13. SEEDING MACHINES

This chapter deals with seeding machines of the most important types. The idea to sow with the aid of machines dates as far back as the antiquity. Persians and Hindu are said — according to old chronicles — to have availed themselves of seeding machines — the idea had not at any rate been adopted by Europeans, where sowing used to be done by hand — that is, broadcasting — up to the end of the 17th century and even later in all European countries.

The first European drill was developed in 1636 by Joseph Locatelli of Corinth. The machine was named "sembradore" by the designer. It had a cylindrical, wooden tank, inside which a shaft with spoons rotated throwing seeds through holes into sagging tubes falling short of the soil surface. The "sembradore" could not deposit seeds in the ground but laid them only in rows on the surface nonetheless, in comparison with manual sowing, seed location was less confused.

At the end of the 17th century, Locatelli's drill was improved by Jehtro Tull an Englishman who reconnoitred the advantages offered by mechanical sowing on a more carefully prepared soil. In 1785 James Cook designed a seeding machine, the principal idea of which has survived to our times. This machine was extensively used in Great Britain (Fig. 13.1).

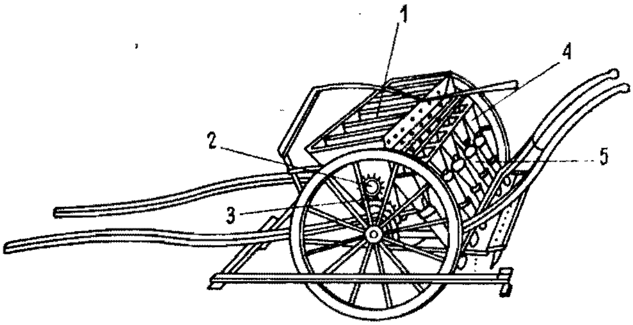


Fig. 13.1. James Cook's seeding machine: *1* — seed box; *2* — shaft; *3* — gear transmission; *4* — seed compartments; *5* — furrow openers.

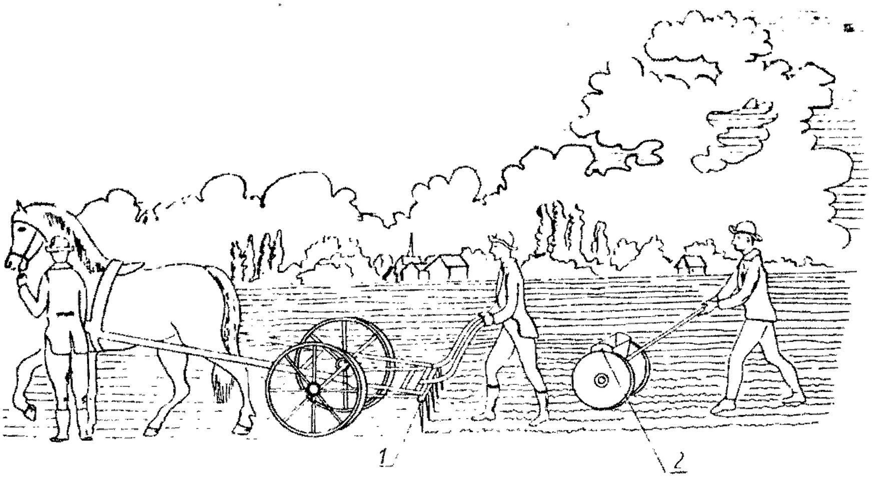


Fig. 13.2. Ducket and Alban seeding machine: 1 — marker; 2 — drill.

In 1804, Ducket, a German, designed a seeding machine consisting of two separate parts independent of each other (Fig. 13.2). One part in front of the seeding mechanism was designed as six-row marker, forming furrows into which seeds, sown by the proper three-row, manually pushed drill, fell down. Seeding was done by three grooved shafts placed on the bottom of a seed box and mounted on a ground wheel axle. Compared with Cook's drill, the double-component machine of Ducket was primitive. It was not until this drill had been improved by Alban of Austria, that it had found broader uses.

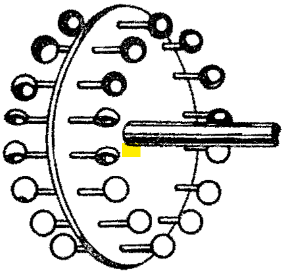


Fig. 13.3. Disks with Garret spoons.

In 1844, Garret built a seeding machine with a distributing appliance consisting of a series of disks mounted on a common shaft. Fixed to each disk on both sides were spoons on arms (Fig. 13.3) to remove seeds from the box and throw them into tubes connected with furrow openers. This arrangement had the disadvantage that the drill was highly sensitive to shocks and to inclination when worked on slopes.

13.1. Seed spacing

In order to obtain the highest possible yield of crops in farm cultures, an essential thing — apart of fertilizing and favorable weather conditions — is to ensure appropriate spacing of seeds in soil. Optimum distances between individual seeds or seed groups (what is known as hill-drop drilling) and optimum depth of seeds to be placed down under soil surface depend on a great many variable factors (for example, sort and variety of plants, fertility and type of soil, soil preparation before the sowing procedure, field weedery conditions, etc.). For this reason mechanical placing and spacing of seeds by means of drills cannot alone be the decisive factor and a prerequisite of a good crop yield. For the same reason, the required quantity of seeds sown and distributed per unit field area (say, per 1 hectare) is also subject to variation.

Mechanically sown seeds are mostly spaced in rows. Depending on seed sort, rate of seeding, and whether it is necessary to adopt interrow tillage, various sizes and widths of interrows are used. On the other hand, the depth at which seeds are placed depends on their actual size and type of soil. Seeds of some plants (say, of corn) can be deposited in groups of several seeds, forming what is called hills. Individual hills are appropriately spaced in the direction of the drill travel and also in transversal direction (hill-drop or checkrow drilling).

Present drills now in use can be divided into the following basic types:

a) Garden drills — hand-, barrow-, horse- and tractor-drawn (garden tractors).

b) Grain, universal to a varying degree drills, horse-, and tractor-drawn, semimounted, mounted and fixed on tractors and even self-propelled drills.

c) Special seeding machines which include machines for precision (single grain) seeding of prepared beet or corn seeds and — if need be — seeds of some other kind, as also machines for corn hill-drop drilling which are — as a rule — designed as tractor-drawn ones (semimounted, or mounted) with the exception of precision drills which are sometimes designed for horse draft. Reckoned as special drills are machines for experimental seeding on plots and for aftercrops (although the latter machines have drill of the type described under b), as also drills and grass-seed drills.

d) Combined drilling machines for simultaneous seed and fertilizer distribution or for simultaneous grain and grass seeding (also simultaneous distribution of all three components is possible).

Material for seeding is very differentiated in shape, dimensions, bulk density and type of the cuticle.

Listed in Table 13.1 are various basic dimensions and weights of the most important crop plants and also seeding rates and interrow spacing.

Certain Physical Indices Concerning Seed,

Type of seed	Size		Thickness	Weight of 1000 grains	Bulk density
	length	width			
dimensions	mm	mm	mm	g	kg/cu decim
Wheat	5.0—8.6	1.6—4.6	1.5—3.5	25.0—50.0	0.72—0.80
	6.8*	3.1	2.5	37.5	0.76
Rye	5.0—10	1.5—3.5	1.5—3.0	26.0—50.0	0.68—0.74
	7.5	2.5	2.25	38	0.71
Barley	7.0—13.5	2.5—5.0	1.5—3.0	24.0—48.0	0.58—0.68
	10.25	3.75	2.25	36	0.64
Oat	8.5—20.0	2.0—3.5	1.0—2.6	14.0—34.0	0.4—0.5
	14.25	2.75	1.8	24	0.45
Flint corn	10—18	8—12	5—10	300—1200	0.75—0.84
Pea	6.6—8.6	5.6—7.9	4.7—7.3	78—560	0.74—0.84
					0.79
Corn	10—20	5—12	2—5	100—200	0.65—0.75
	15	8.5	3.5		0.70
Lucerne	1.7—2.8	1.2—2.0	0.8—1.3	1.4—2.8	
	2.25	1.6	1.05	2.1	0.80
Beet tubers	6.5—8.5	5.5—8.0	5.0—7.0	15—30	0.65
Rape	1.7—2.8	1.6—2.8	1.2—2.5	3.5—7.0	0.66

* Average size.

Example of a grain and its dimensions is presented in Fig. 13.4.

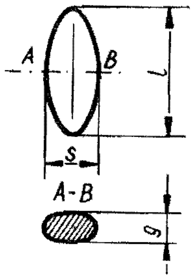


Fig. 13.4. Main dimensions of grain: *1* — length; *2* — width; *3* — thickness.

Operational drill requirements, consequential partially from the above-mentioned table, are as follows:

(a) The number of seeds spaced simultaneously in particular rows should be roughly the same over each meter of the row length, or in each hill (if hill-drop drilling is practiced), in other words, longitudinal and transversal uniformity of seeding should be maintained. This requirement concerns not only the various kinds of seed, but also the various seeding rates;

(b) Control (metering) of the seeding rate within limits of 6–300 kg/hectare — that is, the possibility to change the seeding-rate density in individual rows as also to change the width of rows;

Table 13.1

Seeding Rates and Interrow Width

Angle of repose degrees	Number of grains per cu cm	Seeding rate kg/hectare	Interrow width cm	Cover thickness cm	Remarks
30—38 35	20	100—200	10—15	2.5 5	
32—36 34	21	100—180	10—15	2—3	
34—40 37	16	110—160	10—15	3—5	
34—43 38.5	17—20	140—180	10—15	3—5	
32 28—34 31	8—12	120—280	20—35	3—8	first successive figures concerning pea size, denote the greatest diameter, second — medium, third — the smallest
31	4.3	50—80	60—70	4—8	
32.5	430	6—25	15—30	1—2	
45	5—10	20—30	40—50	1.5—4	
—	—	6—12	30—40	1—2	

(c) Metering of the required seeding rate should be easy to adjust and reliable;

(d) Maintenance of constant (adjusted) width of interrows as required during operation;

(e) Placing of seeds at an appropriate depth (as required) and their covering with a soil layer; this depth must be independent of the microrelief of the soil surface;

(f) Seeds should not be exposed to injury by the seeding devices;

(g) Operating efficiency of the drill should not be dependent on its inclination when seeding undulated fields and should remain unrelated to the travel speed (6–15 km/hr).

Considering the great differentiation of sowing material in regard to its physical consistency, and the extensive range in seeding rate, the requirements specified under a, b, e, f, and g are very difficult to meet as will be explained in detail in section 13.2.

13.2. Grain drills

Grain drills consist of the following principal parts: grain box with an agitator, feed sets, seed delivery tubes, furrow openers and transmission gear sets for the agitators and feed sets. Precision drills are provided neither with seed tubes nor with agitators. The frame of horse-drawn drills is hinge-connected with the forecarriage consisting of an axis placed on two wheels. The function of the forecarriage is to guide the drill rectilinearly and to allow for turning the machine round to go back. Figure 13.5 shows a scheme of the horse-drawn drill in two plans.

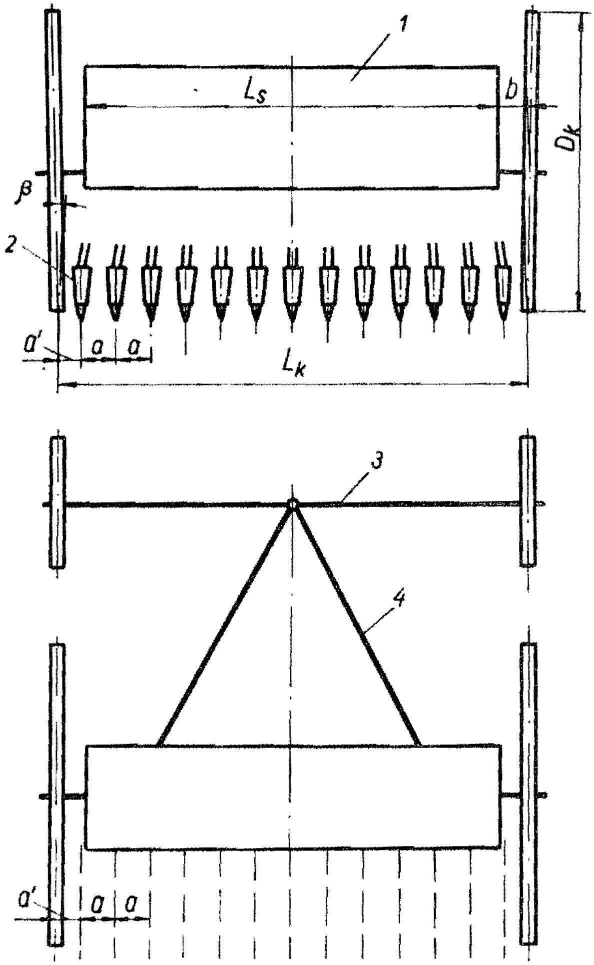


Fig. 13.5. Schematic diagram of a horse-drawn grain drill with the forecarriage: *1* — box; *2* — furrow openers; *3* — front wheel axle; *4* — brace.

The mobile parts of plot drills (barrow drills), horse- and tractor-drawn, semimounted and mounted on a tractor hydraulic system are driven by ground wheels. In drills set up on tractors, the moving parts are driven either through the rear wheel of the tractor (for example, by means of a chain transmission) or by a PTO shaft.

The working width of the drill is expressed as follows

$$S_r = z \cdot a$$

where

z — number of furrow openers used,

a — width of interrows.

If the distance between extreme furrow openers and the middle point of the wheel band or of the tyre of ground wheels equals $\frac{a}{2}$, then

$$S_r = L_k$$

If

$$|a'| > \frac{a}{2}$$

then

$$S_r < L_k$$

and if

$$|a'| < \frac{a}{2}$$

then

$$S_r > L_k$$

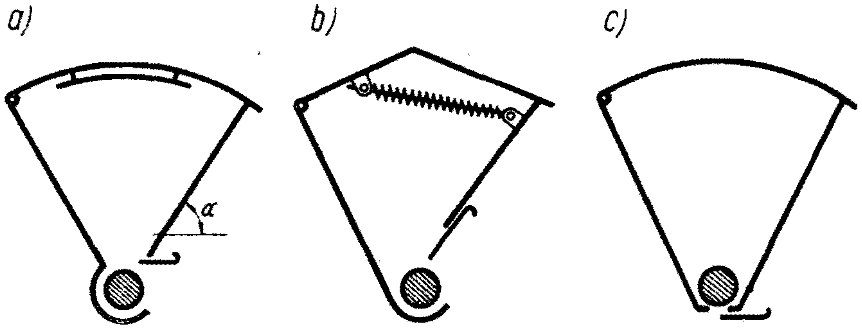


Fig. 13.6. Examples of shapes of seed box and of placing feeding rolls: *a*) under the box bottom; *b*) on the box side wall; *c*) inside the box.

The grain box is made of steel sheet (thickness $\geqslant 1$ mm). The cross section of the box can be trapezoid or triangle shaped (Fig. 13.6), whereas the angle of inclination of front and rear walls is greater than the maximum angle of repose of seed material used, even if moistened by insecticide chemicals ($\alpha \leqslant 60^\circ$). The box is covered with a convex hinge-connected lid, the width of which — appropriately selected — should protect from losses in seed when poured into the uncovered box. Besides, the cover is provided with a device to keep it fast in position when shut and when fully open (Fig. 13.6*b*).

The grain box length is expressed as follows

$$L_s = L_k - 2b$$

where b denotes the distance between the side box wall and wheels determined by structural dimensions of the transmission gear used; in practice $b = 150\text{–}200$ mm.

In a case of setting wooden ground wheels (Fig. 13.5) at a certain angle ($\beta \leqslant 4^\circ$), in order to better secure the rectilinear direction of travel it is necessary that

$$L_s = S_r - 2b + D_k \sin\beta$$

The unit volume of the box amounts to

$$V_s = \frac{Q_s}{\gamma} = 10F_s \text{ (cu decim)}$$

where

Q_s — unit weight of the load (kg/m),
γ — bulk density of seed material (kg/cu decim),
F_s — cross sectional area (sq decim).

In practice

$$V_s = 80\text{–}110 \text{ cu decim/m}$$

Transverse partitions in the interior of the box, welded to the front and rear walls, are used when grain-box length is greater than 2 m. These partitions prevent material from shifting to one side of the box, when it heels over on one side (when drilling on slopes), and also stiffens the box structure. Longer boxes sometimes require two lids.

Feeding sets can be placed on the bottom of the box (Fig. 13.6*a*), outside its rear wall (Fig. 13.6*b*) or inside the box (Fig. 13.6*c*). Since feeding sets of recent design are mostly mounted on the bottom of the box or outside the box, only these two systems will be considered here. In the first case, the orifices delivering seeds to particular cups of sets are placed perpendicularly to the direction in which seeds are poured out. In the second case, they are placed at an angle of setting of the front wall of the box. In order to prevent congestion caused, among other things, by seed bridging in front of the orifice and due to the action of internal forces of friction between individual grains, agitators are installed (as already mentioned), the role of which is identical to that in fertilizer distributors. Consequently, while the material is poured through the orifices into the cups of feeding sets, individual seeds are constantly on the move. This process reduces the bulk density of material to be distributed as it accumulates near the orifices in the box and, thereby, increases its flow ability. Steady pouring of the mass of seed through orifices — that is, a uniform quantity of seeds delivered to the feeding sets, is the prerequisite of uniform distribution. Anyhow — due to great differences in the shape, dimensions, weight and the like (Table 13.1), which occur not only between particular kinds of seed but even between their varieties — the process of emptying is a very complicate and the progress of grain pouring is frequently random. Naturally, small seeds, ball-shaped and with smooth cuticle fill the box more easily and regularly and, consequently, pour out more uniformly than spindle-shaped seeds (oats) or those with coarse cuticle or irregular in shape (for example, beet seeds). Besides, in all cases a seed stream represents an irregular flow to a greater or lesser extent.

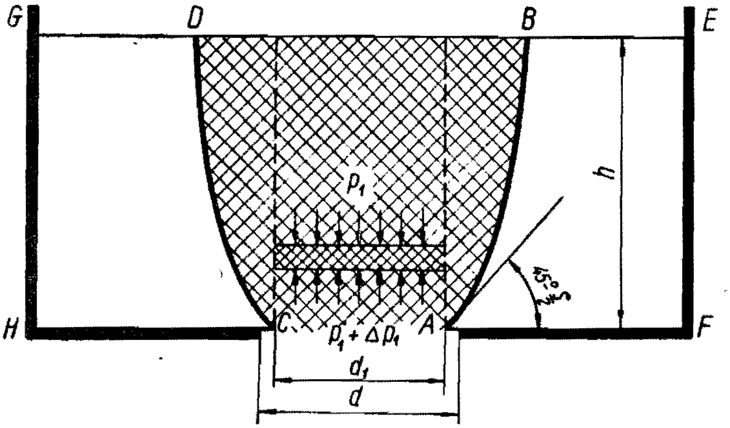


Fig. 13.7. Automatic pouring out of seeds from the box. (After Welschof).

The grain mass placed in a vessel, the bottom of which is provided with a circular opening having a given diameter d (Fig. 13.7) poures out in the form of a cylinder $d_1 < d$. Thus the quantity of material poured out through the circular orifice is equal to the volume of solid $ABDC$, whereas in the zones $ABEF$ and $CDGH$, the material is at rest. The inclination angle of the pouring planes near the orifice $\alpha = 45° - \frac{\varrho}{2}$ (ϱ is the angle of internal friction of material). For dry wheat $\varrho =$ 32–34°, and for oats $\varrho =$ some 38°.

If the initial speed at which material with high flow ability pours out is low, a formula typical for flow of liquid can be applied for calculation of the quantity poured out in a unit of time

$$G = \sigma \gamma_1 F_1 \sqrt{2g \frac{p}{\gamma_1}} \qquad (13.1)$$

where

σ — index of flow as determined from measurements; for loose material it is considerably lower than for liquid because of the higher loss of energy required to overcome higher internal friction (for liquid σ 0.6–0.9),

γ_1 — bulk density of material as it pours out from the orifice; this bulk density is lower than statical bulk density γ,

F_1 — cross sectional area of the seed stream being lesser than area F of the orifice,

p — static pressure in the orifice produced by the weight of the seed mass.

For practical purposes the value p can be expressed as follows

$$p = \frac{d_1 \gamma_1}{\lambda \tan \varrho}$$

where

$$\lambda = \tan^2\left(45 - \frac{\varrho}{2}\right)$$

After introducing the value p into the formula (13.1), we obtain

$$G = \sigma \pi \gamma_1 d_1^{2.5} \sqrt{\frac{g}{8 \cdot \lambda \tan \varrho}} \tag{13.2}$$

$$d_1 = d - d'$$

where

d' denotes contraction of the diameter which is always smaller than the diameter of the orifice; the size of d depends on the sharpness of the orifice edge, and on the value of friction between the material as it pours out and the orifice. According to the results of investigations — $d' = (1.5\text{–}3)\, d_z$, where d_z is the grain diameter. After substitution of the expression for d_1 into the formula (13.2), we obtain

$$G = \sigma \pi \gamma_1 (d - d')^{2.5} \sqrt{\frac{g}{8\lambda \cdot \tan \varrho}} \tag{13.3}$$

This formula proves that the stability of G and, consequently, the maintenance of a uniform quantity of seeds pouring out, depends on keeping the values γ_1 and $(d-d')$ constant.

The invariability of γ_1 and $(d-d')$ depends not only on the kind of seeds, but also on the manner of maintaining the travel of the seed mass — that is, on the action of the agitator (that is, on its structure and way of mixing). The more regular are γ_1 and $(d-d')$, the more regularly the seed material pours out. As d increases, variations of the values γ_1 and $(d-d')$ decrease and, consequently, variation in the value G decreases — that is, the regularity of pouring out seed mass improves.

If d decreases, the orifice edges and friction of seeds against the edges have greater bearing on changes in values d' and γ_1 with the resultant deterioration of the pouring regularity. Formula (13.3) indicates that the quantity of material poured out in a unit of time and, thereby, the speed of pouring depend neither on bulk density nor on height of the seed mass, but on size of orifice d and on angle of internal friction ϱ.

For dealing with seed pouring through rectangular orifices, mostly used in drills, the following formula can be used

$$G_1 = \sigma_1 \gamma_1 \frac{(a-d')^{1.5}(b-d')^{1.5}}{(a+b-2d')^{0.5}}\, 2 \sqrt{\frac{g}{\lambda \tan \varrho}}$$

In this formula value σ_1 differs from the value of σ for circular orifice. Also value γ_1 can be different.

Bridging of material being poured out can occur in the corners of the orifices in the case of their shape being rectangular which causes a change in the quantity of seeds delivered in a unit of time to the feeding sets. The bridging frequency depends on the kind of seed used and on the size of orifices. From this angle, circular orifices are better, but control of the quantity of seeds poured out and changement of the orifices, while their angular shape is preserved, is more complicated and expensive.

If the rectangular orifice is set at a certain angle α (angle of inclination of the box rear wall), the quantity G_1' of seeds pouring out in a unit of time can be approximately determined by the following formula

$$G_1' = G_1 \cos\alpha$$

Agitators in grain drills, as opposed to the agitators used in fertilizer distributors, are mostly designed as rotary elements. The agitator can be designed as a shaft with spaced straight or curved rods fixed to a shaft. The agitator should be placed close to the orifices as to ensure movement of the seed mass as it is passed through the orifices. If the feeding element is placed inside the box, it can also act as agitator.

13.3. Feed sets

The function performed by the feed sets is to form a layer of seeds fed from the box and also to shift it simultaneously aside and push into feed tubes streamlike. Before the war, various models of feed sets and assemblies were in use. Practice has proved, however, that two models — extensively used at present — perform this duty satisfactorily. We shall, therefore, confine ourselves to the design and operation of those two types of mechanisms.

In both models, the feed set consists of two parts: the rotary element displacing seeds, called also a feed roll, and immobile guiding surface called the bottom. The slot between the roll and the bottom is to a greater or lesser extent filled with seeds. At present, we find feed rolls of two types: fluted roll (Hoozier type) and studded roll (Siedersleben type). In order to prevent seed damage in the course of shifting as also roll damage if a shingle or other hard body happens to get into the box — the bottom plates are made of spring steel or propped by a spring. The feed rolls and the bottom plate are protected by walls fixed on either side of the box, forming what is called a feed cup.

Figure 13.8 shows diagrammatically the operation of the Hoozier type feed set.

Volume of seeds fed by one flute as accepted in theory is expressed by the following equation

$$V_t = (F_1 + F_2)l = Fl \text{ (cu cm)}$$

where

F_1 and F_2 — areas of cross sections shown in the diagram (sq cm),
l — length of the flute (cm).

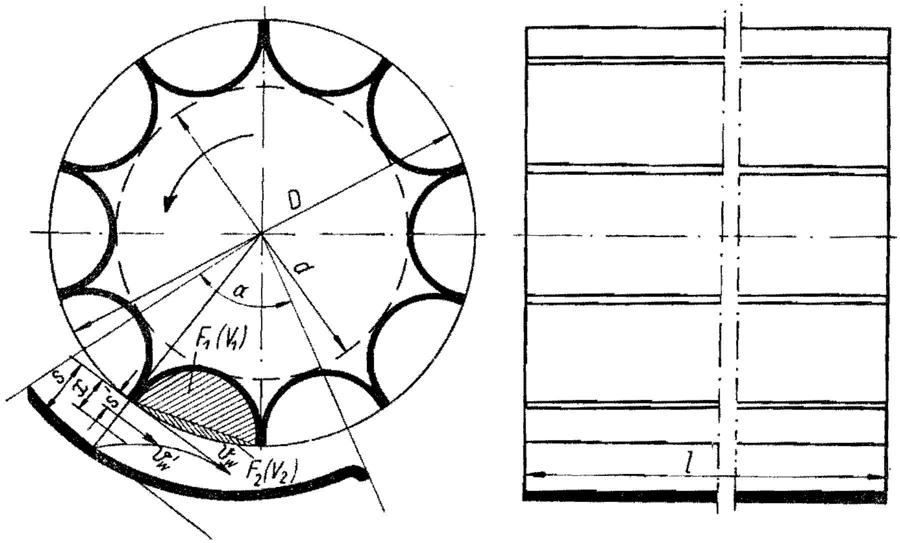


Fig. 13.8. Operational diagram of the fluted feed unit (Hoozier system). (After Turbin et al.).

The volume V_0 of seeds fed by one turn of the fluted roll can be calculated either by assuming the required quantity (in kg) of seeds of stated bulk density γ (in kg/cu decim) fed per 1 hectare, interrow width a (in cm), driving-wheel diameter D_k (in m) and total drive transmission ratio i, or assuming value D (in m), d (in m), l (in m), and the number of flutes z.

In the first case

$$V_0 = \frac{\pi D_k Q_{ha} a}{1000 \gamma i} = \frac{V_0'}{i} \text{ (cu cm)}$$

whereas the volume of seeds fed by one turn of ground wheel (drive wheel) is

$$V_0' = \frac{\pi D_k Q_{ha} a}{1000 \gamma} \text{ (cu cm)}$$

Direction of revolution of the fluted roll, shown in the figure, gives what is called "bottom seeding". If we change the direction of roll revolution then its flutes act as scoops giving what is called "upper seeding".

While the feed roll rotates, the friction between grains causes — independently of the material contained in flutes — that the outer layer of seeds s, the thickness of which is determined by resistance of friction against bottom, is moving forward. The thickenss of this layer, being displaced at decreasing speed when moving away from the roll, depends on the kind and the moisture content in the material. Therefore, if the width of the slot in greater than the value characteristic of the given kind of seeds, then a layer of material being on the bottom plate remains practically at rest. Occasional displacement of individual grains in this layer is incidental and incoherent which adversely affects the regularity of the removed stream.

The change in speed of shifted seeds in the external layer can be expressed — according to Soviet research workers — by the following empirical formula

$$v_x = v_w\left(1-\frac{x}{s}\right)^m \tag{13.4}$$

where

$$v_w = \frac{\pi D n_w}{60}$$

The index of power m is determined experimentally. According to Soviet experiments for grains of wheat, oats and barley $m = 2.6$, for seeds of flax $m = 1{,}7$, and for seeds of millet $m = 1.4$.

If by s' is denoted the distance of seeds from the perimeter of feed roll, moving with the same speed as seeds shifting on the roll perimeter then — processing from formula (13.4) — the relation between s and s' can be expressed as follows

$$v_w \int_0^s \left(1-\frac{x}{s}\right)^m dx = s'\cdot v_w$$

hence

$$s = s'(m+1)$$

s' can be calculated from the equation

$$\left(\frac{D}{2}+s'\right)v'_w = \frac{D}{2}v_w$$

$$\frac{D}{2}v'_w + s'v'_w = \frac{D}{2}v_w\cdot$$

$$s' = \frac{D}{2}\,\frac{v_w - v'_w}{v'_w} = \frac{D}{2}\left(\frac{v_w}{v'_w}-1\right)$$

According to the findings of Soviet research workers, the value s' varies rather slightly in consequence of changes in the operating length of fluted roll

6'

and its peripheral speed. For grain seeds these differences amounted to 0.5 1 mm. Only in corn seeds, these differences were up to 5 mm, which can be explained by large dimensions of seeds.

The actual total volume of seeds delivered by one turn of the roll, the active layer being taken into account, is expressed as

$$v_{rz} = (\varepsilon F z' + \pi D s')l \qquad (13.5)$$

$D\pi S$

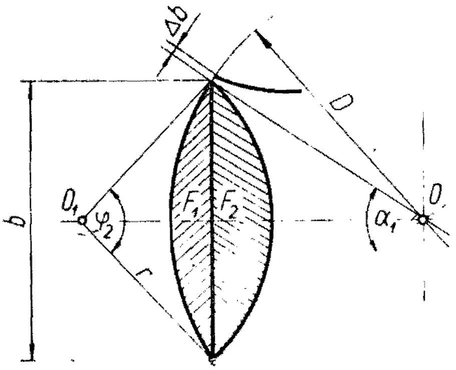


Fig. 13.9. Active areas of fluted feed rolls. (After Turbin et al.).

where

$F = F_1 + F_2$

ε — the coefficient of filling flutes with seeds,

l — active length of the roll.

z' — number of flutes.

The value of ε depends on the size and shape of seeds, as also flute profiles and on the direction of feeding grains to cups. In bottom seeding, however, as borne out by the formula, the value of ε does not depend on the peripheral speed of the roll (at least up to $n_0 = 40$ rpm). For perpendicular feeding of grain seeds, excepting oats, $\varepsilon = 0.7–0.85$, and for feeding fine-grained seeds, for example, clover $\varepsilon = 0.9$. It follows from Fig. 13.9 that

$$F = F_1 + F_2 = \frac{D^2}{8}(\alpha_1 - \sin\alpha_1) + \frac{r^2}{4}(\varphi_2 - \sin\varphi_2)$$

$$\alpha_1 = 2\arcsin\frac{b}{D} \quad 2\sin^{-1}\sin\frac{b}{D}$$

$$\varphi_2 = 2\arcsin\frac{b}{2r}$$

$$b = D\cdot\sin\frac{\pi}{z} - \Delta b$$

Assuming D, d and l (cm) as given in Fig. 13.8, and taking into consideration the volume of seeds displaced by flutes

$$V_1' = \frac{\pi}{4} l(D^2 - d^2) \text{ (cu cm)}$$

and taking into account that $z' \cdot V' = \alpha V_1'$ the volume of seeds fed directly by the roll can be expressed as

$$V_1 = V_1' - \alpha V_1' = (1-\alpha)V_1' = (1-\alpha)\frac{\pi}{4} l(D^2 - d^2) \text{ (cu cm)}$$

The volume V_2 of seeds, fed in the layer of thickness $s (s > s')$, is

$$V_2 = (D+s)\pi l s \text{ (cu cm)}$$

The total volume of seeds sown by one turn of the roll accepted in theory is

$$V_0 = V_1 + V_2 = (1-\alpha)\frac{\pi}{4}l(D^2-d^2)+(D+s)\pi ls$$

$$= \left[\frac{\pi}{4}l[(1-\alpha)(D^2-d^2)+4(D+s)s]\,(\text{cu cm})\right]$$

Since the actual volume of seeds removed is always somewhat lower than the theoretical value V_0, then $V_{rz} = \beta V_0$ (β is the coefficient of material feed reduction equal to 0.6–0.8). The volume of seeds fed during one turn of the ground wheel of the drill is equal to

$$V'_{rz} = \frac{\pi}{4}ln'\beta[(1-\alpha)(D^2-d^2)+4(D+s)s]\,(\text{cu cm}) \qquad (13.6)$$

where n' is the number of revolutions of the feed roll per one turn of the ground wheel.

To relate the parameters of the feed set with the quantity of seeds sown per hectare, the latter can be expressed by the following equation

$$Q_{ha} = V_{ha}\gamma \; (\text{kg/hectare})$$

where V_{ha} is the volume of seeds sown out per hectare. The area A sown during the travel by 1 m, amounts to

$$A = Sr1 \text{ m} = Za1 \; (\text{sq m}) \qquad (13.7)$$

where Z is the number of furrow openers. The volume of seeds sown per square meter is

$$V = \frac{V'_{rz}Z}{A} \; (\text{cu m})$$

The volume of seeds sown out per hectare amounts to

$$V_{ha} = 10{,}000V = 10{,}000\frac{V'_{rz}Z}{A} = \frac{Q_{ha}}{\gamma} \; (\text{cu m})$$

Hence

$$Q_{ha} = 10{,}000\gamma\frac{V'_{rz}Z}{A}$$

After substituting in the above expression values for V_r' and for A from formulas (13.6) and (13.7) respectively, we obtain

$$Q_{ha} = 10{,}000\frac{\pi ln'\beta[(1-a)(D^2-d^2)+4s(D+s)]}{4a}$$

From this expression, we are able to calculate the outer diameter of the feed roll as follows

$$D \lessapprox K\sqrt{\frac{ZaQ_{\mathrm{ha}}}{2800\gamma\pi(1-\alpha)\beta l n'}}$$

where K is the coefficient which takes into account the width of the slot. For fluted rolls $K = 0.80$–0.90, and for studded ones $K = 0.90$–0.98.

The diameter D increases with the increase in the root value of Q_{ha}. For fluted rolls $\alpha = 0.30$–0.40.

The expression (13.5) indicates that the quantity of seeds sown by one turn of the roll depends on its diameter, number of flutes, their capacity and their length. As regards the quantity of seeds sown out per unit of length of the drill travel (say, per 1 m), it depends also on the rate of roll rotation — that is, on the proper selection of transmission ratio.

In practice, the seeding rate per hectare is obtained by changing the working length of the roll or by changing the number of its revolutions. The first method is simpler and less expensive. The tests made indicate that the quantity of seeds poured out is roughly directly proportional to the length of the fluted roll. At present, fluted rolls manufactured in this country are no more of gray cast iron but of iron powder Högamas MH 100 and Hametag, graphite PL 996 and of stearate of zinc. The mixture, after

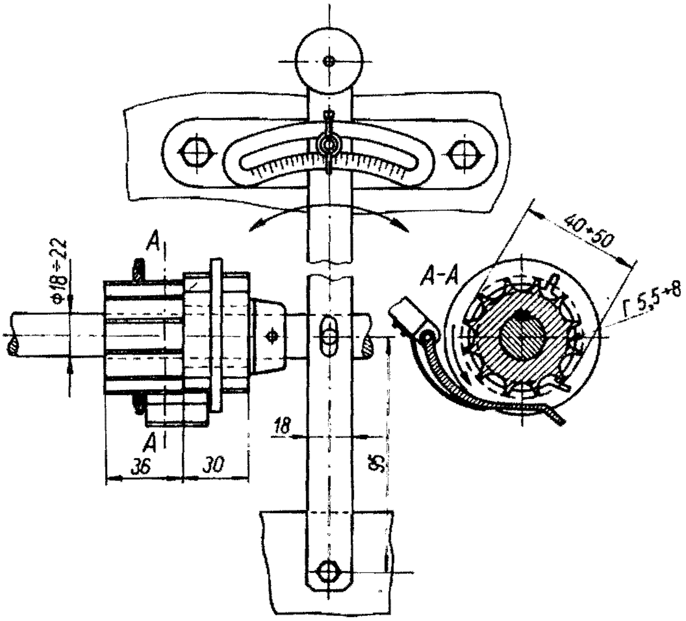


Fig. 13.10. Example of control of the seeding rate on applying fluted feeds.

thorough stirring and compressing is sintered. Rolls manufactured by this method are superior by their smooth surface and high accuracy in dimensioning.

Figure 13.10 shows an example of the device for axial displacement of rolls. The change of length of rolls should simultaneously take into account the change of the size of feed orifices in the box. Therefore, extension of fluted rolls constitute a smooth cut-off blocks provided with screens closing the slot. These cut-off blocks can be mounted on sleeves as an extension of fluted rolls and cast together with them or can make individual components fixed on a common shaft together with fluted rolls.

As the wrapping angle α of the feed roll (Fig. 13.8) increases, the rate of seeds removed per one revolution of the roll initially distinctly diminishes; this diminution disappears with further extension of the bottom plate to increase again together with an increase in the wrapping angle ($\alpha > 60°$) (Fig. 13.11). The most suitable wrapping angle for the bottom plate is 40–50°. The number of flutes is mostly 8–12, and the lower is the number of flutes the deeper as a rule they are designed. The axial shift of sets of fluted rolls and cut-off blocks requires openings to be made in various and suitable shapes in both lateral walls of the cups (at the side of feed rolls the openings are rosette shaped).

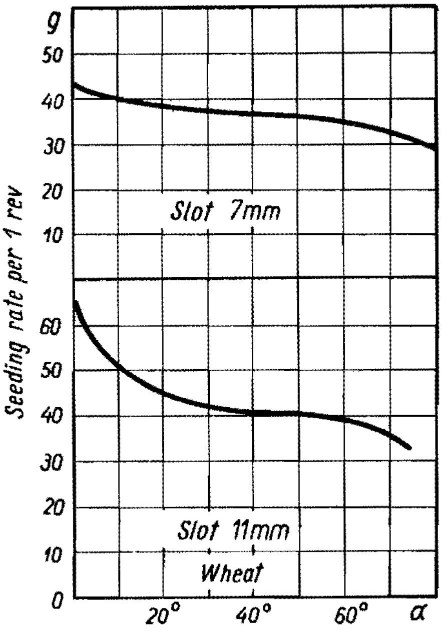


Fig. 13.11. Example of the influence of the wrapping angle α of the bottom plate on the seeding rate at a given setup of the fluted seeding unit. (According to the results of the present authors' investigations).

The width of the slot should, on the one hand, take into account prevention of seeds from being damaged and, on the other, thickness of the layer with seeds. Some designs provide for adjustability of the width of the slot by means of altering the position of the bottom plates according to the size of seeds sown out. The most frequent rate of revolutions of the fluted roll is 30–60 rpm.

