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Substantiation for Structural and Technological Parameters of The Unit for Separating Branching Cloned Rootstocks

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The present-day machinery condition and efficiency for mechanical layer detachment of apple clonal rootstocks have been analyzed. The promising scheme of machine suitable for this operation has been found out, and the main parameters have been determined.

Key words: breed shed of clonal rootstocks, mechanization of branching cuttings, optimization.

The most time-consuming operation in the production of clonal apple rootstocks is separation of cuttings, which is still done manually using shears. Hard working conditions do not allow making quality cuts of offshoots. In addition, every year stumps remaining after cutting offshoots that are above the ground worsen the quality of separated rootstocks and increase the consumption of substrate for covering growing offshoots.

Development of a machine that ensures separation of cuttings from grafters, apple clonal rootstocks, as well as regenerative pruning of mother cue, is of paramount importance, important and promising component in addressing production of high quality planting material.

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The goal was to analyze the status and effectiveness of the existing technical means for mechanical separation of cuttings clonal apple rootstocks, to identify promising layout of a machine for these purposes, and to determine the optimal parameters of main working parts that ensure separation of offshoots from grafters, placing then into cylinder without damage and orienting in the direction convenient for subsequent collection.

Many devices for trimming bushes, branches or roots of plants, cutting bud axis, detaching cuttings of vegetatively reproduced rootstocks, digging seedlings, etc. have been developed. They are different in design of both cutting elements and auxiliary mechanisms that ensure quality cutting and removal of cut weight without its additional grinding and injury, as well as excluding repeated action of cutting parts of the ”stubble”.

There are working parts, for example, for root pruning[1, 2] with a horizontal cutting knife installed at an angle to the direction of movement; its cutting edge may be smooth[1] or have the shape of sawtooth[2]. When working, such knives are dipped into the soil, and in moving cut rhizomes and stumps occurring on the way.

The main disadvantage of these working parts is that during separation of cuttings for vegetatively regenerated rootstocks, they pulled out mother plants, especially when the cutting edge becomes blunt[3].

The most perfect are working parts with active drive, containing one[4-10], two[4, 11-15] rotors that rotate toward each other or in opposite directions[16].

Rotary cutting element of the working bodies is a flat or convex[17] disk that may be smooth[4,5] or with rivet-on segments: conventional mowing[6, 10] and of special form[9]. Also disk saws[16] or a yokes are used with knives secured in holders[7, 8, 12] or by joints[11, 18].

Rotors also differ by the method of cutting. There are devices with cutting without support[6, 7, 12, 16, 18] and equipped with the counter-cutting[9, 10] or holding[5, 11] elements ensuring higher quality of cut than without them, and excluding damage of mother tail.

The cut off mass is sometimes left in its place[1, 2]; often it is pushed along the working parts due to natural pressure during machine movement[4, 5, 7, 8, 17, 18]. In general, in order to avoid obstruction and clogging of working parts, it is captured with various devices and discarded along the way[12, 13, 15] or side wise[9, 10, 19]. For moving alongside, usual blades are used as well - one[6] or two[16].

Table 1. Ccommercial quality and biometrics indicators of cuttings of clonal rootstocks (54-118, planted 2004) after mechanized pruning of grafters (Kuplin E.A., 2011))

No	Variant of experiment	Return of rootstocks		Standard from control, %		Biometric indicators		
		total, pcs	including %			diameter, mm	height, cm	rooting, zone cm
1	Pruning with a continuous rotary knife	36	25	69.4	58.1	4.8	72.9	8.7
2	Option 1 + mechanized opening of grafters	55	29	52.7	67.4	5.0	75.8	8.7
3	Pruning with a disk knife with segments	55	25	45.5	58.1	4.9	78.9	7.2
4	Option 3 + mechanized opening of grafters	56	36	66.7	83.7	4.9	77.6	8.7
5	Technology used at the farm (reference)	87	43	49.4	100.0	4.9	75.9	5.8

Simple[9] or spring loaded[10] vanes, conveyors made in the form of corrugated looped strips[13, 15], and various drums[12, 14] are used as devices for forced pushing the cut mass. Besides, for these purposes it is proposed[19] to use rakes attached to eccentrics with a drive, or directed with air flow[20].

