5. Implements for soil preparation

5.1 Symmetrically operating implements

5.1.1 Ard

5.1.1.1 Designs, manner of operation and distribution

Soil preparation with ard plows of many various types is appreciably widespread worldwide. According to Schultz-Klinken (1981) approximately 75% of the farmers in North Africa, Southeast Europe, the Near and Far East, and Latin America work with this type of implement. The models are distinguished by the material from which the plows are manufactured, wood or metal, and their design.

Depending upon the specific design ards have three basically different functions:
- breaking a furrow and leaving a ridge on both sides, and partially turning the soil,
- breaking a furrow and leaving a ridge on one side, and partially turning the soil,
- loosening the soil in layers.

The various designs of the point, frequently clad with an iron reinforcement, yield either a more breaking, digging or cutting effect (Schultz-Klinken, 1981).

The ard plow is known for its superficial and efficient operation. The chief characteristic function of the ard plow is soil preparation which does not turn the soil and may leave some unworked patches. Should a totally worked plot be necessary for the subsequent tillage, then several work operations in criss-cross fashion must be carried out. Because of its particular design the ard does not leave a clean field with the first attempt. This need not be a disadvantage. Unworked patches and a rough surface prevent wind and water erosion (Hopfen, 1969). Ards are directly connected to the yoke by means of a long drawbeam and usually have a single wooden handle. Since they have no support wheel, the working depth can only be regulated by the pressure expended by the farmer. This depth is 5 – 15 cm for simple ards and 15 – 20 cm for further developed implements and metal ards.

According to the survey the working width is between 5 and 25 cm, independent of whether a simple or more improved version is being employed. The weight of the implement also varies, but is generally under 30 kg since the ard must be carried to the fields by the farmers.

Most ard plows can be built by village artisans or by the farmers themselves. Thus, they are of low cost and repairs present no insurmountable problems. However, only certain types of wood can be used due to stability requirements.

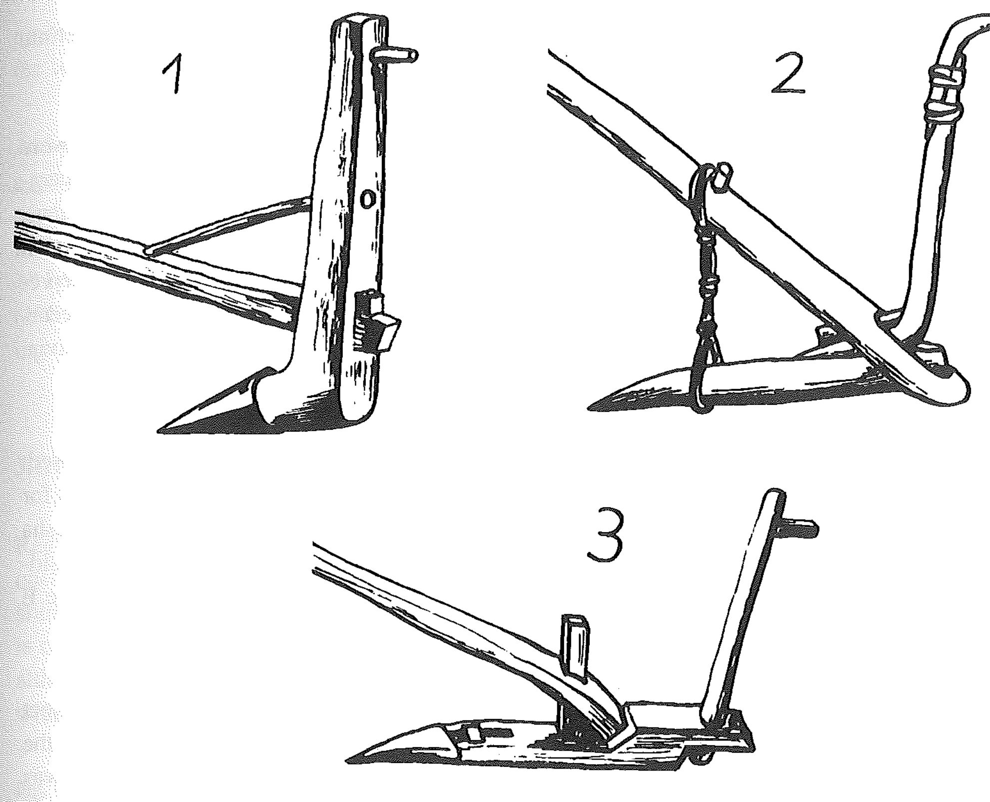


Fig. E 21: 1 = Body ard, 2 = Beam ard, 3 = Sole ard. Source: according to Hopfen (1969)

Hopfen (1969) distinguishes initially between two basic types of ards: the body ard and the beam ard. As for the body ard the plow beam and the handle are constructed of one piece and the drawbeam is directly attached to this component (figure E 21).

The beam ard usually has a curved wooden drawbar through which a working tool, for example a peg or the plow beam, is pierced. The handle is connected separately to the plowbody or drawbar.

Variations which are specific to certain countries or regions have evolved from these two basic types. The sole ard is an example of a third type.

Body ards are the most commonly found of all ard plows. They are sturdy implements and have a relatively great working depth. They have a shoe-type share and are used in soils having sufficient moisture content. Body ards are found in the Mediterranean region, Asia and in some Latin American countries, especially Peru.

The beam ard is probably the oldest form of ard plow and has a limited working depth. It is primarily used for surface working of the soil and has a kind of prong used as a tool for drier, stony soils, and occasionally a slip-shoe type share for heavy soils. The design of the beam ard has several problematic points. It has a narrow plow body with a point-shaped share tip, which is exposed to the soil resistance without any further supporting brace. Due to the concentration of soil resistance on this small surface the beam ard is difficult to manoeuvre and to keep in balance. Furthermore, strong draft forces are placed on the contact point between the plowbody and the drawbar. By means of the insertion of a connecting link made of leather or wood the draft force is better distributed and absorbed. Because of these weak points this type of ard plow is best used on soils having no obstacles such as roots and tree stumps. This implement is chiefly found in the Mediterranean region as well as eastern India.

The sole ard works the surface of the soil and is easy to manoeuvre. It has a long, flat plow body, upon which the handle and the drawbeam are fastened. Due to its shallow layer-wise loosening operation it is well suited for drier areas. Deep plowing is not possible because of the long sole. Sole ards are found in the Mediterranean region, Afghanistan, Pakistan and Nepal.

The first two plow types ridge and mix the soil on both sides of the furrow; this leads to considerable moisture loss.

Because of the manner of operation ard plows are less popular in wet climates. Krause et al. (1984) consider this implement to be more suited for drier conditions in comparison to the mouldboard plow, since it reduces expansion of the soil surface area that is exposed to wind and water.

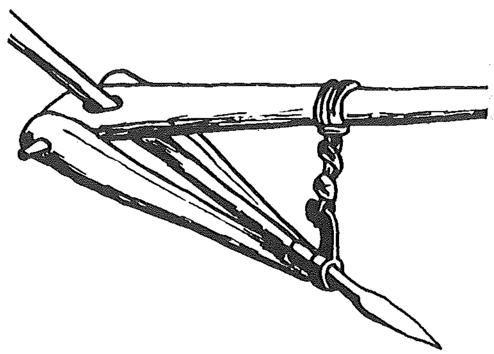
The large number of various ard plow and share types demonstrates that with these implement variations adapted solutions can be found for locally occurring problems. Further developments should receive appropriate attention.

In the survey in 85 cases ard plows were mentioned 15 times regarding soil preparation. In comparison to the world-wide significance of the ard plow this is only a small proportion; the reason lies in the non-representative execution of the survey. The occurrence of the ard plow is recorded for Bolivia, Ecuador, Peru and Ethiopia.

In Bolivia and Ecuador the beam ard is used. In spite of the suitability of the body ard for wetter regions (Hopfen, 1969), the maresha is widely distributed in Ethiopia; it is considered to be a type of the beam ard (figure E 22).

It is utilized in Vertisols, which are subject to severe expansion and shrinkage due to the high proportion of clay. In the survey it was reported, however, that the maresha is well suited to heavy soils, since other implements would require a greater power input. When wet, the soil sticks to all the metal parts, increasing the weight and causing a poor work result due to smearing. An advantage is the

Fig. E 22: Maresha. Source: according to Hopfen (1969)



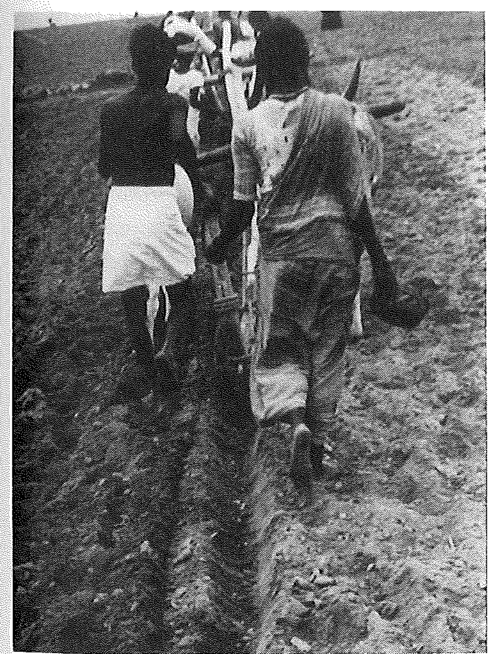
narrow working width of 5 cm, which offers the soil only a small surface for sticking.

Ard plows in Latin American countries have a greater working width of 10 – 25 cm. According to the survey the area performance in the Andes countries is approximately 30 – 40 h/ha and in Ethiopia according to Starkey (1989) 40 – 50 h/ha, whereby several working operations are necessary.

5.1.1.2 Experience

Regions where ard plows are utilized demonstrate a relatively high quotient of draft animal use. In half the cases animal traction is common on more than 50% of the farms, although regional differences are evident within the countries.

Fig. E 23: Hand seed following the ard (Photo: Neunhuser)



The primary application is for soil preparation. Weed control and breaking furrows for seeding are also carried out with the ard plow. The seed is placed by hand directly into the furrow that has been dug by the ard and is immediately covered by a second movement (figure E 23).

94% of the draft animals used for pulling ards are oxen teams. Horses, donkeys and mules are seldom employed, except for weeding or transportation.

According to the survey the regions where the ard plow is primarily used are all above an altitude of 1000 m. The soils are heavy, mainly in Ethiopia, and medium soils are found in Latin American countries.

Wherever the ard plow is widely distributed there is also a high land-use intensity. In three-quarters of the responses permanent cropping is almost always conducted and obstacles are hardly evident. On the other hand, in 44% of the cases stony ground exists.

The cropping area on all the farms lies under 5 ha; more than half farm less than 2 ha. Tendentially, the Latin American countries have the largest arable area. The plots are very small (in 66% of the responses under 0.4 ha). Cropping on ridges is very uncommon in ard-plow regions.

In the Andes countries modifications of wooden ard plows are employed, all having a relatively great similarity with each other (arado combinado, arado andino) (figure E 24).

They are designed according to the traditional concept, however they consist of metal

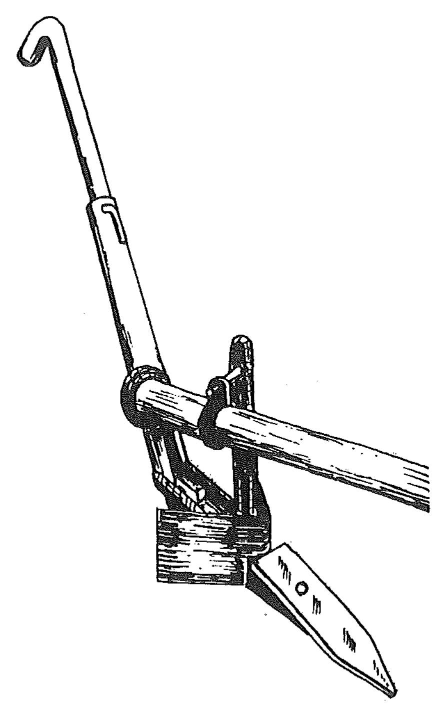


Fig. E 24: Arado combinado. Source: manufacturer's brochure

except for the drawbar. Various tools can be mounted (ridger, mouldboard, cultivator tines), so that their use is multifunctional.

Improved models have gained poor access to practical situations and their application is limited to development projects. Several reasons however could speak for their utilization. Meier (1987) reported from the highlands of Peru that the wooden plow represents a commandable technique, but it breaks quicker and appropriate wood is scarce. The metal plow is not heavier than the traditional implement so that the farmer can carry it to the field. In addition, the improved ard is easier to pull, has a greater working depth (13 – 15 cm) and can work the soil in two operations, as opposed to the normal three runs.

A significant hindrance to their dissemination is the high price, approximately four times that of the traditional wooden plow. Since the farmers in ard plow regions predominantly grow crops for their own subsistence (Gryseels et al., 1984; Meier, 1987), they are not able to pay for them and must resort to manufacturing their own implements.

5.1.2 Ridger

5.1.2.1 Manner of operation

The ridger does not turn the soil completely. It leaves ridges on the surface of the soil, and does not work the soil under the ridges (figures E 25 and E 26).

Usually, the old ridges are plowed through and thus broken up prior to the subsequent cropping period. Another approach is to plow diagonally to the previous ridges. If the plow is adjustable the ridges can have a variety of forms: gentle or steep slope, narrow or broad ridges.

Fig. E 25: Preparing ridges in Malawi (Photo: Nelles)

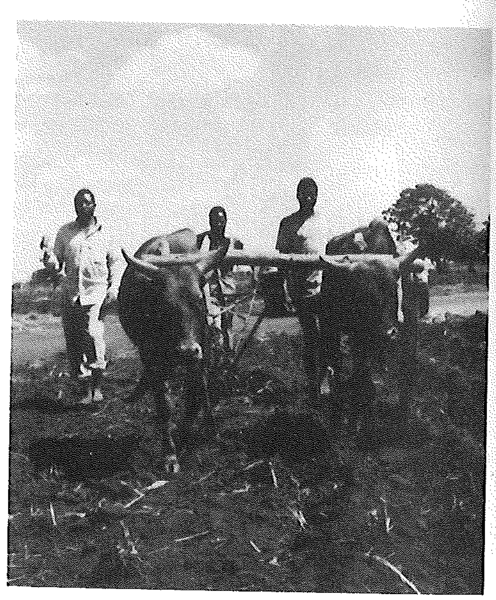


Fig. E 26: Ridger in Malawi (Photo: Nelles)

The shape of the ridger body has an impact on the soil and the draft power requirements. Ridger bodies having a broad share tip, a smooth body edge and steeply set high wings (figure E 27) split up the soil in wedges and leave a well rounded furrow. The bottom of the furrow and the side of the ridge thereby acquire an undesired compaction and the smooth, compressed surface dries more quickly, leading to a loss of moisture.