It results from the analysis carried out on the process of feeding seeds through openings in the box, as well as on removal of grains that a uniform flow of seeds in the strict sense is not obtained with the

Hoozier's system (irregular filling of cups and of particular flutes attended by variation in the active layer width). Consequently, the seed stream is subject to some pulsation. This pulsation decreases as the peripheral speed of feed rolls increases but becomes higher when flutes are made deeper. Therefore, by increasing the operational speed of the drill a decrease in the pulsation rate takes place. Consequently, an increase in the operational speed of the drill (say, to 12 km/hr) does not affect the index of transversal uniformity of seeding. If a small quantity of seeds is fed — that is, when the roll length is small, the size of slots in the box decreases considerably which, as already mentioned, affects seeding uniformity. Therefore, control of the seeding rate by changing the number of revolutions of feed rolls, the size of the slot being constant, may be of some advantage as compared with the "sliding" control system. In order to diminish the pulsation, a fluted roll is used, with two rows of short flutes reciprocally shifted by half-pitch (Fig. 13.12*a*) or rolls with oblique flutes (Fig. 13.12*b*). In both instances, change in seeding rate requires adequate change in peripheral speed of rolls, which can be attained by gear transmission.

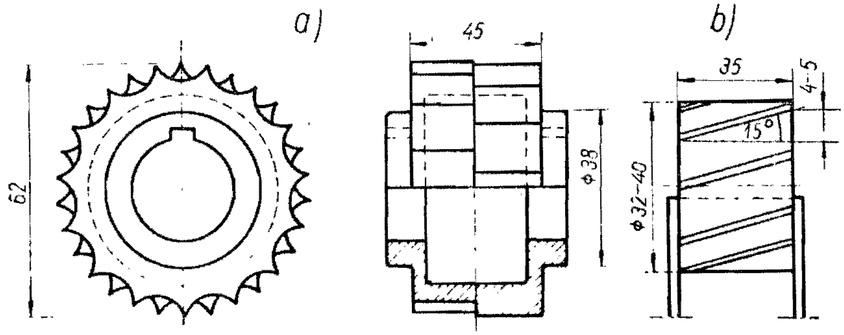


Fig. 13.12. Fluted roll with reciprocally shifted rows of flutes: *a*) system of Dehne; *b*) feed roll with oblique flutes.

The pulsatory nature of the removed stream of seeds is not of decisive importance for the uniformity of placing seeds along the rows, since this longitudinal uniformity is furthermore affected by the walls of seed tubes, furrow-opener action and seed bed preparation.

It would be delusory for a designer of feeding sets in the drill of classical type, to presume that a regular and accurate distribution rate in furrows may be obtained, since such is in practice unattainable. However, the more uniform the seeding stream, the higher, in general, the likelihood of a quantitatively more uniform seed distribution in particular furrows. As shown in the following (13.4) section, however, this relation can be altered owing to the influence exerted by several types of seed tubes. Therefore, endeavors should be made that the differences in the quantities of seeds removed by individual sets per unit of drill travel, be as small as possible.

Obtainment of low differences in seeding rates requires adequate structural parameters of the feed units (roll diameters, number and shape of flutes, bottom-plate length, etc.), an exact manufacture and accurate mounting of feed cups. It is evident that even when optimum technical conditions are kept, the transversal seeding uniformity depends on the kind and preparation of the seeding material (accurate cleaning and sorting).

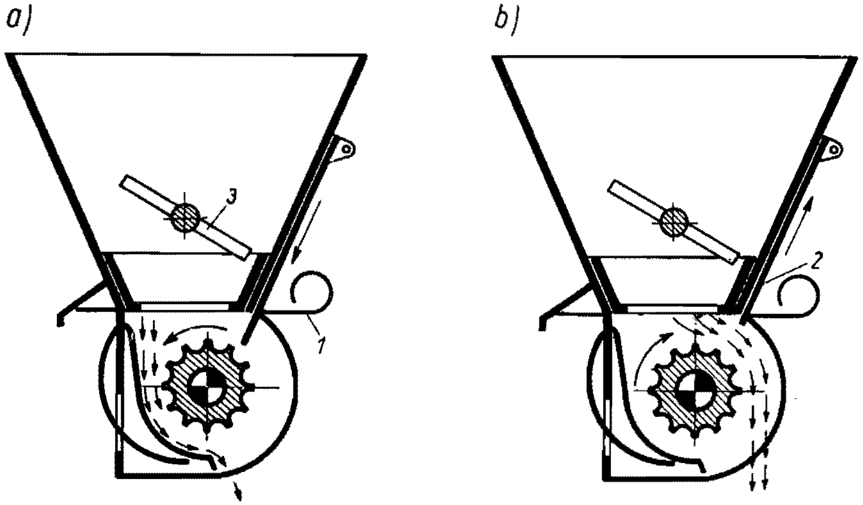


Fig. 13.13. *a*) Bottom feeding system; *b*) upper feeding system; *1* — horizontal damper; *2* — oblique damper; *3* — agitator.

Nowadays, the required index of seeding irregularity δ should not exceed 5 percent, and the index of deviation σ from the average feed rate should not be higher than 12 percent. As far as seed damage is concerned, the quantity of seeds damaged should not exceed 0.3 percent, and 5 percent with grain seeds and pulse seeds, respectively. In modern drills of Hoozier system the rate of damaged grain seeds amounts to 0.15–0.20 percent. Also in this case the damage rate of seeds depends on their kind (size, shape, cuticle susceptibility). Thus, for example, the damage rate of easily cleavable vetch seeds, provided that the bottom plate is adequately set up, can exceed even 3 percent, and in oat seeding can shrink to zero.

Sometimes for feeding coarse-grained seeds (for example, pea) or oats — that is, those most of all exposed to damage and difficult in seeding, the possibility of changing the direction of fluted roll revolutions is utilized — that is, what is called the upper feeding system is applied (Fig. 13.13*b*). In this case, feeding run is obtained by a corresponding setup of the upper iron sheet damper. Our own experiments have proved, however, that the operational quality is — with this system — obviously worse than with a bottom feeding system (Fig. 13.13*a*).

Although the feed system according to the Hoozier model is generally considered to be universal — that is, adaptable to seeding various kinds of seeds, the feed of fine-grained seeds is sometimes (for example, in USSR) carried by means of a somewhat modified design.

The seed distributing process by means of studded feed units resembles in general the above-described fluted roll process. Figure 13.14 shows an example of the structure of a studded feed roll, made of polyamide (Tarnamid T 27) and Fig. 13.15, the diagram of a drill with studded units. As indicated in Fig. 13.14, the center of the roll perimeter is shaped in such a way as to make it possible to divide the shifted layer of seeds into two parallel streams and, furthermore, to facilitate appropriate arrangement of long-shaped seeds as, for example, of oats. The seed layer is shifted by frontal pressure of stud surface and by the friction force oc-

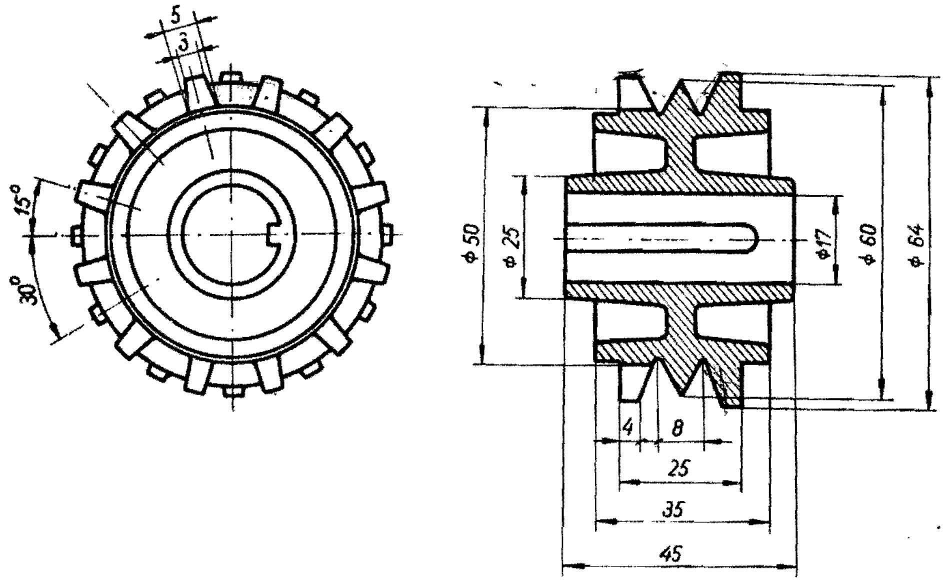


Fig. 13.14. Example of studded feed roll.

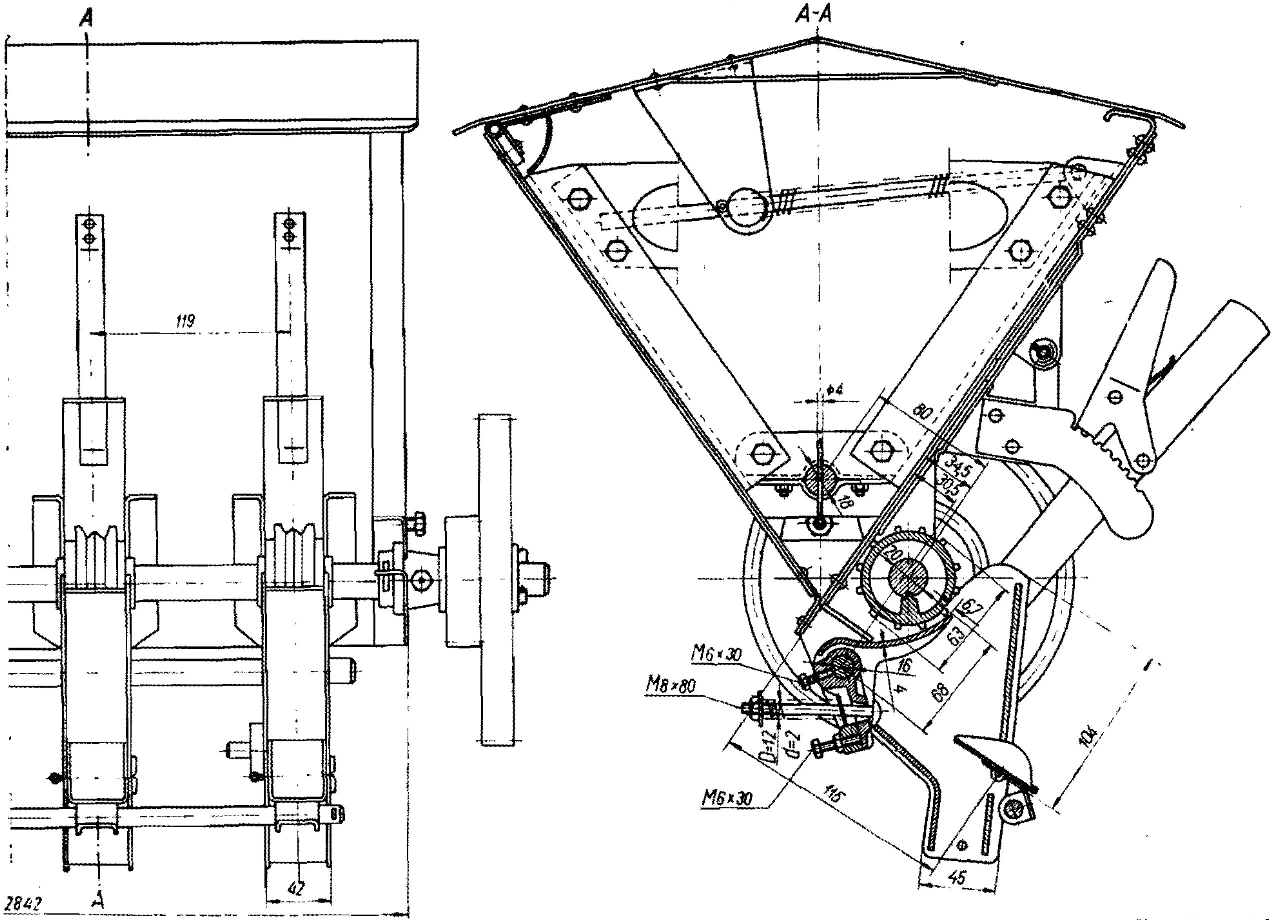


Fig. 13.15. Example of a drill with studded feed unit (Siedersleben's system). Note: component parts are listed in Fig. 13.20.

curring between seeds and contacting with them side surfaces of studs, as also by friction between indivudal seeds.

When making use of formulas (13.6) and (13.8), it is necessary to adopt coefficient $\alpha = 0.30$–0.40.

The required, possibly the least, width of interrows determines the length and, consequently, the necessary number of feed units, falling per 1 m of length of the grain hopper. Control of the seeding rate by means of studded rolls is possible only by changing their peripheral speeds — that is, by maintaining a constant size of the openings in the hopper. This, as already mentioned, favors keeping the seed stream sufficiently uniform, even if the seeding rate per 1 hectare is low. Moreover, the frequency of immediate influence of studded roll on seed layer in the slot is higher than that of fluted roll. Due to these two factors, values δ and σ are lower for the Siedersleben system than for the Hoozier system. Also the damages to grain seeds are slight (0–0.1 percent). Figure 13.16 presents variation, according to tests made by the present authors, in the longitudinal irregularity of seeding δ by the two above-described feed systems for the

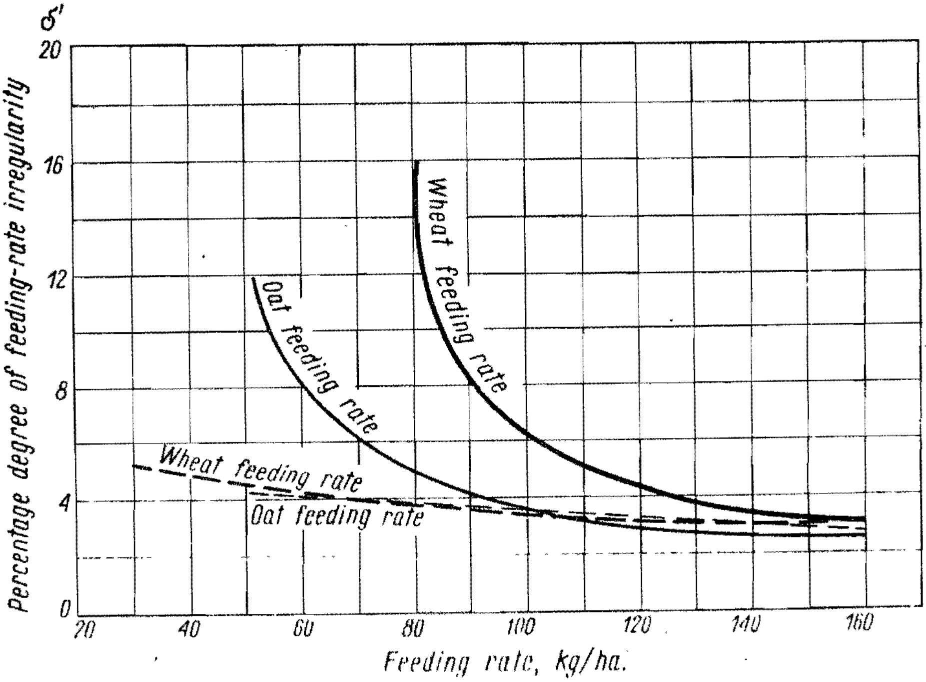


Fig. 13.16. Example of variation in the index of seeding irregularity δ' as a function of the seeding rate for fluted unit (dashed lines) and for studded unit (full lines). (According to the present authors' investigations).

same soil conditions, with the use of the same furrow openers. It will be seen from the run of curves that the operational quality of seeding for higher seed rates is more or less identical but as the seed rate decreases it is found to be distinctly different in favor of the studded unit.

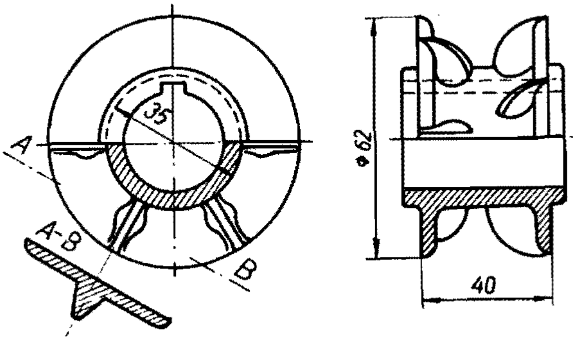


Fig. 13.17. Example of feed roll for feeding coarse seeds.

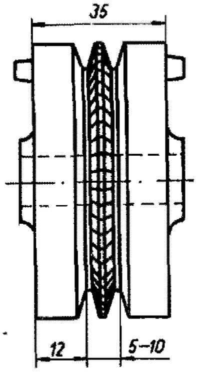


Fig. 13.18. Example of feed roll for feeding fine-grained seeds.

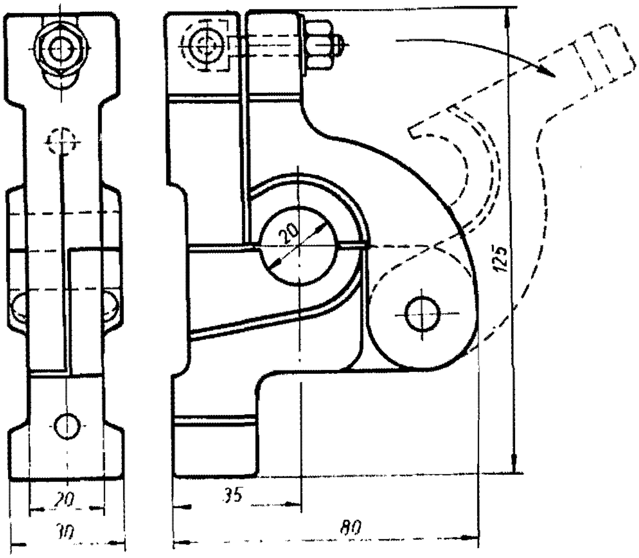


Fig. 13.19. Manner of providing with bearings the roll in studded feed unit.

When coarse-grained seeds are used, a corresponding enlargement of the slot is needed. However, in this instance, seeds resting on the bottom plate do not travel uniformly, and this worsens the uniformity of distribution. Therefore, the studded roll, as opposed to the fluted one, cannot be considered as a universal feeding element.

Sometimes, in place of studded roll, an element for feeding coarse seeds (pea, corn, beam) is used as presented in Fig. 13.17. In this feeding element, oblique blades of flanges are pushing coarse seeds which can easily fill the middle part of the element and, therefore, are not exposed to damage. Shown in Fig. 13.18 is the diagram of a feed roll designed for feeding fine-grained seeds in small quantities. In this element the mobile feeding part is a center notched ring (the least obtainable seeding rate about 800 g/hectare). During the feeding process, the bottom plate is set up in the utmost elevated position. Hubs of all the types of feed rolls described are usually provided with a spline entering the appropriate slot milled on the entire length of the driving shaft. The last (Fig. 13.19) is mounted on bearings, which allows for easy and quick dismantling it from the machine. After the shaft with feed rolls is removed, they are withdrawn manually and in their place appropriate rolls of other kinds are assembled. In order to develop a universal machine, studded rolls made of rubber have been incorporated by some manufacturers. But the effect, particularly when fine-grained seeds had been used, was on the whole worse than for feed with special removable rolls.

Figure 13.20 indicates that the manner of positioning the bottom plate allows not only for its self-deflection in case a greater pebble happens to get into the shifted layer, but also for regulation of the slot in individual feeding sets with the use of adjustable screw.

A manual lever can simultaneously deflect all bottom plates which allows to remove the remaining seeds from the box. These seeds drop into a curved trough hinge-connected with the drill. The same trough allows for setting the drill for the required seeding rate per hectare. In this instance, bottom plates are put in working position suitable for feeding seeds of a given kind.

Figure 13.20 presents position of the trough while residual seeds are being removed from the box. Feed rolls are now made mostly of polymer.

Several years ago, a drill (mounted on three-point hitch linkage of the tractor) was designed by Stockland of Norway; the principles of its operation and construction are so original and differing to anything that has been done in this line up to the present that it is worthwhile to familiarize with the operational qualities of this machine (at present this drill is produced, among others, by the well-known IHC company).

A diagram of operation of feed device of the drill in question is shown in Fig. 13.21*a*.

Seeds placed in the grain box, in the shape of a cylindrical hopper, the bottom of which is frustrum of cone, are sent through a series of openings into a funnel-shaped iron sheet shield. Revolving inside this shield is frustrum-of-cone shaped rotor (diameters 270 and 45 mm respectively) with welded curved blades (guides). The height of the frustrum is 150 mm, and the angle of generating line — about 40°. Through the opening at the bottom of the rotor, seeds get into its interior. Agitator 5 (in Fig. 13.21*b*), shaped as a curved finger and placed opposite the intake

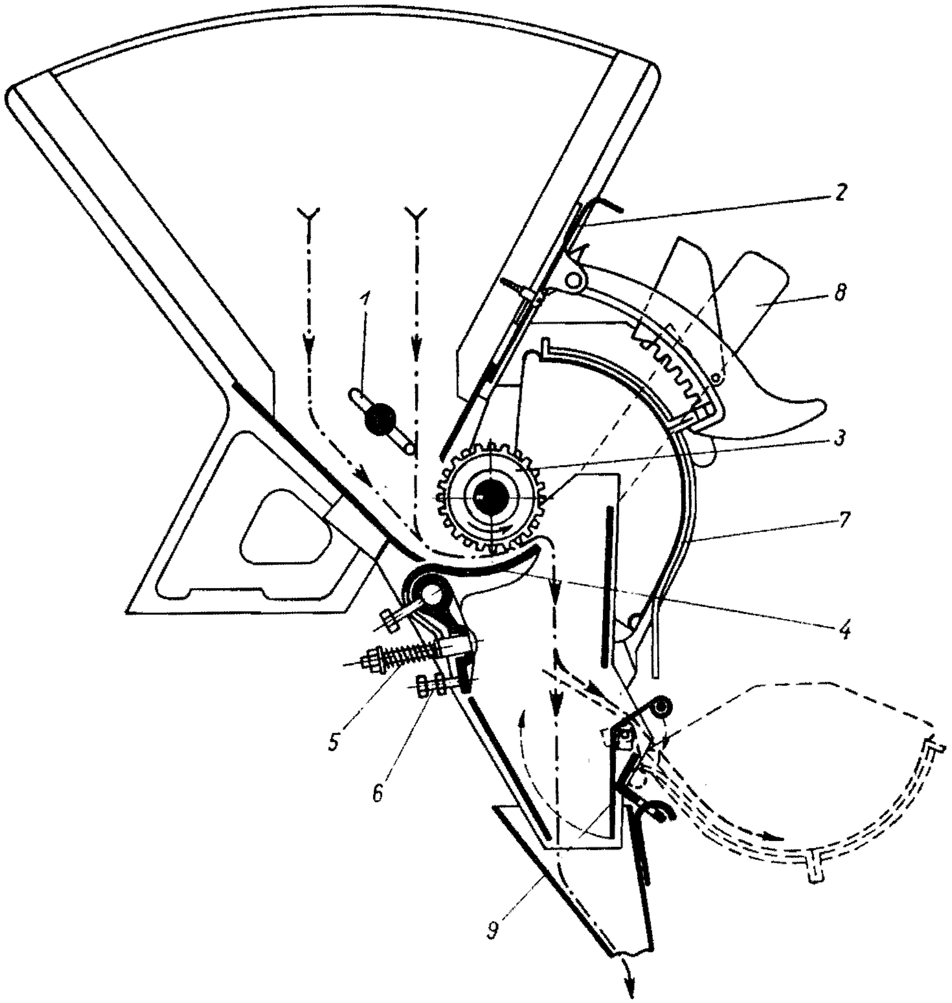


Fig. 13.20. Placing the trough for adjusting the drill for the required seeding rate (dashed lines), and during the operation (full lines): *1* — agitator; *2* — adjustable damper; *3* — studded roll; *4* — rigid bottom plate; *5* — spring; *6* — screw for accurate adjusting the bottom plate; *7* — trough; *8* — lever for setting up bottom plate; *9* — rotary damper.

opening, forces the flow of seeds. This agitator gathers the seeds being placed around the rotor, and pushes them into its interior. The air current, produced by the ventilating action of the rotor blades, rises upward and carries away dust and fine impurities therefore additionally cleaning up the seeds before seeding. The size of the feeding slot in the rotor can be altered by turning an appropriately shaped hand-operated diaphragm and, therefore, regulation of the feeding rate can be obtained. Once inside, seeds, through obliquely running openings and tubes, are ejected into the feed tubes.

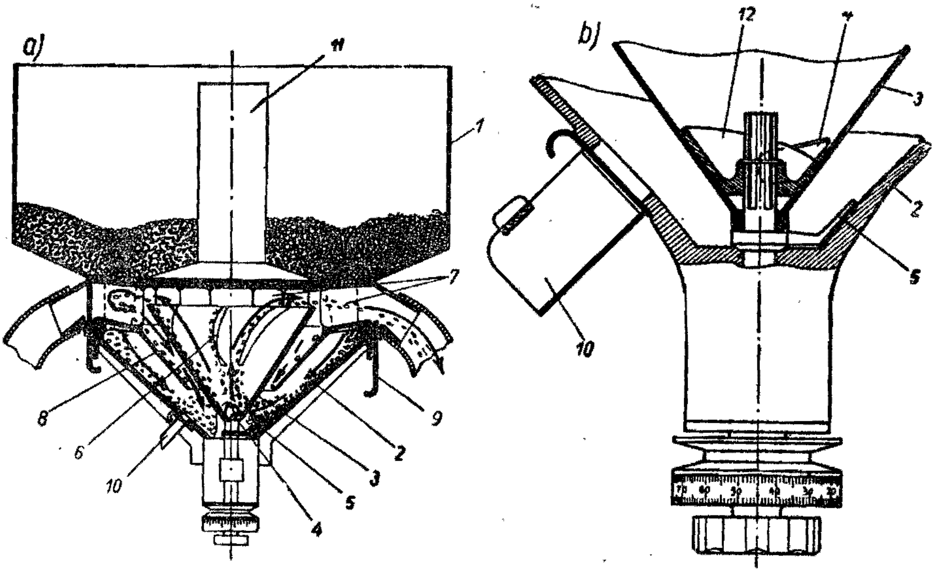


Fig. 13.21. Scheme of operation of feed device with rotary funnel (Stockland's system): *a*) cross section of the drill; *b*) detail of control unit: *1* — seed hopper; *2* — conical shield; *3* — funnel-shaped rotor; *4* — inlet to the rotor interior; *5* — agitator; *6* — rotor blades; *7* — outlet openings; *8* — cone slot; *9* — damper; *10* — discharge opening for the remaining seeds; *11* — airflow outlet tube; *12* — adjustable diaphragm of the feeding inlet.

Individual tubes can be shut, if necessary, by means of dampers. Seed that miss the openings but are knocked off the barriers between openings, fall down back into the conical shield through the cone passage formed between the rotor surface and the cone surface surrounding the upper part of the rotor. There is an opening in the funnel-shaped shield, provided with a damper enabling the emptying of remaining seeds from the funnel.

Let us consider the travel of the material point M on the rotating smooth conical surface. Acting on this point are (Fig. 13.22): force of gravity $G = mg$, normal reaction N, friction force T, and forces of centrifugal inertia B_n. These forces produce the resultant motion of the point in question, whereas forces of friction and gravity are engaged during its displacements over the rotating surface. Similarly, when considering the travel of a particle on the rotating plate, angular and linear speeds of transportation ω_u and v_u, as well as relative speeds ω_w and v_w and absolute ones ω_b and v_b are also taken into account. The interrelations between these speeds can be expressed as

$$\omega_b = \omega_u - \omega_u$$

while

$$\omega_u = \omega$$

$$\vec{v}_b = \vec{v}_u + \vec{v}_w$$

Figure 13.23 shows the speed resolution of the considered particle (grain) in two plans.

If we assume that the initial position of the grain considered is in point A at a distance OA from the axis of rotation O of the rotor then, with the unchanged position on the internal conical surface of the rotor, the grain would take, after a certain time period t, the position A' describing the arc AA' with radius OA corresponding with a certain angle α.

This arc determines the transportation path of the grain. However, since the grain slides on the rotating surface, being simultaneously raised hence it will, in the same period of time t, cover absolute path AA_1. The distance of point A_1 from the axis of rotation is equal to certain radius r. A certain angle φ corresponds with the path AA_1 while the radius OA_1 is deflected from the radius OA' by a certain angle γ. Thus, we can present the following interrelations (Fig. 13.22)

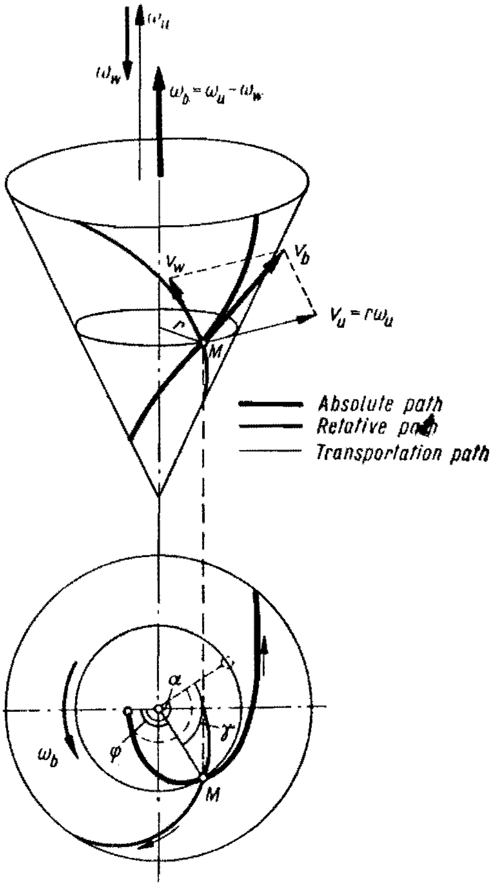


Fig. 13.22. Travel of material point M on rotating cone surface.

$$\omega_u = \frac{d\alpha}{dt}; \quad \omega_w = -\frac{d\gamma}{dt}; \quad \omega_b = \frac{d\varphi}{dt} = \omega_u - \frac{d\gamma}{dt}$$

If for the purpose of determining the position of point A_1 on the absolute path, we shall avail ourselves of the coordinates $r = f_1(t)$, $\varphi = f_2(t)$ and $z = f_3(t)$, where

z denotes the height of grain transportation, and we shall resolve the speeds v_b, v_u and v_w in the above mentioned system r, φ and z, then — as results from the directions of speed vectors shown in Fig. 13.22 — these components will amount to: projection of speed v_u on direction r is equal to zero, and the projection of speed v_w will amount to: $v_{wr} = \frac{dr}{dt}$. The resultant of these speeds, as an algebraic sum, will be expressed as follows

$$v_{ur}+v_{wr}=\frac{dr}{dt}$$

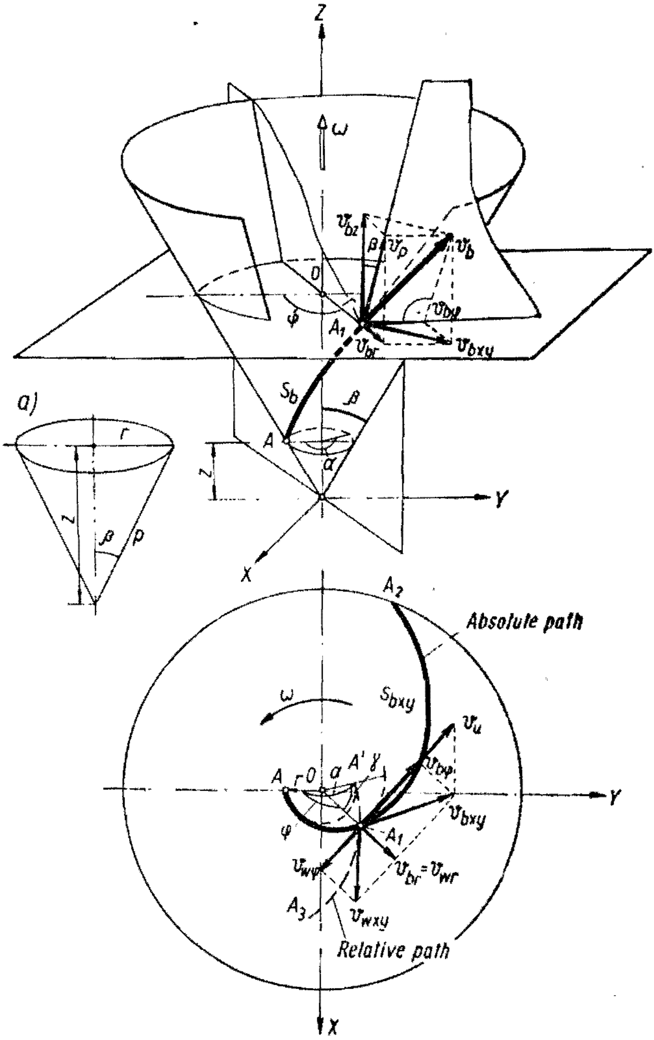


Fig. 13.23. Speed resolution of the point placed on rotating surface.

Projection of speed v_u in relation to φ makes $v_{u_\varphi} = v_u = \omega_u r$, on the other hand, projection of speed v_w $v_{w\varphi} = -r\frac{d\gamma}{dt}$. The resultant constitutes also an algebraic sum of the given components, therefore

$$v_u + v_{w\varphi} = \omega_u r - \frac{d\gamma}{dt} r = r\left(\omega_u - \frac{d\gamma}{dt}\right)$$

Since

$$\omega_u - \frac{d\gamma}{dt} = \frac{d\varphi}{dt}$$

then, on substitution we obtain

$$v_u + v_{w\varphi} = r\frac{d\varphi}{dt}$$

Projection of speed v_u on direction z equals zero ($v_{uz} = 0$), and projection of speed v_w is expressed as

$$v_{wz} = v_{bz} = \frac{dr}{dt}\cot\beta$$

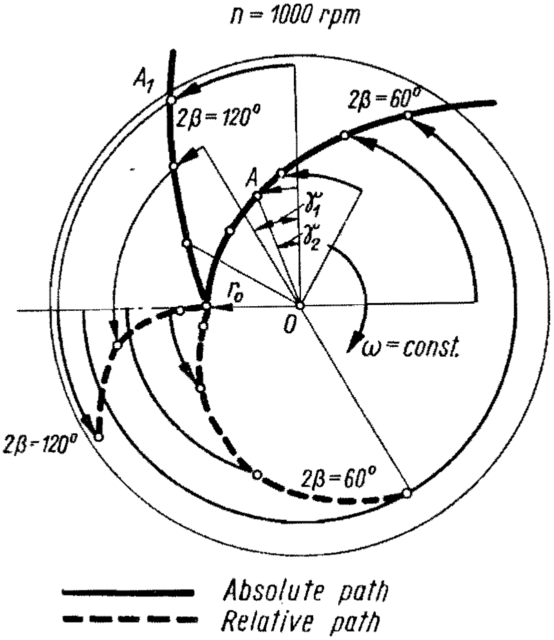


Fig. 13.24. Example of horizontal projections of relative and absolute paths of a material point on the rotating conical surface.

The curve AA_1A_2 (Fig. 13.23) represents the horizontal projection of the absolute path of the grain as observed outside the rotor. On the other hand, the curve A_1A_3 determines the horizontal projection of the relative path seen by the observer turning, for example, together with the rotor. While the direction of the absolute path of the grain is consistent with the direction of rotation of the rotor, the direction of the relative path is reversed (owing to delay in the grain travel caused by its sliding).

Figure 13.24 shows a diagram of horizontal projections of paths, relative and absolute, for two sizes of the coning angle ($2\beta = 60°$ and $2\beta = 120°$) and at a constant number of revolutions. It can be deduced from this graph that the higher the coning angle, the steeper are the paths, and the more curved are the relative paths.

From the point of view of accelerations, the transportation acceleration (a_u), relative acceleration (a_w) and Coriolis acceleration (a_c) should be examined. The resultant acceleration (absolute acceleration) is the geometrical sum of all the above accelerations. Therefore,

$$\vec{a}_b = \vec{a}_u + \vec{a}_w + \vec{a}_c$$

On the basis of the same considerations when examining the accelerations (as in speed testing) we obtain the differential equations of the travel of the grain along the generating line p of the conical rotor in the following forms

$$\mu N \frac{v_{wp}}{v_w} + mg\cos\beta = m\left[\frac{d^2p}{dt^2} - \left(\frac{d}{dt}\right)^2 p\sin^2\beta\right]$$

$$\mu N \frac{v_{wp}}{v_w} = m\left(\frac{d^2\varphi}{dt^2}p + 2\frac{d\varphi}{dt}\cdot\frac{dp}{dt}\right)\sin\beta$$

where

μ — coefficient of grain friction against the conical surface,

N — normal grain pressure against the conical surface,

v_{wp} — projection of the relative speed on the direction of the cone generating line.

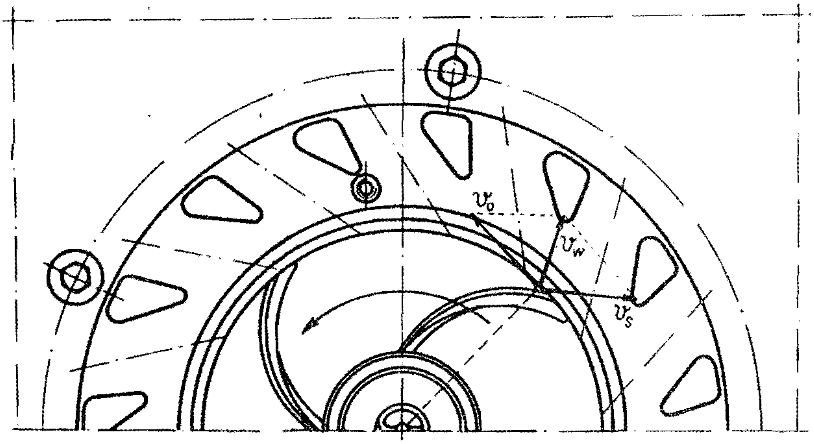


Fig. 13.25. Direction of resultant speed v_w on blade ends.

Solution of these equations is very difficult and requires the determination of initial conditions. These conditions, as also the solution of equations, have been checked experimentally and analytically.

Relative travel of the grain is conditioned by

$$\frac{\omega^2 r_0}{g} = \left(\frac{\omega}{\omega_0}\right)^2 > \frac{\cos\beta + \mu\sin\beta}{\sin\beta - \mu\cos\beta} = \frac{1+\mu\tan\beta}{\tan\beta - \mu}$$

The higher the coefficient of friction μ or the lower the value of the angle β the higher will be ω, in other words, the higher the revolutions of the rotor. It follows from the aforesaid that at a given value of β, seeds with higher coefficient of friction bring about the lower number of rotor revolutions.

