7. IMPLEMENTS FOR SOIL PREPARATION FOR SOWING

Plow tillage alone does not prepare soil adequately for sowing. The upper soil layer after plowing is not uniformly and not thoroughly loosened and, therefore, does not provide appropriate uniform conditions for germination and growth of seeds. Preparation for sowing consists in loosening the upper soil layer — that is, in increasing and uniformly displacing the voids in soil and in crushing up clods. Certain implements for soil preparation can be used for loosening untilled plowland and preparing for sowing. Shallow tilth of soil is necessary because by destroying the system of capillaries in the upper soil layer an isolating layer is formed which hinders evaporation of water from the deeper layers of land. Soil preparation can also contribute to the destruction of weeds consisting in drawing and pulling out rootstocks, couch grass or in mechanical scaring of sprouting weeds; it can also create, by means of soil loosening, good conditions for sowing and growth of weeds which can be destroyed mechanically or chemically after having grown up. Preparation of soil for sowing can also consist in crushing up clods, inverting narrow furrow slices and compacting the already pulverized soil. The range of agrotechnical measures performed by means of implements for preparing soil for sowing is rather very large, and hence the great variety of these types of implements.

The first implements for the preparation of soil for sowing probably originated simultaneously with primitive plows. They were dry branches of various shapes drawn by men and more seldom by animals. Not until the Roman times does the toothed harrow with wooden teeth (Fig. 7.1) appear. With time, the shape of the harrow frame has altered. Harrows consisting of several bars tied crosswise were used in the Middle Ages. At the beginning of the 19th century, wooden harrows were provided with rigid iron teeth. Harrows with spring tines were manufactured half-a-century later. Cultivators with spring and rigid tines had been produced on the pattern of harrows with spring tines. At the end of the 19th century, cultivators were supposed to replace plows. In this connection, cultivators for deep tillage were designed. In distinction from harrows, cultivators made of steel were first of all adapted to tractors. Disk harrows began to be used at the same time as disk plows. New types of implements for preparation of soil for sowing appeared at the beginning of the 19th century, and are now continually improved. Modern implements

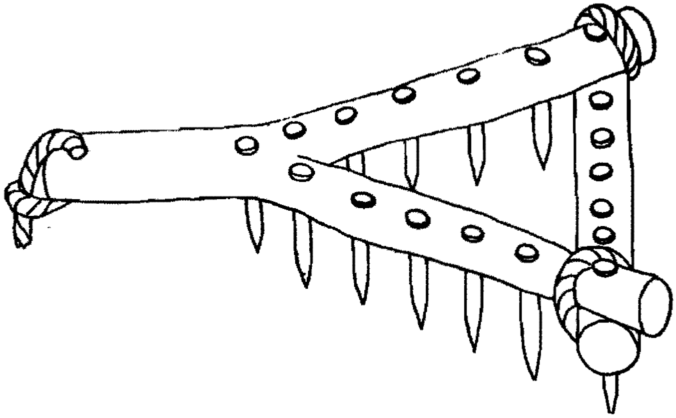


Fig. 7.1. Roman harrow.

of this kind are manufactured exclusively from steel. Implements for the preparation of soil for sowing are divided into: pulverizing — as drags, harrows and cultivators, and packing — as packers.

7.1. Drags

The drag is the simplest implement designed for scarifying shallow (1–2 cm) soil in the early spring period when excessive moisture content in the soil after the snow thaw makes it impossible to use more powerful implements. When land plowed before winter is dragged, the remaining ridges of the furrow slices are cut off and the plowland becomes leveled. The principal task of dragging is the prevention of the soil surface from encrusting and water from evaporating from the lower soil layers. Dragging creates good conditions for quick drying up of the land surface and quick heating up of soil. Dragging is performed obliquely to the tillage direction.

Drags are trailing implements and no essential difference exists between a horse- and a tractor-drawn drag, except in the working width. Tractors used for dragging should be light and provided with widened wheels, in order to prevent bogging in wet land. The drag consists of one or several sections attached to the common hitchbar.

Working width of one section ranges from 0.7 m to 1.0 m.

The simplest drag has two sections consisting of two or three wooden beams, with square or rectangular cross section, connected by chains with intervals of about 50 cm (Fig. 7.2).

In beams with rectangular cross section, the ratio of height to thickness is 5 : 4. Beams are constructed of hardwood (hornbeam, beech, oak).

In order to facilitate cutting of ridges of furrow slices and to make beams more durable, it is advisable to protect their front and bottom edges by steel flat bars fixed by countersank screws. The weight of beams is chosen according to soil firmness within limits from 2.5 to 10 kg/m. Particular sections of the drag should be so located that adjoining beams would overlap at a width of about 5 cm which is to assure proper pulverization

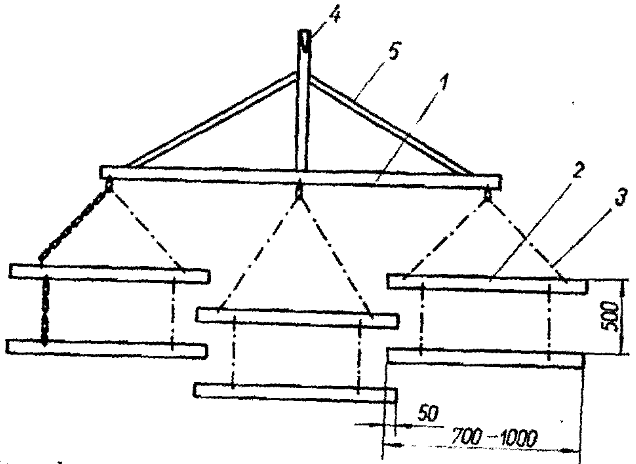


Fig. 7.2. Wooden drag: *1* — hitchbar; *2* — working beam; *3* — chains connecting beams; *4* — hitch hook; *5* — angle struts.

of soil along the entire width of the drag. Steel drags exert a more powerful action on the soil. Beams of steel drags are most frequently made of angle bars set up under various angles, beginning from 90° (Fig. 7.3). The

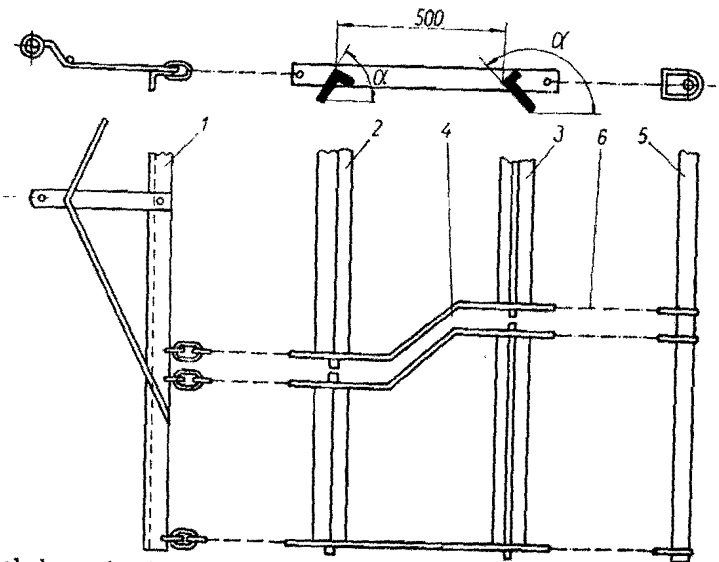


Fig. 7.3. Steel drag: *1* — hitchbar; *2* — cutting beam; *3* — leveling beam; *4* — longitudinal strips; *5* — leveling beam; *6* — chains.

first beam is used for cutting off ridges of furrow slices, the others to level out and partly pulverize the surface of the ground. These two beams are rigidly connected by means of flat bars and form a frame. To this frame is attached, by means of chains, a third beam which is used to crush clods and pulverize the soil. The beam can be made of an angle bar, channel bar or screwed flat bar.

Certain steel drags are fitted with beams whose setting angle is variable. It is known that the degree of pulverizing and sinking capacity of the wedge into the soil depend on its setting angle. This type of drag can easily be adapted to various soil conditions without needing to alter its weight. The range of change of setting angle can be from 60° to 150°, and from 75° to 120° for the first and for the second beam respectively. Specific weight of steel drags is contained within limits of 20–40 kg/m. A drag fitted — instead of the second adjustable beam — with a toothed beam (Fig. 7.4) can be applied for a more firm, easily crusting soils.

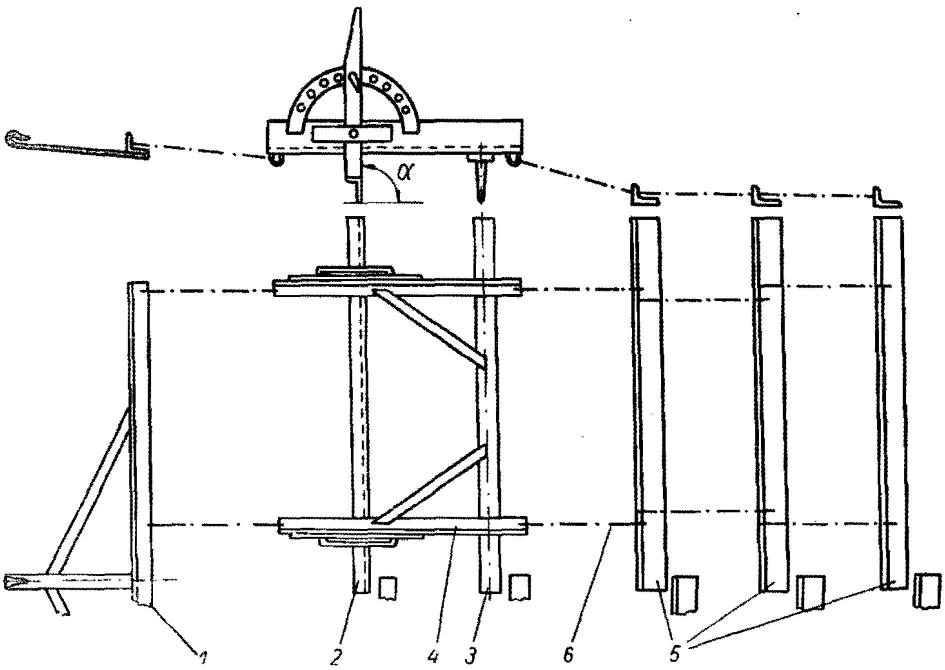


Fig. 7.4. Drag with beam of varying angle and with toothed beam: 1 — hitchbar; 2 — adjustable beam; 3 — toothed beam; 4 — longitudinal beam; 5 — leveling beams; 6 — chains.

Specific weight of this drag is higher and amounts to 35–50 kg/m. Drags whose two out of four or more beams are fitted with short knife-shaped teeth are used for dung and molehill scattering on meadows and pastures.

Single sections of drags are sometimes used on light and medium soils for simultaneous land surface leveling, while seed plowing is performed. The drag section is attached to the outrigger fastened on the left side to the plow frame.

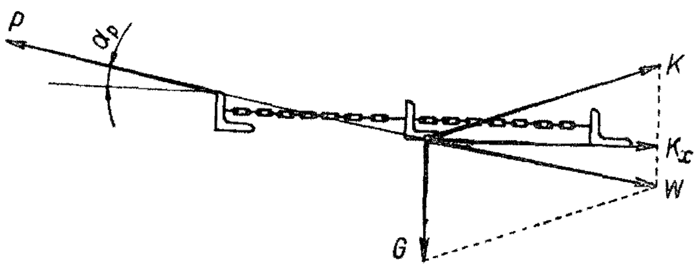


Fig. 7.5. Forces acting on the drag.

Drags are often made by farmers by their own means using various wooden beams, segments of narrow-gauge rails, old bands of wheels, etc. for their construction. Drags of this kind are adapted to the given soil conditions. Drag resistance K_x depends above all on its weight G (Fig. 7.5).

$$K_x = C_w G \text{ (kg)} \tag{7.1}$$

where

C_w = 0.4–0.6 for wooden drags,
C_w = 0.5–1.0 for steel drags,
C_w = 0.8–1.2 for drags with toothed beam.

To maintain balance of forces, the resultant of drag weight and of soil resistance K should be on the extension of the draft P which ought to be directed under angle α_p = 15–20°.

7.2. Harrows

The purpose of harrowing is leveling out the land surface, pulverizing the soil and preparing the soil structure for sowing, destroying weed roots and sods, skimming, mixing of fertilizers with the soil and covering seeds after sowing.

The range of tasks to be fulfilled and variety of soil conditions to be met brings about differentiation of types and models of harrow.

Harrows consist of one or several sections or segments interconnected by means of joints or by chains. Horse- and tractor-drawn harrows do not differ in their basic structural features.

Harrows are divided into three groups: tooth, tooth rotary and disk harrows.

Table 7.1

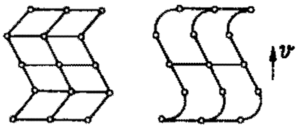
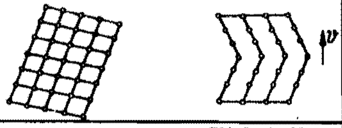
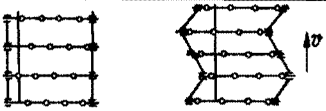
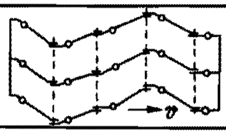
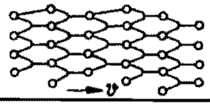
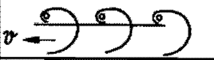
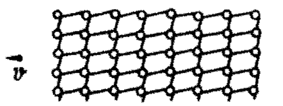
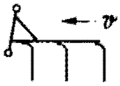
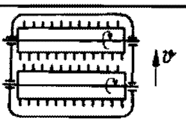
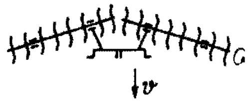
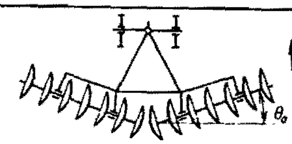
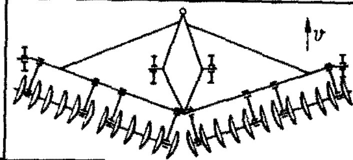
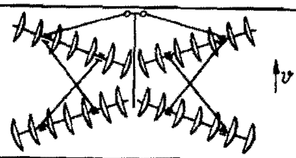
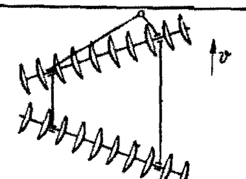
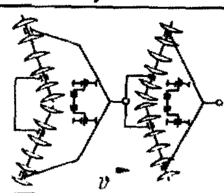
Name of the harrow	Type	Scheme	Main parameters					
			a	b_1	S_z	g_z	P_z	i
1. Toothed harrow	Light		3-5	75-85	3.0-3.5	0.5-1.0	1.5-2	3-6
	Medium		3-6	75÷100	3.5-5	1.0-1.8	2-3	3-6
	Heavy		4-10	100-120	5-6	2.0-3.5	3-5	2-5
2. Toothed harrow, oblique	Light		2-4	75-100	2-3	0.5-0.8	0.8-1.5	3-5
3. Toothed harrow with adjustable beams	Medium		3-6	75-100	3-5	1.0-2.0	2-3	3
	Heavy		4-8	100-120	5-6	2.0-4.0	3-5	3
4. Toothed harrow, articulated	Heavy		4-8	100-120	5-6	2.0-3.5	3.5-5	3
5. Knife harrow with segments	Constructed by Laacki		2-5	125-200	10	1-1.5	2-3	1
6. Spring harrow	Cultivating harrow		3-7	70-200	12-15	5-9	8-15	1
	Grassland harrow		3-7	70-100	6	5-6	7-12	1-3
7. Weeder net harrow	Light		1.5-3.0	100-200	2-3	0.2-0.45	0.6-0.8	1-3
	Medium		2-3.5	100-220	2-3.5	0.4-0.6	0.8-1.0	1-3
	Heavy		2.5-4.0	100-220	2.5-4	0.6-0.8	1.0-1.2	1-3
8. Spring weeder	Mounted		1.5-3.5	100-250	3-4	0.4-0.6	0.6-1.2	1
9. Spike-toothed harrow			a	b_1	S_z	g	P	i
	Toothed		3-6	100-200	4-6	1.2-1.8	1.0-1.5	1-3 x 2-3
	Star-harrow		3-6	100-120	7-10	1.5-2.5	1.0-1.5	1-3 x 2-3
10. Paddle harrow, mounted	Single-action		3-10	100-150	15-20	0.5-0.7	0.7-1.0	2
	Tandem		3-10	100-150	15-20	0.7-1.0	1.0-1.5	4
11. Rotary tiller	Passive		3-10	150-200	10-12	1.2-1.5	0.7-1.5	3×2

Table 7.1 (continued)*

Name of disk harrow	Type	Scheme	Main parameters					
			a	b_1	s_z	g	P	θ_0
1. Single-action	Horse-drawn		4-7	60-70	12-15	1.5-1.7	0.7-1.5	0-25°
2. Single-action, skimming, trailing			4-10	100-120	12-15	2.0-2.5	1.5-2.5	15°-25°
3. Single-action, skimming, mounted	Symmetrical		4-7	100-150	13-16	1.5-1.8	1.2-2.0	20°-35°
	Asymmetrical		4-7	100-200	13-16	1.3-1.8	1.2-2.0	20°-35°
4. Tandem harrow, symmetrical	Light		4-10	100-150	12-15	1.8-2.2	1.5-2.0	0-25°
	Heavy		5-12	100-150	13-16	2.3-2.8	1.8-2.5	0-25°
5. Offset harrow	Trailing		5-12	120-200	13-16	2.2-2.5	1.8-2.5	0-30°
	Mounted		4-10	120-200	13-16	1.8-2.2	1.5-2.0	15°-30°
6. Tandem harrow, two-piece	Mud		8-18	120-150	20-25	2.5-3.0	4-8	0-30°

7.2.1. Tooth harrows. Tooth harrows are divided according to the tooth structure (with rigid and spring tines) according to shape of section (rigid, articulated, net, and segment), as well as according to destination (tiller, grassland, weeder) or, finally, according to the weight (light, medium, heavy).

Harrows with rigid teeth (Fig. 7.6) are the most popular. The frame can be "zigzag" or "S"-shaped, can be straight or oblique. Sections of these harrows are connected by short chains with the hitchbar and inter-connected. Horse-drawn harrows differ from tractor-trailed harrows only in the number of these sections. These harrows are not fitted with travel

* For explanation of the main parameters see p. 381.

equipment and are brought dismantled on a trailer platform to the land to be tilled.

Tractor-trailed harrows designed for tilling very weedy lands can be equipped with a device lifting particular sections in order to remove couch

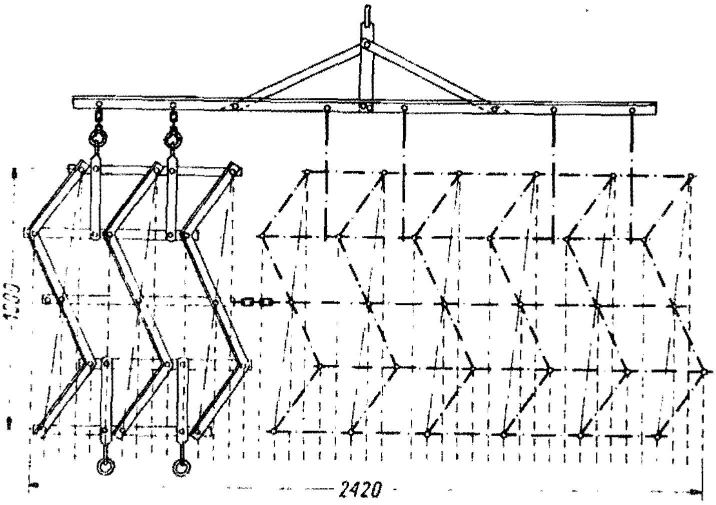


Fig. 7.6. Three-sectional horse-drawn "zigzag" harrow.

grass and other weeds and to clean the teeth (Fig. 7.7). The hitchbar of the harrow is provided with outriggers welded on, at the end of which a lifting beam is mounted in bearings, supported by two wheels. Lifting bows are fixed on both sides of the beam and a pawl mechanism in the middle. By pulling a rope tied to a lever, wrenching the roller out of the cutout in the disk of pawl mechanism occurs. Release of spring *13* then shifts the pawl lever forward which results in a certain rotation of the pawl wheel rigidly connected with the lifting beam. In consequence, bow lugs are dug into the soil and their further full rotation (Fig. 7.8) causes that the lifting beam rapidly throws up the harrow sections by means of the hangers and later on gently lowers them down. Couch grass and weeds accumulated on the teeth fall down from harrow section. Wheels supporting the lifting beam are demountable and can be used for transport of the harrow. One wheel is mounted on the lifting beam, the other on the hitchbar, so that their axis of their rotation would be perpendicular to the beam. The other side of the frame of the harrow is attached to the tractor, therefore in transport position the harrow is set up perpendicularly to the working position.