Flatter ridger bodies having a sawtooth-like body edge (figure E 28) can avoid creating

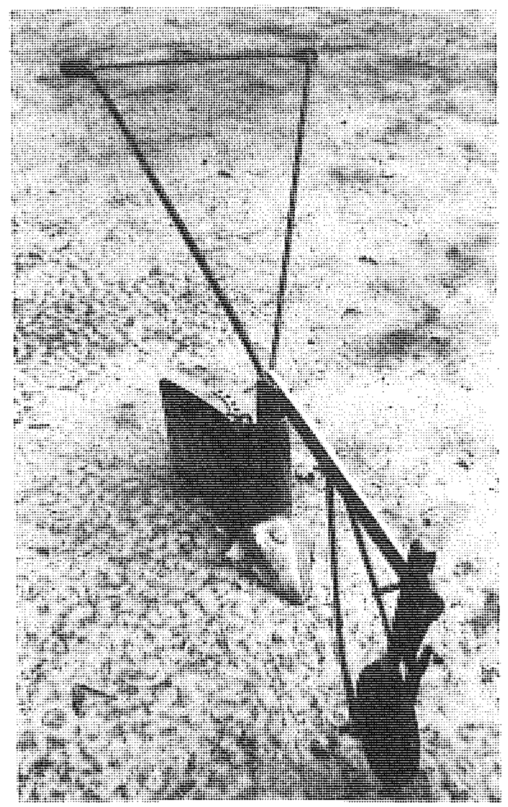


Fig. E 27: Ridger with a smooth body shape in Paraná (Photo: Schmitz)

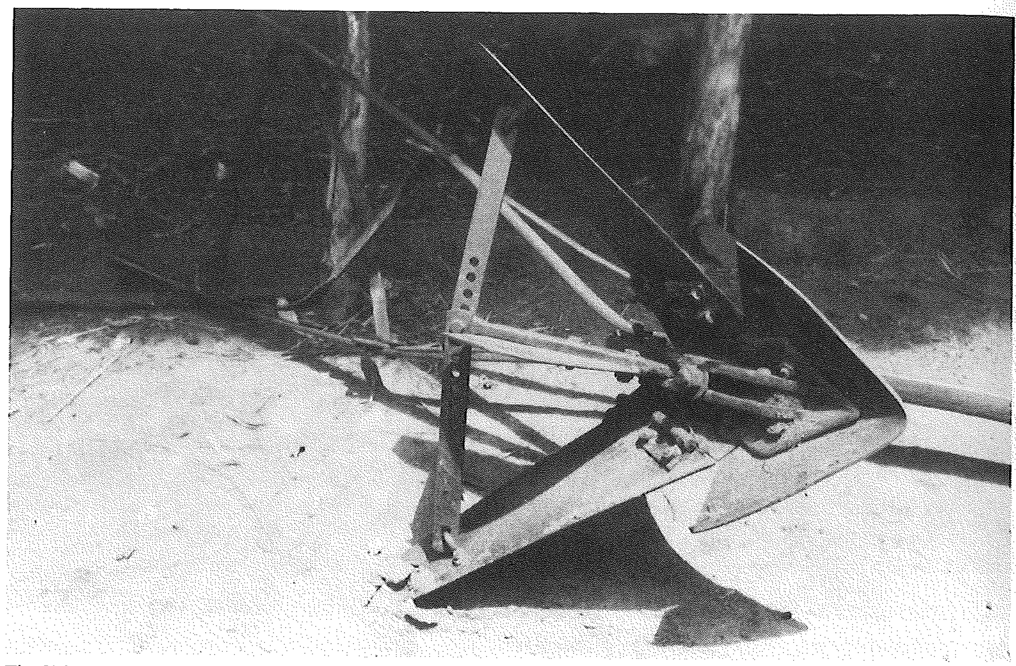


Fig. E 28: Ridger with a sawtooth-like body shape in Malawi (Photo: Nelles)

compaction and allow a surplus of loose soil to pass over the mouldboard, which spreads over the furrow and the ridge, thus yielding a protective cover. Moreover, the draft power requirement is less for this shape. (Franz, 1969)

Ridgers can be constructed as swing plows (figure E 25) or as single-wheel plows, whereby the wheel increases the stability for guiding the implement and also makes the work easier.

5.1.2.2 Distribution and experience

For many of the countries in the survey the ridger may be characterized as a universal implement. Ridgers are often the only animal-drawn implement of African farmers. They are used for working operations in seedbed preparation, ridging as well as weed control.

A comparison of the distribution of the ridger and mouldboard plows showed that in 58% of the regions where the mouldboard plow is employed the ridger also exists. It has scarcely been accepted in ard-plow regions such as the Andes countries and Ethiopia. Here, its use is limited to development projects or special requirements, such as irrigation crops in Peru and the Dominican Republic.

The traditionally widespread practice of ridging in some of the regions in the countries of Togo, Senegal, Zambia, Ghana, Malawi,

Mali and Burkina Faso make the ridger one of the most frequently used implements. Its rapid and superficial manner of working the soil is highly prized. Contrary to the recommendations of extension services, which propagate the prior preparation with a mouldboard plow, the ridger is often used directly for seedbed preparation. In the Savanes region in North Togo, for example, the time for a more intensive seedbed preparation is too short at the beginning of the rainy season.

In contrast to the mouldboard plow the ridger achieves approximately double the area performance (Nelles, 1989; Viebig, 1982), because of the greater working width and since it only works half the field. However, with a corresponding working width the draft power requirement is higher.

A disadvantage for direct building of ridges is that the vegetation under the ridges is not disposed of and weed infestation can rapidly occur. Therefore, the effect of weed control with the ridger for soil preparation is generally not as useful as the mouldboard plow.

In wetter regions with a longer vegetation period, for example Bobo Dioulasso in Burkina Faso, the mouldboard plow is used first, followed then by ridging operations.

The effectivity of the ridger against weeds is not very highly estimated; particularly high plants cannot be easily destroyed simply by covering them with earth. The survey showed however that in half the responses the ridger was in fact employed for weed control. This is frequently the case in all countries with the exception of the Andes countries, Brazil and Zambia, where the ridger is not or seldom used for this work operation.

If work is carried out with the ridger, the crop rows are easy to identify in fields with high weed invasion. In Togo the ridger is used in combination with the hand hoe since sufficient labour forces are available; after weeding the implement is then employed to build up the ridges.

The survey showed that generally there is a higher land-use intensity in regions where the ridger is common than in mouldboard-plow regions. Problems with obstacles were not mentioned by the respondents, with one exception in Chad. This can be attributed to the fact that the soil had already been worked with a mouldboard plow.

The workmanship and material quality is in general assessed as good. Because of the symmetrical direction of draft power the handling is less complicated than with the mouldboard plow. The risk of error with the adjustments is lower. The width adjustment is placed directly on the plow body, where it is better protected against damage. In contrast to the mouldboard plow the point of attachment is more stable, since it is not connected with the width adjustment. In general, an uneven abrasion is counteracted by the symmetrical distribution of force. In Togo it was ascertained in a survey that the parts exposed to abrasion wore out slower on the ridger than on the mouldboard plow.

5.1.3 Chisel plow

5.1.3.1 Manner of operation

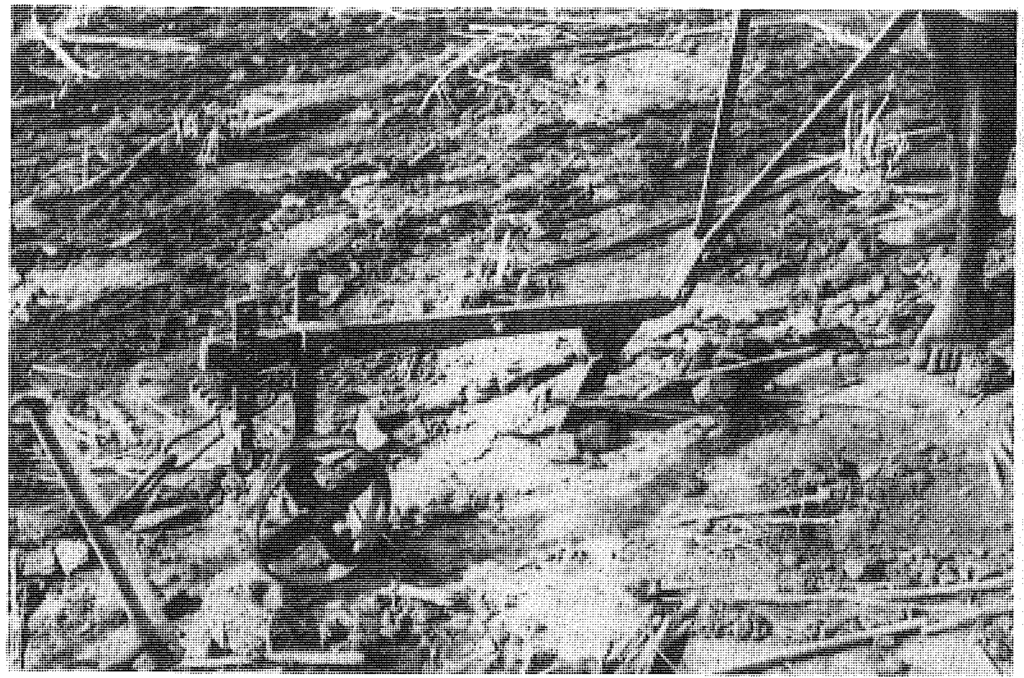
This section deals with chisel plows and cultivators having rigid and semi-spring tines. They may be identical with implements used for weed control. For soil preparation however narrower tools are more frequently employed; thus the implement has a mode of operation similar to that of the chisel plow.

The chisel plow works the surface of the soil and creates a loose structure on the top soil layer without turning it. The vertical tine breaks the compacted horizon by simply pushing the soil towards the front and then to the side. Some unworked strips remain between the furrows, but smaller voids are created than with plowing. (Preuschen, 1951) Simultaneously, a separation occurs, transporting small crumbs downwards and larger clods to the surface (Segler, 1956). This can be beneficial to the soil, since the covering with clods prevents evaporation during dry periods and also counteracts surface sealing and erosion caused by hefty rainfalls.

Various tools can be connected to the tines. Chisel shares, semi- and full duckfoot and sweep shares are commonly found in practice. A narrower tool such as the chisel share creates a nearly triangular furrow profile in the soil by pushing the compacted horizon. With increasing soil moisture the profile becomes narrower and the soil is broken up to a lesser extent. When broader duckfoot or sweep shares are employed a trapezium-shaped profile is created (Gill et al., 1968 in: Wieneke and Friedrich, 1983).

The wider the tool, the greater the draft power requirement. If the chisel plow consists of only one tool, its function becomes similar to that of the ard (figure E 29 and E 30). The bico de pato and the fuçador belong to this category of implements, as discussed in the case study on Brazil (see section G 2.4).

Fig. E 29: Tool with a chisel plow-type coulter in Niger (Photo: Wäldele)



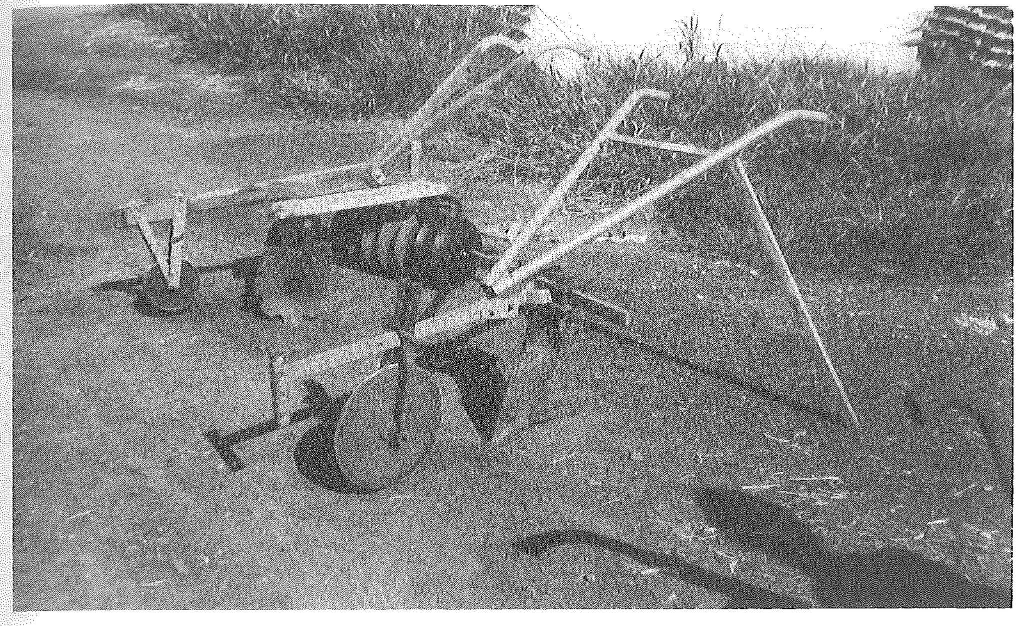


Fig. E 30: Chisel plow with a single tool in Brazil (in the foreground) (Photo: IAPAR)

In most cases designs incorporating several tools are concerned, which usually belong to the category of multifunctional implements. The following types showing various designs are distinguished:

- a main frame (Houe Occidental, Senegal <see figure F 17>; Peco-tool, Sierra Leone; Houe Manga; Niger, Burkina Faso),
- T-shaped frame (Houe Sine, Senegal <see figure F 18>; Arara, Senegal <see figure F 19>; CEMAG Policultor 300, Brazil),
- triangular frame (Houe Triangle, Burkina Faso; Togo <see figure F 7>; Planet cultivator by Sans or Tatu <see figure E 62>),
- rectangular frame with two wheels (Ariana, Senegal <see figure F 20>; CEMAG Policultor 600, Brazil <see figure E 40>).

Three or five tools can be mounted on one implement. The working depth can be adjusted by the wheel, if used, and the depth is normally 3 – 5 cm (Metzger, 1988). The chisel plow can achieve a better area performance than the plow. In Senegal the plow required 25 h/ha, whereas the chisel plow only needed 5 h/ha (Metzger, 1988). On hard soils the draft power requirement can be considerable (Preuschen, 1951). According to Starkey (1989) a chisel plow equipped with three tines requires the same draft pow-er as an 8" conventional plow having a work-ing depth of 20 cm. Thus, in most cases three tools are utilized, as also was ascertained by the survey.

5.1.3.2 Distribution and experience

Chisel plows are used as soil-preparation implements individually or in combination with the plow. They also serve the purposes of seedbed preparation as well as weed control shortly prior to seeding.

Fig. E 31: The use of the chisel plow in Senegal (Photo: Schmitz)

Chisel plows are less widely distributed than the plow in the countries surveyed. They are more frequently found in countries such as Senegal, Mali, Niger, Burkina Faso and a few of the regions in Northeast Brazil in semiarid areas having 2.5 – 5 wet months. Precipitation is normally between 500 and 700 mm.

Soil property is the main determinant for the use of the chisel plow. This factor was most often mentioned as a reason for its mobilization or as a constraint. This implement is preferred for light, sandy soils where its manner of functioning has proved to be advantageous against risk of erosion. Frequently, a shallow and rapid soil preparation is desired. In regions where direct drilling is widespread, for example in Niger and Senegal, the chisel plow is utilized for soil preparation. The land however must be essentially free of weeds and vegetation. Since mention is hardly made of clogging, one can assume that the soil surface is free of obstacles and is uncovered. This was stated to be the reason for the use of the chisel plow in one of the regions of Mali. Since the R values lie between 50 and 60 in the chisel-plow regions, the low occurrence of obstacles is not attributed to land-use intensity, but rather to the dry climate and the sparse vegetation (figure E 31).

Ashburner and Yabilan (1988) report of trials for using different implements in Niger. The effect of various implement types on the yield of millet was examined on an experimental station and in the field. Tests were carried out with the mouldboard plow, various types of chisel plows as well as the ridger. The experiments were conducted on sandy soil in the Departement of Tahoua, where traditionally the no-tillage method is employed.

The trials demonstrated that the mouldboard plow increased the yield, however the working speed of 19 h/ha is very slow and the implement is not adapted to this region because of erosion. The ridger also requires relatively a great deal of time, so that it becomes difficult to seed on the same day. In order to be able to use the ridger, the soil must first be worked with a chisel plow.

Soil preparation can be much more rapidly carried out with a chisel plow. The area performance with three tines was 9 h/ha for the Arara chisel plow and the Houe Manga. Although the Arara is well adapted to some regions it proved to be too heavy for these soils. In addition, the design was assessed to be too complicated. The Houe Manga is lighter, but has design deficiencies in the spring tines, thus hampering its operation.

The advantages of working the soil with a chisel plow are best appreciated in sandy soils having a proportion of clay that tends to build a soil crust. A test with various tools attached to the chisel plow (duckfoot, bar-point share) did not bring any significant yield increase. These relationships are also presently being investigated by the ICRISAT Sahalien Centre in Niger.

Overall, it was determined that a significant yield increase could be achieved by soil preparation with the plow and chisel plow and direct subsequent broadcasting, in contrast to traditional, direct drilling without prior soil preparation. It is salient however to apply a rapid method of working the soil, since under these climatic conditions it is more important to minimize the risks than to maximize the yield. For this reason and due to the soil-conserving effect the chisel plow is more adapted to this location.

In heavy soils the utilization of the chisel plow shows up some problems. This was reported for some regions in Ghana, Brazil and Niger. Here the draft power requirement increased considerably (Starkey, 1989) and higher weed growth can no longer be mastered with the chisel plow. Therefore, according to Tchougoune (1988) for heavy soils in valley bottoms and depressions the use of the chisel plow is more advantageous.

In regions where the building up of ridges is widespread, the use of the chisel plow is also not accepted. In Togo the farmers reject the idea of an additional work operation. The implement does not fit into the cropping system in Ghana.

The working and material quality of the chisel plow varies considerably. Houe Occidental, Houe Sine and the Arara have a good reputation. With some of the other implements the critical point is the tine attachment. On the contact point between the flexible and rigid part it has been observed that the tines easily break off. The tines also come loose. The width adjustment is not always easy to manage. Finally, severe abrasion can be caused by inexact assembly.

