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# Soil Tillage in the Tropics and Subtropics

R. Krause, F. Lorenz, W. B. Hoogmoed

| engine (hp) | weight (kg) | main work | characteristics |
|---|---|---|---|
| < 3 | < 100 | tillage, weeding and ridging with the rotary unit, carting, pest control. | management work in row crops and orchard. |
| 3 to 5 | 100 to 150 | ploughing, rotary tillage, puddling, ridging, weeding, crop maintenance, carting. | wide range of work, versatile. |
| 6 to 8 | 150 to 250 | rotary tillage ploughing, carting. | dismountable rotary unit. |
| 9 to 12 | 250 to 350 | rotary work. | deep tillage possible. |

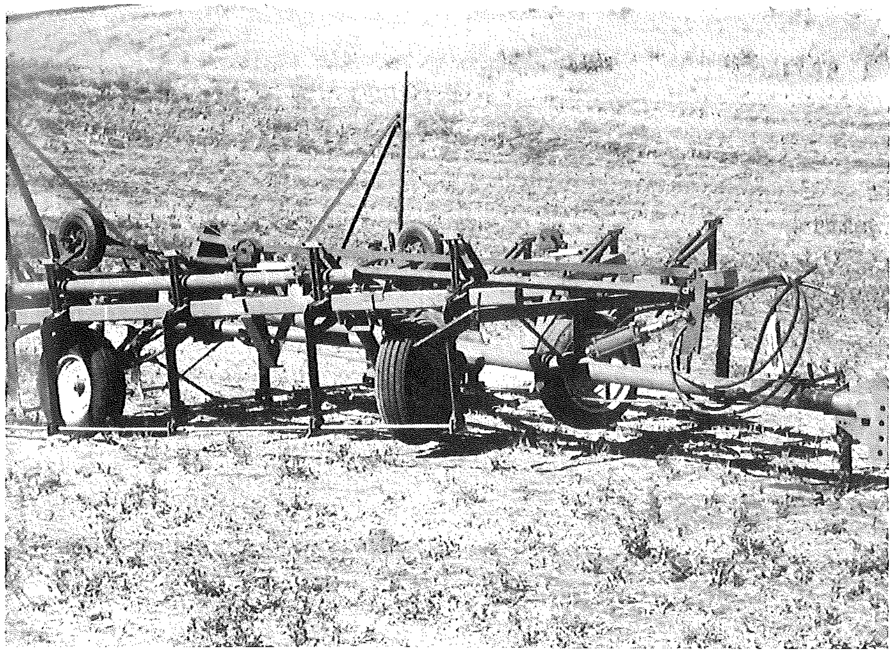
*Table 11. Characteristics of motor hoes and power tillers.*

### 6.2.4 Literature

See literature for chapter 6.0.



# 7.0 SPECIAL IMPLEMENTS FOR DRYLAND FARMING



Dry(land) farming can be defined as crop production in arid or semi-arid zones using only natural precipitation without supplementary irrigation (see Chapters I.3.2 and I.5.1). Water is the restrictive factor for this crop production system.

The principal aim of every tillage operation should be to increase the infiltration and water-holding capacity of the soil and to reduce water losses (by evaporation and deep drainage). Wind erosion should also be prevented (see Chapter I.4.1).

Reduced tillage systems, such as direct drilling, stubble mulch tillage or conservation tillage, are being considered and applied as alternatives to conventional tillage practices (see Chapter 10). The wide variety of factors involved in these methods cannot be examined in detail in this book. A number of implements with special functions for dryland farming are described in the following sections.

### 7.0.1 Literature

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FAO, 1971. Tillage and seeding practices and machines for crop production in semi-arid areas. FAO Agricultural Development Paper no. 92, pp. 53.

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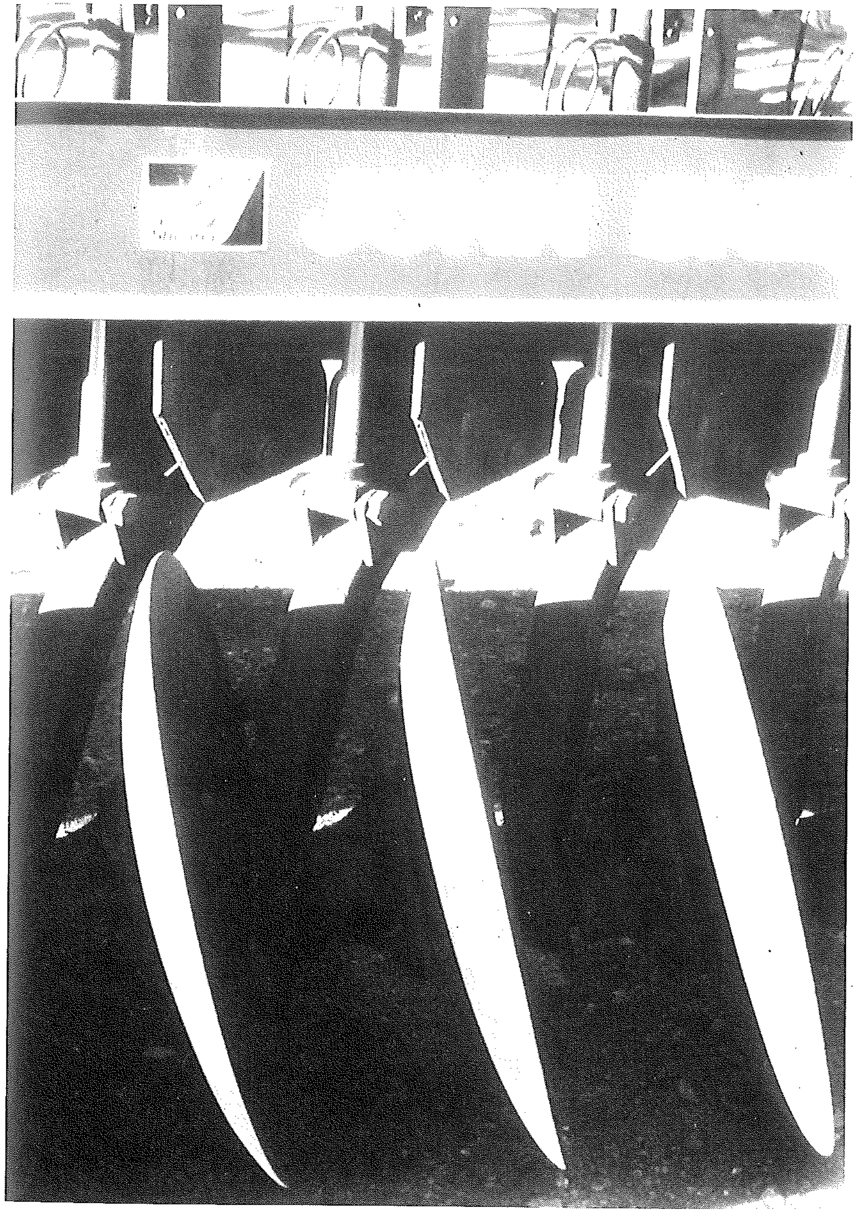
Marston, D. and P.J. Garland, 1978. Conservation tillage machinery. Journal of the Soil Conservation Service of New South Wales, 34(4): 220-227.