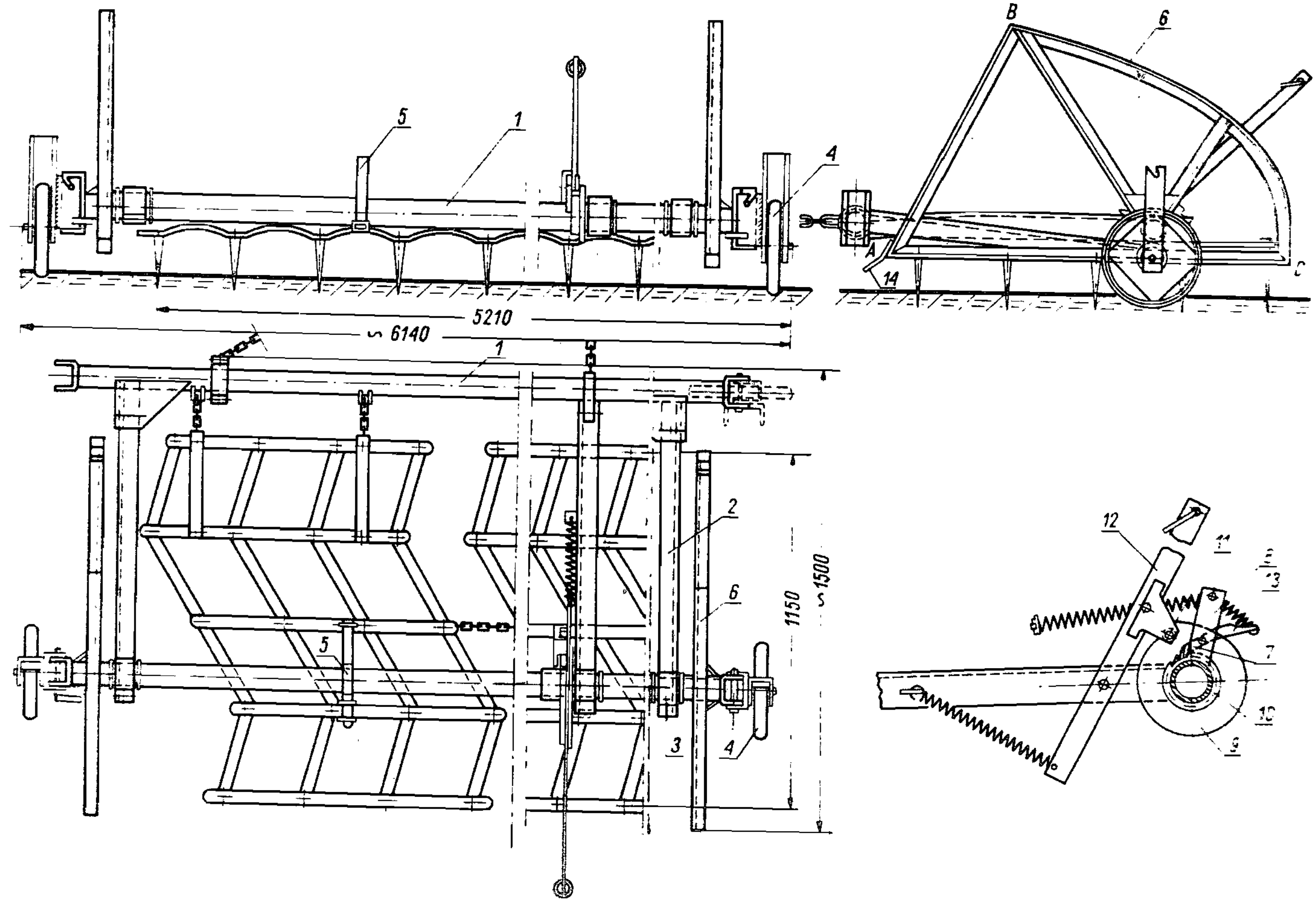


Fig. 7.7. Tractor-trailed harrow with device for raising harrow sections and the pawl mechanism of the power lift: *1* — hitch-bar; *2* — outriggers; *3* — lifting-beam bearings; *4* — supporting wheels; *5* — section hangers; *6* — bows; *7* — pawl finger; *8* — pawl arm; *9* — pawl disk; *10* — pawl wheel; *11* — roller; *12* — disengaging lever; *13* — pawl spring; *14* — bow lug.

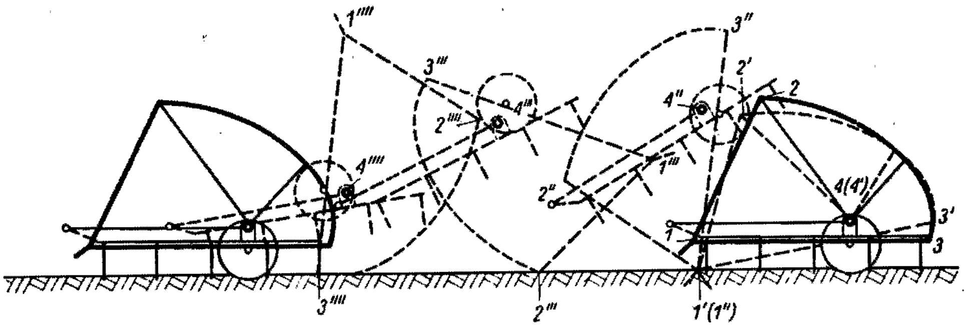


Fig. 7.8. Scheme of operation of the device for raising the sections of harrow.

Mounted tooth harrow (Fig. 7.9) is equipped with a hitchbar fastened to the column and with vertical, horizontal or oblique outriggers on which sections of the harrow are loosely mounted. The hitchbar is most frequently bent, so that the extreme section can be vertically lifted upward when in transport position thus obtaining a transport width of the harrow not exceeding 2.5 m.

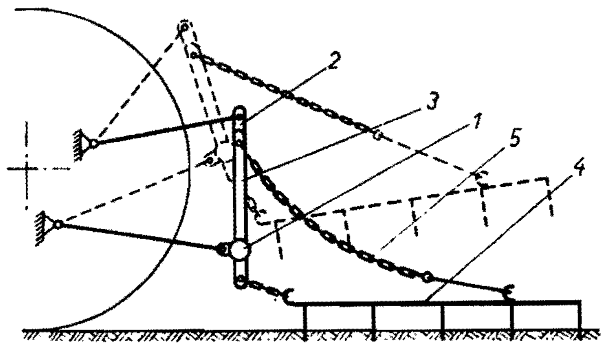


Fig. 7.9. Scheme of mounted harrow: 1 — hitchbar; 2 — mounting column; 3 — vertical outrigger; 4 — harrow section; 5 — lifting chain.

Tooth harrows with adjustable toothed strips with straight or "zigzag" frame are at present constructed only as mounted harrows. Sections of these harrows are interconnected by means of joints.

Articulated harrows are constructed almost exclusively as tractor-trailed harrows. These harrows are of heavy-duty type which, owing to their joints, are better adapted to the longitudinal irregularities of the field assuring unchaging working depth to all their tines.

The working elements in these harrows are rigid tines (Fig. 7.10) bolted to the beams of the sections. The square upper part of the tine enters the square opening in the beam preventing the tine from turning around. Harrow tines are made of carbon steel St 7 or carbon-manganese

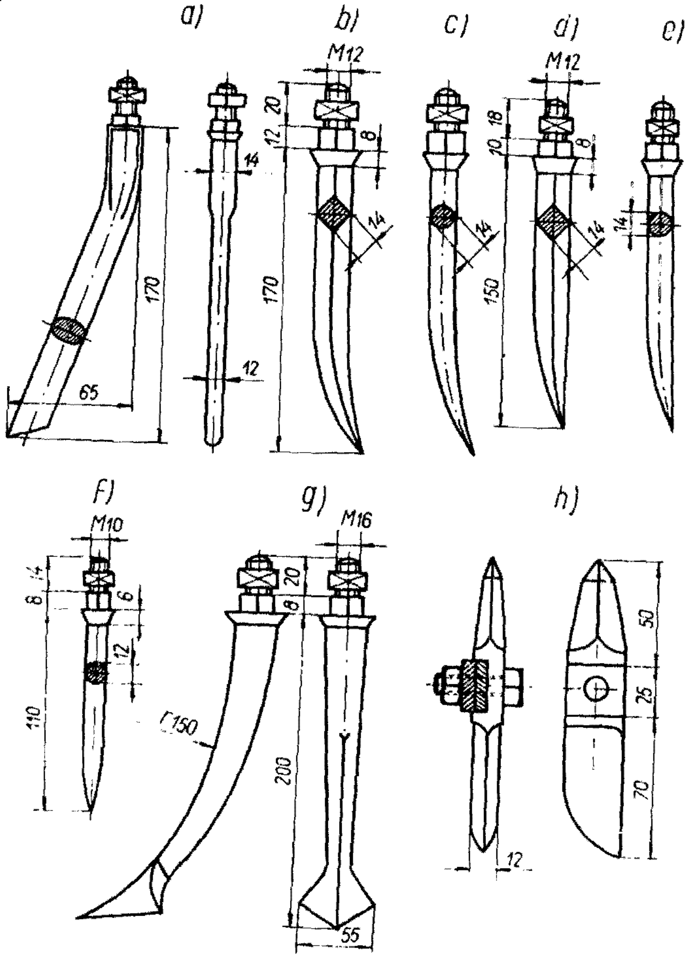


Fig. 7.10. Rigid tines: *a*) bent oval tine; *b*) and *c*) tines of heavy-duty harrow; *d*) and *e*) medium harrow tines; *f*) light harrow tine; *g*) shovel tine; *h*) knife of Laacki's harrow.

steel with carbon content about 0.70 percent. The working part of the tine is hardened up to the hardness of 450–550 H_B.

Pulverizing action of the tine consists in side displacement of the soil and crushing the clods encountered during its travel. One stroke of the tooth is most frequently not sufficient to break the clod; the harrow is, therefore, fitted always with several rows of teeth. Thus, the clod is struck consecutively by several teeth and is crushed. During harrowing, individual tines of the implement do not meet a uniform soil resistance, thus causing a sinuous motion of the harrow, the more sinuous the smaller is the number of teeth and the shallower the implement sinks into the soil. This sinuous motion of light and medium harrows increases their ability of breaking up clods struck not only lengthwise but also transversely to the harrow travel.

Tines of light and medium harrows with rigid beams are set perpendicularly to the plane of the frame. The setting angle of tooth in harrows with adjustable beams can be changed within limits from 70° to 110°. Tines of heavy harrows are mostly bent and the setting angle of their working parts ranges from 70° to 80°. Teeth set up to an acute angle (Fig. 7.11) penetrate into soil more easily than those set up under a right

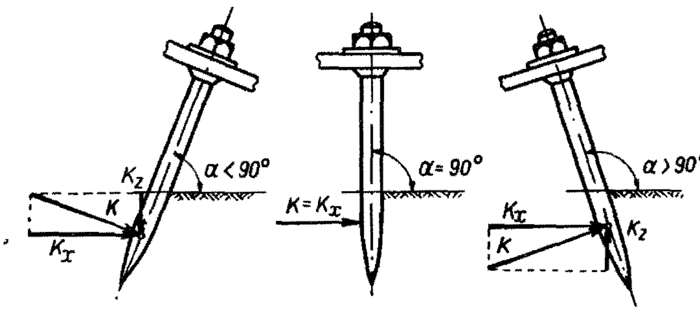


Fig. 7.11. Setting of harrow tines.

or obtuse angle, and they have to resist to the action of the vertical, directed upward, component K_z of soil resistance.

Width of the zone affecting the front and side parts of the tine in the soil depends on the angle of internal friction δ of soil (Fig. 7.12).

In places where zones of influence of tines overlap, excessive accumulation of soil arises and therefore transversal spacing t_0 of tines must always be greater than the width of the zone t_s

$$t_s = 2a\tan\delta + d \text{ (cm)} \qquad (7.2)$$

where

δ — angle of internal soil friction,
d — tine thickness (cm).

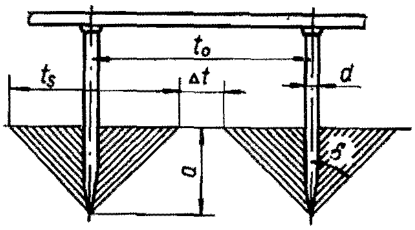


Fig. 7.12. Operating zone of harrow tines.

Transversal spacing of tines is calculated after the formula

$$t_0 = 2a_{max} + d + \Delta t \text{ (cm)} \qquad (7.3)$$

where

a_{max} — maximum working depth (cm),
Δt = 2–5 cm.

It has been assumed in this formula that the mean value of the angle of internal friction of soil $\delta = 45°$ ($\tan 45° = 1$).

Longitudinal spacing of tines between rows should be considerably greater than the zone of forward action of tines on soil in order to reduce to the minimum blocking of the harrow with couch grass and other weeds and crop residue.

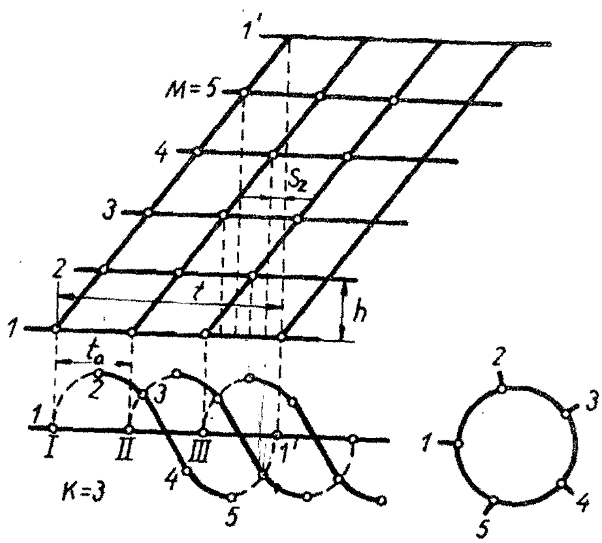


Fig. 7.13. Spacing of harrow tines according to the developed multicoil helix.

When placing tines in a harrow section, maximum spacing should be attained to avoid overlapping of the traces of the tines. Construction of the section of tooth harrow can be based upon the method of development of the multicoil helix (Fig. 7.13).

Introducing denotations:

K — number of coils,

M — number of rows of teeth

we obtain the following relation

$$t_0 = MS_z = \frac{t}{K} \tag{7.4}$$

or

$$t = t_0K = MKS_z \tag{7.5}$$

Numbers K and M cannot be arbitrarily chosen. Assuming that no traces of tines overlap and intervals between traces S_z are the same, the following limitations occur between numbers K and M:

1. $K > 1$
2. $M > K + 1$
3. M and K have no common divisor.

It results from these limitations that there are only several adaptable pairs of numbers K and M, namely:

$M = 5,\ K = 2$ or 3

$M = 7,\ K = 2, 3, 4$ or 5.

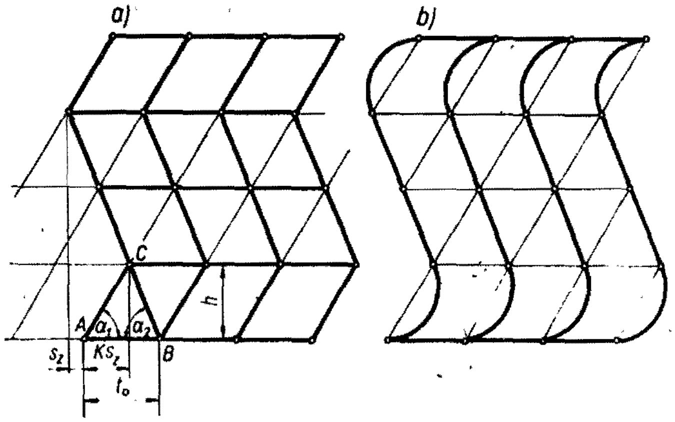


Fig. 7.14. Spacing of teeth in a harrow: a) "zigzag"; b) "S"-shaped; $K = 3$; $M = 5$.

The mutual location of neighboring harrow tines (Fig. 7.14) is determined by the angles α_1 and α_2 which can be calculated from the formulas

$$\tan\alpha_1 = \frac{h}{KS_z}$$

$$\tan\alpha_2 = \frac{h}{(M-K)S_z} \qquad (7.6)$$

Longitudinal spacing of tines amounts to

$$h = C_z S_z \qquad (7.7)$$

$M = 5$ and $K = 3$ are almost always applied for the section "zigzag" and "S"-shaped, and the coefficient C_z depends on the type of harrow:

for light harrow $C_z = 6$–7,
for medium harrow $C_z = 5$–6,
for heavy harrow $C_z = 4$–5.

Desing of sections consists in drawing a net of lines whose intersections determine the location of the teeth. For this purpose section t_0 is first plotted and divided into two parts (Fig. 7.14). The length of the first part is denoted by KS_z and of the second part by $(M-K)S_z$. The perpendicular section h is drawn from the point of division which determines the vertex of the triangle ABC. By extending the sides of the triangle and by drawing parallel lines, a net is obtained on which longitudinal beams, "zigzag", "S"-shaped or straight ones can be plotted without any difficulty. Middle transversal beams are not applied in the "S"-shaped section.

Oblique harrows are constructed mainly as light ones using $M = 7$, $K = 4$ or 5, $C_z = 2.5$–3.

Oblique harrows differ from tooth harrows of other types by inclination of their beams under angle $90° - \Delta\alpha$ in relation to the direction of the harrow travel (Fig. 7.15). Designing of these harrows is similar

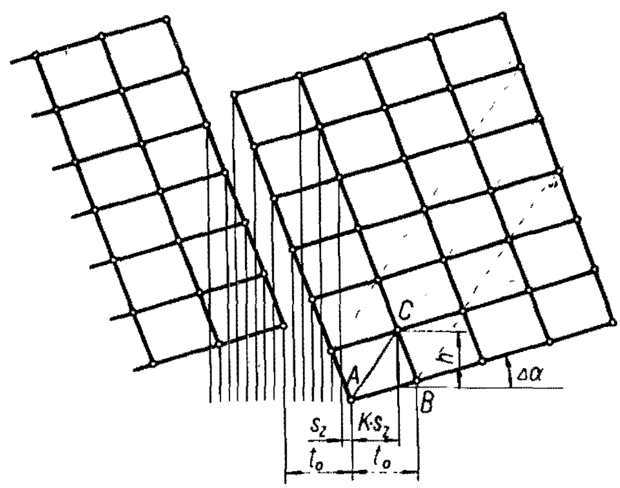


Fig. 7.15. Spacing of teeth in an oblique harrow: $K = 5$; $M = 7$.

to the previously described harrows. First of all a triangle is drawn whose base AB is inclined under angle $\Delta\alpha$ and corresponds to the transversal teeth spacing t_0. The height h, determining the vertex C of the triangle, is set from the point of view of division of the base AB. Next, a net is drawn, lines of which are parallel to the base AB and to the side CB. The number of these lines should correspond to numbers M and K. If sections of a harrow are thus shaped, the extreme tines from above on the left side and from below on the right side mark out traces with double interval if $K = 5$, and with triple — if $K = 4$. The concentration of these traces occurs at the next passing of the harrow section. Connection of oblique sections with the hitchbar and with each other should be — similarly as in other types — exact to obtain contact intervals of traces as identical as intervals of the remaining traces.

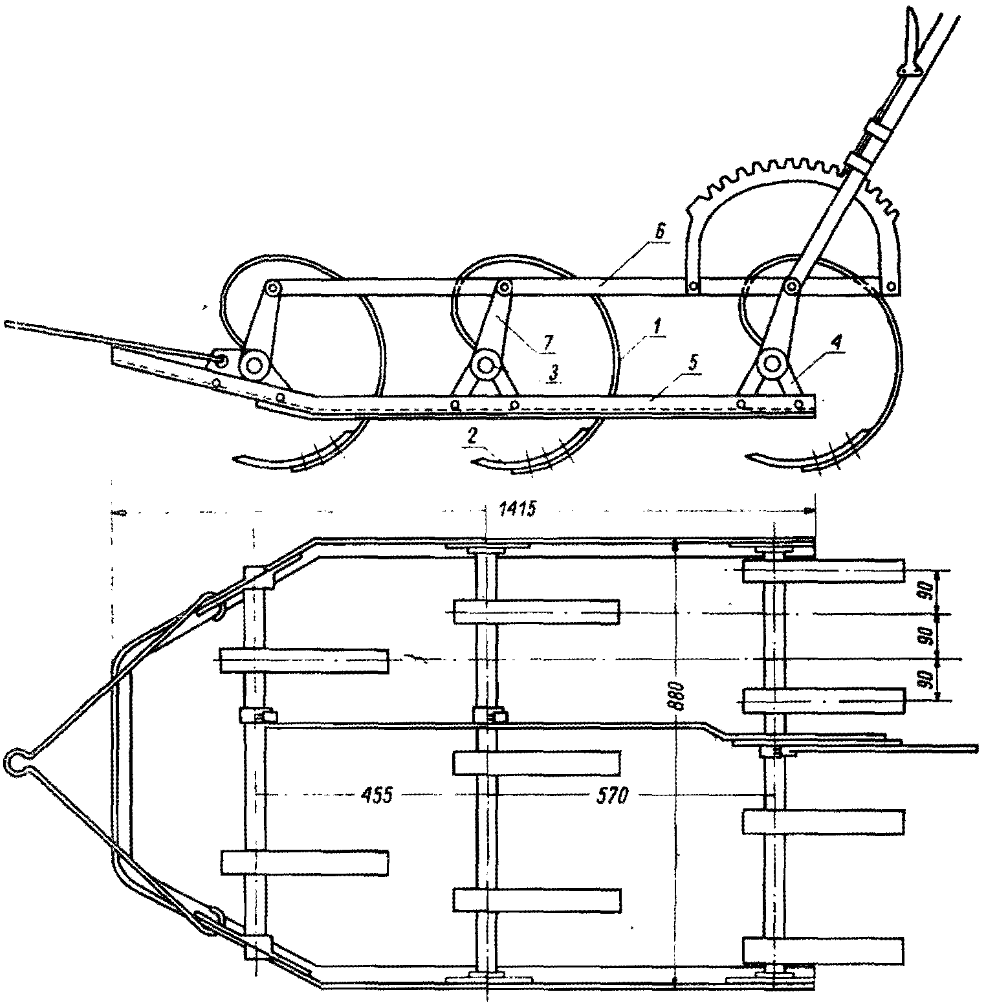


Fig. 7.16. Spring-tooth horse-drawn harrow: *1* — spring tooth; *2* — shovel; *3* — shaft; *4* — shaft holder; *5* — frame; *6* — lifting link; *7* — lifting arms.

Spring-tooth harrows are designed as one-section, horse-drawn trailing or mounted harrows (Fig. 7.16). Travel equipment is, to a certain degree, substituted by the slades of the frame. Working elements of these harrows are tines (Fig. 7.17) made of bent elastic flat bars to which are attached, by means of two countersunk screws, shovels; or of flexible round or square bars flattened at the end. Teeth spacing can be varied what causes a change in the working width of the harrow. Depth of harrowing depends on the angle of teeth setting.

Spring teeth operate on principles different from those of rigid teeth. Soil resistance produces a certain deflection and tension of the tooth during operation. After soil resistance has been overcome, the tooth end rapidly shifts forward. The spring teeth operate in short vigorous impacts. Spring teeth with shovels act in a manner similar to that of narrow cylindrical moldboards, in other words, they pull strips of soil upward and partly invert causing not only a loosening of soil, but also a mixing up contributing to better soil drying. Spring teeth with shovels tear out couch grass runners without disrupting them and are, therefore, of better use in lands overgrown with couch grass. Bar teeth are more rigid than sweep teeth. They are used in grassland harrows to remove in early spring withered plants from the surface of grasslands and destroy molehills.