A certain number of appropriately curved blades should be employed to group into individual portions grains dispersed over the conical surface. The shape of these blades and their curving should be so selected as to prevent seeds from rebounding too violently off them — that is, to make seeds shift along the entire length of the blades. Curving of the blades in horizontal plan should correspond with the shape of relative paths of seeds, as presented in Fig. 13.24. The direction of the resultant speed of the individual ends determines the directions of setting the outlets of particular tubes (Fig. 13.25).

Figure 13.26 presents horizontal plans of absolute and relative paths at two different speeds of the rotor (300 and 1000 rpm) and at β = const.

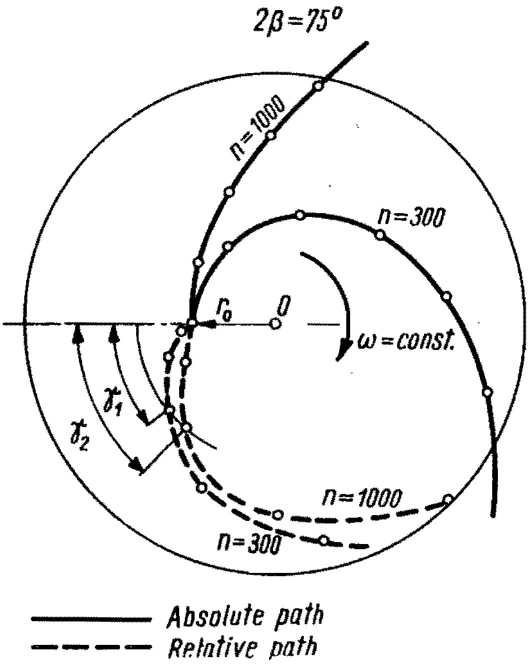


Fig. 13.26. Example of horizontal plans of the absolute and relative paths at two different numbers of the rotor revolutions.

The figure shows that, inasmuch as variation in the number of revolutions of the rotor considerably changes the shape of absolute paths, the shape of relative paths changes only slightly. It can be deduced that variation in the number of revolutions of the rotor should not affect the operational quality of the drill, if the curving of its blades corresponds with the shape of relative paths. Namely, when the rotor is driven with the use of ground wheels of the drill by one belt transmission, a change in the travel speed should not cause neither high variation in the adjusted feeding rate (Q_{na}), nor in the value of index δ of the transversal seeding irregularity. The speed and direction of travel of individual seeds depend usually on their shape, elasticity, dimensions as well as on the coefficient of friction for both the rotor surface and the curved working surfaces of the blades.

In addition, our own investigations and observations have proved that when blades are designed in a complicated manner then the highest values of pressures and the highest forces of impact occur as soon as seeds come in contact with the lower curved part of the blade. In the middle, and particularly in the upper part of the blade, the pressure is subject to rapid reduction, because a great many of seeds, after rebounding from the lower part of the blade, move singly — that is, freely, in an uncoordinated manner (rapid decrease in pressures has been confirmed by calculations).

For the aforesaid reasons, the travel and paths of seeds of different and even the same kinds vary. Our own investigations have proved that if the curved blades are channel shaped, a more uniform distribution of seeds to the individual outlet tubes is obtained. This improvement in uniformity can be explained by the fact

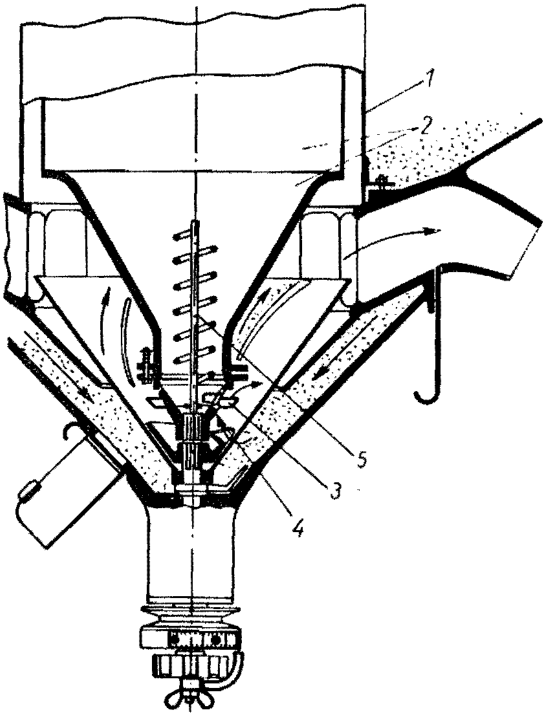


Fig. 13.27. Scheme of Stockland's feed unit for combined sowing: *1* — iron sheet hopper; *2* — cylindrical tank for extra seeds or for fertilizer granules; *3* — plate; *4* — conical diaphragm of the outlet opening; *5* — agitator.

that the upper wall of the channel makes it difficult for individual grains to travel across the blades while those accumulating in the channel reduce the rebound of other seeds.

The results of our grain-feeding measurements (oats, in particular) point out to the fact that when the rate of seeding (Q_{ha}) is being decreased the speed of the machine travel also decreases and, consequently, a decrease in the number of rotor revolutions is observed. On the other hand, when ball-shaped seeds, for example, vetch, are used the increase in the number of rotor revolutions causes a decrease in the adjusted feed rate. This last phenomenon can be explained by the fact that, owing to their spherical shape and, consequently, to a lower rolling resistance many seeds are expelled by the rotor over uncoordinated paths and, as a result, they fall into the conical shield.

In general, transversal irregularity of feed differs only slightly from that observed in drills with fluted and sudded feed units.

The drill of the type indicated can be used for simultaneous feeding of two kinds of materials at various rates. For example, grain seeds (Q_{ha}) and granulated fertilizers or field pea seeds (Q_{ha}) can simultaneously be sown out.

For combined feeding, inside the cylindrical seed hopper, a smaller cylindrical tank should be placed, frustrum-of-cone shaped at the bottom (Fig. 13.27). Wedged on the propeller shaft of the main cone is another

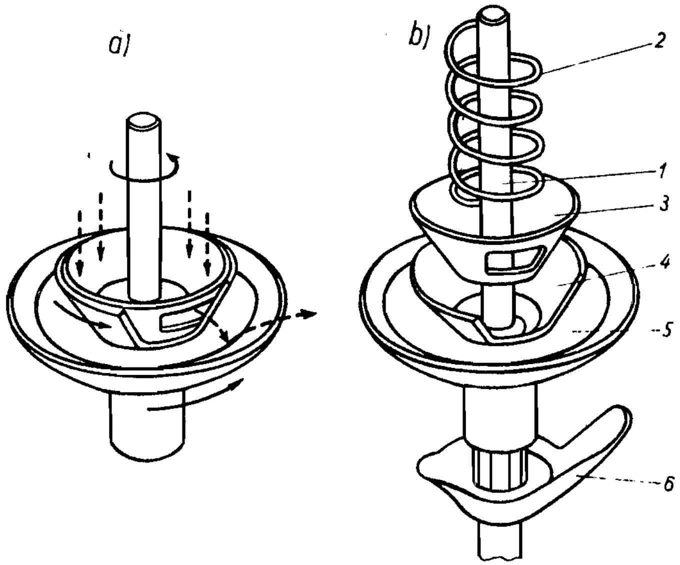


Fig. 13.28. A unit for feeding additional seeds or granulated fertilizer: *a*) feed unit ready for operation; *b*) feed unit with lifted inversed cone: *1* — propeller shaft; *2* — agitator; *3* — inverse cone for feeding rate adjustment; *4* — seat; *5* — feeding plate; *6* — diaphragm of the rotor opening for controlling the feeding rate of main seeds by a rotating funnel.

inverse cone adjoining a conical screen (seat) made together with a feeding plate. The inversed cone is provided with an openning, and the screen (seat) — with a corresponding recess.

By turning the cone, the opening is adjusted to suitable size; grains pour out through this opening onto the rotating plate, then are pushed inside the main rotor and mix with the seeds of the main plant. The agitator is wire spiral, fastened to the propeller shaft.

Figure 13.28 presents diagrams of the discussed unit, indicating the grain path and the direction of the unit rotation.

According to investigations carried out by the present authors, the combined feed of grain seeds and granulated fertilizer or clover seeds yield a constant relation between quantities of each material fed which is a favorable feature from the agrotechnical point of view. This combined feeding is a real advantage of the drill described above.

Lately, a new drill has been designed, the action and structure of which differs entirely from drills of the type so far used. This is a pneumatic tractor-mounted drill of Weist (manufacturer "Record"). Its principle of operation is as follows (Fig. 13.28*a*). From the hopper on the bottom of which is placed a batch meter adjusting the rate of feeding, seeds are entrained by an air current produced by the fan to be further transported into a V-shaped tube. Change of the direction of seed travel causes seeds, initially dispersed by the air current, to press against the wall of the tube at the front of bend, thus forming an agglomerated stream of loose material. This compact layer of seeds afterward penetrates into the widening corrugated section of the tube (diffusor). In this section of the tube, the condensed stream of seeds, on being thrown against the corrugated surface of the diffusor, scatters into single individual seeds (turbulent process of flow), which then penetrate into a flexible head on the perimeter of which are holes connected by plastic conduits with rigid tubes, which have furrow openers attached to their ends. The comparatively uniform dispersion of seeds and the actual peripheral speed cause an approximately equal quantity of seeds to be thrown into each of the holes in the tube head in a given unit of time.

According to the producer's specifications, the transversal irregularity of feeding of fine, medium and large-grained seeds is not in excess of 5 percent.

Since a number of component parts of the drill is made of plastics, the weight of the entire machine is considerably lower than that of other drills of the same width of operation. Controlling of the feeding rates for various kinds of seeds is extremely simple and reliable.

The feeding box can be made in the form of a hopper attached to the tractor. In such a case the weight of the other component parts of the drill mounted on the tractor is so reduced that the working width of a drill, driven by a tractor of some 30 hp, can be increased even up to 15 m. The entire width of the drill then consists of three feeding units, the working width of each amounting to 5 m. In the drill of the type described above the width of interrows is unvaried.

Weist's drill can be used in various combined seed feedings such as, for example, simultaneous feeding of seeds of two different kinds (for example, grain and papilionaceous seeds) or simultaneous feeding of both seeds and granulated fertilizers. For this purpose, furrow openers are connected by two tubes, the lower

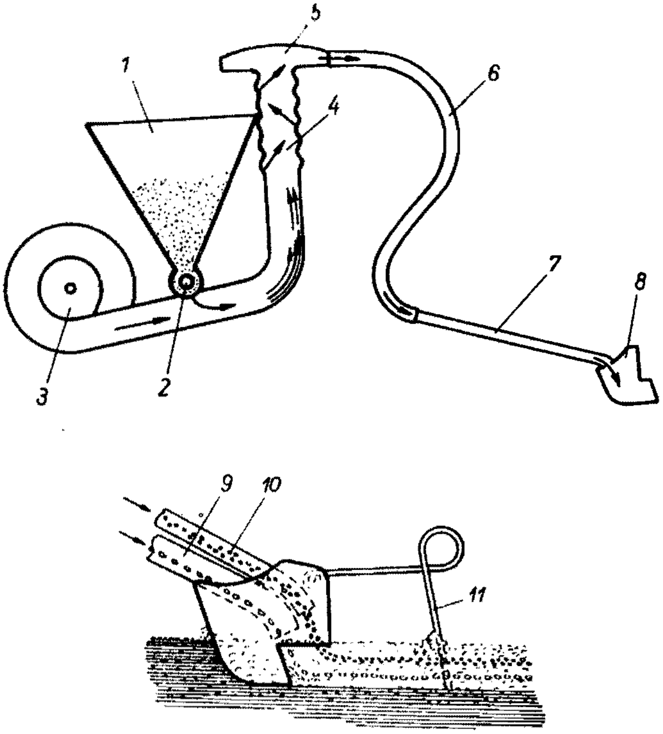


Fig. 13.28*a*. Operational principles of a pneumatic drill: *1* — seed hopper; *2* — batch meter; *3* — fan; *4* — diffuser; *5* — head; *6* — plastic tube; *7* — metal tube; *8* — furrow opener; *9* — main seed tube; *10* — supplementary tube for seed feeding; *11* — covering rod.

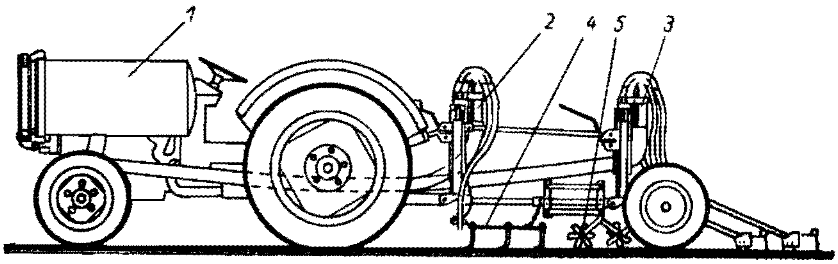


Fig. 13.28*b*. Combined assembly of pneumatic drills with scarifying implements: *1* — hopper; *2* — fertilizer unit; *3* — feeding unit; *4* — scarifier; *5* — rotary harrow.

of which constitutes the opener lever, while the outlet of the upper tube enters freely in between the wings. Consequently, seeds of the one kind (ear seeds) go deep into the soil, while those of the other (for example, papilionaceous seeds) to a slight depth only or merely fall onto the surface of the soil. To the opener is attached a covering rod. In combined feeding two hoppers are used or a single one having a partition which divides it in two separate parts. In both cases, separate heads are to be apllied. The drill referred to, can also be operated as a fertilizer distributor. For this purpose, plastic tubes are provided at terminals with appropriate flat "funnels" which increase the width of distribution of fertilizer material being blown out through individual tubes. In the case of combined distribution of both seeds and fertilizers a special device may be located in between the two feeding units which rips and disintegrates the soil in a manner as shown in Fig. 13.28b.

The above brief description of the Weist pneumatic drill, from which it follows that the device in question may equally be used as a pulverizer or sprayer for pesticide or weed controlling, indicates that the machine may reasonably be considered an all-purpose agricultural implement. If the drill's specifications and its specific qualities revealed in tests are confirmed by practice, the device will emerge as a veritable technological revelation.

13.4. Drill seed tubes

In grain drills the height of location of feeding units in relation to the level of the soil is, for structural reasons, comparatively great (600–800 mm). Seed streams released from individual units require, therefore, special devices to guide them to the furrow openers. Such devices are designed as drill seed tubes. Their structure and the manner of connecting the tubes at one end with cups of the feeding sets, and at the other with openers, should be such as to allow for the possible alteration of distance between these two elements and also for the possibility of lateral displacement of the individual openers in relation to the feeding units. The first of the two requirements is motivated by the uneveness of the soil surface (microrelief), and also by the necessity of lifting openers into the transport position (thus reducing the distance by at least 220 mm); the second requirement, on the other hand, is connected with the slight, yet unavoidable lateral deviations to which the openers are subjected during the operation and, above all, with their spacing in adapting them to the appropriate span between the interrows.

In the popular two-lined set of openers, the tubes connecting feeding units with the front openers are somewhat shorter than similar tubes of the rear opener.

The three basic types of tubes now commonly employed include: spiral, telescopic and smooth tubular (Fig. 13.29). The first two are made of metal, the third — of plastics or rubber (sometimes from sackcloth-rubber hose).

The size of spreading of freely falling seeds depends on the height of dropping, and is increasing with increase in that height (Fig. 13.30).

It is, therefore, clear that a free fall of seeds may be ensured by tubes which widen down their length. In tubes so designed, the greater part of the seeds (60–80 percent) drops down freely without coming into contact with the walls. The other prerequisite is that walls of the tubes should be smooth. Excessive deviation of the tubes from the vertical, or their possible deflection, adds to the irregularity of falling seed quantities to openers in a unit of time. In such an instance, a considerable portion of seeds strikes against the walls of the tubes in falling down, and rebounds in various directions at various speeds.

According to data presented by Soviet research workers, the highest admissible value of the angle of deviation of a seed tube from the vertical should not be in excess of 15°.

The spreading of heavy seeds of smooth cuticle which are released from the tubes is generally lower than that experienced in the case of light seeds with coarse cuticle (for example, oat seeds). It has also been found that the more uniform the stream of seeds released from the feed unit, the more inferior is the regularity of delivering seeds to the openers. If the uniformity of delivery of grain stream becomes lower, the procedure is reversed. This phenomenon occurs primarily in spiral seed tubes. Thus the rebounding of seeds against the walls of the tubes may, in some cases, improve the uniformity of the seeds' delivery to the openers, and in others — make it deteriorate.

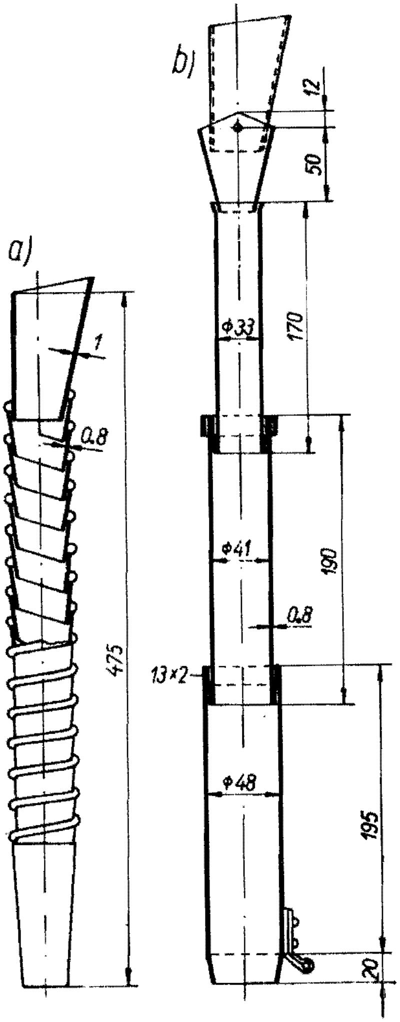


Fig. 13.29. Example of drill seed tubes: *a*) spiral; *b*) telescopic. (After Kühne).

The upper ends of the tubes are mostly shaped like funnels and joined by hinges to the feeding units. They way in which the upper end of the tube is connected with the feed regulator enables not only lateral flection of the tube, but also a convenient and quick removal of the tubes from the units. The lower straight ends of the tubes enter the upper opener opening (throat).

Spiral tubes of about 50 mm diameter are coiled from steel ribbon, 0.8 mm thick. To prevent uncoiling of the ribbon band, it is stiffened by means of a projecting boss. The helix angle is 20–25°. Spiral tubes — though essentially flexible and elastic — if made of inappropriate material or badly produced, have a tendency to partial uncoiling which results in the formation of slits through which part of the seeds is wasted — undoubtedly a very undesirable proposition. The repair of deformed tubes by domestic means is, practically, impossible.

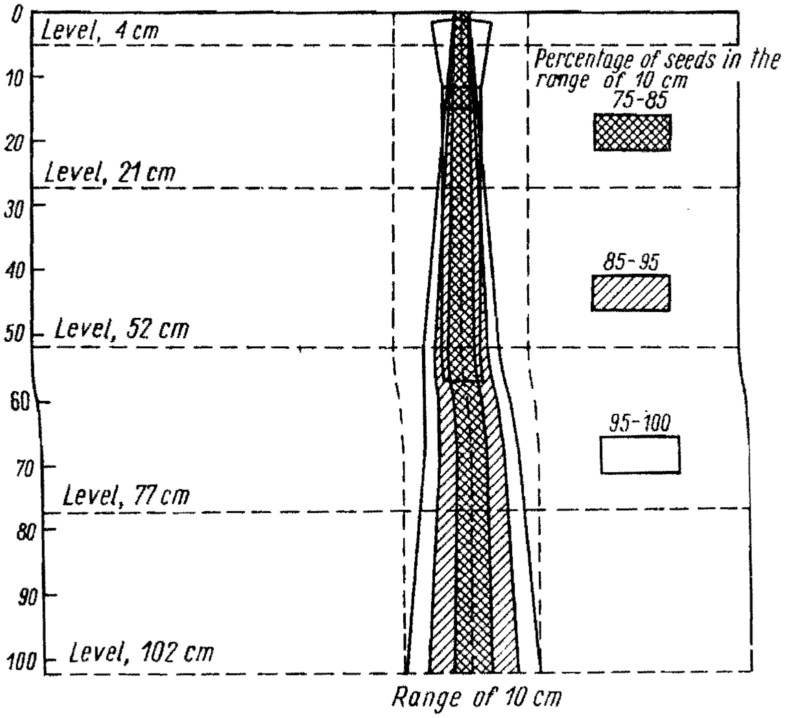


Fig. 13.30. Example of spreading of freely falling seeds from different heights. (After Semionov).

The telescopic tubes comprise two or three smooth pipes of reciprocal sliding capacity which widen down their length. Such tubes operate more regularly than their spiral counterparts in achieving appropriate quantities of seeds to the openers. Iron telescopic tubes, although heavier and more expensive than spiral, are in common use with farmers. Today, telescopic tubes are frequently made of polyamid, which reduces considerably their weight. Rubber hoses are cheaper, but are apt to wear and waste away quickly.

13.5. Furrow openers

Furrow openers are a working element of drills, the role of which is to ensure such deposition of seeds in the soil that optimum conditions for their germination and development may be obtained. This apparently indicates the all-important function of furrow openers. Considering that optimum conditions for plant development depend on the type of soil, its preparation, moisture content and other similar factors, and further — individual kinds of seeds involve different parameters affecting deposition of seeds in the soil (varying depth of sowing and different row widths), it is obvious that the designing of furrow openers cannot be limited to a single universal type, while the engagement of openers with the drill should be so designed as to ensure appropriate changing of the intervening space between parallelly operating openers. Many years of experiments and practice have led to the construction of three principal types of openers for feeding grain, leguminous and other crops: with an obtuse or acute angle of incidence (Fig. 13.31*a*, *b*, *c*) and a disk opener. There are also special furrow openers which are used, for example, for hill-drop drilling, narrow-row drilling and other allied purposes.

The obtuse-angle opener is called a shoe opener or European opener, that with acute angle — a hoe or American, or Russian, opener. Each of the types of furrow openers indicated, maintains an approximately constant feed depth required and ensures that seeds are fully covered by a scarified layer of earth at various individual sowing depth required. The shoe opener has on its top fitted an iron-sheet throat which receives the lower end of the tube. The telescopic tubes are attached to the throat by hinges. Such a throat narrows down its length forming two separate planes, usually set parallel, called wings. The whole can be riveted to the shoe and breast of the opener, or the throat can be joined to the breast and shoe as shown in Fig. 13.31*b*. The role of the shoe is to form a furrow, and that of the wings — to prevent furrow walls (slopes) from sliding too early (before the seeds have been deposited onto the bottom of the furrow). Since the furrow is formed in a way similar to that in which water trail is formed by the prow of a boat, the opener should be of a streamlined shape.

The shoe, although made of hard cast iron, is considerably affected by friction and is subject to deformations. In consequence, after a relatively short span of operation, it tends to produce a shallowed furrow. The worn out original shoe ought to be replaced by a new one. The design of the opener shown in Fig. 13.31*a* enables replacement of the shoe alone, while the opener as shown in Fig. 13.31*b* is so designed that its shoe can be replaced only together with the breast — the component parts to be

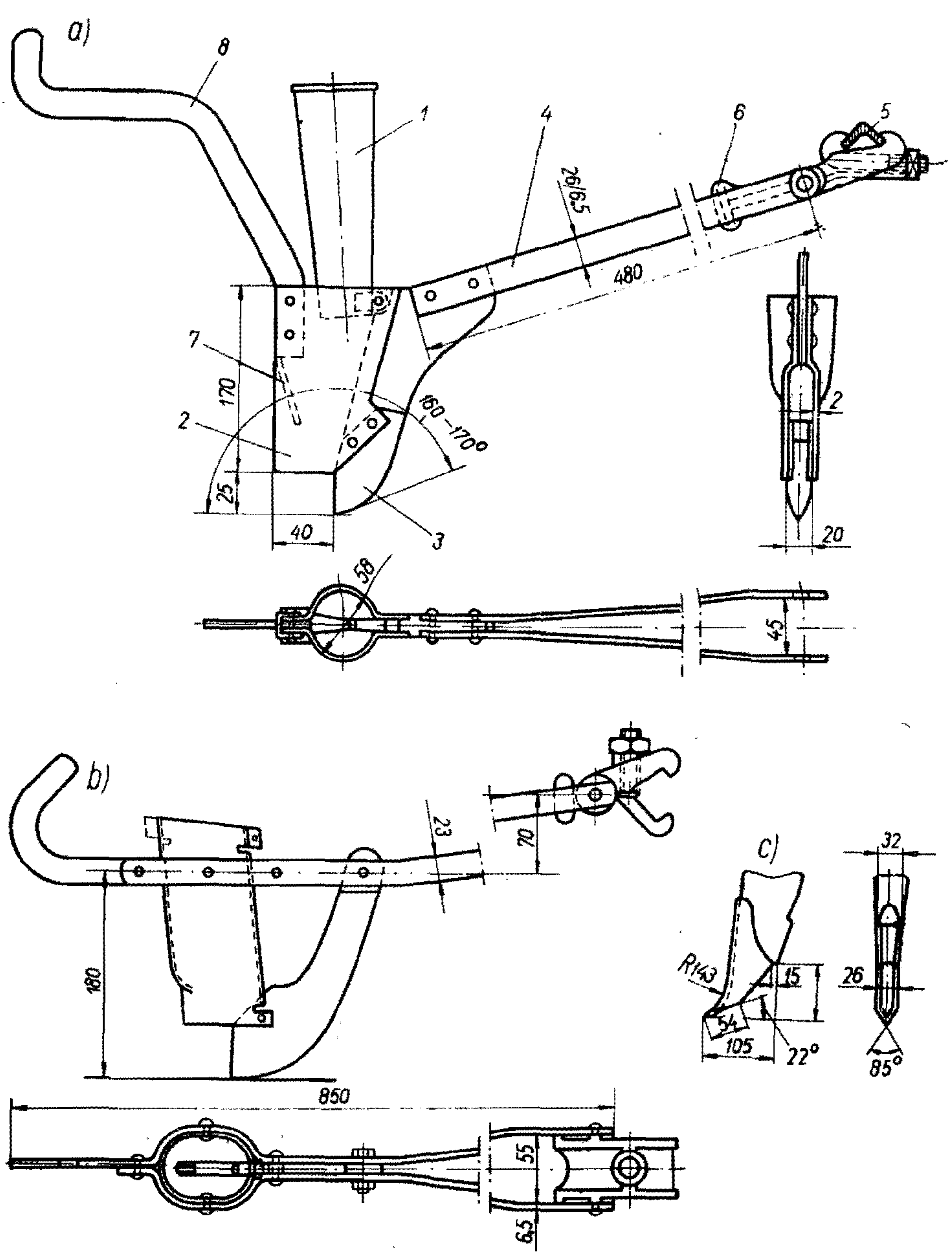


Fig. 13.31. Examples of furrow openers: *a*) opener with obtuse angle of incidence (shoe opener): *1* — funnel; *2* — wings; *3* — shoe; *4* — lever; *5* — crossbar for fixing lever ends; *6* — guide bar of lever; *7* — directional plate; *8* — lever for bob-weighing and for manual lifting of the opener; *b*) modification of shoe opener; *c*) hoe opener.

replaced here are larger and more expensive. However, an opener of this type has numerous specific advantages which will be described below. Adaptation of the shoe to the microrelief of the field, and the lifting of the opener into the transport position are made possible by the hinged connection between the opener lever and the cross beam placed parallel to the transversal axis of symmetry of the drill (relative to lever beam). In between the flat bars of the opener lever are located at the point of its hinged connection the arms of the guide bar, limiting freedom of lateral movement of the opener. The value of lateral deviation of the opener shoe should not exceed 5 mm. The angle (Fig. 13.32), which is formed by

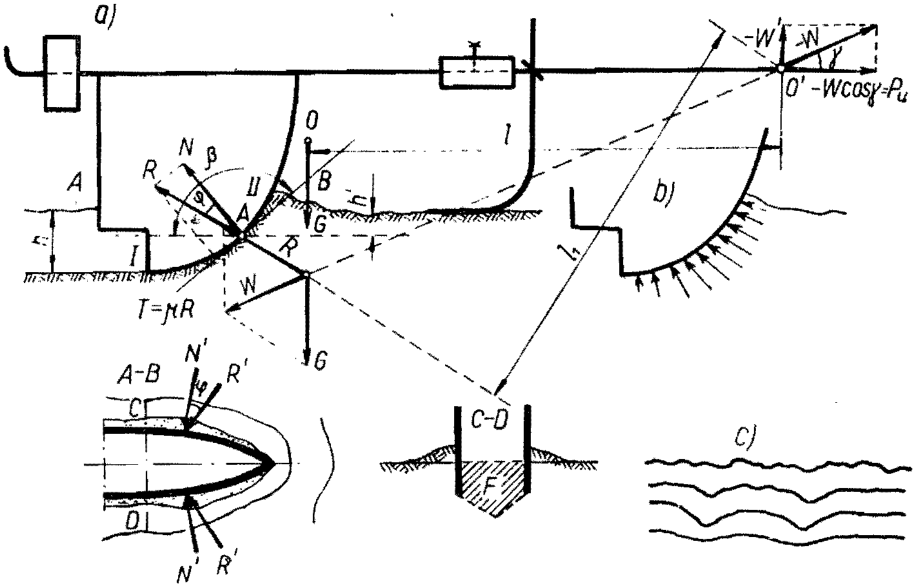


Fig. 13.32. *a*) Forces acting on a shoe opener; *b*) reactions of soil to the shoe; *c*) example of deformation of soil layer after passing a shoe opener. (After Pigulevskii).

the tangent produced to the vertical outline of the shoe at a height of approximately 1/3 of the depth of the furrow (point *A* of application of the resultant soil resistance) with the horizontal, amounts to 140–160°. At the point indicated, there acts a soil reaction *R* and the friction force $T = \mu R$ produced by *G*; if we assume the center of gravity to be situated at point O, then

$$\vec{G}+\vec{R}=\vec{W}$$

The draft P_u is

$$P_u = W\cos\gamma$$

The value R depends on the size of the cross sectional area F of the furrow, on the soil specific resistance k and on the working speed v_m. In actual practice $P_u = 2$–6 kg at $h = 2$–6 cm.

The prerequisite of maintaining the equilibrium of the system and, therefore, of maintaining a constant depth of furrow h, is that

$$R + W + G = 0$$

and

$$Rl_1 = Gl$$

The reduced weight of the opener and of the lever acting on the lower edge of the shoe $G' = 3$–3.5 kg.

Consequent on the unavoidable variation in soil resistance, the values R and l_1 also vary and, as a result, the opener always swings in vertical plane during operation, thus simultaneously varying the depth of the produced furrow. Changes in the value of the reaction R' in the plan also produce lateral deviations in opener's operation. Changes in the setting of the opener are the lower, the more uniform the soil structure. It can, finally, be stated that openers with obtuse angle of incidence are efficiently used on sufficiently prepared soils, such as consist of fine particles or are characterized by loose consistency (sandy soil). On the other hand, in cultivation of lumpy soils or littered with stones, the reaction R frequently increases considerably, resulting in appreciable shallowing of the operation and in turn in inadequate covering of seeds by soil layer.

According to data presented by Soviet research workers the stability of an opener in operation requires that the outline I–II (Fig. 13.32) of its breast edge corresponds to the logarithmic curve. The breast of the opener pushes the upper layer of the soil forward and aside, while the shoe slides against the bottom of the furrow thus creating favorable conditions for the germination of seeds. Pressure exerted on the bottom of the furrow results in an increase of the volume of moisture necessary for the stimulation of the growth of seeds. Because of the tapering shape of the shoe opener, the wings are kept away from the furrow bottom, which prevents the narrowing of the outlet slot to contact with them, which might otherwise have easily led to the clogging of the slot with soil and check the regular release of seeds. As it is, the lower periphery of the opener is above the top of the shoe. An assembly of wings in such a way reduces the thickness of soil layer covering the seeds, because early sliding of the furrow slopes prevents the seeds from subsequently falling into the bottom.

It should be noted that, when the retarding action of the wings is stopped, the soil layer previously turned aside now begins to slide down into the open furrow at the angle φ_1 of a natural slip (Fig. 13.33).

To simplify our reasoning, let us assume that the furrow has been filled with a mass of soil of cross sectional area $2F_1$. After passing of the opener, the furrow becomes covered by a layer of soil, of cross sectional area $F_2 = 2F_1$. As shown in the diagram, the depth h_1 of the seed covering is almost always lesser than the depth h of the furrow produced by the opener. The wider the wings are extended (the greater is a), the smaller h_1. The value h_1 is, of course, affected by the value φ_1, which depends on the type and moisture content in the soil. The lower the value of φ_1, the higher is the value of h_1. If the wings are positioned obliquely and turned downward, h_1 is considerably reduced; the narrowing of the outlet slot between the wings, on the other hand, brings about an increase in h_1, but at the same time facilitates, as indicated, the clogging of outlets with soil.

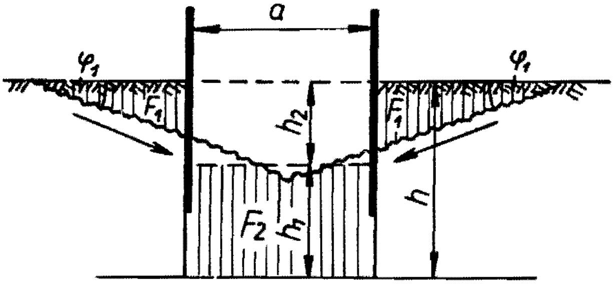


Fig. 13.33. Cross section of soil after passing of the shoe opener wings. (After Semionov).

From the comparison of the double area F_1 with the area F_2 the following formula may be derived for the width of spacing of the wing set at an angle φ

$$a = \frac{(h-h_1)^2}{fh_1} \pm h\tan\varphi$$

where $f = \tan\varphi_1$

If the wings are positioned parallel, $\tan\varphi = 0$, the respective formula being expressed as

$$a = \frac{(h-h_1)^2}{fh_1}$$

It may be assumed in calculations that $\varphi_1 = 45°$ — that is, $\tan\varphi_1 = 1$, and consequently

$$a = \frac{(h-h_1)^2}{h_1}$$

In order to ensure deposition of the seeds on the bottom of the furrow, a should be increased, and the wings flapped down to the level of the lower edge of the opener shoe. To prevent h_1 from reduction to zero, additional covering devices in the form of oblique plates, disks or curved flat bars should be fastened to the lateral walls of the opener (Fig. 13.34).

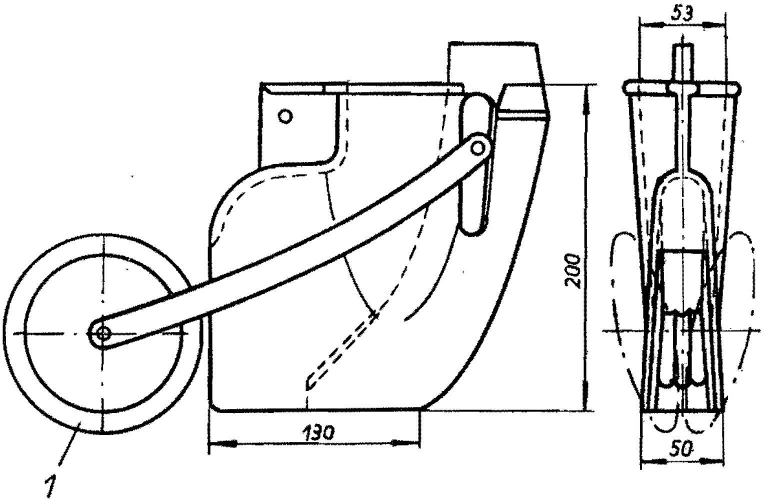


Fig. 13.34. Example of an opener with a wide spacing of wing outlets (Burmester type). (After Kühne).

To the opener are also frequently attached two or three links of steel connected one with the other by articulated joints. In certain drills, openers are linked by articulated joints with four-tine scarifiers which act as a seed harrow. To increase the depth of the furrow the implement may be weighted with a block suspended from the opener lever (Fig. 13.32), which can be slided along that lever, or special weights may be hung from the arm fixed at the rear of the opener housing. This arm can also be used as a handle for manual lifting of the opener, when cleaning the outlet clogged with soil. If the operations are carried out on hard and compact soils, the weighting of the opener has little effect on the depth of sowing, but increases the stablity of the opener considerably.

In shallow sowing, or to prevent deepening of the furrow, a slade is used (Fig. 13.32) with the shank fixed to the lever of the opener. The level of setting the slade is adjustable.

Occasionally, openers are provided with oblique plates directing seeds toward the opener shoe — that is, toward the bottom of the furrow (Fig. 13.31*a*).

To vary the depth of feeding a device is sometimes used which changes the setting of the opener in the vertical plane — that is, the value of the angle β (Fig. 13.32) thus changing the direction of the resultant of the soil resistance R. If the change in the position of the opener is by way of its being connected with the lever by a hinged joint, then — with the moment $G \cdot l$ unchanged — the moment $R \cdot l$ is subject to increase or decrease (change of the length l_1 under the assumption that R = const). Such a system of controlling adds to the complexity of design and ultimately raises the costs of production (each individual opener having to be adjusted separately).

A change in the value of the angle β and of the direction R can also be achieved by varying the level of location of the opener beam (point O in Fig. 13.32). In this case, a change in the angle of the setting of the lever varies together with the distance between the opener and the point of mounting of the lever and, therefore, also the value of the moment $G \cdot l$. It should, however, be taken into consideration that an excessive angle of lever inclination facilitates the clogging of the wing outlet and, consequently, tends to make the operation of the opener and its lifting into the transport position more difficult.

