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Soil Tillage in the Tropics and Subtropics

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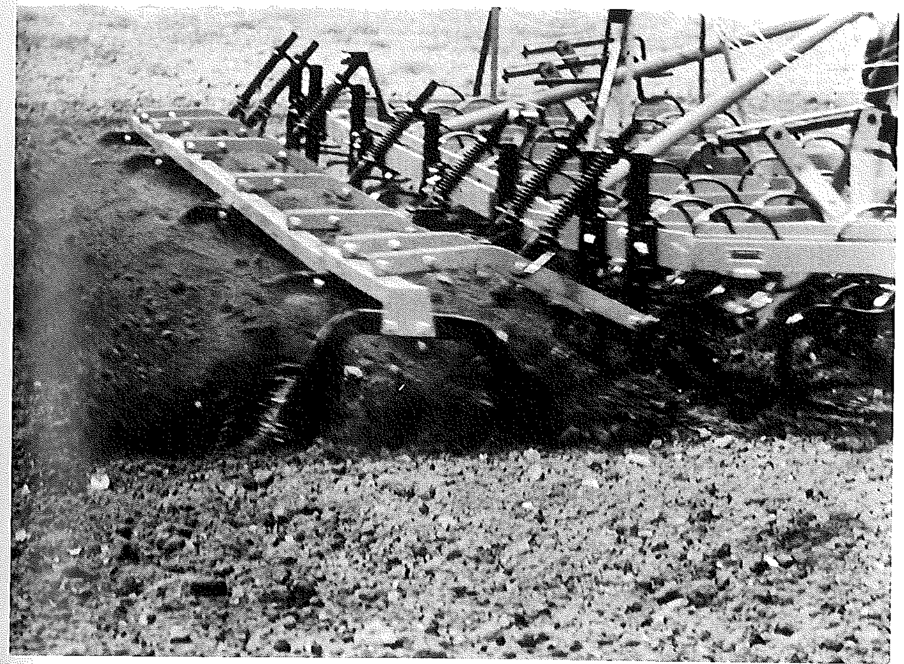
4.0 IMPLEMENTS FOR SEEDBED PREPARATION



After primary tillage operations the soil surface has to be prepared for sowing or planting. Seedbeds may be prepared in one pass in combination with primary tillage or in separate passes with longer intervals between them. This "secondary tillage" operation is intended to create optimum germination conditions with regard to the soil structure, the oxygen, water and nutrient supplies and the temperature. It may also include levelling of the soil surface and working in of manure and chemicals.

A very wide choice of implements is available ranging from the primary tillage implements (which may also be used for this purpose) and the trailer (passive) rigid and spring-tined implements to the driven (active) rotating and oscillating tools. Only the basic implements representing each group can be mentioned in the following chapters.

A warning must be given against over-intensive tillage operations on soils which are susceptible to erosion and slaking in tropical regions. On the other hand, only accurate and correct soil tillage allows precise placement of the seed and suitable soil cover (as protection against the drying-out of the seeds or damage by birds) which is essential for the satisfactory emergence of the plant.

4.0.1 Literature

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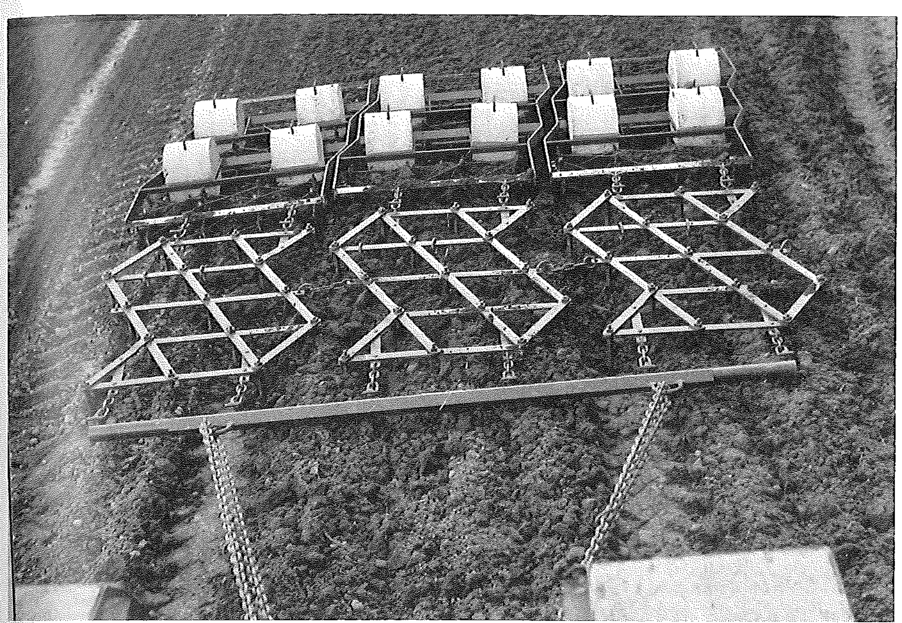
4.1 The Spike Tooth Harrow



The spike tooth harrow was the typical implement used for shallow seedbed preparation in the temperate climatic zones during the era of draught animals but because of the general desire for equipment with high capacities and fewer passes (tracks) on the field, the harrow was superseded by combination implements in many western countries.

The disc harrow is predominant in tropical and subtropical regions but simple "drag harrows", such as the "malla" in Anatolia, are still widespread.

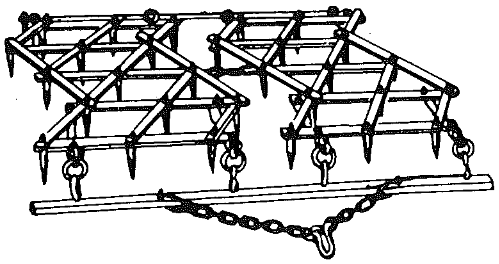


Fig. 65. Spike-tooth harrow.

4.1.1 Use And Assessment

The harrow (Fig. 65) is used for:
- crumbling the soil after primary tillage,
- loosening and roughening the surface of crusted soils,
- aerating the soil,
- working in and mixing organic material,
- working in and mixing fertilizers and chemicals,
- seedbed preparation,
- levelling (ridges, wheel-tracks, undulations).

The harrow can be employed in the tropics and subtropics if correctly used with suitable tools. Particular mention should be made of the harrow and roller combination (se Chapter 8.2).

The advantages of the harrow are:
- suitable for use on all types of soil,
- simple and inexpensive design,
- suitable for motorized and, to some extent, animal traction,
- wide range of applications because of a large variety of tools,
- by combining it with other implements and adjusting the speed of travel, the required crumbling and mixing of the soil can be achieved with a wide range of soil types. One single pass with a combination implement is often sufficient for preparing a field,
- the water infiltration capacity can be increased,
- the harrow can be adjusted to suit:
  - the available power
  - the quality of previous tillage operations
  - the soil conditions
  - adaptations to soil irregularities by various individual sections.

Disadvantages are:
- the harrow starts jumping in hard dry soils; the disintegrating action of the harrow is inadequate,
- the structure of the soil may be destroyed with over-intensive operations,
- a high travel speed is necessary,
- wheeltracks are not always levelled satisfactorily,
- greater risk of erosion when the resultant soil structure is too fine,
- it is rarely possible to prepare a seedbed with one single pass of the harrow; seedbed combinations are preferable,
- harrows tend to work too deeply and to clog up with heavy weed populations, especially on light soils.

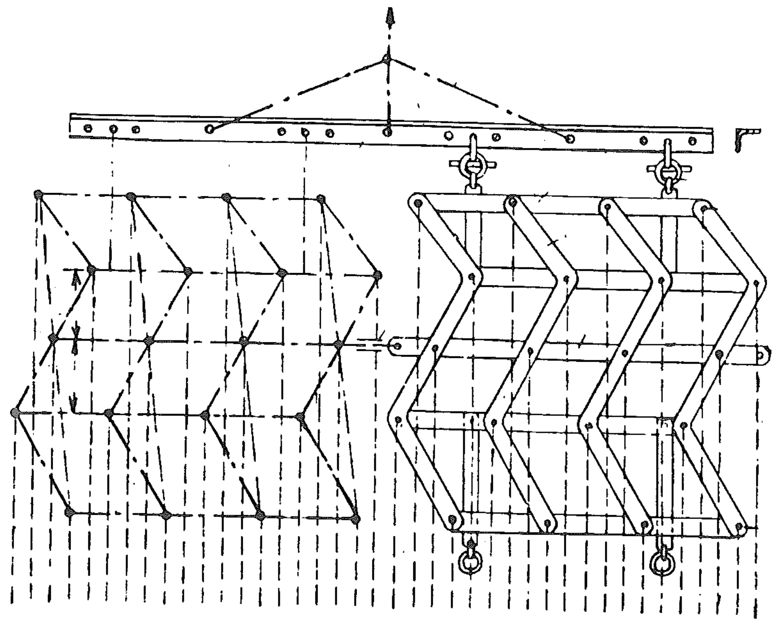


Fig. 66. Top view of spike-tooth harrow with two sections.

4.1.2 Functioning

The harrow functions in keeping with the "scratch and blow" principle. When dragged through the soil the tools run up against soil clods and break them into smaller pieces. These pieces move sideways and are smashed again by the following tools which are staggered (Fig. 66). This process is furthered by the slight swinging (sinusoidal) movement of the harrow which makes it possible to smooth and level surface irregularities but some patches may be left untilled.

On a sling or following harrow, this sinusoidal movement develops into a type of hurling motion. This harrow is designed so that, alternately, one side is held back (by the soil) while the other moves forward at twice the travel speed; the harrow "stalks" through the soil causing more intensive crumbling and mixing and some tearing out of weeds.

Harrow teeth perform a sorting operation: fine soil moves downwards while larger aggregates are transported towards the surface. For satisfactory operation the travel speed should be at least 8 km/h.

4.1.3 Linkage And Drive System

Harrows are designed for dragging or for 3-point hitch mounting by means of a supporting frame. The dragged type is hitched to the (linkage) drawbar. If the 3-point hitch mounting is used, the operation is performed in free-floating mode. No hydraulic control system is necessary. The drag harrow's depth is controlled by the angle of the line of pull. The tractor's lifting capacity should be about twice the weight of the implement. The power required for harrowing is 2-6 kW (approx. 3-8 hp) for each metre of working width at a speed of approx. 8 km/h.

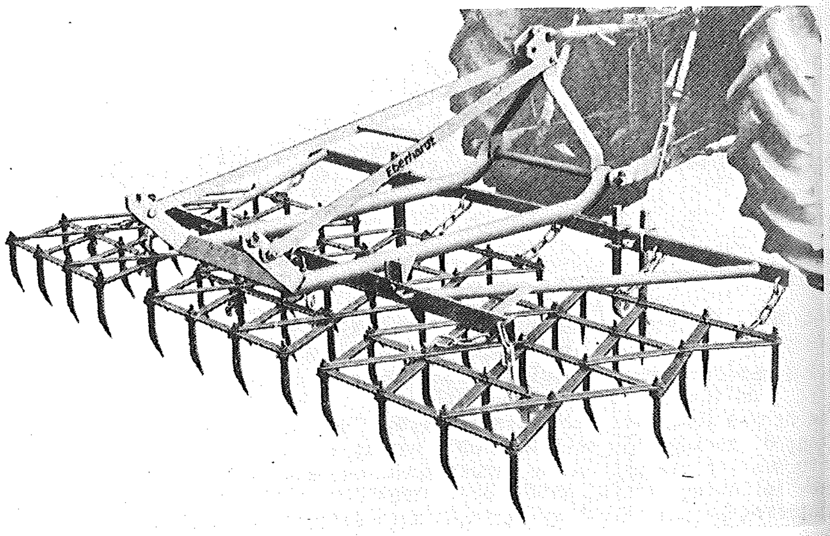


Fig. 67. Harrow with three sections in suspending frame.

4.1.4 Description Of The Implement And Tools

Depending upon the type, harrows are equipped with a rigid or articulated frame which carries the teeth (Fig. 67).

type of harrow	light	heavy	heavy zig-zag	spiked-chain	reversible spiked-chain
nr. of teeth per section (approx.)	28	20	24	77-110	24
tooth weight (g)	250-900	1200-2000	1700-2500	115-700	about 2500
tooth length (mm)	110-130	160-220	160-200	120-175	about 120
diameter (mm)	11-13	14-22	16-20	5-10	about 30
furrow width (mm)	25-35	40-55	50-80	20-45	50
working width (m)	1.00	1.00	1.00	1.50-9.00	1.20
weight (kg)	15	26-40	50-75	30-75	60

Table 8. Harrow teeth and spring teeth.

The teeth - weighing 0.25-2.5 kg (Fig. 68 and Table 8) - are arranged in sections approximately 1 metre wide. Chains attach these sections to a supporting frame or hitch bar. The furrow distance (5-6 cm) is the lateral distance between the furrows which the teeth produce in the soil. The rigid harrow has a rigid frame with cross and longitudinal bars. The longitudinal bars may have the following shapes:

a. zig-zag
b. S
c. straight (when these bars also face straight forward the frame is dragged in an oblique position).

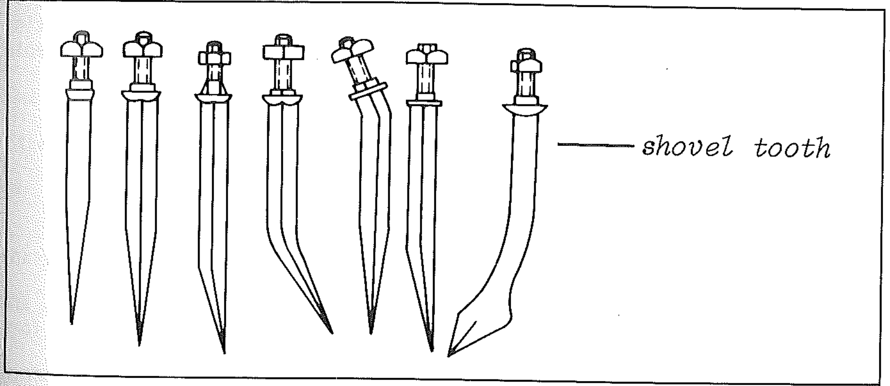


Fig. 68. Harrow teeth.

The teeth are mounted on the bar intersections. These teeth (16-20 cm long) are usually rigid but can also be made of spring steel. Teeth made of high-quality tempered steel generally have a square cross-section and various diameters, lengths and weights. Straight and curved teeth are used (the front row is generally straight and the following one curved towards the direction of travel). The teeth have a square upper section which fits into a square opening in the bar so that they do not turn.
Rigid harrows can be divided into the following categories:
- light harrows : light construction with narrow distance between furrows,
- medium harrows : medium to heavy construction,
- shovel or chisel harrows : heavy construction with shovel teeth.

In principle, the articulated harrow is designed like the rigid harrow but the frame is divided into small sections by cross and longitudinal hinges which allow those sections to follow irregular surfaces.

The spiked-chain harrow or weeder-net harrow is described separately in Chapter 4.6.

The sling harrow is a special version of the rigid harrow. It has a reinforced frame and reinforced longitudinal and cross bars so that this type of construction and linkage increase the swinging movement of a normal harrow until it becomes a hurling motion. This harrow has fixed shanks with replaceable chisels (see cultivator chisels) instead of teeth fitted to the frame by bolts. This implement is dragged by a chain connected to the (linkage) drawbar.

