The development of animal traction equipment adapted to the rainfed areas in the Republic of Niger

by

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Abstract

There are several workshops in Niger capable of making animal-drawn implements, but production of such equipment is currently minimal. This is related to previous credit policies and the existing high stocks of Arara toolbars. Several projects are attempting to identify other suitable implements that could be locally manufactured.

The "Projet recherche, production et formation pour l'utilisation du matériel agricole en zone sahélienne" is one such project. Its main objectives are production of agricultural equipment, training of equipment users, and research, development and evaluation of implements adapted to the rainfed areas. The project carried out on-station and on-farm trials on methods of growing millet using animal traction in dryland areas. Trials were carried out on sandy soils and on "glacis" soils (degraded, sandy-clay soils, recovered by subsoiling and terracing). Tillage treatments included plowing, ridging, tine-tillage techniques and the traditional no-tillage system. The project also studied seeding methods for millet in sandy soils, the effectiveness of different strip-tillage tools and various interactions between tillage systems, crop residues, chemical fertilizers and tillage implements.

All tillage techniques in sandy and "glacis" soils increased grain and straw yields over traditional cultivation practices. Although mouldboard plowing increased yields, the technique was slow and was thought to increase erosion risks. Scarifying was quicker, allowing tillage and planting to be done on the same day. Strip-tillage appeared encouraging, but requires further work on techniques and implements. Ridging may be suitable in sandy soils. Work is continuing.

* Position at the time of the 1988 workshop.
A subsequent address may be found in the workshop participant address list.

Introduction

Animal traction equipment was first introduced in Niger in the 1950s. It was mainly intended for the groundnut production programmes being emphasized at that time, but it was also intended to assist farmers working in the irrigated areas along the banks of the Niger River. These initial importations of equipment were complemented during the 1970s by the launching of local manufacturing programmes. These were carried out in three state-assisted artisanal workshops: Centre de développement de l'artisanat rural et du machinisme agricole (CDARMA), Atelier de construction et de réparation du matériel agricole (ACREMA) and Unité de construction de matériel agricole (UCOMA). One private workshop was also established: Société nigérienne de fabrication métallique (SONIFAME) which has since become the Atelier de fabrication de matériel agricole (AFMA). The credit facilities and subsidies available during the late 1970s and early 1980s encouraged a wide distribution of the implements produced. It was estimated that a peak of some 26,000 animal traction units with some 31,000 animal-drawn carts had been achieved in 1985 (MDR, 1985; Le Moigne *et al.*, 1987).

These subsidies and credit facilities were withdrawn in 1984, during a period of policy reassessment. The sales of agricultural equipment from the workshops practically stopped and in 1985 manufactured stocks to the value of some 352 million FCFA remained in the three state workshops and their national distributor, the Centrale d'approvisionnement (MDR, 1985).

Although the problems in the implement manufacture and supply system were probably due to a variety of causes, it may be that the implements available at the time were not adapted to the rainfed regions. One common view suggests that, although the Arara range may be suited to the irrigated areas by the River Niger and to the low-lying valleys, it is too heavy for the different requirements of the flat or sloping sandy soils.

Programmes assessing equipment needs

By the mid 1980s then, a substantial manufacturing infrastructure had been created, but had halted its local production of implements. In the light of this situation, and in accordance with the desire of the Government of Niger to reduce the drudgery of small farmers, it was felt that it was necessary to understand more fully the various constraints that had been encountered (Ministère du plan, 1987). Thus several programmes were developed that were involved in prototype development and on-farm research.

The Projet productivité de Niamey (financed by USAID) had a specific rural artisan and agricultural engineering section included in its activities (the Cellule d'artisanat rural et du machinisme agricole, ARMA). ARMA had the initial objective of developing improved prototype agricultural equipment with a view to the potential for a future national manufacturing programme. Some 100 lightweight cultivators have been made and have been involved in farm trials within the Niamey District.

Several development projects operating within the rainfed areas of the country have some form of component relating to the introduction of animal traction equipment in their target zones. These include the Projet de développement rural intégré de la vallée de Keita (supported by FAO), the Projet productivité de Tahoua (supported by GTZ) and the Projet de développement rural de Maradi.