Important components of such machines are devices for ensuring required cutting height. It is achieved by adjusting the position of support wheels or slides mounted on the main frame[4-6, 11, 16, 20, 21], or directly on the frame of working part near the separated plant[4, 5, 8, 12-14, 22]. Simple copying devices[8, 12, 13, 15, 18], and devices equipped with various summing elements[4, 5, 22, 24] are possible. They take into account the microrelief of adjacent inter-row spaces. In terms of their operating principles, these devices may be different, for example, mechanical[4, 5] or hydraulic[22].

An important role for obtaining quality cut in separating plants is played by protection from repeated cutting of both plants and remaining "stubble". Typically, in order to avoid repeated cutting, the "stubble" (rotary working parts) are tilted forward along the strike of the machine, but it happens that the cutting disk is covered from the bottom with a cover[6, 7] or frame[12.] Inorder to avoid repeated cutting of separated plants, flat[12] or convex[11, 21] protectors may be installed on top of the cutting disks. These protectors rotate at a speed considerably lower than the angular rotation speed of the cutting discs due to special drive[12] or to natural rolling along the row of plants. For the same purpose, in the non-working zone of cutting

discs[6], a housing may be installed. More sophisticated technical solutions are also proposed, for example, knives can be hidden in the casing during idle run[7].

A device for separating cuttings from plants in soil is also known[11]. It consists of (Fig. 1) a frame with cutting working elements mounted on the shaft so that they can rotate toward each other. Cutting working elements are made in the form of several curved knives fixed on a shaft with a hub, and a spherical disk installed above the knives, with the possibility to rotate without a drive. The distance between the shafts is equal to the diameter of the disc, and the diameter of the hub with knives does not exceed the diameter of the disc. Each hub has two knives installed. Spade bugs in the shape of teeth inclined to the horizontal plane at the angle 20-30° are placed along the circumference of each disc.

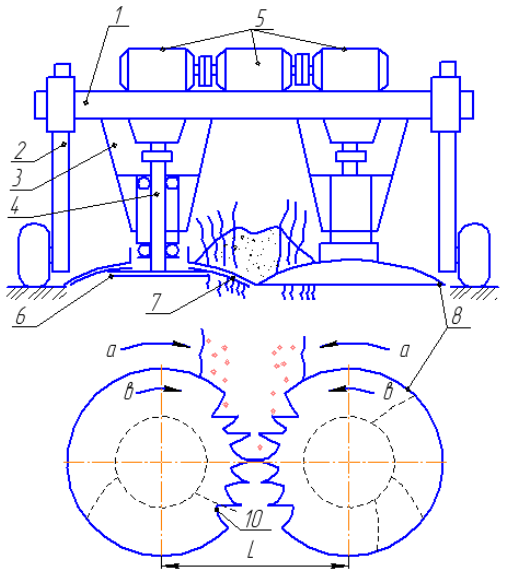
In operation, the machine is placed on a bunched row of grafters. Using support wheels, depth of working elements travel is adjusted. As the machine moves, the right and left working elements grasp the swath from both sides. Spade bugs of the spherical disk penetrate soil and feed it to the spherical disk, thus unloading active knives that cut plants. In the process of cutting, the off-shoots have additional support above the location of the cut. This decreases knives pressure on the grafter, thereby making it impossible to pull it out of soil. Separated cuttings with soil are lifted to the spherical part of the disc and put into the inter-row space. Grafters are covered with the soil that fall apart.

Study of the machine for separating cuttings of clonal apple rootstocks manufactured according to the diagram in figure 1 and provisionally called MOO-1 showed that it ensures quality of work up to 80% in accordance with agricultural requirements[3]. Authors of the project note that preliminary unbunching of the swath before separating improves working conditions and increases cleanness of the cut.