5.1.4 Harrow

5.1.4.1 Manner of operation

The harrow works at a comparably shallow depth. The clods are broken up by diagonally placed tines or spikes and thrown to the side. As with the chisel plow, the harrow creates a separation effect. In order to accomplish a successful job the working speed must be high. Therefore, the draft animals used are often horses or mules.

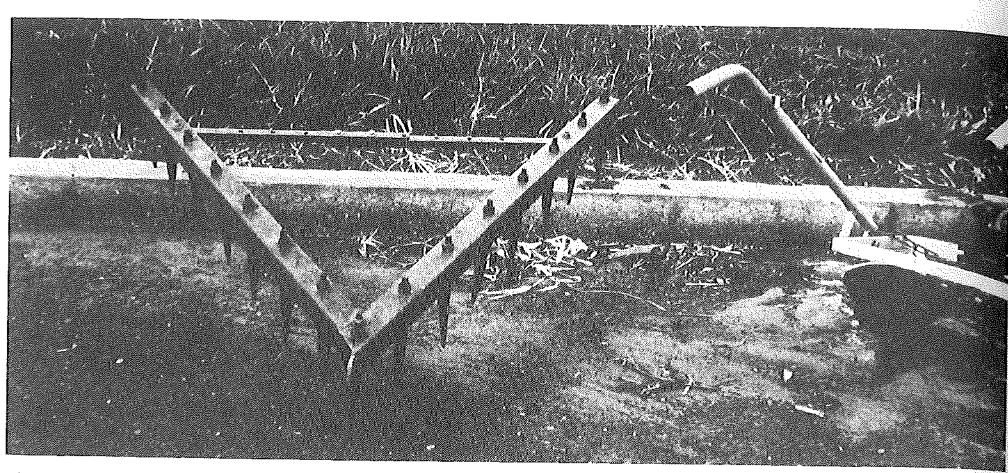


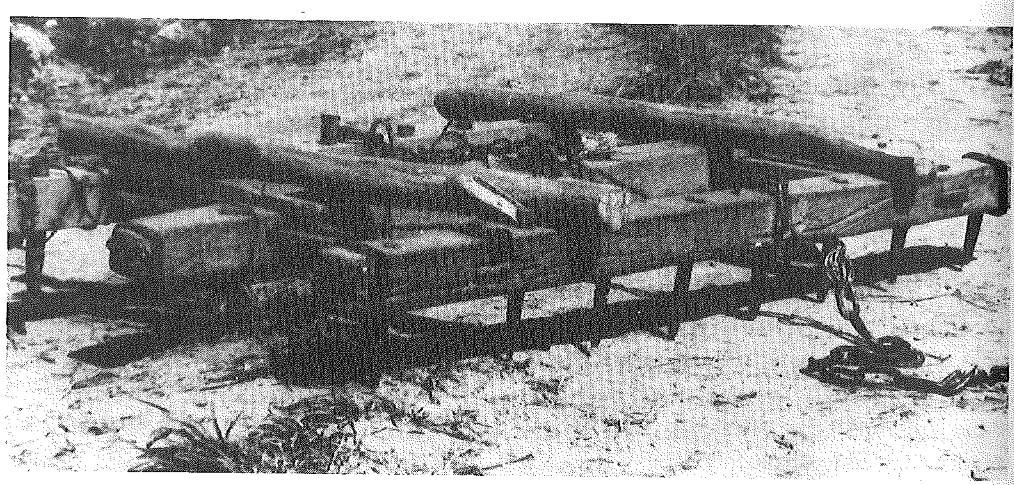
Fig. E 32: Triangular harrow in Brazil (Photo: Schmitz)

The harrow is used to breake up a crust soil surface, for crumbling coarse clods and fine seedbed preparation. It loosens and aerates the soil. It can also serve the purpose of working in the seed after broadcasting, levelling and weed control.

Numerous designs of harrows exist and different tine structures. The tools may be either rigid or spring tines having a variety of dimensions. The frame is manufactured from wood or metal. The most simple design is the single-section, triangular harrow with rigid tines (figure E 32). A further design is the single-section, rectangular harrow (figure E 33).

The zigzag harrows (figure E 34) are more diversified and intensive in their operation.

Fig. E 33: Rectangular harrow in Brazil (Photo: IAPAR)



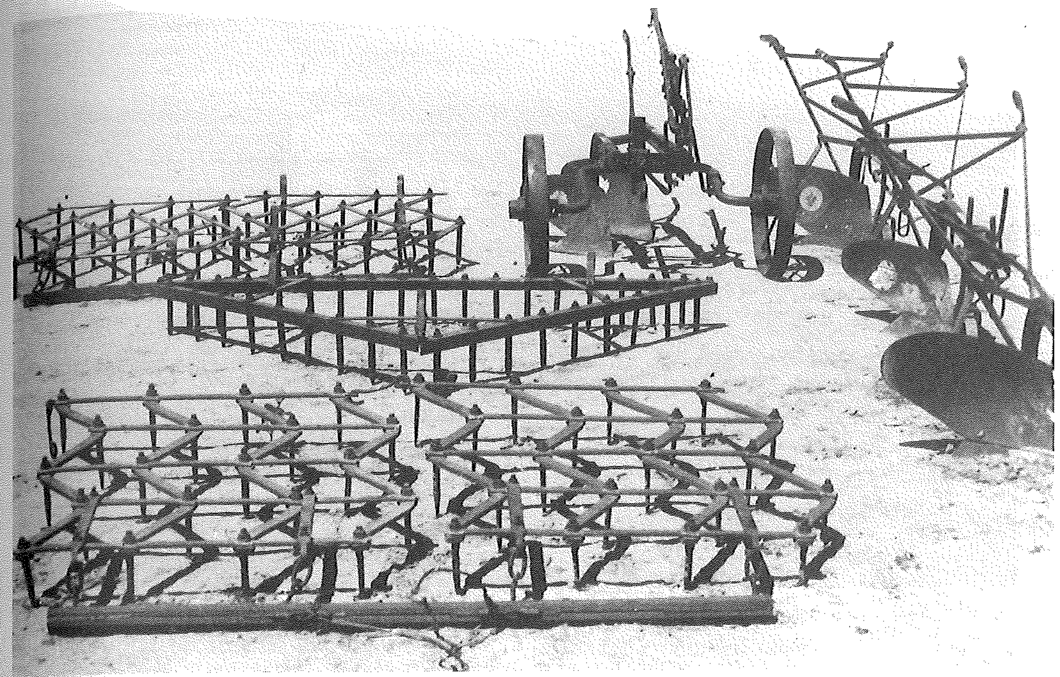


Fig. E 34: Zigzag harrows in Botswana (Photo: Nüsing)

Harrows are available in single and double-section designs. The latter can easier adapt to uneven soil surfaces. In general, harrows can be characterized as simple in design and ease of handling. Working width and depth are not adjustable.

5.1.4.2 Distribution and experience

Generally, the harrow is seldom used in the surveyed regions. In the few differentiated answers all above mentioned types were represented.

The harrow is used primarily in Brazil and on farms in a few African countries (Mali, Zimbabwe, Lesotho, Chad). The concentration in regions having a subtropical humid climate such as Brazil and the semiarid climate in African countries (figure E 35) are rather remarkable.

Permanent cropping (R value 80 – 100) exists in almost all cases. Only in two regions in Mali and Brazil is the land-use intensity low (R value 33 and 42, respectively). Problems of clogging are hardly mentioned. This occurs in regions where the harrow is seldom found in practice and in project areas.

Wherever the harrow is frequently used, seeders are also employed. This was determined for African countries, with the exception of Chad, and also for Brazil. Unfortunately, very little experience and reasons for using the harrow in Brazil has been reported to date, although it was mentioned most (12 out

Fig. E 35: Using the harrow in the subtropical humid climate of Brazil (Photo: IAPAR/CPPP)

of 18) here. Its widespread use can be attributed to both European influence and the frequent subsequent application of seeders.

For some crops and cropping methods the harrow is also advantageous, even if no seeder is employed. This is the case when rice or other grain types are broadcasted. By means of a subsequent run with the harrow the seed is rapidly worked in just below the surface. The use of the harrow in connection with growing rice was reported for Mali, Cameroon and Chad.

On the whole however the harrow is little used. In only 42% of the instances where the implement is known is it actually used (18 out of 43 cases). This means that over half of the farmers reject the harrow as a soil-preparation implement for various reasons. Ecological reasons remain the main grounds for a negative assessment. The harrow removes organic material from the soil and hinders a mulching effect. The heaps of residues left from cleaning the harrow tempt the farmers to set them on fire (Gutsche, 1989). The remaining litter however is of great importance for the conservation of soil fertility in the tropics and subtropics. In addition, apprehension exists regarding the increase of erosion due to the use of the harrow.

Further frequently mentioned reasons for not utilizing the harrow are the growing of crops on ridges, the occurrence of obstacles and the unsuitable topography. On heavy wet soil it functions poorly, since the tines clog and smear the earth instead of breaking the clods. On light soils the harrow can be substituted by a simple dragged device for levelling, which need not be transported from field to field. (Gutsche, 1989) Finally, an additional working operation which appears superfluous to the farmers finds no acceptance.

5.2 Assymmetrically operating implements

5.2.1 Mouldboard plow

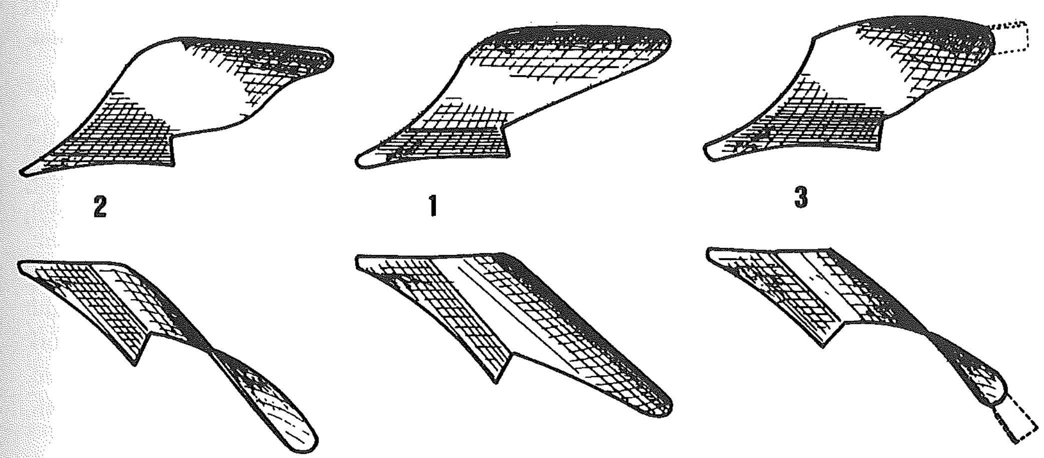
5.2.1.1 Manner of operation

The mouldboard plow turns the soil by cutting a furrow slice and depositing it to one side partially overturned. A coarse loosening occurs thereby and a mixing and crumbling of the soil; the volume increases in the process. An expansion of the surface area can lead to greater evaporation rates and a more rapid decomposition of the humus. Therefore, it is hardly suited for arid areas due to the sensitivity of the moisture supply and only applicable to certain conditions in the humid tropics because of the rapid decomposition of the organic matter (Krause et al., 1984; Viebig, 1982). On the other hand, the operation of the mouldboard plow facilitates the working in of plant material, harvest residues and manure in the soil. In wetter areas with a high weed growth at the beginning of the rainy season this is conducive to seedbed preparation.

The plow body and often also the frame of the mouldboard plow is made of metal. The mouldboard and the share are designed according to the required use. The flatter the slope of these two parts, the easier it is to pull the plow. The crumb formation is however poorer and the tendency of sticking increases with clayey soils. (Preuschen, 1951) The greater the tendency of clod dispersion in the soil, the shorter and steeper the plow body should be shaped. Otherwise the danger exists that the soil does not slide along the entire length of the mouldboard but falls from the mouldboard too soon and hampers the turning process. The tendency of clod dispersion is less in heavy soils and the breaking of grassland. (Eichhorn 1985) Basically, steep share shapes crumble better and require greater draft power, while with extended curved shapes the deflection above the share is less and little crumbling is achieved. (Kühne, 1930; Segler, 1956; Dencker, 1961)

In principle the following mouldboard forms can be distinguished: cylindrical, cylindrical-helicoidal (as a medium shape) and helicoidal (CNEEMA, 1981). (figure E 36)

Fig. E 36: Mouldboard shapes: 1 = cylindrical, 2 = cylindrical-helicoidal, 3=helicoidal. Source: CNEEMA (1981)



Their application is as follows:
– steep cylindrical shape: for light soils (loose sandy soils; as a steep, short shape for light soils that tend to be sticky),
– partly cylindrical, sinusoidal shape: for medium soils, for sandy loam or loamy sands (universal shape),
– helicoidal, flat ascending shape with a pointed cutting angle: for heavy, overgrown cohesive soils, crumbles less.

Starkey (1989) differentiates for Africa between the short, cylindrical shapes suited for rapid tilling in light soils and semi-helicoidal shapes for high weed infestation in humid climates, which cause a less abrupt inversion.

Similarly, there are different share shapes. On hard overgrown and stony soils it is frequently difficult to penetrate the top layer, especially with a worn share tip. Beak-type shares are more suited for such conditions than the normal shares. According to the survey the normal shares (2/3 of all instances) are more widely found than the beak-type share.

The shares are generally manufactured from steel which can be forged out and tempered in rural workshops with the aid of a simple open hearth and the usual dipping in water. They are reinforced at the cutting edge, so that the appropriate material is available for reworking the correct share shape. Shares made of hard cast iron to withstand a greater amount of abrasion, can be constructed to self-sharpen and are cheaper to fabricate; but they cannot be employed on stony soils because of their brittleness and cannot be sharpened by means of forging. Lateral and share pitch provide for the entry of the plow into the soil, especially for hard soils (figure E

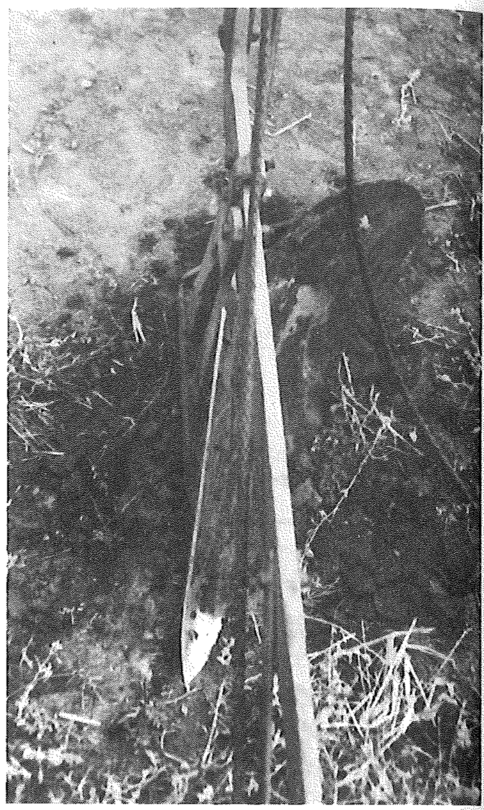


Fig. E 37: Lateral pitch of the reversible "pointed share" plow type (Photo: Schmitz)

37). They change their shape when worn and must be reworked by forging. (Dencker, 1961; Estler et al., 1984; Kühne, 1930; Matthies, 1987)

An adaptation of the furrow width to the draft power of the animals can be accomplished by regulating the working width. This is only possible to a limited extent, since a certain relationship must be maintained between working depth and width (1:1.2 to 1.4), if the quality of the work (turning, crumbling) is not to be hampered. If the plow body works at a constant depth, the risk of plow sole compaction arises.

5.2.1.2 Designs

Four types of plow are commonly found: swing plow without a wheel, a single-wheel plow, gallows plow with two wheels or the frame plow. Conventional mouldboard plows are generally not connected to the yoke with a drawbar but rather are pulled by a chain.

Swing plows are light, maneuverable and can be purchased for a reasonable price. The working depth cannot be adjusted, and thus the penetration of the share depends on the soil resistance. The results are irregular. For soils that are difficult to till fluctuations of up to 50% are recorded, meaning a variation of between 5 and 15 cm for a target depth of 10 cm (Preuschen, 1951). The regulation is controlled by the farmer, so that the work is physically very strenuous.