## 7.1 The One-Way or Disk Tiller



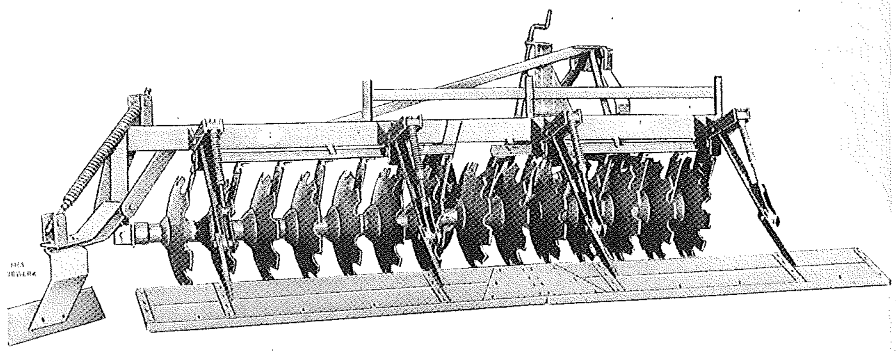


*Fig. 118. One way tiller (3-point hitch, cut-out discs).*

### 7.1.1 Use And Assessment

Unlike the disc plough, the one-way tiller is equipped with discs fitted at short intervals vertically or at a slight angle on a common axle. On larger implements the discs may be mounted in one or more gangs. The one-way tiller is suitable only for shallow tillage. It is used mainly in dryland areas and especially for:

- primary tillage,
- seedbed preparation in one operation,
- seedbed preparation after ploughing,
- stubble tillage, often combined with the drilling of the subsequent crop,
- fallow tillage,
- working in broadcast seeds, manure, spray materials and plant residue.

The success of the one-way tiller (Fig. 118) is due to its specific advantages in dryland farming areas. These include:

- versatility, used for both primary and secondary tillage,
- good mulching action,
- possibility of producing a seedbed in one operation (reduced risk of erosion),
- adaptation to the relief of the soil surface,
- high capacity,
- relatively low energy requirement,
- long life,
- possible combination with sowing equipment.

One negative aspect is the high cost. A heavy weight is required to produce penetration in hard soils (higher costs, difficult to transport). The implement may clog up in heavy weeds or large amounts of plant residue. Large working depths (> 15 cm) cannot be reached.



### 7.1.2 Functioning

Being a disc implement, the one-way tiller does not penetrate into the soil without weight or a load on the discs by springs. Consequently, extra weights can be attached to the frame and furrow wheels. The soil is raised by the discs and deposited in a pouring movement (skim tillage). The resultant mixing of the soil and the surface material increases the infiltration rate, reduces evaporation and does much to prevent wind and water erosion. Cut-out discs can cut into plant residue more efficiently than smooth discs. If travel speed is too high (> 6.5 km/h) the tilled layer becomes too fine and plant residue is buried, increasing the erosion.

Because the discs can be suspended in groups or individually the one-way tiller can easily adapt to an uneven surface. On several implements each disc is loaded (equally and individually) by a spring or hydraulic or pneumatic system. When fitted with a rear-mounted mulcher/leveller it produces better crumbling, levelling and compaction. The one-way tiller may be used as a single implement but is also combined with sowing or fertilizing equipment.

### 7.1.3 Linkage And Drive System

The one-way tiller is usually trailed, allowing a combination of two or three units. As on the disc plough, the implement tools are driven by the soil resistance. Mounted implements are also available. Since large types of this implement are used, the draught requirement may seem high but, when related to the area covered, it is comparable to that of other implements. The power requirement rises with an increased curvature of the discs, increased disc angle and increased travel speed. It ranges between 28 and 45 kW per metre of width at 6.5 km/h. The capacity at this speed is approximately 0.6 ha/h per metre of width.

### 7.1.4 Description Of The Implement And Tools

The implement (Fig. 119) is half-way between the disc plough and the disc harrow. The curved, plain or cut-out steel discs are mounted with dust-proof bearings either in gangs on a common shaft or individually to the frame by means of strong shanks (often spring-loaded). The frame consists of a heavy, usually square welded steel tube from which the discs are suspended at intervals of 150-260 mm. When in operation, the entire implement is aligned oblique to the direction of travel and the discs cut into the soil during the forward movement. The discs are 450-600 mm in diameter and 4-6 mm thick. Their concavity (depth at centre) is between 80 and 140 mm. Each disc is generally fitted with a scraper to avoid clogging.

