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Soil Tillage in the Tropics and Subtropics

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

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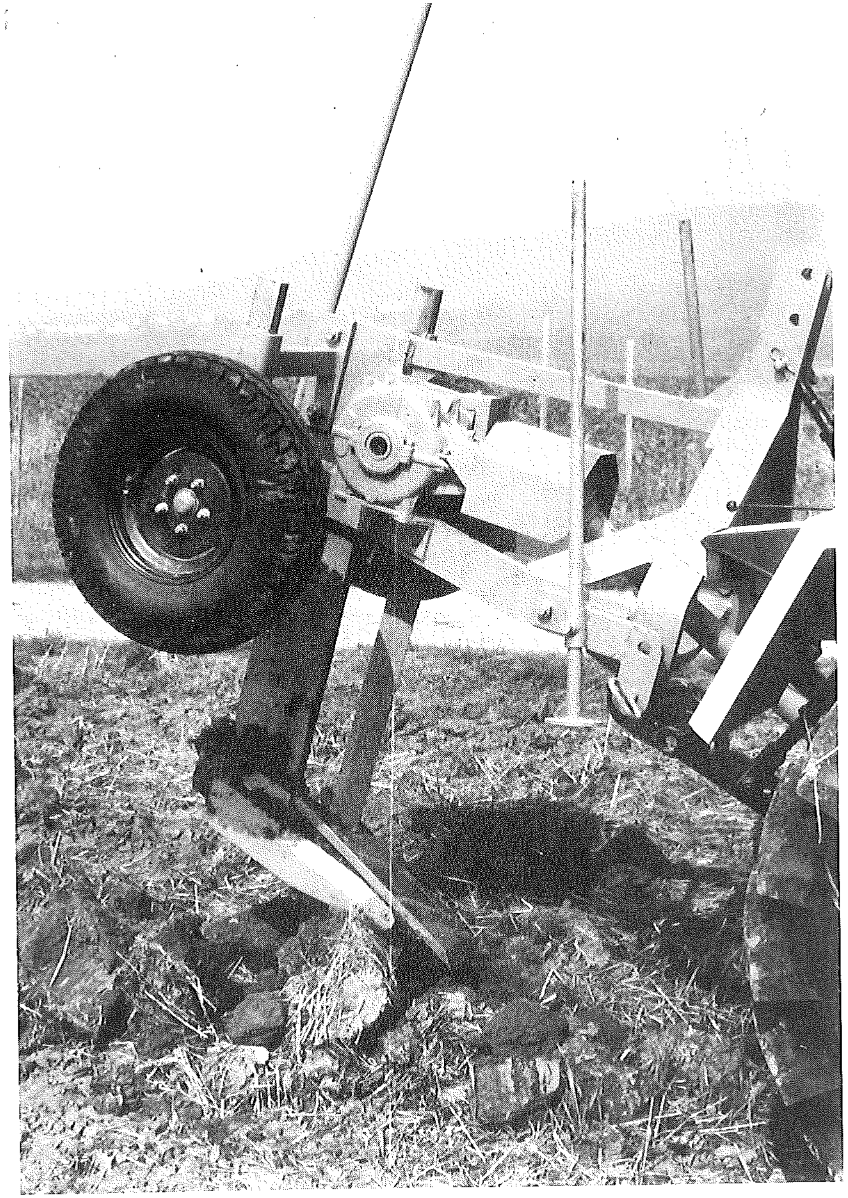
11.0 TRENDS AND NEW DEVELOPMENTS



Constant adaptation, development and improvement of equipment and systems is necessary in the soil tillage sector because of a large number of factors. Some of these factors (which have either a direct or indirect influence are:

- the increasing need for food caused by the growing world population;
- progress in the biological-technical (including breeding, plant nutrition and protection), mechanical and organizational sectors;
- a change in living and eating habits;
- a change in outlook (including a different attitude towards the environment);
- the shortage and rising prices of raw materials and energy.

Any adaptation of tillage methods to these changes should include not only the improvement of machinery in terms of its performance, operation, servicing, life and ease of maintenance and repair (reducing the relative energy requirement) but also the development of entirely new systems, such as the direct drilling systems which were made viable by the use of herbicides.

Some new implements

Compared with other implements used in modern agriculture, the plough, cultivator, harrow, drag and roller have remained unchanged for centuries without causing any problems. This is because their basic design is very simple, they suffer little wear and the maintenance and servicing requirements are very low. The number and diversity of tillage implements available on the markets all over the world are now so great that it is scarcely possible to list them all. This situation is caused not only by marketing and patents but also by the wide range of production methods and conditions, the use of agro-chemicals, the availability of energy and, last but not least, a better understanding of the processes in the soil.