With the single-wheel plow the vertical movements are kept to a minimum by the furrow wheel; therefore it is possible to adjust the working depth. When the working width is adjusted a lateral pressure is exerted on the wheel and the bearing by means of the transverse forces.

Good lateral and depth control is maintained with the gallows plow, which is equipped with a double-wheel forecarriage. Depending upon the model it is also possible to operate it in a self-controlled mode, so that the farmer need not adjust the handles.

The frame plow (figure E 38) is a further development, which has a frame instead of a leg and is suited for the attachment of several plow bodies. All occurring forces can be supported by the wheels. Often there is a third support wheel at the back. The working

Fig. E 38: Frame plow from Zimplow (Zimbabwe) in Botswana (Photo: Nüsing)

depth is adjusted by means of the wheels. This permits total foolproof operation for working depth and width. (Preuschen, 1951) Multipurpose implements such as the Policultor 600 in Brazil or the Ariana from West and South Africa may come under this classification. Because of the self-control mode frame plows make the work easier, however on small plots and steep slopes they are difficult to maneuver due to their considerable weight.

Gallow plows and frame plows are expensive compared to swing plows and single-wheel plows and are preferably used on flat, well cleared land.

In principle mouldboard plows can be designed as conventional plows or reversible plows.

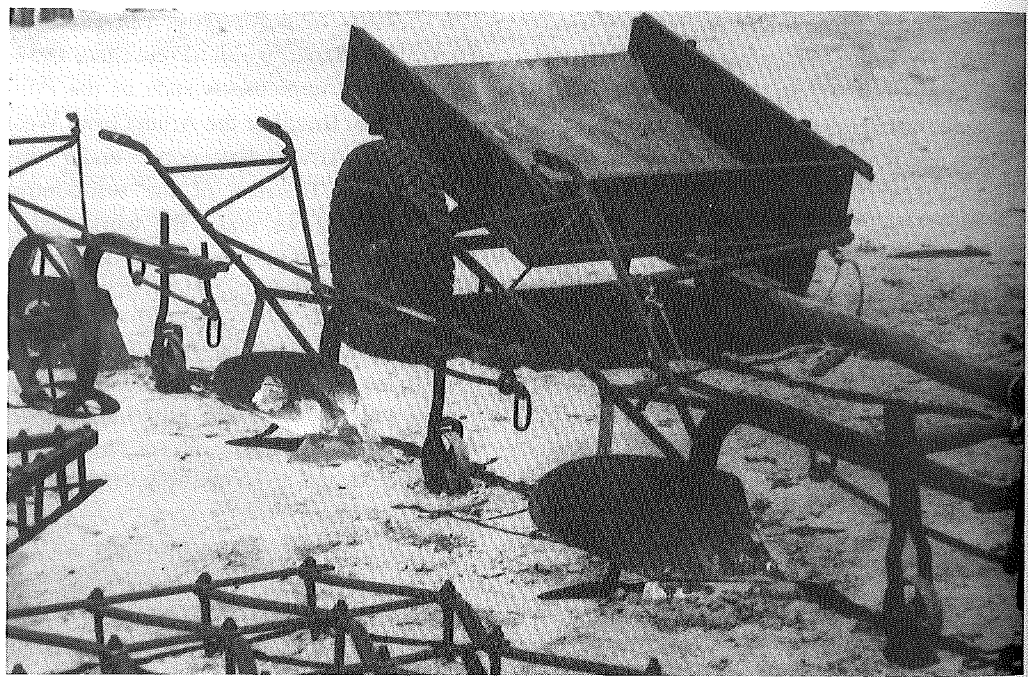
Conventional plows

Conventional plows are equipped with one plow body, which only turns the soil to one side (figure E 39). For return runs through the field separate furrows are necessary. In order that the distance between the two furrows does not become too long, the larger fields are divided into plots (e.g. with a width of about 1/3 the length of the field). These can be plowed by the casting or gathering method. If the plowing is done by gathering the turning circle becomes increasingly narrower to the point where the animals must walk over plowed ground. The conventional plow leaves ridges or a furrow within the field. A continuation of this procedure over the years can cause the soil to be eventually transported out of the field by the casting method, for example, as was reported in the survey. Conventional plows are also unsuited for work on slopes, since the slice of earth falls downhill from the one side of the plot. Its use is recommended only for slight slopes.

In comparison to the reversible plow the conventional plow is lighter, easier to handle and cheaper. Its advantage is the minimal problem of clogging, since the low point of gravity also allows a relatively high frame.

In general, conventional plows achieve a greater working width and low specific resistance than reversible plows due to the suitable design of the plow body. The working width may be adjusted by altering the point of attachment.

Fig. E 39: Conventional plows in Botswana (Photo: Nüsing)



Reversible plows

Reversible plows have plow bodies that can turn the soil to both sides. They are designed as two-way turnover (figure E 40) or turnwrest plows (figures E 45 and G 21).

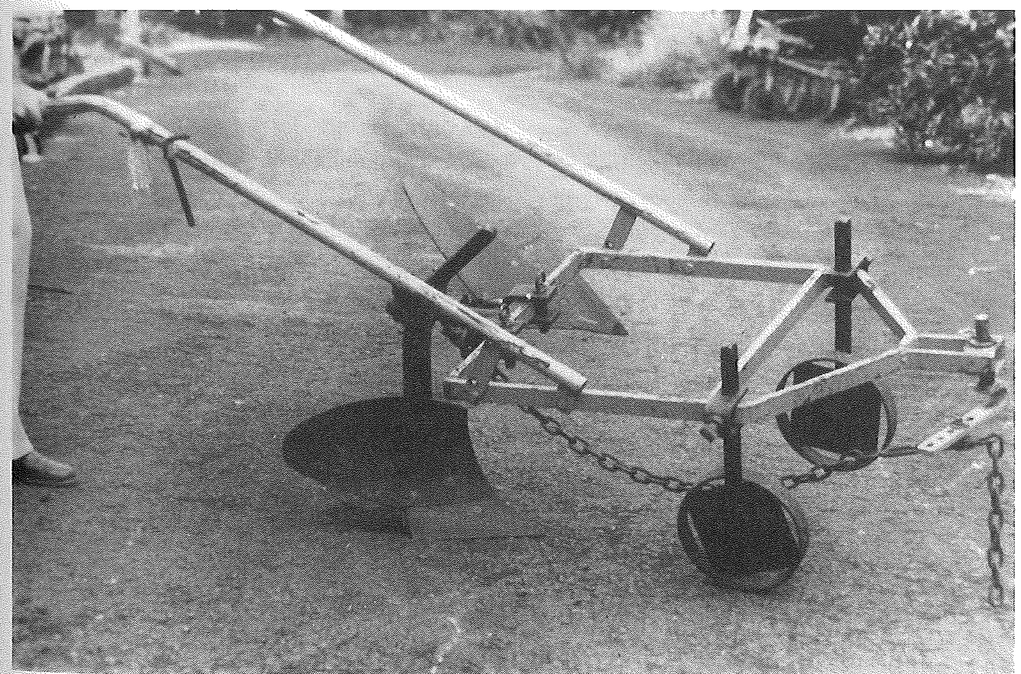
The two-way turnover plow consists of a right and a left inverting plow body; both can be designed to serve their respective purpose in an optimal manner.

The turnwrest plow is equipped with a symmetrical plow body, which can be turned on a bolt hinged on the body under the leg. The plow body cannot always be designed to accommodate all field uses, since the symmetrical mouldboard represents a compromise and its working width and depth are limited by the height of the leg. An advantage is the low point of gravity in comparison to the two-way turnover plow and the low weight of the turnwrest plow as well as the low purchasing cost.

The reversible plow allows the working of a furrow to the same side. Thereby the disadvantages of tilling with conventional plows are avoided and an even field surface is created. The path along the headland to the next furrow is saved and thus a lesser turning time. This is a particular advantage where the turning diameters are small. Reversible plows are therefore especially suited to small irregular plots. Headlands must be somewhat greater when the reversible plow is used.

On slopes plowing must be done so that the soil is thrown to the uphill side to counteract

Fig. E 40: Policultor 600 with two plow bodies at IAPAR, Brazil (Photo: Schmitz)



erosion. This is only possible with the reversible plow. According to Franz (1969) the uphill turning of the soil can be done on slopes up to 25%.

Reversible plows often have a low frame height due to the higher centre of gravity; this can easily lead to clogging. In addition, dirt in the retainer can lead to a delay in engaging the plow body.

5.2.1.3 *Distribution and applications of mouldboard plows*

In two-thirds of the cases where mouldboard plows were mentioned in the survey they are actually used for agricultural purposes. In at least one-quarter of the cases they are used exclusively in development projects or are very seldom applied under practical conditions. Aside from a few pilot projects this is the case wherever other implements such as the ridging plow or the ard are common. In the Savanes region in Togo cropping is done on ridges. For this purpose the ridging plow is employed without prior plowing. In Senegal in the Sine-Saloum region there is not sufficient time for seedbed preparation with a plow, and thus the no-till method is applied.

Obstacles and steep slopes are the most frequently mentioned constraints and this hinders the work with a mouldboard plow. Instead, non-turning implements are used there, which are easier to employ and less problematic under these conditions; also they are less expensive. However, they leave a significantly more inhomogenous seedbed, so that the use of subsequent implements is rendered more difficult or becomes impossible. The occurrence of stones is low in mouldboard-plow areas.

The cropping area of farms having mouldboard plows is on the average larger, with 4.9 ha, than those using ards, where the figure is 2.2 ha. In 22% of the regions the arable areas are between 5 and 10 ha and in 9% between 10 – 20 ha. Only one-fifth of the cropping area of the farms is smaller than 2 ha.

Under tropical and subtropical humid conditions, as for example in South Brazil, the implements must often work on fields that have a great deal of organic matter. Many plows show up problems in working in organic material and can easily clog. This particularly applies where the proportion of fallow is high. But also a winter fallow in humid areas or harvest residues can cause considerable delay for seedbed preparation. In trials on seedbed preparation with one implement in South Brazil clogging was found to require 7 h/ha merely for the cleaning of the implement[1]. (Araújo, 1988b)

If on areas heavily infested with weeds or with the breaking of grassland the turf does not smoothly separate and the plow operation is hampered, a coulter can be used to improve the work. Knife coulters can only be employed in heavy soils however; in light soil the plant residues are not properly chopped. They are caught in front of the coulter, lead to clogging, increased draft power requirement and poorer work quality. A disk coulter can perform well with low soil resistance, but it is more expensive. Therefore, the coulter should only be used if the described situation exists. (Preuschen, 1951) Our study showed that the coulter is not used in practice in agriculture, even if it is offered by manufacturers of farm machinery, as is the case in Brazil.

1 On a surface area of 60 m^2 11 cloggings were recorded with 14 s delay each.

In very clayey soil the soil sticks to the plow body and hampers the smooth functioning of the implement (figure E 41). Nevertheless, the high proportion of clay in the soils, as for example in some regions of Paraná, has not been conducive to the application of disk implements (as has motor mechanization).

In the regions studied the survey indicated that in practice primarily single-wheel plows are widespread. Gallows plows are seldom used (mainly in Santa Catarina in South Brazil; Viebig, 1988); the same applies for two-share frame plows (Zimbabwe, Botswana). In addition multipurpose implements such as the Policultor and Ariana are available.

Frequently, no exact figures were given by the respondents in the survey whether a conventional plow or a reversible plow was employed. According to Starkey (1989) reversible plows, however, are only being used in Angola, Madagascar and on some research stations. In the cases which mentioned mouldboard plows in general a classification for the conventional plow was attempted for the African region. The reversible plow is more often found in South America. According to the survey it is commonly used in practice in Brazil. Also, in the Dominican Republic its use on farms has been confirmed.

Fig. E 41: Smeared plow after working heavy soils (Photo: Nüsing)

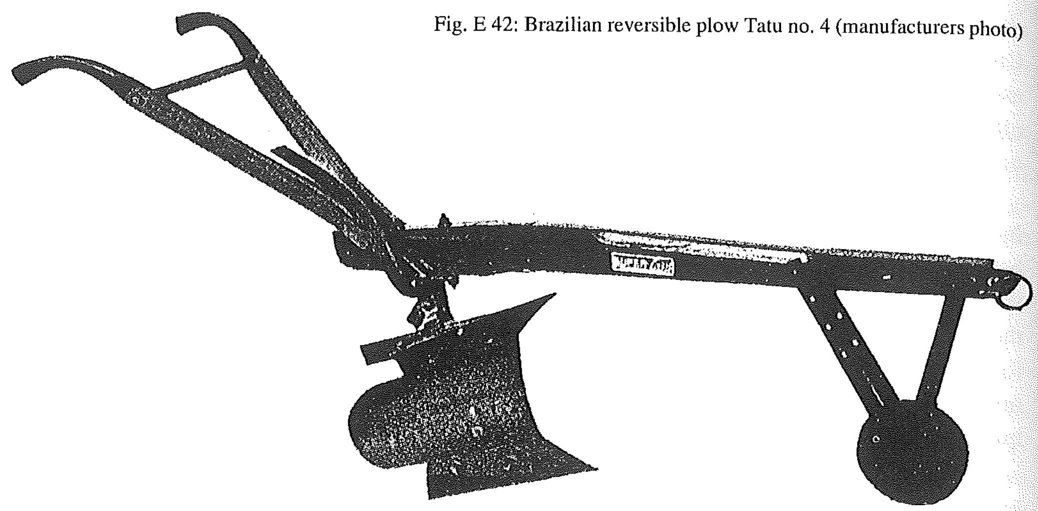


Fig. E 42: Brazilian reversible plow Tatu no. 4 (manufacturers photo)

Most of the reversible plows for draft animals in the regions studied are turnwrest plows, which are designed as single-wheel plows. Their working width can only be adjusted if they are equipped with a variable attaching point. Two-way turnover plows are only on offer in combination with multipurpose implements (as the Policultor 600 in Brazil) and find little use in practice; more often they are found in research and extension facilities. (compare Starkey, 1988a)

Regarding the weight there is a broad spectrum with these implements. The average of the plows mentioned in the survey is 37 kg. The figures for conventional plows lie between 30 and 70 kg, for reversible plows between 30 and 40 kg. The plows can be manufactured totally from steel or be equipped with a wooden frame. The weight of the Brazilian reversible plow Tatu no. 4 can be reduced from 42 to 36 kg if a wooden frame is installed. Swing plows can achieve a significantly lower weight, for example only 16.5 kg for the Tatu H-5 with a wooden frame. During turning, especially on steep slopes, one loses a great deal of time if heavy plows are used and thus a poor area performance is achieved. In a trial a 72kg-implement required 105% more time per hectare than a more efficient plow weighing 42 kg (Tatu no. 4 "twin-share" plow type; figure E 42). (Araújo, 1988b; Casão et al., 1988; Figueiredo et al., 1986)

A low weight of the implements is particularly important where the plots are distant from each other or are located on a slope and transport to the fields becomes a problem.

The use of the conventional plow is unsuited to slopes. Nevertheless, in many regions in South America and Africa it is employed since it is technically simpler and cheaper (table E 6). Especially where no reversible plow is offered the conventional plow or traditional implements such as the ard are found. Conventional plows are far more prevalent in flat areas: in 33 out of 48 responses. Reversible plows only are found in three cases on level to hilly terrain.

Design	All	Flat		Slope	
		Africa	South America	Africa	South America
Conventional plow	48	33	2	7	6
Reversible plow	9	0	3	0	6
no classification	11	–	4	–	7
Responses	68	33	9	7	19

Table E 6: Use of conventional plows and reversible plows in Africa and South America in relation to topography. Valid questionnaires: 63; multiple answers possible; flat = level to hilly; slope = partial to steep slope

The survey showed a slight advantage of the conventional plow over the reversible plow in area performance with 23 h/ha vs. 25 h/ha, respectively. It must be taken into consideration however that the individual figures diverge substantially. In light soils 14 – 16 h/ha was mentioned as being usual, whereas in one region also having light soils 42 h/ha were required. In the latter case however these were farms practising a long fallow period (R value = 38) and having serious difficulty in working the soil due to root residues on newly cleared fields. With respect to the reversible plows, primarily turnwrest plows are concerned, whose working width is limited. Their principle advantage in terms of area performance, given by Preuschen (1951) as 10% for European conditions, cannot be applicable.