The implement is usually trailed (rarely mounted) and, like the disc plough, is fitted with a front and rear furrow wheel which can be set at an angle of up to 45 degrees to the surface. A disc coulter or guiding share is often mounted as well. The rear support wheel and the furrow wheel form the rear bridge on which the implements can be lifted by a remote hydraulic system. When being transported, the furrow wheels are set vertically and the frame is rotated to the direction of travel.

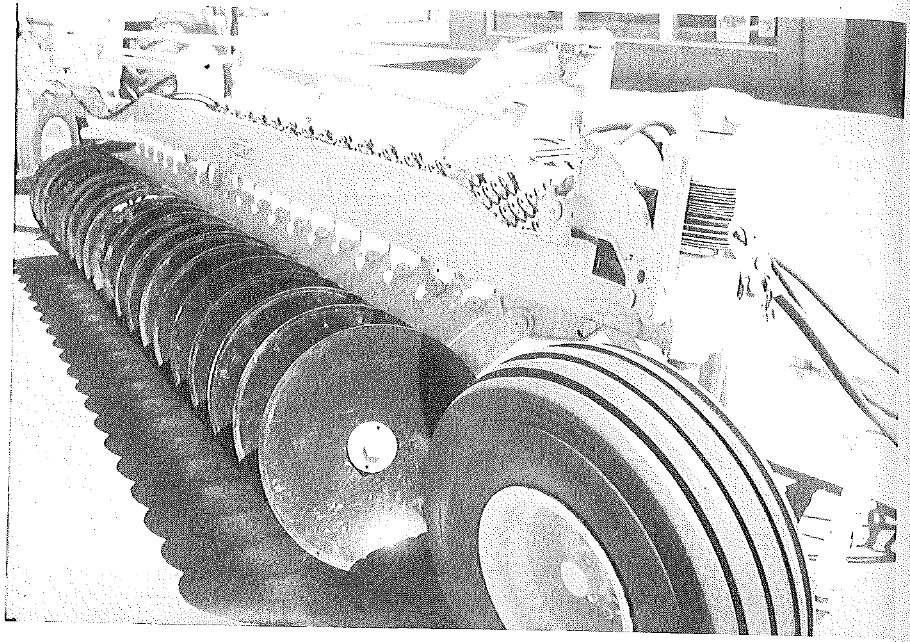


*Fig. 119. One way tiller (trailed type, individually spring-loaded discs).*

### 7.1.5 Adjustments, Operation

The working width and disc angle are adjusted from one central point by a hitch brace rod. With this system every tool has the same setting. The disc angle can be set between 30 and 60 deg (usually 40-50 deg) and the working width between 70 and 100% of the maximum width which may be as much as 4.80 m for a 20-disc implement. The discs are placed vertically or at a fixed tilt angle of about 15 deg.
The depth is adjusted by cranks on the axles of the furrow and depth wheels or by a hydraulic system remotely controlled from the tractor. The front and rear of large implements are raised and lowered simultaneously. The penetrative force reduces as the disc angle is increased (requiring more weight). The hitch point can be adjusted to the line of pull in order to distribute the load uniformly over the entire length of the implement. For accurate guidance the larger implements have not only the furrow wheel but also a disc coulter or guiding share. Link bars connect the wheels to each other and to the hitch system so that the steering is guided during turns (small turning space). The support bars on some mounted implements may be moved laterally, adapting them to the track width of the tractor.