A weeder is exclusively intended for the destruction of weeds germinating on fields sown with corn. It is a one-sectional, tractor-trailed mounted implement equipped with relatively long teeth which hitting the soil lightly damage weeds, sparing rooted plants under cultivation. Three rows of teeth are bolted to the frame beams connected rigidly with

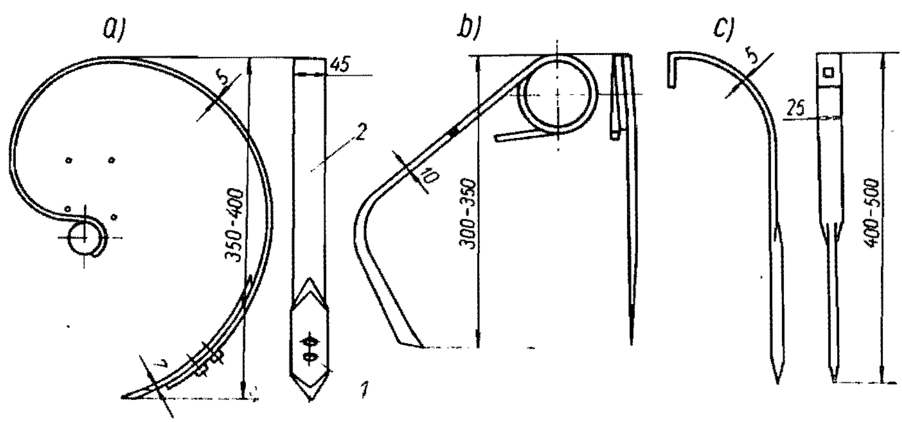


Fig. 7.17. Harrow spring teeth: *a*) tooth of land harrow; *b*) tooth of grassland harrow; *c*) weeder tooth; *1* — shovel; *2* — spring.

the mounting column. Weeders are designed also as a replaceable section of all-purpose cultivators for plant cultivation.

Segment harrows are designed as one-section horse-drawn, tractor-operated or mounted implements. The column of a mounted harrow is fitted with horizontal outriggers on which are mounted last but one segments. In the segment harrows, tooth traces of two and even of several rows of teeth can overlap.

Laacki's grassland harrow is used for grassland harrowing (Fig. 7.18). Its teeth are shaped as two-sided knives and three teeth are screwed on (Fig. 7.10*h*) or riveted to a forked segment.

Segments are connected with each other by chain links. Land can be harrowed by the upper or by the lower part of the harrow: shallower — by shorter tooth ends, deeper — by the longer ones. This type of harrow

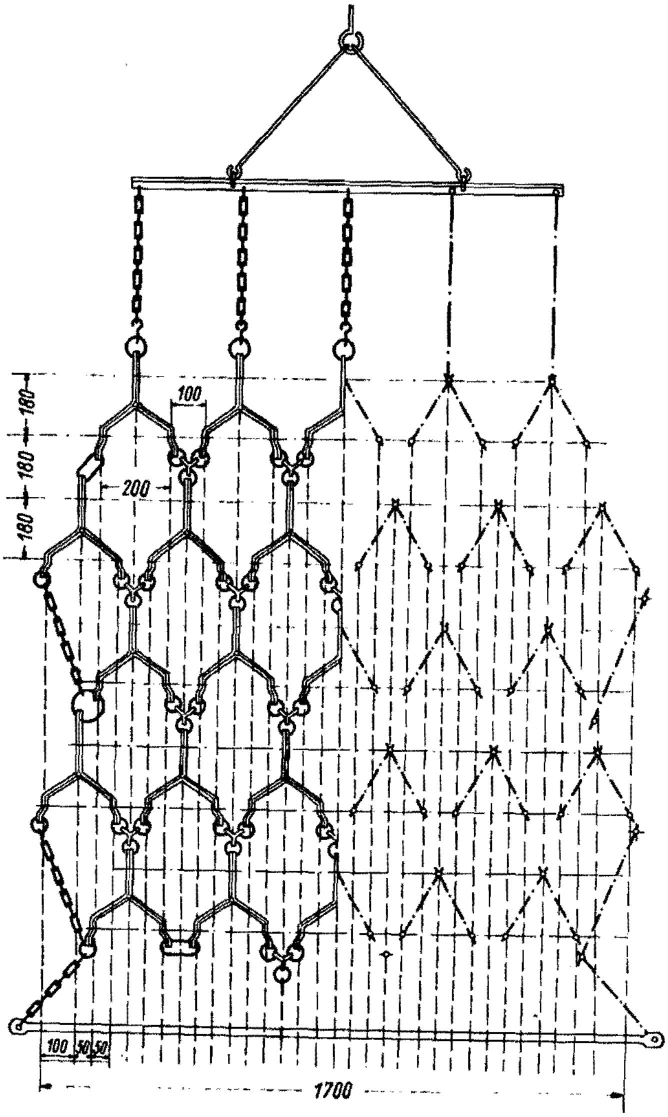


Fig. 7.18. Laacki's grassland harrow.

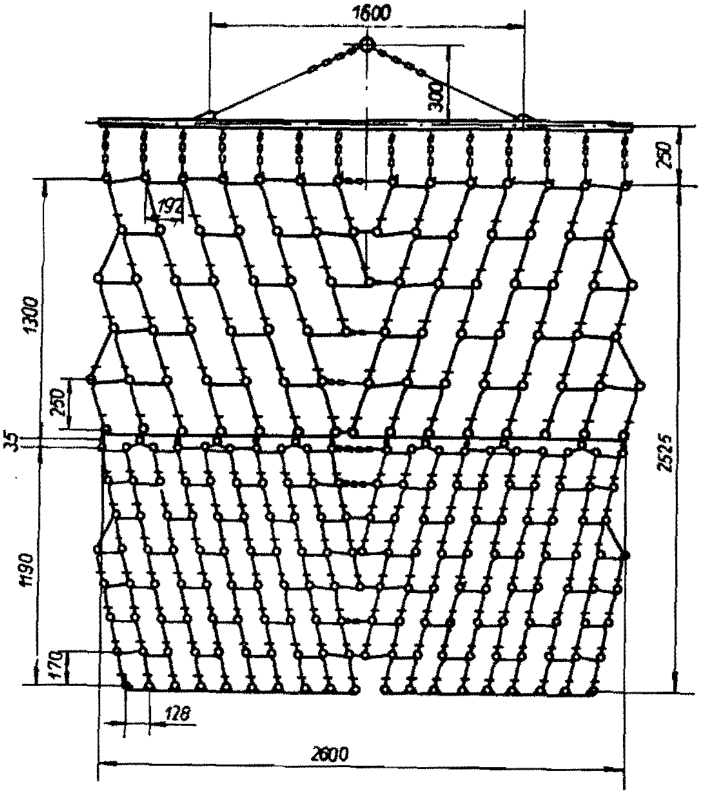


Fig. 7.19. Net harrow (weeder), two-sectional with oblique segments.

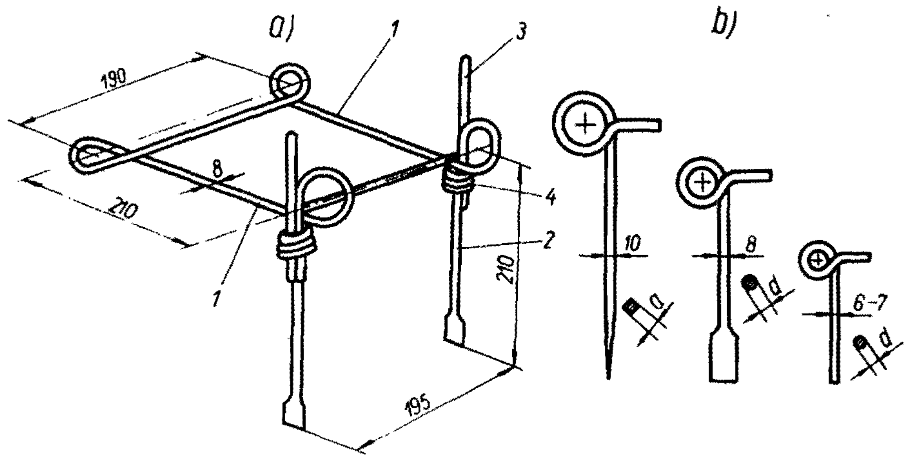


Fig. 7.20. Elements of the net harrow (weeder): *a*) net harrow segment; *b*) various types of teeth; *1* — net element; *2* — tooth; *3* — pin; *4* — clamping ring.

operates less intensely than the grassland harrow with spring teeth, but is much better adapted to irregularities of grassland surfaces. Net weeder (Fig. 7.19) consists of appropriately bent wire segments (Fig. 7.20). Harrow with rectangular segments is set, when in working position, at an angle of about 7° in relation to the rows of plant to avoid overlapping of tooth traces. Harrow sections can be connected, but the last section should be lighter than the front one. Owing to the net construction of the harrow, it is better adapted to transversal and longitudinal land irregularities and it can be used also for harrowing of potato ridges. Teeth of this type of harrow "comb out" weeds well without injuring plants under cultivation, even when these plants are but little grown out. These harrows can also be used before germination of cultivated plants because their teeth operate at very shallow depth.

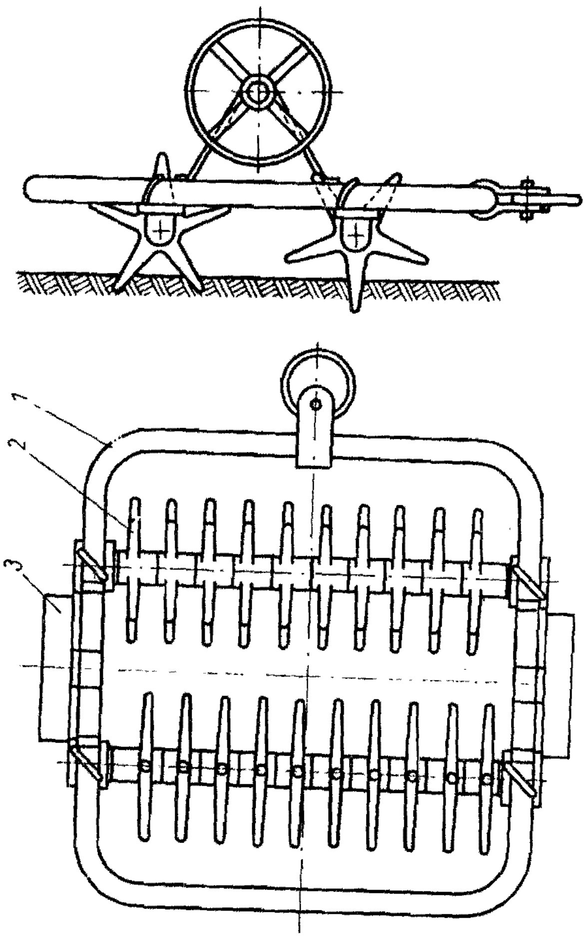


Fig. 7.21. Spike-tooth harrow: *1* — frame; *2* — star; *3* — transport wheel.

7.2.2. Rotary harrows. Rotary harrows consist most frequently of several sections connected with each other by joints. Each section consists of a quadrangular frame made of angle bars, in which one, two, or three shafts are placed in bearings. Working parts fitted with several teeth or paddles are placed on the shafts. Working elements rotating during operation, vigorously break up the clods and pulverize the soil. Harrows of this type do not get blocked by plants. The simplest and most frequently used rotary harrow is the spike-tooth harrow (Fig. 7.21).

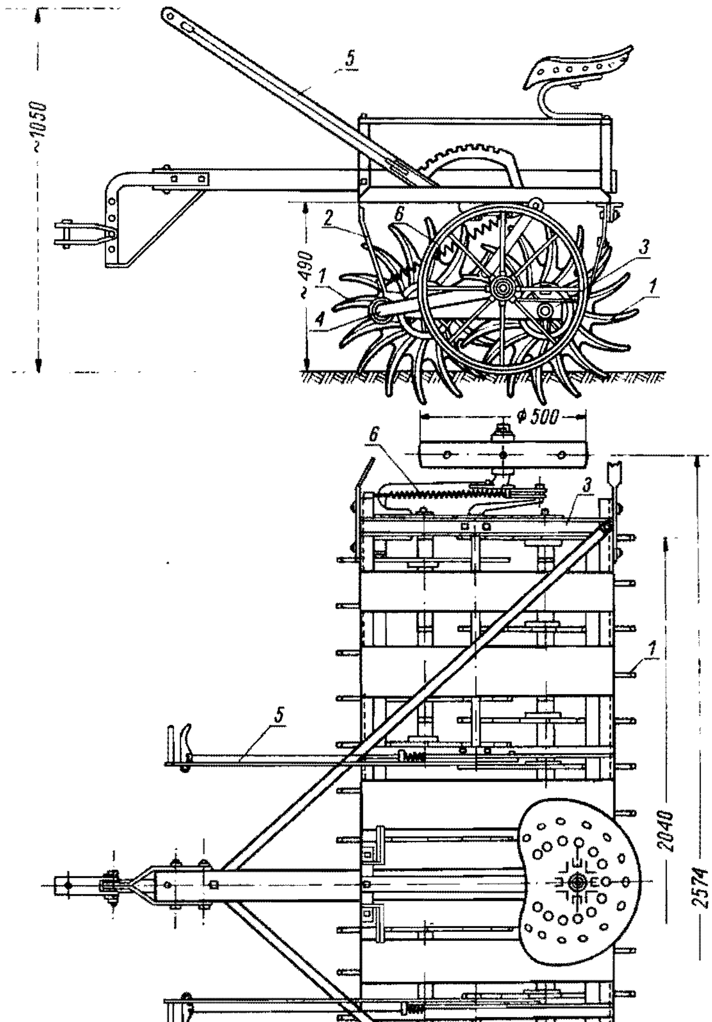


Fig. 7.22. Passive rotary hoe: *1* — tooth disk; *2* — bracket; *3* — frame of disks; *4* — axle of the ground wheel; *5* — control lever; *6* — releasing spring.

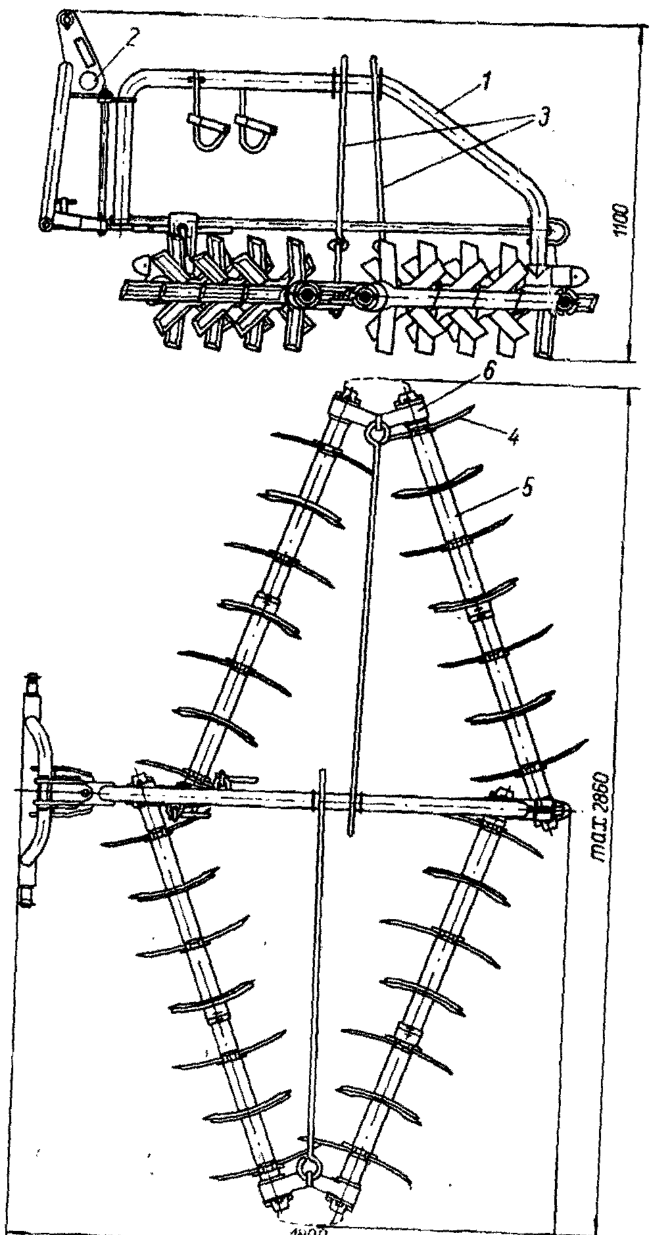


Fig. 7.23. Four-sectional mounted paddle harrow: 1 — frame; 2 — mounting column; 3 — hangers; 4 — paddle; 5 — distance sleeve; 6 — shaft holder.

Five-pointed cast-iron stars, set on shafts with square cross section, or teeth screwed onto the strips on the drum perimeter can constitute operating rollers. Teeth and spikes of the star form on the roller five-coil helices. Rollers of the spike harrow are so set that traces of teeth or spikes of one roller do not overlap the traces of other rollers.

A rotary hoe (Fig. 7.22) is fitted with large toothed, steel, or cast-steel disks. It is a heavy tractor-drawn implement. In this connection, it is fitted with wheels for transport and for control of working depth.

Paddle harrow is an intermediate type between tooth harrows and disk harrows. Its working elements consist of steel disks with several paddles — that is, knives. Disks are set on a quandrangular shaft and intervals between disks are established by means of distance sleeves. The harrow can be constructed as single action with rollers set perpedicularly to the direction of motion or as tandem harrow with rollers set obliquely (Fig. 7.23).

7.2.3. Disk harrows. Disk harrows are used for rough soil preparation for sowing when there are large clods upon land or tilled fields, for sod cutting after grassland plowing and for skimming. Disk harrows should not be used on fields overgrown with couch grass, because by cutting rootstocks they increase overgrowth of the field by couch grass. Working elements of disk harrows are plain or toothed disks which cut and turn furrow slices. The shape of teeth notched in disks can be different but too small teeth should not be used because they enter the soil too deeply and instead of cutting off slices, groove pits in the soil. Only plain disks can be used for skimming. Construction of the disks has been described in section 6.4.6. on plow disks.

Harrow disks are easily packed with soil owing to low pressure of slices and, therefore, they are fitted with scrapers mounted on a common beam.

The beam is, in some types of harrows, so designed that the position of the scrapers can, to a certain extent, be changed in relation to the disks. The section of a disk harrow consists of several disks drawn over a shaft of square cross section. Spacing of disks is fixed by cast iron or cast steel distance sleeves. The section is provided with two slide bearings (Fig. 7.24). Bearing bushings can be cast iron, plastic, or hardwood (beech, hornbeam). Bearings are screwed to the outriggers of the frame. Sections are always set obliquely to the direction of harrowing.

Penetrating depth of disks depends only, to a limited extent, on the setting angle, but above all on the weight of the section. In this connection, almost all harrows are fitted with wooden or sheet-metal boxes placed on frames of particular sections which can be filled with stones or earth to load the sections. Horse- and tractor-drawn disk harrows are transported on cars or trailers or on wheels put under sections or under the harrow frame, while transported and disassembled before harrowing. Harrows wider than 3 m should be disassembled for transport purposes and their sections should be set in two rows, one after another.

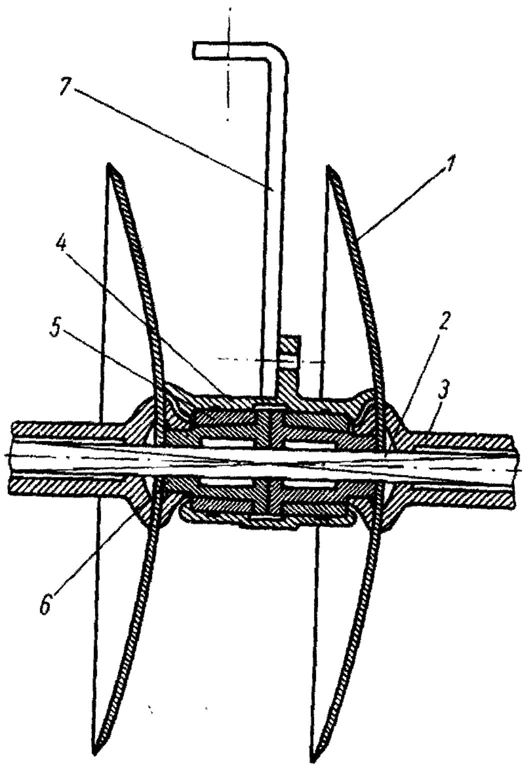


Fig. 7.24. Disk-harrow's shaft provided with bearings: 1 — disk; 2 — square shaft; 3 — distance sleeve; 4 — bearing housing; 5 — bearing bushing; 6 — sleeve; 7 — outrigger of a frame.

Disk harrows are fitted neither with supporting elements for controling the working depth nor with elements for transmission of side thrusts. Only single-section skimming harrows should be equipped with a thrust element. Other harrows are fitted with an even number of sections, whereby one gang (half of the section) consists of disks rotating with their convexity in one direction — the other half in the opposite direction. In symmetric single-action harrows, there would be formed along the symmetry axis a strip untouched by the disks; it is pulverized by the tine of the cultivator fixed to the harrow frame.

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Disk harrows must not be used at speeds higher than 7 km/hr, because then the disks throw the furrow slices too far and the uniformity of the depth becomes lower.

Horse harrows (Fig. 7.25) generally have two sections rigidly connected with the frame resting on the forecarriage. The forecarriage is not designed — as a rule — to control the working depth, but only to eliminate lateral jerks of the harrow result-

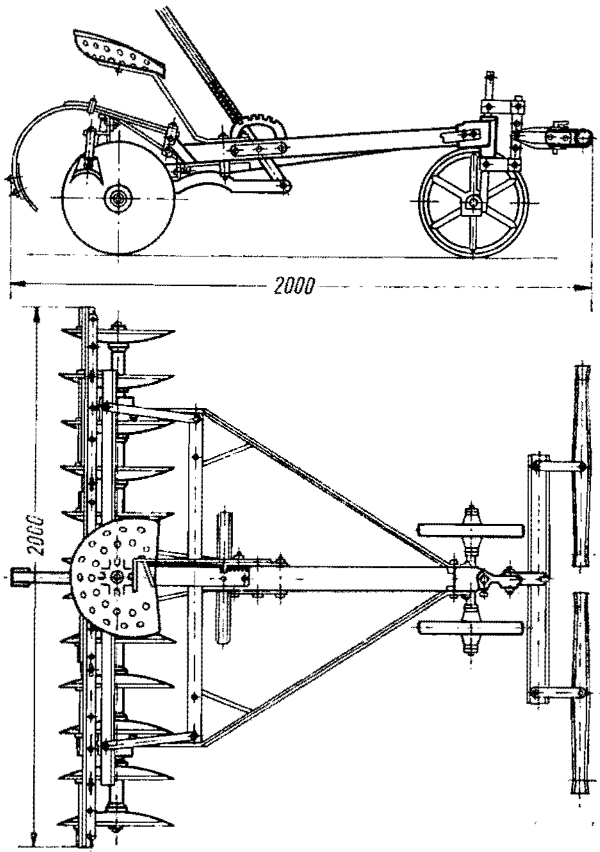


Fig. 7.25. Horse-drawn disk harrow.

ing from inaccurate counterbalancing of resistances of particular sections; such jerks would cause the horses to become tired quickly. A horse-drawn harrow requires a span of 2–4 horses. The operator sitting in the saddle fixed to the frame is taken into account as an additional load; if this load is not sufficient, the frame is loaded by a box with stones or earth. This harrow can be transported for short distances across cart roads on disks, after the shafts of the section have been set perpendicularly to the direction of travel. For a longer transport, two wheels should be mounted under the sections.