Also in trials by IAPAR in Brazil it was determined that the conventional plows examined achieved better results regarding area performance than did turnwrest plows (table E 7). Furthermore, the conventional plows under study had a lower specific resistance with an average 0.38 kp/cm^2 (best value 0.31 kp/cm^2) in clayey soil than the reversible plows with 0.45 kp/cm^2 (best value 0.34 kp/cm^2) and achieved a greater working width (32 cm) than the reversible plows (27 cm). (Araújo, 1988b; Casão et al., 1988; Fi-

Table E 7: Area performance of mouldboard plows in trials by IAPAR in Brazil (Araújo, 1988b; Casão et al., 1988; Figueiredo et al., 1986). Clayey soil: Latossolo Roxo; shallow, stony soil: Solo Litólico; sandy, clayey loam: Cambissolo (according to Brazilian soil classification)

	Hours per ha		
Design	Clayey soil	Shallow, stony soil	Sandy clayey loam
Conventional plow			
Average	21.9		
Best value	18.8		
Reversible plow			
Average	24.9	22.1	21.9
Best value	21.4	18.4	19.6

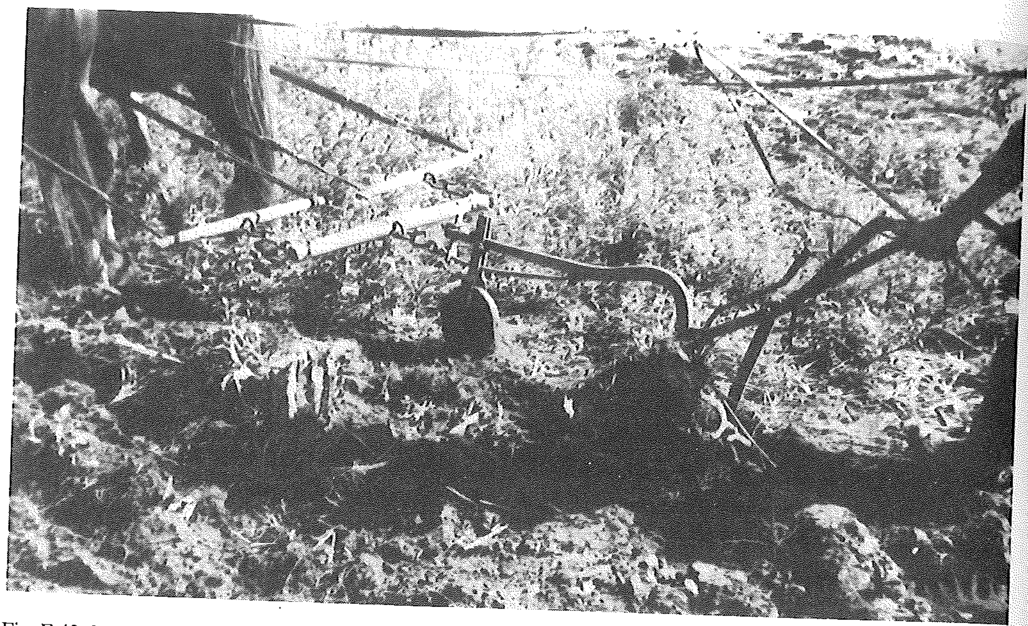


Fig. E 43: Locally developed "pointed share" plow type (Photo: Schmitz)

gueiredo et al., 1986) This may be attributed to the fact that the plow bodies of turnwrest plows cannot be optimally designed.

Reversible plows have only been employed in agricultural practice in some countries to date. Technically and economically viewed however this innovation means a considerable leap ahead. Thus, this implement is found primarily in regions having a developed market structure and a high technical level, as in Brazil. Regarding the turnwrest plow two types are represented: the "pointed share" and the "twin-share" plow type.

"Pointed share" plow type

The "pointed share" plow type has a characteristic cylindrical-helicoidal shaped mouldboard (Araújo, 1988b) and a single pointed share. Since the point of gravity lies relatively low the frame can be designed in a curved fashion, whereby the risk of clogging will occur (figure E 43). The mouldboard must be attached correctly to the leg. The device operates well in high weeds and is primarily used on medium soils of the sandy loam type (figure E 44).

Fig. E 44: Work result of the local plow (Photo: Schmitz)

It is frequently manufactured by artisans, whereby they use pre-fabricated, partially forged plow bodies. Some artisans have difficulty in repairing the implements. Lateral and share pitch change with abrasion. When used incorrectly the plows lose their working characteristics and control stability. Araújo (1988a) suggests the use of a template for the appropriate reconstruction of the angle.

"Twin-share" plow type

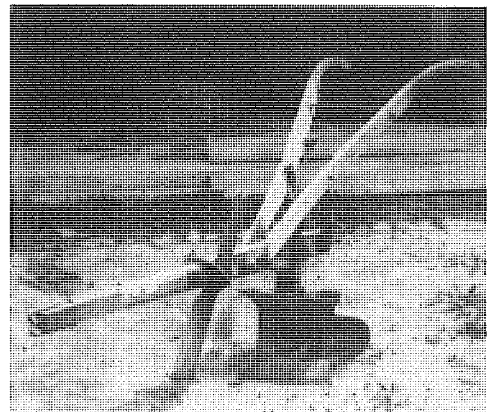
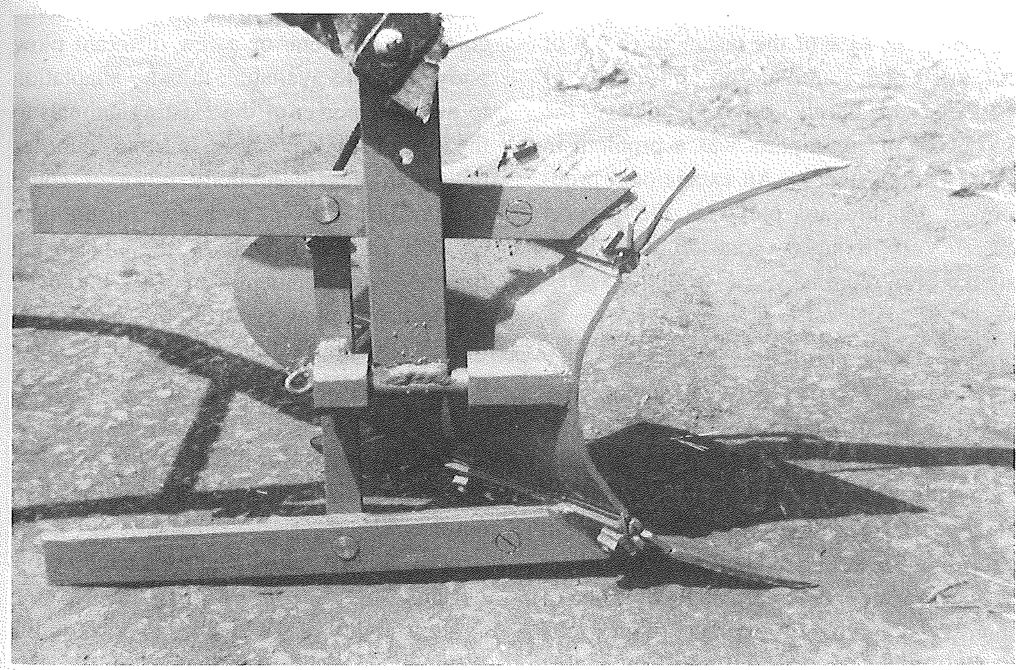


Fig. E 45: Reversible "twin-share" plow type (Photo: Schmitz)

The "twin-share" plow type has a symmetrical plow body with a cylindrical double mouldboard and two separate shares (twin bodies) (figure E 45 and figure E 46). The shape of the plow body requires a higher point of gravity, so that the frame is kept low. In the small space between the share tip and the frame vegetation residues can collect, which can lead to clogging. It is also used in regions having very clayey soils (Oxisols, Alfisols; USST), which behave as sandy soils in a dry condition, but are extremely sticky when moist (see section G 2, case study: Paraná).

Fig. E 46: Symmetrical, cylindrical plow body of the reversible plow (Photo: Schmitz)



A large proportion (54%) of the mouldboard plows are manufactured in national, industrial production. In addition, local fabrication in Brazil plays a significant role. In 21% of the responses the implements are produced in development projects or imported, which means that the production does not yet have a hold in the country. For imported goods the delivery of spare parts could cause a problem. However, also with a central, national production a well functioning distribution is not guaranteed, as the case of Togo illustrates. It is important to have an infrastructure by way of sufficient available stores and suppliers within reach, and artisans who are able to carry out welding.

Design errors were hardly mentioned by the respondents. In most cases the weight of the implements is adapted to the capacity of the animals and the handling ability. Only in Brazil were the implements considered to be too heavy in 25% of the instances (5 out of 20). Also, the workmanship and quality of the material is hardly criticized, however the puchasing of spare parts was a problem in 33% of the instances. An exceptional problem of mouldboard plows is the support wheel. Very frequently abrasion of the bearing has been reported.

Aside from the constraints mentioned in the general text (section E 2.2), some weak points were also mentioned in the survey. Since shares wear out easily they must be frequently replaced or reworked. With unfavourable soil conditions they are worn out after about 5 ha, equivalent to the work of one season on many farms. Reworking of shares is only done in part according to the survey. When exchanged it may happen that the shares do not exactly fit to the plow body and gaps appear; thus a greater draft power requirement is needed. In some countries such as Malawi and Zambia the quality of the steel is generally criticized.

Finally, it was reported that an insufficient stability occurred on the point of attachment (Zimbabwe, Botswana, Togo). Here bending and even tearing away may occur, often leading to the breakage of the width adjustment. A temporary repair job by local artisans eventually can no longer take place and the adjustment of the working width becomes impossible. The poor adjustment of the plow then leads to an unbalanced load on the handle, which then can permanently become bent.

The potential problematic points on the mouldboard plow are explained in figure E 47.

Generally, it is a disadvantage that in some countries only one or a few different plow body sizes are available; thus no adaptation to the draft power of the existing animals to the type of soil is possible. In some countries of Africa this multiplicity however could lead to further problems in the procurement of spare parts. In Brazil, on the other hand, for the development of an improved mould-board plow type for the subtropical humid climate the following demands were placed by IAPAR (Casão et al., 1988):

- various designs for different soil textures,
- different sizes to adapt to existing draft animals,
- conventional plow and reversible plow designs,
- adjustability of the handles to adapt to the different height of the farmers,

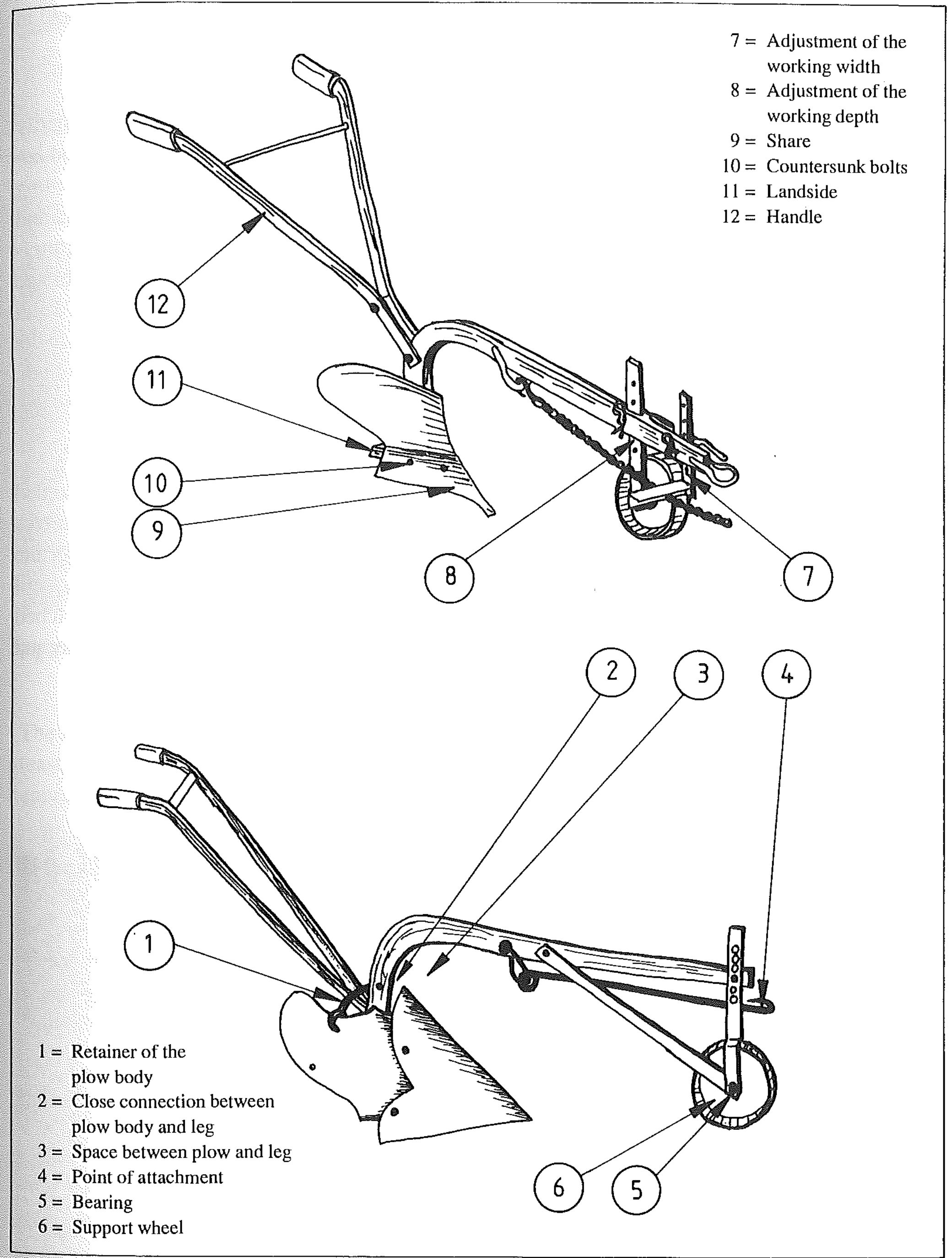


Fig. E 47: Problematic points on the mouldboard plow (the "pointed share" reversible plow and a conventional plow are used as examples)

– suitability for the work in terrain having abundant vegetative residues, i.e. greater space between plow body and frame,
– rapid and practical system for turning the plow body,
– possibility of attaching a disk coulter in order to facilitate the work on fields having thick vegetative growth.

5.3 Rotary implements

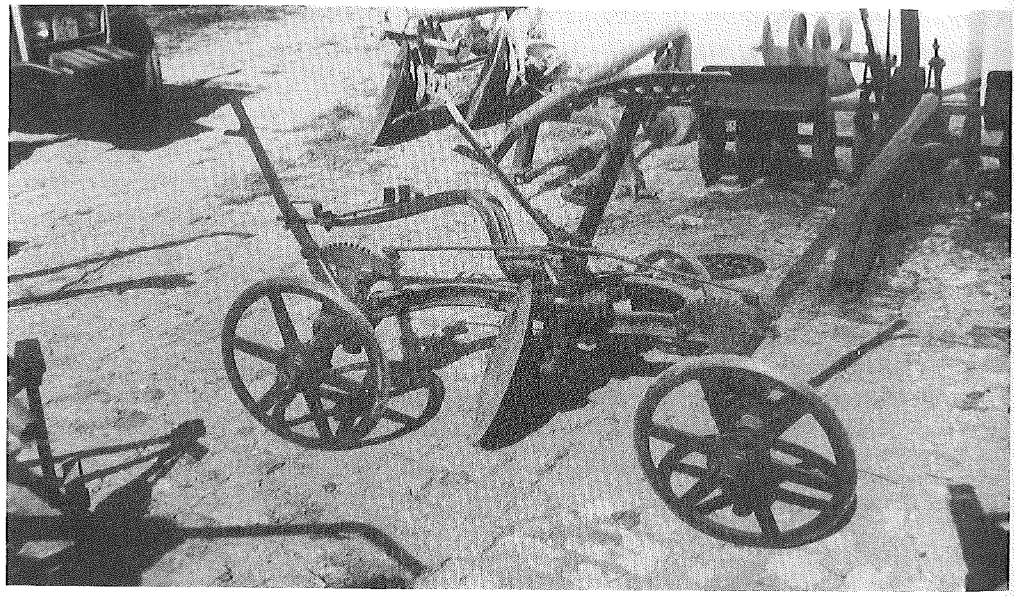
Disc plow, disc harrow

Disc implements cut into the soil under their own weight, and not because of the share angle as other soil preparation implements. Thus, they must be very heavy (ca. 200 to 600 kp per disc). When designed to be drawn by animals this implement is equipped with a seat; this idea originated from North America. The disc plow (figure E 48) is not used in the areas investigated in the survey.