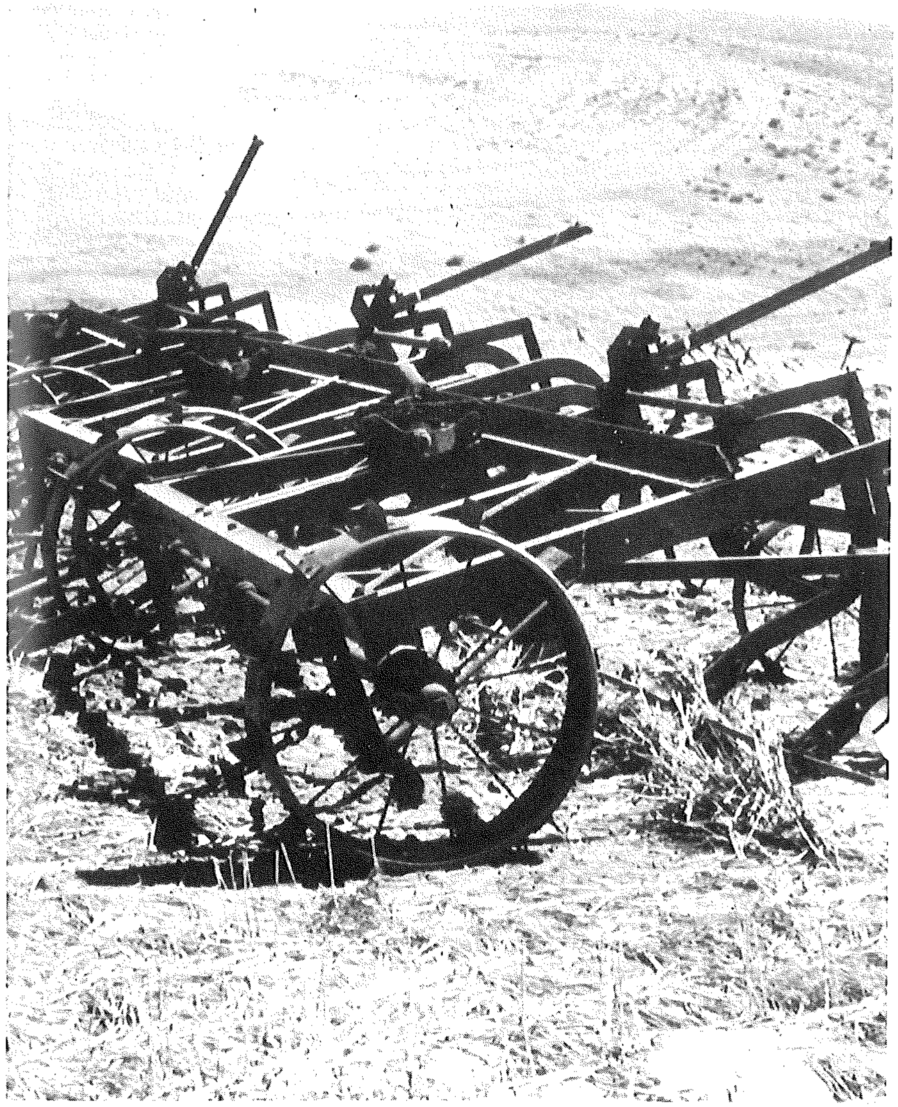
### 7.1.6 Technical Data

| | | |
|---|---|---|
| Length | | 2.00-10.00 m |
| Width | | 1.00-4.00 m |
| Height | | 0.80-1.50 m |
| Discs: | number | 10-40 |
| | diameter | 450-600 mm |
| | concavity | 80-140 mm |
| | thickness | 4-6 mm |
| | interval | 150-260 mm |
| Width of cut | | 150-260 mm per disc |
| Working depth | | 80-150 mm |
| Weight (without extra weights) | | 120-135 kg per disc |
| Possible load for setting by springs | | 150-250 kg (for each unit) |
| Maximum lift per disc | | 250-400 mm |
| Disc angle | | 30-35 deg |
| Tilt angle (fixed) | | 0 or 15 deg |
| Depth adjustment | | manually or hydraulically |
| Power required | | 28-45 kW/m |

### 7.1.7 Literature

See literature for chapter 7.0.

## 7.2 The Sweep Plough



### 7.2.1 Use And Assessment

The sweep plough is used for:
- stubble tillage (mulching),
- weed control during fallow,
- primary soil tillage.

The sweep (Fig. 120) has been developed especially for dryland farming for which implements with a high efficiency and capacity are required. The sweep is particularly suitable for mulching and can to some extent replace the plough. The soil is not inverted but loosened so that precipitation is absorbed with little loss. Weeds are killed mechanically, leaving 80-90% of the plant material on the surface. This protective layer reduces wind and water erosion, increases the infiltration capacity with heavy rainfall, protects against evaporation and surface crusting and prevents pronounced rises in the soil temperature. The sowing method has to be adapted to these conditions. The implement is unsuitable for stony or recently cleared land (stumps, roots). Even on sweep-tilled fields weeds often start to grow immediately after rain and this can be prevented only by using rear-mounted tools.

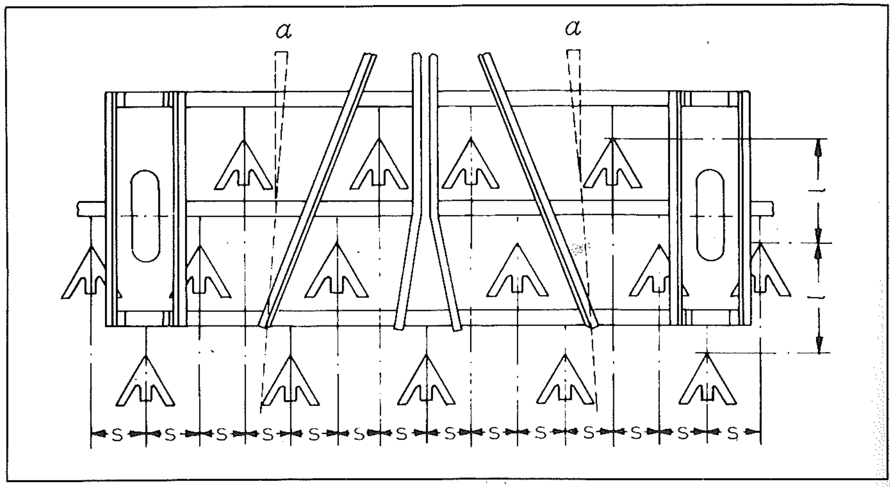



*Fig. 120. Sweep plough with symmetrical arrangement of tools.*

### 7.2.2 Functioning

The objectives of tilling with a sweep are:
a. to cut off the weed roots,
b. to disturb the soil capillary system (reducing water losses by evaporation),
c. to loosen the soil so that the infiltration capacity is increased without too much disturbance of the surface. Plant residue must not be worked in but should remain on the surface to form a protective layer.

These objectives are best fulfilled by a sweep with a broad cutting width. A delta-winged shaped tool is drawn horizontally through the soil at a depth



of 8 - 15 cm (Fig. 121). This cuts the weed roots and disurbs the capillary system. Because of the share lift angle the soil is slightly raised (25-30 mm) and, when dry enough, loosened and crumbled. A certain amount of overlap between adjoining tools ensures effective working over the entire width even if the implement is set at a slight angle from the forward direction. Almost the entire protective mulch layer of stubble and plant residue is preserved (80-90% of the material remains on the surface). A rear-mounted rotary hoe tears out the weeds after they have been cut off and prevents them from growing again during the next rains. The tillage operation is usually repeated with the second run at a shallower depth than the first. The sweep is used after harvest and shortly before sowing or during the summer fallow period.