In 1978, the ACREMA workshop (Atelier de construction et de réparation du matériel agricole) was established at Tahoua with the support of CILSS (Comité inter-etat de lutte contre la sécheresse au Sahel) and with financial backing from the Dutch Government. In view of the uncertain appropriateness for the rainfed areas of the agricultural equipment available in 1983, a new project was launched in 1984. The project "Recherche, production et formation pour l'utilisation du matériel agricole en zone sahélienne" is also financed by the Dutch Government. It is currently entering a second phase and it is envisaged that the Food and Agriculture Organization (FAO) of the United Nations will cooperate in its implementation until the end of 1990.

Initial project activities were mainly confined to the District of Tahoua, selected as a pilot zone. However, recently activities have been extended to cover the Districts of Niamey and Maradi. Activities are organized in three main categories:

- **production** of agricultural equipment (mostly at the ACREMA workshop);
- **training** of the agricultural equipment users;
- **research**, development and evaluation relating to equipment adapted to the rainfed areas.

The results and observations of dryland tillage trials presented in this paper are based on the applied research activities of this project.

Dryland tillage trials

The applied research programme of the Project UNO/NER/003/NSO has been working closely with the Institut national des recherches agronomiques du Niger (INRAN) in the development of an experimental station specializing in agricultural mechanization research located at Birnj N'Konnj, in the District of Tahoua. A series of trials started in 1986 at this station, and also on farms,

Table 1: Yield results of the on-farm trials during the winter of 1987

Production system	Guidan Sourout Grain (kg ha^{-1})	Guidan Sourout Straw (kg ha^{-1})	Roukouzoum Grain (kg ha^{-1})	Roukouzoum Straw (kg ha^{-1})	Birni N'Konni Grain (kg ha^{-1})	Birni N'Konni Straw (kg ha^{-1})	Madaoua Grain (kg ha^{-1})	Madaoua Straw (kg ha^{-1})
Traditional system: no tillage or fertilizer	164 b	1032 a	267 a	1383 b	281 a	1317 a	175 b	858 c
Traditional system: no tillage; fertilizer	236 ab	1270 a	304 a	2308 ab	230 a	1260 a	251 ab	1631 bc
Strip tillage with two rigid tines: fertilizer	251 a	1348 a	350 a	2900 a	363 a	1624 a	399 a	2702 a
Scarifying (capping soils); ridging; fertilizer	289 a	1315 a	282 a	1934 ab	272 a	1424 a	339 a	2455 ab
Total rainfall (mm)	328		255		272		725	
Observations	sand storm + 20 rain days in Aug		64 mm heavy rain-damaged ridges		late rains		late rains	

Note: Mean results within the same split-colum or split-line that are followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

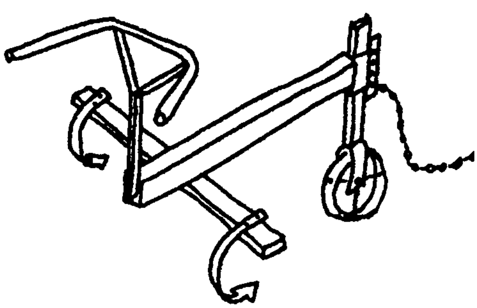
designed to study appropriate dryland tillage techniques for the region.

Four main cultivation techniques were reviewed:

- use of the mouldboard plow;
- scarifying, using spring tines fitted with reversible points;
- ridging;
- strip-tillage, using two rigid tines fitted with duck's foot points.

The Arara equipment range was used for the trials, since it had been locally manufactured and widely distributed in Niger. Several other makes and models from neighbouring countries were also studied, as were some prototypes developed by the project. Although final conclusions have not yet been reached, some interesting aspects of the work have been reported by the project team (Lecca, Stevens and Mignolet, 1987 and 1988). Some of the salient features are noted in the following sections.

Fig. 1: Basic prototype tillage implement used for the 1986 strip-tillage trials.



Results of 1986 trials

Tillage methods on sandy soils for millet

An increase in grain yield was noted for all tillage systems studied when compared with the traditional zero-tillage method of direct seeding. No significant differences were recorded in the straw yields of the four treatments. Both mouldboard plowing and strip-tillage with a rudimentary prototype (Fig. 1) gave significantly increased grain yields, compared with scarifying with the *Houe Manga* cultivator or the "control" treatment of traditional direct seeding. However, mouldboard plowing was very slow. It required 19 h ha^{-1}, while strip-tillage required 11 h ha^{-1}, and scarifying, 9 h ha^{-1}.