Inverting tillage with the plough is no longer unrestrictedly advocated. The disadvantages (risk of erosion, water losses, loss of organic matter) have become quite obvious, particularly in the climatic regions on which this book concentrates. It is impossible to over-emphasize the importance of conserving the soil fertility in view of the constantly increased areas under monocultures and the systems with higher cropping intensities. Only very careful soil tillage can produce profits from the high input of labour, capital and materials, especially fertilizers. In the USA these activities are grouped together under the heading of "conservation tillage". A careful balance between mechanical weed control and the use of herbicides not only saves costs but also reduces pollution of the environment with agro-chemicals. The need to use energy thriftily requires a continuous assessment of the entire production system. Since of all field operations soil tillage consumes the most energy, a very critical evaluation is necessary. The greatest savings can undoubtedly be achieved by omitting or combining operations, as the term "minimum tillage" indicates. The scope of this book allowed only a brief examination of minimum tillage in Chapter 10 but mention should also be made of strip tillage (as part of the seedbed preparation) since this system offers specific advantages as regards efficient water use and weed control.

Basically, however, the aim of these activities should be to optimize (rational tillage) rather than minimize. The further development of tools and implements so that they make more efficient use of energy will probably be given more attention in the future.

The disadvantage of drawn implements as regards the transmission of power (low efficiency, structural damage to the soil because of slippage) and the desire for more specific intensive and controlled mechanical soil tillage (in one operation, if possible) are matters receiving constant attention from machine designers. This has already resulted in implements with active rotating or oscillating tools, such as the rotary plough, spading plough, oscillating subsoilers, as well as the rotary tiller and rotating and reciprocating hoe which have already proved succesful.

Attempts to reduce the draught force requirement by using high-frequency vibrations have not yet achieved any lasting success. Non-metal tools, coatings for tool surfaces (Teflon), lubrication of tool surfaces (liquid polymers) and air cushions between the soil and steel surfaces have all been tried as means of reducing the friction and adhesion on tool surfaces. The experience so far gained indicates that none of these systems can be recommended for (sub-)tropical regions because of their unsatisfactory life, the high costs involved in applying surface lubrication and the limited availability of the lubricants.

A clear trend can be observed towards implements with different tools, especially combinations of passive cutting and loosening tools with active mixing and crumbling tools. The objective is to obtain deep loosening and intensive shallow mixing and crumbling in such a way that the flow of soil through the active tools is, in part, supplied by the passive tools. A typical example of this trend is the chisel plough/rotary tiller combination developed in the U.K. (NIAE) and West-Germany (Hohenheim). It must be remembered, however, that pto-driven tools require not only better construction, operation and maintenance but also high-powered tractors and suitable operating conditions. Unfortunately, all of these factors are problematic in less developed tropical countries.

Another reason for the (further) development of soil tillage implements is the harmful soil compaction resulting from the weight placed on the soil by heavy tractors, implements and trailers. Consequently, pto-driven implements for loosening the subsoil are being used more frequently. In many places experiments are being carried out with production systems in which no traffic at all passes over the production areas and permanent tracks are used for all operations ("controlled traffic").

New developments can also be observed in connection with the recompaction of loosened soils when insufficient time is available to allow natural consolidation. Mention can be made of the plough with a rear-mounted packer, the "tiltrotor" (a rear-mounted tool for the plough with a driven rubber roller) and the "vibro-packer" which uses packing discs vibrating at a frequency of approximately 60 Hz.

Very wide implements and implements operated at high travel speeds have been developed, partially because of the high wages paid to tractor drivers in the industrialized countries but also because of the need for correctly timed soil tillage operations. This trend will probably be perceptible in the developing countries too in the future. Pto-driven implements can also be adapted to higher travel speeds (by changing the number of revolutions). These implements make it possible to work heavy soils with a wider range of moisture contents.

In the past it has been possible to observe a move away from multi-purpose implements (such as the wedge plough) with a wide range of applications towards special-purpose implements over the entire field of agricultural mechanization. The use of special-purpose implements does, however, require that a large number of implements are available with a high capacity over a comparatively short period of use. This is feasible only for large farms and/or cooperatives. This trend is less marked in relation to soil tillage. Great care must be taken when choosing this type of implement for tropical and subtropical developing countries.

The objectives set for the development of soil tillage implements which are particularly suitable for use in tropical and subtropical regions must be:

- conservation and treatment of vulnerable soils in order to maintain the level of soil fertility,
- a positive effect upon the water balance,
- careful use of the limited supplies of energy,
- high output during periods favourable to agricultural operations (short periods in close crop rotations),
- aligning the requirements for operating the implements with the skill and experience of the potential users (combined with further training),
- creating servicing and repair facilities in countries with a low level of development,
- preserving the level of employment in agriculture.

The next chapters will briefly discuss a number of implements chosen from the many recent developments. It is impossible at this stage to give a final assessment of those implements because they have only recently been put to practical use.

Unfortunately, none of these implements fulfils the particular requirements of the vast majority of small and very small farms in developing countries.

11.0.1 Literature

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11.1 The Diamond Plough

As regards its functioning and use the diamond plough (Fig. 134) is very similar to the mouldboard plough. This plough has been the subject of considerable discussion since its introduction in 1973. It was designed primarily to cope with the problems produced by the use of increasingly larger tractors (and tractor tyres) and implements:

- The width and clearance of the furrow achieved with the current depth:width ratio of traditional mouldboards are no longer sufficient; the wide tyres of large tractors do not fit the furrows and so some of the loosened soil is recompacted.
- Multi-body mouldboard ploughs, especially the reversible type, are very heavy and the centre of gravity is located well away from the tractor so that the load on the front axle is greatly reduced and the tractor's steering is affected.