The grassland or spiked-chain harrow is a special chain harrow with short, knife-shaped teeth which tear out moss and lichen from the sod with only a shallow penetration. It is also used to spread straw and farmyard manure and to scatter molehills. Its design is similar to the weeder-net harrow and is either mounted (support frame) or trailed (hitchbar).

4.1.5 Adjustments, Operation

4.1.5.1 **Working Depth** - This can be changed by alternating the weight of the harrow itself or by adding extra weights to the support frame. The line of pull or 3-point hitch is also adjustable. Angled and curved teeth will penetrate more deeply into the soil than straight teeth when pointing forward but not so deeply when pointing backwards. The working depth decreases as the travel speed increases.

4.1.5.2 **Working Intensity** - The working intensity can be affected by changes in the travel speed, the type of hitching and the type of tools.
This means that:
- at low speeds (< 4 km/h): coarse structure-conserving tillage, hardly any crumbling or mixing but loosening and aeration of the soil;
- at high speeds (> 4 km/h): intensive tillage, pronounced crumbling and mixing; if the speed is too fast there is a risk that furrows will form (soil particles are thrown some distance) and the harrow will jump;
- close mounting of the harrow sections on the supporting frame: minimum swinging action by the harrow, coarse tillage which is uniform over the entire working width;
- loose mounting of the sections: lateral swinging of the harrow, intensive tillage but with untilled patches;
- sharp teeth will crumble more satisfactorily than blunt ones;
- blunt teeth will have more of a bulldozing action so that the soil will be pushed aside: more mixing effect;
- teeth which are curved forward will drag more deeply into the soil; the harrow will have a better "grip";
- as the weight of the harrow increases, the teeth penetrate more deeply into the soil;
- the front row of teeth will be raised when the line of pull is too high.

4.1.5.3 **Operation** - The harrows can easily be mounted by one man. On trailer or dragged harrows the hitchbar (whipple-tree) is connected to the tractor (linkage) drawbar by a chain.
Disadvantage: A trailer should be available for transporting drag harrows (the harrow is often transported by being dragged upside-down!).

When mounted, the harrow can be connected to the 3-point hitch system, possibly even by a quick-coupling system. For greater widths the supporting frames are fitted with folding outriggers so that the tractor can be driven on public roads without exceeding the permissible transport width.

Working with the harrow does not impose heavy demands on the driver. A clean tillage operation can be achieved by using zig-zag type harrows or by working with an overlap of approx. 10%.

4.1.6 Technical Data

The main data for teeth and teeth sections are given in Table 8.

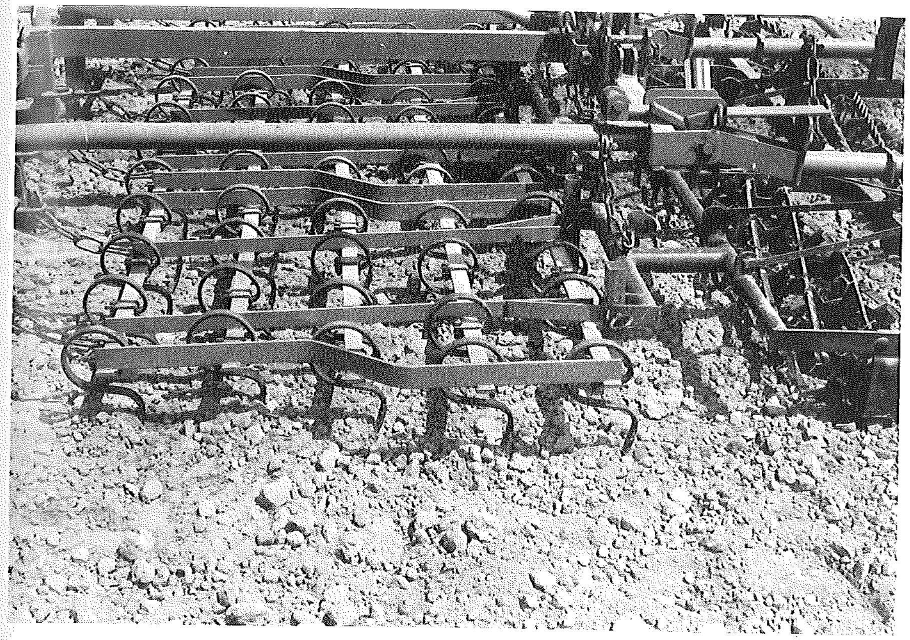
Total working width	up to 14 m
Working depth	up to 8 cm
Power required	approx. 3 kW per m width (at 8 km/h)

4.1.7 Literature

See literature of chapter 4.0.

Starkey, P. and H. Verhaeghe, 1981. A modified triangular spike tooth harrow and swamp leveller. Appropriate Technology, 8(2): 8-9.

4.2 The Field Cultivator



4.2.1 Use And Assessment

A field cultivator can be used for the following purposes:
- seedbed preparation (especially shallow and medium deep),
- stubble tillage (only spring tine cultivator; short stubble without straw),
- weed control, also in row crops,
- working in manure,
- levelling,
- grassland maintenance and clearing,
- tillage for dust mulch fallow.

At one time the use of cultivators with various types of tines declined but, as new tines made of better materials have been developed, these implements are again extensively used, especially in seedbed combinations (Fig. 69). They are employed particularly to accelerate seedbed preparation and to reduce the number of wheel-tracks. Their "precision tillage" permits precise placement of the seed, which improves the emergence of the crop.

These major advantages will be obtained only on light to medium-heavy soils in good condition (i.e. not many stones or roots). Choking of the implement can be expected in the case of high weed populations. The work is not satisfactory on difficult soils (very dry with a large proportion of foreign materials). The implements are unsuitable for stubble mulch systems because they are liable to choke.

4.2.2 Functioning

The light (Danish type) cultivator can be used on all types of soils. They are suitable only for deeper tillage because of the furrow distance of approx. 10 cm. To ensure complete coverage the working depth should be at least equal to the furrow distance.

If the tines are set at a steep angle to the soil surface, wet soil is not brought up. Hardly any choking may be expected when the implement has four crossbars with rows of tines. Special mention should be made of their pronounced levelling action, even on fields with large clods after ploughing or with wheel-tracks. Two or more passes are necessary (crosswise, if possible) on hard soils. On light soils care should be taken to avoid excessive pulverization.

The light cultivator can also be used for stubble tillage (without straw) but at least 2 or 3 passes (with increasingg depth) are needed. Occasionally the cultivator can even be used for ploughless drilling of cereals after root crops on light loose soils.

If the right type of tines are correctly arranged, this cultivator can be employed for weed control in a standing row crop and in fields laid out for furrow irrigation (Fig. 70).

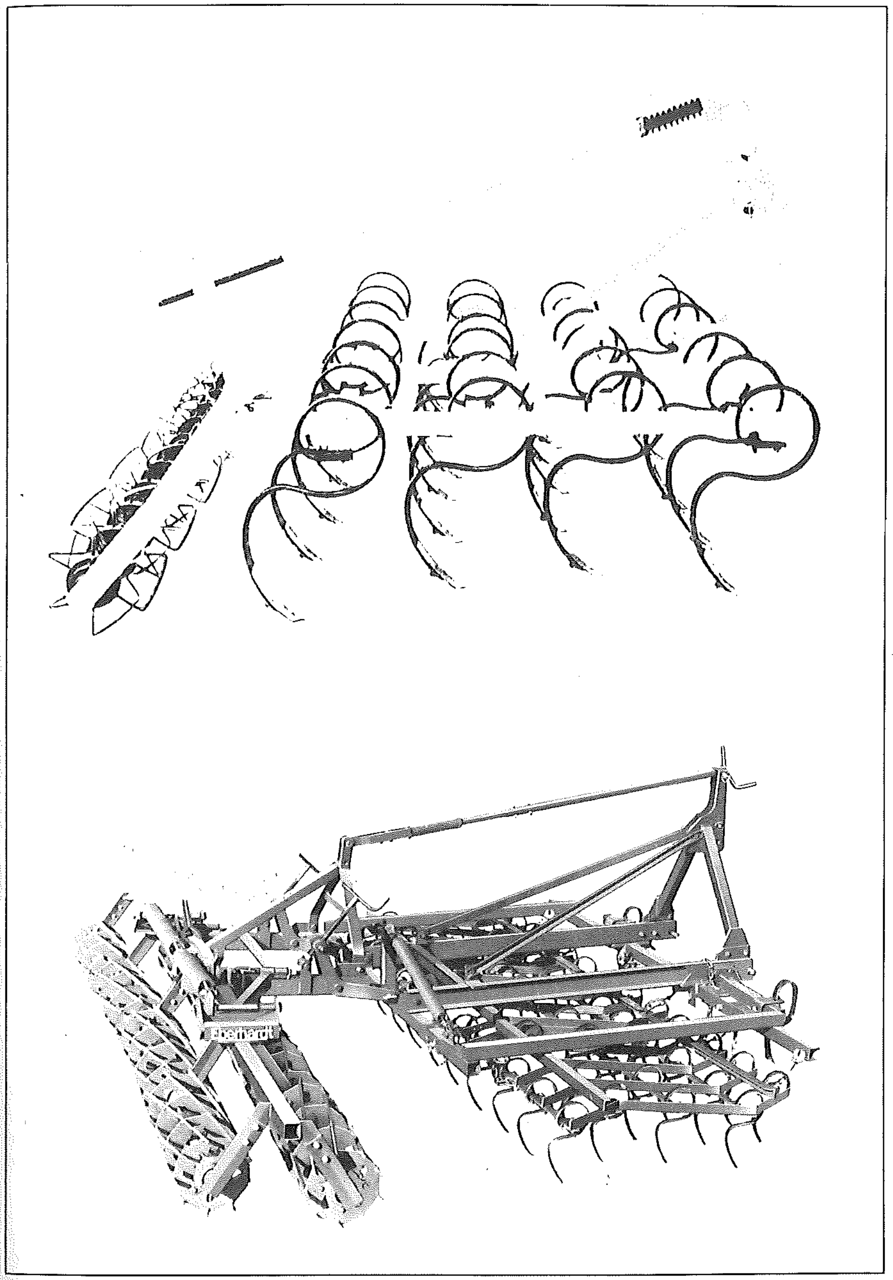


Fig. 69. Top: light cultivator (Danish type) with rear-mounted roller, Bottom: flexible tine cultivator with two rear-mounted rollers.

Flexible tine cultivators can also be used on nearly every type of soil. The strongly vibrating tines produce intensive crumbling of the soil and sufficiently shallow tillage (i.e. shallow seed deposition) is possible because of the narrow distance between the furrows (approx. 5 cm). The risk of choking is still slight with a large distance between tines (several rows). Rooted weeds are pulled upwards towards the surface and the soil is shaken off by the vibration so that the weeds will dry rapidly.

Unlike rigid harrows, flexible tine cultivators till evenly over the entire working width and depth because of the depth control (by wheels, if necessary) and the strictly-followed line of direction. Rear-mounted attachments may considerably improve the action of light cultivators and flexible tine cultivators.

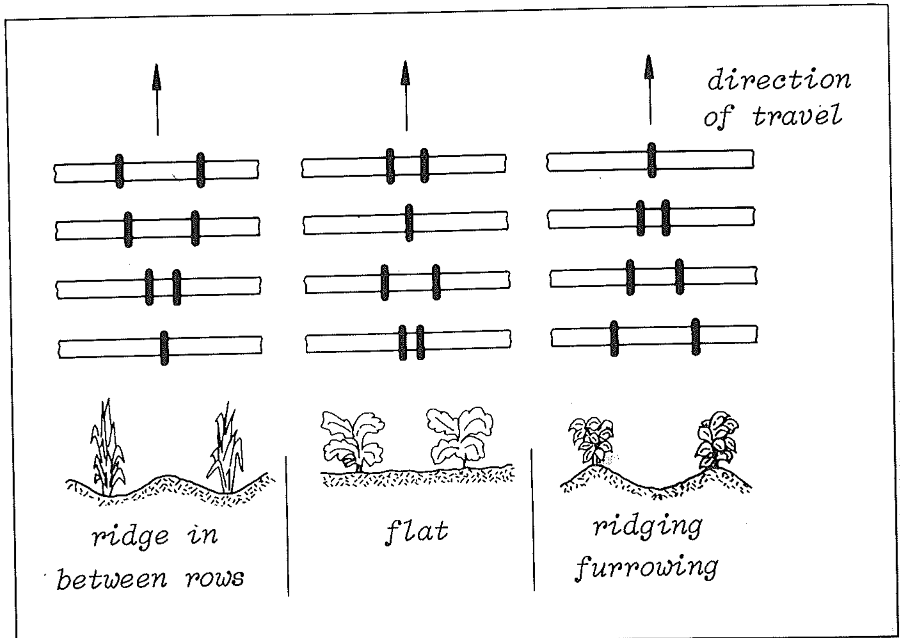


Fig. 70. Arrangement of the tines of a light cultivator with four crossbars in ridge and bed systems.

4.2.3 Linkage And Drive System

(Light) cultivators and flexible tine cultivators are mounted implements suited for the 3-point hitch systems in category I-III, depending upon their working width. Quick-coupling devices may be used since mounting and dismounting the large implements may cause problems, especially on loose soil (sinking into the soil).

The implements are mainly used in combination with harrows, packers or levellers to form "seedbed combinations". Since these implements are heavy and the centre of gravity is located comparatively close to the rear of the implement, the easing of the load on the tractor's front axle must be taken into account. Outriggers can be folded mechanically (springs) or

hydraulically on very wide implements. Care should be taken to ensure that the tines of the folded sections do not protrude too far (danger to traffic). The working speed of these implements is around 5 km/h. They require 0.75 kW per tine or around 7.5-15 kW per metre of working width. The power required for seedbed combinations is between 11 and 18 kW per metre.

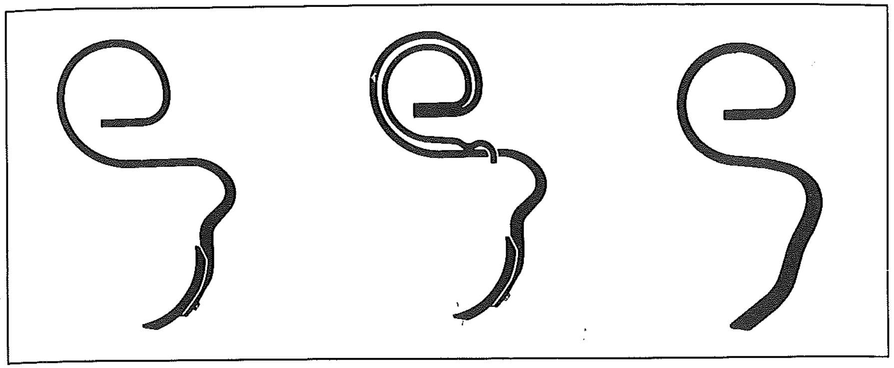


Fig. 71. Spring tines for light cultivators.