Table 2: Strip tillage equipment test results: millet production on sandy soil during the winter of 1987

Equipment used	Plant growth rate 40 dap (cm)	50 dap (cm)	Stands (mean no.) (No. ha^{-1})	Grain yield (mean) (kg ha^{-1})	Straw yield (mean) (kg ha^{-1})
Two rigid tines with duck's foot points	89 ns	218 ns	7 298 a	567 a	937 b
Two rigid tines with reversible points	87 ns	222 ns	8 896 a	547 a	1106 ab
Two spring tines with duck's foot points	92 ns	233 ns	9 452 a	653 a	1231 ab
Fort prototype; one rigid ripper tine with wings; no leading tines	101 ns	257 ns	11 537 a	787 a	1626 a
Control plot; no tillage; direct seeding	89 ns	211 ns	7 854 a	500 a	984 b
Coefficient of Variation	28%	20%	30%	34%	32%

Notes:
dap = days after planting. ns = not significant at the 5% level according to (F) test.
Mean results followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Tillage systems for millet on "glacis" soils

A series of comparisons was organized to assess different tillage systems for millet production on the "glacis" soils. These are degraded outwash, sandy clay soils, recovered by subsoiling and terracing. Unfortunately, all plots were affected by drought. Higher grain yields were recorded on all the tilled plots.

The best results were observed in a plowed plot on one location and a plot scarified with the Manga cultivator at a second location.

Tillage systems for millet on sandy soils

An exceptionally intense rain and sand storm destroyed the tillage plots prepared by the plow, by scarifying and by strip-tillage. The plots were resown with cowpeas following ridging, which allowed a reasonable harvest. The benefits of ridging in this very sandy soil were noted.

Ridging systems in sandy soil for millet

Ridging was carried out both with an Arara ridger and with a mouldboard plow (Fig. 2) and a comparison was made with scarifying as well as the control of direct seeding.

No significant increase in grain yield was observed on any of the tillage plots. It was, however, observed that the ridging operation eliminated the need for subsequent inter-row weeding owing to an almost total absence of weeds.

Fig. 2: Arara toolbar fitted with ridger. Mouldboard plow body also shown

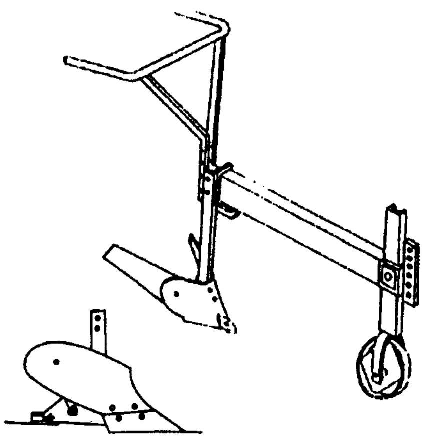


Table 3: Effects of different tillage treatments on yields

Main treatments	Mean grain yield (kg ha^{-1})	Mean straw yield (kg ha^{-1})
Scarifying with the Manga cultivator	1256 a	2894 a
Strip tillage with two rigid tines and duck's foot points	1064 b	2444 b
Ridging with Arara ridger	1157 ab	2419 b
Control: direct seeding; no tillage	1021 b	2256 b

Table 4: Crop residue effects

Sub-sub-treatments	Mean grain yield (kg ha^{-1})	Mean straw yield (kg ha^{-1})
Crop residue (1000 kg ha^{-1})	1198 a	2618 a
No crop residue	1052 b	2389 b

Mean results followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Seeding methods for millet in sandy soils

This study was directed towards seeding techniques. It was recorded that grain yields from the strip-tillage plots, hand-sown in the tilled area, gave 1214 kg ha^{-1}, while traditional sowing with zero-tillage yielded only 683 kg ha^{-1}.

Results of 1987 trials

On-farm trials for millet on sandy soils

Six farmers were chosen in each of four distinct areas in Tahoua District. The areas had all been previously identified as being of high potential for animal traction (Ohler, 1986). Comparisons were made between the traditional direct-seeding system practised in Niger, strip-tillage and also scarifying followed by ridging. Table 1 shows the grain and straw yields for the different treatments. Few significant differences were recorded, but there were numerically higher grain and straw yields in three of the four regions on the plots tilled by either strip-tillage or ridging methods.