Single-action tractor disk harrows are designed for skimming. Disk setting angles can be changed to the extent of $\Theta_0 = 20$–$35°$. Skimming performed by means of the disk harrow is not so exact as skimming by means of a moldboard plow. High efficiency of harrowing, resulting from considerable width of operation is the advantage of the harrow. Multi-sectional skimming trailed harrow (Fig. 7.26) is fitted with sections con-

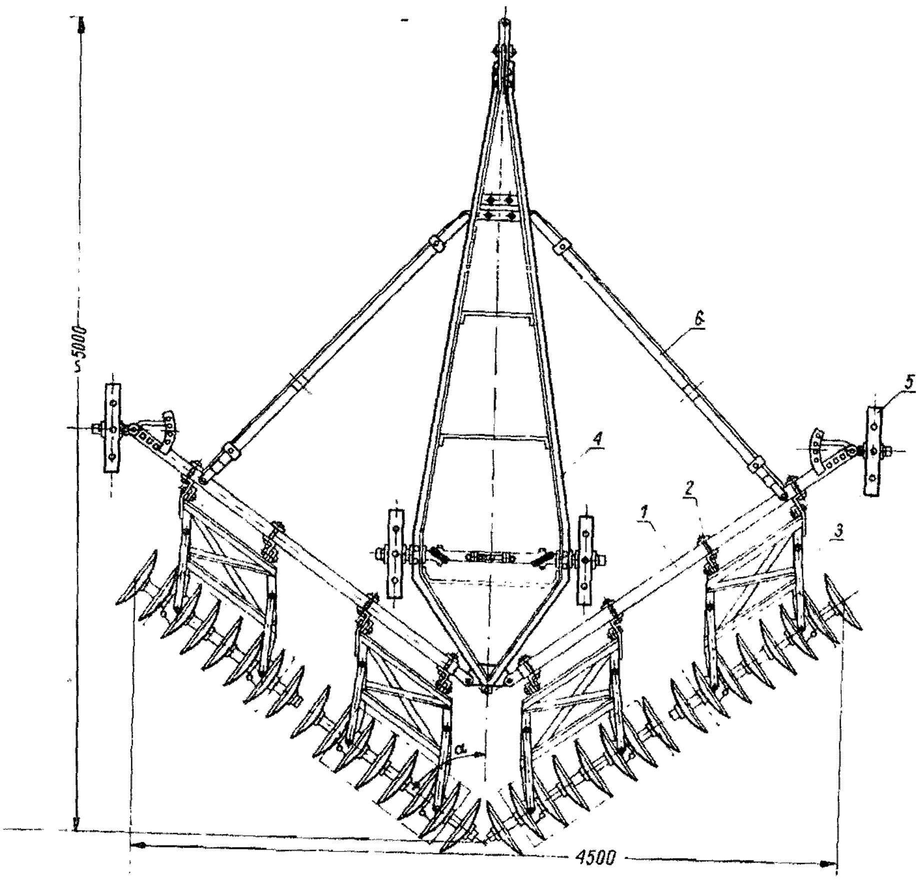


Fig. 7.26. Single-action trailing disk harrow: *1* — oblique hitchbar; *2* — yoke of the frames of the section; *3* — section frame; *4* — hitch frame; *5* — supporting wheels of oblique beams; *6* — angle strut of the hitch.

nected by hinged joints with oblique beams by means of rigid frames making lateral shifting of the section impossible. In this way, the entire harrow forms a rigid system in a horizontal plane. Beams and angle struts of the hitch form a heavy frame supported by wheels in order to avoid its dragging across the land. Setting angle of sections is regulated by the

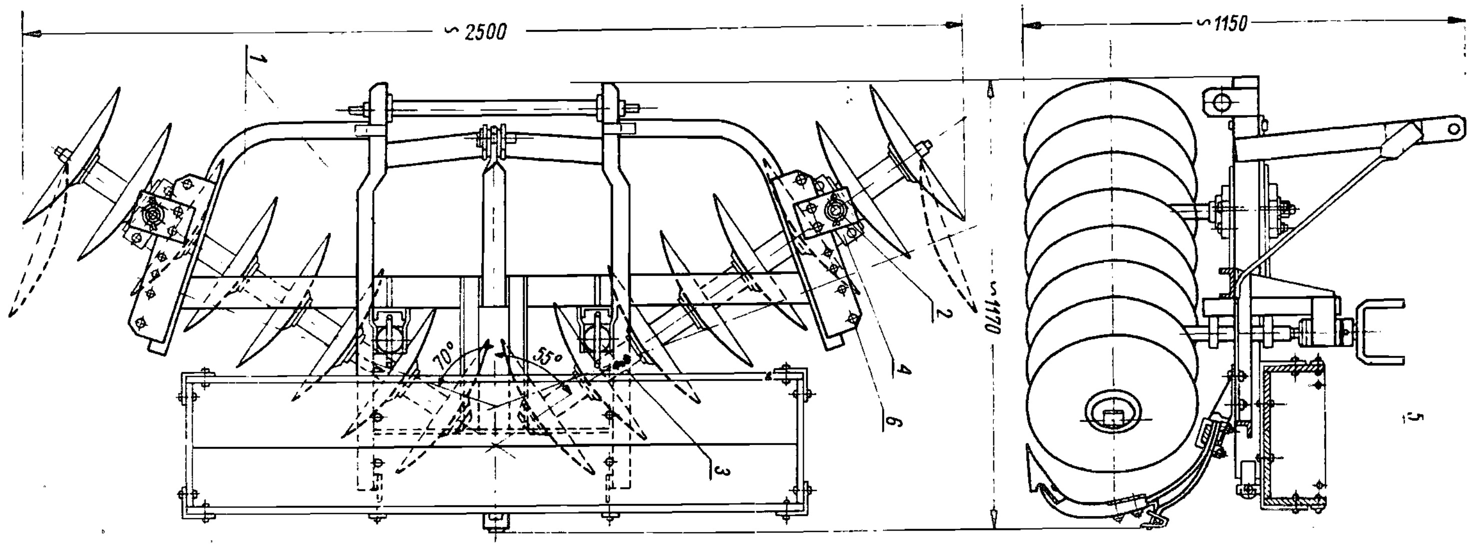


Fig. 7.27. Single-action mounted disk harrow: 1 — frame with mounting column; 2 — vertical shaft; 3 — regulated vertical shaft; 4 — shaft bearing; 5 — controlling crank for section leveling; 6 — control of angle of section setting.

length of angle struts which extend during harrowing, and — when making turns — one of them is compressed. Forces occurring in the hitchbar can easily be determined from soil resistance acting on sections.

Mounted skimming harrows are more convenient in operation (Fig.

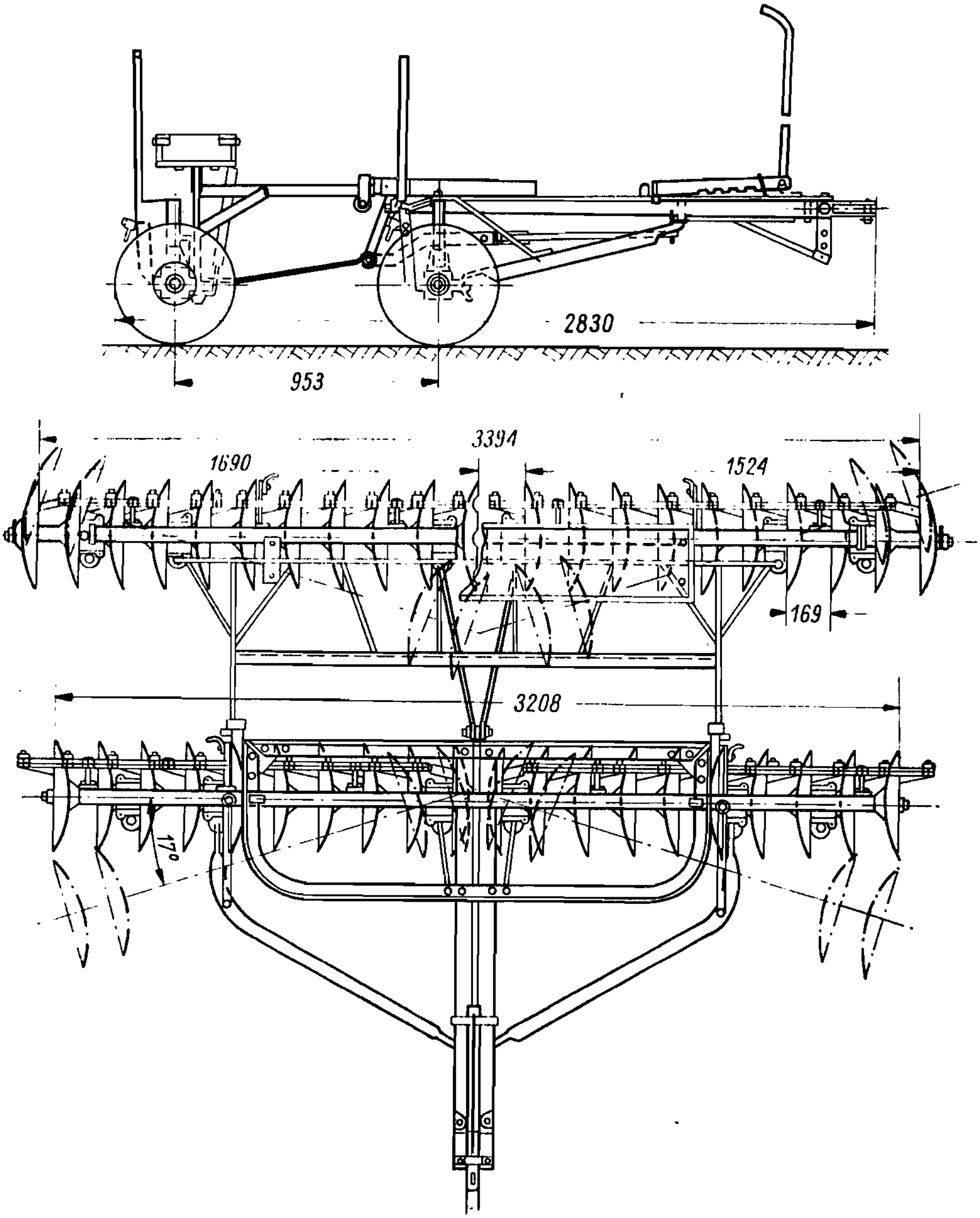


Fig. 7.28. Tandem, trailing disk harrow.

7.27). Two sections of this harrow are rigidly connected with the frame by means of vertical shafts and helical spindles whose task is the leveling of the section. Daily efficiency of a tandem harrow is not much lower and sometimes slightly higher than the efficiency of a four-section trailing harrow; with the latter, we have to foresee high losses of time for assembling and disassembling purposes before and after the operation and for turns during harrowing.

Single-action harrows can also be used for field harrowing but most frequently one harrow travel is not sufficient to accomplish the purpose and the field must be harrowed twice.

Tandem harrows are better suited for soil harrowing. Tandem, four-section harrows (Fig. 7.28) make up a heavy aggregate and are, therefore, designed mostly as tractor-trailed implements. Disks of the front sections are placed in such a manner that their convexities are turned inward,

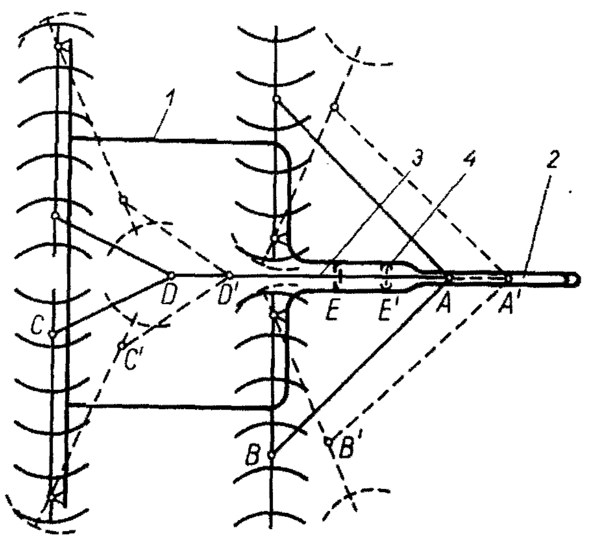


Fig. 7.29. Connections of the section of tandem, trailing disk harrow: 1 — frame; 2 — hitch; 3 — longitudinal link of the slider; 4 — locking of the slider (pawl).

while those of the rear sections in the opposite direction. This assembly of the disks enables pulverizing of the entire surface intensively and exactly enough without turning the furrow slices. For this reason, tandem harrows cannot be used for skimming, because skimming requires the furrow slices to be turned and the stubble to be covered; they can be used — on the other hand — for tilling the stubble before aftercrop sowing.

Harrow sections are interconnected by links (Fig. 7.29), and setting

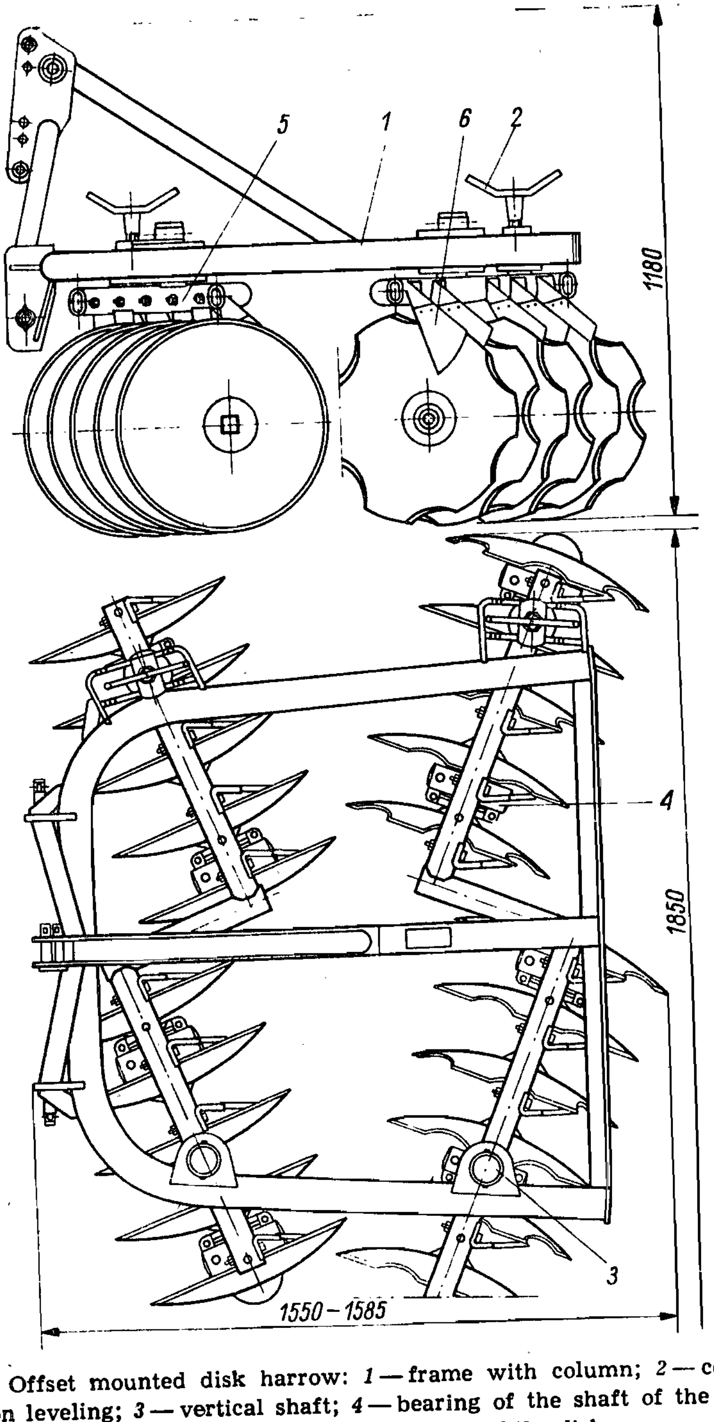


Fig. 7.30. Offset mounted disk harrow: *1* — frame with column; *2* — control crank for section leveling; *3* — vertical shaft; *4* — bearing of the shaft of the section; *5* — beam of scrapers; *6* — scraper of the disk.

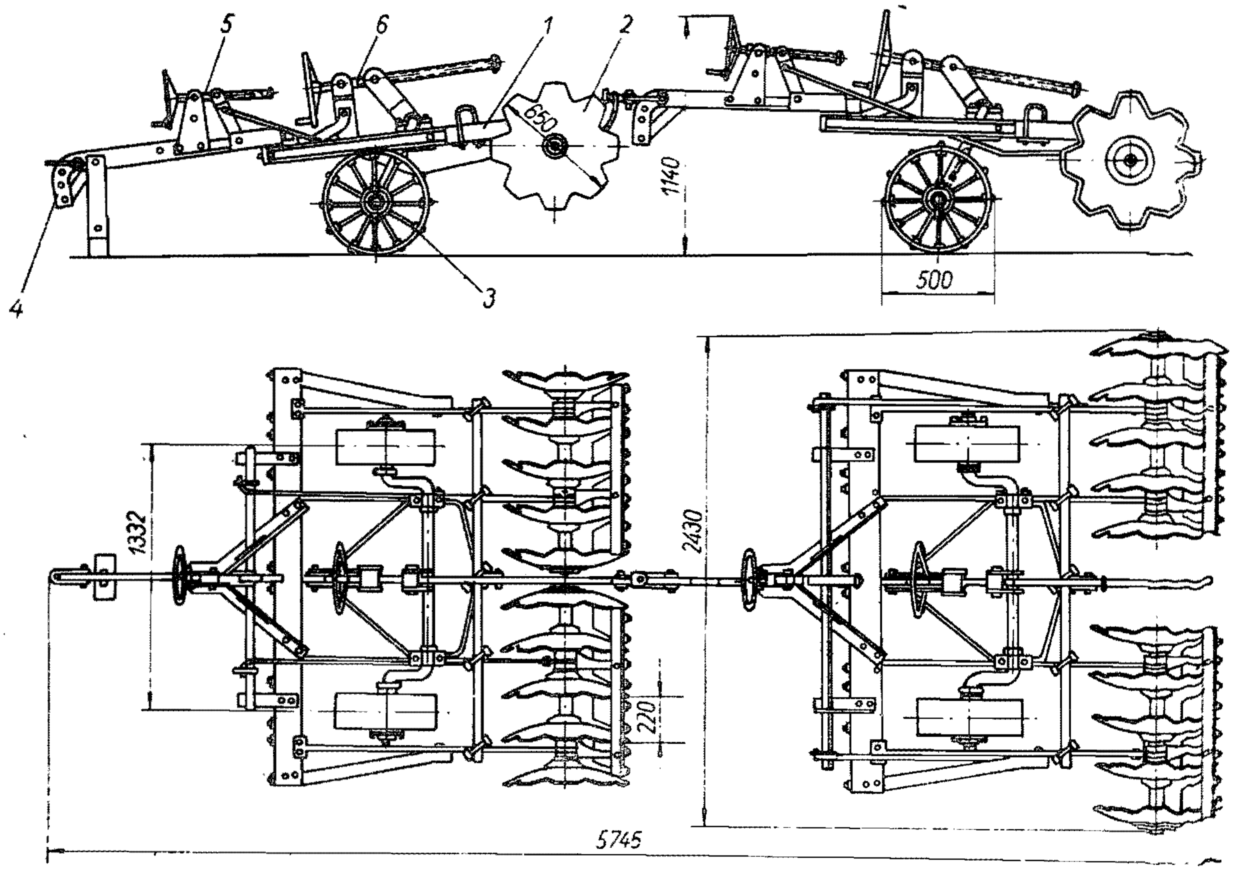


Fig. 7.31. Aggregate of heavy disk harrows: *1* — frame; *2* — disk section; *3* — supporting wheel; *4* — hitch; *5* — spindle controlling hitch setting; *6* — spindle controlling supporting-wheel setting.

the sections under the required angle can be effected by withdrawing the harrow backward. The location of the hitchbar in relation to the links is fixed with the use of the slider locked by a pin or — more simply — by a pawl mechanism (strip with cutouts).

Easier in operation are offset harrows (Fig. 7.30). In order to reduce the harrow length, each section is divided into two gangs, shifted in relation to each other. The second section of the harrow can be fitted with toothed disks. Disk harrows destined for working in orchards are designed as offset harrows and differ from other types by having the rear section offset laterally in relation to the front one. This makes it possible the lateral mounting or attaching the harrow to the tractor, which can now travel far from trees when harrowing adjacent fields.

Heavy trailing harrows, fitted with disks of diameters exceeding 600 mm, are used for new ground and muddy wasteland tillage. These are rather aggregates consisting of two single-action harrows trailed one behind the other (Fig. 7.31). Harrows of this type are equipped with sufficiently wide wheels for depth control and for transport. The position of the wheels in relation to the harrow frame is fixed by means of a helical spindle cranked by hand.

7.2.4. Stability of harrows. As already indicated, harrows — as a rule — are not fitted either with supporting elements limiting their working depth, or thrust elements counterbalancing side forces. Two forces — weight G of the harrow section and soil resistance K (Fig. 7.32) act, therefore, on each harrow section.

Balance of forces acting on the section, connected by joints with the beam or hitching frame, is conditioned by the passage of component W_1 of the weight of section and of soil resistance through the point of application. But considering that the instantaneous soil resistances are variable, both as regards their value as well as their direction, the instantaneous moments $M = W_1 \cdot l$ occur around the point of application (Fig. 7.32c) whose average value, in fairly short periods, is equal to zero. Variable moment $M = W_1 \cdot l$ brings about

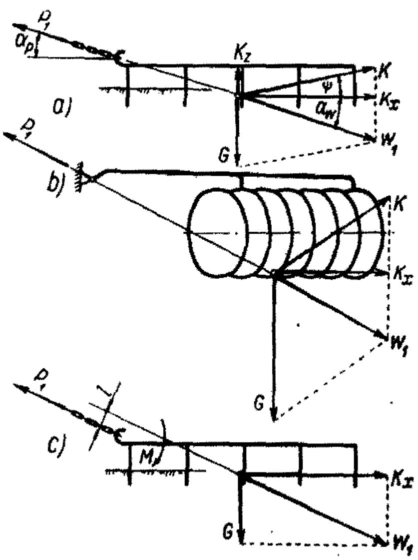


Fig. 7.32. Forces acting on single sections of harrows: *a*) and *b*) in equilibrium; *c*) unequilibrated.

alternate increase and decrease in working depth of the section. In order to reduce these fluctuations to the minimum, the weight of the harrow section should be adopted to the type of soil, since the soil resistance depends on the weight of the section. The greater the working depth the higher is the soil resistance.

