The development and assessment of a donkey-drawn weeder in Niger

by

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Abstract

A donkey-drawn experimental weeder was designed to measure and investigate the technical parameters influencing the weeding process. This research should lead to the preparation of location-specific guidelines for the construction of strong and cost-effective donkey-drawn weeders.

Some results on draft force requirements and achievable working qualities are presented. The draft forces, which increased with working width and working depth, were around 250 N for the blades investigated at a working depth of 3 cm. Comparable weeders would therefore be suitable for use with a single donkey.

In some cases, the animal-powered weeding was as efficient as manual weeding, with no subsequent reductions in yield. The measured draft force requirement and the weeding efficiencies obtained suggested that a blade of German standard DIN 11112 can be recommended. Steerability and driving behaviour with 200 mm wide blades favour an overall working width of 500 mm.

Introduction

As part of the special research programme 'Adapted Farming in West Africa', the Institute for Agricultural Engineering at the University of Hohenheim, Germany, has been investigating animal traction as an intermediate source of power for mechanising field work in Niger.

In developing mechanical methods of weed control, it is very important to take account of local conditions. In contrast to the practice in some neighbouring states of this semi-arid region, rainfed agriculture in Niger is based almost exclusively on very time-consuming and labour-intensive manual work. As rainfall in Niger is very variable, weeding becomes necessary before sowing has been completed, resulting in crucial labour bottlenecks.

Millet (*Pennisetum glaucum*) is the main crop in Niger because of its comparatively low demand for high quality soil and precipitation. Other crops are found only near rivers and in the far south of the country.

Initial development work

The first prototype of the simple donkey-drawn weeder *Hata* (Houe à traction asine) was developed for weeding millet on light, sandy soils (Betker, 1990). Using this weeder, it was possible to reduce weeding labour time from more than 40 h/ha for manual weeding to less than 20 h/ha (Betker, 1993).

The prototype weeder with three blades was well-accepted, especially because of the integration of the traditional *Hiler* blade. Being of simple forged and riveted construction, the *Hata* could be manufactured, repaired and maintained by local village blacksmiths, with a sale price of about US$ 35.

Initially it operated as a swing-frame and so the working depth was regulated by the implement's weight, the soil resistance and the manual force of the operator. The cultivator was difficult to use because the front blade often penetrated too deeply into the sandy soil. The problem was solved by fitting a cheap and simply-constructed skid and moving to a stilt frame construction. The desired working depth of 5 cm could then be maintained easily.

The hook position of the draft beam attachment became of great importance. If the hook position was wrong the adjusted working depth might not be achieved or the frictional resistance and overall draft force requirement might become unnecessarily high.

The traditional *Hiler* blades have subsequently been abandoned as they were not robust enough for animal traction use. The ends were often distorted and the rivets could not withstand the forces acting on them. After a single passage

Figure 1: The experimental cultivator

weeding efficiencies were about 50% compared with more than 90% for manual weeding.

A new blade design was developed in cooperation with farmers and blacksmiths. The most important criteria were ease of manufacture, durability and the support of a drawn cut. The blade was 200 mm wide, 160 mm long, and produced from 3 mm strong mild steel. The opening angle was about 87º at the point, decreasing to 70º towards the base. The cutting edges were sharpened on the top. This blade design was quite similar to that of the traditional *Iler* tool of the Wolof people of Senegal and The Gambia (Volz, 1989).

The *Hata* was provided with an ergonomically improved handlebar. The hook of the draft beam attachment was shifted to the back. Samples of this version of the *Hata* were distributed to several development projects throughout Niger (Emhardt, 1994).

Systematic research on weeding

To maximise weeding efficiency and minimise labour and draft requirements, it is necessary to investigate all aspects of the weeding process. The development of a weeder should not be restricted to an empirical, engineering approach. Recommended construction guidelines for both local manufacture and maintenance of a cost-effective and strong weeding implement must be based on the evaluation of the tool's working characteristics under field conditions. It must take into account the combined effects of the draft animal, the implement, the farmer and the cropping system.