The disc harrow (figure E 49) primarily breaks the clods and does not mix the soil appreciably. Therefore, it is useful for levelling and crumbling the soil after plowing and processing residues (working in or scattering); it can be applied as a primary tillage implement on light soils. The working depth is limited to a few centimeters, otherwise the draft-power requirement would be too high. (Wieneke and Friedrich, 1983)

Since the discs are arranged on shafts angled to the direction of travel no lateral forces occur with this implement. The angle of the shafts can be adjusted so that the discs till the soil at various cutting angles. Notched discs are better suited for breaking clods and working in organic material.

Fig. E 48: Disc plow (IAC farm machinery research institute in Brazil) (Photo: Schmitz)



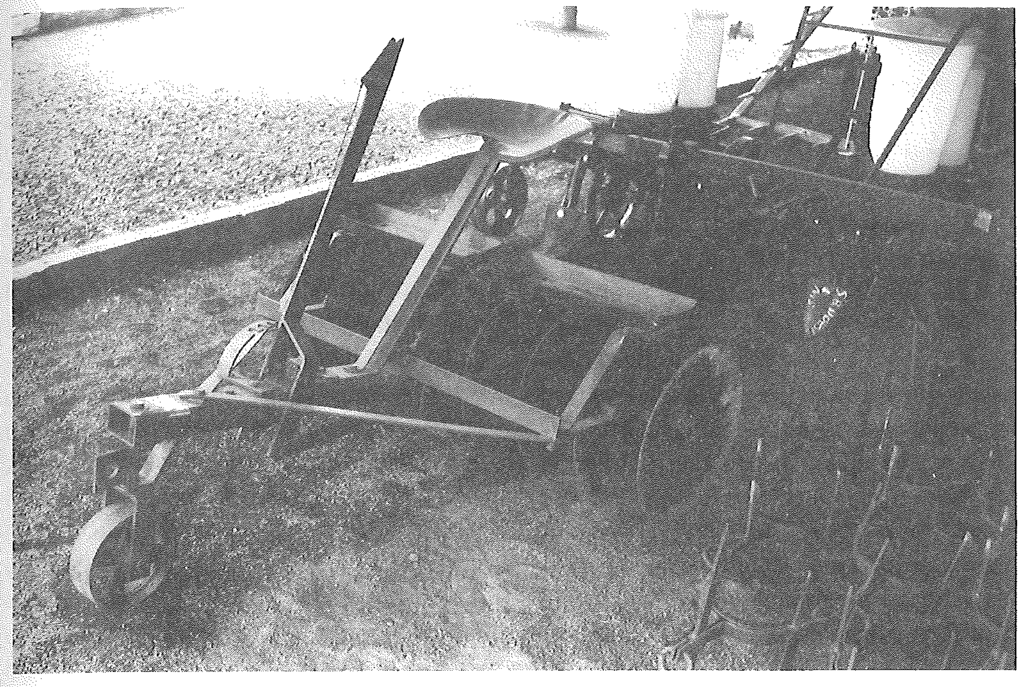


Fig E 49: Disc harrow (Regência farm machinery outlet, Iratí) (Photo: Schmitz)

The implements usually are equipped with at least eight discs, have a working width of approximately 1.6 m and a weight of 140 kg.

In the survey the disc harrow was known in 10 cases, all in Brazil. They are offered by several farm machinery manufacturers in south Brazil, but are seldom found in practice. The substantial weight and relatively high purchasing price (five times the reversible plow according to Rêgencia company in Iratí) are the main constraints. Transportation of the implement is also difficult.

The disc harrow is very common on farms having tractor mechanization. Apparently animal-drawn disc harrows had already been in use prior to tractorization. The implement is not used in Africa (Starkey, 1989), which was also confirmed by the survey.

6. Seeding

6.1 Requirements of seeding

Seeders represent the highest technical demands of all the implements in the survey in the area of animal traction to date. They require precision in manufacturing and assembly, since many parts need to be milled and shaped. As a lack of parts however can hinder the distribution of implements, the technical aspects are dealt with in greater detail here. The experience gained can reveal information on the further developments of draft-animal technology.

In principle, seeding can be done by three methods:
- broadcasting,
- dibbling,
- drilling.

Additionally, there are three procedures for planting or transplanting (tubers, cuttings, seedlings).

Broadcasting takes place on the soil surface and is generally done manually. The procedure is primarily applied for small seed that does not require a great seeding depth, as for example wheat and rice. The seed is subsequently worked into the soil by harrowing. After seeding no further work occurs with draft animals.

Drilling procedures necessitate the transition to seeding in rows. This means a higher draft power requirement, so that the use of hand-pushed seeders is only possible on well prepared soils. On the level of animal traction two procedures are applied: manual seeding in furrows, which are prepared by animal-drawn ards (figure E 23), or the use of drilling machines.

Animal-drawn planters, for example for sweet potatoes, potatoes, yams cassava or sugar cane, are not employed in cropping measures in the regions investigated. Star-type planting holers are only known in pilot projects.

A transition from broadcasting to hand seeders or animal-drawn seeders is occurring for the following reasons:
- increase of area performance,
- more exact seed depositing in regard to depth and spacing,
- ease of work by means of greater seeding density,
- maintaining rows more precisely to facilitate subsequent work operations.

A more appropriate adaptation to the various soil fertilities or the planned quantity relationship of adjacent crops in mixed cropping should be achieved by means of the exact maintenance of the seeding density. Further goals are the saving of seed, a more even distribution regarding emergence and maturing and a better distribution in the stand spacing. Saving seed is particularly economical if expensive seed (e.g. hybrid) is being used. An adaptation to the supply of moisture and the requirements of the respective crop can be accomplished with an exact regulation of the depth of depositing the seed. The exact maintenance of the seed depth facilitates an increase of yield for sensitive crops. Sowing in rows is a pre-condition for the use of animal-drawn seeders.

In contrast to simple manual methods the area performance increases fourfold and in comparison to manual implements such as the jab planter it is approximately doubled. According to the survey the area performance of animal-drawn seeders is about 6 h/ha (with maize). In an experiment with Brazilian implements 3.5 to 4.0 h/ha were recorded (Casão et al., 1987).[1] For a manually operated dibbler an area performance of 3.5 h/ha was achieved (Wijewardene and Waidyanatha, 1984), which appears to be very high. Seeding in rows required for animal-drawn implements does not always offer an optimal space for the crops. If the seeds are deposited singly, as is occasionally the case for maize, the seed spacing is less important, for example for precision seeding.

Under certain circumstances draft-animal implements offer the possibility of practising non-tillage on unprepared soil, which can also be carried out with manually operated jab planters or dibblers.

1 Trial conditions: draft power of medium load (seed and chemical fertilizer); 25 rows of 25 m length; 15 repetitions; when clogging occurred the operator briefly lifted the implement without interrupting the operation.

6.2 Implements for seeding

6.2.1 Furrow breaker and row marker

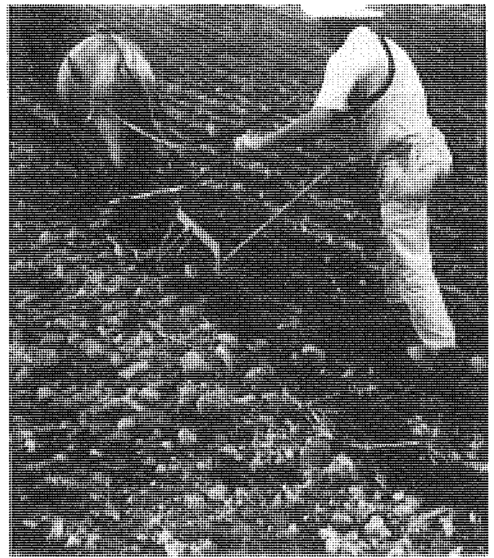
Furrow breakers (figure E 50) are frequently used for keeping orderly rows or facilitating the work with animal-drawn seeders. They are then a particular advantage when organic residues or clods lead to clogging of the implements.

For marking the row spacing simple own designs as shown in figure E 51 are appropriate.

6.2.2 Seeders

With regards to seeders one distinguishes between the dibbling and row-seeding method.

Fig. E 50: Furrow breaker in South Brazil (Photo: Schmitz)



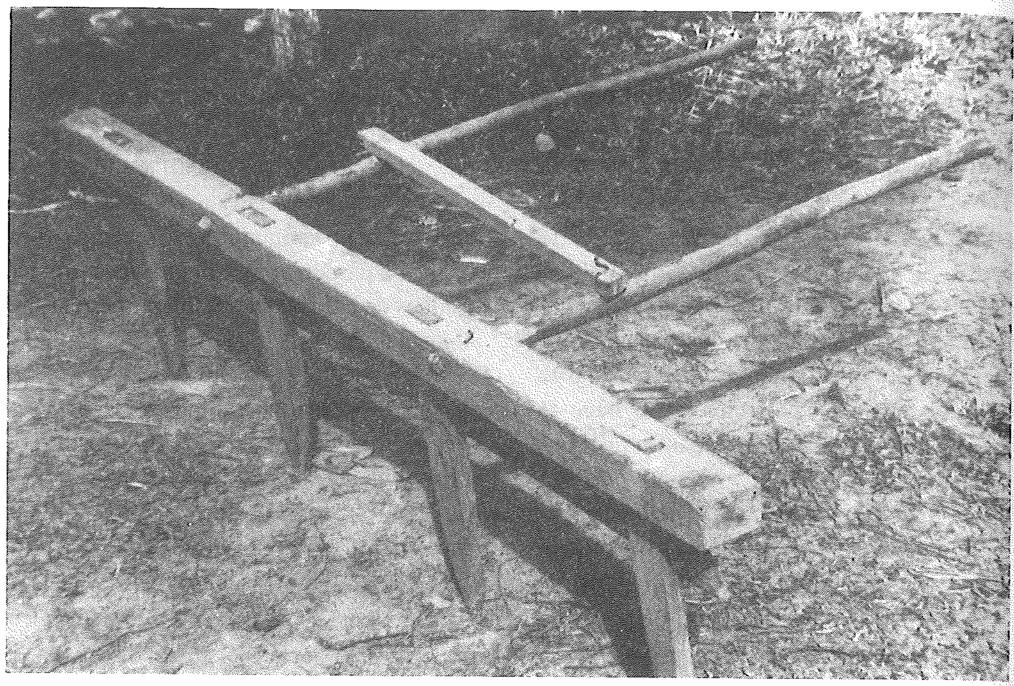


Fig. E 51: Row marker in South Brazil (Photo: Schmitz)

6.2.2.1 *Dibbling seeders*

Pulled or pushed dibbling seeders follow the example developed by IITA (Wijewardene and Waidyanatha, 1984) having a hopper and equipped with a wheel. The tips, which are opened by a lever when the earth is touched, penetrate the soil and release the seed. The lid is subsequently automatically closed by gravity. Because of the fixed spacing of the tips the number of kernels in the row can only be modified by the spacing wheel, lead-ing to pocket drilling. An exact number of plants cannot, however, be assured per row. Dibbling seeders can be equipped with small front wheels for the purposes of transport and maintenance of working depth. The adjustment of depositing depth is done by a press roller.

The implement has the advantage that without possessing any substantial weight it can nevertheless penetrate unprepared soil or cut through a mulch cover. It also hardly becomes clogged in fields having a high proportion of vegetation residues. According to our experience, however, the implement has in practice proved to be a failure in the survey regions, both as a hand-operated implement and for animal traction. It has a tendency to prematurely trigger the opening mechanism, for example by pebbles or root residues or simply by centrifugal forces, which are too high even at speeds usual for draft horses. Furthermore, the tips become stuck with high humidity or in clayey soils. The seeding mechanism (planting jaws) is subject to breakdown; it closes poorly if only slightly damaged. It is difficult to exchange the seed-

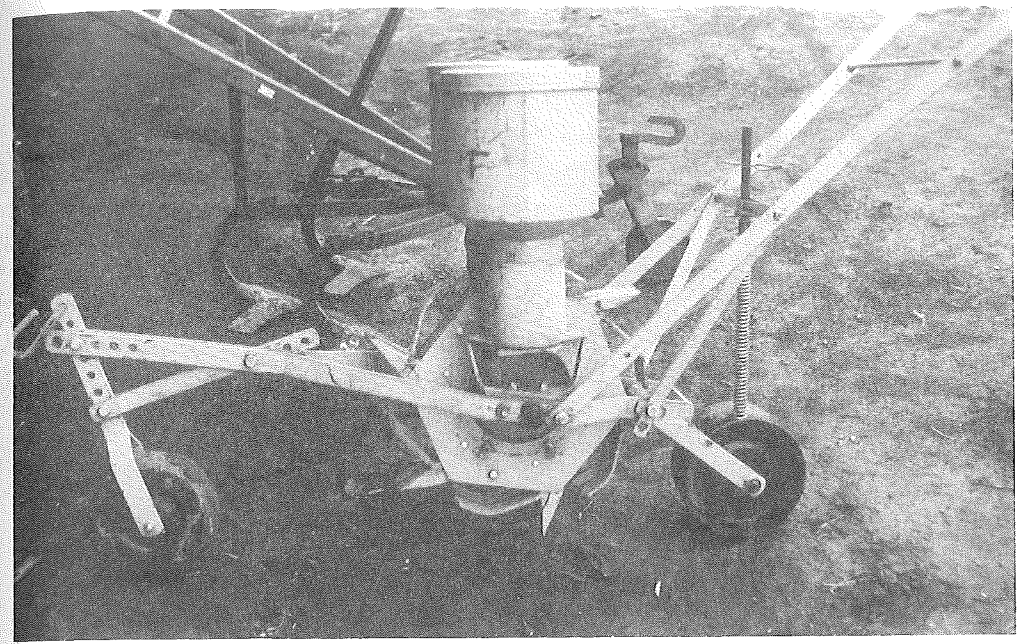


Fig. E 52: Dibbling seeder (rotary injection planter) manufactured by Grazia Co., Brazil (Photo: Schmitz)

plate which regulates the spacing. (Casão et al., 1987; Nüsing, 1989; v.d Decken, 1989)

In trials with various seeders in Brazil the Grazia rotary injection planter (figure E 52), which did not go into production, achieved the best results in terms of weight, maneuvering time, clogging susceptibility and area performance, and second lowest in draft power requirement. However, it is not suited for planting cotton. (Casão et al., 1987) In order to exploit the basic advantages (no clogging, possibility of seeding in mulch, low power requirement) a further development of this principle would be worthwhile. Its disadvantages could possibly be eliminated by the selection of a different principle for dosage and the punching mechanism (e.g. the spade principle; compare Shaw and Kromer, 1987).

6.2.2.2 *Row seeders*

For row seeders a distinction is made between drills and precision seeders. According to the survey usually single-row precision seeders are used for animal traction where rainfed cropping is practised. The seeders have been partially developed for the regionally prevalent cashcrop, e.g. the Super Eco for sowing groundnuts in Senegal (figure E 53). Usually, the adaptation of designs to other crops took place later. A compromise had to be found between the precision of seeding of individual crops and the suitability for various crops, since the procurement of special implements is not worthwhile otherwise. Multi-row drills for small-kernel seed are not used in practice in the area surveyed. Various models of direct drilling machines do exist in Brazil for the purposes of experimentation.

Fig. E 53: Super Eco seeder, Senegal (Photo: Schmitz)

These seeders are suited for the planting of larger seed such as maize, beans, groundnut and soybeans. With alteration some implements (e.g. most Brazilian seeders) can plant undelinted cottonseed. In Senegal the Tamba implement has been developed for this purpose; it is used for pocket drilling. Precision seeders are less suited for planting small-kernel seed, which can more easily be distributed by slide and cam wheels than by holediscs or spacing wheels. Nevertheless, precision seeders are often used for sowing of millet and sorghum.

To date there are no special seeders for ridged crops which allow the track, the frame height as well as the position of the press roller to be adjusted for width and height of the ridges. Furthermore, the seeders are notorious for their poor stability on the ridges. For this purpose Nolle (1984, in: Bordet et al., 1988) states that a draw-beam is required. He suggests a prototype having a stabilizing furrow opener, adapted to the ridge shape and the design of ridger. Another problem is that the farmer cannot walk on the ridges and that in any case two draft animals are required. The combination of mechanical ridging and seeding is not satisfactorily possible due to these special requirements. The poor adaptation of seeders to sowing on ridges is also due to the fact that in some countries, e.g. Senegal, ridging is not the object of a development programme and under certain circumstances seeding is not a bottleneck in regions having ridged crops due to the longer vegetation period. (Havard, 1988a; Bordet et al., 1988)

The precision seeder requires the farmer to adjust the implement to the respective seed by exchanging the hole disk. Generally, precision seeders demand clean and calibrated seed. If no hole disks are available for the desired crop the farmer cannot utilize the implement, if he does not want to risk considerable damage to the seed or too high seeding density.