4.2.4 Description Of The Implement And Tools

Light cultivators have relatively large C-, G- and S-shaped tines (Fig. 71), fitted with interchangeable points or chisels (Fig. 72), giving a furrow distance of approx. 100 mm. The furrow distance can be halved by using double-spring tines (Fig. 73). Like the flexible tine cultivator, the light cultivator can be employed for shallow tillage. Pointed chisels are mainly used but various chisel shapes for light (approx. 35 mm wide) and heavy soils (10 mm) can be fitted. If equipped with an extra spring, the tine may produce a uniform working depth even on heavy soils and at high speeds.

The front rows can sometimes be fitted with tines pointing backwards to avoid over-penetration of the tines in front of the implement.

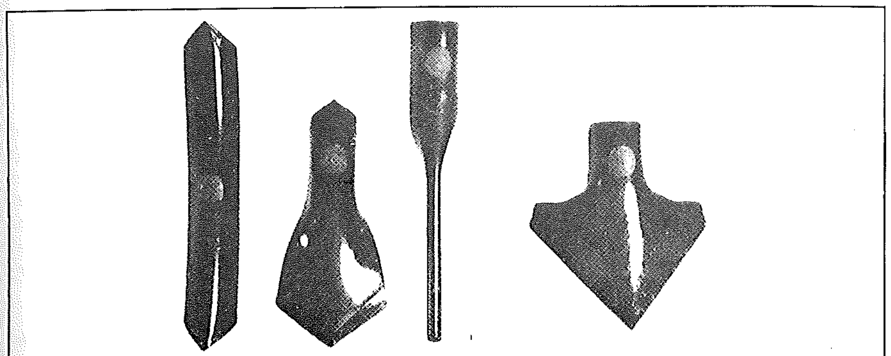


Fig. 72. Chisels for light cultivators: From left to right: standard (pointed) chisel, duckfoot chisel for stubble, grassland chisel for pasture, duckfoot chisel for tillage in row crops.

Sufficient frame clearance (400-550 mm) allows the implement to be used in row crops. The guidance (along the direction of travel) can be improved by mounting disc coulters (this is important when working along contours). Precision work can be achieved with independent parallelogram linkage for each tine.

Flexible tine cultivators are similar to light cultivators but are fitted with a lighter rigid frame and three to six rows of spring tines with interchangeable shares of various shapes and widths which are arranged to give a furrow distance of 50-80 mm. They have narrow (30-55 mm) C- and G-shaped tines which vibrate strongly (Fig. 71). The width of some implements may be as much as 3 m but a system comprising separate sections of 0.75-1.5 m (possibly with parallelogram linkage) built into combination implements is preferred. These models have a much larger total working width but can still closely follow the field surface.

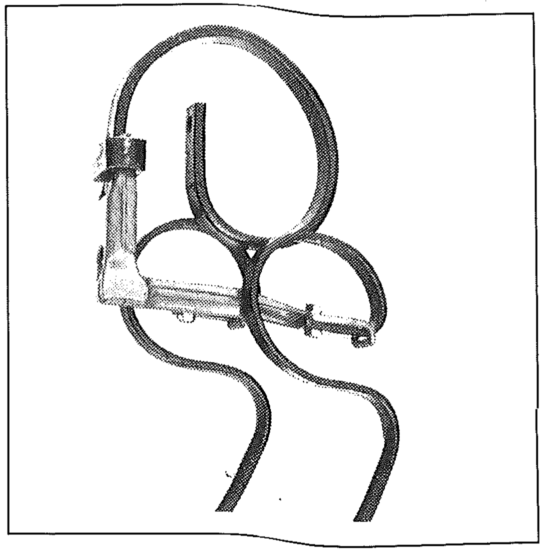


Fig. 73. Dual spring tines for flexible tine cultivators.

4.2.5 Adjustments, Operation

It is essential to maintain a uniform shallow working depth during full-width preparation of a seedbed. Flexible tine cultivators work at shallow depths because of the narrow distance between tines. The depth is controlled by gauge-wheels on the supporting frame, by adjusting the upper link of the tractor and by reducing or increasing the load on the rear-mounted roller. These rear-mounted tools may be adjusted by chains (Fig. 74), a spindle or pin-and-hole system (Fig. 75) or by auxiliary springs on the parallelogram linkage (Fig. 76).

The tilling intensity of any implement can be increased only by increasing the travel speed. Speeds of 10 km/h or more are possible. When used alone, cultivators are very simple to operate but seedbed combinations require quite considerable skill by the operator if they are to be correctly adjusted.

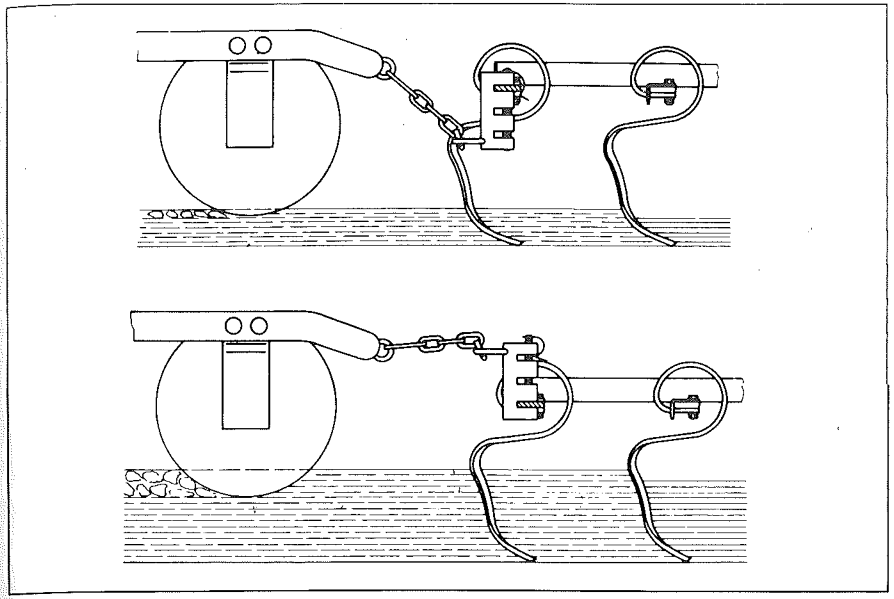


Fig. 74. Flexible tine cultivator with rear-mounted roller; adjustment of depth.

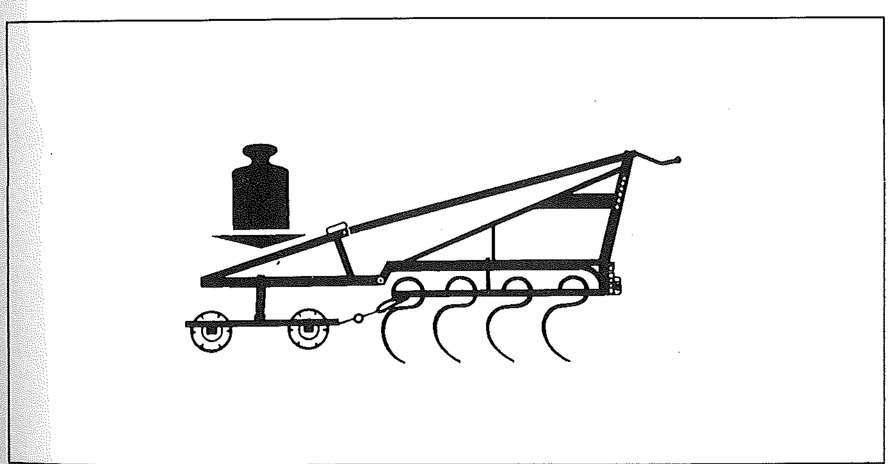


Fig. 75. Light cultivator with two rear-mounted rollers; depth adjustment by spindle system.

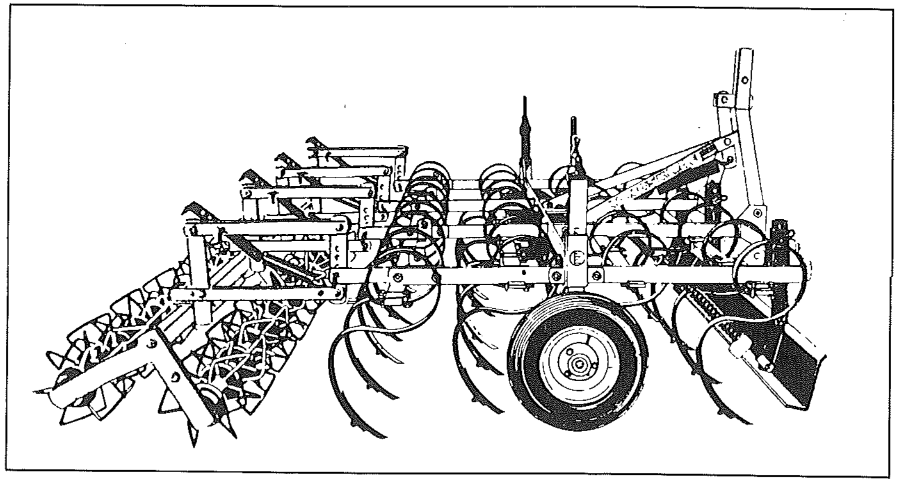


Fig. 76. Light cultivator with rear-mounted rollers in spring loaded parallelogram linkage.

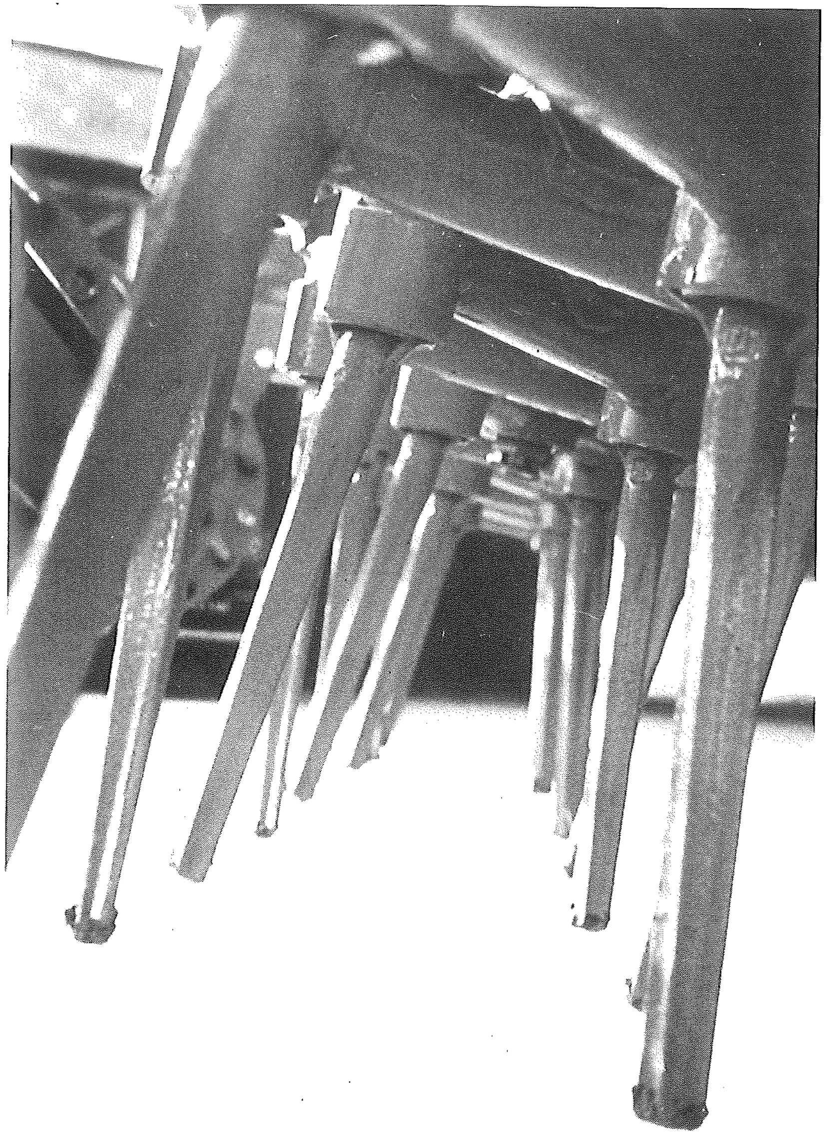
4.2.6 Technical Data

Working width	up to 18 m
Working depth	50-150 mm
Width of tines (chisels)	10-105 mm (the latter figure is for duckfeet)
Number of rows	1-6
Distance between tines	no. of rows x furrow distance
Furrow distance	
- flexible tine cultivator	approx. 50 mm
- light cultivator	approx. 100 mm
Travel speed	5-10 km/h
Power required	0.75 kW per tine
- seedbed combinations with high speeds	up to 18 kW/m
Weight (single implement up to seedbed combination with double roller harrow)	100-300 kg/m

4.2.7 Literature

See literature for chapter 4.0.

4.3 Pto-Driven Implements for Seedbed Preparation



The essential characteristic of pto-driven implements for seedbed preparation is that tine- or knife-shaped tools, moving horizontally or vertically, are driven by the tractor pto.

The fact that, especially for heavy soils, the number of these implements is increasing more rapidly than trailer seedbed-preparation implements can be attributed to the following advantages which are essentially valid for every pto-driven tillage implement:

1. The crumbling action can be adapted more satisfactorily to the prevailing conditions by changing the tillage intensity. Consequently, a field can be prepared for sowing in one single pass - even on heavy soils - so that the number of wheel-tracks is reduced.
2. The tractor's power can be used with a high level of efficiency from the power transmission system (about 80% compared with 50% for trailer implements) because the tractor-wheels do not slip.
3. The short length of the implements makes it possible to combine them with sowing machines, permitting seedbed preparation and sowing in one operation.

Although the advantages of pto-driven implements are essentially valid for the soils of the arid and semi-arid regions and the time saved is very valuable in a closely integrated crop rotation, very careful consideration should be given to any recommendation for their use in developing tropical countries. Many of the tractors available in those countries are not equipped with a power take-off system and, even if they are, the system may have a different number of revolutions, direction of rotation, shaft profile or location. Good training is required to tune the equipment to the correct combination of forward speed and rpm and to adjust the implement so that the required effect is achieved under the given conditions. It is scarcely possible for implements to be too simple in view of the well-known problems concerning supplies of spare parts. Complicated drive systems and bearings are particularly problematic and also involve safety risks.

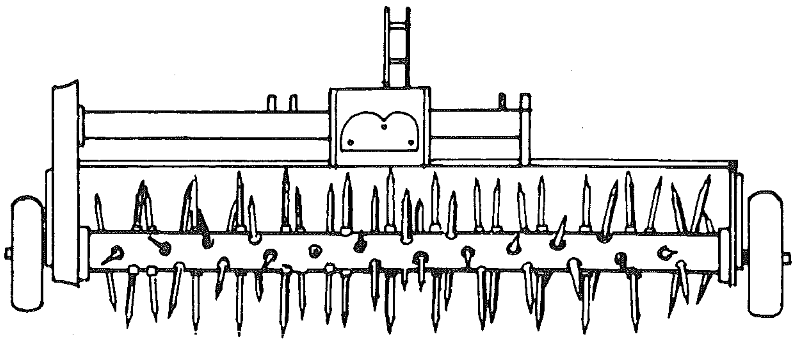


Fig. 77. Tine rotor.