The greater the number of tools/shanks and the smaller the cutting widths of those tools, the more the sweep produces the same effect as a cultivator with duckfeet. A narrower shank distance and smaller tools are suitable for stubble mulch tillage while a broad shank distance and wide tools are better for weed control (preserving the surface, reducing evaporation and protecting against erosion). The quality of the tillage operation can be improved by placing cut-out disc coulters in front of the shanks and by using rear-mounted tools (e.g. rotary hoes).

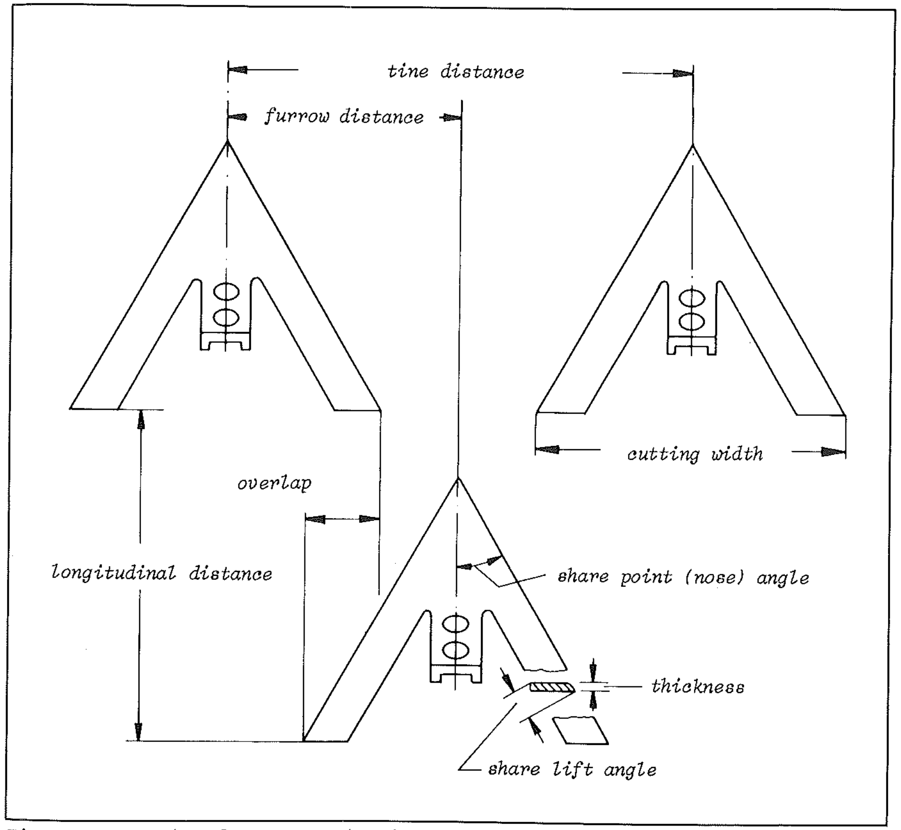



*Fig. 121. Tools of a sweep plough.*

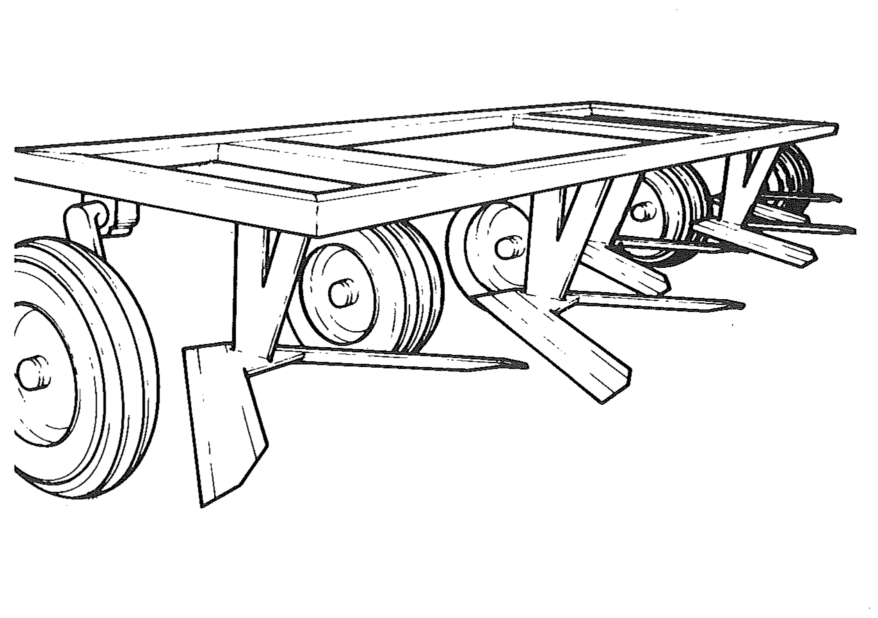


*Fig. 122. Wide sweep plough.*

As in the case of tillage with a chisel plough, the quality of the operation depends upon the soil moisture content. Penetration is difficult on hard dry soils while smearing can be expected in plastic soils. A small share lift angle and thin blades will increase the penetration. Guidance is improved by large working widths and a slight tilting of the tools towards the point and also by a reduced downwards suction.

When moving backwards, flexible tines change the depth and tilt angle, producing irregular depths. Rigid tines with large tools are very vulnerable to obstacles in the soil (stones, roots).

### 7.2.3 Linkage And Drive System

Small implements are equipped for the 3-point hitch system for which quick-coupling devices may be used. The lifting capacity required for mounted implements is more or less the same as for chisel ploughs. Large implements with working widths of up to 12 metres are trailed or semi-mounted.