Work rates were fairly uniform in all regions, requiring some 5 h ha^{-1} for strip-tillage as compared to 7 h ha^{-1} for ridging. This was in addition to the time needed for any previous scarifying soil preparation (as required at Guidan Sourout and Roukouzoum).

Strip-tillage implements for millet in sandy soils

The following prototypes were used:

- two rigid tines with duck's foot points;
- two rigid tines with reversible points;
- two spring tines with duck's foot points
- one rigid and deep tine, with wings. This implement was based on that described by Fort (1973), although the two shallow, leading tines were removed for this trial;
- control, consisting of traditional direct seeding.

The results are presented in Table 2. From this the following points emerge:

- There was better plant establishment (measured by counting the number of stands) in the plots prepared by the Fort prototype. A marginally superior growth rate was recorded in the strip-tillage plots. However, none of these differences was statistically significant.
- Grain yields resulting from the use of the four different prototypes were between 9% and 36% greater than the control. However, none of these were significantly different in the statistical analysis.

- Straw yield from the plot prepared with the Fort prototype was significantly higher than the control plot and that prepared by strip-tillage with two rigid tines and duck's foot points.
- The Fort prototype proved very heavy to operate. The three other prototypes with 2 rigid or flexible tines were both unstable in work and difficult to control.
- Field observations have given the impression that the main factor governing the success of strip-tillage lies in the width and depth of the zone fractured and disintegrated by the tine. This is determined by the overall tine design and their arrangement (Fort, 1983; Inns, 1988).

Interactions with tillage, residues and fertilizer

In order to study the interactions between tillage systems, crop residues and chemical fertilizers for millet production on sandy soils, a factorial experimental design was used, with split-plots in randomised blocks as follows:

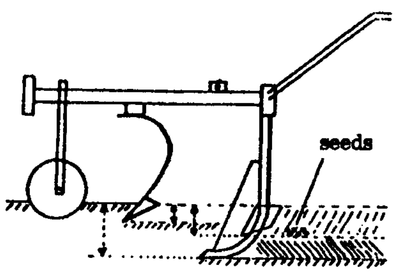
Four main tillage treatments:

scarifying with the *Houe Manga* cultivator;
strip-tillage;
ridging;
control of zero tillage and direct seeding.

Two sub-plots for nitrogenous fertilizer (both plots already broadcast with 100 kg ha^{-1} of superphosphate):

with 100 kg ha^{-1} of urea in two doses;
without any nitrogenous fertilizer.

Fig. 3: The tillage prototype developed by Fort. It has two shallow leading tines and one deep-winged tine.



Two sub-sub plots of straw residue:

with 1000 kg ha^{-1} of straw residue;
without straw residue.

The results show significant differences between:

- the tillage treatments (Table 3);
- the sub-plots of straw residue (Table 4);
- the tillage - nitrogenous fertilizer - crop residue interactions.

The interpretation of the tillage results (Table 3) is not clear and indeed appears to be contradictory to the observations made above. It may be that the results were partly due to a concentration of the phosphate fertilizer around the seeds, provoked by the use of the ridger or the Manga cultivator. Table 4 shows the benefits of leaving straw residues on the surface. This has already been well reported (ICRISAT, 1988).

Interaction: fertilizer and tillage

In this comparative study, it was intended to determine the interactions between chemical fertilizer and various strip-tillage prototypes being used in sandy soil for millet production. An experimental design of randomized blocks with split plots was adopted, for which the treatments were as follows:

Two main plots for the fertilizer:

100 kg ha^{-1} of single superphosphate plus 100 kg ha^{-1} of urea (in 2 applications);
without any fertilizer.

Five sub-plots (tilled and sown after the rains):

strip-tillage with 2 rigid tines;
as above but tilled before the rains in dry soil;
strip-tillage with the Fort prototype;
strip-tillage with the Arara ridger but with the wings removed;
control with no tillage.