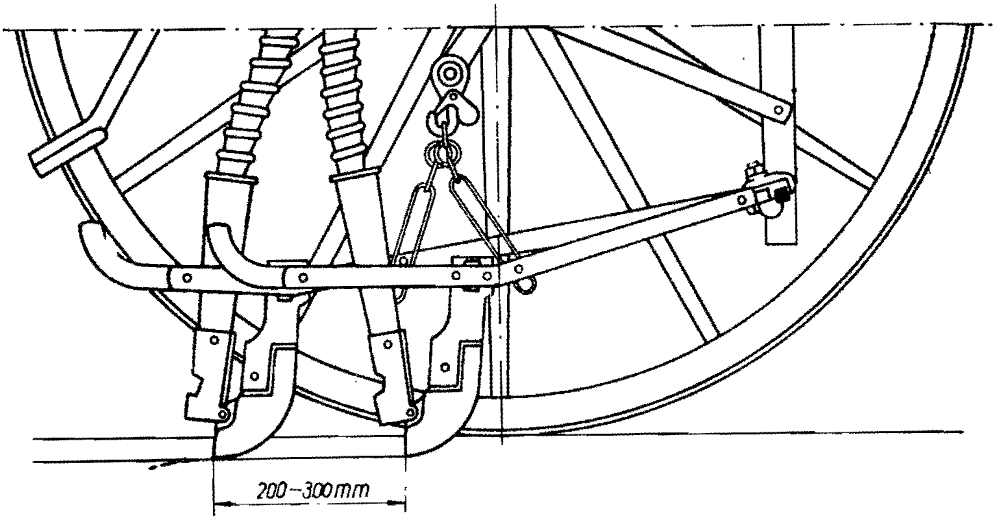


Fig. 13.35. Example of the setting of openers in two lines.

In trailed drills, the level of the opener beam should be not more than 400 mm, and in mounted drills — not less than 250 mm. The number of openers designed must take into account the assumed least widths s of the interrows (10–12 cm). Since at a small value of s, openers would be spaced too closely, and thus would graze the surface of the field like a rake, they must be arranged in two lines. With a single common lever beam, the rear openers must, of course, be provided with longer levers than the front ones. In Fig. 13.35 is shown, by way of example, a two-lined system of openers (the distance between the front and the rear openers varying within limits of 200–300 mm). Such a variation — as already indicated — entails a change in the value of the angle β and in the direction of the reaction R. The shape and the setting of front openers differ, therefore, somewhat from that of rear openers. Nevertheless, there is always a difference in seeding depth as between front and rear openers, but this difference, as in the case of openers shown in Fig. 13.35, is very small.

Irrespective of the setting of openers of the first and second lines, seeds sown from the front openers are always stuck deeper into the soil, because the rear openers turn over additional soil slices into the furrows formed by the front openers. In order to maintain a similar length of levers, two appropriately spaced opener beams are occasionally used.

As already indicated a premature sliding of part of the mass of furrow slopes varies the deposition of seeds in both the vertical and horizontal plane, forming what is known as scatter cylinder (Fig. 13.36). This cylinder can be circular or elliptic in shape and it is desirable that it should have the least possible cross sectional area. It is more advantageous when the longer axis of the elliptically shaped cylinder is positioned horizontally since this indicates a more uniform value of depth of feeding.

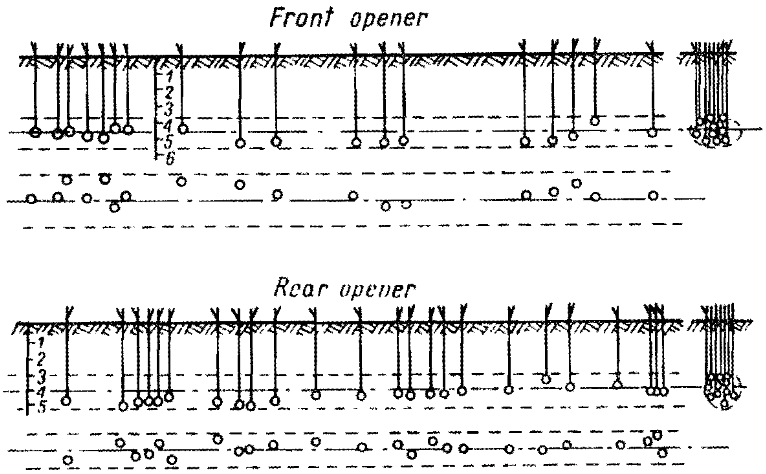


Fig. 13.36. Example of distribution of seeds in the soil after passing of a shoe opener. (According to the present authors' investigations).

The direction of operation of the forces affecting a hoe opener is different from that in the previously described device. In the case under consideration, the reaction of the soil (Fig. 13.37) is directed at a certain angle downward and the direction of operation of its horizontal component R' coincides with that of the weight G of the system. Consequently, if the upper soil layer offers an increased resistance, the opener shows no tendency toward running shallow or even rising entirely over the soil surface, as is the case in openers with an obtuse angle β. It is, therefore, apparent that a hoe opener is better adapted for cultivation of compact and lumpy soils than is European-type counterpart.

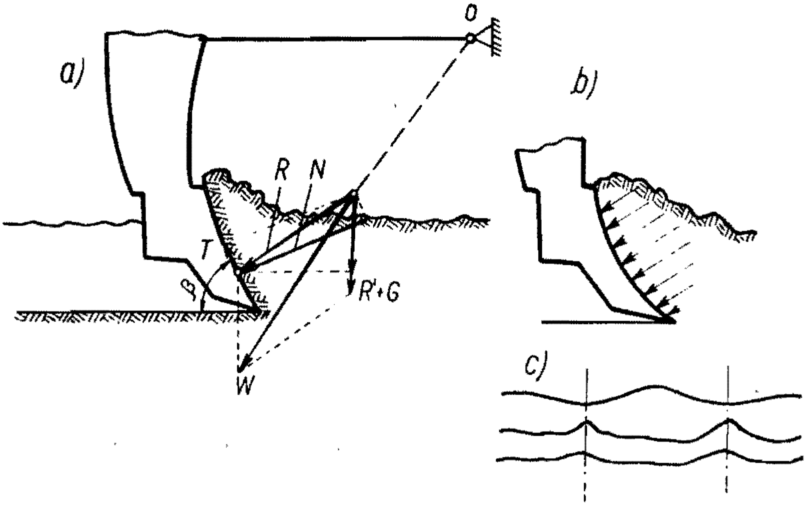


Fig. 13.37. a) Forces acting on a hoe opener; b) reaction of soil to the forming of a furrow by an opener; c) example of displacement of the upper soil layer after passing of an opener. (After Pigulevskii).

Since the resultant $\vec{W} = \vec{R} + \vec{G}$ is directed to the horizontal plane at a greater angle than in the case of a shoe opener, the maintenance of equilibrium requires a shorter length of lever than in the European-type opener (for a given depth of furrow). In openers arranged in a double line, frontal openers are positioned somewhat differently to the rear ones. Openers sometimes also differ in shape. The resistance of a hoe opener amounts to 3–8.5 kg.

The hoe cuts off the surface of the soil, turning up its more humid underneath — a process which leads to the drying up of the field. In front of the hoe and on either side of the opener, soil rises and on passing of the opener, soil mass covers partially the furrow leaving a concave trace (Fig. 13.37c). By reason of the smaller size of the wings, their action of preventing furrow slopes from sliding down is less efficient in the case of the shoe opener. In other words, a hoe opener is, from the agrotechnical point of view, operationally inferior to similar shoe openers, but only in the case of a cultivated field previously well prepared for drilling.

In discussing disk openers we shall consider double-disk openers only. The former type of single-disk openers is now no longer produced. The disks of such openers are so positioned one in relation to another at a small angle β (Fig. 13.38) that they come into contact at a certain point a. The

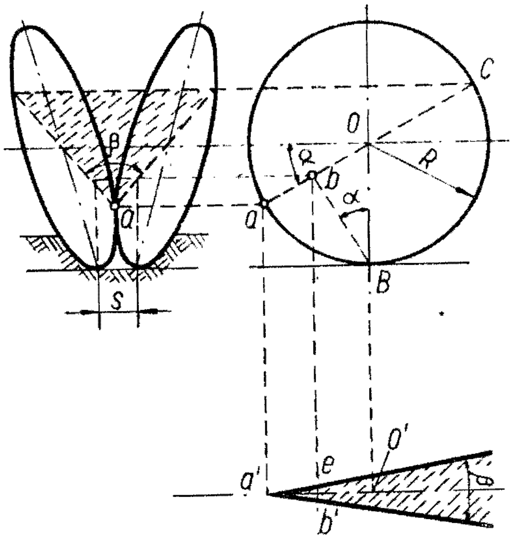


Fig. 13.38. Diagram showing the relative position of disks in a double-disk opener.

level at which the disks come into contact with one another and the exact point of such contact is of primary importance, since on that point of contact depends the width of the furrow produced by the disks. If we denote by α the angle of the point of contact in relation to the horizontal axis, then the plan of the section drawn through ac will determine the angle β at which the disks are inclined to each other.

From the point B is led a perpendicular to ac; the resulting point b projected on the axis in the horizontal plane determines the point b'. If through this point is further led a perpendicular in relation to $a'O'$, the obtained segment eb will represent the width of the produced furrow. From the diagram it follows that

$$eb' = s = 2a'e\sin\frac{\beta}{2} \qquad (13.9)$$

Since

$$a'e \approx ab = R - R\sin\alpha = R(1-\sin\alpha)$$

on substituting this expression into the equation (13.9) we obtain

$$s = 2R(1-\sin\alpha)\sin\frac{\beta}{2} = D(1-\sin\alpha)\sin\frac{\beta}{2}$$

It follows from the above formula that the width of the furrow depends not only on the angle α, which determines the level of contact of the disks, but also on their diameter and the obtuse angle β. Increase in the value of α results in a decrease in s, and an increase in β increases the width of the bottom of the furrow.

The most frequently met dimensions of disk openers are: $D = 280$–330 mm (generally, 300 mm), $\beta = 9$–12° (generally, 10°) and $\alpha = 30$–40°.

In order to prevent accidental reversal of motion of the seed stream delivered between the disks, the stream should be directed to the approximate point of contact of the disks. This purpose is served by a guiding plate (Fig. 13.39) located in between the disks. The disk opener is pressed down by a special resistor spring preventing shallowing of sowing. Note, however, that when, on encountering a rising of ground or some other obstacle, the opener is raised, the pressure of the spring increases, result-

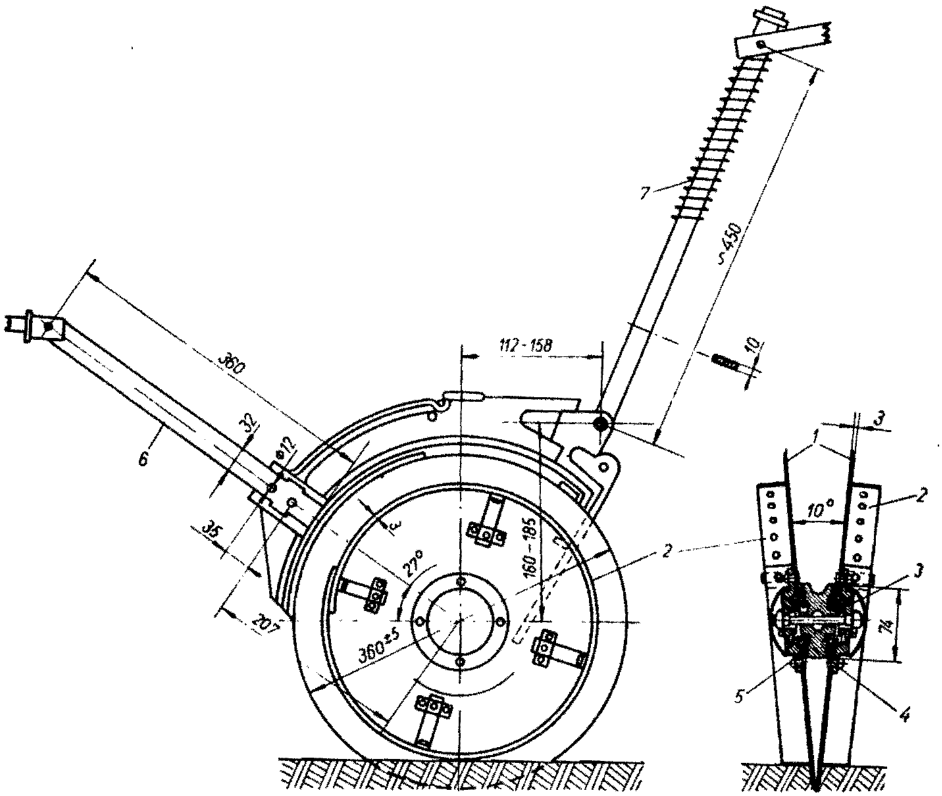


Fig. 13.39. Example of a double-disk opener: *1* — disks; *2* — adjustable flanges controlling feeding depth; *3* — tapered hub; *4* — insert; *5* — packing ring; *6* — opener lever; *7* — push spring.

ing in an increase in the depth of furrow and in seeds being deposited too deeply in soil. To prevent this undesirable effect, sheet iron flanges are frequently used fixed at one side of each of the disks.

The manner in which edges of the two flanges are connected permits variation of their periphery and, consequently, enables adjustment of the feeding depth. Rotation of disks upsets the furrow slope produced, and facilitates spontaneous sliding of soil. To the rear of the opener is frequently attached a coverer which constitutes two or three links of chain.

A disk opener, cutting the surface downward, slides easily over possible obstacles encountered on its path such as hard lumps of earth, garbage, fragments of plants, etc. For this reason, such openers are satisfactorily employed on compact, hard soils not sufficiently prepared for spring sowing.

A disk opener is also free from the disadvantage of being chocked up by wet soil and, subsequently, shifting it in its front, which enables the use of that drill on hard soils in early spring or late in fall.

Because of the comparatively large dimensions of disk openers, the minimum distance between the adjacent openers should be not less than 14–15 cm. For this reason disk openers of the type indicated are arranged in a single row only. Disk openers are also considerably heavier (10–14 kg in weight), of more complex design and more expensive than the hoe or shoe-type openers. They are, consequently, seldom used in west- or central-European countries, where cultivation of soil and its appropriate preparation for spring sowing is much more superior. The resistance of

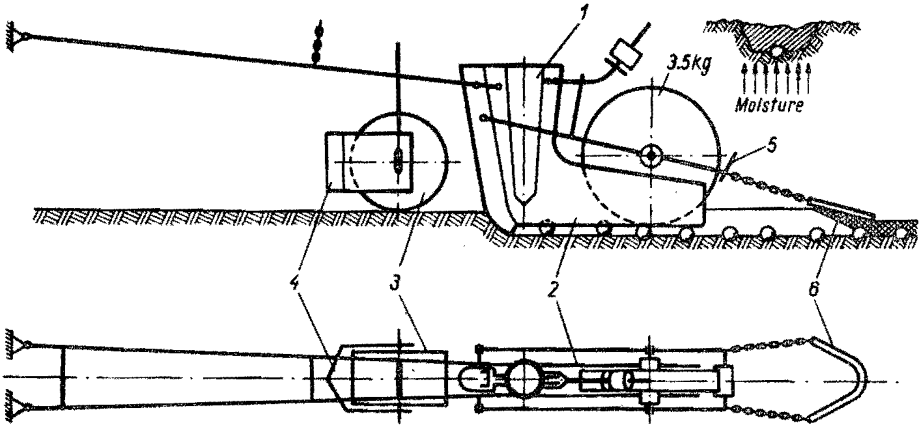


Fig. 13.40. Sugar-beet sowing opener: *1* — throat; *2* — extended wings; *3* — adjustable gauge wheel; *4* — lump pusher; *5* — scraper; *6* — covering rod.

a disk opener in operation varies, subject to the type of soil, within limits of 5–12 kg.

Among special-type openers must also be included openers designed for seeding multigerm beet seeds. Figure 13.40 shows an exemplificatory furrow-opener unit. Ensuring optimum conditions for the germination of beet seeds requires providing them with sufficient moisture through filtration. For this purpose seeds ought not only to be placed on the bottom of the furrow, but also to be pressed down into a rammed subsoil. This is achieved by extending the wings of the opener and placing in between them a wheel of 3.5–5 kg in weight.

A scraper is used for clearing the press-wheel perimeter from adhering soil. For covering the opened furrow serves a bow-shaped coverer attached by means of chains. In front of the opener is a device for clearing aside the heaviest soil clods consisting of an adjustable wedge and an adjustable gauge wheel which ensures maintaining a uniform sowing depth. According to the present authors' investigations, the efficiency of the opener indicated operating on sufficiently prepared soil is, as regards plant development, some 8 percent higher than in the case of a common-type opener, owing to a better uniformity of feeding it ensures, and a considerably better covering of the seeds by soil. The weight of an opener of that type is about 22 kg.

In hill-drop drilling (for example, corn seeds) can be used an ordinary opener fitted with a special accessory appliance. In Fig. 13.41 is shown,

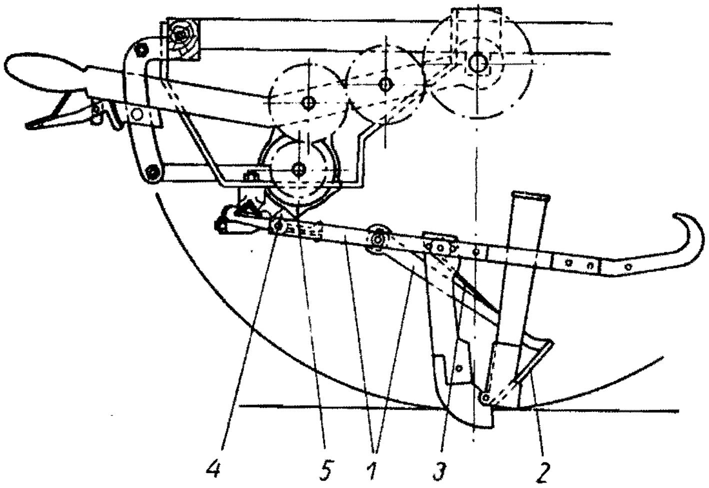


Fig. 13.41. Example of a shoe opener adapted for hill-drop drilling: 1 — two-armed lever; 2 — shutter; 3 — spring; 4 — jut on the two-armed lever; 5 — jut on the rotating disk.

for purposes of example, a diagram of an opener whose outlet slot is shielded by a sheet iron shutter connected with a two-armed lever. On the front end of the lever is a projecting jut which, on meeting a revolving jut on the disk, causes a momentary lifting of the shutter and a simultaneous release of the few seeds which have accumulated during the closure of the outlet slot. Automatic closing of the shutter is by means of a flat spring acting on the arm of the lever connected with the shutter.

The interval between hills of seeds in individual rows can be varied (within limits of 25–30 cm) by an appropriate replacement of the gear wheels driving the disk with the jut. The number of seeds in individual hills may, in turn, be varied by changing the number of revolutions of the feeding stud rolls.

To special-type openers may also be included an opener for narrow drilling of flax (Fig. 13.42). Such an opener is provided with two outlets spaced at a distance of 7–10 cm.

Investigations of the present authors have, however, shown that with this particular type of opener, seeds are deposited on the walls of the furrow instead on its bottom, and, in consequence, are insufficiently covered. Openers of this type are, therefore, not in frequent use. Special openers finally include also what is known as a runner opener for seeding of corn and cotton. This individual type will be discussed in Chapter 14.

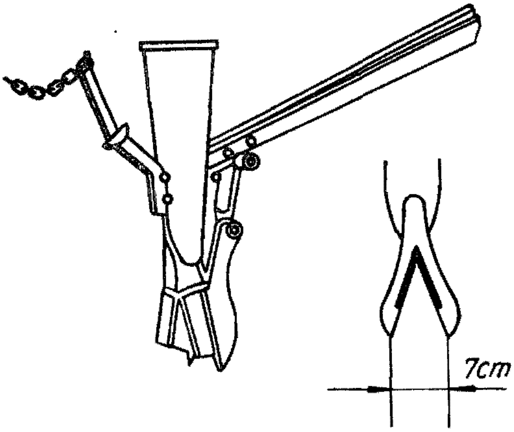


Fig. 13.42. Opener for narrow drilling of flax.

Into transport position and on reversal of seed drill, the openers are lifted by chains of links, connecting the opener levers with the arms of small levers, both fitted on a common beam parallel to the seed box.

When openers are lowered, the chains sag loosely. In adjusting the total level of the fitting of openers, two factors must be taken into consideration: sufficient penetration of the openers into the soil during operation, and the flattening of the tires of the drill or, in the case of a steel-wheeled drill, the depth of the track rut. The clearance between the hoe ends of openers lifted and the field surface should not be less than 120 mm. In horse-drawn drills, lifting the openers is by hand lever and in tractor drills — either by means of hydraulic mounting system (in mounted drills) or (especially in lifting heavy disk openers) a mechanical pawl lifter similar to the device used in trailed plows (in semimounted drills), or finally (as in the case of drills combined with the tractor), a hydraulic lift cylinder.

In Fig. 13.43 is exemplified a system of levers for manual lifting of an assembly of openers. A designer of openers must bear in mind that the lifting of openers must be preceded by the disengaging of the power drive of the feeding mechanism. If the procedure is reversed, certain amount of seeds will be released during the lifting of the opener resulting in a loss. When lowering the openers the sequence should be reversed — that is, the engagement of the power drive should not take place before the openers have sunk into the soil. It follows from the diagram, therefore, that it is necessary to select an appropriate ratio of arm lengths $l_4 : l_3$.

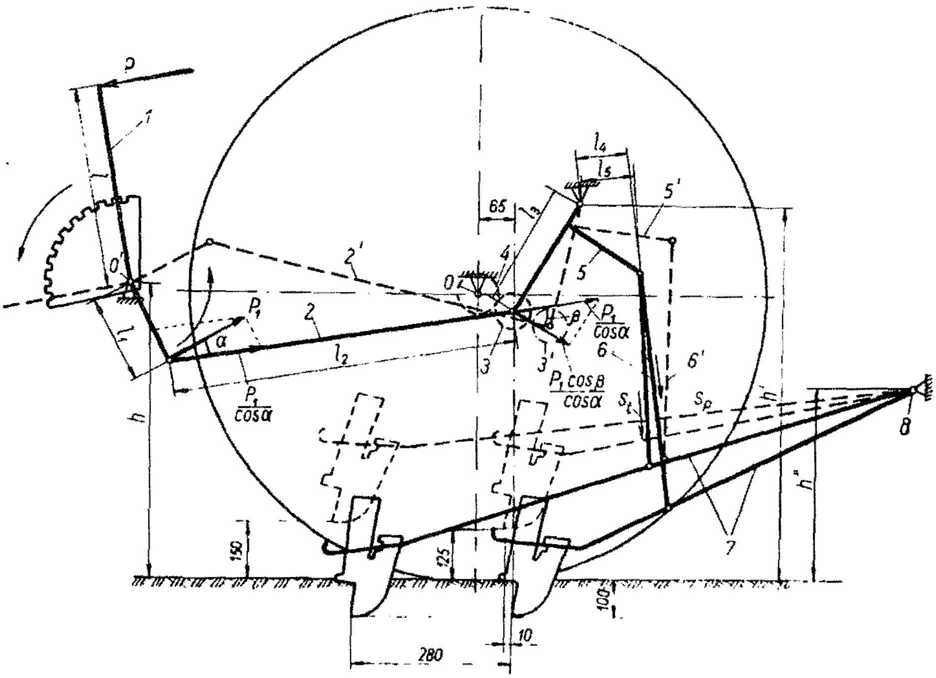


Fig. 13.43. Example of a lever system for manual lifting of openers: *1* — hand lever; *2* — link; *3* — toothed wheel driving the drilling units; *4* — gear wheel mounted on the hub of ground wheel; *5* — lever arm; *6* — links for lifting the opener lever; *7* — opener levers; *8* — hinged connection of lever with the lever supporting beam. Note: working position of the openers is marked with continuous lines, transport position — with dashed lines.

From the resolution of forces and moments it further follows that

$$P_1 \frac{\cos\beta}{\cos\alpha} l_3 = i_1 S_p l_4 + i_2 S_t l_5$$

where

i_1 -- number of front openers,

S_p -- force necessary to raise a single front opener,

i_2 -- number of rear openers,

S_t -- force necessary to raise a single rear opener.

Since

$$P_1 = P\frac{l}{l_1}$$

on substitution we obtain

$$P\frac{ll_3}{l_1}\,\frac{\cos\beta}{\cos\alpha} = i_1 S_p l_4 + i_2 S_t l_5$$

Adopting an effective pressure exerted manually on the lever which is not in excess of 20 kg ($P \leqslant 20$ kg), and such a length of lever as would enable easy and convenient manipulation at known levels h, h' and the distance OO', the appropriate lengths l_1, l_2, l_3, l_4 and l_5 are selected. The levels h and h' and the distance OO' result from the overall dimensions of the drill.

Figure 13.44 exemplifies a system of levers for lifting disk openers with the aid of a pawl mechanism, fitted on the axle of the drill's wheels.

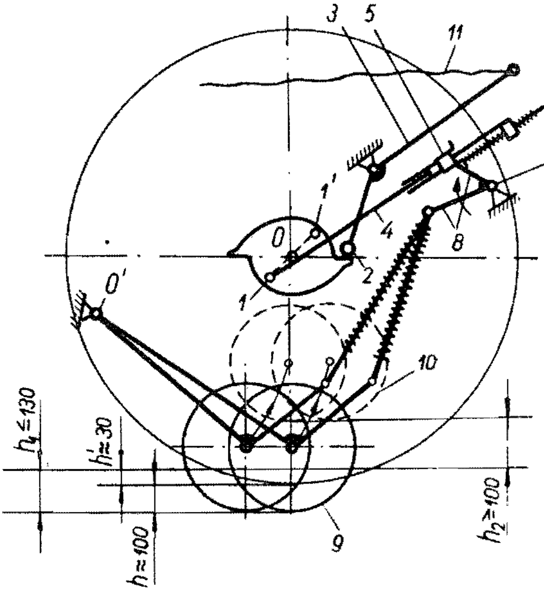


Fig. 13.44. Example of an automatic mechanism for lifting and lowering disk openers in tractor-trailed drills: *1* — crank journal; *2* — roller; *3* — two-armed roller lever; *4* — connecting rod; *5* — slotted lever block; *6* — crank for adjusting the slotted lever block (to control the idle motion of the connecting rod); *7* — square shaft; *8* — lever arms; *9* — openers in working position; *10* — openers in transport position; *11* — cable engaging the lifting system.

A lifter of other type can also be used similarly fitted on the wheel axle or on a special shaft located parallel to the wheel axle and driven by a chain transmission. It is clear from the diagram that the hand crank with which the positioning of the slotted lever block is altered may also be used to vary the level of raising the openers.

Since the driving power of feeding units in tractor-mounted drills is obtained from the supporting wheels, the lifting of the entire machine simultaneously with the lifting of openers results in stopping the process of feeding.

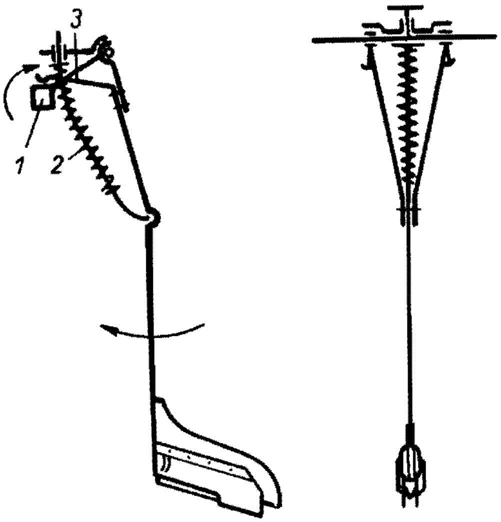


Fig. 13.45. Example of a system for lifting openers embodying no links or lifting chains: *1* — lever beam; *2* — spring pressing down the opener lever; *3* — arm limiting feeding depth.

In certain mounted drills no chains for lifting openers are used. Figure 13.45 shows an example of an original method of connecting the opener lever with the lifting beam which eliminates the chains altogether, while

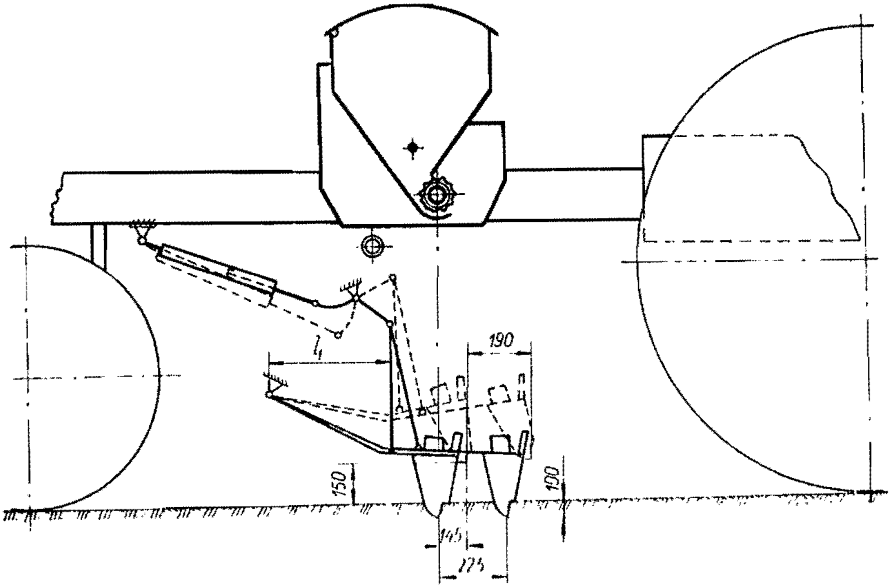


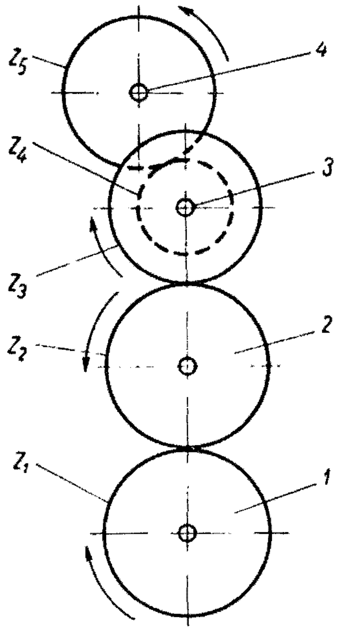
Fig. 13.46. Example of a hydraulic lifting of openers in a drill mounted on a tool carrier.

the design presented enables free motion of openers during operation in vertical plane. It is worth mentioning that here, too, guides of the lever are needless.

In drills fixed to the tractors, hydraulic oil cylinders for lifting openers are most frequently used (Fig. 13.46). On selecting an appropriate leverage system (that is, the positioning of the rotation axis of levers and the length of their arms), it is possible to determine graphically that position of the arms at which the obtained moment is highest and to calculate the oil pressure in the cylinder accordingly.

13.6. Driving systems of feeding units and of moving accessories

In drills embodying feeding units of continuous feeding rate (standard Hoozier type) the driving mechanism of feeding units and of the agitator is very simple, consisting of several gear wheels (Fig. 13.47). Certain American and Soviet drills include, in addition to gear wheels, an additional chain transmission. In drills, on the other hand, in which the feeding rate is controlled by the alteration of the number of revolutions of feeding rolls, a multistage gear transmission (Norton transmission) must be employed. Recently, variable-speed transmission have begun to be introduced with considerable success. In all cases both as regards horse-drawn and tractor-trailed drills, driving power is essentially obtained by the contact of the wheels with the ground. Only in drills mounted on tool carriers their moving parts are occasionally driven by the tractor's PTO shaft. A multistage transmission is, of course, more expensive than a simple toothed wheel transmission.



Z_1	Z_2	Z_3	Z_4	Z_5
22	22	18	13	18

Fig. 13.47. Example of the drive gear of a Hoozier grooved drilling assembly and of an agitator: *1* — gear wheel keyed on the hub of the drill's wheel; 2 — intermediate wheel; 3 — shaft of feeding units; *4* — agitator shaft.

In designing a multistage transmission it is necessary to take into consideration that the successive variations in the number of revolutions of feeding rolls would be as small as possible and also that such variations should be uniformly distributed. These requirements are met by geometrical gradation of transmission.

Final number of revolutions n_K (number of revolutions of the feeding units' shaft) is calculated according to the following formula

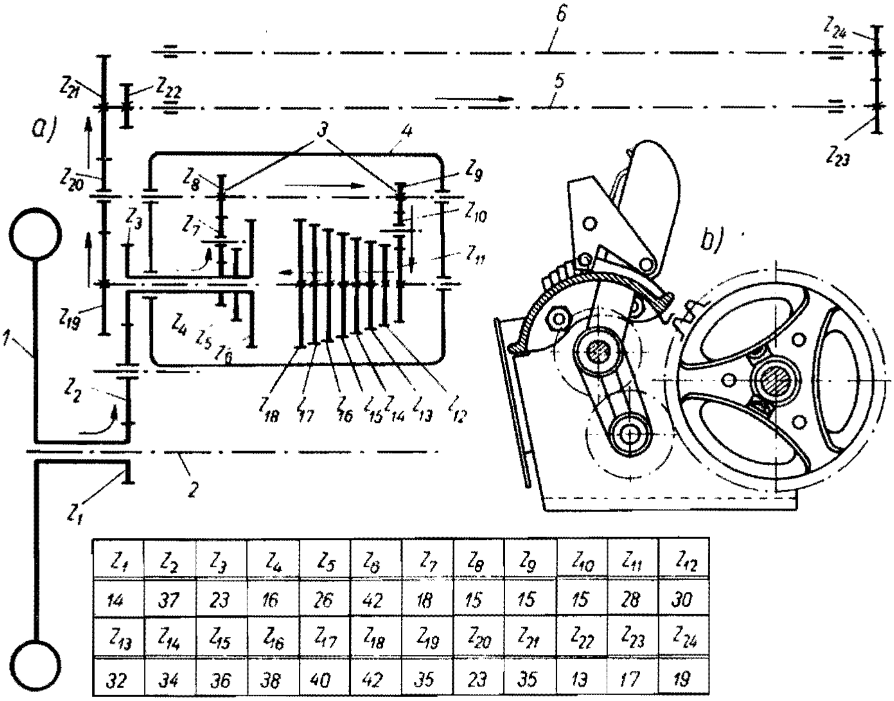
$$n_K = n_p K^{z-1}$$

where

n_p — initial number of revolutions (number of revolutions of the drill's wheels),

z — number of changes in revolutions (number of transmissions),

$$K = \text{from } 1.05 \text{ to } 1.10$$



z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	z_9	z_{10}	z_{11}	z_{12}
14	37	23	16	26	42	18	15	15	15	28	30
z_{13}	z_{14}	z_{15}	z_{16}	z_{17}	z_{18}	z_{19}	z_{20}	z_{21}	z_{22}	z_{23}	z_{24}
32	34	36	38	40	42	35	23	35	13	17	19

Fig. 13.48. *a*) Example of Norton transmission gear for driving studded feeding rolls and the agitator in horse- and tractor-drawn drills: *1* — ground wheel of the drill; *2* — wheel axle; *3* — sliding levers with toothed-wheel units; *4* — transmission casing; *5* — feeding roll; *6* — agitator; *b*) detail of Norton transmission gear.

In Fig. 13.48 is shown a diagram of power drives in a drill with studded feeding rolls. Directions of transmission of drives are marked with arrows. It is clear from the diagram that 3×8 = 24 different speeds of feeding rolls are obtained. Figure 13.49 presents a diagram of similar power drives of feeding rolls in a drill mounted on a tool carrier. In this particular case, the drill consists of two parts and — as in shown in the figure — 6×6×2 = 72 variations of speed can be obtained. Such a number of variations with a constant number of revolutions of the PTO shaft enables four ranges of speed to be obtained: for small feeding quantity (for example, of small-sized seeds), and for a low, standard, and high speed of the drill.

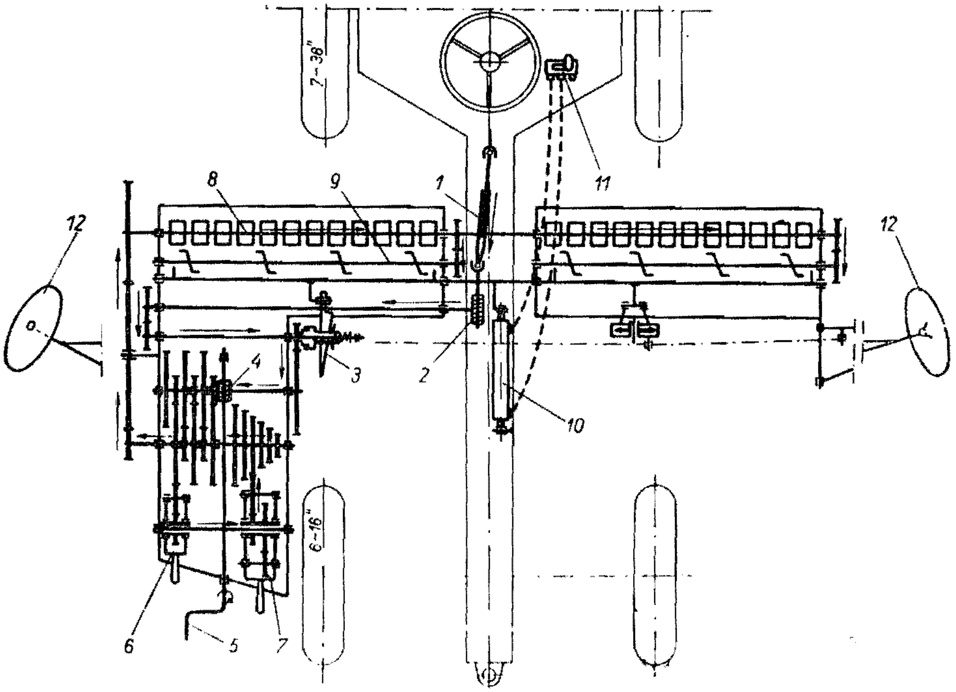
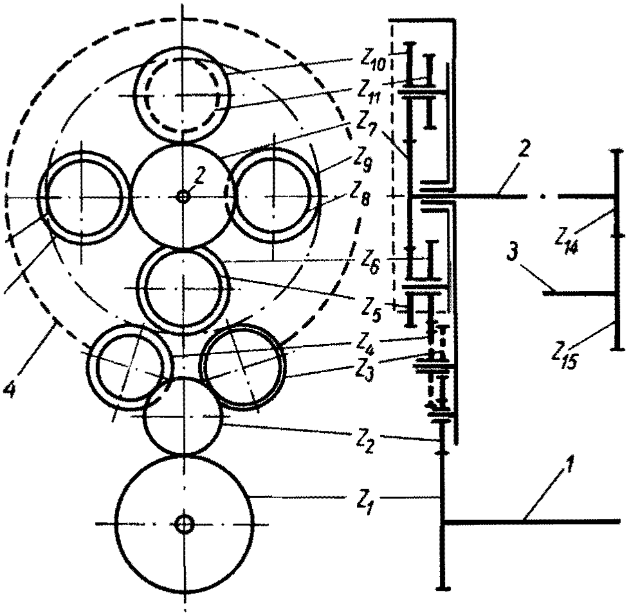


Fig. 13.49. Example of power drives in a drill mounted on a tool carrier with studded feeding units: *1* — PTO shaft; *2* — worm gear; *3* — key for engagement and disengagement of coupling; *4* — worm gear; *5* — hand crank for wheels rotated by means of a worm gear; *6* — sliding lever with two-wheel gear set; *7* — sliding lever with two-gear sets; *8* — shaft with mounted studded rolls; *9* — agitator; *10* — hydraulic cylinder of the opener lifter; *11* — oil pump; *12* — disk markers.