The most widely used pto-driven implements for seedbed preparation are the rotating and the reciprocating hoe and the rotary tiller (see chapter 2.4) which for this purpose may be equipped with a tine rotor (Fig. 77) instead of a blade rotor. The large number of tines produce a better crumbling action despite the lower energy requirement while a tillage pan cannot be formed. On the other hand, the levelling and mulching action is markedly less satisfactory than with the blade rotor.

Table 9 shows the total power required and the proportions used for draught traction and for working the pto-driven implements.

implement	total energy requirement per m working width kW (hp)	share of total for draught	for drive
rotary tiller (on ploughed land)	18-22 (25-30)	0	3/3
rotary tiller with tine rotor	15-18 (20-25)	0	3/3
reciprocating hoe	11-18 (15-25)	2/3	1/3
rotating hoe	15-18 (20-25)	1/3	2/3

Table 9. Power requirement per m width for pto-driven implements for seedbed preparation.

A more detailed comparison of the implements in this group is given in Table 10 which also includes the "reciprocating rotor" harrow. This implement is mentioned for completeness only: it has a very limited use in some European countries. In some ways the functioning of the tine sets is similar to that of the rotating hoe but the design is such that they require satisfactory maintenance and cannot be used on difficult soils.

For safety reasons the use of implements with rotating or oscillating tools calls for particularly careful training for drivers or operators.

implement	freq. or rpm tines	tool speed m/s 1)	depth ave. cm	max. cm	opt. speed km/h	req. tractor kW/m 3)	capacity ha/h 2)
recipr. hoe	constant	0.9-1.1	4)	15	5-6	10-15	0.3-0.4
recipr. rotor	constant	ca. 1.4	4)	20	5-6	15-20	0.3-0.4
rotating hoe	variable	5-4	4)	20(40)	6-8	15-20	0.4-0.5
rotary tiller with tines	variable	3-13	4)	15	6-8	15-20	0.4-0.5

1): at standard pto rpm: 540 or 1000
2): per m working width
3): at 5-7 cm working depth
4): according to required sowing depth

Table 10. Some characteristics of pto-driven implements for seedbed preparation.

One of the most recent developments is a dual-rotor machine (Fig. 78), with a deep- working rotor in front and a shallow-working rotor immediately behind it. The rotation speed, type and size of the tools on these two rotors differ. They produce very intensive tillage.

A ground-driven version of this machine has also become available; the deep-working front rotor drives the second rotor which rotates about 3 times faster. The rotors are equipped with spoon (or shovel)-shaped tines. They work at depths of up to 10 cm.

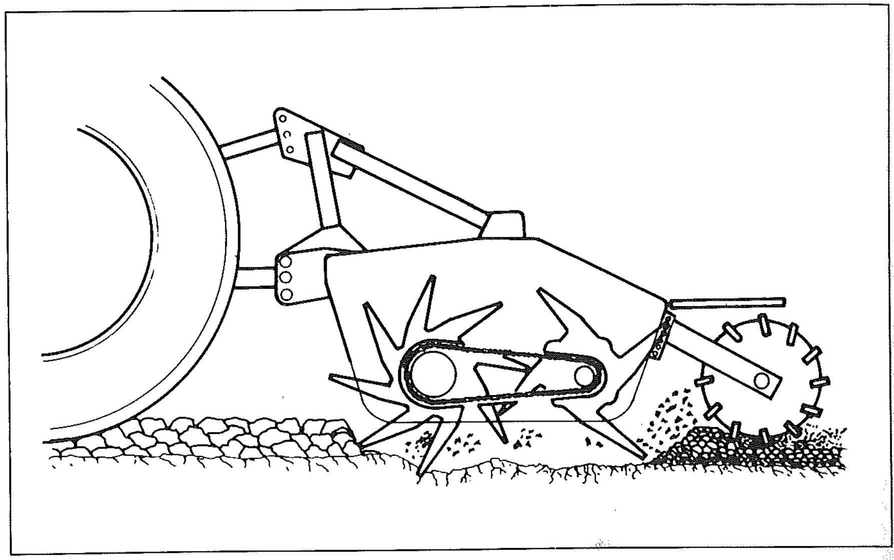


Fig. 78. Dual-rotor combination.

4.3.0.1 Literature

See literature of chapter 4.0.

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Irla, E., 1980. Vergleichsuntersuchung von zapfwellengetriebenen Eggen. FAT Blaetter fuer Landtechnik, No. 166, pp. 12.

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Stroppel, A. and R. Reich, 1982. Vergleichsuntersuchungen an Geraeten zur Saatbettbereitung mit zapfwellengetriebenen rotierenden Werkzeugen. Grundlagen der Landtechnik, 32(3): 86-95.

4.3.1 The Rotating Hoe

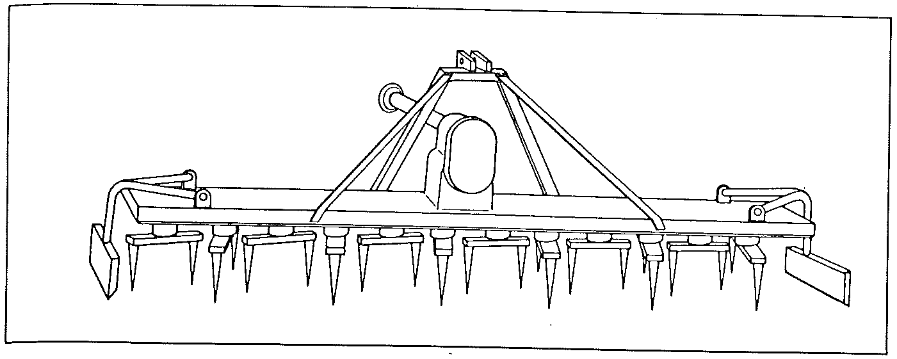


Fig. 79. Rotating hoe.

4.3.1.1 Use And Assessment

The main use of the rotating hoe (Fig. 79) is for seedbed preparation. In special cases it can also be employed for stubble tillage or grassland clearance. Since it is possible to vary the tillage intensity both by changing the gears and by varying the travel speed, a well-crumbled and level seedbed can be prepared in one operation even on heavy soils. Generally speaking, the rotating hoe cannot be recommended for (primary) stubble tillage, especially when straw also has to be worked in. Even if angled special-purpose tines are fitted, satisfactory mixing may not be achieved despite the high power requirement but this implement is very suitable for secondary tillage of (chisel-)ploughed stubble fields.

The rotating hoe is rather vulnerable to damage by stones. The performance is not satisfactory on moist fields. Its ability to prepare a field for sowing in one pass and, possibly, to combine this operation with the actual sowing reduces the number of wheel-tracks on the field which in turn reduces the time and costs involved.

Strip cultivation is possible if working sets are omitted. The rotating hoe is a relatively expensive implement to purchase and operate.

4.3.1.2 Functioning

Since the travel and circumferential speeds of the tine elements which mesh in the horizontal plane are aggregated, the tines move in a horizontal cycloid path (Fig. 80). Each element rotates in the opposite direction to its adjoining element. The shape of this trajectory and the intensity of the implement's operation depend upon the ratio between the tools' forward travel and circumferential speeds of the tools.

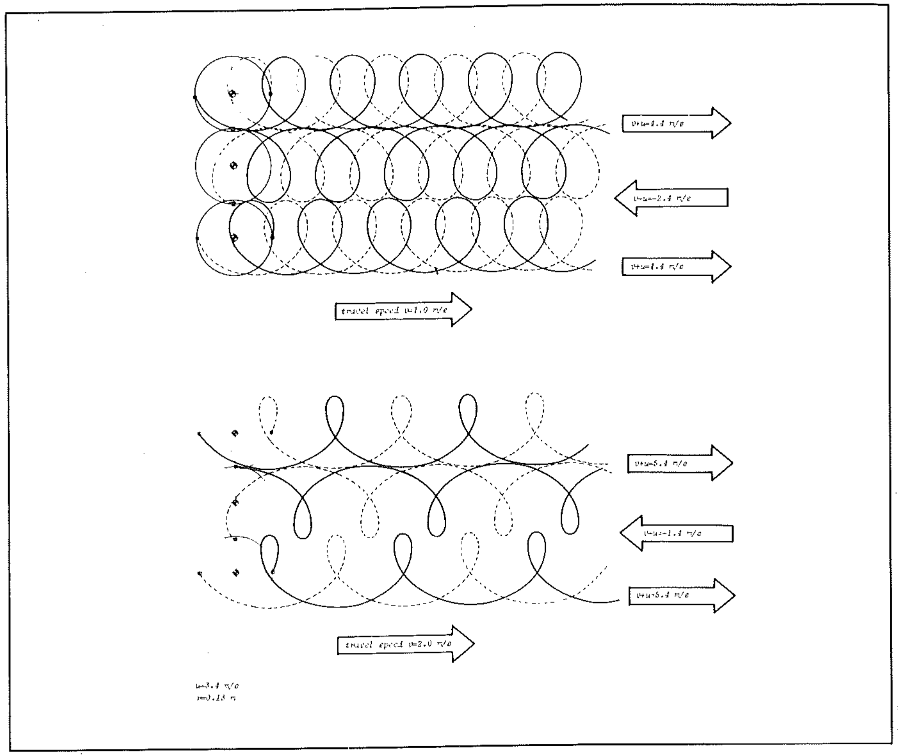


Fig. 80. Path of the tines of a rotating hoe in the soil (three adjacent elements). Forward travel speed 1.0 m/s (top) and 2.0 m/s (bottom).

Little crumbling is produced by a high forward speed and low rpm while a low forward speed and high rpm cause pronounced crumbling. The optimum effect will be achieved only with a specific ratio for the given soil type and conditions. A general rule for the rotating hoe is that the circumferential speed should be twice the forward speed but, for satisfactory operation, the latter should not exceed 6 km/h.
In addition to a good crumbling performance the rotating hoe also produces good levelling. The formation of ridges between adjacent passes is prevented by (spring-mounted) shields on both sides of the machine (see Fig. 79). The vertical mixing action is weak and so only the (dry) soil on the surface is crumbled and no moist soil is brought up (low water losses). Various jobs can be done by choosing a specific length or shape of the tines.
Tines about 25 cm long are usually employed for shallow seedbed preparation although tines up to 40 cm in length are used, for example, for preparing a field for potatoes or for cultivating in a row crop. The rotating hoe may be fitted with special angled "skim tines" for stubble tillage but this implement rarely operates satisfactorily on untilled soil after the harvest and requires a high power input. A special form of the implement with tines

pointing outwards and forwards (for better grip) produces stronger penetration (up to 25 cm) and a better mixing action.

The rotating hoe is very suitable for secondary tillage of (chisel-ploughed) stubble fields even if large amounts of straw have been left on the surface. Although it does to some extent compact and level the loose seedbed, the rear-mounted cage roller (Fig. 81) is essentially used to control the working depth of the rotating hoe.

Its ability to create a tilth in keeping with the soil type and conditions means that the easily-operated rotating hoe can be used for a variety of purposes on light to heavy soils. If the soil conditions are suitable, sowing is possible in one pass by combining the hoe with sowing machinery. When fitted with special attachments, the rotating hoe can also be used for ridging.

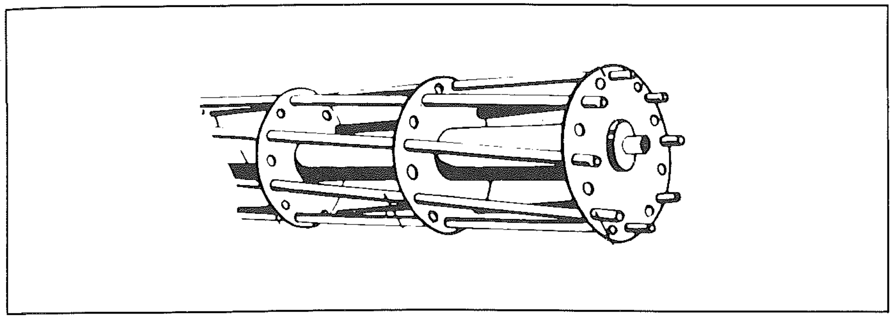


Fig. 81. Cage roller.

4.3.1.3 Linkage And Drive System

The rotating hoe is usually designed for 3-point hitch mounting (category I-III) on the tractor and is used in free-floating mode with the depth being controlled by rear-mounted rollers or (in a few cases) support wheels. When the lift arms of the 3-point hitch system are equipped with slots allowing a movable attachment of the lower links, this setting permits completely independent levelling of the machine (i.e. by the rear-mounted roller alone). The centre of gravity is very near the tractor and so the tractor's lifting capacity will rarely be a restrictive factor. When a sowing machine is mounted (Fig. 82), however, care should be taken to ensure that the lifting capacity is sufficient (the hopper on the sowing machine also has to be filled). If a front pto is available, the rotating hoe may be mounted in front of the tractor. The rotating hoe is driven by the pto at 540 or 1000 rpm through an oil-filled gearbox (placed along the same axis as the pto shaft) to a central gear-wheel which drives the other gear-wheels to which the sets of tines are attached. On some rotating hoes the rotor sets are driven from the gearbox by lateral profiled shafts. The advantage of these implements is that the working width can easily be extended by adding extra sets. Very wide rotating hoes (up to 9 m) can be driven by an auxiliary engine.

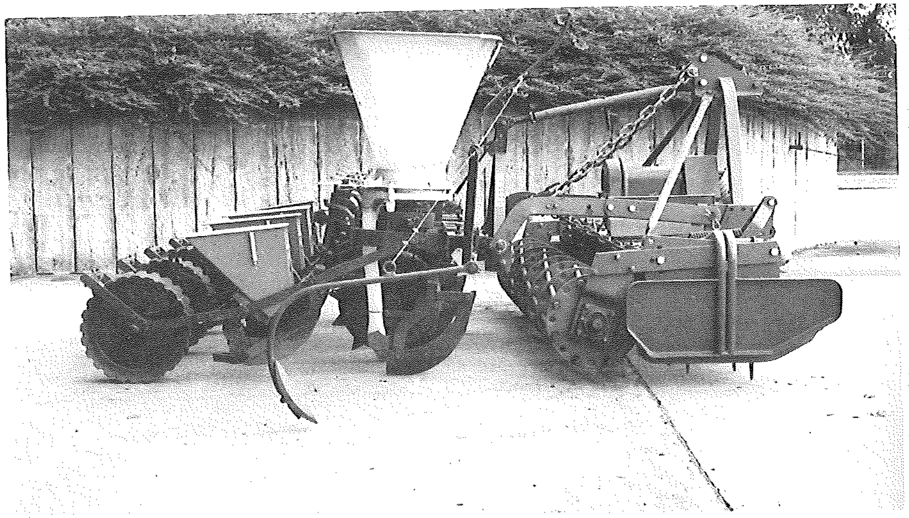


Fig. 82. Rotating hoe with rear-mounted precision drill.

The rpm of the rotor sets can be varied from approx. 130 to 480 by changing the gears. The hoe's gearbox can be equipped with a rear extension shaft so that pto-driven sowing machines, for example, can be mounted.