The fluctuations of soil resistance are disregarded in calculations, and it is assumed that its point of application happens to be in the center of symmetry of working parts and in the middle of the working depth. In this way, the direction of the resultant W, running through the point of application of force can easily be determined as follows

$$\tan\alpha_w = \frac{G+K_z}{K_x} = \frac{G}{K_x} + \frac{K_z}{K_x} = \frac{q_z}{p_z} - \tan\psi \qquad (7.8)$$

where

α_w — angle of inclination of the resultant W_1,

G — weight of the section (kg),

K_z and K_x — components of soil resistance (kg),

q_z — weight falling on one working element of the harrow (kg),

p_z — resistance falling on one working element of the harrow (kg),

ψ — angle of inclination of soil resistance, accepted as positive, when the resistance K is directed downward.

The angle ψ depends on the type of working parts, on their setting angles and on the type and state of soil. The firmer and drier is the soil the lower is the value of the angle; average values of this angle are most frequently negative and are contained within fairly wide limits (Table 7.2).

Table 7.2

Harrows	Toothed		Rotary		Disk	
	with straight tines	with bent tines	toothed	with paddles	tillage	skimming
ψ_{sr}	0° to —15°	—5° to +10°	—20° to —50°	—30° to —60°	—30° to —55°	—20° to —40°

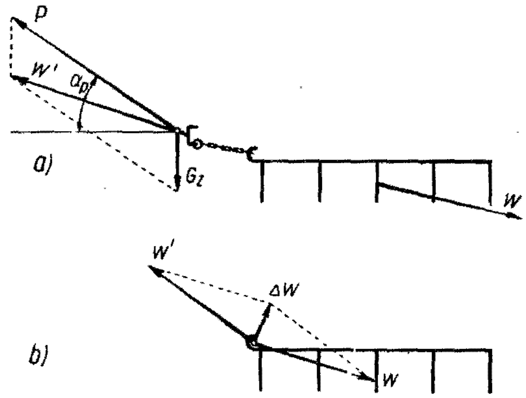
To attain equilibrium of forces of the entire harrow, resultant W must be counterbalanced by the force P and by the weight of the hitchbar G_z (Fig. 7.33).

Thus, the direction of action of the force defined by the angle α_p is of importance for the balance of harrow

$$\tan\alpha_p = \frac{G_z+G+K_z}{K_x} \qquad (7.9)$$

The angle α_p is determined, in horse-drawn harrows, by the inclination of ropes, which should be contained within limits of 15–23°; in tractor-trailed harrows — by the point of hitching of the harrow to the tractor; in mounted harrows — by the instantaneous point of rotation being the point of intersection of the mounting links.

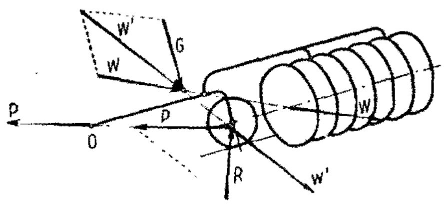
Fig. 7.33. Forces acting on toothed harrow: a) in equilibrium; c) unequilibrated.



If the harrow is not properly trailed and the resultant W' of the weight of the hitchbar G_z and of the force P does not overlap the resultant W of the weight of the section and of the soil resistance K (Fig. 7.33b) — then there occurs force ΔW, which lifts, in dependence on the direction of action of this force, the front or rear part of the section out of the soil.

In multisectional harrows (Fig. 7.28) hitchbars consist of heavy frames which must rest on wheels. In this type of harrows (Fig. 7.34) hitching of

Fig. 7.34. Equilibrated forces acting on disk harrow with hitch frame supported on wheels.



the harrow to the tractor must not be effected in an exactly determined point, if on the supporting wheels acts only soil reaction R, which — together with the weight of the hitchbar and the draft — balances the weight of the section and soil resistance. In order to determine the direction of the draft, the weight of the hitchbar G_z is added to the resultant W, and the resultant W' is obtained, whose point of intersection with the direction of soil reaction R on the supporting wheel, connected with the point O of the hitching of the harrow to the tractor, determines the line of action of the force P.

Certain types of harrows are fitted with sections rigidly connected with the harrow frame. In horse harrows of this type, the frame rests on the forecarriage (Fig. 7.35) which serves as supporting element not restricting, however, the working

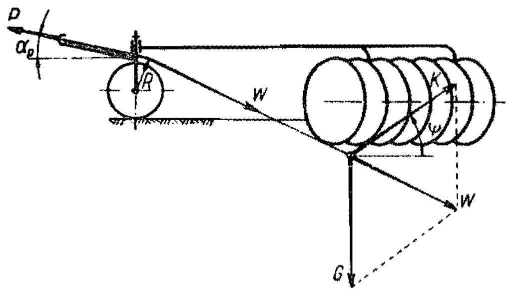


Fig. 7.35. Equilibrated forces acting on horse-drawn disk harrow with forecarriage.

depth. Soil reaction against the wheels of the forecarriage can occur only if the value of the angle of inclination of the force P is lower than that of the resultant W. Soil reaction R to the wheels of the forecarriage should amount to at least 25 kg, but not more than results from the weight distribution of the harrow in transport position.

In tractor-trailed harrows with rigid frames the resultant W must pass through the point of hitching the harrow to the tractor or through the instantaneous point of rotation (point of mounting) (Fig. 7.36). Point O

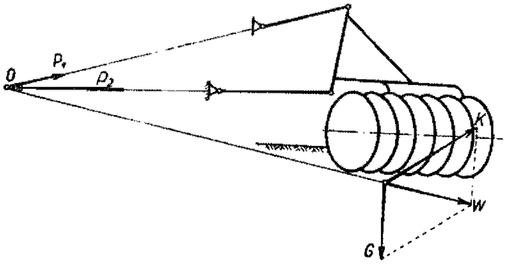


Fig. 7.36. Equilibrated forces acting on mounted disk harrow.

of harrow hitching or mounting has an influence on the direction of the resultant W, and thus on the soil resistance. Position of the point of hitching is limited by the position of the hitchbar of the tractor. In mounted harrows the instantaneous point of rotation can be situated very low, even at the rear of the harrow, owing to which the weight of the harrow can be low.

Soil resistance in disk harrows undergoes frequent changes of the direction of operation and this is the reason why uniformity of their working depth is so poor. The choice of weight of a harrow is of basic importance for attainment of the adequate depth at a given type of hitching or mounting of a harrow. It sometimes happens that maximum additional loading of a harrow is, under firm soil conditions, not sufficient to attain the required working depth and that, under conditions of light soils, the deadweight of the harrow is too high and the harrow penetrates too deep. This dependence of the working depth — particularly in disk harrows — on weight of the harrow, on firmness of soil, and on the direction of action of its resistance often makes it difficult to comply with agrotechnical requirements as to penetration depth and proper working uniformity.

Should the mounted disk harrow be intended for operation under various soil conditions, and uniformity of working depth is aimed at — there is only one solution: use of at least one supporting wheel in front of working elements in the midpoint of the width of the harrow. It is necessary to have the possibility of changing the point of mounting by transposing the upper mounting link so, that at maximum penetrating depth, the pressure on the supporting wheel is almost equal to zero and at average penetrating depth — is at least about 100 kg for each meter of working width of the harrow. Such supporting wheel as these ensure stability of the mounted disk harrow in the vertical plane and secure a considerable uniformity of the working depth. This is of particular importance for skimming.

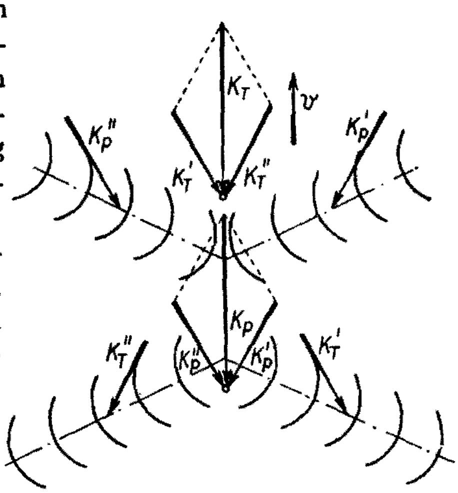


Fig. 7.37. Equilibrated forces acting on four-section disk harrow in the horizontal plane.

In the horizontal plane each harrow has freedom of turning around the point of hitching or of mounting. Equilibrium of forces, acting on the harrow in this place, can result from the symmetry of spacing of the sections. Nonetheless, instantaneous soil resistances on both sides of the harrow are not identical and this produces an alternately variable moment in relation to the point of hitching creating a sinuous motion of the harrow. The teeth of heavy harrows penetrate relatively deep and can transfer certain side forces and thus equilibrate to a certain degree variable moments. As a result, the sinuous motion of these harrows is minimum.

Disk harrows have sections always set obliquely, the horizontal component of the soil resistance being also obliquely directed to the axis of the section (Fig. 7.37). Shifting of the harrow sidewise produces, as a result of variable forces, a change of the angle of section setting and, consequently, a change in working width of particular disks. Therefore, all sections of the harrow must be thoroughly leveled for attaining as uniform penetration of all disks as possible because then the sinuous motion of the harrow is minimum. The sinuous motion has an adverse influence on the quality of harrowing and causes jerks sometimes making steering of the tractor impossible. Single-action harrows are considerably less stable than tandem harrows. To obtain good stability of a single-action harrow in the horizontal plane, the harrow should be equipped with a colter (Fig. 6.162), a share or a disk colter. Figure 7.38 presents how the sinuous motion of

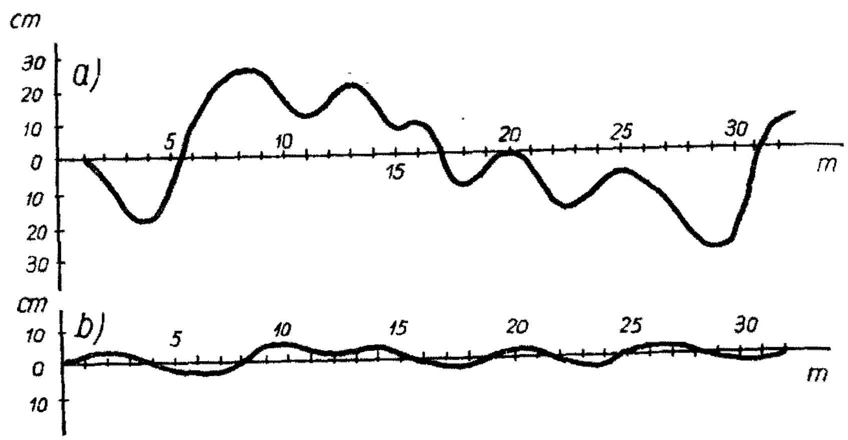


Fig. 7.38. An example of a trajectory of disk harrow: *a*) without the colter; *b*) with the colter.

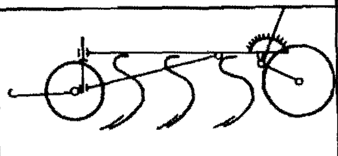
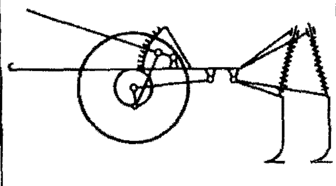
the harrow has changed after using a share colter. Harrowing on hillsides, lengthwise or obliquely to contour lines with the use of disk harrows is impossible without colter; harrows slip down and, taking a position oblique to the direction of travel, cause the tractor to be pulled down.

Single-section disk harrows — similarly as disk plows — have to be provided with colters consisting most frequently of flanges on supporting wheels. Such colters must be calculated for transferring the entire pressure produced by the transversal component of the soil resistance acting on the disks. The action of colter has been described in section 6.9.

7.3. Cultivators

The task of the cultivators is to deeper pulverize and partly to crush the tilled and musty soilbeds. Cultivators can be used for scarifying stubble before sowing aftercrops, for destroying turf on the land to facilitate sinking of the plow during tillage, for mixing fertilizers with soil and other work connected with preparation of soil for sowing (Table 7.3).

Table 7.3*

Types of cultivators	Type of tines	Scheme	Main parameters				
			a	s	g	p	i
Horse-drawn	Spring tines		5-10	12-15	0.9-1.1	15-30	5-11
	Knife tines		5-8	10-15	0.9-1.1	20-30	5-11
Semimounted	Semirigid with sweeps		8-12	15-25	1.2-1.5	30-50	13-19
	Rigid with sweeps		10-16	20-25	1.5-2.2	30-60	13-19
	Rigid with shovels		10-22	15-20	1.5-2.0	30-150	7-17
Mounted	Spring tines		6-10	12-20	0.7-0.9	20-40	13-19
	Semirigid with sweeps		8-12	15-25	0.8-1.0	30-50	11-15
	Rigid with sweeps		10-16	20-30	1.0-1.3	30-60	9-13

Horse-drawn and semimounted tractor cultivators are fitted with frames which rest on wheels (for transport and for depth control). Wheels in mounted cultivators serve only for working-depth control. The ground-working parts of a cultivator are teeth — spring, semirigid or rigid; their ends constitute: shovels, sweeps or knives spaced in two or three rows on the frame.

Horse-drawn cultivators (Fig. 7.39) can be equipped — after the spring tines have been dismounted — with knife teeth serving for cutting turf in order to aerate grassland. Cultivators with rigid knife teeth are called scarificators. The triangular frame of a horse-drawn cultivator rest on one- or two-wheel forecarriage. For locating the frame on the forecarriage serves a sleeve with a clamp screw. The position of the rear wheels is set by means of a hand lever with pawl.

Semimounted tractor cultivators (Fig. 7.40) can be provided with tines of various types. They have two steel or pneumatic wheels, one of which is joined by means of a chain transmission with a similar power lift device as is used in plows. The lifting mechanism can raise tines alone, if they are fastened to the lever hinge-joined with the frame, or the entire frame, if tines are fastened rigidly to the frame. Helical spindle controls setting up of tines or of the frame in relation to the wheels and, consequently, sets up the working depth.

* For explanation of the main parameters see p. 381.

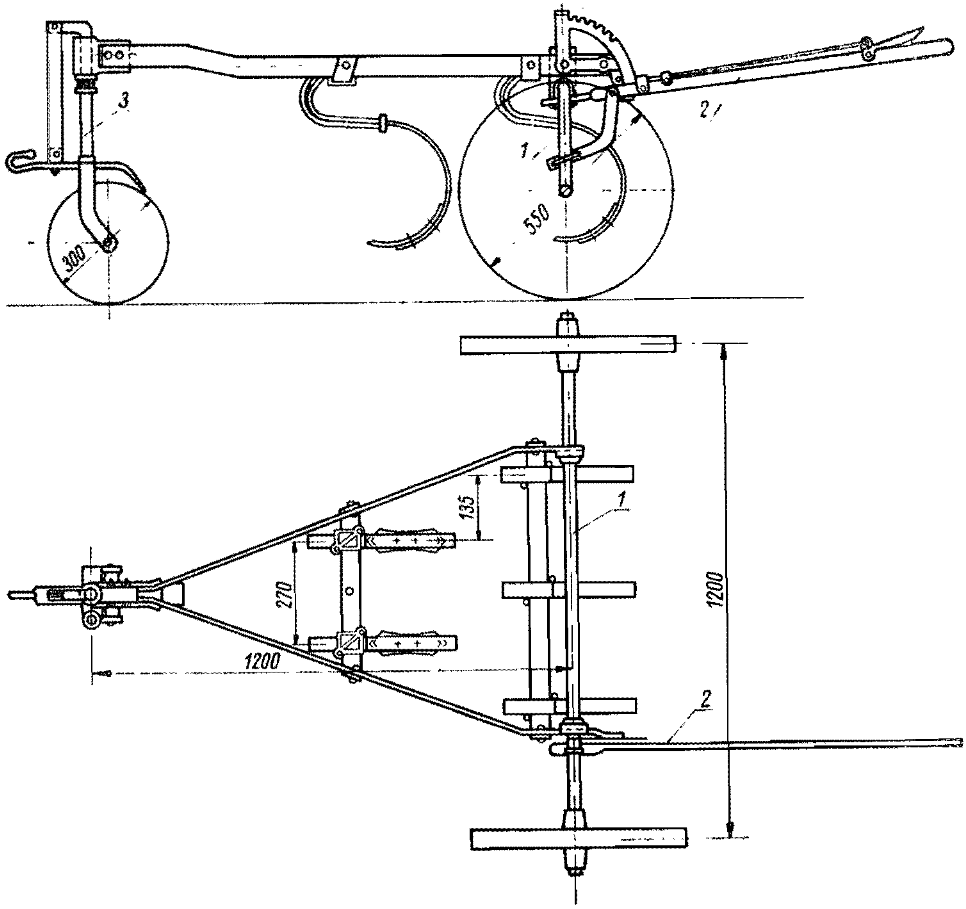


Fig. 7.39. Horse-drawn cultivator: *1* — rear wheel axle; *2* — lever for control of wheel setting; *3* — one-wheel forecarriage.

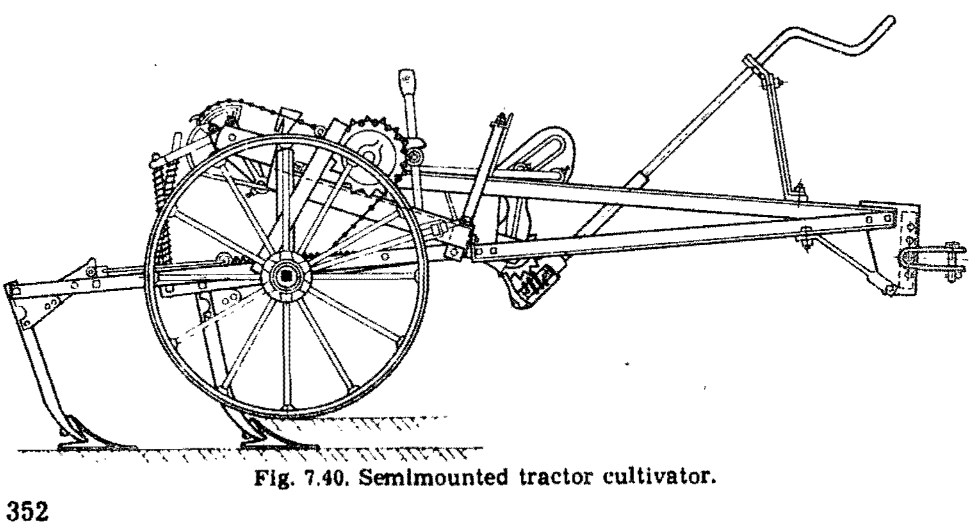


Fig. 7.40. Semimounted tractor cultivator.

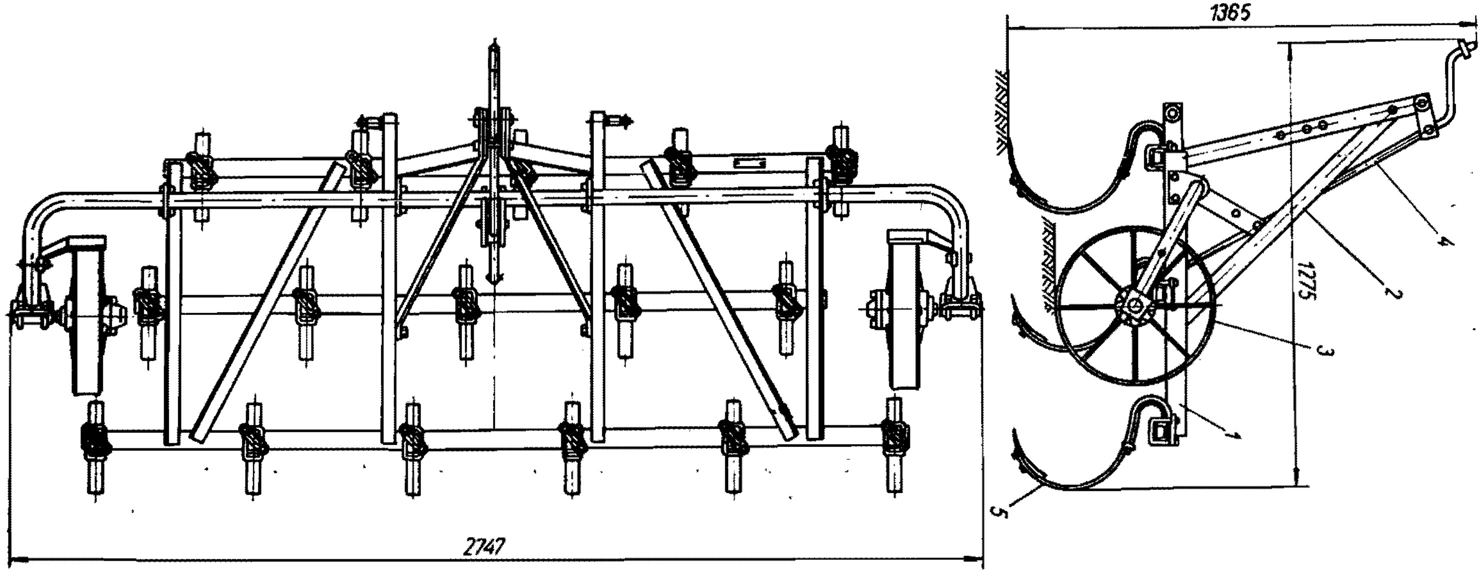


Fig. 7.41. Mounted cultivator with spring tines: *1* — frame; *2* — mounting column; *3* — gauge wheel; *4* — spindle for controlling gauge-wheel setting; *5* — spring tine.

Semimounted cultivators have three and more meters in width. Mounted cultivators are (Fig. 7.41) about 40 percent lighter than semimounted ones, thus more handy in operation and in transport. Cultivators coupled with tractors, equipped with hydraulic lifts with automatic draft control, have no wheels and can be still lighter.

7.3.1. Cultivator teeth. Spring teeth of cultivators (Fig. 7.42) are of a similar design and action as spring teeth of harrows but, because of higher resistances, they are strengthened by another spring; their working elements can be the shovel or sweep. Spring teeth are fastened to the frame of cultivator by means of yokes.