Changing of the number of revolutions of feeding rolls can also be achieved by using a planetary gear which is shown diagrammatically in Fig. 13.50. In the diagram indicated, the power drive of feeding rolls is cut out. By an appropriate setting (revolution) of the disk on which are fitted intermediate wheel gears z_3 and z_4 engagement of the driving wheel z_1 with the wheel z_5 and ultimately with the wheel z_{15} is obtained. The individual planet wheels consist of sets of two wheels of different diameter. In practice, a change within limits of 28.5–88.5/min in the number of revolutions of feeding rolls may be achieved.

Variable-speed transmission is obtained by using the well-known V-belt transmission.



	z_1	z_2	z_3	z_4	z_5	z_8	z_7
	23	13	13	14	13	14	18
z_8	z_9	z_{10}	z_{11}	z_{12}	z_{13}	z_{14}	z_{15}
12	15	15	12	13	14	14	19

Fig. 13.50. Example of a planetary gear transmission of the power drive of feeding units: *1* — ground wheel axle; *2* — countershaft; *3* — shaft for feeding units; *4* — ring for changing engagement of driving wheels (z_3) with planet wheels.

Figure 13.51 exemplifies changes in the number of revolutions of feeding rolls per single revolution of the driving wheel, for three different setups of three types of multistage transmissions. The diagram shows that the curves of changes in the number of revolutions are approximated to parabolas, such changes in the case of small feeding quantities being insignificant, but increasing considerably with adjustment for large feeding quantities.

Gears can be made of cast iron or plastics. Module pitch commonly used amonts to 4–5.

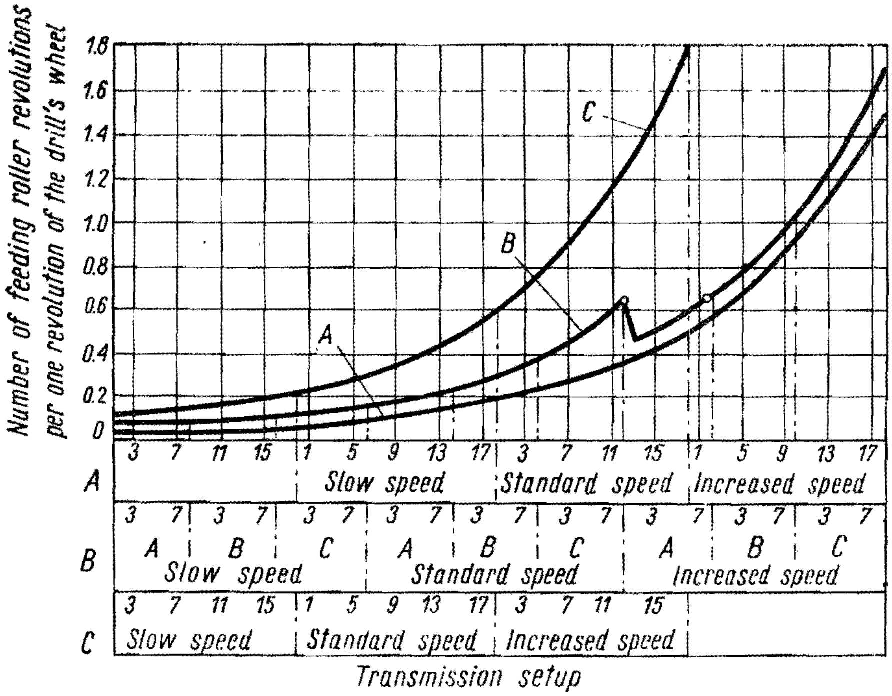


Fig. 13.51. Pattern of variations in quantity of feeding with studded feeding units with the application of A — variable-speed transmission; B — Norton transmission; C — planetary transmission.

13.7. Other parts of drill

The drill's frame permanently supported on ground wheels (in horse-drawn and semimounted tractor drills) or only during the operation (in mounted drills) may be made of angle bars or be of tubed structure. There are also frameless drills in which the seed box is also the carrying element. Wheel axle may either extend across the entire frame length, or the wheels may be fitted on relatively short axles, or pivots, joined with the lateral bars of the frame. The frame of a horse-drawn or tractor-trailed drill constitutes a rigid arrangement with a triangular brace (Figs. 13.5 and 13.52), whose front part is hinged to the axle of the forecarriage (in horse-drawn drills) or with the tractor's hitch (in semimounted drills). In the case of horse-drawn drills, the forecarriage axle is supported on two wheels the diameters of which are usually half that of the rear driving wheels (diameters of rear wheels amount to 1100–1500 mm, and those of front wheels to 550–750 mm).

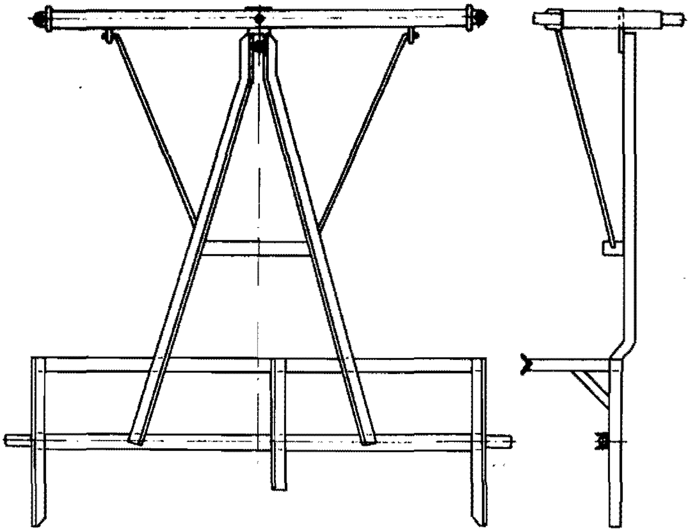


Fig. 13.52. Example of the frame and brace of a horse-drawn drill.

Steering a horse-drawn drill (Fig. 13.53*a*, *b*, *c*) can be performed either by turning the entire forecarriage axle (setting of front wheels on the axle ends) or by turning round front wheels alone fitted on maneuverable axle shafts. In the first case, steering the drill is either by means of one appropriately long lever used by a worker following the drill (in drills of small working width — that is, at $S_r \leqslant 1.5$ m), who at the same time controls the operation of the machine, or by a shorter lever fitted into a lateral recess in the horizontal bow (at $S_r > 1.5$ m).

On turns and during back travel of the drill, the steering lever is shifted into an opposite recess in the bow. This second method obviously requires an additional worker to control the drill's operation but the accuracy of such control is considerably higher. Maneuverable axle shafts of the forecarriage wheels reducing the turning radius were used in horse-drawn drills of relatively great working width (about 3 m), which were steered by means of a lever operated by a worker sitting on one of two saddles fixed at either side of the drill in front of the seed box. In consequence of the advance of motorization in agriculture, production of horse-drawn drills of working width above 1.5 m has been abandoned.

For appropriate utilization of field surface for sowing and also to create uniform conditions of vegetation for the plants cultivated, the widths between individual seed strips should be equal to that of inter-rows. Although this is in practice actually never attained, effort should be made that the differences are as small as possible. With this end in view, the drill's operator, after turning back, should try to keep the front wheel on the track left by the rear wheel in the preceding travel.

If, at determined widths of interrows, the distance between the extreme openers and the center of the rear-wheel rims is equal to a half of the interrow width — that is, when

$$S_r = 0.01 s i = L_K \text{ (m)}$$

where

S_r — drill's working width (m),
s — interrow width (cm),
i — number of operating openers,
L_K — distance between the centers of wheel rims (m),

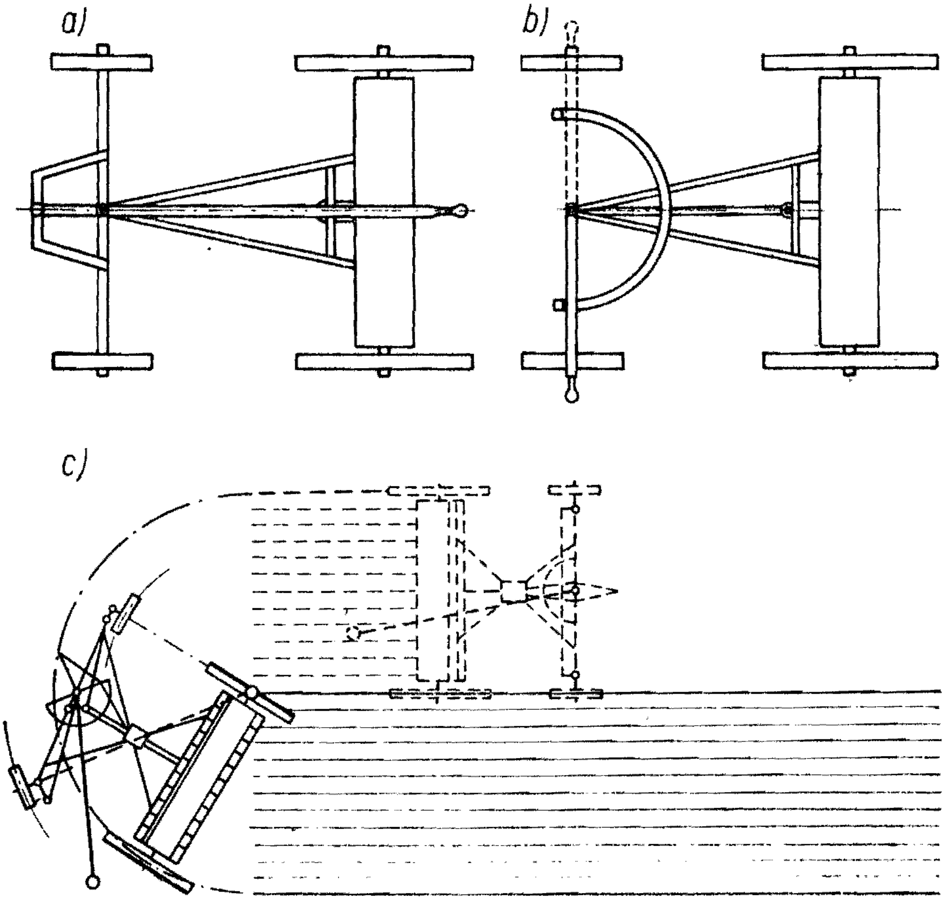


Fig. 13.53. Methods of operating a horse-drawn (forecarriage) drill: *a*) steering by means of rear lever; *b*) steering by means of side lever; *c*) steering of forecarriage with wheels on maneuverable axle shafts.

then the spacing L_p of the front wheels is equal to the spacing of rear wheels ($L_K = L_p$). If, however, at the required interrow width s the distance between the extreme openers and the center of the rear-wheel rims is greater than $\frac{s}{2}$, then the spacing L'_p of the forecarriage is appropriately lesser ($L'_p < L_p$). In the event, however, of the distance between the extreme openers being less than half the required interrow width, then — conversely — the wheels of the forecarriage should be set up wider than the spacing between the rear wheels. In general the following relation should always be maintained

$$2S_r = L_K + L_p$$

Hence

$$L_p = 2S_r - L_K$$

and since $L_K = \text{const}$, then L_p depends only on S_r — that is, on s and i. For this reason the wheels of the forecarriage have detachable axles, and the manner of their connection with the beam should enable the wheel spacing to be altered as required (for example, the wheel axle to be fixed to the beam by means of clamps).

Appropriate steering of a tractor aggregate (tractor+drill) requires the application of markers which skim on the surface a trace in the form of a groove. On turning back, the front wheel of the tractor should be led along the trace left by the marker. The drill is equipped with two such markers, one on either side of the machine. A marker is usually in the form of a concave disk some 300 mm in diameter, set up obliquely to the direction of travel of the aggregate. The disk is fixed to the arm (outrigger) which is hinged to the drill frame by a sleeve (a holder). Such a connection enables folding markers for transport purposes. The working lengths l_1 and l_2 of the two arms differ one from another, but the manner in which the arms (outriggers) of markers are joined with sleeves hinged to the drill's frame allows the alteration of the length of the outriggers within certain definite limits. It follows from Fig. 13.54 that

$$l_1 = S_r - \frac{b}{2} - a$$

$$l_2 = S_r + \frac{b}{2} - a$$

where

b — spacing of the tractor's front wheels as measured between the internal tire edges (m),

a — distance from the center of the drill to the point of hinged connection of the marker's arms (m).

If the required interrow width entails an asymmetric setting of

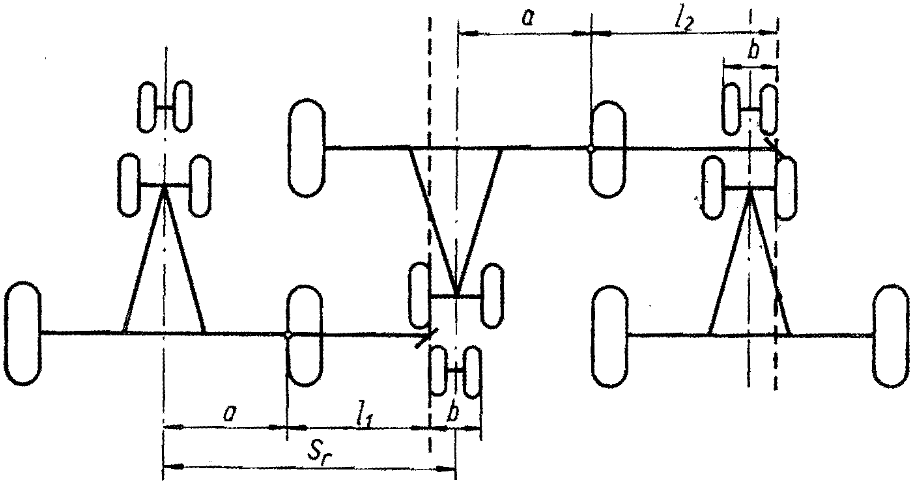


Fig. 13.54. Determination of length of the marker's arms with symmetric arrangement of openers.

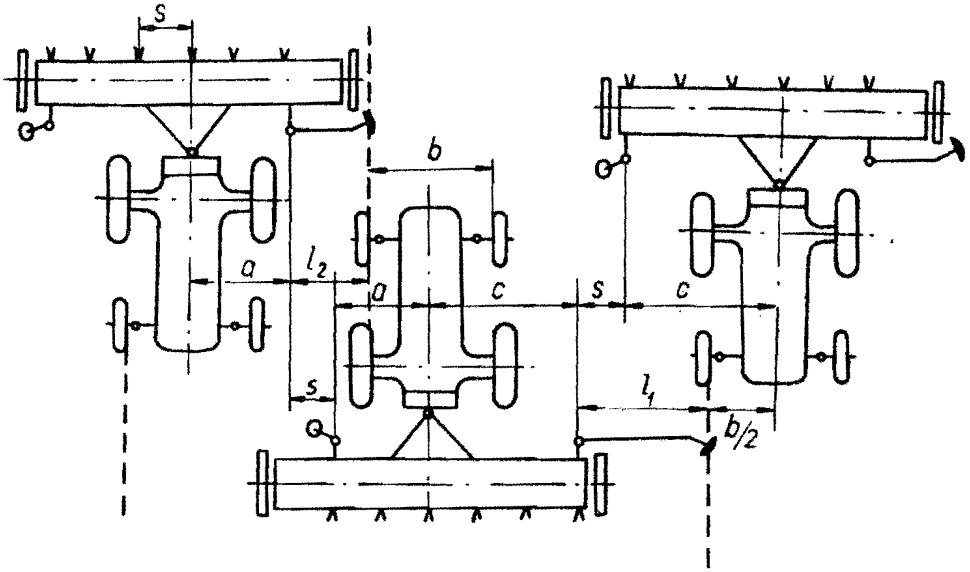


Fig. 13.55. Determination of length of the marker's arms with asymmetric arrangement of openers.

openers (Fig. 13.55) — for example, in sowing beet seeds — and the driver guides alternately the right and the left front wheel of the tractor along the trace made by the marker, then as follows from the drawing

$$l_1 = c + s - \frac{b}{2}$$

$$l_2 = a + s - \frac{b}{2}$$

The wheels of the forecarriage and the rear wheels of horse-drawn drills are most frequently wooden with steel rims and cast-iron hubs (Fig. 13.56) or all-steel (less frequently on rubber pneumatics). Tractor-drawn drills, on the other hand, are generally equipped with pneumatic-tired wheels which, as known, offer less resistance than steel wheels in rolling the machine and, in addition to this, absorb machine's vibrations. The diameters of wheels of mounted drills are considerably smaller (some 510 mm) than those of semimounted drills (4″×36″ or ∅ = 1100 mm).

Pressing of the soil by the tractor wheels has a negative effect on the operation of those openers which make grooves on the wheeled track, especially in sowing on a moistened and compact soil. Not only the penetration of openers in soil is more shallow but also the seeds are inadequately covered with soil. In consequence, there are poorer initial conditions of germination of seeds and, as a result, lowering of the crop.

This can be prevented by scarifying the tractor's wheeled track. The actual scarifiers encountered in practice include a range of types such as, for example, in the form of appropriately set up double sweeps similar to those applied in spring-tooth cultivators (section 7.4), or in the form of teeth of various shapes. Figure 13.57 shows an exemplificatory scarifier unit. Scarifiers are installed on an axle connected with the drill which in revolving simultaneously with the lifting of the opener levers, raises the scarifier teeth.

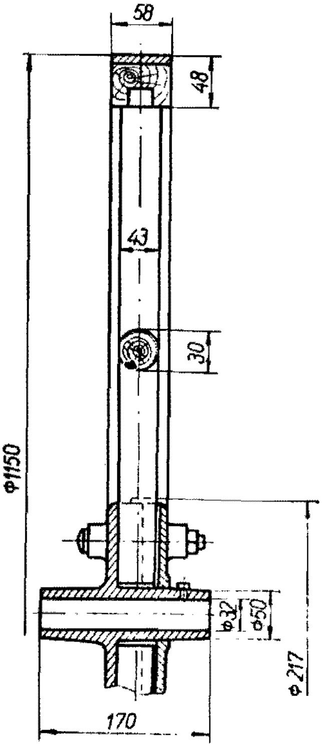


Fig. 13.56. Example of a wooden wheel of a drill. (After Kühne).

In mounted drills, scarifiers must be fixed to the lever beam. In some modern semimounted tractor drills, an automatic opener lifter raises simultaneously not only scarifiers, but also the markers. Occasionally, tractor-track scarifiers are fixed to the tractor. In order to lessen the disadvantageous pressing of soil by the tractor wheels during seeding operations, the rear wheels of the tractor are attached to cage wheels.

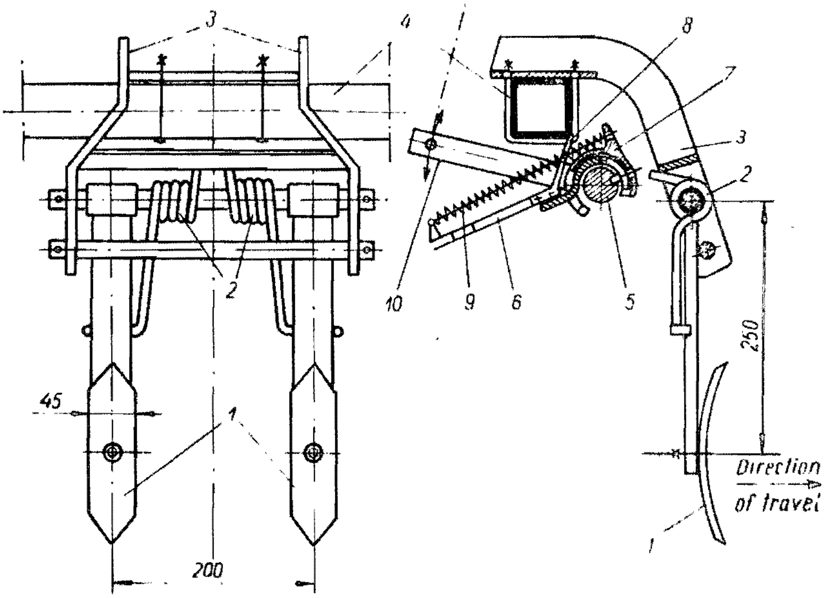


Fig. 13.57. Example of tractor-track scarifiers (rippers) attached to a mounted drill: *1* — scarifying (ripping) hoes; *2* — springs; *3* — ripper arms; *4* — drill frame; *5* — lever bar; *6* — opener lever; *7* — handle of lever enabling movement of openers in vertical plane and damped by buffer; *8–9* — spring pressing the opener lever; *10* — lever turning the handle *7* and thus limiting opener's deflection.

At the rear of semi- and all-mounted drills is sometimes installed a platform for the operator (particularly in drills of large working widths).

Finally, some of the modern drills are equipped with counters indicating the number of hectares sown (hectarometers).

13.8. Resistances and efficiency of drills

The weight of drills depends on their working width, the type of machine (hand-, horse-, tractor semimounted, mounted, combined drills), and the design solutions of individual types (frame construction, wheels, type of furrow openers, transmission, etc.). It may be assumed that specific weight G' (weights calculated per 1 m of working width) for horse-drawn drills vary within limits of 190–230 kg/1 m. Approximately 85 percent of weight falls to the rear axle and some 15 percent to the forecarriage axle.

In tractor-hauled, semimounted drills, G' is 215–290 kg/m. Such drills, although having no forecarriage, are equipped with reinforced frame and a seed box generally of higher capacity. In mounted drills of shorter longitudinal dimensions, $G' = 130–180$ kg/m.

Finally, drills combined with tractor have $G' = 140–160$ kg/m.

The drill's total resistance in operation (total draft P_u) amounts to

$$P_u = P_K + P_r + P_t$$

where

P_K — rolling resistance of wheels,
P_r — resistance of openers in operation,
P_t — friction resistance in bearings and drive gear transmissions.

As is well known, P_K depends on the value of reaction of soil — therefore on the loading of wheels, the type and state of soil and the type and dimensions of the wheels. Since the moment required to put in motion the moving parts of the drill is relatively low it may, in calculations of

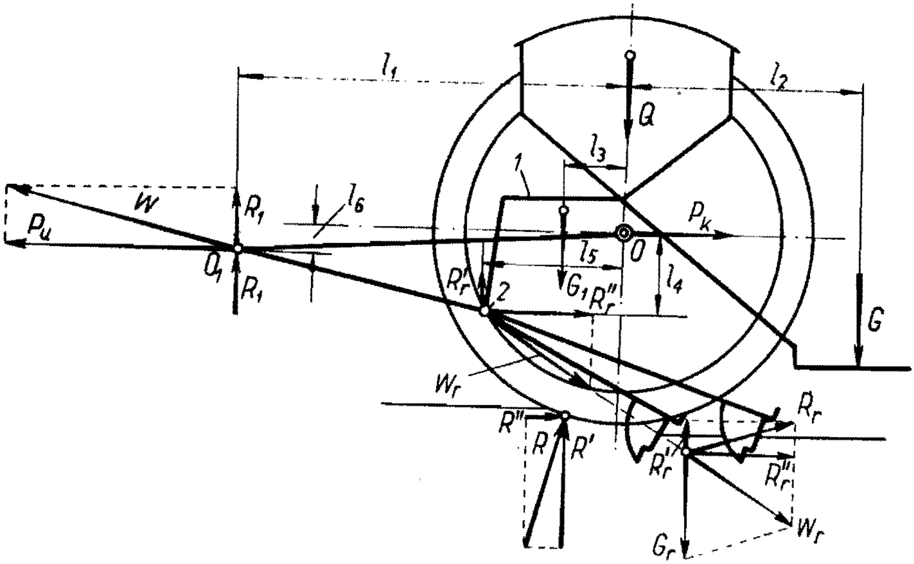


Fig. 13.58. Forces acting on a trailed tractor drill in operation with the use of shoe openers: P_u — draft power; P_K — travel resistance; G_1 — weight of drill falling to the wheels; Q — weight of the load of seeds with an entirely filled box; G — weight of operator; R_1 — reaction on the hitch; R' — vertical component of the soil reaction R; G_r — total weight of the rear and front openers; R_r — total resistance of the rear and front openers; 1 — drill frame; 2 — opener lever bar.

consumption power, be altogether disregarded. In other words, P_K can only be considered for traction wheels during transport. Reaction of the soil to the wheels with openers lowered (Fig. 13.58) is

$$R' = G_1 + Q + G$$

where

Q — weight of seeds,
G — weight of operator,
$G_1 = G - i \cdot r'$ — weight of the drill with lowered operating openers,
i — number of openers,
r' — vertical reaction of soil to a shoe opener (2–2.5 kg).

In the case of hoe openers, the direction of operation of this component as known, changes.

The rolling resistance of a semimounted drill in motion is calculated according to the well-known simplified equation

$$P'_K \frac{D_K}{2} - R'f = 0$$

where

$P'_K = R''$ — horizontal component of soil reaction (rolling resistance in motion),
R' — vertical component of soil reaction,
D_K — wheel diameter,
f — arm of rolling friction dependent on dimensions, type and loading of the wheel, the type and state of the soil and the speed of travel.

Hence

$$P'_K = \frac{2R'f}{D_K}$$

The resistance of the traveling drill during sowing

$$P_K = f'P'_K = (G_1 + Q + G)f'$$

where f' is the coefficient taking into account the value f and the friction resistances in bearings; in practice $f' = 0.12$–0.22.

Conditions of equilibrium of forces are expressed by the following formula

$$P_u - (P_K + R_r'') = 0$$

Hence

$$P_u = P_K + R_r''$$

$$G_1 + Q + G - R_1 - R' - R_r' = 0$$

where R_r'' and R_r' are the components of the reaction of front and rear openers

$$R' = G_1 + Q + G - R_1 - R_r'$$

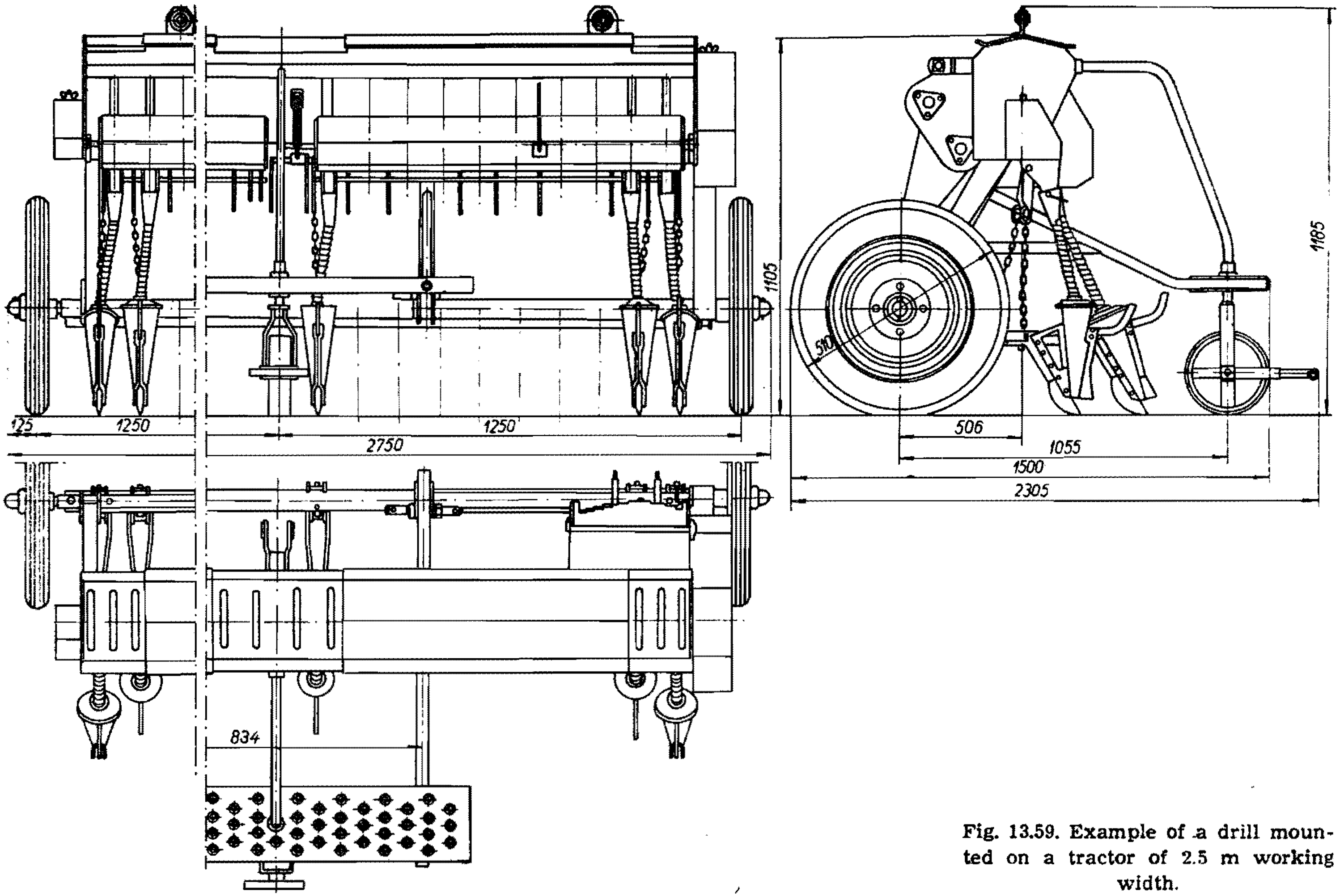


Fig. 13.59. Example of a drill mounted on a tractor of 2.5 m working width.

The equation for the equilibrium of moments in relation to the wheel axles O is presented below

$$M_0 = R_1 l_1 + G l_2 - G_1 l_3 + R_r' l_5 - R_r'' l_4 + P_u l_6 = 0$$

From the above equations of moments one can easily calculate the value of the moment $P_u l_6$. The value l_6 — that is, the level at which the hitch is situated in relation to the wheel axle of the drill, should take into account the horizontal position of the frame, since with this frame is connected the opener bar whose level of positioning over the surface of the field affects in turn the maintenance of a more or less uniform seeding depth by the front and rear openers. It may be assumed that in operating a semimounted drill at a speed $v_m \approx 1.25$ m/sec, the specific draft $P_u' = 40$–60 kg/m of working width. Today, seeding by means of tractor-hauled machines is carried out at a speed of 2.5 m/sec, and sometimes even at more than 3 m/sec.

In seeding large fields with drills of $S_r = 2.5$ m, for the purpose of increasing output, two machines are sometimes axially connected into a single combined unit requiring a tractor of some 25 hp. The theoretical efficiency of such unit is approximately 3 hectares/hr.

In Fig. 13.59 is shown a drill, working width 2.5 m, mounted on a tractor. It will be noted that the throats of the extreme front and rear openers are in many drills screened by sheet-iron guards. Such guards are fitted in order to protect the throats against the penetration of particles of soil raised from the surface by the drill's wheels. Guards for the extreme opener throats are also applied in horse-drawn and semimounted drills. Connection of the drill's frame with a three-point hitch linkage should envisage in beet seeding an odd number of openers, which requires the possibility of an asymmetric mounting of the machine (shifting by half the width of interrows). The drill in question is mounted on a tractor of some 15 hp. In Fig. 13.60 is shown an example of the transverse irregularity of seeding with a drill of this type.

The range of variations in the values of resistances of individual types of openers, and the specific weights of the drills described were given in section 13.5 above. In seeding on a compact soil at a depth of 3—4 cm, under difficult operating conditions, the resistance of 31 shoe openers in a horse-drawn drill of 3 m working width amounted to some 20 percent of the total resistance, and in a semimounted drill, working width 4 m, and subjected to similar operating conditions, the resistance of 27 disk openers amounted to about 25 percent (both drills had steel wheels). In the first case, the drill's speed was some 2.7 m/sec, and in the second — about 1.6 m/sec. The total resistance of a semimounted drill, working width 2 m, on pneumatic tires and operating on a medium compact soil is approximately 240 kg. Horse-drawn drills of $S_r = 1.5$–2 m, in operation on a medium compact soil require a span of two horses, and a 3-m drill — of 3–4 horses.

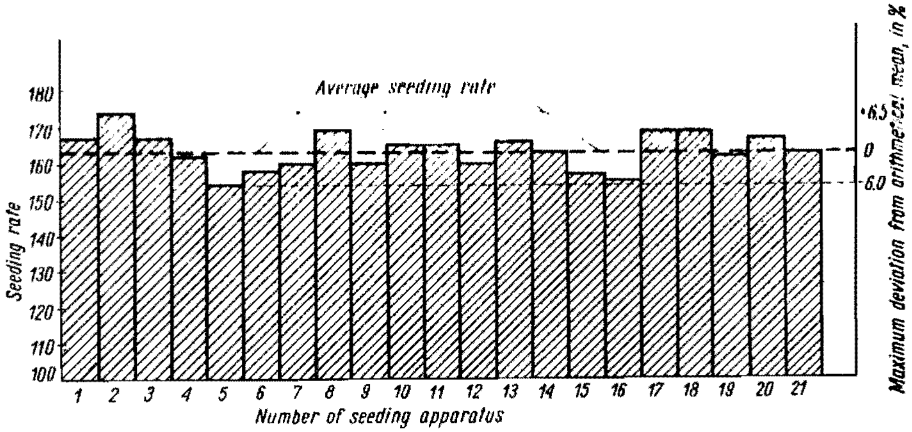


Fig. 13.60. Example of transverse irregularity in rye seeding, Q_{ha} — 170 kg. (According to the present authors' investigations).

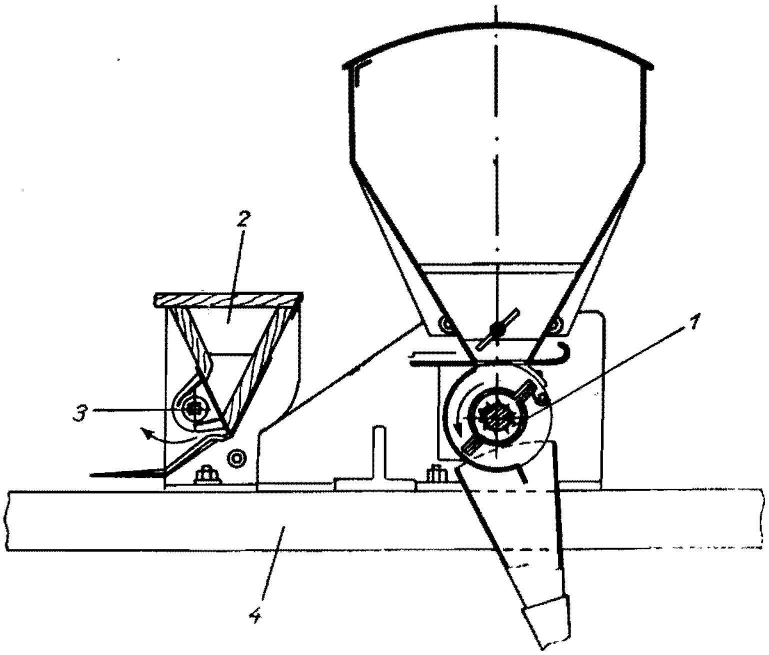


Fig. 13.61. Example of a combined grain- and clover-seed drill: *1* — grain seeding unit; *2* — clover-seed box; *3* — clover-seed feeding unit; *4* — frame.

Knowing the working width of the drill and its speed, one can easily calculate its theoretical operational efficiency. The actual output depends on the length of the strip of field — that is, on the frequency of turns on headlands, on the frequency of filling boxes with seeds — which in turn depends on the capacity of the box — further, on the frequency of choking of openers with soil, the organization of work and the frequency and type of technical defects occurring during the operation. The ratio of the time used in cleaning choked openers from soil and removing technical defects to the total time of seeding is expressed by the coefficient of serviceability. The value of this ratio, which is dependent on the structure of the drill and the quality of its performance, varies within limits of 0.90–0.98.

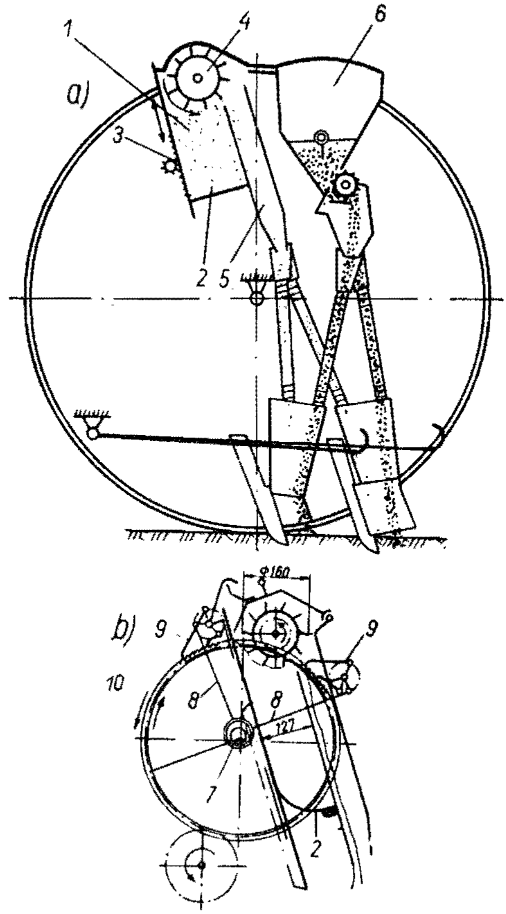


Fig. 13.62. Example of a combined drill for simultaneously seeding of grain and granulated fertilizers. *a*) Schlör system: *1* — fertilizer container; *2* — sliding bottom of the container; *3* — drive of the container wall linked with the bottom; *4* — geared drum removing fertilizer; *5* — tube conveying fertilizer to tubes and openers; *6* — seed box; *b*) mechanism lifting the container bottom: *6* — dual eccentric; *8* — arms; *9* — pawls; *10* — ratchet wheel.

In some cases, simultaneously with the seeding of grain seeds, grass and clover seeds are sown. Grass seeds are most frequently sown by broadcasting. Figure 13.61 presents an example of a drill in which on a common shaft is located an accessory box with an auxiliary seeding device. This device can be made in the form of a fluted roll smaller in dimensions than the roll embodied in the standard Hoozier system, or eventually in the form of blades fixed on a common shaft.