Marking discs are seldom used on seeders. This is possibly attributable to the fact that precise seeding in rows is first required when multi-row weed control becomes necessary.

6.2.2.3 Experience with design and maintenance

Drive and distribution mechanism

Most Brazilian seeders have a front wheel which operates the drive e.g. the Sans seeder (figure E 54).

The press roller propels the drive of the Brazilian Triton (figure E 55) or the Safim in southern Africa. The transfer mechanism can be simplified by means of the side wheels in the Super Eco (figure E 53). Under certain circumstances utilization is also possible on low ridged crops (Metzger, 1988; v.d. Decken, 1989). Implements with two wheels are more susceptible to clogging and can hardly be used on slopes. The

Fig. E 54: Sans seeder, Brazil (Photo: Schmitz)

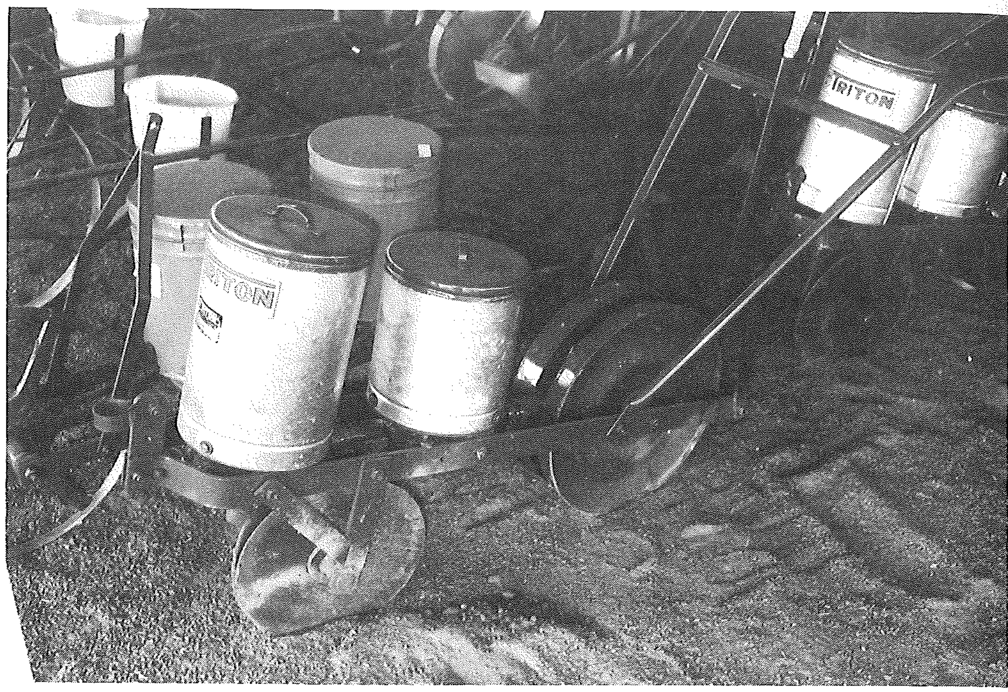


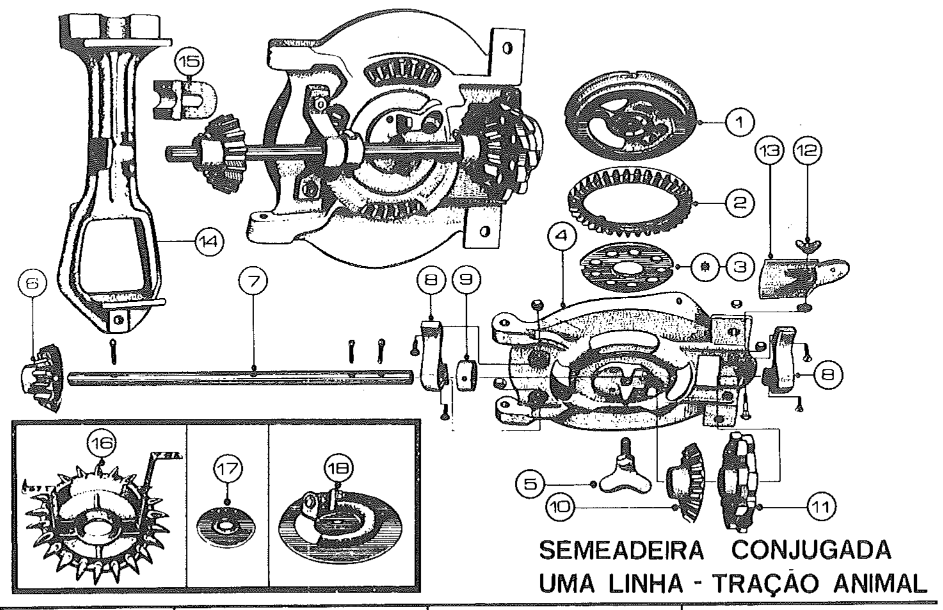
Fig. E 55: Triton seeder with double disc shares, Brazil (Photo: Schmitz)

Super Eco is only suited for light, well prepared soils. It tends to plug up where weeds, vegetation residues and moist soil exist.

The drive wheels must turn freely and faultlessly in order to assure an even seeding density. If they are not equipped with a tread (e.g. Super Eco) they can slip on loose soil. Also, larger clods or failing to grease the drive wheels can lead to a blockage of the drive. On slopes the front wheel tends to deviate from the row.

A special gear must be placed between the drive wheel and the dispenser in order to be able to deposit the desired amount of seed. Generally, the gear cannot be adjusted, but rather the seeding density is adapted to the selected spacing wheel (metering mechanism). Moreover, the transfer path should be as short as possible to prevent the chain from slipping off (e.g. when turning). Also it should be avoided designing machines with too many bearings and cog wheels. Finally, it should also be possible to disengage the fertilizer and seed distributor by means of a clutch when the end of the row is reached.

Most seeders have either a horizontally or diagonally mounted dispenser. The sloped attachment of the hole disk, as with the Super Eco, is advantageous for sensitive seed such as groundnut (Wieneke and Friedrich, 1983). The dropping distance of the seed should be kept to a minimum, in order to achieve the most exact depositing of the seed possible. The planting wheel can be designed as a hole disk, seed plate or spoon-fed mechanism. The latter are less sensitive towards calibration errors. For small-kernel



1	Conj. suporte distrib.	C-102	6	Engrenagem pinhão	2314-A	11	Tirador semente algodão	1010-A	16	Disco dentado	1002
2	Arruela dentada	1003	7	Eixo do conj. distribuidor	2316	12	Paraf. francês c/borboleta		17	Arruela de apoio do disco	1008
3	Discos (vide relação)		8	Mancais do eixo	1013	13	Reg. saída sem. algodão	1094	18	Capa do disco-amendoim	1004-A
4	Corpo conj. distribuidor	1001-B1	9	Anel do encosto	6064	14	Suporte corpo adubadeira	1045-A			
5	Paraf. fixador da arruela	1109.	10	Engrenagem pinhão	1014	15	Encosto do eix o	2323			

Fig. E 56: Distribution mechanism of the Brazilian Sans seeder (manufacturers brochure)

seed (e.g. sorghum and rice) only pocket drilling can be achieved with precision seeders.

On the whole, the inadequate precision of the distributor mechanism is criticized. The poor design of the dispenser frequently causes damage to the seed. In the survey fault is found with the manufacturing quality of the hole disk and the conveyor wheel (cast iron), and polishing is suggested as a solution. A figure from Brazil states that 5 – 10% of the seed is damaged by the spacing wheel. This is confirmed by Casão at al. (1987), who record a 5% damage rate with maize. Thus, the spacing wheel as well as the seed knockout and dispensor should be as smooth as possible (made of plastic), in order to avoid damage to seed. The holes of the planting wheel should be slanted from below to prevent blockage of the seed. Erroneous mounting can be hindered by means of the recessed design. Faults have been described for both Brazilian seeders and the Super Eco (Casão et al., 1987; Starkey, 1981). This also certainly occurs with artisanally manufactured planting wheels. The seed of smallholders is often not calibrated. Frequently, the appropriate planting wheels are lacking for certain crops, and their thickness is sometimes not uniform. Many farmers have severe difficulty adjusting the implements.

The hole disk of Brazilian seeders must be replaced by a cogged wheel necessary for transporting to plant cotton. The expulsion

Fig. E 57: HMC seeder, Brazil (Photo: IAPAR)

takes place sideways by means of a fluted roller. For groundnuts a covering lid is inserted.

The Tamba developed in Senegal for the sowing of non-defibered cotton seed has a distribution mechanism consisting of a stirring apparatus in a housing and a fluted roller under the seed container, which regulates the expulsion. It deposits the seed in pockets, but has been poorly assessed because of fluctuations of seed density (Havard, 1988a).

Seeders are delivered equipped with various planting wheels. The Brazilian made HMC (figure E 57) is normally offered with 5 hole disks having 4, 5, 6, and 10 holes, a disk without holes, which can be fitted by the owner, and the dispensor for cotton. The apparatus for groundnut seeding must be ordered as an accessory.

Opening furrows, depositing and covering of the seed

The furrow should be pointed at the bottom in order to prevent rolling of the kernel in the furrow. Sabre-type shares sometimes disk shares, are used to open the furrows. In hard soils hoeing shares tend to glide less than gently curved sabre-type shares (Havard, 1988a). Disk shares are better suited to fields having roots, over which they can glide. However, they can become damaged by stones. As applies to all turning parts, they are expensive. The Triton seeder from South Brazil is the most reasonably priced implement on offer, according to information provided by the farm machinery outlet Regência; they are equipped with double disk shares and have eliminated the front wheel (figure E 55). The Super Eco from Senegal has a knife coulter to facilitate the penetra-

tion of the furrow opener. It was, however, not accepted by the farmers (Havard, 1988a).

With the occurrence of larger clods or vegetation residues the furrow opener can become clogged. Wide shares heap up a considerable amount of earth and organic mass. To improve the work prior furrow breaking is recommended. In some cases clogging can be a result of farmers wanting to sow immediately following a fall of rain as is done in manual operations (v.d. Decken, 1989).

Substantial fluctuations in the precision of depositing the seed have been observed with the seeders. In a trial with Brazilian seeders, average deviations of 40% were determined in the rows, approximating that of dibbling. The depositing depth is generally adjusted with the aid of the press roller. However, on some implements the depth adjustment is only possible by means of the point of attachment (e.g. Safim, southern Africa). Aside from the dibbling seeder (Grazia, figure E 52) most implements can maintain a maximum depositing depth of 4 cm (Casão et al., 1987). The Super Eco (figure E 53) is also considered inadequate, since it is not suited for sowing seed deeper, e.g. millet at 6 – 8 cm on dryland. The regulation of the depositing depth is accomplished by adjusting the furrow opener. Frequently the farmers get the furrow opener welded, so that it does not become lost (Havard, 1988a). Generally, reports are often heard that serious problems occur with the depositing depth of the seed. Seed covering scrapers and press rollers take care of covering the furrow with earth and assure good soil resealing. Thereby, the moisture supply is sufficiently guaranteed.

The seed covering scrapers must cover the furrow properly with soil without allowing organic material to be drawn in or stones to be transported into the furrow which depends on the mounting position. They should be easy to adjust for height and angle (as with the Sans models, figure E 54) in order to adapt to the field conditions at all times and to prevent clogging. The Super Eco is equipped with seed covering scrapers in the form of duckfoot shares, which simultaneously achieve weed control. Faulty function of seed covering scrapers is often mentioned in regard to clogging and poor covering of the soil, especially if they are attached too close to the ground and the press roller.

The shape of the press roller is important: it should provide for optimal covering and resealing by means of the shape of the wheels; larger wheels are preferred in order to avoid clogging. Generally, the press rollers are only adjustable for regulation of the depositing depth.

Application of chemical fertilizer

All implements, including the Super Eco and parallel developments in neighbouring countries, are offered with attachments to spread chemical fertilizers (2/3 of all the cases). Thereby a more precise spreading in comparison to hand spreading is achieved, a saving of fertilizer and more rapid access by the plants. A further aspect is easing the workload. The farmers, however, must be able to precisely adjust the dosage.

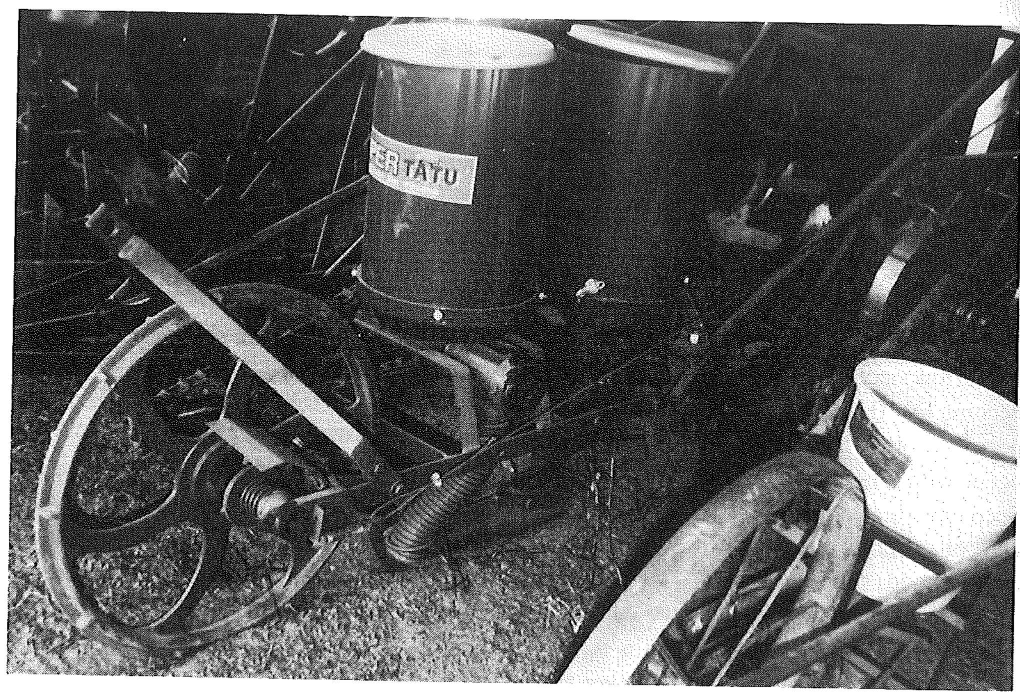
Seeders that can simultaneously spread fertilizer are generally longer and heavier, whereby the machine then becomes clumsier to handle. Fertilizer application occurs through an auger or stirrer and dispenser. Separate depositing of seed and fertilizer is important, so that the seed does not "burn", as has been reported from Zambia.

There are essentially three solutions for separation. The best separation is achieved if the fertilizer is deposited with a detached share from the side (Baldan, Safim) or is placed under the seed. In the latter case usually a second deeper share precedes the first following the same line (Sans). On a dibbler a second, complete planting wheel with a beak tip is attached, which takes care of a clean separation (Grazia). On implements with two shares, especially if there is a staggered arrangement, more draft power is required and risk of clogging increases.

On some implements (e.g. HMC, Triton, Tatu, figure E 58) only one share is available for sowing the seed. The fertilizer falls in front of the seed on to the ground and it is subsequently worked in with the share. This is considered to be an adequate solution (Casão et al., 1987).

In many countries the dissemination of chemical fertilizers is a component part of the extension services. If they are applied however, in practice it is often found that seed and fertilizer are deposited in separate work operations. This can be attributed to common cropping practices as well as to the weight of the seeder.

Fig. E 58: Tatu seeder, Brazil (Photo: Schmitz)



Material and design

High weight (e.g. Tatu) as well as a high point of gravity (Baldan) make the handling of the implements awkward, especially on slopes and in small plots. Seeders with a light weight can easily be lifted when they become clogged. There is, however, a minimum weight originating from the seed and fertilizer, for example the seed and fertilizer hoppers of Tatu implements weigh 13 and 23 kg, respectively. The average weight of the implements occurring in the survey was 43 kg. The seven implements tested in Brazil weighed between 53 and 72 kg. If the implement is too long it is difficult to handle on hilly terrain having curves (HMC). Single-row implements have a width of 40 to 58 cm (Tatu). Two-wheeled implements are wider, e.g. Citra = 96 cm (figure E 59).