Material and methods

In order to determine in detail the influence of technical parameters involved in weeding, an experimental animal-drawn measuring weeder was developed (see Figure 1). It was fabricated using A1MgSiF22 (Mannchen, 1993).

Experience suggested the need to provide the option of using blades with different cutting edge geometries (opening angles and angles of attack). During the experiments three different blade designs were used:

- the *Hata* blade (Figure 2a)
- a blade made according to the German standard DIN 11112 (Figure 2b). Made of hardened boron steel, 200 mm wide, with an opening angle of 72º, it supported a drawn cut. Its shape led to the soil being lifted and moved, resulting in improved loosening and mixing
- a blade based on the widely-used groundnut lifter, also 200 mm wide, made of mild steel with a strength of 3 mm (Figure 2c). With an opening angle of 120º, it deviated from the recommended 85º–87º in order to realise a drawn cut (Schilling, 1985). The cutting edges were sharpened on the top.

The measuring weeder, including the sensors, weighed 12 kg (similar to the *Hata*). Ease of adjustment and mode of operation, as well as simplicity in changing blades, were additional design criteria that contributed to trouble-free experiments. The hook position for draft force attachment could be adjusted in height and longitudinal direction. Working width and depth were finely adjustable within a given range. Position and height of the handlebar were also easily adjustable to suit the user.

To measure draft force requirement and working depth, the weeder was equipped with a load cell, an ultrasonic sensor and two inclinometers. The correct voltage for the sensors was supplied by two 12 V, 2 amp–hour batteries. The sensors could measure non-stop for six hours. Batteries could be recharged by solar energy to increase the versatility of the portable data acquisition system.

The sensor information was joined in a portable signal conditioning unit and then transmitted via a monitor to a portable multi-channel data recorder. Finally, experimental data were analysed after analogue/digital conversion by means of a personal computer.