Simultaneously with grain seeds, granulated fertilizers are also sometimes drilled. Fertilizer can be conveyed to the furrow openers in which grain seeds are simultaneously accumulated. Figure 13.62 presents an exemplificatory diagram of a combined drill having two separate seed boxes. For distribution of fertilizer, this system adopts a geared drum with fingers. The delivery of the fertilizer mass is by stepped lifting of the container's bottom by means of a ratchet and a wheel gear (Schlör's system). The wheel gear is driven by a pawl mechanism which is in turn driven by the drill's ground wheel. On the seed box's bottom, reaching the extreme upper position, the drive is automatically cut out and the bottom is lowered into its extreme lower position. The capacity of the seed box is 220 cu decim, and that of the fertilizer container — 110 cu decim. The specific weight of the machine is some 400 kg/m of working width.

A different type of combined drill is shown in Fig. 13.63. This unit has a single box divided by a partitioning screen in two compartments, the front one serving for grain seeds, and the rear — for fertilizer.

Distribution of fertilizer is performed by a studded roll which is a novelty in feeding this particular material. The capacity of the seed box is 310 cu decim, and that of fertilizer container — 260 cu decim. The specific weight of the machine is some 314 kg/m of working width — the drill is, therefore, apparently lighter than the other type.

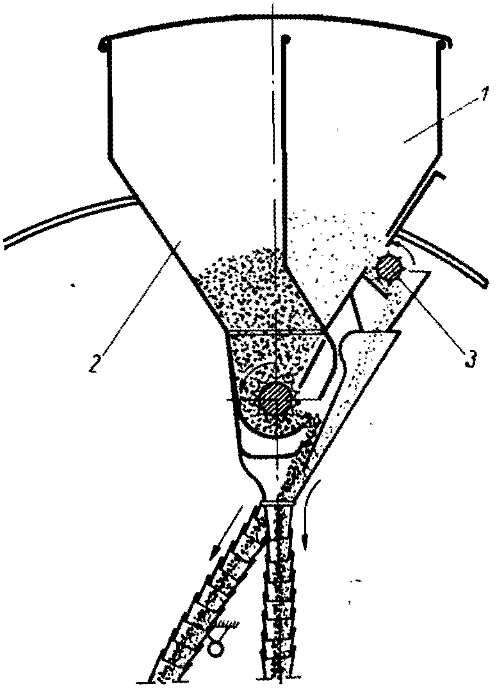


Fig. 13.63. Example of a combined drill with a common box for simultaneous seeding of grain and granulated fertilizer: 1 — granulated fertilizer compartment; 2 — seed compartment; 3 — studded feed roll for distribution of granules.

In simultaneous seeding of beet seeds and granulated fertilizers are sometimes used special openers fitted with two throats (Fig. 13.64). Fertilizer is fed through the front throat and seeds through the rear, the fertilizer being deposited deeper than the seeds. This procedure adds to a better utilization of fertilizer and eliminates the possibility of damage to seeds arising from their immediate contact with the fertilizer.

In countries, which for a long time now have used in farming large quantities of fertilizers, the use of combined drills is losing in importance. In countries, on the other hand, where the available quantities of fertilizers are inadequate for the proper supply of soil with the necessary nutritive constituents, the use of combined drills is rightly justified since it enables a better utilization of granulated nitrogenous fertilizers. It should be emphasized that agriculture has not yet received a type of combined drill which would be able to satisfy the user's requirements. On the other hand, however, there is no firmly established opinion among the farmers as to the optimum deposition of fertilizer in relation to the seeds.

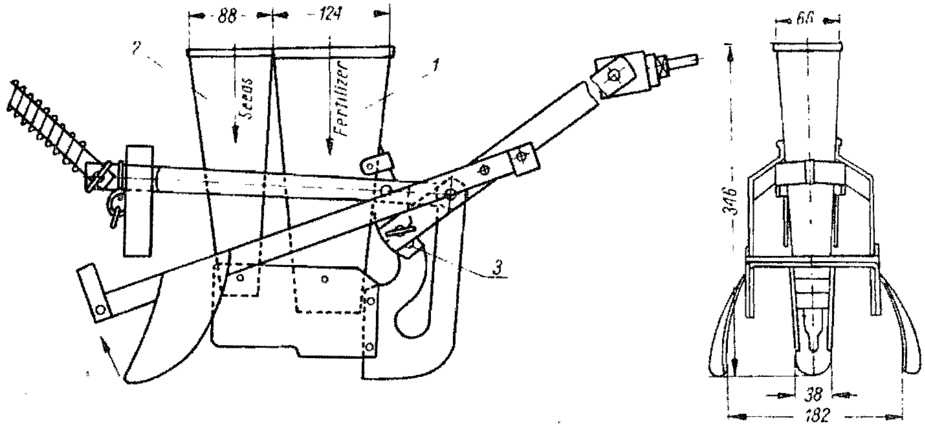


Fig. 13.64. Opener for combined seeding of sugar beets and fertilizer: *1* — front throat; *2* — rear throat; *3* — holes receiving the bolt.

The period of time between the finishing of harvest and the starting of prewinter cultivation should be devoted to the seeding of aftercrops. For this seeding is used a mixture of vetch seeds with rye, lupine, Austrian winter pea, and others. The obtained green foliage can be used as fodder or plowed-in for plant manure. The quicker the stubble land is prepared for sowing and sown after harvest, the higher the crops that may eventually be obtained. Tillage of stubble land with skim plows and harrows, followed by subsequent drilling operations, requires a relatively long span of time during which the soil loses much of its moisture, and the appropriate season of vegetation is in consequence considerably shortened. The further consequence is the lowering of the crop. Much better results are achieved if the tillage of the stubble land and the sowing are performed simultaneously. This purpose is served by agricultural machines consisting of a drill and disk harrow.

In such drills emphasis is placed on the shortening of the sowing time rather than on the accuracy of the deposition of seeds in soil and of covering them with earth.

It is, therefore, considered sufficient to break up the stubble and to sow-in seeds by means of tubings (sackcloth-rubber or plastic) without resorting to openers. It is required that all growth of the stubble is undercut by disks but it is enough if the cut plants are only in half covered by scarified layers of stubbel.

Aftercrop drills are tractor-hauled machines trailed or mounted at the rear of the tractor by means of a hydraulic lift. The drills referred to may have a single section of disks (mounted drills) or two such sections (trailed drills). In the first instance, seeds fed by tubings situated beside the disks are released into the scarified soil with the result that many

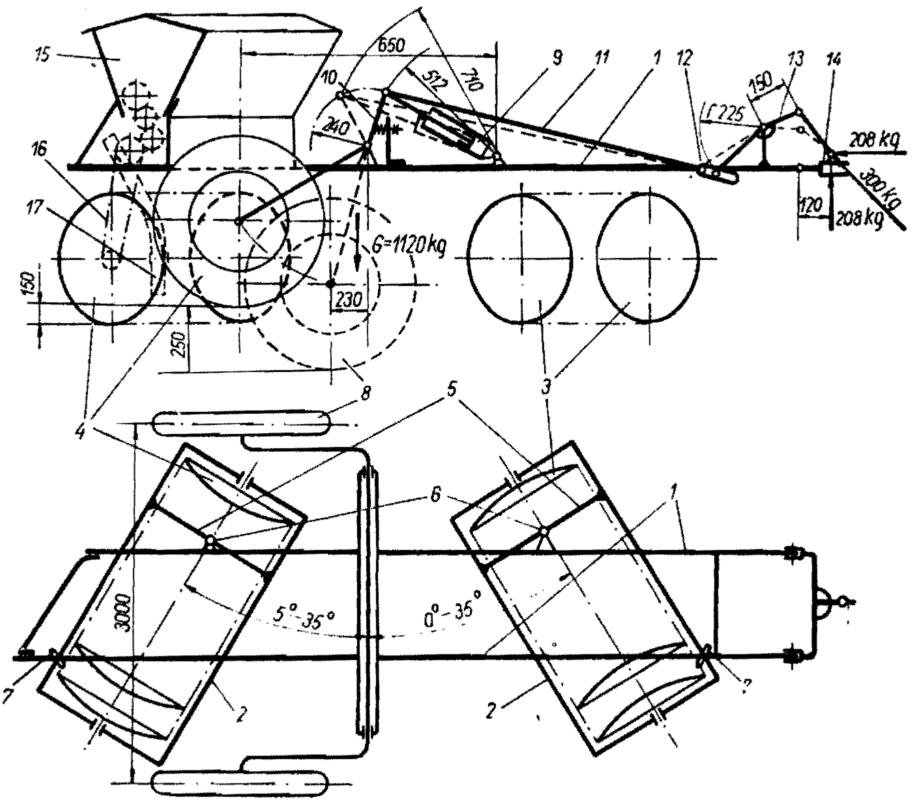


Fig. 13.65. Diagrammatic example of an aftercrop drill: *1* — main frame; *2* — disk section frames; *3* — front section disks; *4* — rear section disks; *5* — brace; *6* — articulated linkage of brace with the main frame; *7* — yoke connecting frames of section with the main frame; *8* — ground wheel 6"×16"; *9* — hydraulic cylinder; *10* — arm of the wheel cranked axle; *11* — link; *12* — slotted lever; *13* — lever system; *14* — hitch; *15* — seed box; *16* — chain transmission; *17* — seed tubes.

seeds remain uncovered, and the future yield is to be poor. In two-section harrows, the first section breaks the stubble, while the disks of the second section cover with soil the seeds released from tubings located beside the disks of this section; in addition, the operation of the disks of the rear section results in leveling of ridges of soil.

In Fig. 13.65 is shown diagrammatically an example of a drill designed for aftercrops, in which the frame is lifted into the transport position by means of a hydraulic lift cylinder supplied with oil fed from the tractor's hydraulic pump. It is clear from the diagram that the lifting of the frame is accompanied by a simultaneous pressure directed on the hitchbar of the tractor. In drilling, fluted or studded seeding units can be used. The system of connection of the section frames with the main frame enables changing of the angle of reciprocal inclination of the frames which, as indicated (section 7.3.2), affects the inversion of furrow slices (covering of seeds), the depth of furrows and the values of resistance (section 7.2.4). It should be indicated that there exist, for individual ranges of the angles of reciprocal inclination of sections, the optimum situation of the nozzles of seed tubes in relation to the disks at which seeds are deposited precisely on the furrows' bottom. For this reason, the design of the drill must provide for the possibility of longitudinal shifting (with respect to the box) of the cleat to which are clamped the seeds tubings.

Results of our own investigations indicate that the best agrotechnical effect in tillage on a medium compact and therefore hardened soil was achieved with the reciprocal inclinations of sections at an angle of approximately 54°. At this inclination of the section the depth of the furrow was some 8 cm, and the average total resistance of the combined machine of some 2200 mm working width — abount 1100 kg (approximately 65 kg/sq decim or 500 kg/m of working width). At an operational speed of some 6 km/hr, the required draft varied within limits of 21.2–26.4 hp which indicates the necessity of employing a tractor of 45–50 hp. After removing the box and dismounting the disk sections the frame is suitable for attaching to it the cultivator tines.

The drill can also be combined with a cultivator having semirigid tines ending in sweeps. In this case the tubings run along the tines while the nozzles are situated near the sweeps, which — in addition to the function of scarifying the soil — also perform in part the role of openers. Such a combined unit is, however, less efficient in covering seeds than a disk machine.

13.9. Special-type drills

This group of drills includes machines for precision (single-grain) seeding, corn-seed, grass-seed drills, etc.

Precision drills are used in seeding, appropriately prepared sugar-beet seeds, corn seeds for grain silage, and vegetable seeds.

Since beet tubers differ considerably one from another in dimensions and their surface is highly irregular, sowing of such seeds will not give uniform deposition of them in the rows. Moreover, a single tuber produces several offshoots which makes their singling difficult. For this reason, seeds used in precision sowing are suitably processed in special machines. Processing of seeds may consist in segmentation (crushing of tubers), then grinding, calibrating on a special machine or in segmentation and further in pelleting with a mass containing fertilizer and easily dissolving in moisture of the soil.

Segmented seeds are screened through sieves of an appropriate size of mesh (calibrated). Processed seeds not only constitute a material of more regular size and shape — which facilitates a mechanical precision sowing — but also having one or two sprouts are much easier in manual singling. As a result, precision seeding saves some 40–50 percent of labor expenditure in subsequent necessary operations as compared with the seeding of multigerm tubers without aid of a standard drill (in the case of a soil free from weeds) or with a simultaneous use of herbicides[1].

For this reason precision drilling of beet and, therefore, the use of precision drills is today more and more in common practice (for example, in GFR some 95 percent of cultivated under beet surface is sown by means of such drills).

The following sizes of prepared seeds are now generally employed. For segmented, calibrated seeds $\Phi = 3$–4.5 mm, and for pelleted $\Phi =$ 4–6 mm.

In precision seeding the average spacing in the row between the adjacent prepared seeds should amount to 3–4 cm. (Nowadays, there is a tendency toward increasing this distance to some 6–8 cm or even to 12–15 cm, provided however that at least half of the sown seeds will sprout and develop.) Permissible deviations from the average spacings as given above should not be in excess of the following:

0–3 cm — 15%
3–7 cm — 75%
over 7 cm — 10%

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[1] The percentage values of labor expenditure reduction refer to hand-singling operation requiring 130 manhours/hectare.

The distance between the deposition of the seeds and the row axis should not be more than 1 cm, and the transversal irregularity of sowing should not exceed 3 percent. The depth of location in the soil of segmented seeds is 1.5–3 cm, and of pelleted seeds — 2–4 cm. The commonly employed amount of segmented and calibrated seeds used in sowing is 6–10 kg/hectare, and that of pelleted seeds 20–40 kg/hectare.

In sowing corn seeds for grain, the average distance in the rows should be 25–30 cm, and for silage mass — 6–8 cm (with an interrow width of 75–85 cm). Finally, seeds of certain types of vegetables, for example, of onion, should be spaced in individual rows at an interval of 8–10 cm.

The numerical data quoted represent agrotechnical requirements of today to be satisfied provided the soil is carefully prepared for sowing.

Precision drills can be divided, according to the type of seeding sets employed, into the following types:

(a) plate drills,
(b) belt drills,
(c) pneumatic drills.

In addition, we distinguish manually operated one-row drills (garden drills), several-line horse-drawn drills, and tractor-mounted drills.

In order to obtain as uniform spacing as possible between individual seeds deposited in furrows, the level from which seeds are sown should be minimum. For this purpose, appropriate seeding units are located next to the opener or are frequently placed in the shield serving as an opener. Each of such units is provided with a seed box. In short, each individual row is sown by means of a separate section each of which constitutes a small independent seeding sets.

These sections are connected with a common crossbar or frame in such a way that the spacing between individual sections can be altered (change in interrow width), similarly as in opener levers of standard-type drills. Some designs provide also for connecting the crossbar or the section frame with an all-purpose frame which enables — after removal of sowing units — the attachment of appropriate implements for interrow tillage.

The seeding sets can be actuated in several ways. Frequently they are operated by the motion of ground wheels rolling on the surface and situated at each section (individual drive). For simultaneous drive of all sections, a common shaft can be used supported on two wheels serving as prime mover.

The driving power of the mobile parts can be transmitted from the shaft by means of chain transmission or by bevel gear transmission. For central drive can also be used the tractor's PTO shaft branching off to the individual seeding sections.

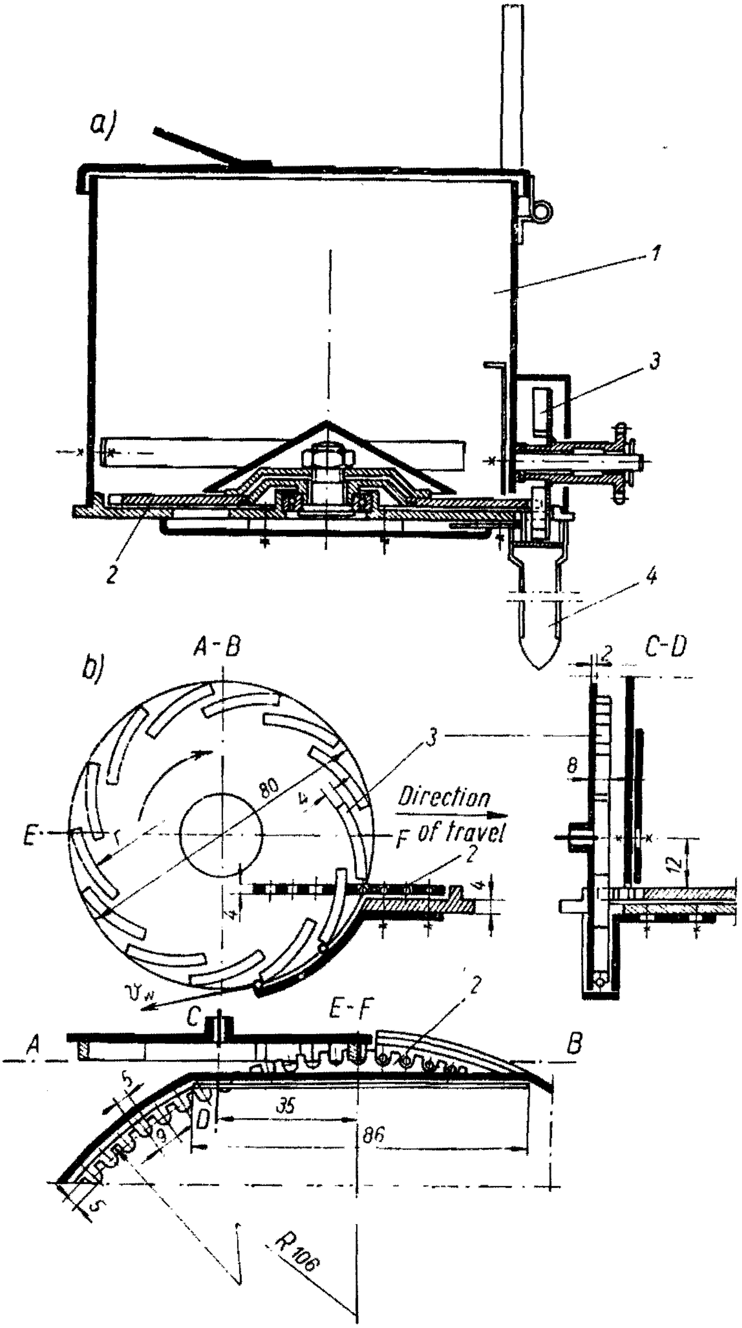


Fig. 13.66. Precision drill with horizontal plate (Hagno system): *1* — hopper for prepared seeds; *2* — plate with indents; *3* — ejector; *4* — opener.

Figure 13.66 shows an exemplificatory plate drill embodying a horizontal plate having at its perimeter indents the size of which must be suited to the dimensions of calibrated seeds. The ring-shaped plate with indents is placed in a rotatable way immediately above the bottom of the seed box of 6-liter capacity. At one side the cylindrical box is slightly flattened and has a slot out of which projects outside a sector of the plate's perimeter. The thickness of the slot formed between the lower edge of the flattened panel of the casing and the surface of the ring can be varied by means of an adjustable screen which enables the release of only those seeds which are able to pass through the ring indents. Outside the flattened part of the box is placed an ejector in the form of a vertical disk with a series of involute crooked teeth and driven by means of a chain transmission from a supporting wheel. The ejector, in engaging its teeth with the ring indents, sets the ring in rotary motion. Seeds dropping from the indents are initially led by the frontal surfaces of the ejector's teeth along the bow-shaped slideway, subsequently to fall down inside the opener. The effect of this arrangement is that the distances between individual sown seeds are set up by the ejector and not by the spacing between the adjacent indents on the plate's perimeter. The slideway is fitted with lateral screens preventing seeds from running astray. The value of the angular speed of the ejector plate, at a given diameter and a given number of teeth, affects the movement of a given type of seeds alongside the slideway.

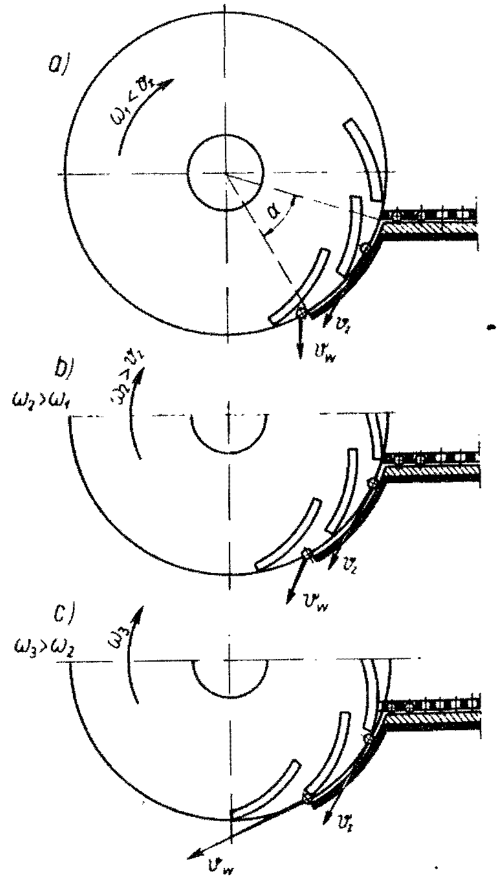


Fig. 13.67. Traveling of seeds along the slideway surface at the ejector's three different angular speeds *a*, *b*, and *c*.

At a low angular speed, less than that at which seeds of a given type roll down the slideway, the seeds catch up with the nearest tooth of the disk (Fig. 13.67*a*) and are run in between the ridge of the tooth and the slideway surface. If the ω of the ejector increases to such an extent that seeds are no longer able to catch up with the teeth, they automatically roll down the slideway surface and drop into the opener in an uncoordinated manner (Fig. 13.67b). With further increase in ω, each tooth catches up with seeds rolling down, and with its frontal surface hurls them inside the opener (Fig. 13.67c). It is obvious that in the first and third case, seeds are released at more or less equal intervals of time and are consequently spaced one from the other at more uniform distances than in the second case in which time intervals between successive release of seeds differ one from another. The speed with which seeds roll down the slideway depends on the shape and the type of the cuticle of seeds, as also on the degree of smoothness of the surface of the slideway.

The final position of seeds in relation to the teeth depends on the length of the slideway (wrapping angle α). Assuming all successive plate indents to be filled with single prepared beet seeds, the percentage variation in the spacing of seeds at theoretical distances (for example, 4 cm

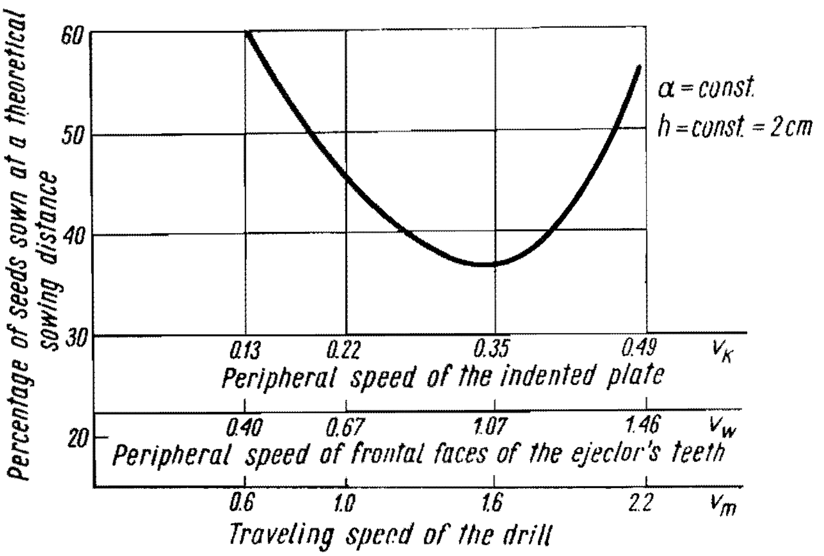


Fig. 13.68. Technical characteristics of an involute teeth ejector at constant level of free falling of seeds (h = const).

for beet seeds) depends on the peripheral speed of the ejector and, therefore of the indented plate, or on the speed of the drill's travel (at a fixed transmission ratio of the ejector drive) in a manner as shown in Fig. 13.68 (according to the results of the present authors' investigations).

The curve presented characterizes the action of the ejector, and the course of the curve confirms the previously given theoretical reasoning concerning the travel of seeds alongside the slideway.

Let us consider in turn, the effect of the value of the slideway's wrapping angle α on the distance of ejection of seeds (Fig. 13.69). It follows from the diagram that at a certain wrapping angle α_1

$$h = H - R\sin\alpha_1 = v'_w \cos\alpha_1 t + \frac{gt^2}{2} \qquad (13.10)$$

$$S_1 = v'_w \sin\alpha_1 t$$

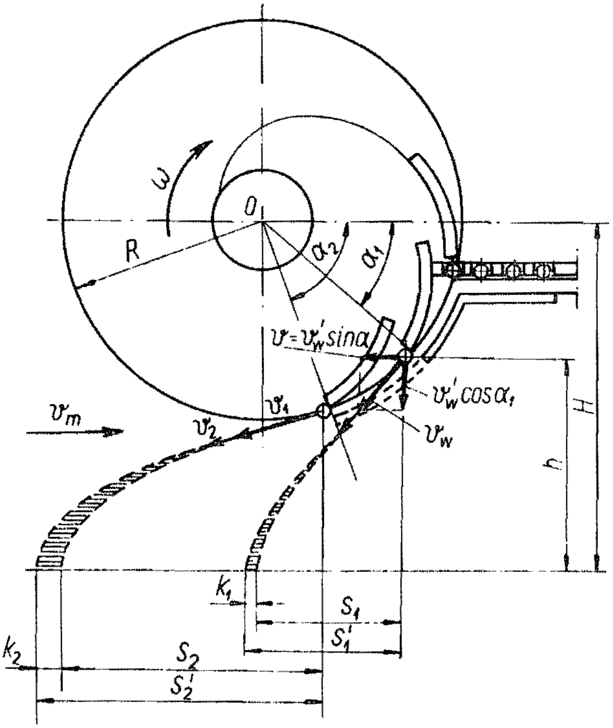


Fig. 13.69. Dependence of the length of the flight path of seeds on the angles of the ejector's wrapping by the slideway.

hence

$$t = \frac{S_1}{v'_w \sin\alpha_1}$$

On substituting in (13.10), we shall obtain

$$H - R\sin\alpha_1 = v'_w \cos\alpha_1 \frac{S_1}{v'_w \sin\alpha_1} + \frac{gS_1^2}{2(v'_w)^2 \sin^2\alpha_1} = S_1 \cot\alpha_1 + \frac{gS_1^2}{2(v'_w)^2 \sin^2\alpha_1}$$

$$S_1 \cot\alpha_1 + \frac{gS_1^2}{2(v'_w)^2 \sin^2\alpha_1} + R\sin\alpha_1 - H = 0$$

hence $$S_1 = (v'_w)^2 \sin^2\alpha_1 \Big| -\cot\alpha_1 \pm \frac{1}{\sin\alpha_1}\sqrt{\cos^2\alpha_1 \frac{2g}{(v_w)^2}(R\sin\alpha_1 - H)}$$

This formula indicates that with an increase of the angle α, there is an increase in S_1 and, therefore, the scattering K of seeds along the bottom of the furrow left by an opener increases also. Our own investigations have proved that in seeding calibrated beet seeds pushed by the ridge of the ejector's teeth, the peripheral speed of their ends should not be in excess of 0.4 m/sec and when seeds are ejected by the frontal surfaces of teeth — it should be higher than 1.5 m/sec. Such results were obtained with all plate perimeter indents being filled with seeds.

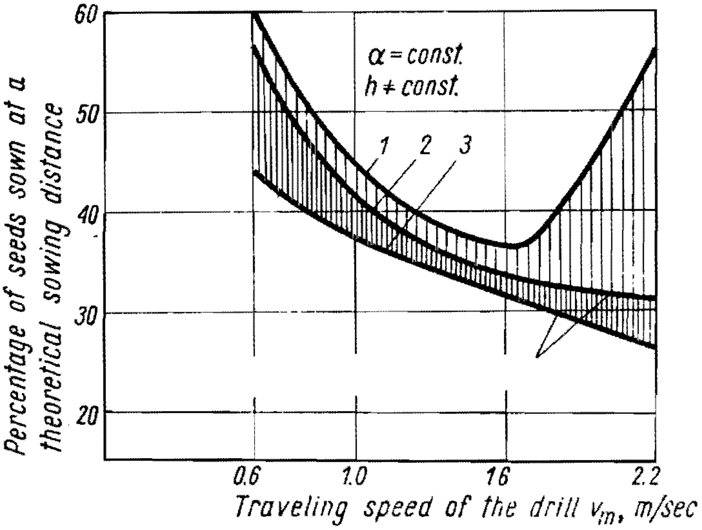


Fig. 13.70. Dependence of the percentage amount of seeds deposited at theoretical distances on the traveling speed v_m for two levels of free fall: *1* — ejector's characteristics; *2* — $h = 2$ cm; *3* — $h = 10$ cm. (According to the present authors' investigations).

At a fixed transmission ratio of the drive of the ejector (of given dimensions), the increase in the peripheral speed of teeth is achieved by increase in the speed of travel. It is obvious that this is accompanied by an increase in the peripheral speed of the indented plate. The increase in the speed of the plate leads to a poorer filling of the indents with seeds and, consequently, to a deterioration in the uniformity of seed deposition in furrow.

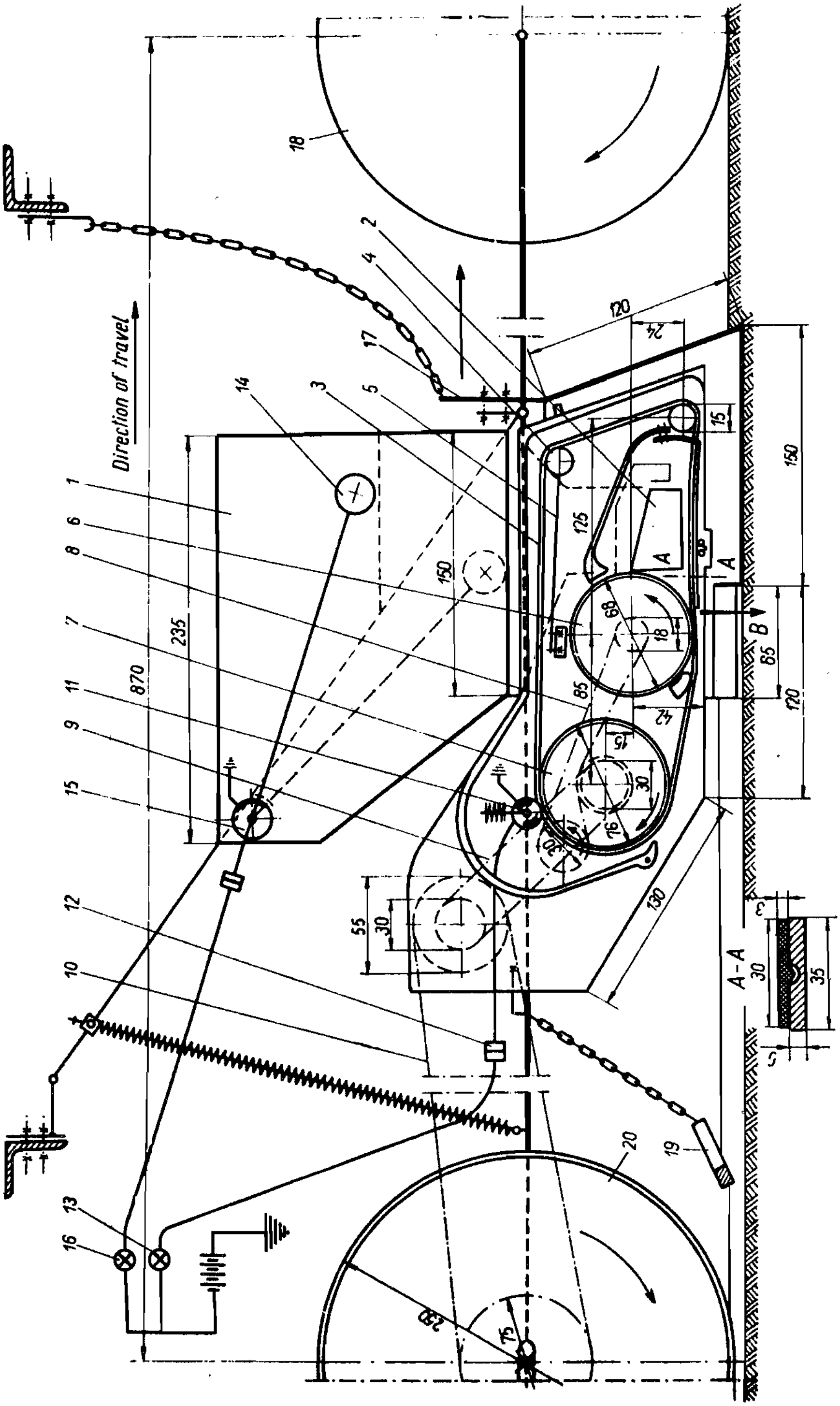
Figure 13.70 shows an example of the percentage quantities of seeds deposited at theoretical distances as depending on the speed of the drill's travel for two levels of free falling of seeds. This diagram indicates that with increase in the peripheral speed of the plate the percentage of obtained required distances between seeds falls off as a result of the deterioration in the filling of the plate indents with seeds (formation of gaps in distribution of seeds). To maintain a moderate peripheral speed of the plate and at the same time to ensure an adequate peripheral speed of the ejector's teeth, it is necessary to design an ejector of the greatest possible diameter but with a reduced number of teeth. In addition, in order to reduce the speed of rolling down of seeds alongside the slideway, it is necessary to increase the coefficient of friction by the application of a rough slideway surface. The size of indents on the plate's perimeter as well as the dimensions of the ejector and its teeth should be suited to the type and, therefore, to the dimensions of sown seeds (for example, to the pea, corn, onion, etc.). Such elements should, therefore, be easily replaceable.

Figure 13.71 examplifies a section of a tractor-mounted precision drill with a conveyor-belt sowing arrangement. This arrangement, located in a housing made of aluminum alloys, consists essentially of a continuous sackcloth-rubber belt having appropriate holes (∅ 6 mm) in which are placed beet seeds and of a driven repeller wheel located at the contact point of the belt and the slideway. At the line of holes, the conveyor belt has at its underneath a projection ridge which enters into an appropriate groove on the surface of the slideway. In this way is obtained a correct running of the conveyor. A repeller wheel rotating in the opposite direction to the belt's shifting facilitates the falling out of seeds placed in the conveyor belt's holes.

For a higher speed of the drill ($v_n \approx 6$ km/hr), a replaceable conveyor belt has been provided with two parallel rows of alternately arranged holes. This is so because a single-line conveyor belt would travel too quickly and, as a result, a substantial quantity of seeds would not be able to be placed in the holes. A double-line conveyor belt has two continuous ridges, and the replaceable slideway — two grooves.

Seeds arrive from the box by a gravity chute through a lateral opening in the housing. The conveyor belt and repeller wheel are, as shown in the schematic diagram, driven by a pressing wheel through a V-belt

Fig. 13.71. Example of a conveyor-belt precision drill (after Stanhay): *1* — seed box; *2* — orifice in the lower part of the box; *3* — belt having a row of holes; *4* — tension roller; *5* — spring; *6* — repeller wheel; *7* — belt-driving roller; *8* — chain transmission; *9* — V-belt transmission; *11* — circuit breaker; *12* — capacitor; *13* — flash bulb; *14* — weight bob resting on the surface of seed material; *15* — circuit breaker; *16* — signal lamp; *17* — connection of the opener with the drill's body; *18* — supporting wheel; *19* — coverer; *20* — pressing and driving wheel.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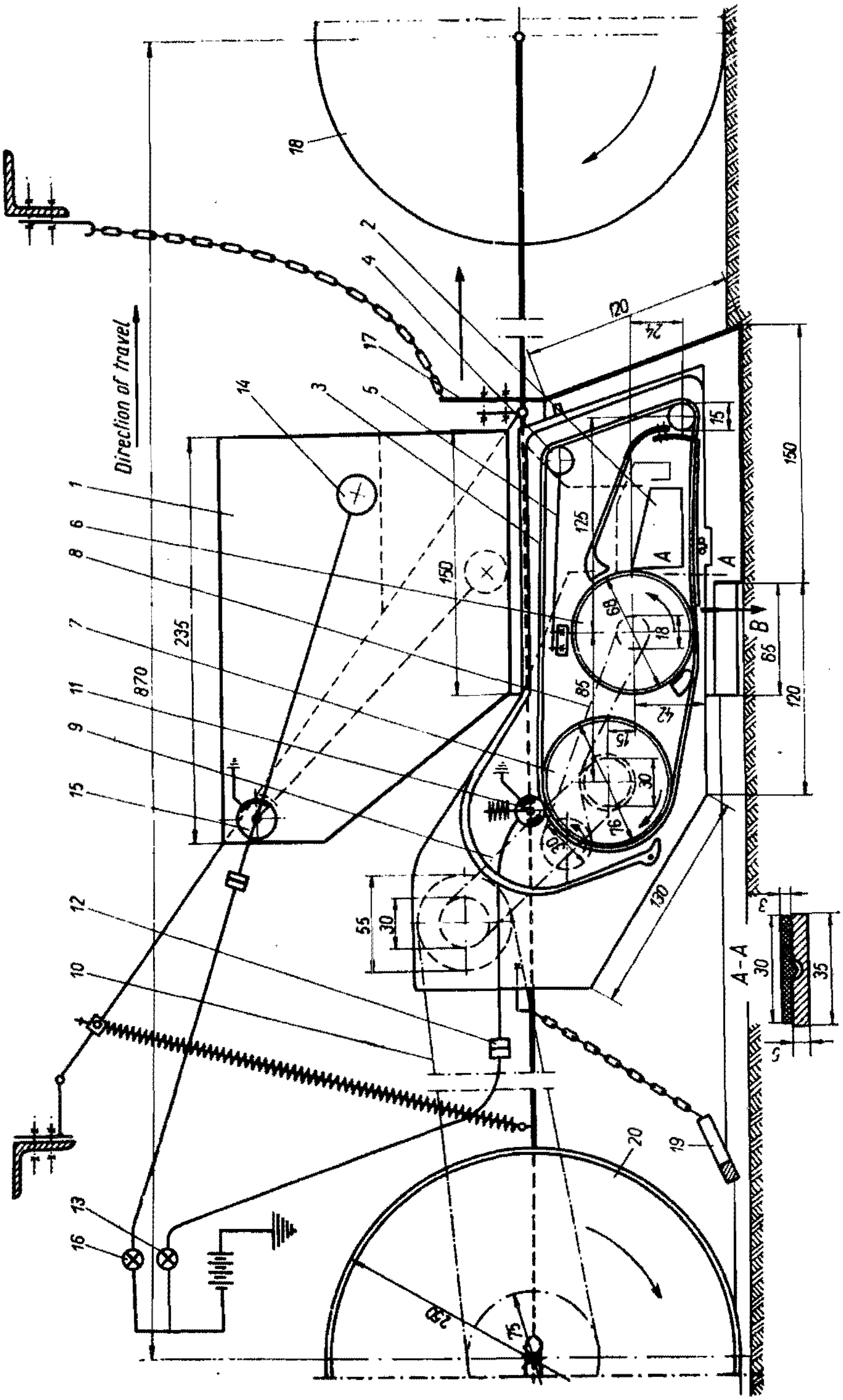
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transmission and two chain transmissions. An appropriate tension of the conveyor belt is obtained by means of two small additional rollers, the upper one being suspended on a spring. Each section of the drill is equipped with a separate frame to which are rigidly fixed the front roller leveling the field surface, the opener, drill's body, and the rear pressing wheel. The depth of seeding is varied by lowering or raising the opener in relation to the section frame and subsequently fixing it in position with bolts.