The sweep is a passive drawn tool. As in the case of cultivators, the power required depends upon the number of tines, the design (rigid, spring-loaded), size of tools, depth, tilt angle, soil condition and soil type. The power obviously increases with the depth, speed and share lift angle. The power required from the tractor is comparable to that required for the cultivator. This is approximately 10 kW for a tool 400 mm wide at a speed of around 8 km/h. The sweep is often combined with other tools,



especially the rotary hoe. When moving backwards, this implement acts as a stubble treader, as it is called in the USA, destroying weeds and embedding plant residue more firmly in the soil.

### 7.2.4 Description Of The Implement And Tools

Leaving aside its tools, the sweep plough (Fig. 120) looks very much like the chisel plough. The solid main frame is usually made of flat and tubular steel. The rigid or flexible tines are mounted either on fixed welded steel clamps or on adjustable flanges. They are placed on one to three crossbars (distance between bars: 650-700 mm) staggered one behind the other. Rigid tines have an overload protection device, shearbolts or springs. The tines (shanks) are fitted perpendicularly to the frame or slightly curved or angled towards the front. The V-shaped tools are mounted on the shanks. The shape, dimensions, nose angle and share lift angle determine the functioning of these tools (Fig. 123). The dimensions and nose angle also determine the number of tines, the distance between them, the number of (and distance between) the crossbars and the furrow distance.

The tool shares (wings) are 6-8 mm thick with a total (cutting) width of 310-2100 mm and they usually work with an overlap of approximately half the width of one wing (a quarter of the tool's width). The tines may be fixed symmetrically around the implement's central axis, giving an odd number of tines (Fig. 120) or asymmetrically, giving an even number.
The latter type can be expected to deviate on hard soils. Spring tines are used only for tools with a narrow cutting width. Penetration can be improved by tilting the tool slightly forwards.

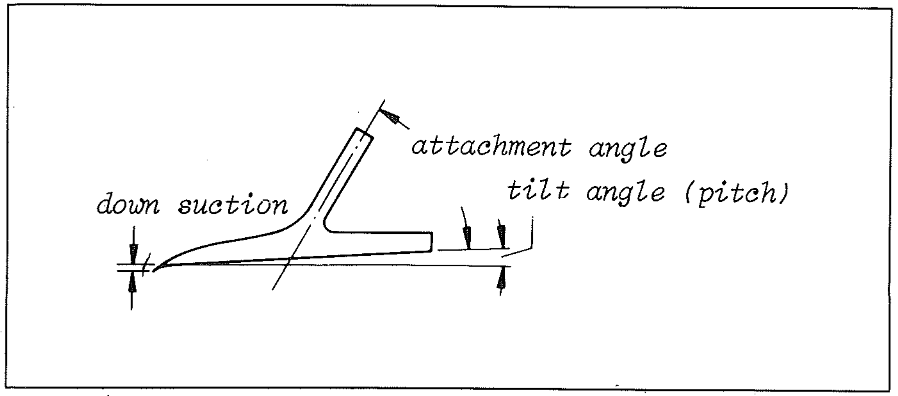



*Fig. 123. Geometry of a sweep.*

The frame height and the distance between the crossbars and tines must be sufficient to allow the mulch layer to flow freely. Disc coulters are often mounted in front of the tools to prevent choking and the creation of surface furrows (rills, water erosion).

The frame is carried by support wheels which also control the depth. Multiple-use tool carriers are frequently used for mounting the tools. The frame is usually too unstable for tools with a broader cutting width. The tool's cutting widths average 400 mm with an overlap of 50-100 mm. Implements equipped with much wider tools (up to 2100 mm on the wide sweep plough, Fig. 122) require fewer shanks, thus causing less disturbance to the surface and reducing the risk of choking. A heavier and therefore a more expensive design is required for this. The implements are used particularly for deeper tillage.

The nose angle is 30-50 deg and so roots, plant residue and stones can slide off the tool. If the share lift angle is too small, the soil will not be sufficiently loosened. If it is too large, penetration is poor, the flow of soil and plant residue is uneven (leaving bare spots) and the draught requirement is high. Implements are either trailed or mounted, depending upon their size. Trailed implements can achieve widths of up to 12 m with an articulated frame. Working depths are between 6 and 12 cm.

### 7.2.5 Adjustments, Operation

Different share sizes may be used on implements on which the distance between tines can be adjusted. The depth is controlled almost entirely by the support wheels; by a crank system on smaller implements and hydraulically on larger ones. As on the cultivator, the working depth is determined by the frame height blocking the flow of soil and plant residue. Inadequate penetration in dry soils may be improved by changing the tilt angle (pitch) or by adding extra weights. The tillage intensity depends upon the speed, the number and type of the tines (rigid, springs), the size of the tools, nose angle, overlap and the working depth. The distance between tines and the tool size can be adapted to the specific purpose of the operation.

The implement is simple to use and can be operated by one man. Mounted implements can be fitted with quick-coupling devices. The driver has to leave the tractor to make any adjustments (except in the case of hydraulic depth control). The only maintenance required is lubrication of the support wheels.

### 7.2.6 Technical Data

| | |
|---|---|
| Frame height | up to 900 mm |
| Number of crossbars | 1-3 |
| Distance between crossbars | 650-700 mm |
| Tool's cutting width | about 400 mm (300-2100 mm) |
| Nose angle | 30-50 degrees |
| Share lift angle | 12-25 degrees |
| Distance between tools | up to 2.00 m |
| Working width | up to 12.00 m |
| Power required | up to 25 kW/shank |
| Overload protection | shearbolts, springs |



