a central knife position.

The digging process is performed in the same way as in the first case. Only the cable is passed through the digger rollers and returned to the winch. Thus, the traction is carried out by two cables.

The supporting and adjusting skids allow changing the depth of the knife pass from 25 to 45 cm, which is quite enough for digging out both shrubs and seedlings with deep roots.

In the first option, the depth of the knife pass is changed by changing the angle of attack with the adjusting bolt.

Field tests were carried out on plots of one-year apple tree seedlings grafted on semi-dwarf rootstocks, as well as cherry pear and cherry plum grafted on seed rootstocks.
At the beginning, the indicators characterizing the conditions of the experiment were determined:
- height of seedlings at the time of digging – $h_d$, mm,
- deviation of plants from the row axis – $\Delta z$, mm.
- root depth - $L_n$, mm,
- soil moisture – $W$, %,
- soil solid – $P$, kg/cm$^2$.

The research program provided for checking and clarifying the influence of design parameters and kinematic modes of digging devices on the quality of cutting the root system at different soil moisture.

### 3. Research results

The results of experimental studies of the efficiency of digging seedlings, depending on the location of the cutting knife, are presented in Table 1 and Figure 3.

| Indicator                                      | Cutting depth, cm | Option with a side knife in soil moisture | Option with a central knife in soil moisture |
|------------------------------------------------|-------------------|------------------------------------------|---------------------------------------------|
| Deviation from the set cutting depth, cm     | 28                | 18 to 28%                                | 28% and more                                |
| Damage to plant roots, %                      | 28                | 0, -4                                    | +1, -3                                     |
| Damage to the aerial part of plants, %       | 28                | 0                                         | 0, + 2                                     |
|                                                | 38                | 0, -6                                    | 0, -3                                     |
|                                                | 38                | 3                                         | +1, -2                                     |

Analyzing the experimental studies, it is necessary to note that during the use of option 2 (with a central knife) the damage to the aerial part of the plants is observed (above 1.5 meters) because of the route passing over the plants. However, the movement of the working body at a given depth is more stable in comparison with option 1 (lateral location of the knife), the deviation of which was up to 6 cm. When the soil was pre-moistened, the leveling of the deviation in the depth of root cutting was observed.
4. Conclusion
As a result of the experimental studies, some disadvantages were found.

The disadvantages of the first option of the device were as follows:
- The instability of the knife passes in depth on the soil of heterogeneous density;
- The need abundant watering for their functioning on dense and heavy soils

The disadvantages of the second option of the device were:
- The inconvenience of working with two cables;
- The restrictions on the height of the aboveground part of plants.

When digging in seedlings no damage or loss of market condition was observed under normal working conditions. In both options the cut of long roots was smooth and at the required depth without grinding.

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