The power required by pto-driven implements can be divided into draught-energy and rotational energy, each depending upon the travel speed and the circumferential speed of the tools. An increase in the forward speed greatly increases the draught proportion and the tillage intensity will be reduced, i.e. as the travel speed increases, the advantage of the pto-drive system or its efficiency is reduced. So the travel speed when working with a rotating hoe should not exceed 6 km/h. Any increase in the rpm of the tools also raises the rotation energy requirement. The ratio between the tractor and rotative energy requirements for rotating hoes is about 1:2 and so a large proportion of the energy is transmitted by the pto. There is no danger of wheel slippage. When working at a depth of 8-10 cm at speeds of 5-6 km/h, 15-25 kW/metre of width may be taken as an indication of the total power required.
Very wide rotating hoes can be switched hydraulically from the working to the transport (endways) position.

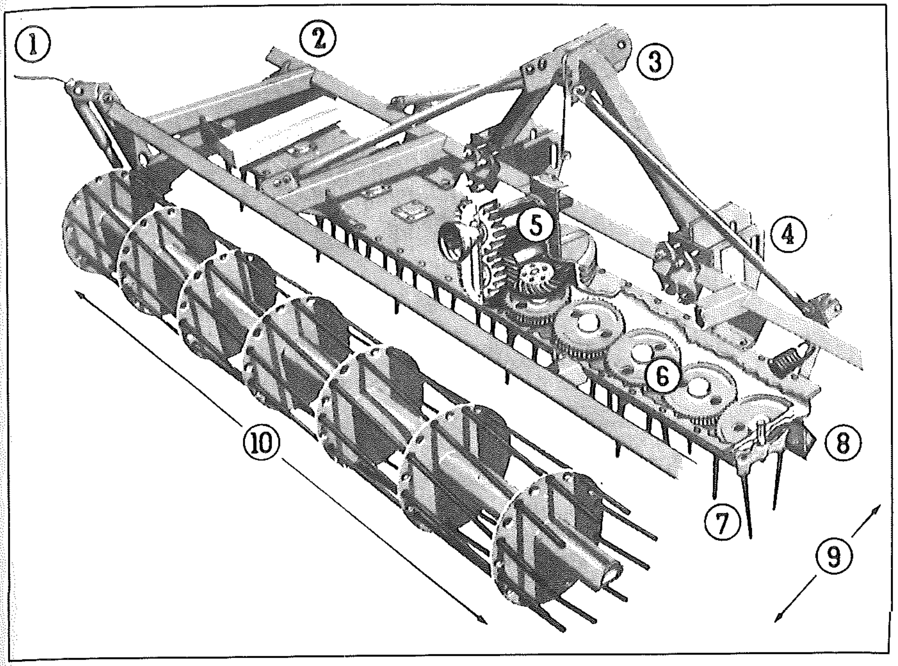


Fig. 83. Rotating hoe:
1. Spindle for depth adjustment (by cage roller),
2. Frame,
3/4. Headstock,
5. Gearbox,
6. Sprocket wheel,
7. Tine,
8. Levelling board,
9. Total length of implement,
10. Packing roller.

4.3.1.4 Description Of The Implement And Tools

The rotating hoe (Fig. 83) has a frame with a headstock for 3-point linkage. A gearbox and housing containing a specific number of gear-wheels (depending on the model and its width) are attached to the frame. Vertical rotor-shafts with horizontal tool "carriers" are mounted in the centre of each of these gear-wheels. These carriers may be fitted with two to four easily replaceable tines or knife-shaped tools. On some implements the tines are angled slightly backwards (when viewed from the direction of rotation). The shape and length of the tines can be chosen to match their intended use. The tines may protrude slightly at the bottom for better mixing. Adjoining sets are counter-rotating (Fig. 84). The system is equipped with a device to protect against overloading. Only rarely is each set of tines protected against stones (shearbolts or a hydro-pneumatic system may be mounted on heavy-duty types).

Rotating hoes are usually equipped with a cage roller and possibly (by special mounting parts) with a sowing machine. Sowing equipment may even be mounted on top of the hoe (i.e. hopper and seed metering system). A levelling bar in front of the tines serves as protection and produces a very smooth level seedbed (sugarbeet, etc.). A special ridging kit (special tines, hoods, support wheels and frame for the ridging bodies) is available.

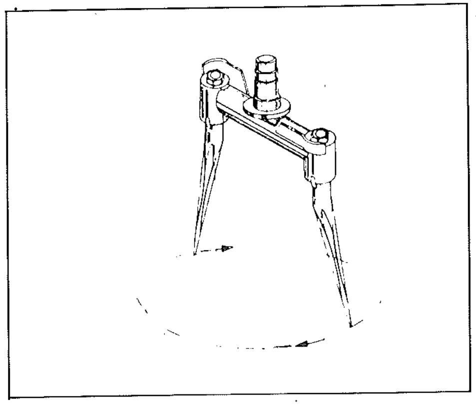


Fig. 84. Tool carrier with two tines.

4.3.1.5 Adjustments, Operation

The depth is usually controlled by the cage roller (adjusted by bolts or spindle). The tillage intensity increases in line with the higher rpm of the rotor sets and the number of tines per set (2 or 4) and also as the forward speed is reduced. Strip tillage is possible by removing certain sets of tines.

The machine can easily be mounted and adjusted and tools replaced by one man. The pto-driven rotating tines require special attention from the driver when in operation (looking out for stones, woods, etc. in the field). The gear-wheels operate in an oilbath and do not require special care.

4.3.1.6 Technical Data

Working width	1-9 m
Working depth	up to 25 cm
Travel speed	5-7 km/h
Rpm of the rotor	(83) 120-530
Rpm of the pto	540 or 1000
Circumferential speed of the rotor sets	1.8-6.5 m/s
Number of sets	2-4 per m width
Number of tines per set	2-4
Weight	170-330 kg per metre of width
Power required	15-30 kW per metre of width

4.3.1.7 Literature

See literature for chapter 4.3.

4.3.2 The Reciprocating Hoe

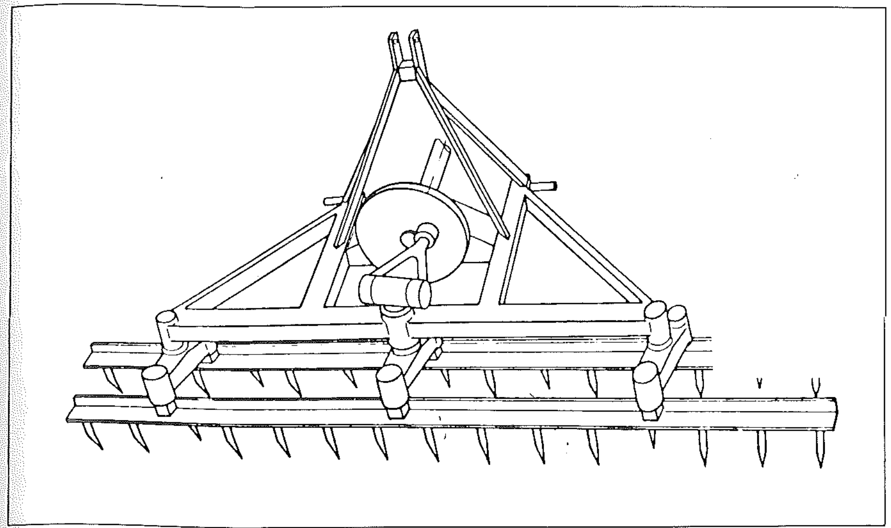


Fig. 85. Reciprocating hoe.

4.3.2.1 Use And Assessment

The reciprocating hoe (Fig. 85) is used mainly for seedbed preparation but may also be employed for secondary tillage of (chisel) ploughed stubble fields. Although, in principle, the intensity of the tillage operation can be varied only by changing the travel speed, it is possible to prepare a field for sowing in one operation, even on heavy soils. The hoe is distinguished by its good crumbling effect and its levelling action but more passes are necessary on hard soils with big clods. The reciprocating hoe can be used on comparatively wet soils without the packing roller. The hoe is sturdy and requires little maintenance cost.

Owing to its short length the reciprocating hoe can be combined with a sowing machine so that the number of passes (wheel-tracks) during the sowing operations can be reduced. Mounting and adjustment can easily be performed by one man.

4.3.2.2 Functioning

Since the tines' reciprocating movement and the tractor's forward movement are aggregated, the tines follow a sinusoidal path in the soil (Fig. 86). The locus followed by the tools is determined by these two speeds. When one of them is changed, the tool's trajectory in the soil and thus the tillage intensity also alter.

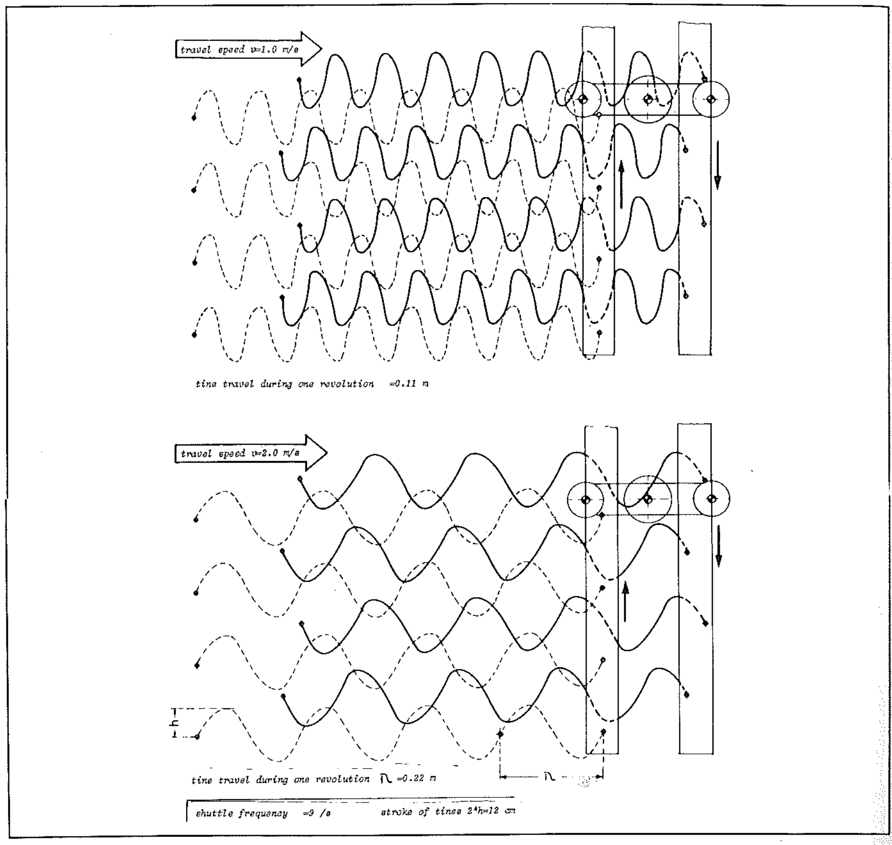


Fig. 86. Path in the soil of the tines of a reciprocating hoe with two bars. Forward travel speed 1.0 m/s (top) and 2.0 m/s (bottom).

This intensity can be influenced only by the forward speed because the shuttle frequency, the stroke of the tines, the number of tines per bar and other parameters are fixed by the manufacturer.
The stroke depends upon the length of the arms driving the bars. On some implements the stroke of each succesive bar increases in stages, e.g. on a 4-bar reciprocating hoe the stroke ranges from 9 cm for the front bar to 49 cm for the rear one. With the same frequency the tool speed and thus the tillage intensity increase with the higher strokes. So 4-bar implements are recommended for heavy soils since they crumble more satisfactorily than the 2-bar types.

The soil is crumbled and levelled by the reciprocating tines. Wheel-tracks are also eliminated if the hoe operates at sufficient depths. Its functioning prevents moist (sub)soil from being raised to the surface (just like the rotating hoe). It is possible to prepare a seedbed in one operation on both light and heavy soils to maximum depths of up to 20 cm (no

more than 15 cm is recommended for efficient operation).

Large amounts of harvest residue on the field may cause clogging. That is why secondary tillage of (chisel) ploughed stubble fields using the reciprocating hoe is possible only if small amounts of straw are on the surface. The tillage intensity decreases as the speed increases; soil piled up in front of the machine is pushed forward. The speed should not exceed 6 km/h for satisfactory results.

Precise depth control can be obtained by using a rear-mounted cage roller which compacts light to medium-heavy soils. Sowing is possible in one pass by combining the reciprocating hoe and a sowing machine.

4.3.2.3 Linkage And Drive System

The reciprocating hoe is designed for the 3-point hitch linkage on the tractor and is used in free-floating mode. As with the rotating hoe, the centre of gravity is located close to the tractor. Care should be taken to ensure that the tractor's lifting capacity is sufficient when a sowing machine is mounted.

The hoe is driven by the tracor pto (540 rpm) through a driveshaft to a crankwheel which converts the rotational motion in a reciprocating motion. So the bars placed in parallel one behind the other are moved in a reciprocating direction. If the moving masses are not perfectly balanced (which includes sufficiently large hinges to act as a buffer), the lateral forces are transmitted to the tractor, causing heavy strain not only on the 3-point hitch but also on the tractor and driver. In severe cases this means that a larger tractor than is really needed for the power requirement is chosen. On modern implements so much of the torque peaks generated by the oscillating movements are absorbed that they do not damage the tractor.

The ratio between the draught and rotational energy requirement is about 2:1 for the reciprocating hoe. The draught requirement increases with the speed while the rotational-energy requirement remains relatively constant. The speed should not exceed 6 km/h in view of the increasing total energy requirement and the resultant unsatisfactory work. A total power requirement of 15-20 kW/m of width can be expected at that speed and when working at depths of 8-10 cm.

4.3.2.4 Description Of Implement And Tools

Up to four bars or "tool-carriers" are mounted on a frame (see Fig. 85) in parallel to each other and perpendicular to the direction of travel. The number of tines on each bar depends upon the make and model (and the intended use) of the implement. An interval of 15 cm between the tines and a length of 20-30 cm are normal. Tines are easily changed. The heart of the machine is a heavy crankwheel with an eccentric for converting the rotating movement of the driveshaft into an oscillating movement for the tine bars. The frequency is between 140 and 540 movements per minute. Most reciprocating hoes are equipped with a cage or packing roller and may have mounting parts for combination with a sowing machine (Fig. 87).

4.3.2.5 Adjustments, Operation

The only possible adjustment on the reciprocating hoe is the depth control exerted by the cage roller or the tractor's hydraulic system. So the tillage intensity is determined solely by the forward speed. The operation of the reciprocating hoe is very simple.

The (pto) drive system requires no attention except for the normal care given to these types of implements (lubrication, checking the bearings).

Fig. 87. Reciprocating hoe with rear-mounted drill.

4.3.2.6 Technical Data

Number of bars	2-4
Working width	2-6 m
Working depth	up to 20 cm
Speed	5-7 km/h
Rpm of the pto	540
Frequency of the bars	140-540/min
Breadth of bars	10-50 cm
Power required	15-22 kW/m of width
Weight (including roller)	200-300 kg/m of width

4.3.2.7 Literature

See literature for chapter 4.3.

4.4 The Leveller

4.4.1 Use And Assessment

The leveller is an ancient implement whose use is still widespread because of its simplicity (Fig. 88). It is used for:
- levelling and smoothing of the soil surface,
- crumbling the surface layer,
- improving the drying-out of the surface soil,
- control of early weeds,
- compacting the soil surface (to a certain depth),
- breaking up crusts.