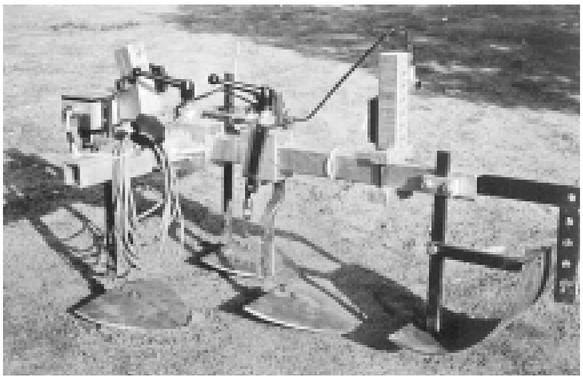

Figure 2a: Experimental weeder with Hata blades

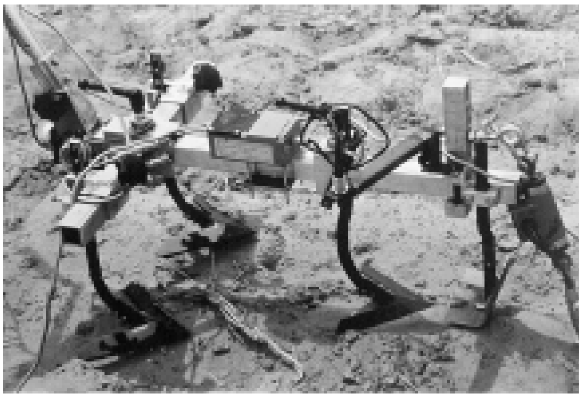

Figure 2b: Experimental weeder with DIN blades

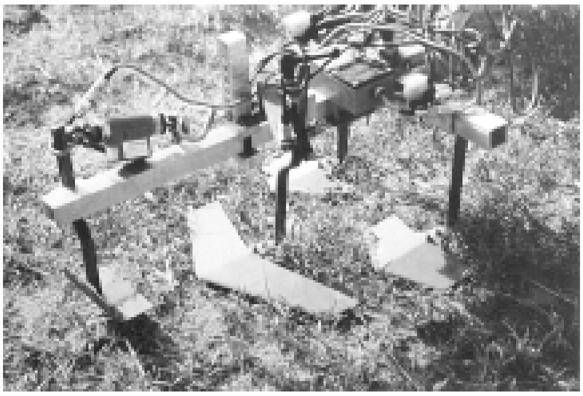

Figure 2c: Experimental weeder with 120° blades

On-station experiments were undertaken at the ICRISAT (International Crop Research Institute for the Semi-Arid Tropics) Sahelian Centre, south-west of the capital, Niamey. The measurements were carried out on several fields with small plots arranged in a randomised factorial block design. Further measurements were carried out on-farm in rural areas around the villages of Bossey-Bangou, Tillabery and Tahoua. Average annual precipitation ranged from 350 mm in Tahoua to about 600 mm in Sadoré (Sivakumar, Maidoukia and Stern, 1993).

Draft force requirements

Table 1 shows mean draft force requirements of the three blades at three working widths, all at an adjusted working depth of 3 cm. During the measurements the soil had a mean moisture content of 6% and a mean shear strength of 0.04 N/cm. Generally the values are within, or near, the optimal range of draft forces expected from single donkeys. According to Betker (1991), the range of draft forces in which 90% of the potential work may be achieved is 130–230 N.

At the working widths tested, the DIN 11112 blade always required the lowest force, and the *Hata* blade required the highest draft force. The latter penetrated deeper into the soil and the bigger blade area resulted in higher frictional forces. With an adjusted working depth of 7 cm the highest draft forces required were 373 N and 386 N for the 120º blade at working widths of 50 and 60 cm, respectively. The values for the *Hata* and the DIN blades were around 300 N, which are definitely not suitable for single donkey traction.

The adjusted 3-cm working depth was best maintained by the DIN blade with 4.1 cm at a 50-cm working width. The greatest deviation was 5.5 cm for the 120º blade at 40 cm working width. In most cases the adjusted working depth was exceeded, because the soil surface was already slightly weakened by rain. A working depth of 7 cm was easier to maintain because penetration resistance was higher.

In order to simplify comparisons between the blades, the specific draft force requirement (draft force requirement relative to the actual working cross-section) was calculated for each blade (see Figure 3).

As the *Hata* was also used by several development projects for weed control, corresponding measurements were carried out

Table 1: Mean draft force requirement (N) at different working widths, at 3 cm working depth

Working width (cm)	*Mean draft force (N)* DIN	*120º*	*Hata*
40	153	229	260
50	129	224	294
60	224	282	288

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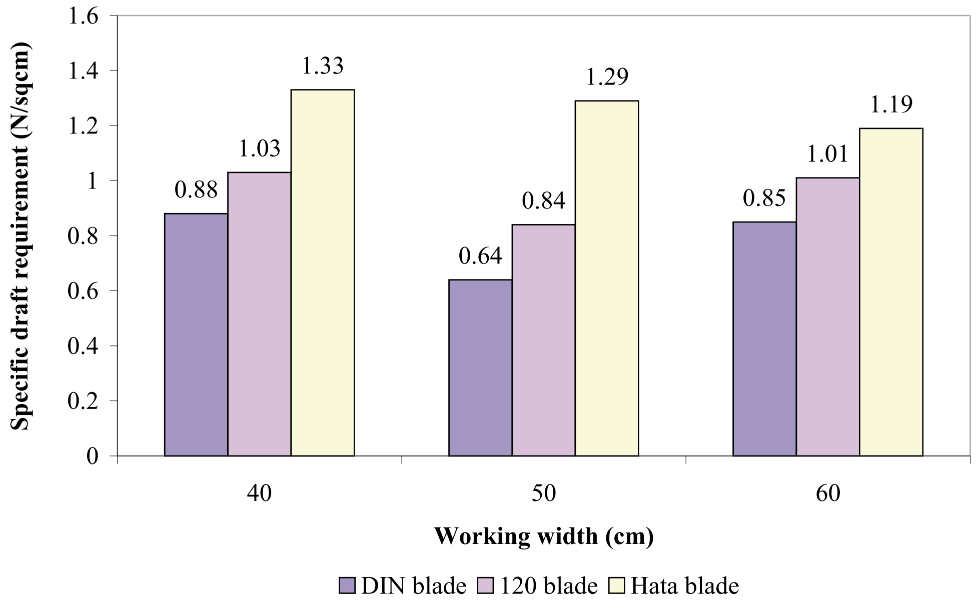


Figure 3: Specific draft force requirements at an adjusted working depth of 3 cm

at different locations. The specific draft force requirement varied by a factor of two from 0.8 to 2.1 N/cm^2 at a working depth of 4 cm. The specific draft force requirement and also the shear strength increased from the light and sandy soils in Sadoré to the heavier soils with a higher clay and loam content in Tahoua.