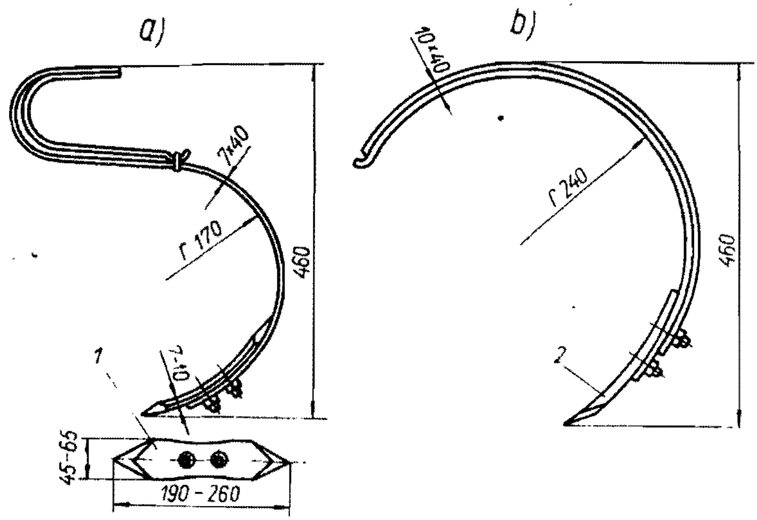


Fig. 7.42. Cutivator spring teeth: *a*) "S"-shaped; *b*) circular; *1* — two-sided shovel; *2* — one-sided shovel.

When operating teeth bend backward. Shape of the spring camber and its dimensions should be selected in such a manner that the deflection f of the tooth be proportional to the component K_x of soil resistance (Fig. 7.43)

$$K_x = Cf \text{ (kg)} \quad (7.10)$$

The constant of the spring should amount to $C \leqslant 6$ kg/cm. The spring tooth is calculated for a double average resistance K_x.

Maximum tooth deflection should not exceed 10 cm, and the load angle α of the shovel (or sweep) should not — at maximum spring deflection — exceed 30°. The load angle α of the shovel, without the spring deflection, should be contained within limits 15–20°.

Spring teeth cannot be applied under each soil conditions. As a result of high deflection, the teeth can pull wet soil out onto the surface, and thus facilitate harmful drying up of soil. Clods pulled upward onto the

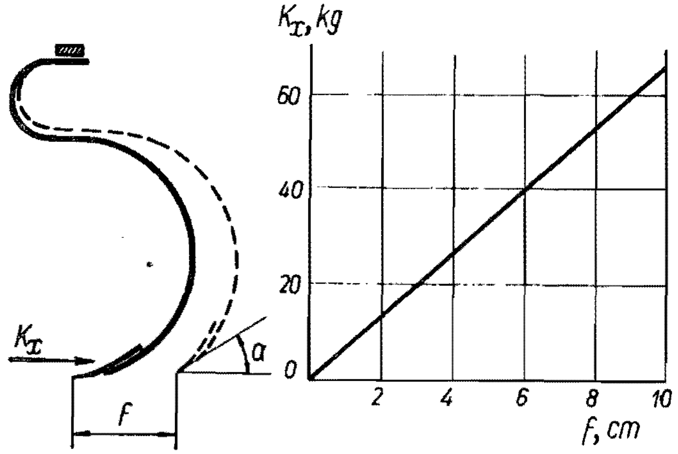


Fig. 7.43. Diagram of spring-tooth deflection.

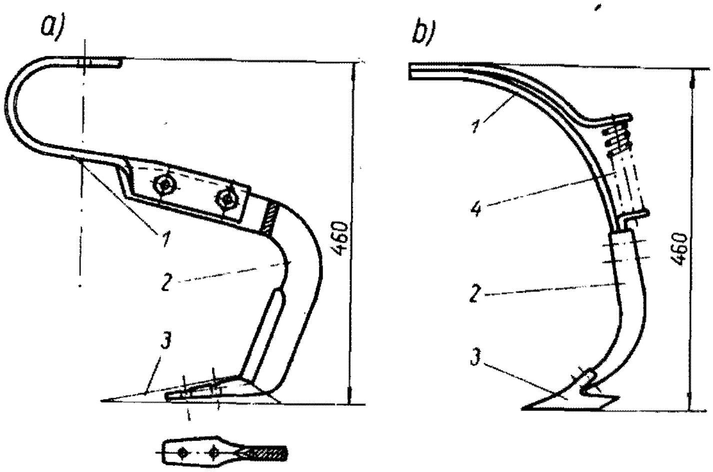


Fig. 7.44. Semirigid cultivator teeth: *a*) with single plain spring; *b*) with additional helical spring (Arns); *1* — plain spring; *2* — shank; *3* — sweep; *4* — helical spring.

surface quickly dry up and become hardened. A drawback of spring teeth is their lack of securing uniform working depth, and their difficult penetration into the soil; their advantage, on the other hand, is their capacity of pulling out rootstocks of couch grass onto the surface without ripping them.

A semirigid tooth (Fig. 7.44) consists of two parts: lower rigid and upper spring part fastened by a yoke to the frame. Semirigid teeth are provided at their ends with sweeps, which penetrate more easily into the soil than the shovels. The constant of the spring (formula 7.10) of the

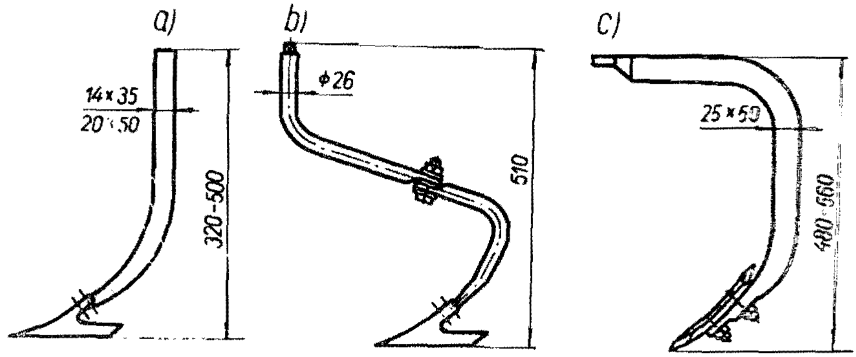


Fig. 7.45. Rigid teeth of a cultivator: *a*) with vertical shank; *b*) with sectional shank; *c*) chisel.

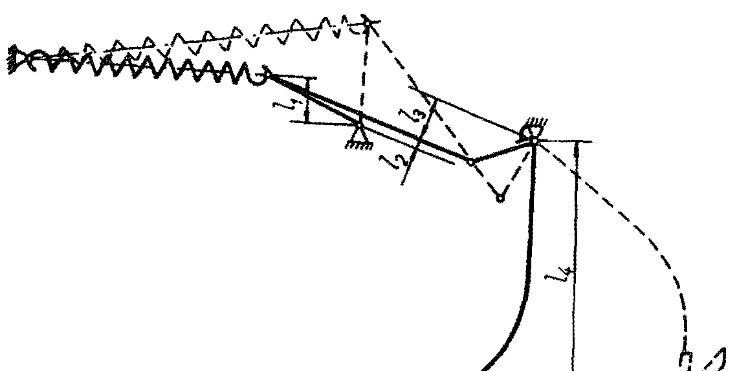


Fig. 7.46. Scheme of connections between cultivator frame and rigid tooth loaded with tightening spring.

semirigid tooth is higher and amounts to $C \leqslant 15$ kg/cm. The spring of a tooth is also calculated for double average resistance K_x.

Arns' semirigid tooth is equipped with an additional helical spring which increases the durability of the tooth without changing its operational effect. The rigid tooth (Fig. 7.45) consists of a shank and a sweep or of a shovel. The tooth shank can be rigidly connected with the frame by means of screws or by joints with frame or a lever. The tooth shank fastened by joints is held in a normal position by means of a link system connected with the spring. The system serves simultaneously as a safety device. If the tooth encounters a stone in the soil, it deflects backward (Fig. 7.46) and tightens the spring.

The initial tension P_w of the spring must be so selected that the tooth be not deviated backward when soil resistance exceeds the value of average resistance K_x by about 1.5 times. The tension of the spring amounts to

$$P_w = \frac{1.5K_x}{i_w} - T_w \tag{7.11}$$

$$i_w = \frac{l_2}{l_1}\frac{l_4}{l_3}$$

where

i_w — ratio of arms of the mechanism connecting the tooth with spring,
$T_w = 0.1P_w$ — friction in the mechanism.

Full backward deflection of the tooth should ensue when soil resistance exceeds three to five times the average resistance K_x. The final spring tension amounts to

$$P_K = \frac{C_d K_x}{i_K} - T_K \tag{7.12}$$

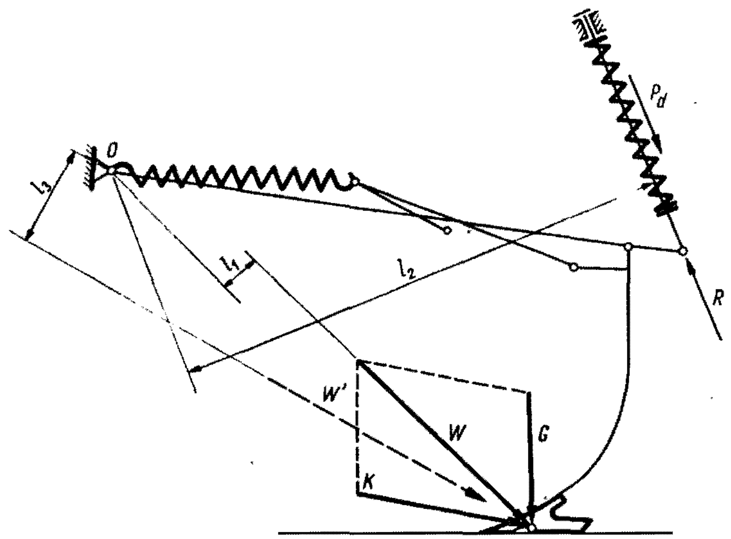


Fig. 7.47. Scheme of connection between lever and rigid tooth with double system of tightening springs.

where

$C_d = 3\text{–}5$,

i_K — ratio of arms of the mechanism connecting the tooth with spring in final position,

$T_K = 0.1P_K$ — friction in the mechanism.

The teeth of the cultivator installed in levers (Fig. 7.47) have additional springs pulled on rods connecting them with outriggers of the lifting beam; these springs also act as safety devices. The soil resistance K, directed under angle ψ, and the weight G of the tooth and of the lever act on normally operating tooth. The resultant W of these two forces should run above the point O of the fastening of the lever to the frame. Equilibrating moment is derived from the force R in the rod on which is mounted the tooth

$$Wl_1 = Rl_2 \tag{7.13}$$

During a suitable increase in soil resistance, when backward deflection of the tooth tightens the horizontal spring, the resultant W' passes below the mounting point of the tooth O and then there occurs the moment, counterbalanced by the tension of the additional spring P_d, which raises the lever upward.

$$W'l_3 = P_d l_2 \tag{7.14}$$

After the obstruction have been overcome, the springs bring the tooth back to normal position.

The cultivator tooth acts on the soil in a manner similar to the harrow tooth — that is, sidewise and forward (Fig. 7.48). Width of zones t_s,

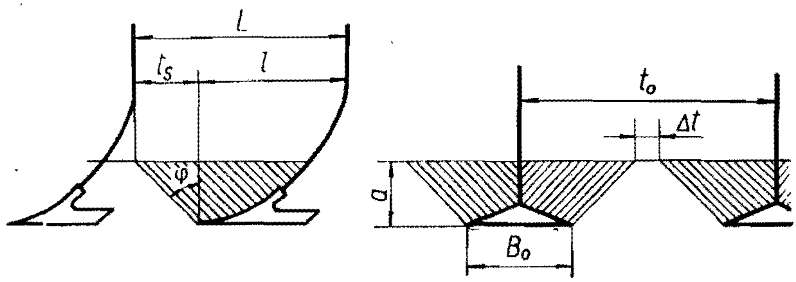


Fig. 7.48. Operating zones of cultivator teeth.

acting on both sides of the tooth, can be calculated according to the formula (7.2), in which B_0, denoting the width of the shovel or of the sweep will be introduced instead of d_r. Transversal spacing of cultivator teeth should amount to

$$t_0 = 2a_{max} + B_0 + \Delta t \tag{7.15}$$

where

$\Delta t = 2$–5 cm for the shovels,

$\Delta t = 0$–5 cm for the sweeps.

Zone of forward action of the cultivator amounts to

$$t_z = a \tan \varphi$$

It can be assumed that $\varphi = 45°$ and then spacing L of the rows of teeth should amount to

$$L \geqslant a_{max} + l \tag{7.16}$$

where l is the distance of the blade point from the tooth shank.

Sweeps are spaced in cultivators most frequently in two rows, so that their tracks overlap on a width $C = 2$–3 cm. Sweeps of the second row can be wider than those of the first row. The working width of the cultivator with sweeps amounts to

$$B_K = B_0 n - C(n-1) \tag{7.17}$$

where

n — number of all sweeps,

B_0 — width of a sweep.

Shovel teeth are spaced most frequently in three rows.

7.3.2. Ground-working parts of cultivators. Ground-working parts of a cultivator may constitute shovels, sweeps or knives. The latter are often called scarifiers. Shovels of spring teeth (Fig. 7.42) are adequately

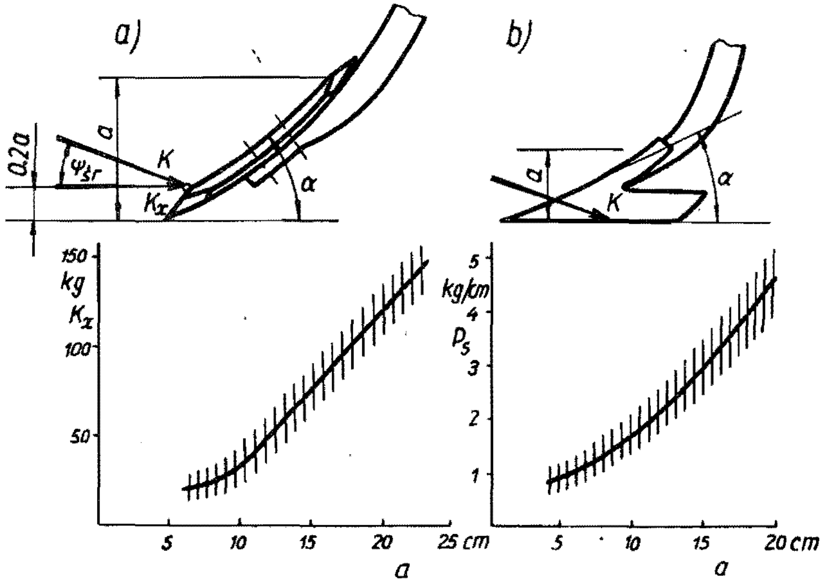


Fig. 7.49. Dependence of soil resistance on working depth: a) cultivator tooth with a shovel; b) with a sweep; p_s — specific resistance in kg/cm of working width.

bent and are screwed down to the spring by means of two countersunk screws. The shovel is most frequently bilaterally sharpened thus enabling transposition of points in the case of one point being blunt. Shovels of rigid teeth (Fig. 7.45) can be sharpened unilaterally. Load angle α of a shovel is contained within limits of 20–45°. Narrow shovels with load angles greater than 30° are used to rigid teeth, called chisels. The apex angle of the points of the shovels amounts to $2\Theta = 70$–90°. Width of shovels ranges from 45 mm to 100 mm, their thickness being 7–10 mm. Shovels are made of the same carbon steel as plowshares or disks. Blade of the shovel is hardened on a width of about 40 mm up to the hardness of 500 H_B. Hardness of the remaining part of the shovel should be below 300 H_B.

Soil resistance acting on the shovel is directed downward under angle $\psi_{sr} = 10$–25° which is the higher the greater is the working depth and the smaller is the load angle α. It can be assumed that the average soil resistance is applied to the shovel at the height of $h = 0.2a$ measured from the point of the blade. The horizontal component of soil resistance, acting on the rigid tooth with shovel, increases together with the increase in depth (Fig. 7.49).

Sweeps (Fig. 7.50) form a kind of two interconnected shares. The relation between angles of the sweep is the same as in plowshares

$$\tan\gamma = \frac{\tan\alpha}{\sin\Theta_0}.$$

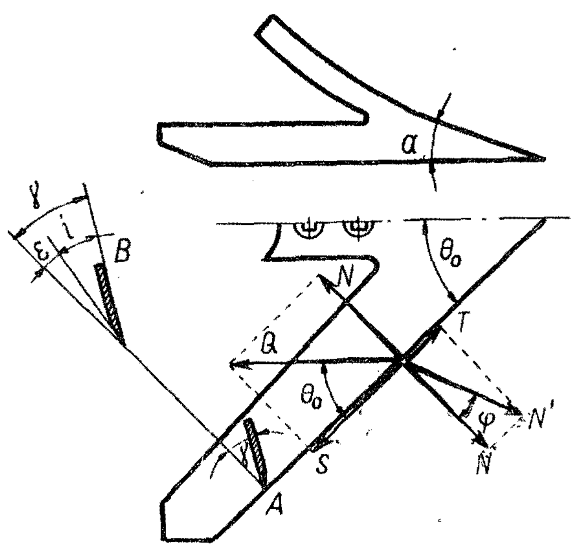


Fig. 7.50. Distribution of forces during cutting of weed roots by the sweep: A — sweep sharpened from above; B — sweep sharpened from below.

Sweeps not only pulverize the soil but also serve for cutting roots of weeds. Therefore when selecting the apex angle $2\Theta_0$ conditions for easy undercutting of roots of weeds by the sweep blades should be taken into account. While sweep is moving (Fig. 7.50) pressure Q on roots of weeds conforms to the direction of motion. This pressure is distributed on normal force N and tangential force S. Normal force produces friction $T = N\tan\phi$ of the root against the blade. The root is cut through when the tangential force S becomes higher than the friction force T

$$N\tan\varphi < Q_0\cos\Theta_0$$

$$N = Q\sin\Theta_0$$

$$\tan\varphi < \cot\Theta = \tan(90-\Theta_0)$$

$$\varphi < 90-\Theta_0$$

and then the angle of setting of the blade should amount to

$$\Theta_0 \leqslant 90-\varphi \tag{7.18}$$

The friction angle of crushed roots and stalks of weeds does not exceed 45°. Assuming that $\varphi = 45°$, we obtain

$$2\Theta_0 \leqslant 90°$$

In practice, the apex angle of sweep ranges from $2\Theta = 60°$ to 90°, most frequently 70°.

Load angle α of the sweep ranges from 12° to 20°. Smaller angles α are applied in sweeps of spring teeth and larger angles when rigid teeth are used. The range of cutting angle should be from $\gamma = 18°$ to 30°. Because of the durability of the blade, the angle of sharpness should be contained within limits of $i = 12$–15°. Sharpening of shovels or sweeps of a cultivator can vary but sharpening from above is considered as being the best, because in this case the angle of relief ε is equal to the cutting angle, and the blade does not blunt quickly. But this type of blade involves diminution in its cutting capacity of roots.

There are two types of sweeps: straight and with a nose. Sweeps with a nose are more difficult to make. Sweeps are pressed of steel sheet with carbon content of about 0.70 percent. Thickness of the steel sheet depends on working width B_0 of the sweep

$B_0 < 200$ mm	$\delta = 3$–4 mm
$B_0 = 200$–300 mm	$\delta = 5$ mm
$B_0 = 300$ mm	$\delta = 6$ mm

The blade of the sweep is hardened on a width of 25–40 mm up to the hardness of about 500 H_B. The remaining part of the sweep should indicate hardness not exceeding 350 H_B.

To make a sweep, an appropriate pattern must be cut out of the sheet. Blanking dies are made in conformity with the spread surface of the sweep. Spreading of a straight sweep is quite easy. Cross sections *CD* and *EF* are drawn on plans of the sweep (Fig. 7.51), and the width of the

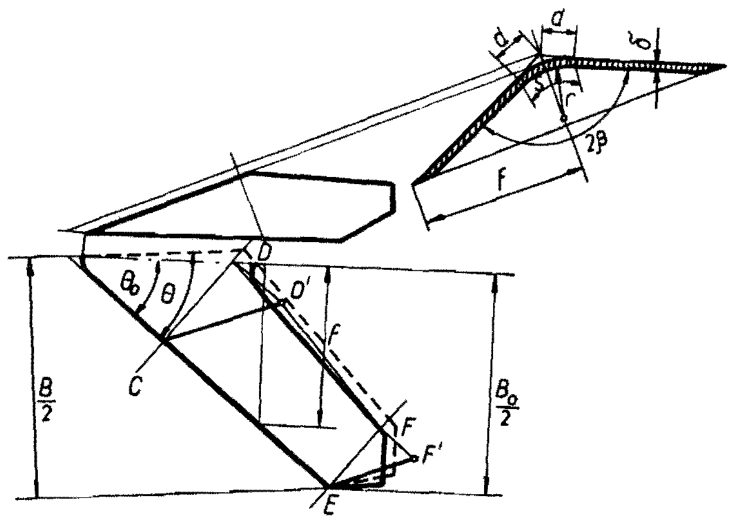


Fig. 7.51. Spread view of a straight sweep.

wings b_1 and b_2 are determined. Wing width can be arbitrary. The following widths are more frequently used

$$CD' = b_1 = 40\text{–}60 \text{ mm}$$

$$EF' = b_2 = 30\text{–}50 \text{ mm}$$

Then, revolved sections of these cross sections are worked out and the outline of one wing is drawn. After having supplemented symmetrically the drawing with the second wing, a spread surface accepted in theory is obtained, where

$$\tan\Theta = \frac{\tan\Theta_0}{\cos\gamma} \tag{7.19}$$

$$B = B_0 \frac{\sin\Theta}{\sin\Theta_0} \tag{7.20}$$

But in reality the breast of the sweep has a rounding with a radius $r = 1\text{–}1.5$ cm. An allowance must therefore be made, when preparing a spread view of the sweep, which takes into account both the difference between the arc *S* and the sum of the lengths of sections *d* as also the sheet thickness δ

$$S = \frac{2\pi\left(r - \frac{\delta}{2}\right)(90 - \beta)}{180}$$

$$d = r\cot\beta$$

The corrected width of the sweep after spreading will amount to

$$B = B_0 \frac{\sin\Theta}{\sin\Theta_0} - 2\left[r\cot\beta - \frac{\pi\left(r - \frac{\delta}{2}\right)(90 - \beta)}{180}\right] \qquad (7.21)$$

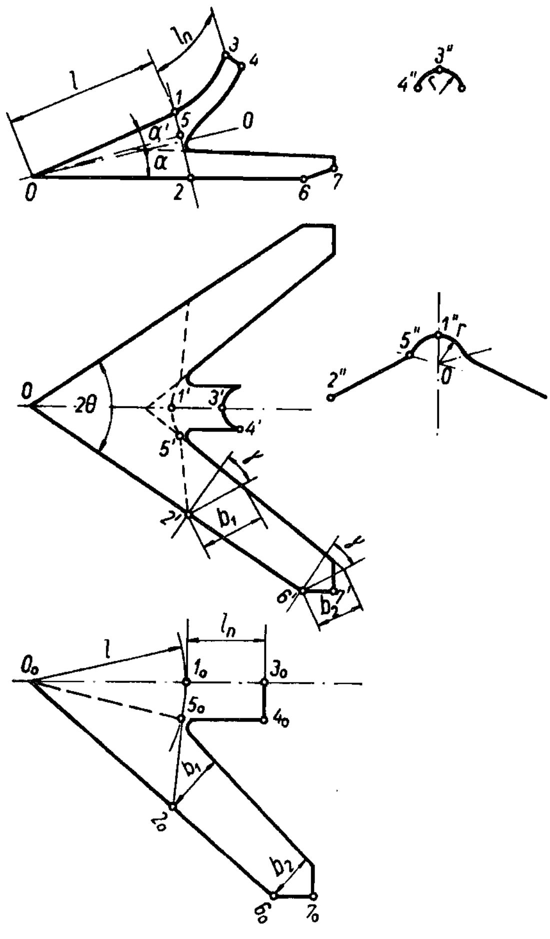


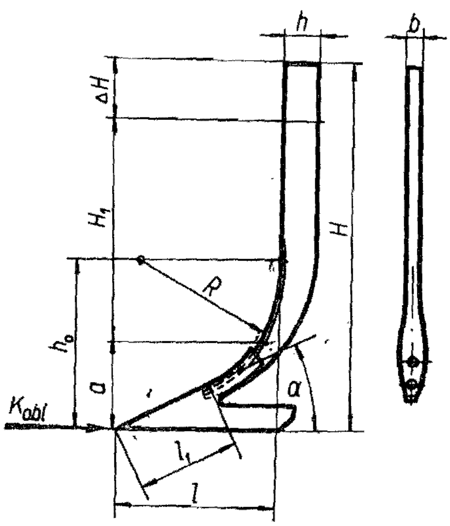
Fig. 7.52. Spread view of a sweep with a nose.

where $$\cot\beta = \frac{\sin\alpha}{\tan\Theta_0}$$

Sweep with nose consists of three geometrical surfaces: flat wings, conic breast and nose which forms a sector of a ring (Fig. 7.52). The angle of the conic breast is assumed to be $\alpha' \cong 0.5\alpha$. Due to the shape of the nose and to the arched transition between flat wings and conic breast, the sweep with nose presents a surface which cannot be spread. In this case spreading can be carried out only roughly.