The leveller is suitable for use in the tropics only under certain conditions since the risk of erosion is increased by leaving a bare smooth and finely aggregated surface.

The advantages of the leveller are:
- simple and sturdy construction,
- the user does not require a high standard of skill,
- the soil surface dries out uniformly,
- an insulating layer is created on the surface, preventing serious losses of water,
- it can be produced by local craftsmen.

Its disadvantages are:
- smearing on moist soils, thus reducing the infiltration capacity,
- some compaction of the soil,
- fine material is deposited on the surface with larger cavities below,
- the travel speed is limited,
- 3-point hitch linkage is not easy to use (transport problems).

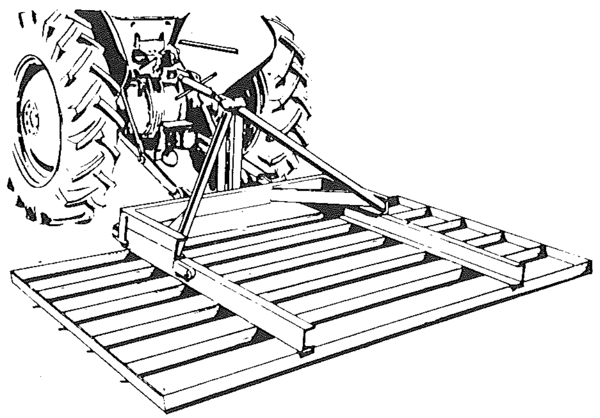


Fig. 88. Leveller (3-point hitch type).

4.4.2 Functioning

The leveller pushes soil forward, pulverizing and depositing it in local depressions. Weeds are torn away and will dry out. The leveller should not push too much soil. The tillage depth and intensity on heavy soils may be influenced by extra weights, special linkage or the travel speed. In many cases the required effect can be achieved only by mounting several units behind the other and/or by more passes over the field. On moist soils a compromise must be found between sufficient levelling and the prevention of smearing.

It is important for the implement to be well adapted to the surface, and this may be achieved by suspending separate units independently on a toolbar. The best effect is obtained when the levelling is carried out at an angle to the direction of the previous (main) tillage operation.

4.4.3 Linkage

The majority of levellers are designed as dragged implements. A hitch system with a toolbar is used to mount tools one behind the other. The angle of pull and thus the working depth and intensity are changed by extending or shortening the hitch device or by choosing a higher or lower linkage point. The tools may be staggered. Levellers are sometimes used in combination implements. Three-point hitch linkage is not normally employed.

4.4.4 Description Of The Implement And Tools

Levellers are divided into:
a. Levellers using beams,
b. " " boxes,
c. " " hoops (tyres),
d. " " chains.

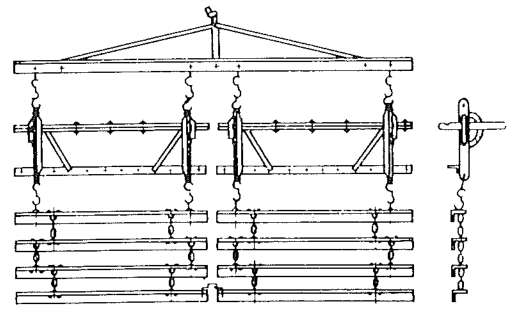


Fig. 89. Beam leveller (drag type).

a) Beam levellers.
These levellers (Fig. 89) consist of either a single beam or plank (possibly fitted with stones, short tines or other tools at their base) or a number of beams placed one behind the other. These beams are all set perpendicularly to the direction of travel and attached to a toolbar by chains or links. These levellers usually are made of wood. They may be staggered. The front (working) edge usually covered with a steel strip.

Beams (or floats) are also extensively used for surface-irrigated farming, (see Chapters 5 and 6).

b) Box levellers.
Unlike the beams the boxes permit an extra load and adjustment of the tool plane's angle of attack. This adjustment can produce planing or compacting. Other levellers have a frame consisting of a mesh of branches which can be filled with stones. These implements belong to the same group.

c). Hoop levellers.
At least three hoops set in staggered formation are attached to and pulled by a toolbar (Fig. 90). Steel hoops or rubber tyres may be used.

Steel hoops, about 50 mm in height, are attached to each other by short chains or eyes. Tyres are usually cut in half and the two rings formed in this way are attached "back to back" so that the leveller may be used either way up.

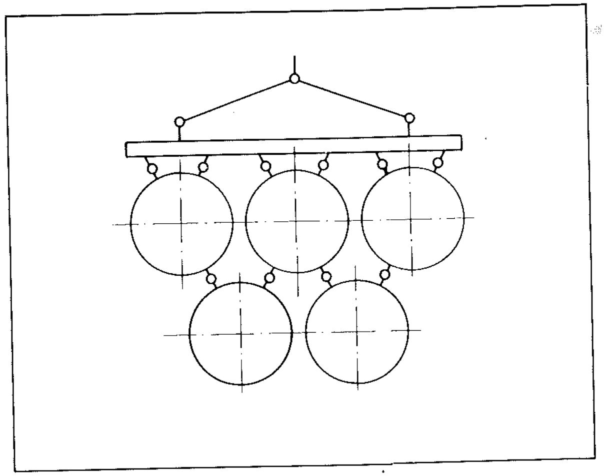


Fig. 90. Hoop-leveller (drag type).

d) Chain levellers.
Several strong chains are attached to the hitchbar to form various patterns. Both the tyre and chain leveller are also used on pasture (dung spreading).

4.4.5 Adjustments, Operation

The effect produced by a leveller depends not only upon the design but also on the following adjustable parameters:
a. Weight of the leveller (including extra weights)
b. Angle of pull
c. Angle of the working plane
d. Travel speeds
Passes with the leveller may also be repeated until the required effect has been achieved. Although a smooth surface can be obtained, the soil will be considerably compacted when a tractor is used. A beam leveller makes it possible to vary the action from strong cutting to cutting/planing or compacting in keeping with the angle of the beam.

The leveller requires no special knowledge and is very easy to use.

4.4.6 Technical Data

Working width	up to 8 m
Working depth	up to 50 mm
Number of tools	up to 12
Weight	30-50 kg/m
Working speed	up to 8 km/h
Power required	approx. 5 kW per metre of width

4.4.7 Literature

See literature for chapter 4.0.

4.5 The Roller

4.5.1 Use And Assessment

Rollers (Fig. 91) are used for:
- compacting the soil at various sections of the arable layer,
- filling cavities,
- breaking up clods,
- breaking up surface crusts,
- controlling the water movement in the soil by compacting the soil surface, thus accelerating evaporation,
- levelling the soil (including molehills on grassland),
- compressing the soil around young plants when the topsoil is not closely integrated with the subsoil,
- maintaining grassland.

If fitted with suitable tools, rollers may be used under certain conditions in the tropics and subtropics.

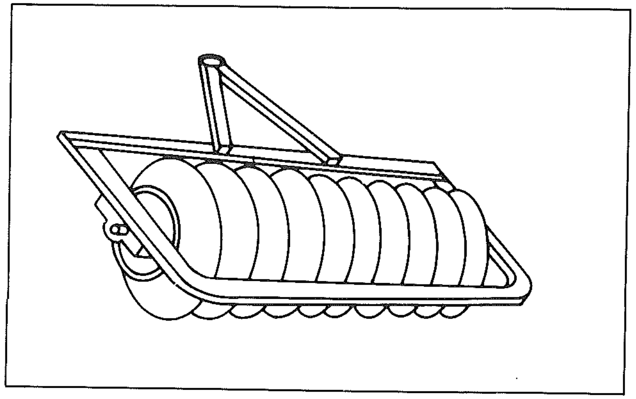


Fig. 91. Roller.

The advantages of rollers are:
- almost unlimited use,
- good crumbling of hard clods if the correct tool is fitted,
- highly efficient,
- may be used on slopes and undulating land (articulated rollers),
- high capacity,
- low draught requirement,
- suitable for the heaviest soils,
- simple sturdy construction so that hardly any wear or breakdowns occur,
- easy to build.

Their disadvantages are:
- soil compaction cannot be avoided even when only crumbling is required,
- the soil's infiltration capacity is reduced when a smooth roller is used
- the drying process is accelerated (this may be an advantage),
- a drying heavy soil may completely clog up an open roller,
- soil erosion may be increased.

4.5.2 Functioning

The primary soil tillage operation often causes excessive loosening of the soil. Especially in a closely integrated crop rotation (allowing scarcely any time for the soil to consolidate naturally), it may be necessary to compact the soil mechanically, possibly in combination with the ploughing. The roller's compaction effect is produced by the pressure on the surface. The degree of pressure depends upon the roller's weight, its diameter, the shape of its surface and the manner on which it adapts to the soil surface but, in the last analysis, the essential factor is the degree and direction of the forces exerted on the soil surface which is actually in contact with the roller. The duration of the pressure (determined by the travel speed) is another important factor. The pressure causes compaction and, simultaneously, pulverization of the clods on the surface. The roller's shape is the essential parameter determining the amount of crumbling and compaction at various depths. Since the force is always transmitted downwards from the surface (especially with smooth rollers), however, the compaction obtained is always greatest near the surface and decreases with the depth. In deeper layers the effect is limited.

To achieve a uniform action over the entire area the rollers are often divided into single rings with various shapes which move independently. This system also allows better cleaning. The roller's diameter is the crucial factor. Rollers with large diameters produce less penetration and less (negative) slip; the pressure per area unit is less but the effect on the deeper layers is greater.

The degree and duration of the pressure on the surface determine the depth to which the rollers compact. With smooth and open rollers compaction is achieved down to 15 cm while with subsurface packers this increases to 20 cm.

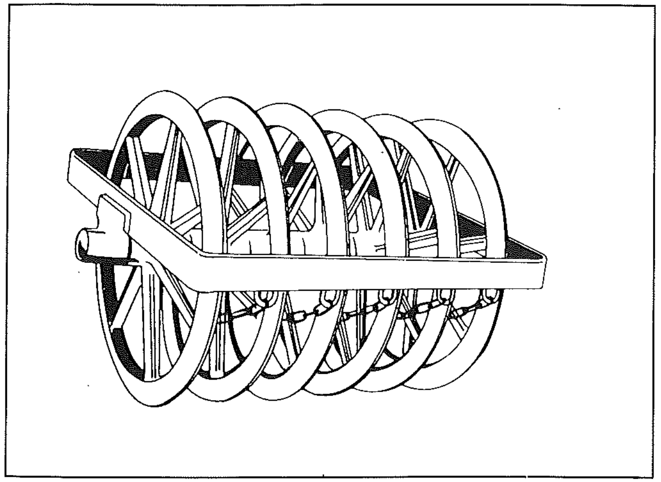


Fig. 92. Subsurface packer.

The subsurface packer (Fig. 92) is used for deeper action. The narrow spiked wheels penetrate deeply into the soil and cause compaction at penetration depth. The spikes pick up loose soil and raise it to the surface, creating a loosened layer near the surface.

4.5.3 Linkage

Rollers are used mainly as trailed tillage implements. Hitching to the 3-point system is, however, becoming more widespread. The advantages are simpler mounting, troublefree operation and especially easy transportation. When equipped for use as trailer implements, the rollers are hitched to the tractor's (linkage) drawbar.

Packers in particular are being increasingly used on light soils as rear-mounted implements on the plough, drawn by a chain or catching bow in the case of two-way ploughs. They require little power which is inversely proportionate to the diameter of the roller.

4.5.4 Description Of The Implement And Tools

Rollers can be divided into:
a. Smooth rollers
b. Corrugated rollers
c. Subsurface packers
d. Crust breakers

a) On smooth rollers one or more smooth steel cylinders with diameters of approx. 300-700 mm (up to 1500 mm on special purpose rollers for use on pasture or marshy land) can rotate freely on an axle mounted on a frame with bearings. The frame is suitable for either trailed or 3-point hitch mounting. Smooth rollers are usually operated as single-unit implements (Fig. 93) but more units staggered in 2 or more rows are also possible.

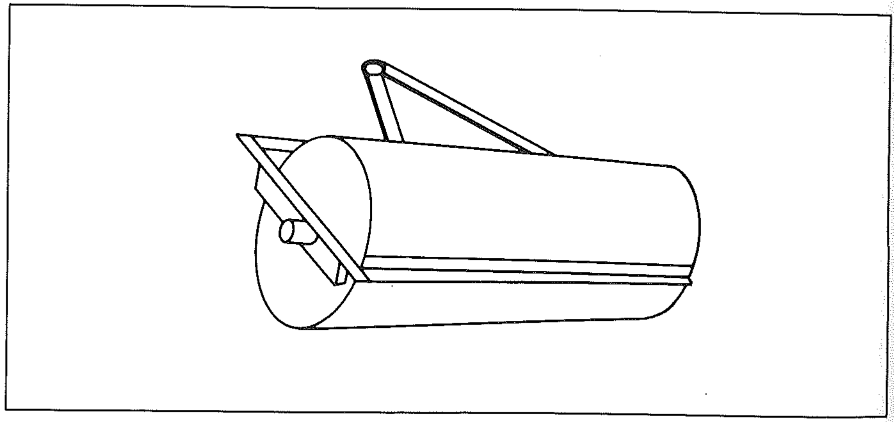


Fig. 93. Smooth roller.

b) Corrugated rollers (Fig. 94) are available in the form of:
- ring rollers,
- sprocket-wheel rollers,
- Cambridge rollers,
- Croskill rollers.

As on smooth rollers, the various elements (approx. 8-12 per metre) rotate on an axle but the diameter of the ring's central opening is larger than the axle's diameter. Corrugated rollers are generally designed as a set of narrow rollers. On the Cambridge roller plain and toothed rings with different diameters are mounted alternately, 10 of each for each metre of width. They are arranged to allow independent and eccentric movement so that the rollers follow the soil surface as closely as possible and a good self-cleaning action is obtained. On the Croskill or crowfoot roller the rings are fitted with teeth and lateral lugs alternately, producing more intensive crumbling, even on heavy soils.

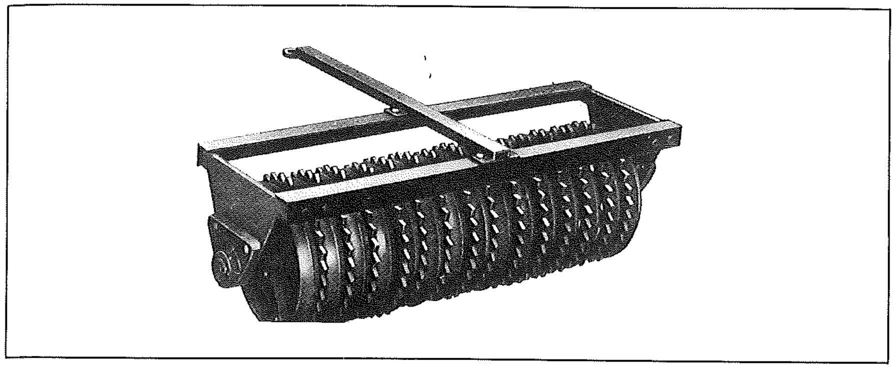


Fig. 94. Cambridge roller.

c) Subsurface packers. The general design and construction of these packers (Fig. 92) are similar to the smooth and corrugated rollers. Narrow cast-iron spiked wheels - usually with a wedge-shaped rim and a diameter of 700-1100 mm - can rotate freely on a common axle. The distance between the wheels is 100-180 mm. Since the wheels are freely mounted on the axle, the roller can be turned easily and does not cause problems in curved fields. The packers may be mounted behind the plough and, in some cases, even in combination with sowing equipment, allowing sowing in one operation.

d) The crust breaker is a special type which enables seedlings to emerge through a crust. Tines or teeth are mounted on the circumference of a smooth steel drum and they merely penetrate and break the crust without damaging the plant.