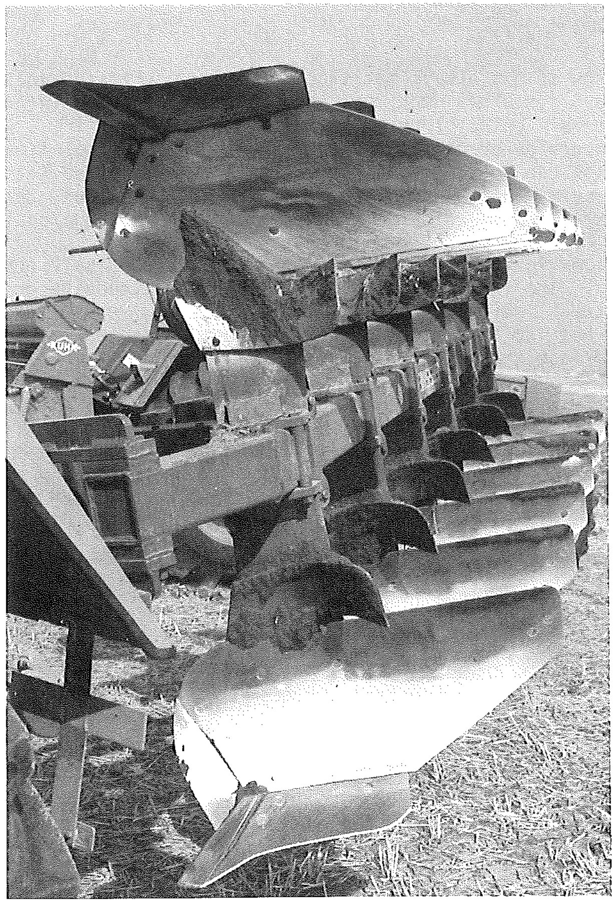

Fig. 134. Diamond plough.

The diamond plough is distinguished from the ordinary mouldboard plough by the fact that the furrow slice is diamond-shaped instead of rectangular. Consequently, the furrow is wider at the top, allowing more room for broad tyres (Fig. 135). There is less risk of recompaction even though the pressure on the soil at the bottom of the furrow is not reduced. Unlike the conventional mouldboard, the working width per body (35-50 cm) can be set quite independently of the depth. Sufficient inversion is obtained over the entire range of depth:width ratios from 1:1 to 1:1.4.

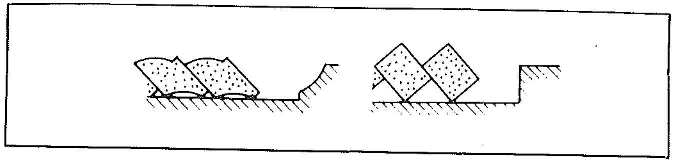

Fig. 135. Cross sectional view of furrows made by a diamond plough (left) and a conventional plough (right).

The clearance of the furrow is not always satisfactory since coulters cannot be used. In particular, problems may be expected to occur when large amounts of harvest residue are being ploughed in.
Owing to the different inversion process and the trajectory of the soil flow the length of the bodies can be less than the conventional bodies so that the plough's centre of gravity is closer to the tractor. The height of the frame must, however, be correspondingly greater than on conventional ploughs.
The plough bodies are cylindrical and marked by a shin which curves well out to the front (Fig. 136). The individual bodies do not have a landside and to ensure that the lateral guidance is still adequate a very large spring-loaded landside has to be fitted to the last body. Pointed shares are generally used to increase the grip of the plough.

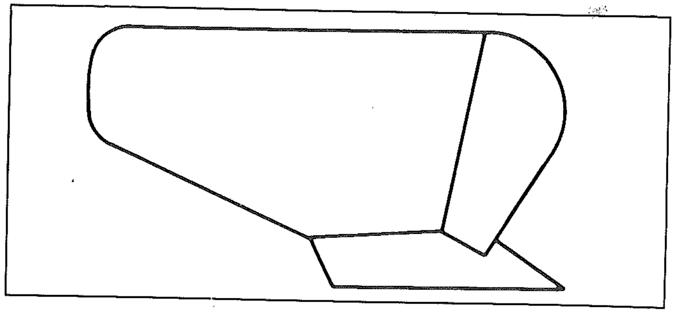

Fig. 136. Body of a diamond plough.

Measurements which compare the performances of conventional mouldboards and diamond ploughs usually show that diamond ploughs require (slightly) less energy. The reasons for this difference have not yet been thoroughly investigated but it could be caused by the different soil flow, reduced soil crumbling, and by the lower rolling resistance of the tractor in the open furrow.
The diamond plough is available with 3 to 6 bodies as one-way and reversible type. The bodies are semi-mounted and mounted to the 3-point hitch.

Literature

See literature for chapter 11.0.

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11.2 Sweep Combined With A Pto-Driven Rotary Hoe

Attempts have recently been made to use the sweep plough, which was developed especially for dryland agriculture, for tilling heavy and moist soils. For this purpose the sweep is combined with pto-driven tools.
These implements are used for:
- stubble and primary tillage,
- working in green manure or other organic matter,
- preparating a seedbed,
- sowing, combined with tillage to form one operation,
- clearing grassland,
- weed control.