Cross section *1–2* is made on the plan of the sweep and is perpendicular to the axis *0–0*, being the axis of the cone forming a breast. The cross section is made in the place where the breast passes into the nose. Then, an arc is drawn from the point 0_0 with the use of the section l determining the length of the breast and the point 1_0 is marked. An arc is traced by means of the radius *1″5″* from the point 1_0 and in the point of intersection with the foregoing arc the point 5_0 is found. Then, an arc is drawn from this point the radius of which is equal to the section *2′5″*, and from the point 0_0 another arc with radius *02′* enabling to find point 2_0. Now the point 0_0 is connected with point 2_0 and the point 6_0 ($06_0 = 06'$) is found on the extension of the line.

The width of the wing b_1 and b_2 is measured from ponts 2_0 and 6_0 and the upper edge of the wing is found. Then the spread view of the nose is drawn. From point 1_0 on the axis of symmetry of the sweep the sector l_n is laid off equal to the section of the curve *1, 3*. The length of arc *3″4″* is laid off from point 3_0 and point 4_0 is found. Then the nose edge is drawn and connected by means of an arc with the upper wing edge. The second half of the sweep is then drawn symmetrically.



Rys. 7.53. Shank of cultivator tooth with sweep.

7.3.3. Shanks of rigid teeth. Shape of the shank (Fig. 7.53) is determined by the slope l and by the radius of curvature R which is dependent on the load angle α of a shovel or a sweep

$$R = \frac{h_0 - l_1 \sin\alpha}{\cos\alpha} \tag{7.22}$$

whele l_1 is the length of the breast of the sweep.

The slope of the shank is most frequently adopted in the range from 200 to 250 mm, and the radius of curvature $R \leqslant 120$ mm. The height H of the shank depends on the manner of its fastening to the lever or to the frame. Minimum clearance H_1 between the land surface and the lower edge of the frame of the lever edge should amount to > 200 mm. H_1 equal to about 300 mm is most commonly used in practice

$$H = a_{max} + H_1 + \Delta H. \qquad (7.33)$$

where ΔH is the length of the upper part of the shank serving for shank fastening.

The shank of the tooth is exposed first of all to bending in consequence of soil resistance. We assume for calculation purposes that soil resistance K_{obl} is horizontal and acts in the axis of symmetry of shovel or sweep. This calculation resistance K_{obl} of the soil is assumed to be 3–5 times higher than the average resistance K_x, similarly as adopted for calculation of tightening springs. The average resistance of one tooth can be taken from Table 7.3 or calculated in accordance with the following formula

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$$K_x = a\frac{B_K}{n}p_K \text{ (kg)} \qquad (7.24)$$

where

a — working depth (decim),
B_K — cultivator working width (decim),
n — number of cultivator teeth,
p_K — specific resistance of soil at cutting by means of a sweep (kg/sq decim).

Specific resistance of soil p_K when cultivating to a depth of 15 cm amounts to:

light soil	about	12	kg/sq decim,
medium soil	,,	15	,,
heavy soil	,,	20	,,
very heavy soil	,,	25	,,

Average specific resistance of soil against a single shovel or sweep not cooperating with other shovels (this does not occur in the cultivator) can be 2–4 times higher than the above values. Shanks of shovels or sweeps in the first row are more heavily loaded than those of the second row. For calculation purposes they are assumed as being of the same value owing to the possibility of their interchanging.

Stress, causing the shank to bent amounts to

$$\sigma = \frac{M_{zg}}{W} = \frac{6K_{obl}(H_1 + a)}{bh^2} \qquad (7.25)$$

Torsional stress is calculated according to the formula

113.4
20375

$$\tau = \frac{M_{sk}}{W_0} = \frac{9K_{obl}\frac{B_0}{4}}{2hb^2} \qquad (7.26)$$

Reduced stress amounts to

$$\delta_{zr} = \sqrt{\sigma^2 + 4\tau^2} \tag{7.27}$$

Owing to the fact that the shank of the tooth is sinking into the soil, care is taken to keep its thickness b as small as possible. Most frequently it is assumed that $b : h = 1 : 3$. Shanks are manufactured of carbon steel with carbon content 0.45–0.65 percent.

7.3.4. Stability of cultivators. Due to the fact that soil resistance acting on the teeth of the cultivator is always directed downward, the penetrating conditions of cultivators into soil are considerably better than those, of harrows, and weight of the cultivator is here not decisive. In consequence, the cultivator can be of as light a structure as possible on the condition that sufficient strength is assured.

The horse-drawn cultivator always has a forecarriage in order to maintain its stability (Fig. 7.54); an equalizer with cords under angle α is hitched to the fore-

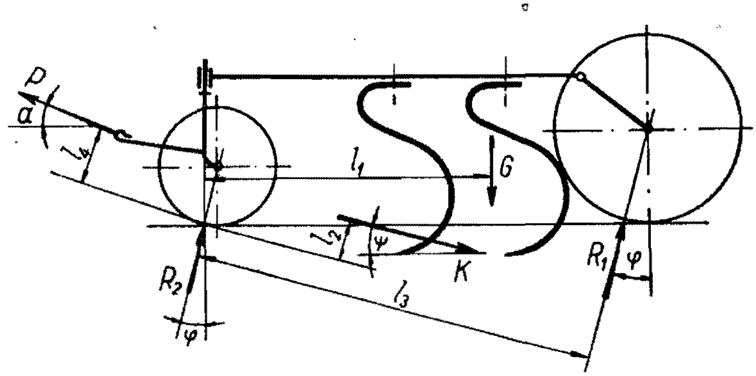


Fig. 7.54. Forces acting on horse-drawn cultivator with forecarriage.

carriage hook. The draft P acts along the cords and has to counterbalance soil resistance K, cultivator weight G and soil reaction R_1 and R_2 against wheels of the forecarriage and of the cultivator. Although the direction of the action of these forces is known, it is not easy to find graphical values of soil reaction against wheels. We avail ourselves here rather of the equations of foces and moments.

Equation of moments relative to the point of support of the forecarriage wheels has a shape

$$Gl_1 + Kl_2 - R_1 l_3 - Pl_4 = 0$$

Projection of forces gives two equations

$$P\cos\alpha - R_2\sin\varphi - K\cos\psi - R_1\sin\varphi = 0$$

$$P\sin\alpha + R_2\cos\varphi - G - K\sin\psi + R_1\cos\varphi = 0 \tag{7.28}$$

We have here a system of three equations, unknown quantities of which are P, R_1 and R_2. The stability of the horse cultivator is conditioned by the reaction R_2, not lower than 25 kg/m of cultivator working width, acting on the wheels of the fore-carriage, while reaction R_1 against rear wheels should be not lower than 50 kg/m of the working width. At the same time soil reactions R_1 and R_2 on both wheels should not be higher than pressures resulting from the distribution of the weight of the cultivator in transport position. Too high reactions R_1 and R_2 unnecessarily increase the rolling resistance of the cultivator. On the other hand too low reactions would signify that penetrating capacity of the cultivator is low. In order to obtain appropriate reactions against cultivator wheels under various soil conditions, the hitching hook should have control device of height setting.

Tractor cultivators are designed as semimounted or mounted implements (Fig. 7.55). Direction and value of the draft P and of the reaction

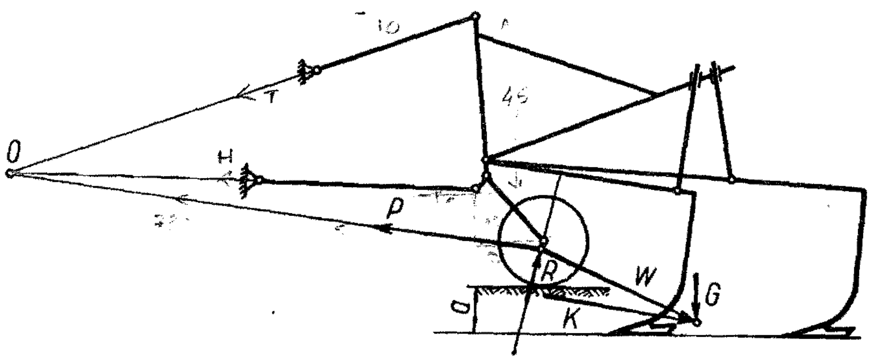


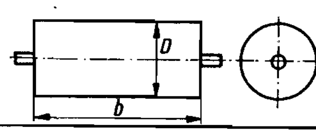
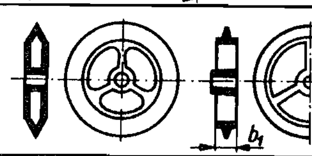
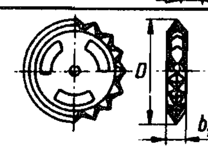
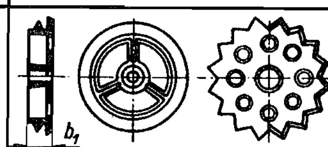
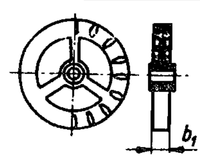
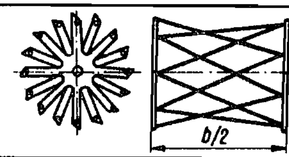
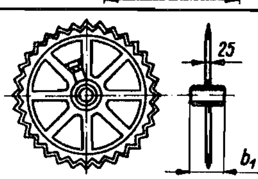
Fig. 7.55. Forces acting on mounted cultivator.

against supporting wheels can be graphically determined in these cultivators. Stability in these cultivators is conditioned by soil reaction R acting on supporting wheels which should be not lower than 50 kg/m of the working width. At the same time this reaction should not surpass the weight G of the cultivator. The resultant W from the weight G of the cultivator and from the soil resistance K has to pass over the point of the instantaneous rotation.

Mounted cultivators without supporting wheels are equipped with tractor lifting mechanisms controlling effective working depth, similarly as in plows. Automatic draft control operates well only with cultivators whose resistance is adequately high. Cultivators designed for shallow work (below 10 cm) indicate, with automatic draft control, excessive non-uniformity of depth and have to be, therefore, equipped with supporting wheels.

In the horizontal plane, all cultivators display a good stability resulting from the symmetry of the spacing of the teeth. Certain fluctuations in soil resistance do not produce a distinctly "sinuous" movement. On hillsides when cultivator is traveling transversely to the hill inclination, pulling down of the cultivator can be obeserved and, therefore, cultivator designed for operation under those conditions should be provided with collars on the wheels.

Table 7.4*

Name of packer	Type	Scheme of an element	Main parameters					
			b_1	b	D	g	p	i
Plain	Light		70-200	70-200	32-50	1.2-3.5	0.4-1	1-3
	Heavy		100-150	100-150	80-120	10-15	3.5-5	1
Corrugated	Plain		7-8	70-120	32-45	1.1-1.8	0.7-1.0	3-5
	Toothed		8-10	70-120	32-50	1.2-2.0	0.7-1.1	3-5
Cambridge			9-10	70-120	37-48	2.0-2.6	1-1.5	3
Croskill			8-10	70-120	35-55	2.1-2.8	1.2-1.8	3
String packer			100-120	100-120	25-30	0.5-1.0	0.3-0.6	3
Campbell	Plain		14-16	100-150	60-70	2.5-3.5	1.0-1.5	2-3
	Toothed							

* For explanation of the main parameters see p. 381.

7.4. Packers

The principal purpose of the packers is superficial or deeper packing of pulverized soil in order to reduce its porosity and to speed up its settlement, to even out the field surface and to crush hard lump or pack them into the scarified field, where they will get wet and soften.

Packers can be used as horse-drawn or tractor-trailed implements, and there are no basic differences in their construction, except thills with which horse packers are frequently provided. Packers have one, two or three sections. Main parameters of packers are presented in Table 7.4

7.4.1. Plain packers. Light plain packers are used for rolling shallowly sown seeds (of beets, carrots and other seeds) in order to increase oozing of water from lower land layers; water is necessary for germination of seeds. These packers can also be used for smoothing the field surface before sowing of seeds or planting potatoes, for crushing green manures before plowing, for slackening off development of too rich vegetation and filling up crevices which sometimes appear on sown fields after heavy frosts.

Heavy packers are used mainly on plowed grassland, pastures and wasteland for pressing down inverted slices to furrow bottoms, making the field surface even and speeding up the process of turf decomposition.

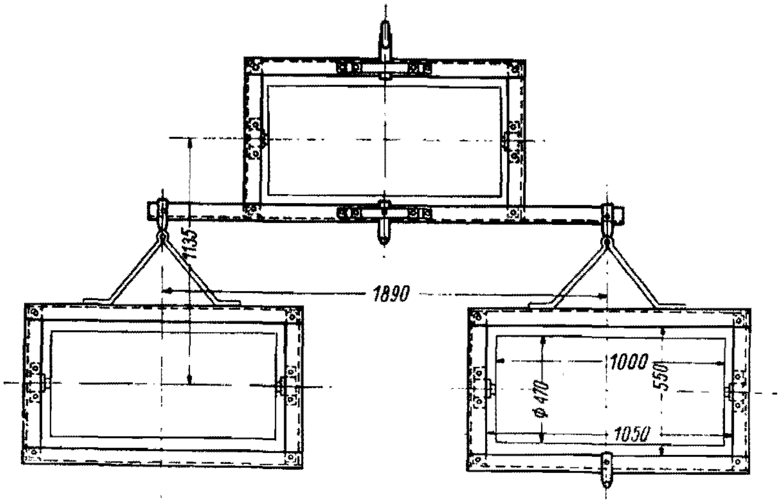


Fig. 7.56. Plain three-sectional packer.

Besides light and heavy plain packers there are also designed medium weight packers for field and grassland rolling. A section of a plain packer (Fig. 7.56) consists of the operating part, shaped as a long roll placed in two slide bearings screwed onto the rectangular frame. The roll can be made of hardwood or of steel-sheet metal 4–6 mm thick. The wooden roll can be dressed with a thin sheet. Sides of the roll can be welded or riveted to the flanks of the roll. Cast-iron sides are most frequently riveted. Sides of working roll are fitted with journals set in slide bearings. Holes covered with lids, serving for filling the roll with water or with sand, are also bored in the sides. The roll must be entirely filled with water to avoid jerks caused by flowing over of water in various directions. The roll can be filled entirely or partly with sand, thus allowing control of its load.

Heavy rolls can be filled with sand or concrete (mixed with lumps of steel or iron scrap) or with water and then they have a constant weight. Single-section rolls of light type have a working width in the range from 1.5 to 2.0 m, sometimes to 2.5 m. Such long rolls accumulate excessively the soil at turns and do not adjust themselves to uneveness of land surface; therefore, three-section rolls, whose sections have the working width about two times smaller, are generally applied.

Frames of rolls are made of flat or angular bars of a standard steel. The frame of the first section has outriggers on both sides of the rear part with hooks for hitching two other sections. Tracks of the rear rolls should overlap the track of the front roll by 5-cm wide strips. Two yokes for fixing the thill are screwed to the frame of the first section of the horse-drawn packer.

The packer can be transported by means of a special truck on which the frame of the packer is suspended (Fig. 7.57). But most frequently,

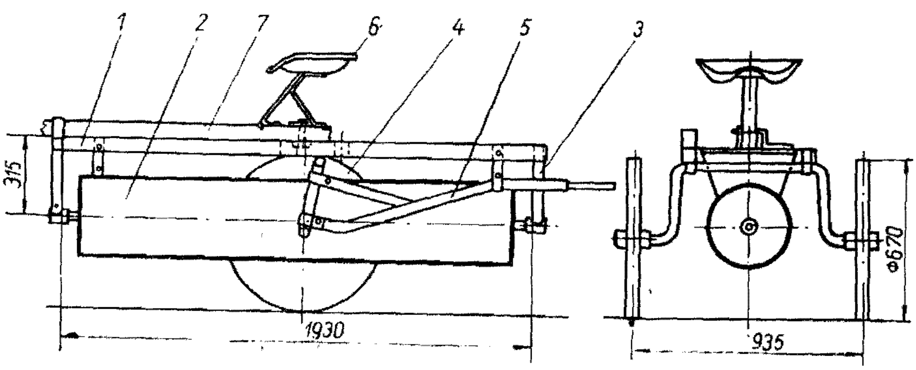


Fig. 7.57. Truck for packer transportation: 1 — truck frame 2 — roll; 3 — outrigger for mounting of the roll; 4 — wheel; 5 — frame lifting lever; 6 — saddle; 7 — thill.

packers are rolled on the ground with their sections running one after another.

Plain packer, rolling on the land surface, exerts a pressure causing packing of the soil to the depth h. If this depth is not great — less than 2 cm — the specific pressure q exerted by the packer can be calculated according to the formula (6.127), determining the dependence of the sinkage of the wheels on the pressure Q, soil firmness q_0 and initial packing p_0. Assuming that the pressure Q is equal to the weight of the packer G and the soil did not undergo any initial pressure ($p_0 = 0$), then from transformation of formula (6.127) we obtain

$$G = \frac{1}{2} B q_0 h \sqrt{hD} \text{ (kg)}$$

to which, after substituting specific weight of the packer

$$\frac{G}{B} = g \text{ (kg/cm)}$$

we arrive at

$$h = \sqrt[3]{\frac{4g^2}{q_0^2 D}} \tag{7.29}$$

where

h — sinkage of the packer (cm),
D — diameter of the packer (cm),
q_0 — soil firmness (kg/cu cm),
B — length of the packer (cm).

The specific pressure q, which is a measure of soil packing after the packer has traveled, amounts to

$$q = q_0(h + h_1) \text{ (kg/sq cm)} \tag{7.30}$$

where h_0 is the initial sinkage corresponding to the initial soil packing p_0.

By substituting into this formula the formula (7.29) and assuming that $h_0 = 0$ (no initial soil packing is foreseen), we obtain

$$q = \sqrt[3]{\frac{4g^2 q_0}{D}} \text{ (kg/sq cm)} \tag{7.31}$$

If the same soil will be rolled again in a short period of time, the specific pressure q from the formula (7.31) will be considered as initial soil packing p_0, and sinkage from the formula (7.29) will be initial sinkage h_0. The value of sinkage h of the packer at its second travel can now be calculated according to the formula

$$g = \frac{1}{2} \sqrt{hD}(q_0 h + 2p_0) \text{ (kg/cm)} \tag{7.32}$$

By inserting the calculated value h and h_0 into the formula (7.30), soil packing $p = q$ after second travel can be determined. Soil packing can also be calculated in the same manner after subsequent travels. Figure 7.58 shows how soil packing changes as depending on the number of subsequent packings and on the specific weight of the packer. As can be seen, soil packing, after the second travel, is by about 20 percent, and after the fifth travel by about 50 percent higher than after the first travel. It is,

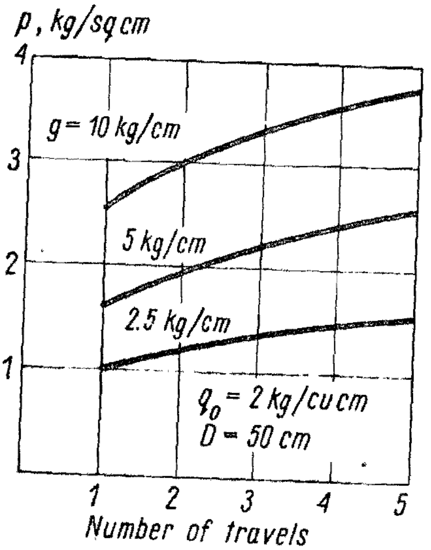


Fig. 7.58. Dependence of soil packing p by a plain packer on the number of travels; q_0 — soil firmness; D — diameter of packer; g — specific weight of a packer.