4.5.5 Adjustments, Operation

The potential adjustments are: changing the travel speed (3-10 km/h) or changing the load on the rollers by means of extra weight or by filling them with water or sand. The intensity of the operation depends upon the type of roller:

- corrugated rollers: good clod crushing action;
- packers: good compaction of the subsoil (=lower sections of the arable layer);
- smooth rollers: good levelling and compaction of seedbeds for fine seed.

The intensity may be improved by using combinations of various types of rings or by combining the rollers with other tillage implements (e.g. harrows). The trailer and mounted rollers can easily be handled by one man. Only very short preparation times are needed. The driver does not require special skills for operating the roller but choosing the correct type and the correct time to use it is very important.

4.5.6 Technical Data

Working width	one-unit type	up to 4.5 m
	more units	up to 9 m
Number of elements	smooth rollers	1-2 /m
	corrugated rollers	8-20 /m
	packers	5-10 /m
Diameter	smooth rollers	300-1500 mm
	corrugated rollers	350-650 mm
	packers	700-1100 mm
Average pressure on the surface	smooth rollers	1.00-5.30 kN/m
	(grassland rollers	up to 30.00 kN/m)
	corrugated rollers	1.00-5.00 kN/m
	packers	2.50-5.00 kN/m
Travel speed		up to 10 km/h

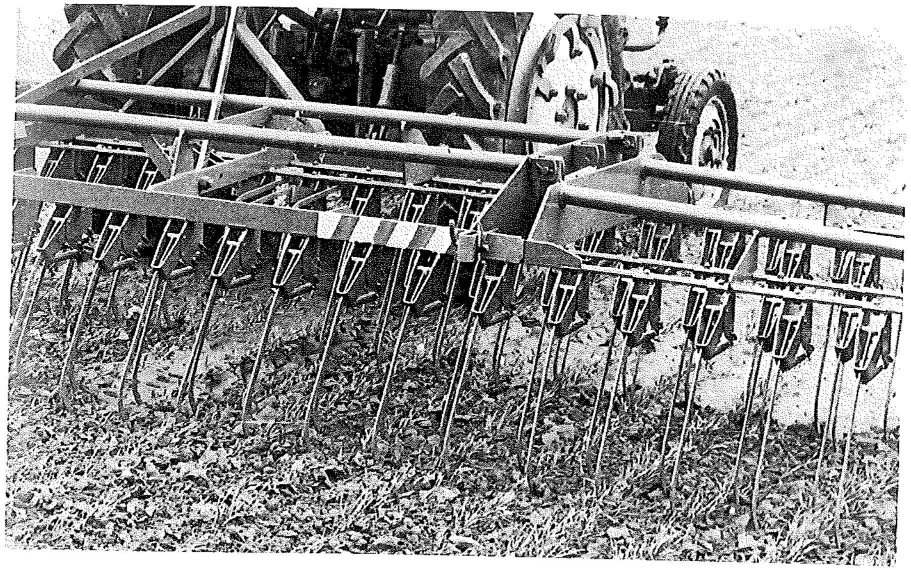
4.5.7 Literature

See literature for chapter 4.0.

Renaud, J., 1981. Rouleaux et herses roulantes. Motorisation et Technique Agricole, 30: 5-13.

Werner, K., 1982. Rotary wire cage cultivator improves weed control. American Vegetable Grower, 30(4): 85,86.

4.6 The Weeder



As its name indicates, this implement is used essentially for weeding. Two quite distinct types of implements can be classified as weeders: the spring-toothed weeder (Fig. 95) and the spiked-chain harrow (Fig. 96).

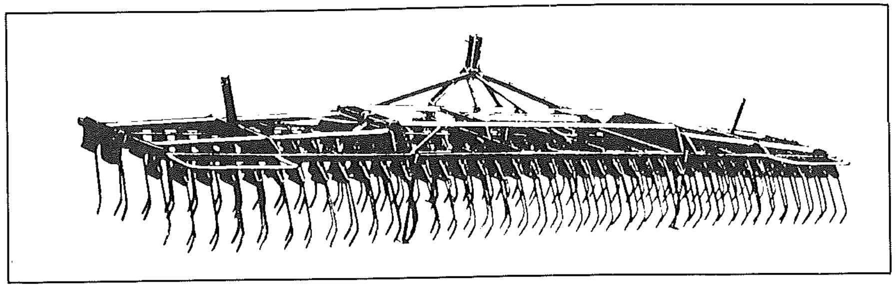


Fig. 95. Spring-toothed weeder.

4.6.1 Use And Assessment

The weeder is used for:
- mechanical weed control,
- loosening and roughening the surface layer of crusted soils,
- crumbling the soil,
- aerating the soil,
- working in seeds and chemicals,
- spreading manure (fertilizer).

The weeders are suitable for use in the tropics and subtropics if correctly operated.

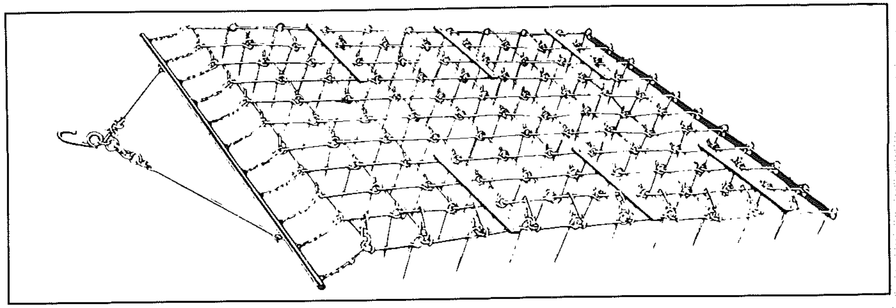


Fig. 96. Spiked-chain harrow (net).

Their advantages are:
- suitable for many types of soil,
- simple and inexpensive construction,
- they increase the soil's infiltration capacity,
- coarse crumbling of the soil,
- high travel speed,
- can be used as levellers in root-crops before the plants emerge and as harrows after emergence,
- can be used in bed and ridge systems.

Their disadvantages are:
- not suitable for heavy soils,
- after repeated use, the soil becomes too fine and risk of erosion increases.

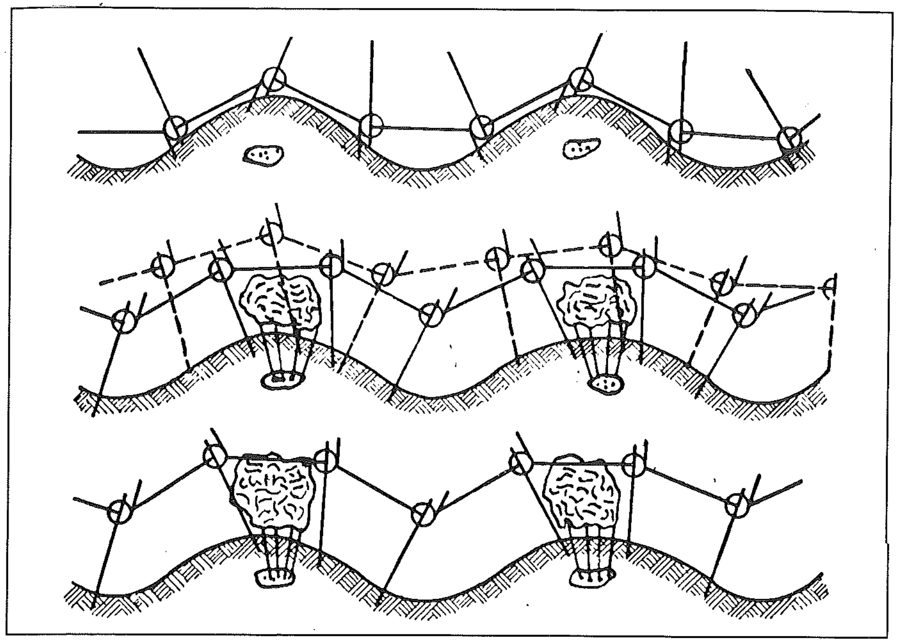


Fig. 97. Spiked-chain harrow operating on ridges.

4.6.2 Functioning

The weeder functions on the "scratch-blow" principle. The tools closely follow the soil's surface relief even in ridge systems. On the sring-toothed weeder this is made possible by separately hinged spring-loaded teeth or tines while on the spiked-chain harrow tools assembled in an articulated mesh perform this function (Fig. 97). This also produces a uniform working depth.
The leaves of firmly embedded plants move sideways to allow the tools to pass and only lightly rooted plants are caught and, possibly, torn out. On the other hand, the weeder's tools can independently divert around obstacles. Weeders loosen and crumble the topsoil and may even have a slight levelling and mixing effect.

4.6.3 Linkage And Drive System

The spring-toothed weeder is a mounted implement for the 3-point hitch system: the hitch system is set at a fixed height and no hydraulic control system is needed.
Essentially, the spiked-chain harrow is a trailer implement but nowadays it is usually suspended in a frame and mounted to the 3-point hitch system. It should be mounted in such a way that the spikes reach a uniform depth and follow their own individual tracks. For these implements the tractor's lifting capacity should be more or less twice their weight. Some 3-7 kW/per metre of width is required for these operations.

4.6.4 Description Of The Implement And Tools

As mentioned above, two different designs can be distinguished - the spiked-chain harrow (a) and the spring-toothed weeder (b).

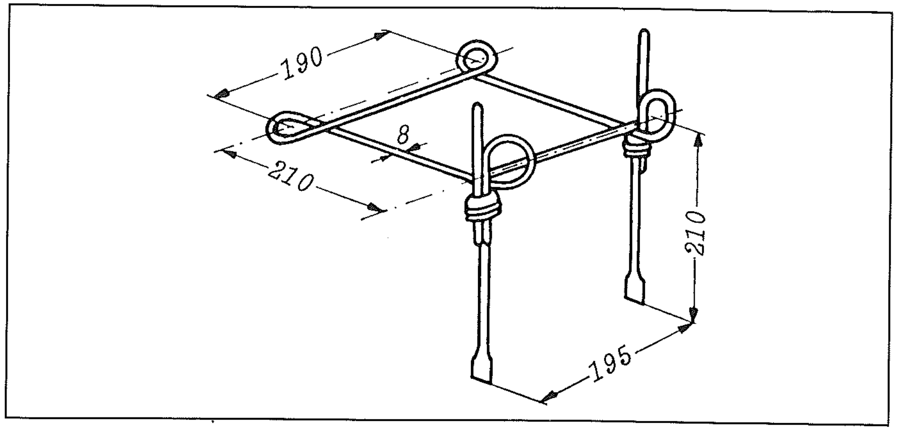


Fig. 98. Link with tines of a spiked-chain harrow.

(a) The links of the spiked-chain harrow form a mesh without a frame. Each link is made of bent steel wire in various shapes (an example is given in Fig. 98). The horizontal parts of each link determine both the forwards and sideways spacing. The links are attached to each other by the eyes in their corners. Two tines are fitted to each link perpendicularly to the surface of the mesh (and thus to the soil); short tines are placed on one side and longer ones on the other. The tines penetrate the soil under the pressure of the total weight.

The shape of the tools (tines, spikes, see Fig. 99) chosen with respect to the condition of the soil's surface rather than to the type of soil. The harrows may be used upright or on their backs with the short tines pointing towards the surface of the soil.

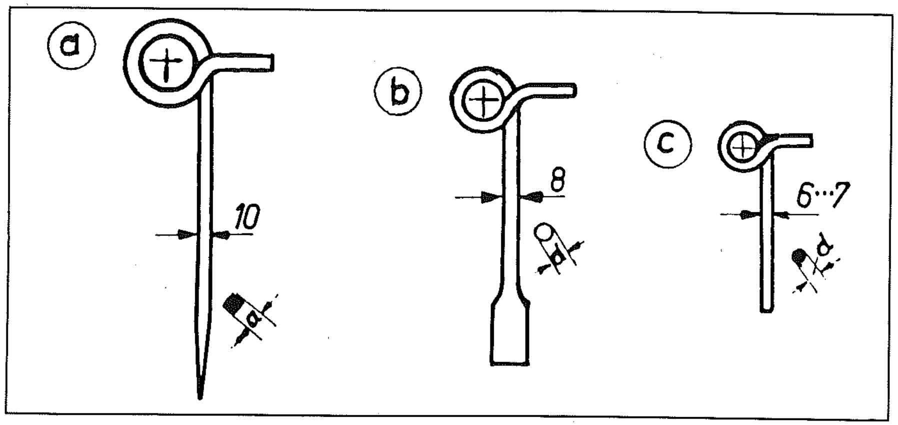


Fig. 99. Spikes of a chain harrow.

(b) The teeth (made from spring steel) of the spring-toothed weeder are mounted on the frame so that they point downwards and backwards (see Fig. 95).

The teeth have a circular or square cross-section and are straight or curved about 10 cm above the point. The tines are mounted by an adjustable tipping device so that the pressure on the teeth can be changed (Fig. 100). Individual tines or groups of tines may be folded back and not used for tillage in rows or ridges. The frame may be folded to transport width. Quick-coupling devices for the 3-point hitch may be used.

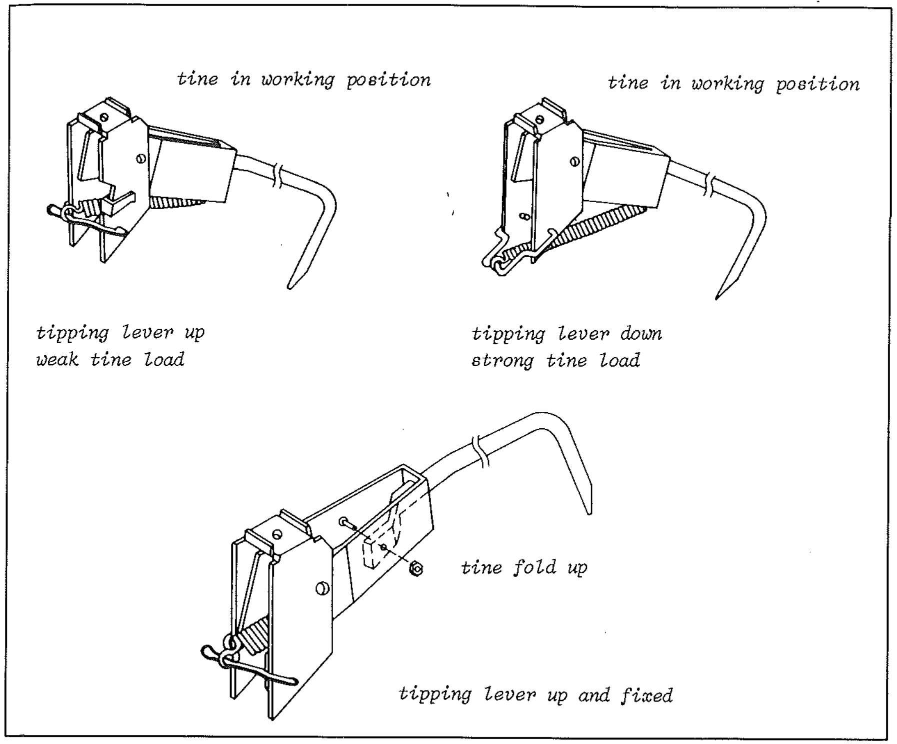


Fig. 100. Tipping device of a spring-toothed weeder in different positions.