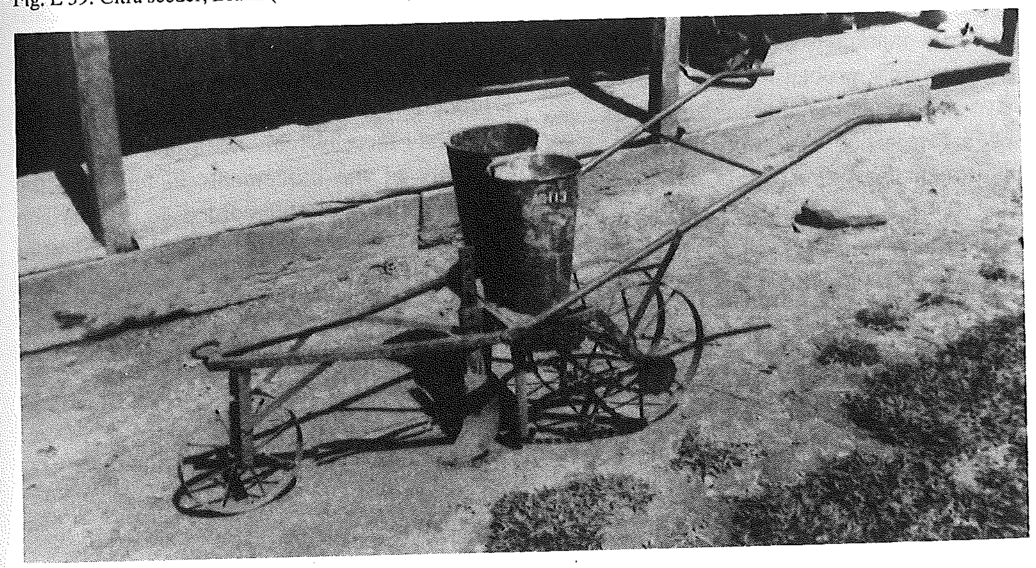
All bearings should have greasing points to prevent sliding of heavy-geared drive wheels and thus a disruption of the seeding operation (Casão et al., 1987).

The hoppers should be easily removable. This is necessary for emptying, adjusting (exchange of spacing wheel) and cleaning operations. Especially implements which spread fertilizer should be cleaned regularly to prevent corrosion, which is a frequently occurring problem. This could be solved by manufacturing the part out of other material (e.g. fiberglass), but it would entail a higher cost and the new material would create additional difficulties for the artisans.

In the survey numerous problems were listed regarding unsatisfactory design, negligent fabrication and maintenance. The material is predominantly considered to be of medium to poor quality and the high weight is criticized. The bearings cause further problems. Poor assembly causes cumbersome access to bearings, missing sealings lead to the breakdown of bearings, especially due to sand.

In some cases the bearings can only be replaced by the manufacturer. The risk of down-time is high: breakage of chains, gear

Fig. E 59: Citra seeder, Brazil (Photo: Schmitz)



parts and bolts, wear to gear wheels in the drive mechanism, loose bolts and loss of individual parts were mentioned in the survey.

The required draft power is dependent on the weight and the parts which come into contact with the soil. The Super Eco requires 20 kp on sandy soil and 30 kp on more clayey soils (with coulter, furrow opener and duck-foot shares) (Havard, 1988a). In a test with Brazilian seeders measurements of 20 to 30 kp were also recorded. The Grazia dibbler required the second-lowest draft power after the HMC implement, which only has one share for seed distribution. (Casão et al., 1987)

From a technical point of view an improvement of seeders, the design of which has not been further developed for many years, could be achieved by a lighter construction with modern materials. At the same time, demands on seedbed preparation could be reduced. As a result a direct drilling machine could be created that would work more independently of the field conditions. It appears that such an implement however could not be easily marketed in sufficient quantities, given today's problems which the farmers have regarding the mechanization of the seeding operation, especially due to the high investment cost.

6.2.2.4 Discussion

On the whole, seeders are seldom utilized, only in 30 cases in our survey, including the cases of very occasional use. Limiting conditions for their employment are elucidated in the following assessment (in brackets the number of instances):

- Economic reasons rank first, such as too high price (17) and too low labour and productivity distribution margins (14) (available labour force, labour savings too small or cropping area not sufficient).
- Limited conditions for utilization due to topography (8), unsuited soils (e.g. too clayey and sticky in Zambia and Ethiopia) (4), mixed cropping or lack of row cropping (6), obstacles on the fields (6) and poor seedbed preparation (3) rank second.
- Third follows the lack of adaptation to the agricultural farm system, including the fact that the implement is not known or not obtainable or it does not have any tradition of use or that animal traction is still in the introductory phase (9).
- Finally, it was mentioned that the use of seeders is difficult for the farmers (adjustment, handling), little know-how is available or more extension services are necessary (5).

In fields with roots or stones and much organic matter (fallow and harvest residues) seeders do not function properly. The seedbed must be prepared well for most implements, if the soil is not very light. Calibrated seed is necessary for the precision seeder, which hardly applies for the smallholders. Patchy and double sowing can be caused thereby. In addition, inadequate quality of the implements in terms of the work result is often recorded. In comparison to other implements there is a higher number of worn out parts and points to repair; this requires greater preparedness of the farmers to carry out maintenance and more experience by the artisans.

Multi-row seeders have hardly found acceptance in practice. They require a greater investment. A better seedbed preparation is necessary and their handling is rendered more

difficult due to the greater width and weight. An entirely exact seeding in rows is only required, on the other hand, where multi-row weed control is being carried out.

In the regions examined, seeders are primarily being utilized under the following conditions:

- In regions having a short vegetation period such as Mali and Senegal seeding represents a work peak and rapid sowing is necessary, which can in part take place by direct sowing. This also allows an expansion of the cropping area.
- Their acceptance is particularly high for the cropping of cotton and groundnuts, for which they were partially developed. If the investment does not pay in terms of a better yield, the farmers cannot pay the high price. The market production must therefore be quite advanced.
- The supply of accessories (e.g. hole disks) and spare parts must be guaranteed by an industrial and artisanal structure.

Animal-drawn seeders have been, due to their limitations, only disseminated in a few countries such as Brazil, Senegal, Mali and southern Africa.

6.2.3 Fertilizer applicators

In some countries such as Brazil fertilizer applicators are increasingly being used, independent of the sowing time. They are appropriate for the spreading of chemical fertilizer, dry and organic manure. In part this is combined with furrow breaking prior to seeding. Some implements have two applicator tubes in order, for example, to apply nitrogen directly to the plants when passing between the rows. The applicator mechanism consists of augers or stirring devices with spreaders.

7. Weed control

7.1 Requirements of weed control

Depending upon the climatic zone, weed control is one of the most labour-intensive operations, especially if it is carried out with the hand hoe.

The importance of weed control also depends on the competitive forces of the respective crop as well as the amount of time required to build a canopy. The more rapidly the plants grow, the more effective is the shading of the soil as a weed control measure. According to rank, crops having a small spacing possess a relatively greater competitive force. Maize and rice are very sensitive crops due to their slow initial development.

For permanent cropping and high weed invasion it is necessary to apply weed control measures already prior to seeding, since with mechanical hoeing devices only an average success rate of 50% can be achieved (Walter, 1990). Moreover, the weed-control effect of the implements is poor in row crops. An intensive soil preparation and an additional work operation, for example with the harrow, directly before seeding shifts the competitive conditions in favour of the crops. Seeding must take place in parallel rows, as the cultivator works at a constant width. A very high and more lasting effect can be accomplished if the weeds are eliminated during the first germination phase. Simultaneously, a better aeration of the soil is achieved, the infiltration rate of the water is increased and the surface capillaries are destroyed; thereby the evaporation of moisture is hampered.

As long as no root system has already developed, weed control should begin as early as possible – when the first weeds appear – in order to eradicate the germinating weeds. It should be done as close to the surface as possible, a maximum of 3 – 5 cm deep, in order not to raise lower lying weed seeds to promote their germination. For the farmer however the field is still clean at this stage of development and there is no reason to intervene. (Almeida et al., 1983)

The number of work operations fluctuates depending upon the crops and the growth of the weeds. The later the weeding takes place, the greater the root penetration of the weeds, demanding deeper working of the fields. The subsequent work operations depend on the type of crop, the climate and weeds; here superficial work operations are recommended in order to prevent damage to the root system of the crops.

The practice of mechanical weed control is receding with the increasing application of herbicides, leading directly to problems of toxicity and cost. Contact of the poison with the skin, including the sensitive parts such as the eyes and mouth are unavoidable. Masks and protective clothing are seldom worn.

Fig. E 60: Use of herbicides with draft-animal implements: The boy drinks a coke after the work, in his own words "to neutralize the effect of the poison." (Photo: Schmitz)

The problems connected with chemical weed control have given rise to an increasing interest in green manure in Brazil; its use can control weeds when done at the correct time.

Chemical weed control can save a great deal of time. It is often employed where labour forces are scarce and its use makes weed control on stony fields much easier. However, it has been reported from Brazil that results are not satisfactory because of underdosages and the subsequent appearance of resistance of the plants. In mixed crops the problem occurs that herbicides are usually only suited for one of the two crops (Vieira, 1985).

7.2 Implements

One, three and five-share cultivators, ridgers and ards are employed as implements for weed control. They have already been described under the section on soil-preparation implements, since they are often identical with them.

The advantage of the single-share hoeing (figure E 61) implement is its multipurpose use and simple handling. It can be employed where obstacles occur and is effective where high weed growth is present. Also it can be applied for most crops and with mixed cropping due to the narrow working width. Since a width adjustment and wheel are not incor-

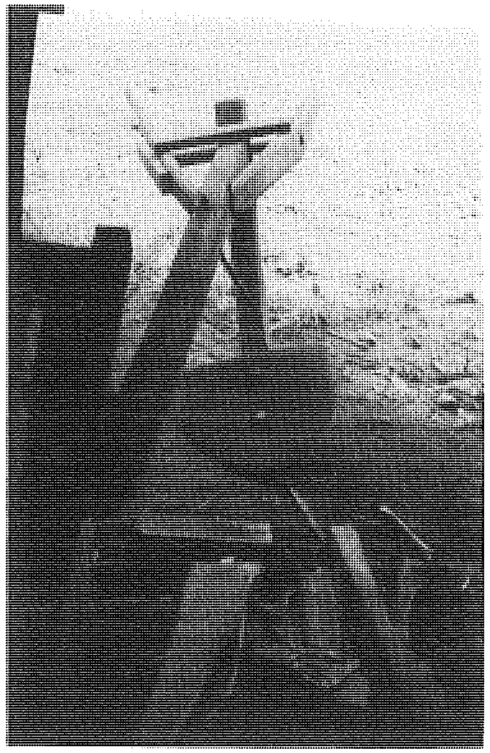


Fig. E 61: Single-share hoeing implement (small fuça-dor), Brazil (Photo: Schmitz)

porated into the machine for depth adjustment, there is a severe risk that roots may become damaged; this is frequently criticized by the extension services. The implement is sturdy, easy to manufacture and to repair, and has a reasonable cost. It is offered by local artisans and farm machinery distributors.

Multiple-share cultivators (e.g. Houe Occidentale, Houe Triangle, Houe Manga, figure F 16, F 7) can be adjusted in the width and various small tools (e.g. bar-point share, duckfoot) can be mounted. The working depth can be regulated by the support wheel. Thereby the danger can be reduced that the roots of the crops will become damaged. When the cropped plants are still small it is recommended to carry out weed control with narrow tines, since they only move the earth slightly to the side. Larger plants are less sensitive to this problem. In this case wider

Fig. E 62: Planet cultivator at the ACARESC training centre (Photo: Schmitz)

tools (duckfoot, sweepshare) can be used for a shallow working of the soil; this prevents damage to the roots.

The Planet cultivator (figure E 62) was developed at the turn of the century by the Frenchman Planet as an "ideal" cultivator. In Brazil it is sold by Sans, Tatu and Baldan companies. Its design allows manifold possibilities of adjustment. Nevertheless, it is little used, since the price for the farmers is too high. In addition, it tends to clog.

Usually three-share cultivators are used. Five-share implements are offered by the distributors but are seldom found in practice. In Brazil three-share cultivators, sometimes with adjustments, are also fabricated by local artisans (figure E 63).

The multi-share cultivators are usually of the adjustable type. From the survey it was established that in Brazil only part of the artisanal-manufactured implements and in Botswana only one cultivator type mentioned in the survey was not adjustable. The width adjustment can be done by loosening the fixture and resetting the tines, as is the case with the cultivators in Senegal, or by modifying the frame width by a lever or spindle, as is done with the Planet cultivator, or by loosening a clamp bolt.

Ridging has an effective result for controlling weeds in rows. Sufficient earth is heaped up against the plant to simultaneously cover and smoother the weeds. No other implement is available which so successfully achieves this purpose in rows.

However, heaping up is only possible with larger plants; smaller crops could become damaged.

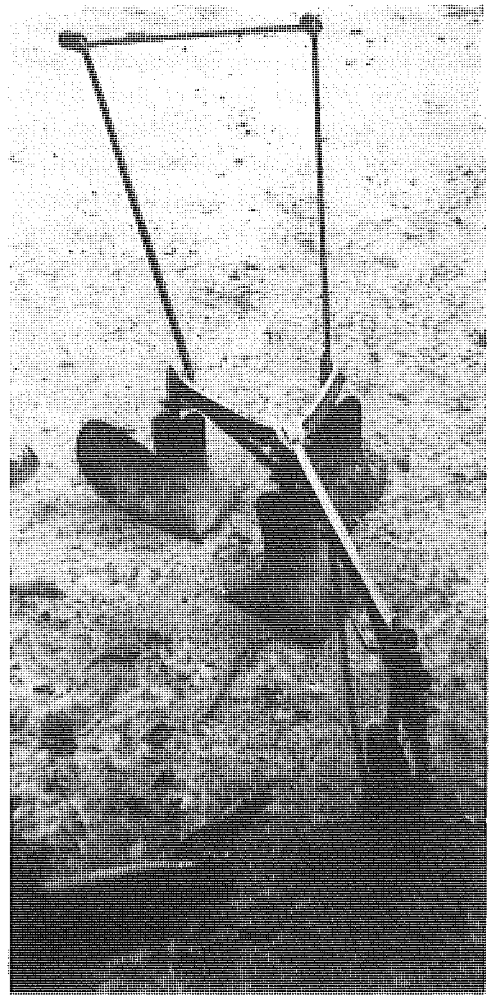


Fig. E 63: Cultivator with single-sided ridging shares (without adjustment), Brazil (Photo: Schmitz)

7.3 Distribution and Experience

Weed control with animal-drawn implements is done in 73% of the cases (51 out of 70 instances) in the regions investigated. In Brazil in 87% of the cases (20 out of 23 instances) cultivators are used in agricultural practice, while in the African countries they are common only in 64% (25 out of 39 instances) of the cases.

In African countries ridgers and multi-share hoeing implements were mentioned for weed control. In practice however these are only utilized under certain circumstances. The existence of a work peak and the cropping in rows tend to favour their use. Cropping without any particular order, broadcasting and mixed cropping tend to be a hindrance for their application. The application of the ridger for weed control purposes is associated with the regions where ridge cropping dominates. This is the case in some regions in Togo, Ghana, Cameroon, Malawi and Zambia. Cultivators are mainly used in Mali, Niger, Burkina Faso and Senegal, where shallow seedbed preparation is common.

In Brazil three-share cultivators having single-sided ridging shares are used (figure E 63). Single-share cultivators with broad swallowtail shares or a shovel-shaped tool, e.g. bico de pato (figure G 26) or the small fuçador (figure E 61), are utilized. On the other hand, ridgers are seldom employed for weed control.

Permanent cropping is almost always found in regions where mainly multi-share cultivators are used. Correspondingly few obstacles exist and the occurrence of stones is minimal. In the Andes countries and Ethiopia the ard is employed for weed control. In Ethiopia this work operation is seldom conducted since teff, the primary crop, is broadcasted.

Generally, difficulties were mentioned regarding the training condition of the animals and the too late weed control. Weeds are frequently not removed before they reach a height of 20 – 30 cm. If weeding is done by hand the weeds can more easily be gripped and can be completely pulled out. However this development stage of weeds has gone beyond the bounds of effectivity for the mobilization of implements.

F. Case studies: West Africa