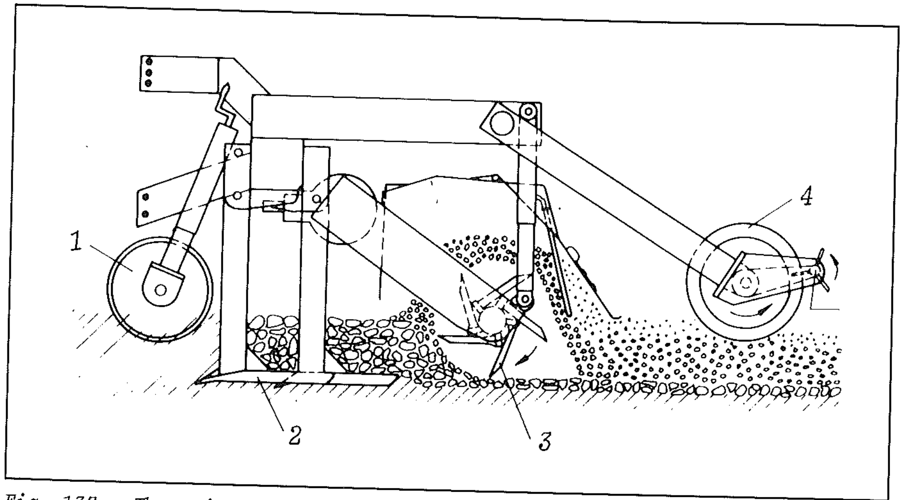

Fig. 137. The main parts of the "Justus":
1. Disc roller, 3. Tine rotor,
2. Sweeps, 4. Packing roller.

Variants of this basic design are now available. Although similar designs can be obtained elsewhere (U.K. etc.), we shall describe two examples from West-Germany:
The "Justus", a complete unit comprising a sweep plough with a pto-driven rotary hoe (Fig. 137), and the "Weichel", a model which can be assembled from various parts including a sweep plough and a pto-driven rotary hoe (Figs. 138 and 139).

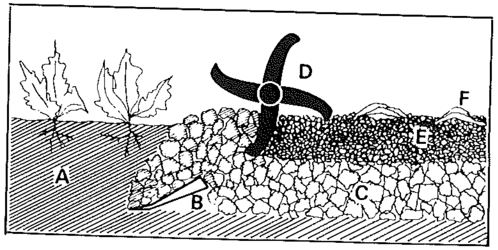

Fig. 138. Functioning of the sweep (B) with rotary hoe (D).

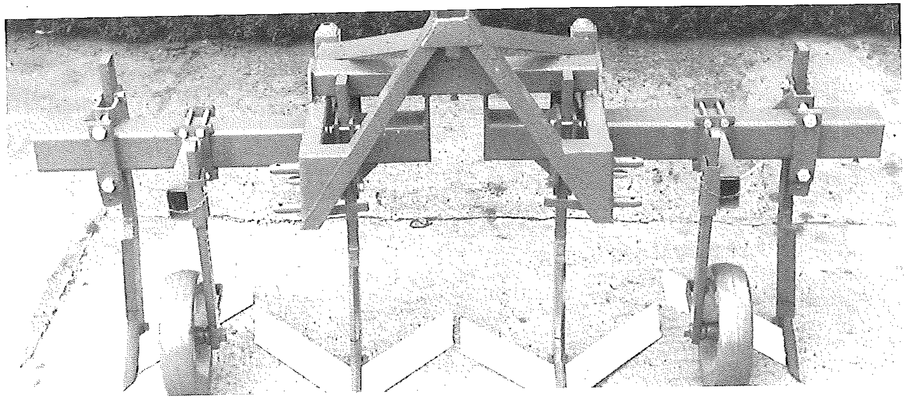

Fig. 139. Sweeps of the "Weichel".

The implements are designed for intensive soil tillage under difficult conditions. The combination of passive and active pto-driven tools and the numerous possible adjustments have produced a versatile and sophisticated machine. It must be used with higher-powered tractors and perform satisfactorily on heavy wet soils. The number of passes can, of course, be reduced but a relatively high proportion of the land is covered by wheel-tracks because of the small working width (about half the width of seedbed combinations suitable for similar tractors).

The Justus combination consists of a line of tools and elements arranged one behind the other (see Fig. 137). A disc roller placed in front controls the depth and produces a vertical separation of the soil. Behind this roller the wide sweep blades cut the soil over the entire working width at a depth of 5-40 cm. The separated soil slice is fed directly into a tine rotor fitted with pointed spoon-shaped tines (Fig. 140). This rotor can be rotated in either direction and its rpm can be adjusted.