Working effects and weeding efficiencies

As well as implement-specific adjustments, and type, texture and moisture content of the soil, the varieties and stage of development of the weeds also influence the success of weed control. The life-cycles of the weeds, predominantly *Cenchrus biflorus, Hibiscus sabdariffa, Commelina forskalaei, Eragrostis tremula* and *Merremia tridentata* (de Fabregues, 1979) are adapted to the specific conditions of shifting and rainfed cultivation in Niger.

All weeders work deeply under the soil surface and crumble even encrusted soils (Bernhardt, 1983). They also smooth the soil (especially those with a wide working width).

With regard to the effect on weeds, three factors are important. Apart from cutting and uprooting weeds the desired effect can also be achieved by covering them. The multiple tined weeders common in southern Africa stand out for both their hoeing and cutting characteristics. Their covering effect can be increased by mounting additional hillers.

Optimum results are obtained when the weeds are completely uprooted and left exposed on the soil surface, when they wither within a few hours. Cutting weeds which reproduce vegetatively does not stop new sprouts developing quickly from the remaining parts of the roots. If rain falls immediately after treatment even cut plants can re-root.

Acceptable treatment through covering can be achieved more easily on light, sandy soils, such as those predominant in the south of Niger, than on heavy soils with higher clay or loam content. According to our experience weeds should be covered by at least 3–5 cm of soil.

After treatment, samples of dead and surviving weeds were collected from 1-m squares and dried (three replications per plot). The weeding efficiency (e) was calculated from:

$$e = \frac{m}{m + m_A} \times 100 \quad [\%]$$

m = dry matter of dead weeds

m_A = dry matter of surviving weeds

Figure 4 shows mean weeding efficiencies for different blade designs and working widths. The DIN blade was the most efficient, and the *Hata* blade the least, over all working widths. Single pass donkey-drawn weeding could not reach the standard of manual weeding, but an efficiency of more than 90% of that of hand weeding was obtained, an improvement on earlier prototypes.

In Niger, weeds have many uses including medicines, vegetables, spices, and above all, animal feed. It is therefore undesirable to

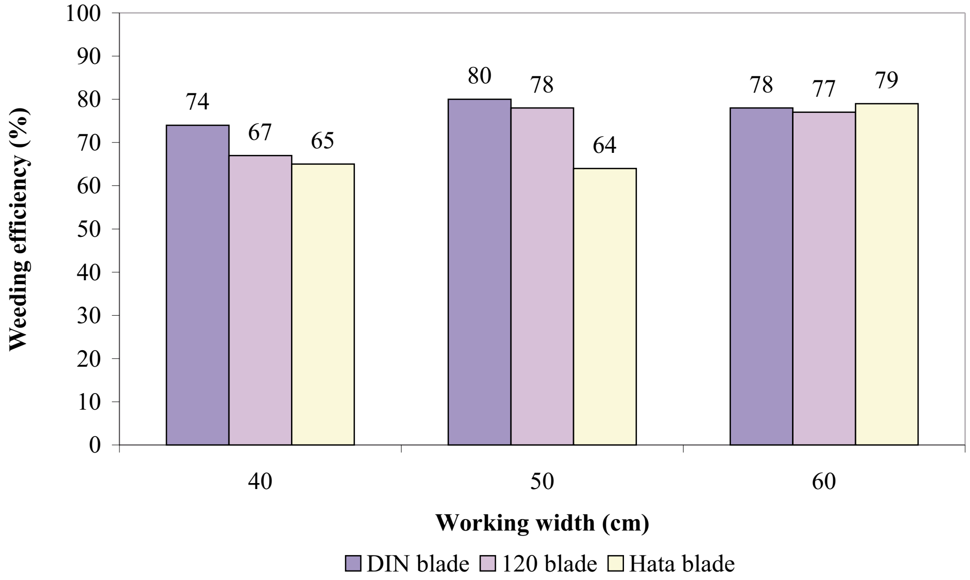


Figure 4: Mean weeding efficiencies at different working widths

remove them completely and the objective should be to reduce them to a level which does not hinder crop growth. This seems to be possible with the blade designs investigated. So far, no negative effects on yields have been observed in field experiments accompanying the technical measurements.