4.6.5 Adjustments, Operation

4.6.5.1 Working Depth -
(a) Spiked-chain harrow: the working depth may be changed by the speed, the height of the hitch point, the load on the supporting frame or by turning the harrow on its back (short tines downwards).

(b) Spring-toothed weeder: the depth is adjusted by the speed, by changing the height of the tractor's 3-point hitch system and by altering the pressure on the tines by means of tension springs or a tipping device. The distance between the teeth clearly influences the working depth.

4.6.5.2 Tillage Intensity -
The fineness of the tilth formed by the weeders can be changed by altering the speed, the number of teeth and the distance between them, as follows:
- slow speed: less weed control, coarse soil surface;
- minimum number of widely-spaced teeth: less weed control, coarse soil surface,
- high speed (up to 12 km/h) and maximum number of teeth: fine crumbling and mixing, maximum weed control.

4.6.5.3 Operation -
The operator needs no special skills. The implement can be mounted and used by one person. The exception is when the spring-toothed weeder is used in row crops, in which case the driver must steer precisely between the rows.

4.6.6 Technical Data

	spiked-chain harrow	spring-toothed weeder
Width	up to 4 m	up to 6.5 m
Number of tines	77-110	68-156
Length of tines	12-17.5 cm	approx. 30 cm
Furrow distance	2-4.5 cm	approx. 4 cm
Adjustable pressure on the tines	-	20-40 N
Weight	30-75 kg/m. of width	200-460 kg/m.
Capacity	up to 5 ha/h	up to 7 ha/h
Power requirement per m width	approx. 4 kW	approx. 7 kW

4.6.7 Literature

See literature for chapter 4.0.

4.7 The Ridger

4.7.1 Use And Assessment

Ridgers (Fig. 101) are used for:
- building ridges,
- covering seed, tubers,
- rebuilding ridges,
- constructing ridges and furrows for surface irrigation.

Ridgers are used extensively in the tropics and subtropics because numerous crops, such as cotton, maize, sorghum, potatoes and sugar-cane are grown mainly on ridges. A ridge system is also a logical part of a furrow irrigation system. The mouldboard and disc ridgers will be examined in detail in Chapter 5.2 in the description of special machinery for irrigated crop production. The mouldboard ridger which is widely used in the crop production systems of humid climates will be discussed in this section.

The advantages of ridgers are:
- they can be used as single or multiple-row units,
- suitable for animal and motorized traction,
- they can be used in combination with other implements,
- the toolbar for ridging bodies may be used for other tools (weed control in row crops).

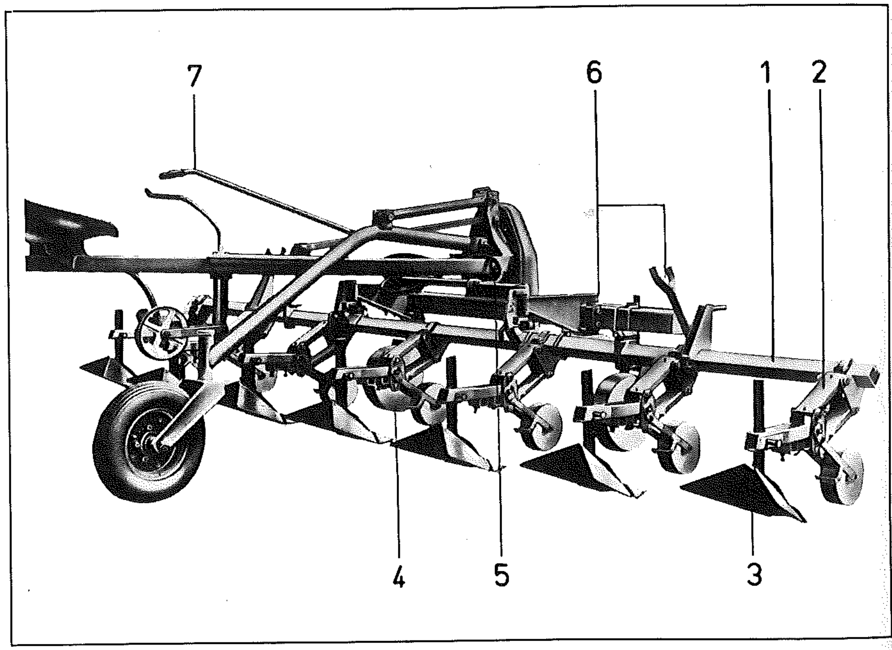


Fig. 101. Ridger:
1. Toolbar,
2. Paralellogram mounting,
3. Ridging bodies,
4. Support wheel,
5. Hydraulic cylinder for lateral shift of toolbar,
6. Hinge and support for folding to transport position,
7. Auxilliary steering lever.

The disadvantages of ridgers are:
- compaction of the surface (smearing effect),
- a special guiding system is needed (parallelogram, single or four-hinged mountings) on undulating fields,
- additional steering to compensate for slopes is needed when working on contours,
- difficulties on stony hard soils or soils containing roots.

Tied ridging

A special type of surface configuration is the tied-ridging system whereby the ridges are "tied" to each other at regular intervals by cross-dams, thus blocking the furrow. The system can be used when surface run-off has to be prevented. The run-off may be caused either by natural rainfall or by high intensity sprinkler irrigation systems.

Various types of implements are available:
- The basic concept is a shovel dragged over the bottom of the furrow, collecting soil; a cross-dam is formed by lifting the shovel.
- Large multiple-furrow implements using a four-blade rotor which is dragged along in a blocked position; a cross-dam is formed when it is allowed to rotate over 90 degrees by operating an hydraulic release system.
- Simpler units (also suitable for animal traction) operate a shovel attached to a frame which jumps at regular intervals as a result of the action of a triangular or off-centre support wheel.

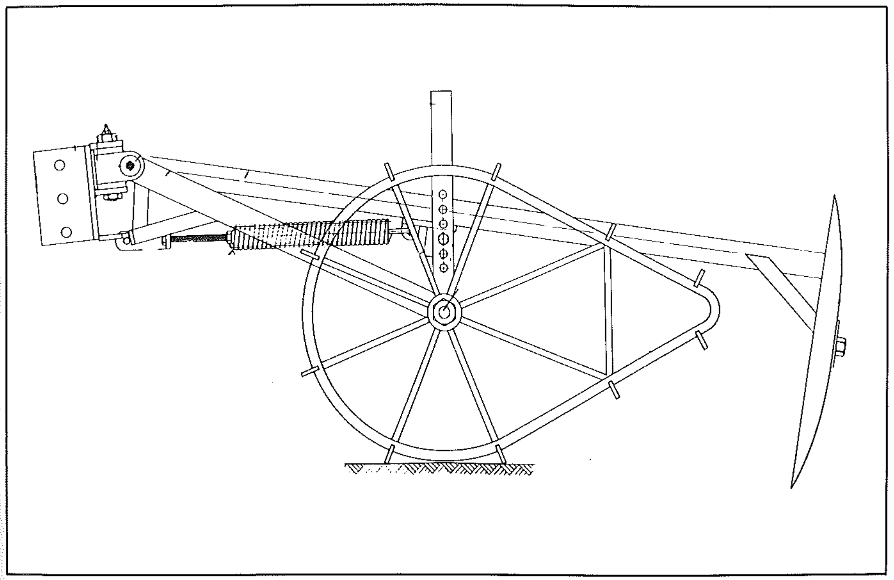


Fig. 102. Tied-ridging unit.

With these systems provision must be made for ploughing out the cross-dams in subsequent operations by using mouldboard ridging bodies mounted in front of the tractor's front wheels.

4.7.2 Functioning

The share or shovel of the ridging body penetrates the soil in keeping with the angle of attack and the depth control setting. The soil is lifted and transported evenly along the breast and wings onto the shoulders or top of the ridge. The required shape of the ridging body is determined by the type and condition of the soil, the desired shape of the ridge and the potential travel speed.

4.7.3 Linkage

Ridgers are usually designed for 3-point hitch linkage and consist of a frame (toolbar) bearing a number of ridging bodies. The depth is controlled by support wheels fitted to the toolbar or to each individual body. The steering system may be added for extra guidance.

Implements with more than one unit may be built with a supporting frame and wheels.

In addition to these two rear-mounting systems the toolbar with the bodies may also be mounted between the front and rear axles. This type is preferable because it provides good visibility and assists the steering (working on contours) although the available space is limited.

A system with the toolbar mounted in front of the tractor may be used for combined weeding and re-ridging operations. Front-mounted bodies are also used for tied ridging systems to smooth the furrow for the tractor-wheels.

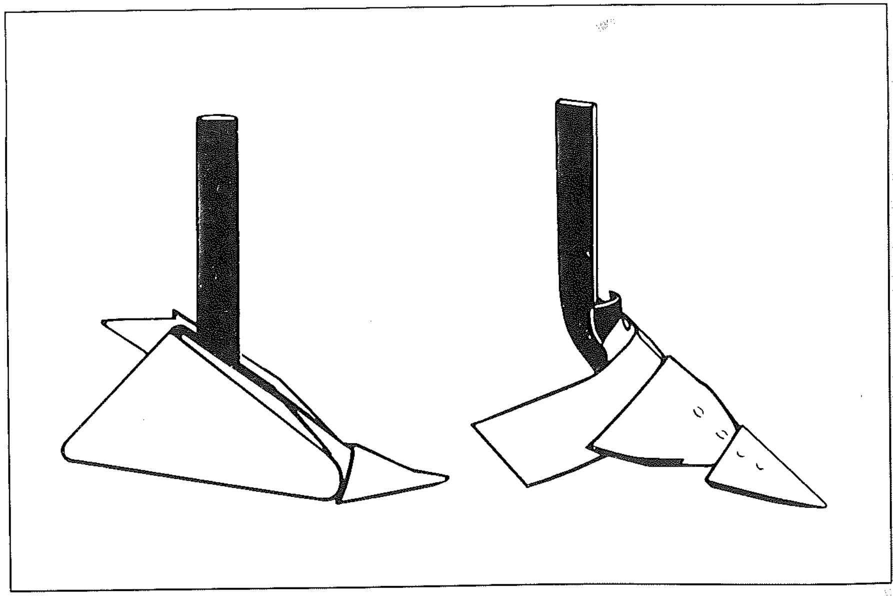


Fig. 103. Ridging bodies: Left: standard body, right: high speed body.

4.7.4 Description Of The Implement And Tools

Two types of ridgers (Fig. 101) are available:
a) with toolbar construction
b) mounted between the tractor's axles
They can also be sub-divided in keeping with the shape of the ridging bodies (Fig. 103):
a) bodies for speeds up to 6 km/h
b) bodies for higher speeds
The implement itself consists of a toolbar (except on models with only one body) placed perpendicularly to the direction of travel. The ridging bodies whose width and height are adjustable are mounted on this toolbar. For precise steering the bodies may be guided by a lever and parallelogram system (Fig. 104).

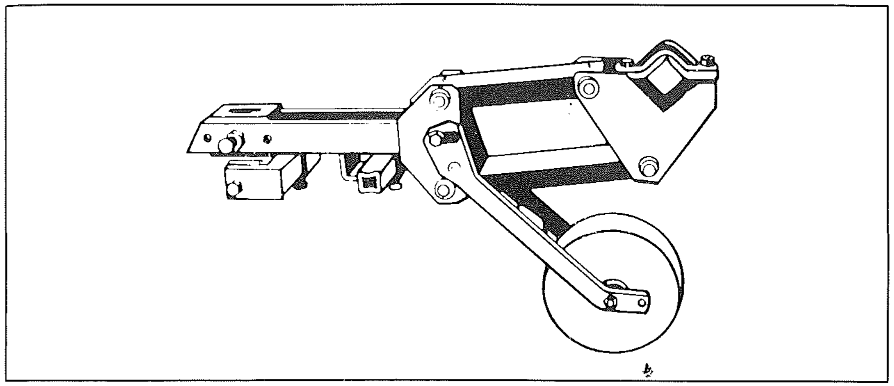


Fig. 104. Paralellogram mounting for ridgers.

The ridger is mounted (via the toolbar) either to the (rear) 3-point hitch or to a mounting device between the axles.
The ridging bodies consist of (see Fig. 103):
(a): a shank, (b): a breast, (c): a share or shovel, (d): wings.
Some designs allow the wings and/or shank to be adjusted (Fig. 105).

4.7.5 Adjustments, Operation

4.7.5.1 **Working Depth** - The shape and size of the required ridge determine the working depth. The shape and tilt angle of the ridging share are important in this respect, as is the depth setting fixed by means of support wheels or guide wheels on each body.

4.7.5.2 **Working Width** - The effective width of each body depends upon the construction. Bodies are designed for a specific width (or range of widths). Some bodies have an adjustable width (Fig. 105) but this feature is not often used. The implement's total width is determined by the length of the toolbar which may be up to 9 m.

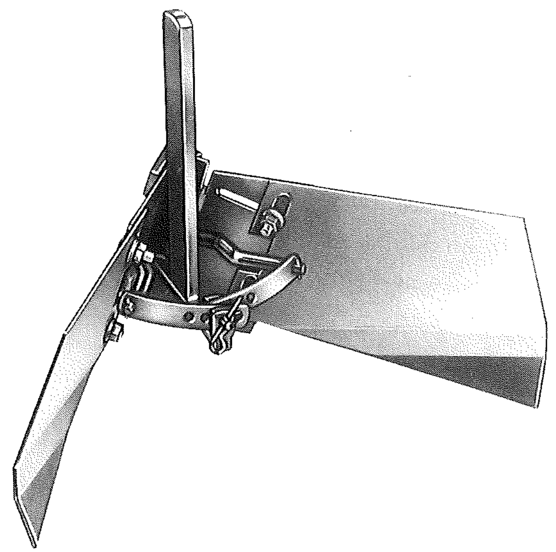


Fig. 105. Adjustable ridging body.

4.7.5.3 **Tillage Intensity** - The manner in which the soil is distributed depends upon the speed and angle of the body. The shape of the ridge is an important factor. The slope of the ridge's shoulder should not exceed 40 degrees; if it does, fine soil material may fall back into the furrow.

4.7.5.4 **Operation** - Mounting the implement is simple but some skill is required for adjusting and steering it.

4.7.6 **Technical Data**

Working width	row distance per body	up to 1 m
	total width	up to 9 m
Working depth		up to 28 cm
Power required		approx. 10 kW per body
Speed	standard bodies	4-6 km/h
	high-speed bodies	6-10 km/h
Angles	of the share	30-40 degrees
	of the wings	30-50 degrees

4.7.7 **Literature**

See literature for chapter 4.0.

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