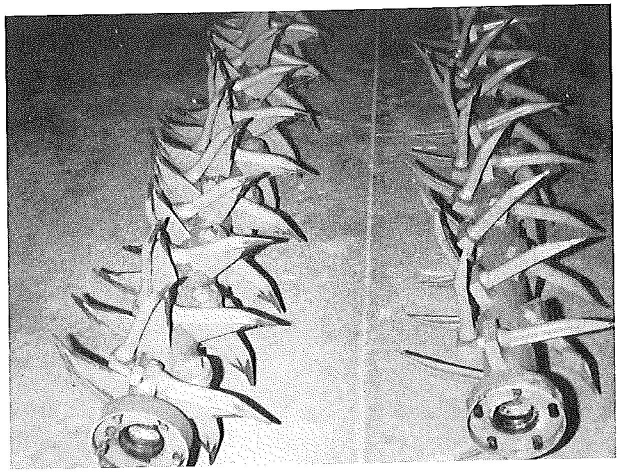

Fig. 140. Tine rotor of the "Justus".

A crumbling/packing roller mounted closely behind this unit helps to control the working depth (especially when the front disc roller is omitted) and recompacts the soil (Fig. 141). The roller is coated with Teflon and can be fitted with a counter-rotating scraper for use on sticky soils.

Like the Justus, the Weichel model must be mounted to the 3-point hitch but its sweeps are mounted on a compact toolbar with a 3-point coupling at the rear. So it is possible to mount the rotary hoe mentioned earlier or any other type of implement (possibly pto-driven), such as a second set of sweeps, sowing or planting equipment, etc.
These machines have to be driven by heavy tractors and are therefore suitable only for large farms or cooperatives. The Weichel model may be used with lighter tractors because it can work in narrower strips, using a device which shifts the toolbar to a lateral position to obtain a close fit between successive passes.

Special care should be taken to preserve a coarse surface structure when working on soils susceptible to erosion.

The operation, adjustment and servicing of these machines are complicated and require highly-skilled personnel and supervision.

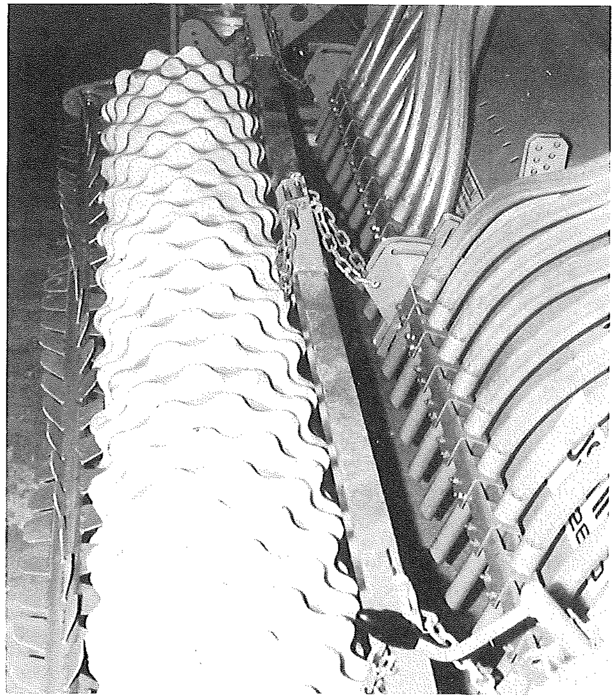

Fig. 141. Packing-roller (Teflon coated) with rotating scrapers.

Technical data

	Justus	Weichel
Working width	2.10 and 2.60 m	0.80-3.00 m
Working depth: sweep	5-40 cm	5-35 cm
rotor	5-40 cm	2-15 cm
Working speed	3-9 km/h	
Nose angle	35 degrees	
Share lift angle	20 degrees	
Rpm of the rotor	200-580	adjustable
Weight	1200-1450 kg	
Rpm of pto	540 or 1000	540 or 1000
Power required	from 25 kW per m	from 30 kW
Overload protection:		
rotor	friction clutch	friction clutch
sweeps	shearbolts	shearbolts, spring loaded reset
Front disc roller, dia.	250 mm	
Rear mounted roller, dia.	450 mm	varies
Total length	2.20 m	
height	1.30 m	
width	2.50 or 2.90 m	

Literature

See literature for chapter 11.0.

11.3 The Clod Breaker

Two types of implements for tilling hard dry soils will be discussed in this chapter - the "Multitiller" and the clod pulverizer.

The multitiller*

Heavy implements are expedient for dry hard soils in the semi-arid and arid regions. The "Multitiller" (MT, Fig. 142) was developed for the following jobs:
- stubble tillage,
- seedbed preparation,
- levelling, mixing and packing,
- crumbling; pulverizing and breaking up clods,
- soil preparation and sowing in one operation.

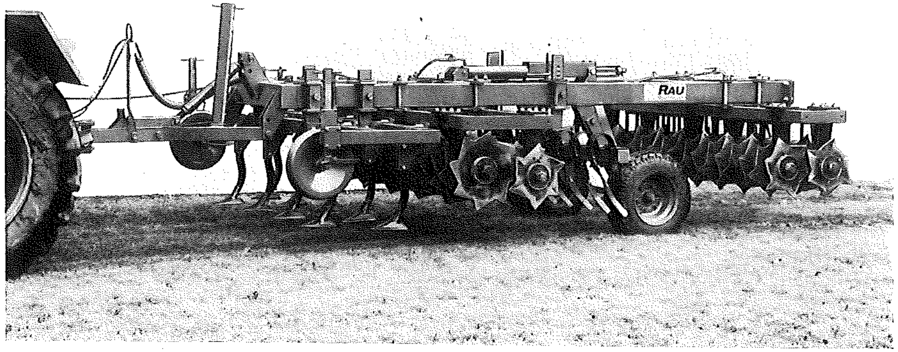

Fig. 142. The Multitiller with 2-row chisel plough.