### 7.2.7 Literature

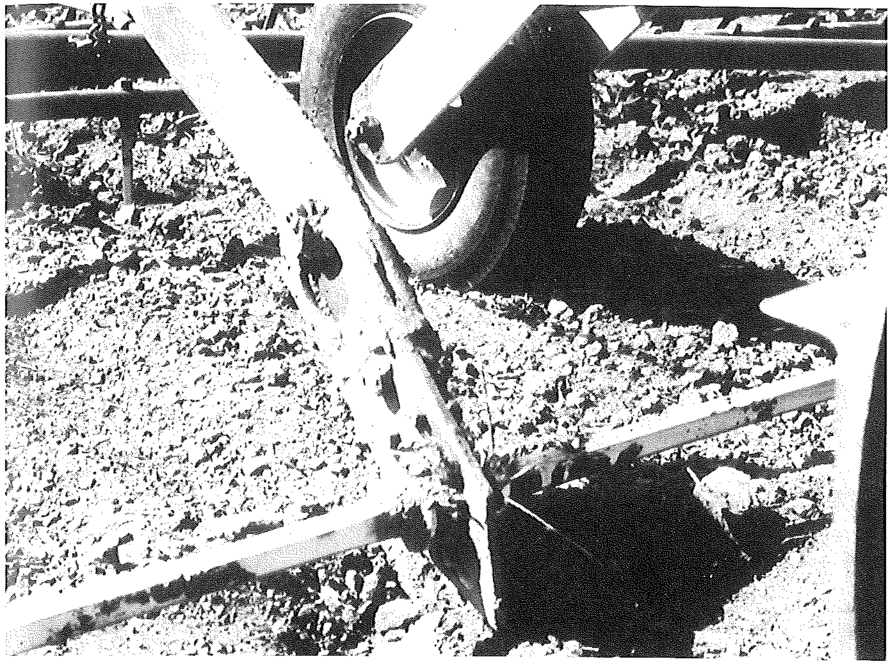
See literature for chapter 7.0.

Kiss, G.C. and Bellow, D.G., 1981. An analysis of forces on cultivator sweeps and spikes. Canadian Agricultural Engineering, 23(2): 77-83.

Sial, J.K. and H.P. Harrison, 1978. Soil reacting forces from field measurements with sweeps. Transactions of the ASAE, 21(5): 825-829.

Speedie, T. and K. McSwain, 1977. Blade ploughs reduce erosion in the Mallee. Journal of Agriculture, Victoria, 75(2): 59-60.

## 7.3 The Rod Weeder



#### 7.3.1 Use And Assessment

The rod weeder (Fig. 124) has been developed specifically for dryland farming systems. The implement is used, principally for:
- stubble tillage,
- weed control during the summer fallow period,
- secondary tillage before sowing.

The rod weeder was developed primarily for mechanical weed control on fallow land susceptible to wind erosion in the dry-farming areas. This implement is suitable only for soil in a proper mulch condition. Like the sweep, the rod weeder's main advantages are that the soil is loosened, the capillary system is disrupted and weeds are controlled while the surface is scarcely disturbed and soil water and organic matter are preserved. Only 10% of the plant material on the surface is worked into the topsoil. The resultant mulch layer provides protection against erosion, evaporation and excessive heating and also increases the infiltration capacity of the soil under heavy rainfall. The implement is unsuitable for recently cleared land (stumps, roots); penetration is a problem on hard and dry soils.

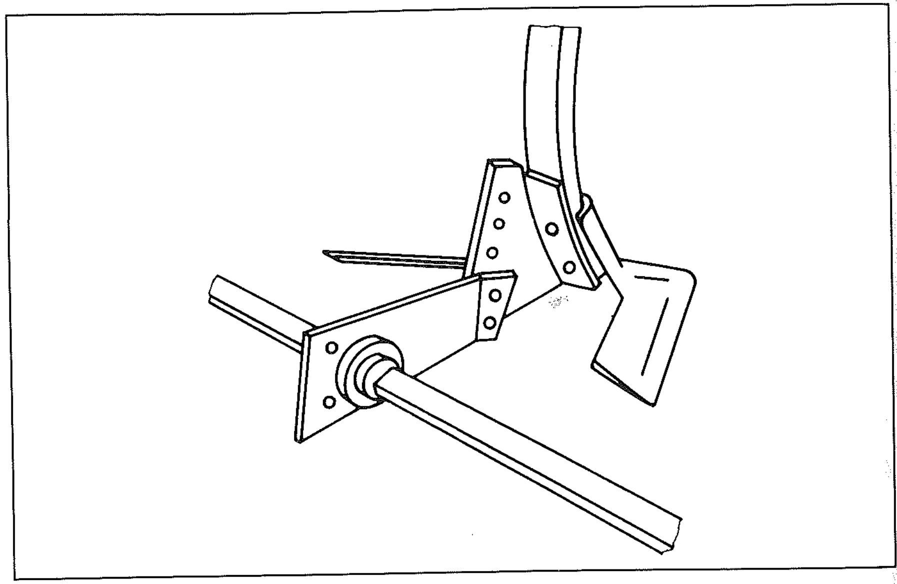


*Fig. 124. Rod weeder mounted on a sweep plough.*

#### 7.3.2 Functioning

A square rod slowly rotates against the direction of travel at a depth of approximately 5-10 cm, moving parallel to the surface. The tilled layer is slightly lifted and loosened, increasing the water infiltration capacity without unnecessarily accelerating the decomposition of organic matter. The capillaries at that depth are interrupted, reducing evaporation from deeper layers. The reverse rotation of the square rod pulls up roots of weeds from deeper layers and deposits them on the surface where they will dry out. Up



to 90% of the plant material remains on the soil surface and forms an effective protective layer against erosion and evaporation. Pronounced loosening occurs only immediately around the tines. Coarse soil material is moved upwards and fine material downwards (protection against erosion).

Extra tines and chisels improve the implement's loosening action. When tilling soil which is too wet, the weed control is less effective and choking, smearing and coiling may result. Although every unit has an overload protection device, the implement is unsuitable for heavy soils and soils with many stones and roots.