The main disadvantage of the MOO-1 machine, in our opinion, is the inability for the operator to visually monitor the cut quality of separated cuttings and urgently interfere during the process, if necessary.

Thus, for separating cuttings from grafters of vegetatively reproduced apple rootstocks, working elements of rotary type containing auxiliary devices that ensure retaining cuttings, pushing cut mass, protection from repeated cutting and copying of grafters profile are most promising.

Drawing of a new machine is shown in Figure 2. It contains hinge 1 with support-and-adjustment wheel 2, to which movable frame 4 is attached by means of the parallelogram mechanism



1 - frame; 2 - supporting and adjusting wheels; 3 - racks of working elements; 4 - drive shafts; 5 - reduction units; 6 - hubs; 7 - knives; 8 - spherical wheels with spade bugs

Fig. 1. Diagram of the MOO-1 machine for separating cuttings of clonal rootstocks

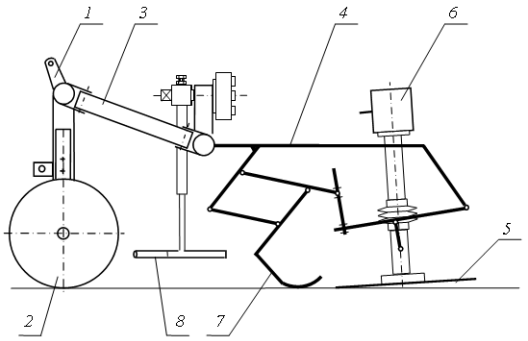


Fig. 2. Diagram of a machine for separating cuttings of vegetatively reproduced apple rootstocks

1- hitch; 2 - support-and-adjusting wheel; 3 - parallelogram mechanism; 4 -movable frame; 5 - rotary knife; 6 - drive; 7 - copying mechanism; 8 -automatic guide

3. Knife 5 with drive 6 and copying mechanism 7 is attached to the movable frame. The machine is equipped with an automatic guide 8.

The machine is mounted on the tractor, connected to the PTO shaft and to the hydraulic system. In operation, the machine covers plants, automatic guide 8 orients the circular knife 5 along the axis of the row, and copying mechanism 7 keeps it at desired cutting height above the grafters. Cut plants are discarded in the inter-row space.

For the basic device for separating cuttings and stacking them into a swath, we chose top-cutting unit of top-cutting machine BM-6 of beetroot-lifting system[25], which contains a disk knife, a blade thrower and a copying mechanism with mechanical drive. The main working element of the device is the circular knife made in two versions (Fig. 3): a) with riveted-on segment cutting elements; b) with sormite welded along the perimeter.

To find out the effect of design of the cutting disk and its rotation speed on the quality of separating cuttings, an installation was made (Fig. 4) that consists of a cutting disk with a drive mounted on a frame with adjusting and supporting wheels, and a copying mechanism that controls height of the disk. Mass-produced cutting disks of the top-cutting unit of the BM-6 machine were studied. Diameter of disks is 410 and 420 mm, respectively (see Fig. 3) a) and b). Angular speed was changed by switching rotation speed of tractor's PTO shaft between 540 and 1000 rpm. With regard to drive's gear ratio, the maximum angular speed of the knife was 1200-1300 rpm.

The research was performed in the breed shed of the experimental-industrial department of the All-Russian Research Institute for Certification n.a. I.V. Michurin between 26.04.2011 and 19.05.2011, with execution of technical operation

(a) (b)

Fig. 3. Cutting discs: a - segment; b - solid

Fig. 4. The working elements of the machine for separating cuttings

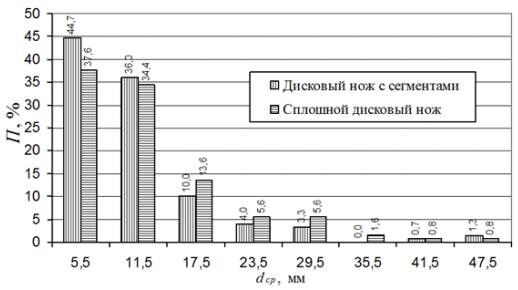


Fig. 5. Distribution of measured values of cut diameter, d_{av}, with a disk knife

of pruning grafters in rows No. 13 (rootstock 62-396, planted in 1996), No. 20 (rootstock 54-118, planted in 1998), No. 45 (rootstock 54-118, planted in 2003) and No. 69 (rootstock 54-118 planted in 2004).