The MT can be classified as one of the group of stubble tillage and seedbed preparation implements, as are the disc and rotary harrow. The machine is heavy and combines passive (rigid or spring tines) and active tools (rotating star-shaped discs). This design produces satisfactory destruction of clods and also cutting and compaction even on the dry soils of arid regions, which saves time and reduces the number of passes and wheel-tracks on dry and (under certain conditions) moist fields.
The functioning of the machine depends upon the type of tools which are mounted in rows perpendicularly to the direction of travel (Fig. 143). After the surface has been smoothed by a levelling tool (bar or rake) any coarse lumps are pulverised by two rows of "rotostars". The following rows of tines bring up clods which are fed to the two rows of "rotostars" at the rear of the unit. In the course of this operation smaller soil aggregates may fill cavities near the bottom of the furrow.
The MT is a trailer implement. Hydraulically operated (pneumatic) tyres are available for transport. The manufacturer gives the power required as 26 kW per metre of width which means that tractors in the medium and heavy class (up to 260 kW) are necessary for working widths of 2.5-6 m. Trailer implements of this size should be used only on suitably large fields.
* "Multitiller" is the trademark of the RAU Company.

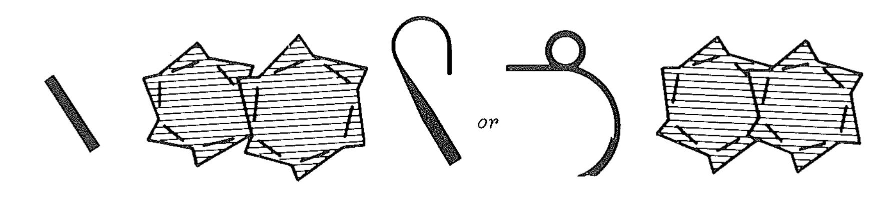

Fig. 143. Tools of the Multitiller (side view with two alternatives for the deep working tine section).

The implement operates at two depths: the tines' working depth can be set independently of the "rotostars". The working depth is reduced as the speed increases. The rotostars in the second, third and fourth gangs are identical. Each star has 6 points bent left and right alternately to produce more compaction. The rotostars in the front row are larger and have the special funcion of breaking up large lumps. The first and second rows are inter-meshed, as are the third and fourth rows. Hitch points for 3-point mounting of sowing equipment can be attached to the rear of the machine (Fig. 144).

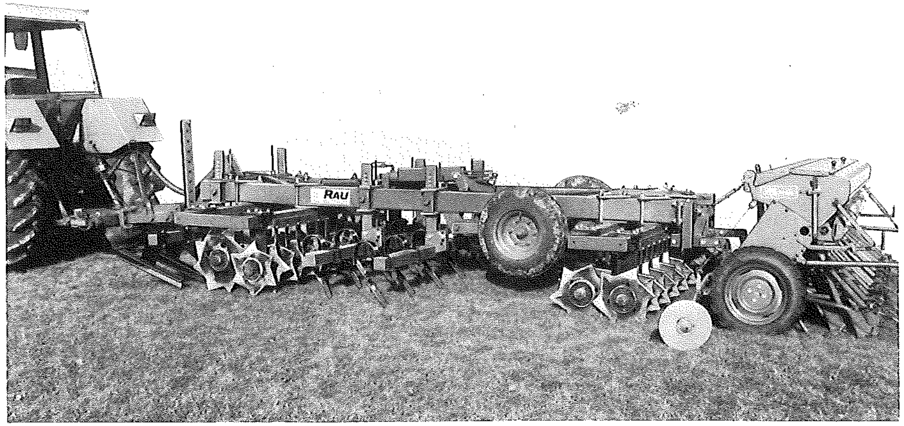

Fig. 144. Multitiller with leveller and rear-mounted drill.

Technical data

Working width	2.5, 3, 4, 5 and 6 m
Weight	approx. 1000 kg/m
Power required	from 26 kW/m
Speed	from 5 km/h

The clod pulveriser

A much simpler tool for breaking up hard and large clods has been developed in Israel: a roller which functions on principles similar to the Cambridge or Crosskill roller but with much heavier and larger toothed rings (Fig. 145). The rings' central opening is much larger than the diameter of the central axis so that they can roll over the soil surface independently.

Curved teeth or chisels around the circumference of each ring are angled forward and hit the soil clods with a sudden blow so that they break up or pulverize.

The effect is satisfactory only when the clods are hard and dry enough to break up under the impact. If the soil is too moist, the result is excessive compaction and the rings clog up. If all the clods are not broken up after one pass, a second pass should not be made until a chisel plough has been used to raise the larger clods to the surface, thus preventing the creation of very fine material on the surface.

The implement is available for 3-point hitch mounting (narrow implements) and as a trailer model (wider types). It can also be used as a rear-mounted tool on a chisel plough or disc harrow.