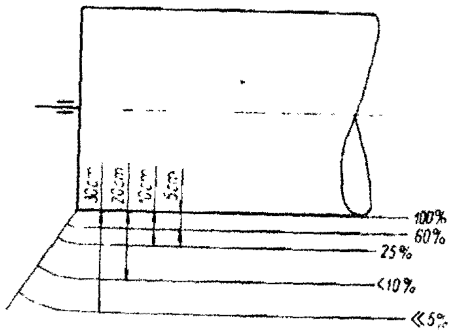


Fig. 7.59. Distribution of soil packing by a plain packer as a function of its depth.

therefore, advantageous to apply a heavy packer giving the same packing after one travel as a light one after several travels. It results from the formula (7.31) that a twice heavier packer gives soil packing by 58 percent, and a four times heavier packer by 152 percent higher. The packing of the soil, resulting from the action of a packer, reaches into the depth of the soil but the greater the depth the significantly lower is the packing efficiency (Fig. 7.59). In well-pulverized soil, compactness to the depth of 20–25 cm amounts to not more thant 5 percent of the compactness of soil surface.

While packing a part of the packer's perimeter, sunk in the soil, produces at the beginning consolidation of soil particles in the direction *ab* (Fig. 7.60) and then cutting off the upper layer just before the packer in the direction *cd*. Consequently, when rolling loose and easily deformable soil, a distinct elevation of soil arises before the packer. This soil elevation indicates the action of crushing of the packer and is the case of increased rolling resistance.

Two forces act on the packer: its weight G and soil reaction R. These two forces are counterbalanced by the draft P

$$P(r-s) = Gl$$

Since arm s is very short in relation to r it can be disregarded in this equation of moments; hence

$$P = G\frac{l}{r} \qquad (7.33)$$

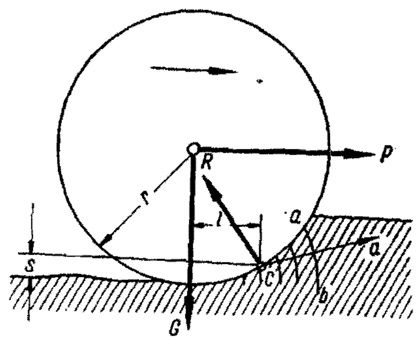


Fig. 7.60. Principle of soil packing by a plain packer.

This equation indicates that the packer draft P is the lower the greater is the diameter of the packer. The arm l depends on the penetration depth h of the roll into the soil, and the elevation of soil before the packer; therefore, the resistance of the packer is comparatively higher on light and unpacked soil. Under normal rolling conditions, if the sinkage of the packer does not surpass 2 cm, the ratio $l:r$ ranges from 0.15 to 0.30 depending on the type and on the state of soil pulverization.

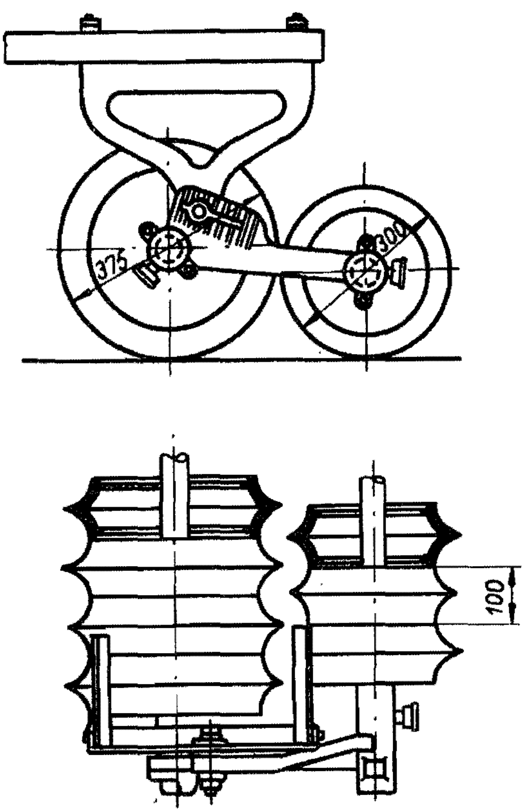
7.4.2. Crushing packers. Plain packers crush lumps of soil on land surface somewhat poorly and rather press them into the soil. Packers, which beside packing are to crush the soil clods (crushing packers), consist of a series of differently shaped rings. Rings are drawn on a common roll placed in slide bearings screwed onto the frame of the section. Rings are mainly made of cast iron. Crushing packers can be single or three sectional. Frames of sections are the same as in plain packers. The same frames can, therefore, be applied for plain packers as well as for crushing ones.

Individual rings should fit tightly to themselves, but in such a manner that they are free to rotate on the roll independently one from another. This allows free rotation of the sections with great working width and prevents soil from pilling up before the packer. These packers are transported by means of trucks (Fig. 7.57) or towed across the field roads.

Standard corrugated packers consist of wedge, plain or toothed rings with a vertical angle of 60°. The section can contain one or two rolls (Fig. 7.61); the rear roll in the last type has a smaller diameter. Certain packers — similarly as disk harrows — are equipped with boxes for sand or stones or cast-iron bobs.

The corrugated and toothed packer, penetrates more easily into the soil and crushes lumps better than the corrugated plain packer. The crushing action of corrugated packers consists in cleaving clods falling under the blade or teeth of the rings. However, after the field has been rolled by a corrugated packer, many crevices, covered only partly by soil lumps, remain.

The "Cambridge" packer consists of plain rings and flat toothed disks of greater diameters set alternately. The toothed disk is installed on the



7.61. Corrugated packer with two working rolls.

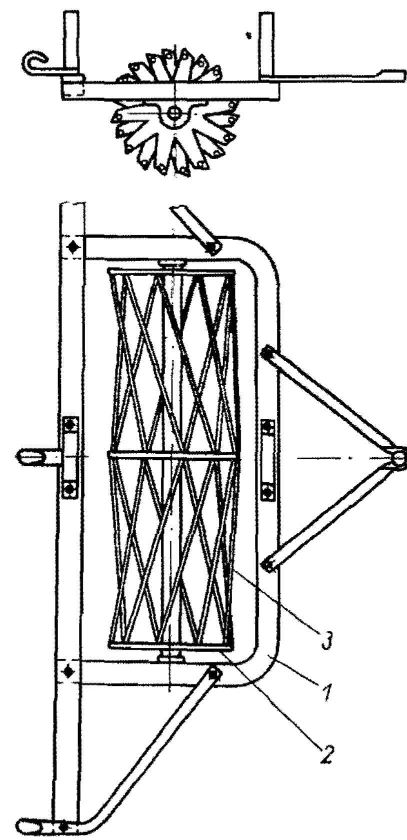


Fig. 7.62. String packer: *1* — front section frame; *2* — disk; *3* — wire.

part jutting out of the ring hub and can rotate on it. Slight difference in the number of revolutions of rings and disks, resulting from different diameters, causes the packer to be self-cleaned of adhering soil particles. Cambridge packers crush soil clods more intensively than the standard corrugated packers and pack the soil more deeply, leaving shallow crevices on the surface and a slightly pulverized soil.

The "Croskill" packer consists of rings provided on the periphery with several lateral lugs intensively breaking and crushing the clods. Rings can be separated by toothed disks similarly as in the Cambridge packers.

The action of the Croskill packer on the soil results in somewhat **shallower** packing than that of the Cambridge packer and the soil **surface is** left slightly pulverized, thus hindering it from drying too quickly.

The string packer (Fig. 7.62) belongs to implements poorly packing the soil but crushing clods well, the smaller ones in particular. The crushing is performed by breaking up and cleaving clods by means of rods. A thin, well-pulverized soil layer beneath which slightly packed layer is left, is obtained after passing of string packer.

7.4.3. Campbell's packers. Both plain packers, and corrugated crushing packers pack the soil surface rather, but are not able to press the lower soil layers down to the substratum and to liquidate relatively large free spaces remaining after plowing-in of lower soil layers. Thus these packers cannot accelerate the process of soil settlement. Using for this purpose very heavy packers would cause better packing of soil sublayers but, at the same time, the field surface would be packed too strongly causing destruction of soil structure and very intense drying up.

Packing of deep soil layers without crushing its surface can be obtained by using Campbell packers. Working elements of this type of packer are narrow wedge rings, plain or toothed, set on spokes. Toothed rings are used on sodded furrow slices. Rings, relatively sparsely spaced, penetrate

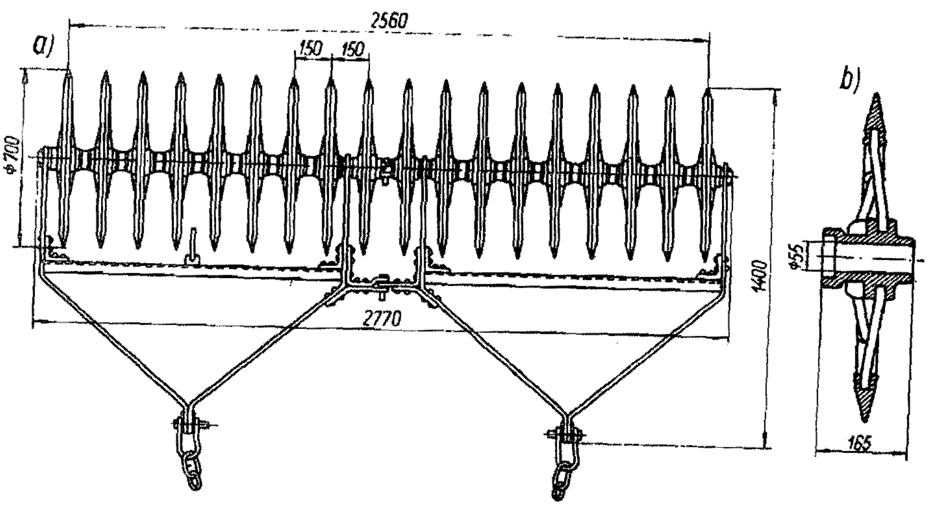


Fig. 7.63. Campbell's packer: a) two sections lined up in one row; b) ring.

more easily into the soil to a depth of a dozen and more centimeters and pack its lower layers. Upper soil layers remain unpacked and even additionally pulverized by the ring spokes.

Rings of the Campbell packer are rotationally mounted on the roll of the section, the roll being placed in slide bearings of the frame or directly in the frame of the section. In this case, each ring should be provided with its own lubricant fitting. These sections can be lined up in one row (Fig. 7.63).

The Campbell packer is a very useful implement for preparing medium firm and firm soils and enables sowing within a short time after plowing.

7.5. Aggregates for sowing preparation

Appropriate preparation of soil for sowing requires most frequently the use of various implements and, consequently, several travels across the land, ruinous for soil structure and increasing the cost of cultivation. In order to raise the standard of efficiency in soil preparation, two or more implements are combined into a single aggregate. These cultivation aggregates are — because of resistances — adapted to power of tractors. When the power of the tractor is high enough then it is possible to include the preparatory implement into the cultivation aggregate. Single or double sections of drags, toothed harrows, spiked harrows and packers can be assembled with the plow. Coupling of these sections is a simple operation (Fig. 7.64). Outriggers for hitching these sections are fastened to the plow

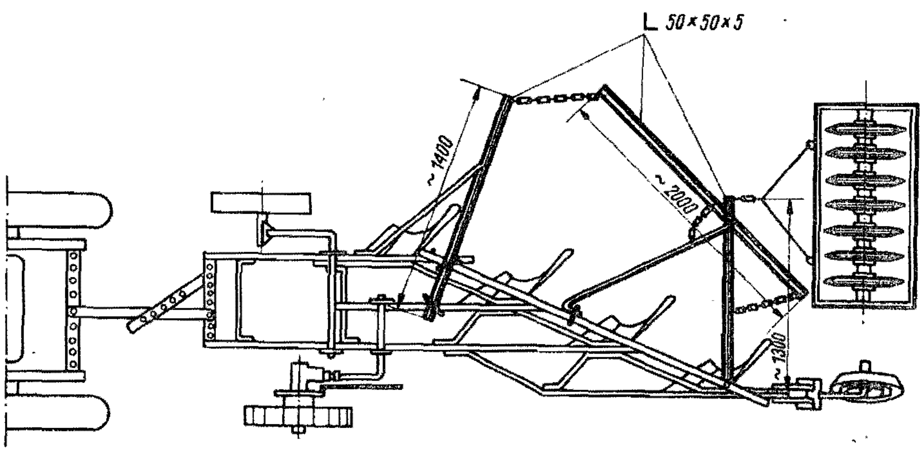


Fig. 7.64. Coupling a trailing plow with Campbell's packer.

frame with the use of yokes. Coupling of a single section with a swivel mounted plow is also a simple matter. One outrigger, if bottoms are reversed by 180°, or two outriggers, if they are reversed by 90° (Fig. 7.65) are fixed to the plow. A hook, to which is hitched a supplementary implement, is fixed on hinges to the ends of the outrigger beams. The implement must be fitted with a hitching triangle on both sides. After reaching the end of the tilled land with the plow, the tractor must be pulled back to unhitch the hook out of the implement, and then the plow can be turned back and reversed. To resume tillage, the hook of the outrigger must be hitched onto the hitching triangle of the implement.

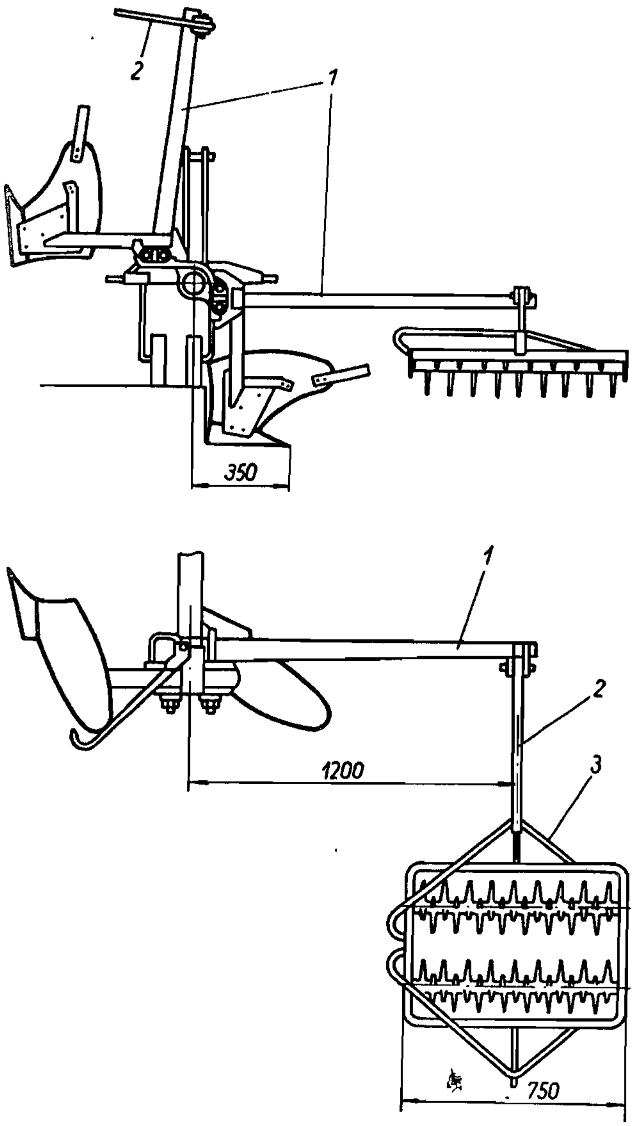


Fig. 7.65. Coupling a mounted swivel plow with spiked tooth harrow: *1* — outriggers; *2* — hitch hook; *3* — hitchbar.

In order to couple the preparing implements with the standard mounted plow, the tractor must have an outrigger fastened to the frame. Second outrigger of implement mounting can be fixed to the frame of the plow to facilitate turns of the aggregate.

The outrigger can be attached in front or in the center of the tractor in the place foreseen for assembling side mowers. The power-lift device of the tractor, designed for the mowing machine, can then be used for lifting the outrigger together with the mounted implement. Often an additional preparatory implement is attached to the cultivator — most frequently a tooth harrow. Trailing cultivator can be provided with a supplementary lifting device for the harrow. For this purpose, an additional shaft (or pipe) is placed in bearings on the cultivator frame having an outrigger for

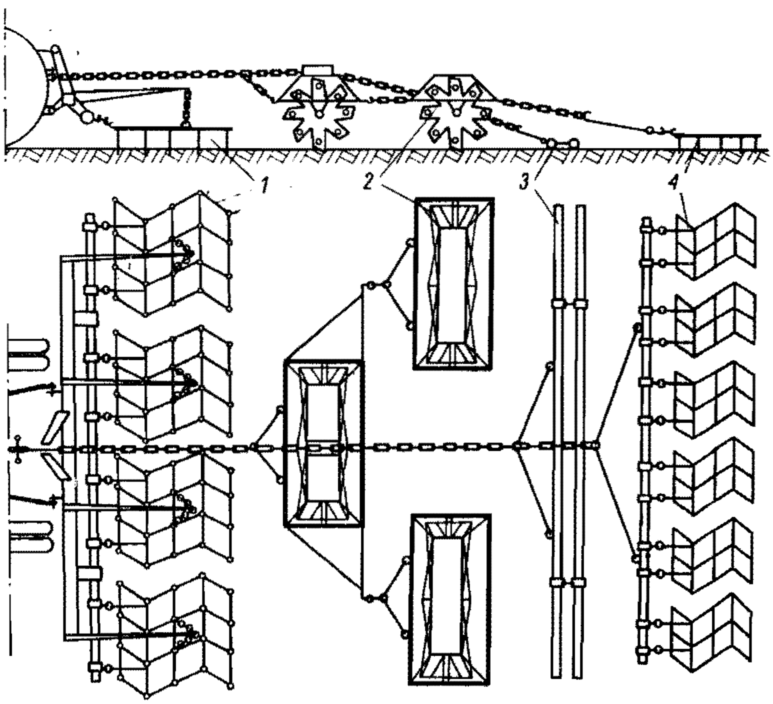


Fig. 7.66. Scheme of an aggregate for soil cultivation prior to sowing of beets: 1 — heavy, mounted tooth harrow; 2 — three-section string packer; 3 — drag from round bars; 4 — light, tooth harrow.

hitching and mounting the harrow sections. The shaft is connected by means of a link with the lifting mechanism of the cultivator.

Implements for preparation of soil for sowing can be coupled with mounted cultivator by hitching them at the back of the frame of the cultivator or — similarly as in plow — to an outrigger fixed to the side of the tractor. Aggregates consisting of more than two implements attached one after another have a considerable length and for this purpose are inconvenient in operation, particularly at turns and during transport, but make it possible to prepare soil for sowing during one travel. There are many solutions of coupling these implements to prepare soil for sowing; one of them is presented in Fig. 7.66. This aggreate enables an exact soil pulverizing and leveling the field surface, indispensable for beet sowing.

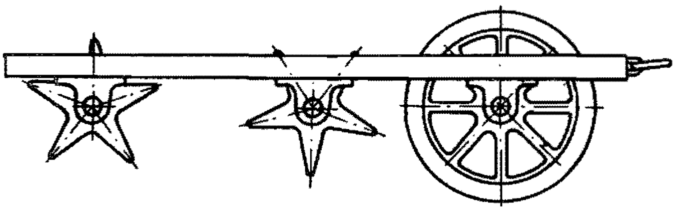


Fig. 7.67. Aggregate of spiked harrow with Campbell's packer.

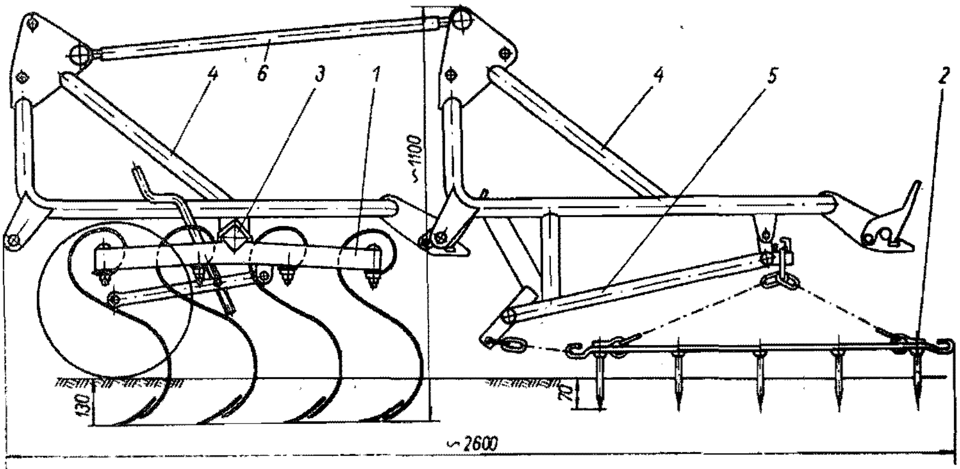


Fig. 7.68. Mounted aggregate: *1* — cultivator; *2* — tooth harrow; *3* — bar for fastening cultivator frame; *4* — frame with column; *5* — outriggers for mounting harrow sections; *6* — link.

The first implement to be used in this aggregate is a heavy harrow with teeth, whose end points have been flattened, or a cultivator. The task to be fulfilled by these implements is to pulverize more deeply the soil plowed before winter. The task of string packers is to crush up clods and to pack the soil. Beams of the drag smooth the field surface and the light, seed harrow pulverize the soil not deeply and crush the remaining lumps.

Another solution is to fix preparatory implements to the common frame. As an example of such an aggregate serves the spiked harrow coupled with Campbell's packer (Fig. 7.67).

For coupling several implements special semimounted, as well as trailing or mounted frames, can be used (Fig. 7.68). Entire implements or their particular sections can be fastened, mounted or attached to the frames. Such frames are relatively short and more convenient in operation than sets of implements hitched together (one after another). A semi-mounted frame is relatively heavy and must be supported by two wheels and be equipped with a lifting automatic mechanism similar to that with which are equipped plows or trailing cultivators.

7.6. Bibliography

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Explanations to Tables 7.1, 7.3, 7.4 and 8.1

Table 7.1:
a — working depth (cm); b_1 — working width of one section (cm); s_z — spacing between tine tracks (cm); g_z — weight per tine (kg); g — weight per cm of the working width (kg/cm); p_z — resistance per tine (kg); p — resistance per cm of working width (kg/cm); i — number of sections, Θ_0 — angle of setting disk-harrow sections.

Table 7.3:
a — working width (cm); s — spacing between tine tracks (cm); g — weight per m of the working width (kg/m); p — resistance per tine (kg); i — number of tines.

Table 7.4:
b_1 — working width of the element or set of elements (cm); b — working width of a section (cm); g — weight of packer per cm of the working width (kg/cm); p — resistance of the packer per cm of the working width (kg/cm); D — diameter of the working roll (cm); i — number of sections.

Table 8.1:
wb — concurrent revolutions; pb — reversed revolutions; z_e — number of working elements in the set; i — number of working sets in the machine; a_m — maximum working depth (cm); b_r — working width of the set (cm); u — peripheral speed of working elements (m/sec); v — travel speed (m/sec); g — machine weight per cm of the working width (kg/cm).