Individual sections are linked by articulated joints with the main frame by means of links which also serve to lift the section into its transport position. The driving wheel which also exerts pressure on the furrow, is loaded by a spring and, in addition, in order to increase its adherence to the ground, is tired with a rubber band.

The described drill is equipped with an electric control circuit which is used by the driver for continual control of the conveyor belt's travel and the amount (level) of seeds in the box. Control of the conveyor belt's travel is by means of a circuit breaker driven by the belt. The rotating circuit breaker causes an intermittent burning of the lamp (red light). Changes in the length of intervals in the burning of the lamp indicate an irregular traveling of the conveyor belt and, consequently, an irregular spacing of individual sown seeds.

Constant control of the level of the seed surface in the box is by means of a second circuit breaker fixed on the lever arm at the end of which is a weight bob resting on the surface of the seeds in the box. When the surface of the seeds lowers beyond a certain level a break in current flow follows which subsequently causes a break in the burning of the second (green) lamp. Both lamps are placed on the tractor's dashboard.

Figure 13.72 shows an example of a section with a vertical rotor sowing unit together with a schematic diagram of the drives. The bottom of the seed box constitutes a sector of the periphery of a vertical rotor on which in two rows are located cells of which one row is shifted by half a scale unit in relation to the second row of cells (diameter of cells — 5 mm, cell depth — 4 mm). Cells with seeds move downward along the enclosing shield (slideway). A baffle, whose lower edge is positioned immediately above the surface of the vertical rotor, prevents the entrainment of redundant seeds.

Instead of the baffle can be used a repeller wheel revolving in the opposite direction to the vertical rotor's revolutions (Fig. 13.73). Underneath are situated two electors which thrust out seeds from cells. The ejectors tapering ends, enter into the grooves in between the cells. The vertical rotor with cells is — similarly as in the previously described types — driven by the pressing wheel through a V-belt transmission and

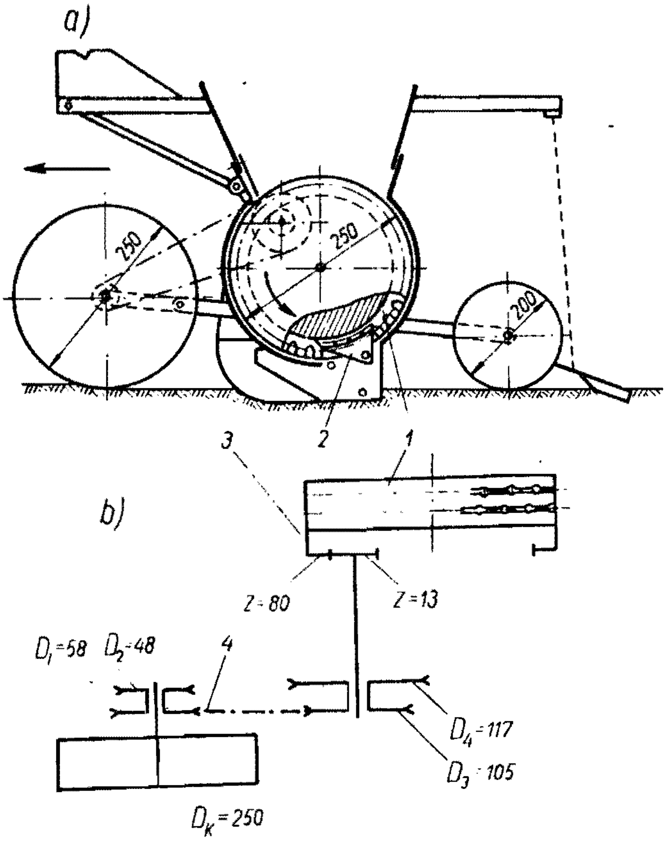


Fig. 13.72. *a*) Schematic diagram of a vertical rotor drill (Fähse system): *1* — rotor having two rows of cells; *2* — seed ejectors; *b*) Diagram of drives; *3* — toothed-wheel rim; *4* — V-belt transmission.

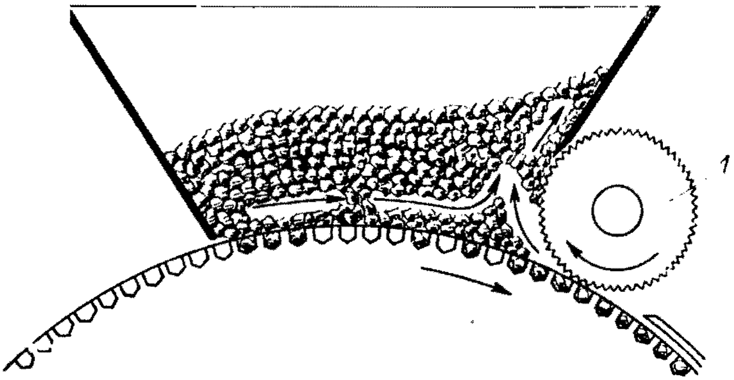


Fig. 13.73. Example of the application of a repeller wheel instead of a baffle: *1* — **repeller wheel.**

a toothed gear. At the back of the opener is, as usual, placed a pressing wheel together with a furrow coverer. The axle of this wheel is connected with that of the supporting wheel by means of two flat bars forming together a frame. Inside this frame is placed the sowing unit, the manner in which this unit is connected with the frame enabling the alteration of the level of setting of the opener and, thus, of the depth of sowing (20–55 mm).

By an appropriate alteration of the reciprocal setting of V-belt wheels, four different transmission ratios and, thus, four different row spacings of seeds (3.5; 4; 4.5; and 5 cm) can be obtained. The number of cells on the rotor's perimeter in a single row is 125, and the weight of the unit — some 30 kg. In certain types the cylindrical shield, serving as a slideway, is replaced by a roller pressed by the action of the spring against the rotor (Fig. 13.74). Seeds pressed into the cells by the roller are subsequently thrust out by the ejector.

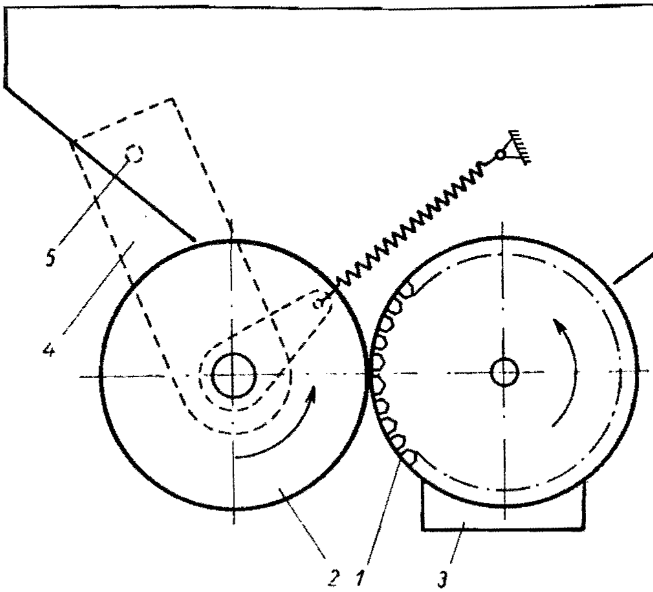


Fig. 13.74. Example of the application of a thrust roller pressed against the rotor (after Massey-Ferguson): *1* — rotor; *2* — pressing roller; *3* — ejector; *4* — arm; *5* — axis of arm rotation.

Another type of seed metering device is shown in Fig. 13.75. In this drill, vertical rotor with three-row orifices located on its perimeter is used. Seeds, after getting into the orifices in the upper part of the rotor, revolve together with the rotor in a casing preventing them from dropping out before the appropriate point of time. The lower part of the

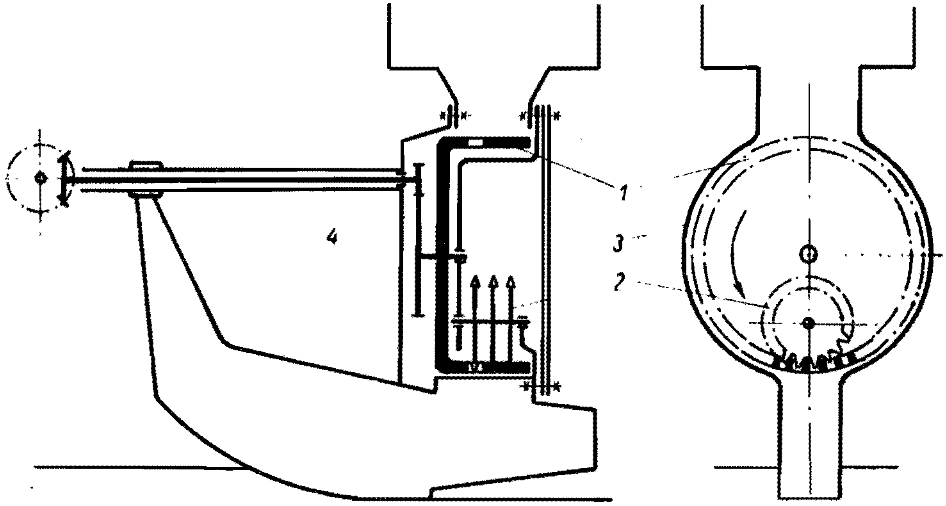


Fig. 13.75. Example of a vertical rotor drill (multicut system): *1* — rotor with orifices; *2* — ejectors; *3* — casing; *4* — gear transmission driving the rotor.

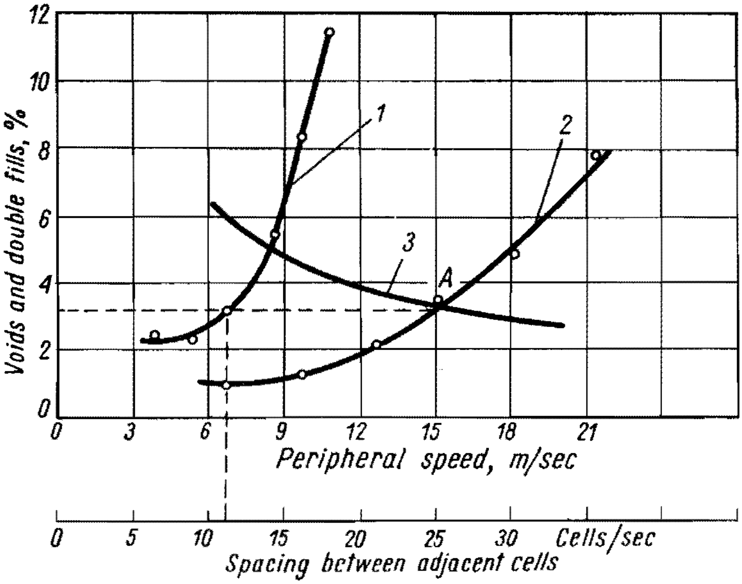


Fig. 13.76. Example of the dependence of the number of void cells and doubly filled cells on the peripheral speed of the rotor (according to our own investigations): *1* — voids in a rotor with a single row of cells; *2* — voids in a rotor with a double row of cells; *3* — double fills in a rotor with two rows of cells.

cylindrical casing is in the form of parallel wings of a runner-type furrow opener. In that part, inside the rotor are installed toothed seed ejectors. The drill described has been designed for precision drilling of calibrated corn seeds and in sowing of such seeds it satisfactorily meets the requirements. The sowing of prepared sugar-beet seeds on the one hand is, with this type of drill, much less efficacious.

The peripheral speed of the rotor and the extent of its diameter have a considerable effect on both: the number of cells unfilled with seeds, and that of doubly filled cells.

Figure 13.76 presents the percentage value of void cells occurring with two extents of diameters in rotors and the percentage value of doubly filled seed cells as depending on the peripheral speed of a rotor of a given diameter. In a rotor of small diameter cells are, at the moment of filling, more obliquely positioned than in rotors of larger diameter. The consequence is poorer conditions of filling with seeds, and an increase in the percentage of void cells. In order to reduce the inclination of cells it is necessary, with a small rotor diameter, to diminish the length of the sector of filling and thus to reduce the number of cells filled in a unit of time. However, to obtain the required row intervals it is necessary, in the course of a second, to fill a determined number of cells, but then the logical consequence is that instead of a two-line, a three-line unit is required. But this finally results in too wide a furrow left by the opener.

Reduction of the peripheral speed of cells is conducive to the double filling of seeds, a fact indicated by the curve in the diagram. An increase in this speed, on the other hand, increases the number of voids as a result of the shortening of time span during which seeds can get inside the individual cells. A solution to the problem must, therefore, be a compromise (for example, point A shown in the diagram).

Today there are several design solutions of pneumatic precision drills, but their principle of operation nevertheless remains the same. Namely, it consists in creating a vacuum in appropriately small orifices which suck in prepared sugar-beet seeds and, on subsequent getting into the region of normal pressure, release them into the opener.

Figure 13.77 shows an example of a pneumatic drill. Seeds get by a gravity chute inside a chamber compartment in which is placed a wing agitator. One side of the compartment consists of a circular rotor with 42 openings, 2 mm in diameter, each revolving together with the agitator. The rotor referred to adjoins, over a considerable part of the periphery of the pitch circle of openings, a duct hollowed out in the casing, in which a vacuum is created by fan driven by the tractor's PTO shaft. Seeds clinging to the openings revolve together with the rotor until they reach the delivery tube inlet. The openings with the seeds subsequently find their way to an aperture in the lower part of the casing which is beyond the vacuum region, and as such is under normal atmospheric pressure which causes the seeds to drop off the openings and fall down to the bottom of the opened furrow. A specially employed scrapper clears off redundant seeds clinging to individual openings leaving single seeds only.

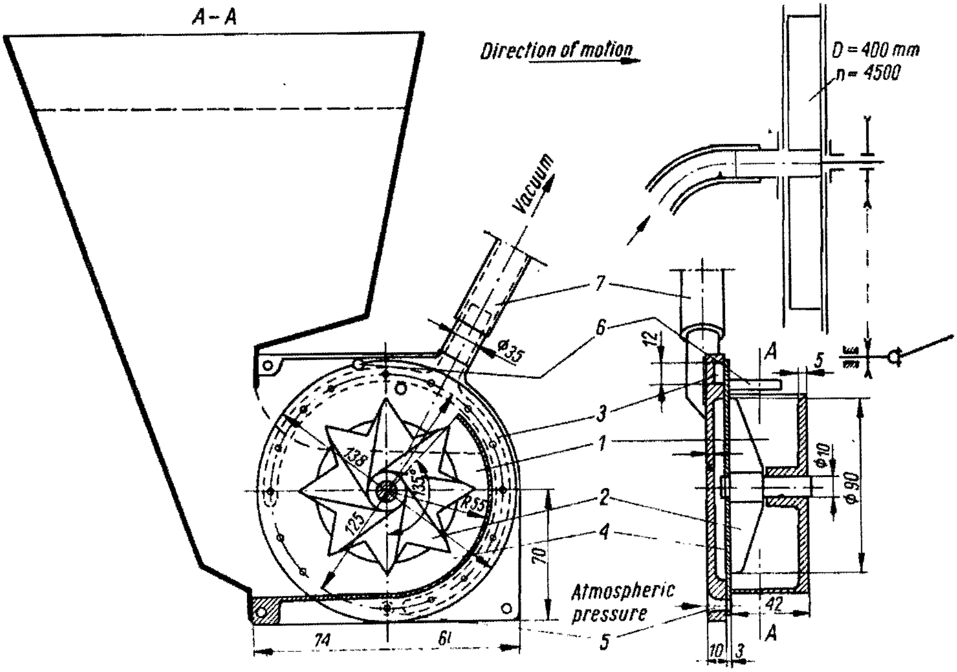


Fig. 13.77. Example of a pneumatic precision drill (Socam system): *1* — seed compartment; *2* — agitator; *3* — vacuum duct; *4* — rotor adjoining the duct and revolving together with the agitator; *5* — atmospheric pressure inlet tube; *6* — suction tube.

Practice has shown that small fragments of segmented seeds or whole sharp-edged seeds are apt to block the openings, thus causing gaps in the continuity of seeding. This disadvantage is considerably reduced in sowing pelleted seeds devoid of sharp edges. In this particular, however, case the use of an agitator is undesirable, since such might have easily crushed the pelleting. This is the reason why pneumatic drills used for seeding pelleted seeds are designed with no agitators.

Similarly to the types of drills already indicated, the moving parts of the drill in question are driven by the thrust wheel through a chain transmission. The application of three pairs of sprocket wheels of appropriate diameters allows three-row spacings (4.35 cm, 4.77 cm, and 5.3 cm) to be obtained.

Change of the seeding depth within limits of 2–10 cm is achieved by altering the position of the frame wheels with which the individual sections are connected. The weight of a single section amounts to some 45 kg, the capacity of the container is about 2 liters (3.6 kg), the diameter of the pressing wheel — 450 mm.

Table 13.2 includes some characteristic results of the present authors' laboratory tests concerning the drills described above. These results concern the percentage amounts of seeds deposited at assumed ranges of section lengths with the row spacing between individual seeds amounting in theory to 4 cm. Dimensions of prepared seeds employed in investigations were 3–4 mm.

Table 13.2

Percentage Quantities of Seed Deposited in Individual Sector Ranges

Type of drill	Seed spacing cm	0—2	2—6	6—10	10	Drill's speed m/sec
Hagno's horizontal plate system	%	4.2	91.6	4.2	0.0	1.1
Stanhay's single-row conveyor-belt system	,,	9.9	83.5	6.6	0.0	1.1
Stanhay's double-row conveyor-belt system	,,	22.3	69.3	8.4	0.0	1.6
Fähse's vertical plate system	,,	2	86	10	2	1.3
Pneumatic Socam system	,,	19.6	75.5	4.7	0.2	1.3
Agrotechnical requirements	,,	15	75	10	0	

The percentage amount of seeds deposited in sectors 0–2 cm long characterizes the compaction of sowing (possibility of simultaneous sowing of two or more seeds). The percentage of seeds deposited in 6–10 cm sectors indicates the frequency of voids. The table indicated presents that the best results were obtained with the use of a Hagno-type drill, and the worst — with belt-feeding units. It should, however, be emphasized hat with increase in the speed of a Hagno-type drill, the percentage of seeds deposited over 2–6 cm sectors markedly deteriorates.

Figure 13.78 shows the percentage amounts of seeds as a function of row spacing for three different types of drills.

The operational quality of a drill can also be characterized by the index K of the uniformity of seed deposition in rows, expressed by the following equation

$$K = \frac{a}{a'}$$

where

a — row spacing between adjacent seeds accepted in theory,

a' — actual spacing achieved.

If $K = 1$, precision of sowing is perfect, at $K < 1$ there occurs voids and at $K > 1$ — overpopulation of seeds (sowing of double seeds).

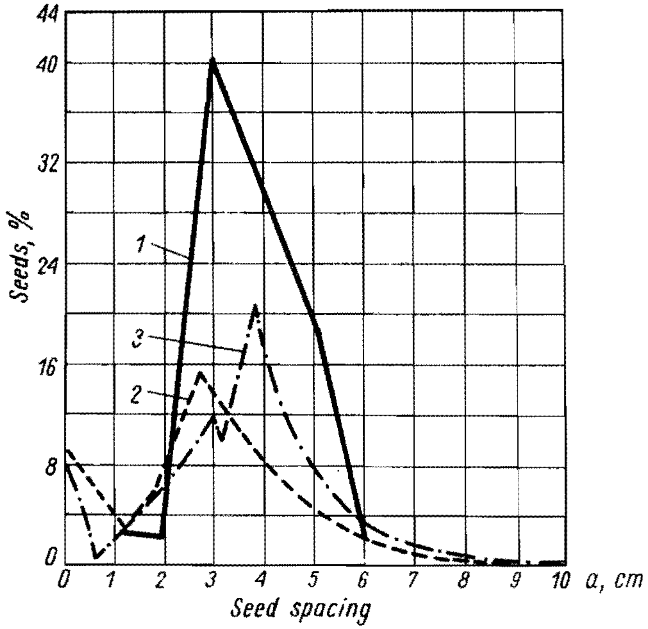


Fig. 13.78. Example of the percentage amounts of seeds spaced at different rotor intervals: *1* — Hagno-type drill; *2* — Stanhay-type drill; *3* — Socam-type drill. (According to the present authors' investigations).

Results listed in Table 13.2 were obtained under laboratory conditions. Under field conditions, the precision of drilling operations deteriorates.

The peripheral speed of seed rotors, as well as the linear speed of sowing belts, is calculated according to the required spacing a between the adjacent seeds in the opened furrow.

If the amount of seeds i is sown at intervals of a cm, the length of the path traveled by the drill amounts to

$$s = ai$$

and the time of travel to

$$t = \frac{ai}{v_m} \tag{13.11}$$

In this period of time, there must be filled and emptied i cells or belt cavities. For a seed rotor this is expressed by the formula

$$t = \frac{ia_1}{v_0} = \frac{ia_1}{\frac{\pi r n}{30}} = \frac{30 \cdot ia_1}{\pi r n} \tag{13.12}$$

where

v_0 — rotor's peripheral speed (m/sec),
r — radius of the rotor (m),
n — rpm of the rotor,
a_1 — distance (interval) between two adjacent cells (m).

Comparing the formula (13.11) with (13.12), we obtain

$$\frac{30 \cdot ia_1}{\pi r n} = \frac{ai}{v_m}$$

where v_m is the speed of the machine, m/sec.
Hence

$$v_m = \frac{\pi r n a}{30 a_1}$$

For the sowing belt

$$v_m = v_t \frac{a}{a_1}$$

where v_t is the speed of belt travel, m/sec.

Assuming v_m and a and r, and also adopting for a given type of seeds the size of openings and the interval unit a_1, one can easily calculate the required number of revolutions of a vertical rotor. The speed of belt travel can also be easily calculated analogically. The interval unit a_1 depends on the size of calibrated seeds and the number of rows of cells. For example for sugar beet, seeds of a size within limits of 3.5–4 mm and for openings situated in a single row — $a_1 = 6$ mm, for two-row openings — $a_1 = 4$ mm, and for three liners — 2 mm. Assuming the speed of the drill's travel to be consequent on the drive from the pressing wheel, it is necessary so select the transmission ratio of the drives and the rotor's diameter that the rotor's peripheral speed should not create too many voids (over 4 percent). The same applies to the linear velocity of the sowing belt.

Figure 13.79 shows an example, according to the present authors' investigations, of the number of long intervals devoid of seeds as depending on the traveling speed of the sowing belt with a single line of openings.

Today, precision seeding is more and more frequently accompanied by spraying with herbicides of individual rows aimed at preventing the development of weeds' seeds which may occur in the drilled rows. In addition to this, a single-row distribution of fertilizers is occasionally employed with the sowing of seeds.

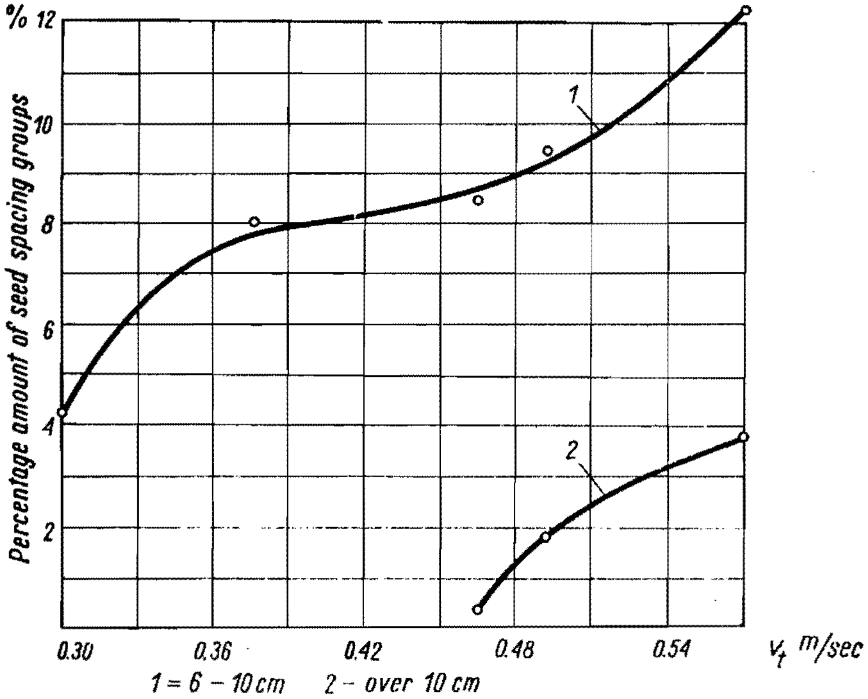


Fig. 13.79. Example of the dependence of groups of void (seedless) sections on the belt's linear speed in a Stanhay-type drill. (According to the present authors' investigations).

In sowing of very small seeds, such as, for example, clover seeds, and particularly in the case of grass seeds in cultivation of greenlands, special-type broadcasters can be used. Such sowing machines can distribute seeds in such a manner that these are broadcast either by strips or over a whole spot of a field surface.

In Fig. 13.80 is shown diagrammatically a brush-type sowing device. It embodies a revolving shaft on which are fitted at regular intervals wooden rollers having on their periphery rigid cylindrical brushes. The sheet-iron bottom of the box has rectangular openings, and underneath is a strip with round orifices which can be manually shifted along the box axis and which serves to control the rate of seeding. The strip orifices are so arranged that under the rectangular openings there can be found from one to six of such.

The two-wheeled drill described above distributes seeds stripwise. It can be manufactured as a hand-operated barrow seeder or as a single-horse machine of 3-m working width.

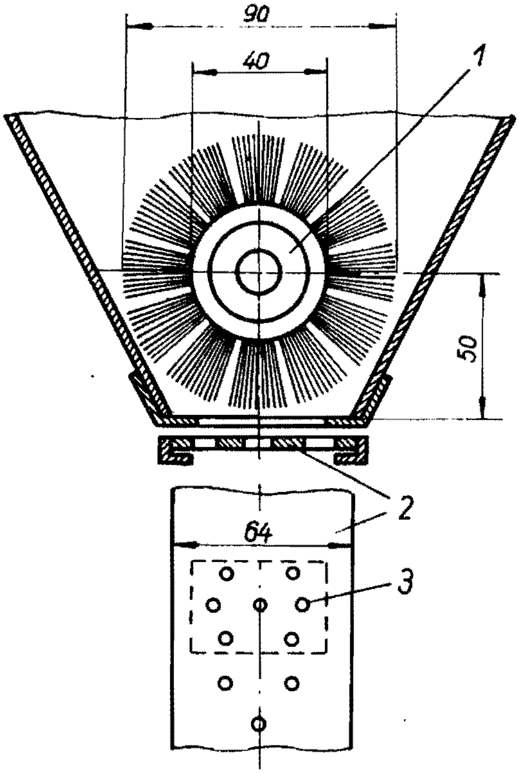


Fig. 13.80. Example of a brush-type device for sowing grass seeds: *1* — brush roller; *2* — sliding plate for adjusting the rate of seeding; *3* — openings releasing seeds.

In sowing grass seeds, a mixture of different types and sorts of such is commonly employed, and it is required that the appropriate quantitative proportions between the individual components be possibly maintained during sowing. Grass seeds differ considerably, however, from one another as regards dimensions, weight and the type of cuticle. Seeds may have a smooth and polished or a coarse and pily surface. For this reason, in a mixture of different seeds set in a rotary motion by revolving brushes, smooth and small seeds are apt quickly to get to the bottom, while the larger and pily grains remain on the top. In consequence, a mixture of a considerably changed composition is sown. The use of some other types of elements revolving inside the box (such as, for example a "butterfly" rotor) exhibits a similar disadvantage.

Figure 13.81 shows a concept diagram of a seeding unit for sowing grass seeds which practically involves no change of the composition of the distributed mixture. The sowing (distributing) element consists of a tube having on its periphery shallow and narrow grooves (1 mm wide, and 0.6–0.8 mm deep) spaced at 10 mm intervals. In the upper part of the grooved roller are placed two felt belts extending over the length of the box. One of these belts (the rear belt) permanently extends along the tube's periphery and serves a dual purpose: to provide sealing of the tube and to clear it of seeds which might have incidentally got stuck in a groove. The front belt can be positioned closer or farther off the grooved surface (a narrower or wider sowing run). In this way the amount of released seeds is adjusted according to requirements.

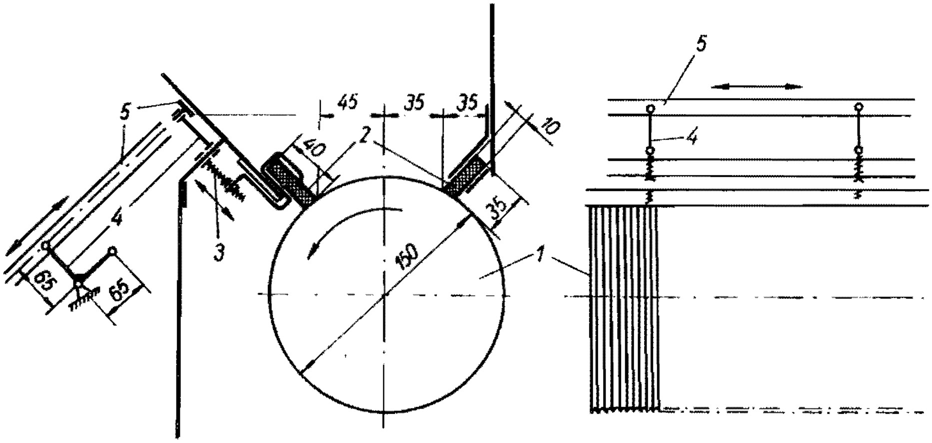


Fig. 13.81. Example of a seeding unit for sowing grass seeds: *1* — grooved surface tube; *2* — felt inserts; *3* — adjusting screw for precision control of the sowing groove; *4* — lever system for adjustment of seeding rate (width of sowing groove); *5* — slat located over the length of the seed box.

The width of the sowing groove can be altered by means of rectangular levers connected at one end by an articulated joint with a slot which is able to be shifted longitudinally. In order to achieve a uniform width of the grooves over the entire length of the box (3 m), several adjusting screws are fixed at intervals alongside the box. To prevent a displacement of the seed mass inside the box, a wooden plank is laid on the distributed material. This simple method has proved sufficiently efficacious.

The revolving-grooved tube performs well the role of a seed-distributing element, provided the peripheral speed is not too high. If the unit's traveling speed increases, thus causing the grooved roller's peripheral speed to increase, the slipping between seeds and the grooved surface increases, too, with the result of reduction of the required rate of seeding (Fig. 13.82). The revolving tube causes only a slight mixing of the seed mass. The level of free falling of seeds is 250 mm. Box capacity, about 0.5 cu m. The seeder described is a two-wheel horse-drawn machine or mounted on a tractor. The grooved roller is driven by one of the ground wheels through a spur gear transmission with one repleceable gear. The transmission ratio $i = 1.8$ or 2.6. At a speed of about 6 km/hr, the peripheral speed of the grooved roller amounts to some 0.3 or 0.2 m/sec. A lower peripheral speed is envisaged for small seeding rates (15–20 kg/hectare). The results of our own investigations have shown that the percentage share of the individual components of the mixture, above all due to the prevention of the seed mass inside the box from revolving, varied only insignificantly at different seeding rates. Thus by means of a very simple structure there has been achieved a result unparalled by any of the hitherto produced seeder types. As protection against wind action — special suspended screens can be employed.

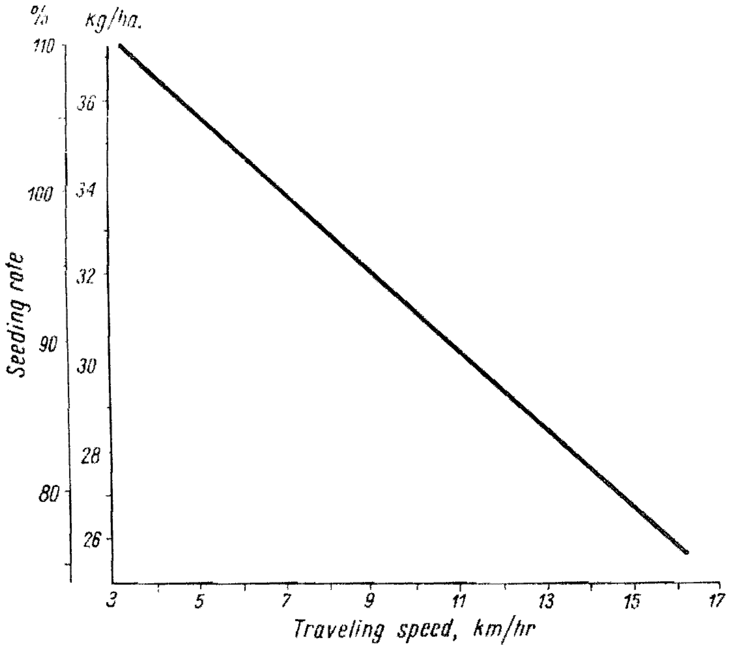


Fig. 13.82. Dependence of the seeding rate on the traveling speed of the drill shown in Fig. 13.81. (According to the present authors' investigations).

Among special-type drills should also be included vegetable seed drills as also several- and single-row barrow seeders. Today, in sowing vegetable seeds, precision drills are more and more frequently used. Designs of small barrow drills will be left out of our considerations.

There exist also special-type drills for sowing forest seeds. Finally, to the special-type drills category are also included single-row experimental-plot drills used in sowing small test areas in charge of institutes experimenting in plant cultivation.

13.10. Sugar-beet thinning machines

Assuming that in sowing prepared sugar-beet seeds with the aid of an efficient precision drill the average spacing in individual rows between sprouted seeds is 4–5 cm, the number of plants per 1 m, accepted in theory, is 20–25 units. It is also a frequent occurrence that from a single seed of two sprouts double plants develop. The result is that a 1-m area is covered by more than the above given number of beets. But for the appropriate development of beets it is required that the particular 1-m area includes not more than 4–5 plants. The excess plants should, therefore, be removed (destroyed). To this purpose is performed what is called thinning operation and next a row-crop singling operation. Manual thinning is carried out by means of appropriately wide mattocks set on long handles and enabling working in a slightly inclined position which is less tiring than a stooping posture. The singling operation, on the other hand, which consists in destroying that beet which grows too close to another, or a weed stalk, is usually done using a crooked hoe with a short handle, in order to prevent damage to the plants remaining. Although precision drilling of prepared beet seeds considerably reduces the labor expenditure required in thinning and singling, these operations are still extensively laborious (over 100 manhours/hectare).

In order to further reduce that labor expenditure, thinning devices are used which cut in individual rows, sectors of certain length, leaving in between untouched sectors of growing beets (Fig. 13.83).

Mechanical thinning can be carried out across or along the rows. In the first case are used oblique blades fastened to an all-purpose cultivator which moves perpendicular to the rows. If two sets of blades are fixed to two parallel, reciprocally sliding bars, it is then quite easy and in a continuous manner to vary the lengths of untouched sectors (Fig. 13.84). In order to protect the sides of remaining plant sectors, there are used special screening circular disks, and to maintain a uniform depth of thinning — tracing rollers positioned in front of blades. Sweeps can also be used for transversal thinning.

In thinning alongside the rows can be employed revolving blades positioned perpendicular to the plane of rotation with handles (most frequently) radially fixed to a revolving disk, or crooked swing knives or cut-out disks obliquely positioned to their direction of motion. In the first two cases the working parts are driven from outside, in the third — the rotary motion of the disks arises from their contact with the soil.

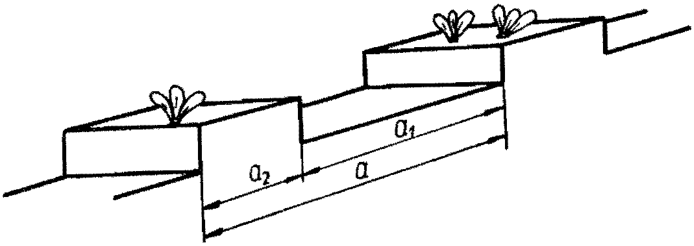


Fig. 13.83. View of a thinned sugar-beet row. (After Richarz).

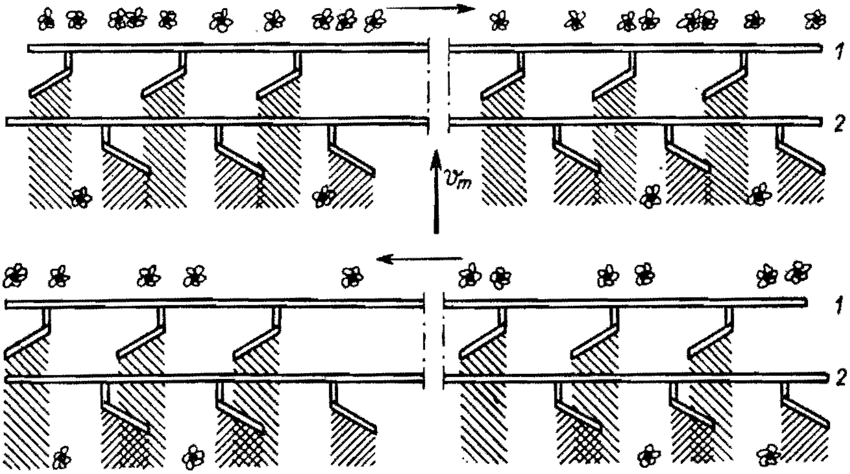


Fig. 13.84. Schematical diagram of transversal thinning with blades fastened to sliding bars. (After Richarz).

With revolving or swinging blades the ratio $\frac{a-a_2}{a} = K$ (Fig. 13.83). The quicker the motion of the thinner (v_m), the lower the peripheral speed of the blades (v_0), and the greater the length of the blades the higher is this ratio — that is

$$K = \frac{v_m}{v\,z}$$

where z is the number of revolving blades.