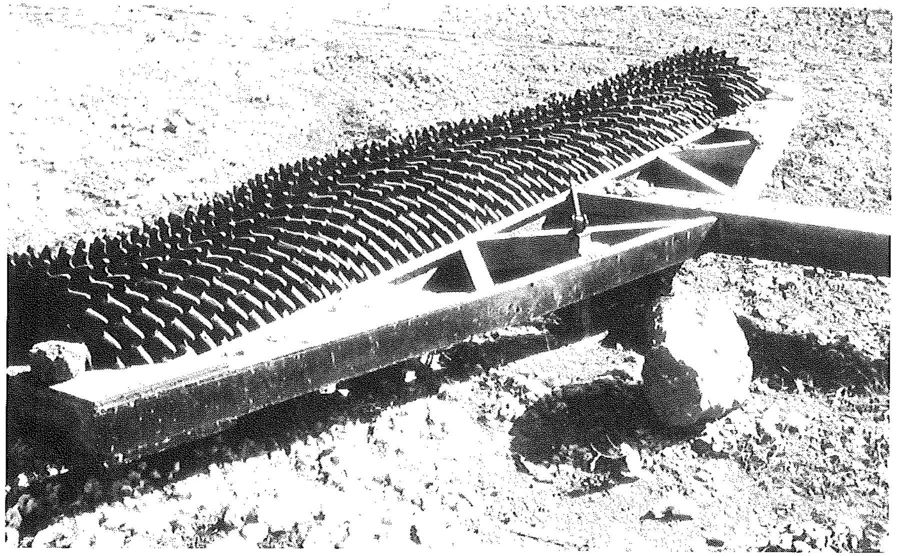

Fig. 145. "Kipnis" clod pulverizer.

Technical data

Working width	1.20-6.60 m
Diameter	
outside ring	420 mm
inside ring	310 mm
axle	200 mm

Literature

See literature for chapter 11.0.

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11.4 The Soil Loosener

The problem of soil compaction by traffic over the field has been repeatedly referred to in this book. Heavier tractors and harvesting equipment tend to exacerbate the compaction problems, especially on soils where reduced tillage or direct drilling has been applied. The "natural" regeneration of the soil structure by root growth and biological activity is often inadequate in soils which are only marginally suitable for reduced cultivation systems.

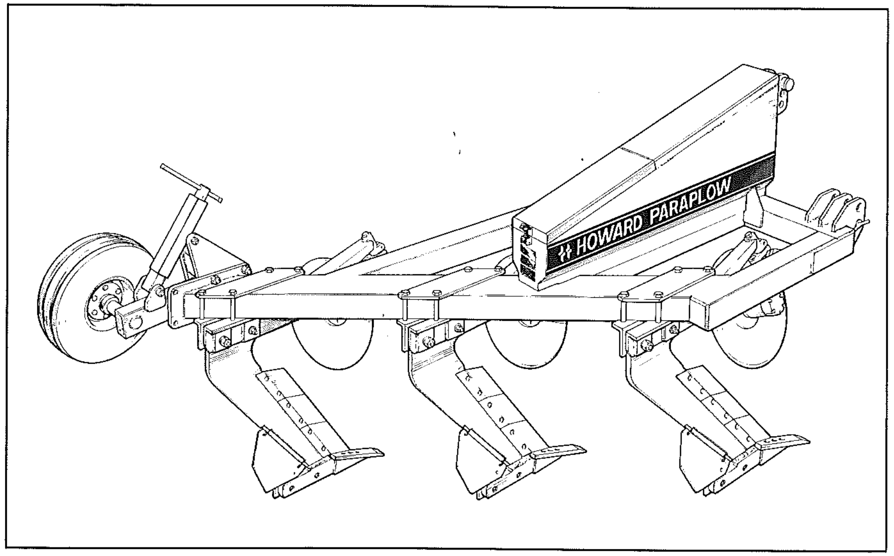

Fig. 146. The "Paraplow".

The Paraplow* (Fig. 146) has been developed in the UK for loosening compacted layers of soil. It is a tined implement but differs considerably from the conventional chisel ploughs or subsoilers. The Paraplow's legs are slanted, producing a forward and lateral angle of about 45 degrees.
Adjustable shatterplates behind the legs cause disturbance of the soil but this can be controlled. Since the soil is lifted as it flows over the legs and plates, the loosening occurs along natural cracks resulting from the tension in the soil slice rather than from compressive forces. The implement leaves the surface more or less undisturbed so that a crop can be drilled without further tillage. Disc coulters mounted at the same angle in front of each leg allow the work to be done without interruption.

The implement is (semi-)mounted to the tractor's 3-point hitch and equipped with a depth wheel at the rear.
* "Paraplow" is the registered trademark of Howard Rotavator Company.

The uses of this implement include the loosening of:

- compacted headlands on fields whose structure is suitable in all other respects,
- fields under reduced tillage or direct drilling which have been damaged by compaction (only when the need arises and not usually every year),
- fields whose soil types are marginally suitable for reduced cultivation systems (annually),
- soil under permanent grassland which must be loosened without seriously disturbing the sward.