One of the most encouraging observations was that a second weeding was required less often on *Hata*-treated plots than on fields cultivated traditionally. This can be explained by the deeper working horizon of the donkey-drawn weeder compared with manual weeding.

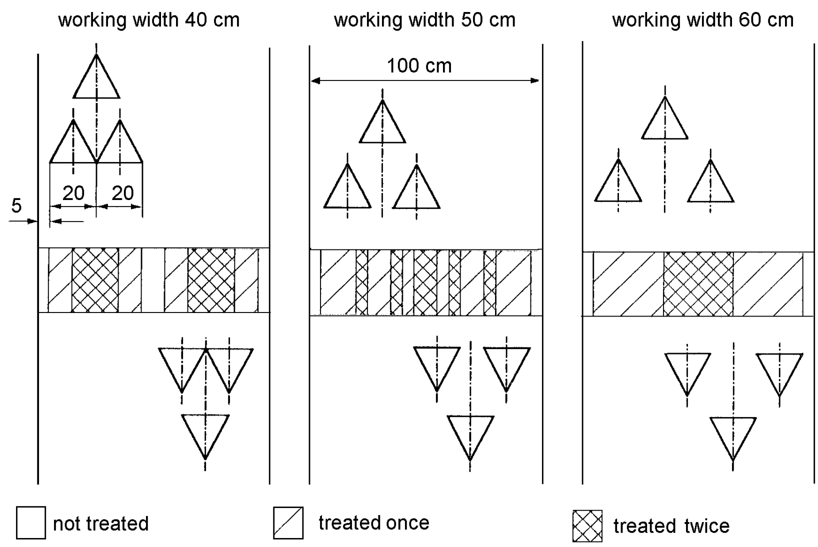
Figure 4 shows that the best results were obtained with a working width of 50 cm. At the same time there was a partial reduction of both absolute and specific draft forces at the transition from the 40- to 50-cm working width. This fact is explained in Figure 5, which shows the intersection of the cutting edges for different working widths.

Millet is sown in rows 0.7–1.3 m apart. On fertile fields near villages, plants are normally sown closer together than on surrounding fields. In on-station tests millet was sown 1 m apart both within and between the rows. At this distance the plants were too far apart to reduce the spread of weeds.

During weeding we tried to maintain a 5 cm safety distance on both sides of the crop plants to avoid damage to crop roots and the above-ground parts. The unweeded zone within the rows required additional hand-weeding in order to guarantee optimal yields. This is an important disadvantage of animal-drawn weeding.

A forward/backward journey between two crop rows with an implement adjusted at a working width of 40 cm led to the comparatively broad area of 40 cm being treated at least twice by a blade. With this adjustment, however, the hoe tended to swing sideways. The lateral combining of the two rear blades led to

Figure 5: Patterns of treatment at different working widths



furrowing and favoured the accumulation of soil and plants on the blades or in front of the blade holders. This hindered the flow of material considerably and the required draft forces increased. The weeding efficiencies were also lower because of a total unweeded zone of 20 cm.

While weeding at a working width of 60 cm the passes were unstable because each blade had to enter untreated soil. There had been no pre-loosening carried out by the front blade that could be a working relief for the rear blades. Thus the draft forces were correspondingly high. An intersection of the weeded zone that influenced the weeding efficiency occurred only in the middle of two plant rows because of the forward and backward journey.

When weeding at a working width of 50 cm there was a blade intersection during each single passage and additionally due to forward and backward walking. This led to a regular distribution of the areas treated at least twice which had a positive effect on draft force requirements and weeding efficiencies.

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