Let us now consider the operation of a rotary thinning device (Fig. 13.85). The peripheral speed of blades v_0 and the traveling speed of the machine v_m yield a resultant speed directed at a certain angle α, with $\tan\alpha = \frac{v_m}{v_0}$

$$\alpha = \arctan\frac{v_m}{v_0}$$

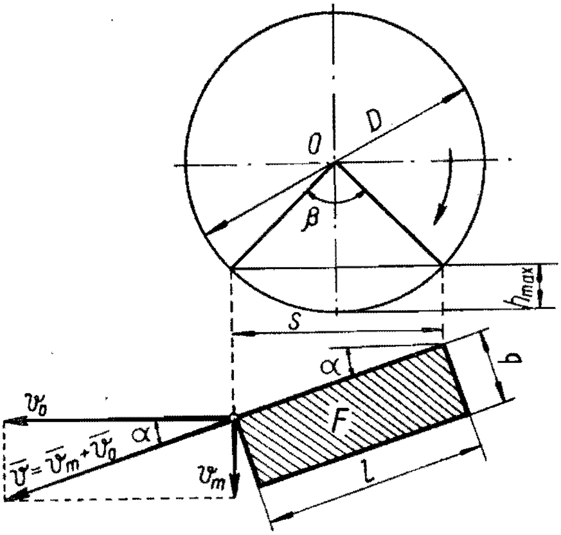


Fig. 13.85. Operation of a rotary cutting head of a thinning device. Blades positioned at an angle α in relation to the machine's forward travel. (After Richarz).

The area F thinned with a single blade travel amounts to

$$F = bl \text{ (sq m)}$$

with

$$l = \frac{S}{\cos\alpha}$$

on substitution we obtain

$$F = \frac{bS}{\cos\alpha} \text{ (sq m)} \tag{13.13}$$

The greatest sinking of the blade in the soil amounts to

$$h = \frac{D}{2} - \frac{D}{2}\cos\frac{\beta}{2} = \frac{D}{2}\left(1-\cos\frac{\beta}{2}\right) \text{ (m)}$$

hence

$$\cos\frac{\beta}{2} = 1-\frac{2h}{D} \qquad \text{and} \qquad \frac{\beta}{2} = \arccos\left(1-\frac{2h}{D}\right)$$

From the diagram it is apparent that

$$S = D\sin\frac{\beta}{2} = D\sin\arccos\left(1 - \frac{2h}{D}\right)\ (\mathrm{m})$$

On substituting the values S and α in the formula (13.13) we obtain

$$F = \frac{bD\sin\arccos\left(1 - \dfrac{2h}{D}\right)}{\cos\arctan\dfrac{v_m}{v_0}}\ (\text{sq m}) \qquad (13.14)$$

If the blades perform n rpm, the total thinned area in one minute is

$$\Sigma F = Fnz\ (\text{sq m/min})$$

On the other hand, the total area thinned and unthinned per one minute is

$$F' = 60v_m S\ (\text{sq m/min})$$

wherein the area untouched by blades is

$$F_0 = F' - \Sigma F\ (\text{sq m/min})$$

or

$$F_0\% = \frac{F' - \Sigma F}{F'}\,100$$

Individual cutting heads are most commonly driven by their own cogged wheels. However, there exist rotary thinner structures, in which all cutting heads are impelled by a central drive. Such power drive can be obtained from the PTO shaft of the tractor or from its rear wheels.

With a drive from tractor's own wheels, allowance must be made for their slipping which, depending on the type and state of the soil, and also the shape of the cogs on the wheel's periphery, varies usually within limits of 8–15 percent. An average of 10 percent can generally be assumed. The wheel slip causes the blades to transgress beyond their operating limit with the result of an increase in the length of the cut-out sector

$$v_m \approx v_K(1 - s')$$

where s' denotes the value of the wheel's forward slip

$$v_K \approx 0.9v_m$$

The number of revolutions of the driving shaft (number of blade revolutions n) is

$$n = n_w = \frac{60v_m}{\pi D_K}$$

where D_K is the diameter of the driving wheel in m.

With a transmission ratio $i = \frac{z_1}{z_2}$ and with account taken of the wheel's forward slip ($v_K = 0.9v_m$), the peripheral speed of blades can be expressed by the formula

$$n = n_m = 0.9\, i \frac{60v_m}{\pi D_K} \text{ (rpm)} \tag{13.15}$$

The peripheral speed of the knives' blades is

$$v_0 = iv_K(1 - s')\frac{D}{D_K} \approx i0.9v_m \frac{D}{D_K} \text{ (m/sec)}$$

From Fig. 13.85 it follows that

$$\tan\alpha = \frac{v_m}{v_0} = \frac{v_m D_K}{i0.9v_m D} = \frac{D_K}{D0.9i} \tag{13.16}$$

In practice

$$\alpha = 22\text{–}32^\circ$$

Substituting in the formula (13.14) the expression for tanα, we obtain

$$F = \frac{bD\sin\arccos\left(1 - \frac{2h}{D}\right)}{\cos\operatorname{arc}\tan\frac{D_K}{D0.9i}} \text{ (sq m)}$$

$$\Sigma F = Fnz = F\frac{0.9i\,60v_m z}{\pi D_K}$$

and on substituting the value n from the expression (13.15)

$$F_0 = F' - \Sigma F = 60v_m S - F\frac{0.9i\,60v_m z}{\pi D_K} = 60v_m\left(S - 0.9z\frac{iF}{\pi D_K}\right) \tag{13.17}$$

$$F_0\% = \frac{F' - \Sigma F}{F'}100 = \left(1 - F\frac{0.9i\,60v_m z}{\pi D_K 60v_m S}\right)100 = \left(1 - F\frac{0.9iz}{\pi D_K S}\right)100$$

Substituting $F = \frac{bS}{\cos\alpha}$ we obtain

$$F_0\% = \left(1 - \frac{0.9izb\frac{S}{\cos\alpha}}{\pi D_K S}\right)100 = \left(1 - \frac{0.9izb}{\pi D_K\cos\alpha}\right)100$$

On substituting $\alpha = \operatorname{arc}\tan\frac{D_K}{D0.9i}$ from the expression (13.16) we finally obtain

$$F_0\% = \left\{1 - \frac{0.9izb}{\pi D_K\cos\left(\operatorname{arc}\tan\frac{D_K}{D0.9i}\right)}\right\}100 \tag{13.18}$$

The expression (13.17) indicates that the unthinned area of the sector is greater, the smaller are the number of blades z, the transmission ratio i, the area of the cut-out sector F, and the driving wheel's diameter D_K. And it follows from the formula (13.18) that at given transmission ratio i, the areas of unthinned sectors increase with a reduction of z, blade length b and with an increase of the cutting head's diameter D.

For the purpose of gradual reduction of the number of plants in the rows, the thinning operation can be repeated twice. The first thinning operation uses a smaller number of blades, but of greater length than in the second. If — for example — in the first thinning $z = 8$ and $b \leqslant 50$ mm, then in the second thinning $z = 16$ and $b \leqslant 25$ mm. In the first case are obtained more widely distributed sectors, but of greater length, and in the second case these are more crowded, but shorter in length. The second thinning operation can be carried out with the machine passing in the opposite direction alongside the previously thinned rows (Fig. 13.86a) or in the same particular direction as shown in Fig. 13.86b.

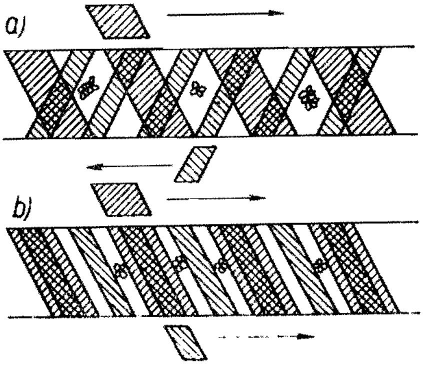


Fig. 13.86. a) Double cross thinning by change of the machine's direction of motion; b) double thinning performed in the same direction of machine's motion. (After Richarz).

Depending on the density of population of the remaining beets, a third passing can be made with the use, instead of blades, of revolving elastic steel rods. If the revolving blades are driven by their own wheels, the number of their impacts against the soil in the course of travel over a certain determined path, is obviously dependent not on the traveling speed but on the actual value of the transmission ratio. The number of cuts made, on the other hand, depends on the number of blades used and on the transmission ratio. It is, however, different when the cutting head is driven by the tractor's independent PTO shaft.

Let us now consider the position of a blade set up at a certain angle in relation to the machine's direction of travel in the final moment of a beet-row's thinning (Fig. 13.87). It is apparent from the diagram that the length a_2 of the cut-out sector depends, among others, on the value of the angle β of the blade's setting in relation to the direction of the resultant speed

$$\vec{v}_w = \vec{v}_0 + \vec{v}_m$$

With $\beta = 90°$, the longest cut-out sector a_2 is achieved with a given length of the knife l

$$a_2 = x + y \tan \alpha$$

because

$$\tan \alpha = \frac{v_m}{v_0}$$

then, on substitution, one has

$$a_2 = x + \frac{v_m}{v_0} y = x + \frac{y}{v_0} v_m = x + A v_m$$

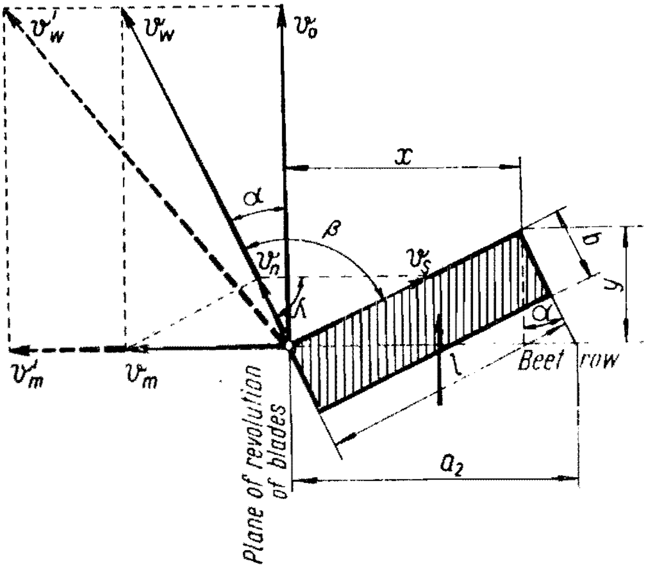


Fig. 13.87. Relation between the length of a thinned sector (a_2) and the traveling speed (v_m and v'_m) at constant peripheral speed (v_0) (hatched rectangle). (After Richarz).

Taking into consideration denotations from Fig. 13.83, the length of the sector a can be expressed by

$$a = \frac{60 v_m}{nz}$$

and denoting $\frac{60}{nz} = B$, one obtains

$$a = B v_m$$

$$a_1 = a - a_2 = B v_m - x - A v_m = (B - A) v_m - x$$

$$\frac{a_1}{a} = \eta = \frac{B - A}{B} - \frac{x}{B v_m}$$

$$\frac{a_2}{a} = \varepsilon = \frac{x + A v_m}{B v_m} = \frac{x}{B v_m} + \frac{A}{B} = \frac{a_2}{a_1 + a_2}$$

With $A =$ const and $B =$ const, and on increasing v_m, one obtains the following relations
when

$$v_m \to \infty \left(\text{that is, when } \frac{v_0}{v_m} \to 0\right)$$

then

$$\varepsilon \to \frac{A}{B}; \quad a_2 \to \infty; \quad a_1 \to 0 \quad \text{and} \quad \eta \to \frac{B-A}{B};$$

when

$$v_m \to 0; \quad \varepsilon \to \infty; \quad \text{then} \quad a_2 \to x;$$

when

$$a \to 0$$

then

$$a_1 \to -x \quad \text{and} \quad \eta \to \infty.$$

In conclusion, it should be stated that the increase in the speed of the thinning machine causes, with the angle $\beta = 90°$, an increase in the lengths of the cut-out sectors in rows ($a_2 > a_2$). In practice, the operational speed averages 3.5–5 km/hr.

To obtain a fair thinning at the least possible power loss, a slide cutting is necessary characterized by a value $\tan\lambda = \frac{v_s}{v_n}$.

For heavy soils $\tan\lambda \approx 1.05$, and for light soils $\tan\lambda \approx 1.09$. This corresponds to $\lambda = 46.5°$ and $\lambda = 47.5°$. A constant value of the angle λ can be kept by giving to the blade a convex shape according to the logarithmic curve.

In addition to the revolving blades, there can also be used for thinning double-edged oscillating blades set at a right angle to a oscillating arm. With such motion of the knive blade its path of traveling constitutes clearly a sinusoid (Fig. 13.88). It follows from the diagram that

$$S = 2r\sin\frac{\beta}{2} = 2r'i$$

where

r' — radius of the crank,

i — power transmission ratio,

$$h = r\left(1 - \cos\frac{\beta}{2}\right)$$

With an oscillating movement of the blade its speed changes as is known from $v_0 = 0$ to $v_{0\,\max} = iv_K$ (iv_K is the peripheral speed of the crank pin), the numerical value of these changes as also the resultant speed and its direction being, of course, dependent on the peripheral speed of the driving crank, the value of the transmission ratio, the length of the rocker arm, and on the speed of the thinning device.

For $S = 200$–300 mm and $\beta = 30°$, and also $h = 35$ mm, the length of the rocker arm is 400 mm.

Oscillation-type thinning devices require a rectilinearity of rows and also great accuracy in following their lines. As is clear from the diagram, a sideward deviation from the row line or a deflection in the symmetry axis of the blade's oscillating movements gives rise to considerable changes in the lengths of the segments (a_1 and a_2) and with higher deflections a_1 can even drop to zero, with the result that the blade no longer reaches the row.

The unit's traveling speed, as also the variable speed of the blade give rise to changes in the value of the angle α (Fig. 13.87) and, therefore, to changes in the value of the slide cutting.

For the purpose of wider distribution of rows, are occasionally employed double oscillating blades spaced at a certain distance one in front of the other.

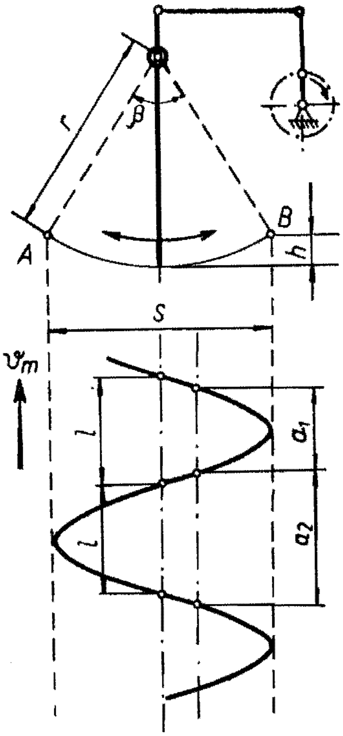


Fig. 13.88. Operational diagram of an oscillating-type thinning blade.

Oscillating devices may consist of two, three or more sections (in practice, no more than six sections are encountered). The number of sections should be equal to the total number — a half, or one third — of the furrow openers. Each of the sections is connected by an articulated joint with the crossbar or the frame. Thinning device sections constitute replaceable working elements in an all-purpose cultivation implement, horse drawn or mounted on a tractor. There exist also thinning devices as special tractor-mounted machines. In both cases, manual control is necessary, which necessitates an operator's saddle and an appropriate steering system.

In Fig. 13.89 is shown a schematic diagram of a section of a rotary thinning device mounted on the frame by means of a four-bar linkage. In this unit the depth of thinning is limited by an adjustable slade. To obtain a proper thinning it is necessary that the blade penetrates to a depth of at least 15 mm. The slade can be made in the form of a curved plate passing along the row or a bifurcated one straddling the row. Instead of a slade my also be used a supporting wheel (of some 200 mm in diameter and 50–80 mm wide), rolling also along the row. For drive may be used instead of steel cogged disks, tired wheels of appropriate treads preventing excessive slipping (D_K = 550–700 mm).

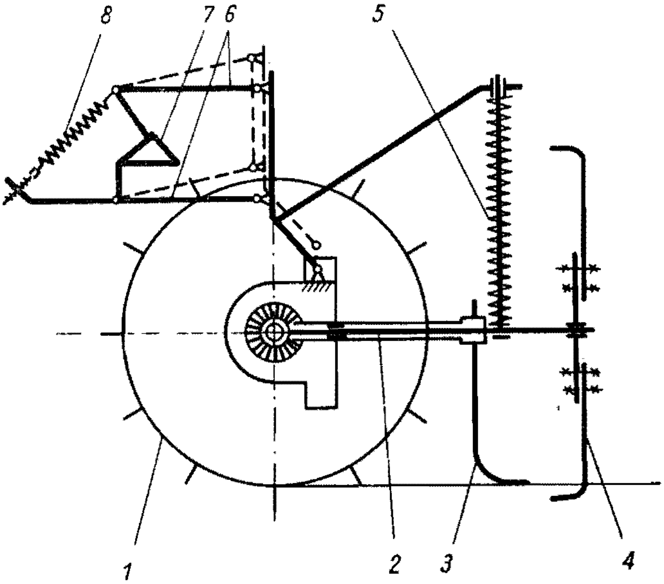


Fig. 13.89. Example of a rotary thinning device's section: *1* — driving wheel; *2* — driving shaft; *3* — adjustable slade; *4* — blades; *5* — thrust spring; *6* — four-bar linkage; *7* — frame; *8* — returning spring.

In multirow rotary thinners, all cutting heads can be driven only by two wheels fixed on the ends of a beam of quadrangular cross section (Fig. 13.90). Such a structure enables the alteretion of the spacing between the individual sections, and thus the appropriate adjustment of their position to the row's width. As protection against the adjacent cutting heads becoming entangled by spurting cut-out material, as also to prevent the accumulation of the cut-out material in interrows, cutting heads are frequently shifted one in relation to the other.

The diameter of the cutting head including blades or the rods amounts to 500–550 mm (width D = 500 mm, β = 30° and S = 125 mm). The length of the shanks of the blades projecting over the disk periphery is some 120 mm, and the length of blades 40 or 20 mm (the shanks with blades are replaceable).

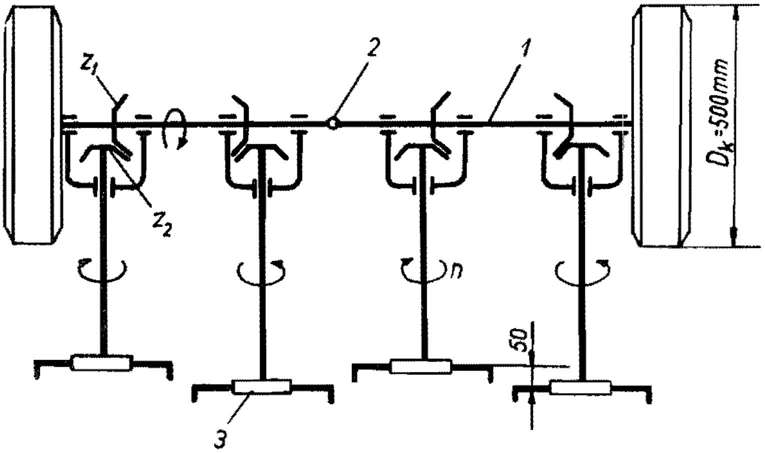


Fig. 13.90. Example of a four-row rotary thinner: *1* — square shaft; *2* — articulated joint; *3* — cutting head.

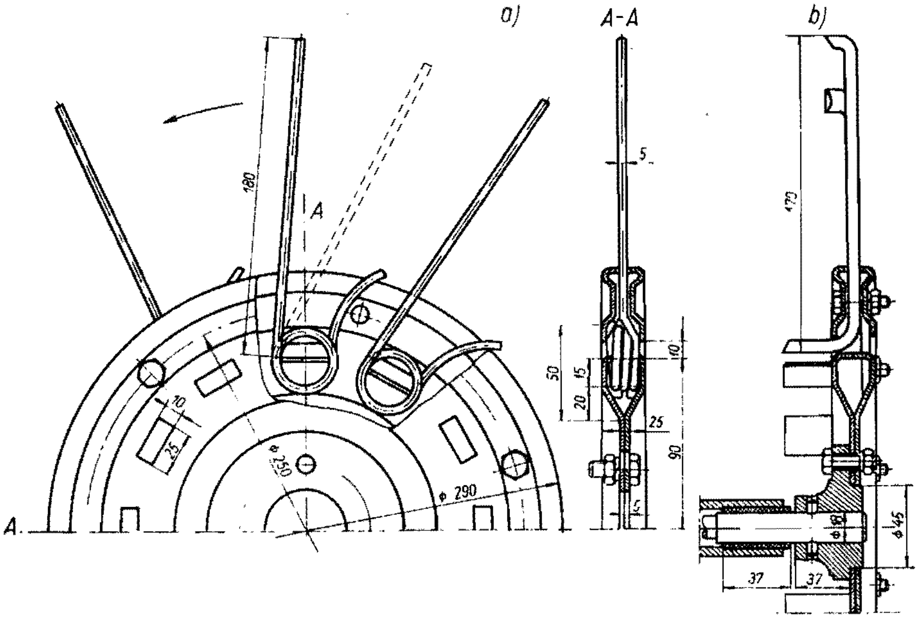


Fig. 13.91. *a*) Example of a cutting head equipped with rods; *b*) example of a cutting head with blades — cross-sectional view.

The manner in which the blade shanks or the rods are fastened to the disk should permit them to be easy removed. The number of blades used depends on the density of beets. The common usage is six long or twelve short blades. The weight of the disk together with 12 blades is some 5.3 kg, and the section's — about 17 kg. The gear ratio $i = 2:3$. To avoid shifting of the thinning device sideward, one half of its disks should revolve in the opposite direction to that of the other half.

Figure 13.91 shows an example of a cutting head's design together with the way of fastening of blades and rods.

In thinning can also be used concave recessed disks (Fig. 13.92) of some 560 mm diameter, made of sheet iron 3 mm thick. The number of recesses on the disk's periphery is 9, their width is 78 mm, depth — 100 mm. The disks are set up at an angle of 30° in relation to the thinning device's direction of motion and are revolving automatically by contact with the soil.

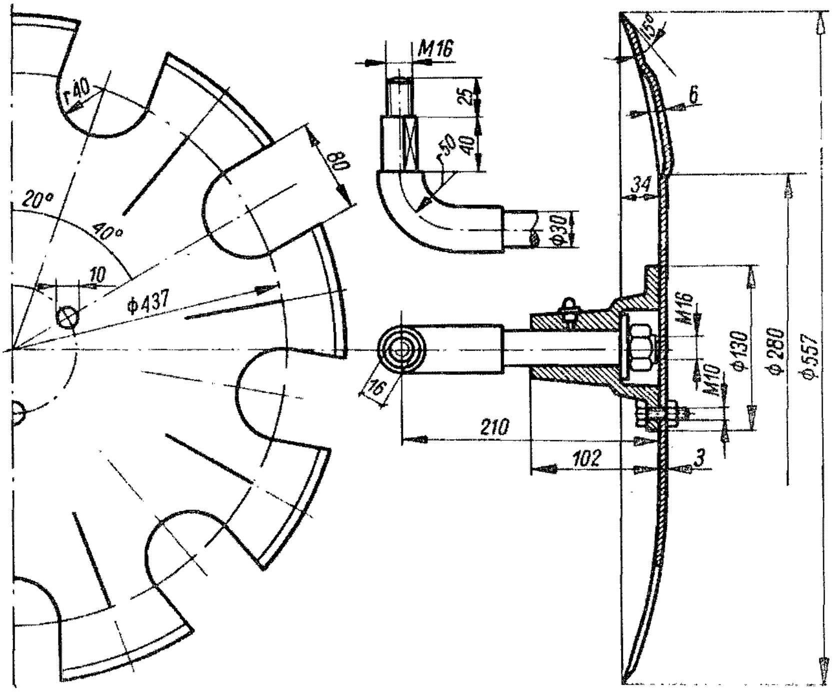
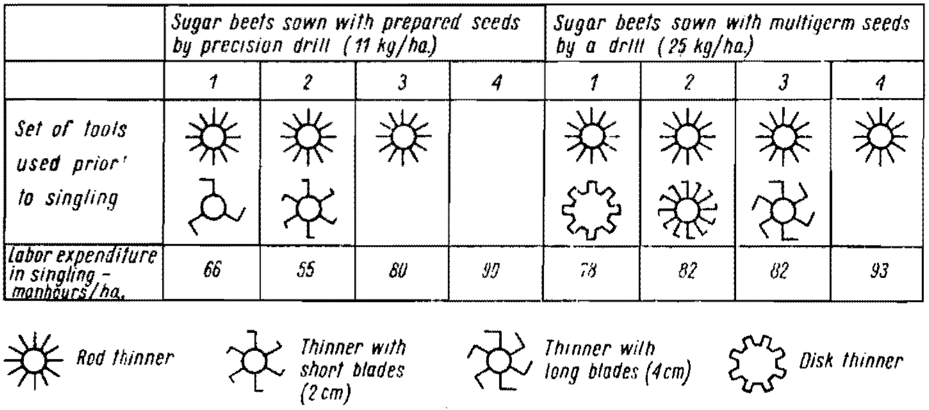


Fig. 13.92. Example of a recessed disk for thinning of sugar-beet rows.

According to our own investigations, with an original seed density of 430,000/hectare some 55 percent of sprouted plants were thinned with the use of disk thinners. The average length of cut-out sectors was some

16 cm, and the average length of the left-over sectors about 8.3 cm, with the disks' slipping value of more than 28 percent.

The thinning disks are replaceable working parts in an all-purpose implement. In such an implement thinning disks are, similarly to blade disks, generally mounted on a four-bar linkage, and the depth of thinning is controlled by the appropriate setting of the supporting wheels. The number of toothed disks should, like that of blade disks, be equal to the number of rows in the seeder. The number of successive thinning operations depends on the density of plants. Mechanical thinning of plants facilitates and lowers considerably the manual labor expenditure required in singling operations, but may eventually lead to a lowering of the beet crop. The optimum final stock should amount to some 85,000 plants/hectare. The thinning devices now in use cannot, therefore, produce a row of spacing of single plants at intervals of 20–25 cm. In other words, manual labor cannot be entirely eliminated by mechanical devices. Even under most favorable conditions of germinating, arising from precision sowing, there always arises a need of auxiliary operations with the use of manual tools to perform corrections in the spacing of plants and, above all, to carry out singling at those points where double beets have developed. Nonetheless, the use of thinning devices can considerably reduce labor expenditure in final cultivation procedures. There have in fact appeared in some West European countries prototypes of rotary singling devices in which the setting of singling elements is controlled by photoelectric cell or an appropriate electronic device, which enables in singling selection of poor plants and leave well developed intact, but these are only experiments in their toddling stage. It seems very doubtful that so expensive agricultural machine should prove rewarding not only in Poland, but also in the highly industrialized countries.



	Sugar beets sown with prepared seeds by precision drill (11 kg/ha.)				Sugar beets sown with multigerm seeds by a drill (25 kg/ha.)			
	1	2	3	4	1	2	3	4
Set of tools used prior' to singling	☼ ✤	☼ ✣	☼		☼ ⚙	☼ ✣	☼ ✤	☼
labor expenditure in singling – manhours/ha.	66	55	80	99	78	82	82	93

Fig. 13.93. Labor expenditure required in hand singling following thinning operations by different methods.

In Fig. 13.93 is shown the percentage reduction of labor expenditure in different thinning operations in precision sowing of prepared seeds of sugar beets and in normal sowing of multigerm sugar beet seeds. It should also be added that in so far as the precision sowing of sugar beet seeds is improved, the role of the singling machines is diminished.

13.11. An outline of methods for testing seeding machines

Laboratory investigations should comprise tests of the operational quality of the sowing unit of a particular seeder and the establishing of the transversal and longitudinal irregularity of sowing. In addition to laboratory experiments, there are also performed utility tests under natural field conditions. In laboratory testing can be used a measuring test stand as shown in Fig. 13.94. The mechanical unit tested on such a stand remains stationary, while in front of it passes a glued conveyor belt on which is established the distribution of released (sown out) seeds. The manner of driving the belt should enable the alteration of the belt's speed together with the appropriate simultaneous alteration of the peripheral speed of the sowing rollers. In addition, the tests in question should also be concerned with different seeding rates employed with different types of seeds.

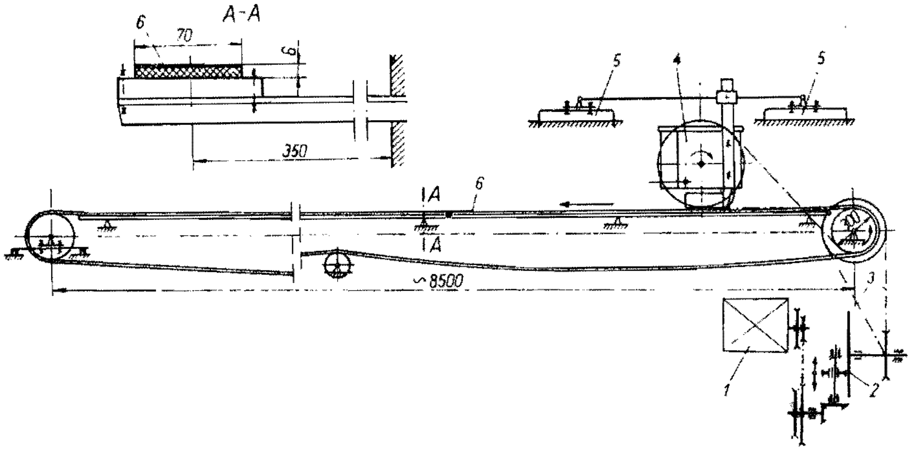


Fig. 13.94. Laboratory measuring stand for testing of sowing units: *1* — electric motor; *2* — friction-wheel transmission; *3* — V-belt transmission; *4* — tested sowing unit; *5* — brackets; *6* — glued conveyor belt.

The distributor of seed on the glued conveyor belt characterizes the operational capacity of the sowing unit investigated. The conveyor-belt stand is especially useful in the testing of precision drills. For the purpose of determining the transversal sowing irregularity, the drill is mounted on motor-driven parallel rolls (Fig. 13.95), and boxes are placed under the individual furrow openers. In adjusting the drill to the required seeding rate, use is made of the simple calculation given below.

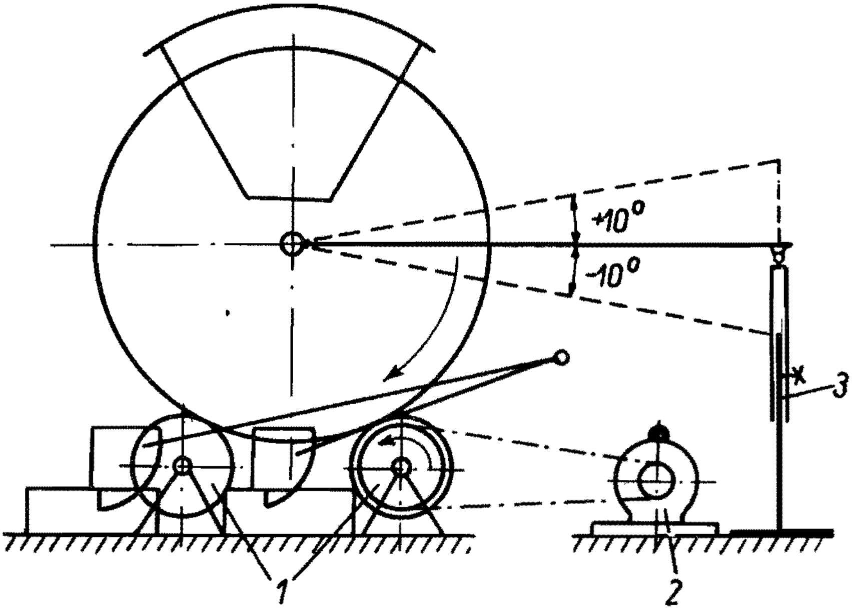


Fig. 13.95. Laboratory measuring stand for checking the transversal and longitudinal irregularity of sowing: *1* — driving rolls; *2* — motor; *3* — supporting rod.

The number of revolutions of the tested seeder's wheels in sowing of 1 hectare amounts to

$$n = \frac{10{,}000}{S_r \pi D_K} = \frac{10{,}000}{0.01 i s \pi D_K}$$

where

D_K — wheel's diameter (m),
s — interrow width (cm),
i — number of rows (of openers).

At the required seeding rate Q_{ha}, the quantity of sown-out seeds during a single revolution of the wheel amounts to

$$q = \frac{Q_{ha}}{n} = \frac{Q_{ha} i s \pi D_K}{1000} \quad \text{(g/1 rev.)}$$

If during a turning test the drill's wheels perform n' revolutions, the quantity of sown-out seeds will be expressed as

$$Q = qn' = \frac{Q_{ha} is\pi D_{K} n'}{1000} \text{ (g)}$$

A similar turning test should be performed by each utilizer prior to starting the actual sowing operation. This is done by raising seeder side adjacent to the driving wheel, and by spreading a cloth under the openers. After engaging the transmission gear, the driving wheel is rotated by hand. In the case of drills driven by the tractor's PTO shaft, the turning test is, as already indicated, performed by means of a special crank. The turing test must occasionally be repeated a number of times, before achieving the required or an approximate rate of seeding; each successive repetition of the test is preceded by an appropriate alteration of the transmission ratio of sowing units (in the case of studded rolls) or of the arrangement of the sowing rolls (in fluted rolls).

Only after the seeder has been adjusted and the boxes emptied can the actual testing procedure be started. After each successive test, the amount of seed poured into the boxes is weighed and the mean deviation and irregularity factor calculated according to the previously given formula (12.11). In addition to this, there is also determined the transversal uniformity of the drill in an uphill and downhill travel at a particular seeding rate. For this purpose, the tested drill should be inclined at an angle of $+10^\circ$ and -10° in relation to the direction of travel.

Of essential importance to the estimation of the quality of sowing is the determination of the longitudinal sowing irregularity in the case of precision drills in particular. However, determination of the longitudinal irregularity factor of seed deposition in soil is very difficult and burdened with considerable error due to the fact that not all of the seeds generally develop. Attempts were made, after a sowing under laboratory conditions, to consolidate soil rows by coating with melted paraffin, and — after cooling of the paraffin and separating the coagulated strips with seeds — to make tranversal and longitudinal sections of the soil fragments. But this has proved to be a very inconvenient method. Toady, is frequently employed the isotopic method — that is, screening the soil with gamma rays. This method, however, is also equally expensive and inconvenient, and gives no clear indication of the cylindrical dispersion of seeds in the soil. The most popular method is by determining the longitudinal irregularity of seed deposition in open furrows. To achieve open furrows after passing of openers, one must use sufficiently moist sand. It is clearly impossible, on the basis of results obtained so far, to assess the operational quality of the drill as a whole, since the method in question takes no account of the operation of furrow openers and, therefore, of the displacement of seeds arising from the sliding of furrow slopes. The "opened furrows" method can, nevertheless, be useful in the assessment of the operational properties of a seeder, and in particular in comparative investigations of different types of seeders.

After sowing the seeds into open furrows, the theoretical spacing between seeds a is calculated with the aid of the following equation

$$a = \frac{L}{z}$$

where

L — measured sector's length

z — number of seeds deposited over the measured sector's length.

Next, alongside the furrow is placed a sufficiently long wire frame the cross pieces of which form sectors called "cages". The appropriate choice of the length of the "cage" is of essential importance to the assessment of calculation results. If this length is smaller than the theoretical seed spacing, the results of measurement will, even in the case of a perfect deposition of seeds in furrow, exhibit a certain longitudinal irregularity, consequent solely on the inappropriate choice of the cage's length. The same applies to the case of the cage's length being greater than the theoretical seed spacing. It is, therefore, necessary that for each particular sowing quantity and interrow width a separate cage of appropriate length is employed. The appropriate distance of the measurement cage can be calculated by means of the following formula

$$l = \frac{100q}{Q_{ha}s} \text{ (cm)}$$

where

q — weight of 1000 seeds (g),

Q_{ha} — seeding rate (kg/hectare),

s — row width (cm).

After determining the number of single, double, treble or so void cages, as well as that of the cages containing one, two, three, or more seeds each, the numerical results obtained are classified as from the greatest number of successive void cages (for example, 5×0; 4×0; 3×0, etc.) to the class of the greatest number of cage seeds. The number of individual classes recurring is called the class quantity (z_i). In further sequence is formed a relative system whose terms (class variant) are denoted by X_i. For example, for the class 3×0 $X_i = -3$, for the class 2×0 $X_i = -2$, for the class 1×0 $X_i = -1$, for the class 1×0 $X_i = 0$, for the class 2 X_i 1, etc. The mean deviation lq_{sr} from the number of cage seeds or seeds in the class interval h is calculated according to the formula

$$lq_{sr} = h\sqrt{\frac{\sum z_i X_i^2}{z} - \left(\frac{\sum z_i X_i}{z}\right)^2}$$

where $h = 1$.
The longitudinal irregularity factor is

$$\delta = \frac{lq_{sr}}{q_{sr}} 100\%$$

where q_{sr} is the arithmetic mean of the number of seeds in a single cage (or a single class interval).

Investigations of drills should also include the determination of the effect of the speed of traveling on the variations in the required seeding rates.

It is also important to determine the amount of seeds damaged by the sowing unit tested, of the different types of seeds sown by it in different quantities. Such tests are made on a conveyor-belt measuring stand. For investigations are taken samples of seed material to the amount of 100 g (large and medium-sized grains) or of 50 g (small-sized grains). In each sample, being a reference material, is determined prior to sowing the percentage amount of seeds damaged to be compared with the corresponding equivalent after sowing.

Investigations concerned with the operational quality of drills under field conditions (laboratory-field tests) consist in the determination of the maximum and minimum depth of sowing and of the degree of seeds' covering. Tests in question should be performed on loose, medium and compact soils of optimal moisture content and thoroughly prepared leveled out surface. For the determination of the maximum and minimum sowing depth, a slat is laid across the rows, seeds (best of wheet or barley) are carefully sought, and measurement is made from the slat's lower edge.

To determine the seeds' covering degree it is first necessary to find the number of seeds to be sown over a particular path of traveling, by release of seeds into boxes placed under the tested openers. Calculation of the number of bare seeds on the soil's surface at a determined section of the path of traveling of the openers will determine the degree of seeds' covering.

In laboratory-field investigations, consideration should be given to the operation of the front and rear openers (for example, to 2 front and 2 rear furrow openers) and it is to be observed that one of the back furrow openers should run along the tractor wheel's track. Measurement of sowing depth should at least be repeated five times over sections 1-m long. Measurements of the seeds' covering degree should at least be repeated thrice over sections of 10 meters. Considering the length of the path necessary for the determination of the operating conditions of the drill and the appropriate path section required in stopping the machine, the total length of the testing plot should amount to 45–50 m. The width of the field, on the other hand, should be equal to twice the tested drill's working width.

Drill's power measurements comprising average resistance, speed and average draft power require larger field surfaces, which need not be so thoroughly evened as in the case of the previously described tests. Power tests should include measurement of both: the trractor's and drill's wheel slip.

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