Technical data

	mounted	semi-mounted
Number of legs	3, 4, 5	6 or 8
Total length	3.4-4.6 m	9.5-10 m
Total width	1.8-2.8 m	3.9-4.7 m
Working width (max.)	1.5-2.5 m	3.0-4.0 m
Working depth (max.)	35.5 cm	35.5 cm
Frame clearance	69 cm	71 cm
Lift capacity required	1,850-2,660 kg	2,500-2,800 kg
Weight	833-1,339 kg	3,200-3,600 kg
Power required	18-26 kW (25-35 hp) per leg	
Linkage	3-point hitch (cat. II or III)	
Overload protection legs	shearbolts	shearbolts

Literature

See literature for chapter 11.0.

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11.5 The Spade Plough

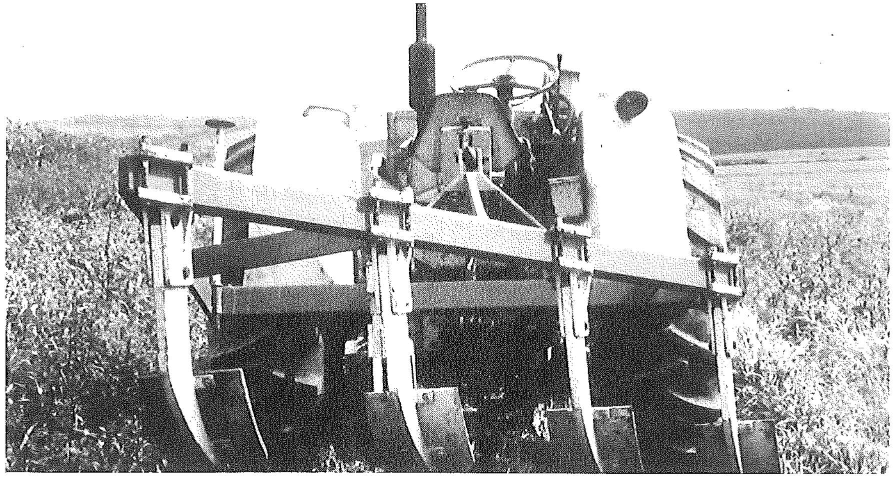

Fig. 147. Spade plough (rear view).

The advantages of a chisel plough as an alternative to the mouldboard or disc plough have been mentioned in Chapter 2.3 but one of its major disadvantages is the clogging problem when the tines are set too closely together. The furrow distance has to be relatively narrow for chisel ploughs because the effective ranges of each chisel should touch or overlap. An interesting development has been reported in Brazil: the "spade plough". This is a very simple sturdy implement fulfilling a function half-way between the mouldboard and chisel ploughs (see Figs. 147 and 148).

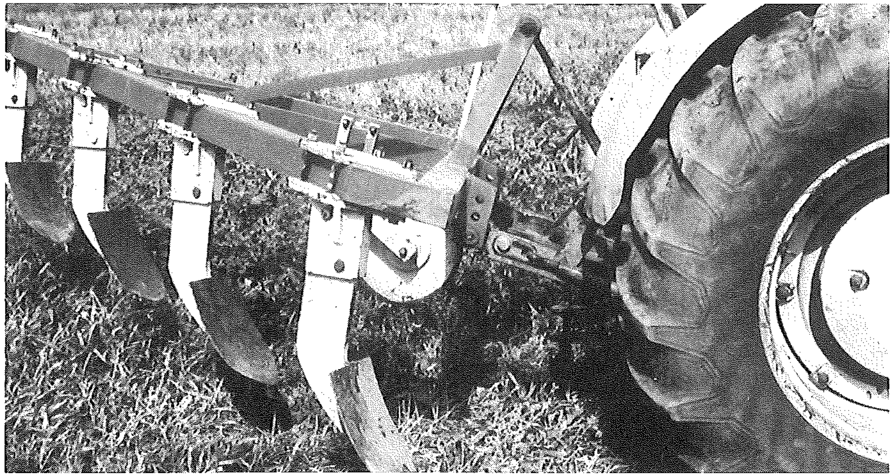

Fig. 148. Spade plough (side view).

Four to five "spade" shovels are attached by rigid shanks to the oblique bar of a flat triangular frame. The spades (300 mm wide with a total height of 300 mm) are set at an angle of about 70 degrees to the direction of travel. The angle of attack of the spades which are lightly curved is about 45 degrees. They produce more inversion than a chisel but markedly less than a mouldboard. The design allows the furrow distance to be varied; tillage is more intensive and a large proportion of the surface trash is covered when the distance is around 30 cm. If it is grater, the implement leaves a rough surface with more trash.

Ploughing occasions some lateral transport of the soil and so the implement should be used as a one-way plough. One major advantage is that hardly any clogging occurs because of the frame clearance (> 70 cm) and the clearance between the spades (70-90 cm depending upon the furrow distance).

The plough is mounted on the 3-point hitch and the depth is controlled by an adjustable support wheel. One problem with the current models is the side draught, caused by the spade setting and which is not absorbed by any wheel or landside so that steering is tiring.
The draught requirement is the same as for the chisel plough.

Technical data

Number of spades	4-5
Working width	30-50 cm per spade
Working depth (max.)	25 cm
Frame clearance	72 cm
Linkage	3-point hitch
Power required	same as for chisel ploughs

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