#### 7.3.3 Linkage And Drive System

The basic frame of small implements is usually a tool carrier so that the square rod can be driven by the pto. Little lifting capacity is required. Large implements (working widths of up to 25 m) consisting of independent units each with a width of 3 m may be driven (individually) by large profiled support wheels by means of a sprocket and chain or by hydromotors.

The power requirement is low owing to the shallow working depth and the tool's rotating movement. It depends upon the speed, working depth, soil condition and soil type. Approximately 5-10 kW per metre of width are required at a speed of 8 km/h; this figure is valid for a rod weeder but not for a chisel plough/rod weeder combination.
A remote hydraulic system is used for depth control and for lifting trailed implements. On very wide implements the support wheels must be placed along the entire width to obtain a uniform working depth.

#### 7.3.4 Description Of The Implement And Tools

Angled or curved tines are mounted in one row on a steel tube frame (in the direction of travel). Replaceable shoes (which can be used on both sides) are mounted with bearings at the bottom of the tines. These bearings allow the square rod (which may be rounded near the bearing) to rotate. The rod is made of high quality steel with a diameter of 20-25 mm (see Fig. 124). Although only shallow tillage is performed with the rod weeder (5-10 cm), the frame should be high enough to avoid choking when working with thick layers of mulch.

The frame is supported by wheels which are also used for depth control and driving the square rod. Power is transmitted by gears and chains (Fig. 125). Very accurate depth control can be achieved on large implements by means of support wheels mounted in tandem behind and in front of the rod. Implements with very large widths (up to 25 m) have articulated frames. Each element about 3 m wide forms an independent unit when driven individually. These units may also have an independent hydraulic depth control system and overload protection device (shearbolts or automatic reset system). On some models the shanks are spring-loaded. The elements' working widths overlap by 10-15 cm. The frame can be loaded with extra weights to assist penetration in hard dry soils.
Special assembly kits of rod weeder components are often used (Fig. 124). These modules can be attached to the last row of tines on a chisel or sweep plough.

## 7.3.5 Adjustments, Operation

The depth is controlled hydraulically (by a crank on smaller implements) through the support and drive wheels supporting the frame. The hydraulic system is controlled from the tractor. The maximum working depth is determined by the frame height. The number of revolutions of the rod must correspond to the travel speed. Rod weeder attachments can be used which combine the rod weeder's weed-killing capacity with the better loosening action obtained by the chisel plough. The rod weeder is often fitted with a rear-mounted tool (e.g. a rotary hoe) which smoothes the furrows produced by the tines or prepares a seedbed.

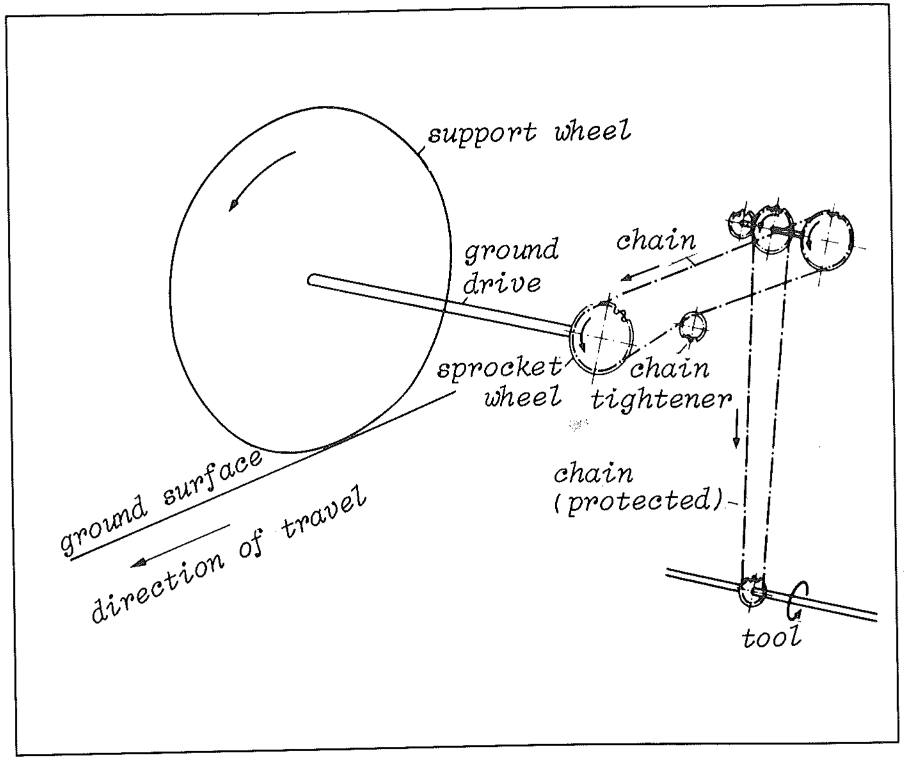



*Fig. 125. Drive system of a rod weeder.*

Extra units (3 m each) up to a total width of 25 m can be added to some implements. Mounted implements may have quick-coupling devices. They are simple to use and can be operated by one man. The switch from working to transport position is done more easily and faster by two men. The following maintenance operations are required: lubrication of the support wheels, drive system, depth control system and (where necessary) the adjustment system of the rear-mounted tool. Chains must be kept at the correct tension. The bearings of the rod are self-lubricating.

## 7.3.6 Technical Data

| | |
|---|---|
| Frame height | approx. 700 mm |
| Working width | up to 25 m |
| Working depth | up to 120 mm |
| Power required | approx. 5-10 kW/m |
| Distance between tines | up to 2.00 m |
| Overload protection | shearbolts or hydraulic system |

## 7.3.7 Literature

See literature for chapter 7.0.

Harrison, H.P. and R.P. Atkins, 1981. Rodweeder soil forces from field measurements. Transactions of the ASAE, 24(3): 590-592,597.

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