It has been found that the copying mechanism ensures height of cutting heads of grafters at 0-10 cm. When adjusted to a certain height, it can maintain specified size with deviation of ± 0.5 cm.

It has been found that the best cut quality is ensured by rotary disk knives with segment cutting elements at angular speed 1200-1300 rpm. Disc knives with sormite welded along the perimeter serve the purpose, too, but the cut is uneven, with splitting of stumps and burrs on surface tissues. For a making the final conclusion about suitability of a dusk knife with sormite welded along the perimeter, an experiment was made with use of both knives on rootstock 54-118 (number No. 69, planted 2004) where regrowth of cuttings and their quality was observed during the 2011 vegetation period. Experimental plots were characterized by the following indicators. Both cutting disks, when moving along the patch with grafters make 14 to 16 cuts of various kinds per 1 meter of the patch. Cut diameter ranges from 3 to 50 mm (Fig. 5). With that, the major part of cuts (72-80%) is within 14 mm, 10-14% of cuts are 15 to 20 mm. Thus, 86 to 90% of cuts are not thicker than 20 mm.

Observations of research professor of the All-Russia Scientific Research Institute for Certification n.a. I.V. Michurin, candidate of agricultural sciences E.A. Kuplin showed (see table) that by their biometric indicators, rooted cuttings on experimental plots with all options are approximately the same, and their root systems excel those in reference group (technology used at the farm) by 24-50%. Also, by the results of standard cuttings, the knife with segments ensures better quality by 16.3%, compared to a knife with welded sormite.

Thus, for separating cuttings of clonal apple rootstocks, it is advisable to use standard circular knifes with segments, rotating at angular speed 1200-1300 rpm.

The experimental model of the machine for separating cuttings of clonal apple rootstocks has two copying slides mounted on the parallelogram mechanism, and located on both sides of the row. Parallelogram mechanisms of the slides are joined over the plants by a summing device designed in the shape of a rocker arm connected to the middle portion by a rod, and a double-arm lever with a rotary knife that can move axially.

During operation (Fig. 6), slides set the knife at certain cutting height and hold it in this position.

In order to ensure monitoring of quality, and to reduce the load on the knife from the covering earth dam, the root system of offshoots is opened before separating cuttings. Depending on operating conditions, a brush or a paddle working element is used.

For separating cuttings, the device is hinged to a tractor, set to the original position above the axis of the patch with grafters with open root system of clonal rootstocks. Using tractor hydraulics, the disk knife rotated by the drive is

Fig. 6. Experimental machine in operation

lowered to the level of the top of the patch with grafters. At the same time, the copying slides are set into adjacent intra-row spaces on the surface of the soil formed by the tool for opening covering bead. Moving along the row, circular knife separates cuttings by cutting them off from grafters and put them aside in a swath. Due to the connections with each other and with the rotary knife, copying sliders ensure longitudinal and lateral following of the relief, moving the knife vertically according to the arithmetic mean relief level on both sides of the row.

Preliminary studies showed that the proposed layout of the machine is effective; the copying mechanism ensures a required cutting height, can be adjusted and maintains predetermined distance from the support plane of a slide with deviation about ± 0.5 cm.

In the 2011 season in the breed shed of the Experimental-Industrial Department of the All-Russian Research Institute for Certification n.a. Michurin we separated cuttings of rootstock 62-396 in three rows (No. 17, No. 18, No. 19) with the total length of about 600 m. Visually, all separated cuttings have no damage, and their quality corresponds to the products.

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