No significant effects were recorded due to the fertilizer treatments. The measurements of crop height and grain yield suggest an there are advantages in carrying out strip-tillage immediately after the rains and on the same day as sowing (Table 5); however, there was a high

Table 5: Interaction of chemical fertilizer, strip tillage and timing

Main treatments	**Inter-stand distance at 11 dap (cm)**	**Missing stands per plot 31 dap**	**Plant height at 48 dap (cm)**	**Average grain yield (kg ha^{-1})**
Two applications (100 kg ha^{-1}) of SSP and urea	118 ns	8 ns	144 ns	621 ns
No chemical fertilizer	119 ns	10 ns	143 ns	652 ns
Coefficient of variation	2%	54%	11%	33%
Sub-plots				
Strip tillage: two rigid tines; duck's foot points	96 d	2 b	173 ns	655 ns
Same but tilled before the rains	139 b	18 a	135 ns	574 ns
Fort prototype: one rigid deep tine with wings	115 c	6 b	138 ns	702 ns
Arara ridger without wings	90 d	5 b	150 ns	740 ns
Control: traditional system	153 a	15 a	122 ns	512 ns
Coefficient of variation	8%	74%	33%	29%

Notes:
dap = days after planting. ns = not significant at the 5% level according to (F) test.
Mean results followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

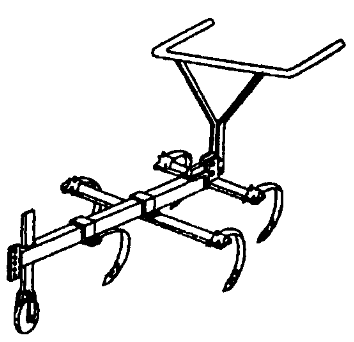
coefficient of variation and the differences were not statistically significant.

Conclusions on dryland tillage

Soil tillage

From the results recorded here, it appears that soil tillage normally leads to increases in both grain and straw yields for dryland millet production on sandy soils and the "glacis" (reclaimed) soils of Niger. The research programme is currently entering its third agricultural campaign in 1988 (Lecca, Nielsen, Kruit, 1988).

Fig. 4: The Arara cultivator fitted with five spring tines and duck's foot points



Use of the mouldboard plow

Significant yield increases were recorded for tillage with a mouldboard plow as compared to the traditional zero-tillage system. However, work rates were slow and consequently expensive. In view of the high risks of wind and water erosion provoked by the use of this technique, it would not appear to be appropriate for dryland agriculture on the sandy soils of Niger.

Scarifying

Both scarifying and strip-tillage are much quicker than mouldboard plowing. Strip-tillage may be done on the same day as sowing. The Arara cultivator (Fig. 4) may be used for scarifying but the implement is heavy and of a complicated design. The *Houe Manga* is much lighter but suffers from a design fault in the spring tine construction which causes a weakness (Inns, 1988); a cheap, lightweight and simple scarifier would be worth developing.

Strip-tillage

The various prototypes with two tines which were tested for strip-tillage proved both heavy and difficult to control; the working depth of 12-15 cm is probably insufficient for full benefits to be obtained from the technique. However, several trials indicated that the technique may well have potential. The prototype originally developed by Fort consists of two shallow leading tines and a deep rigid ripper tine with wings; the draft force measured by Inns (1988) is judged to be excessively high. Trials carried out by the project team of the same prototype but with the shallow leading tines removed, gave more encouraging results. A similar but lighter prototype has been proposed by Inns and is currently being developed and tested. An interim solution that could be immediately adopted by farmers would be the use of the Arara ridger support. This could either have the ridger body replaced with a single, reversible point or the ridger body could be retained but with the wings removed.

It would appear that the success of the strip-tillage technique is determined by the depth and width of work achieved. This aspect will be the subject of future studies. Equally important are the soil physical properties. It would seem that the technique offers the best advantages in crust-forming sands which have a clay content (Hoogmoed and Stroosnijder, 1984). Encouraging results have also been obtained on the "glacis" soils, but in this environment the working depth is critical to success. These aspects are the subject of a collaborative study at present under way with the ICRISAT Sahelian Centre in Niger.

Ridging

The technique of ridging takes longer and is difficult to do on the same day as sowing. It has, however, been shown to be beneficial in sandy soils. The Arara ridger may be used directly after rains, although earlier scarifying is normally necessary in dry soils. The maximum working width is 75-80 cm which is less than the traditional row spacing practised for millet production in Niger. A mouldboard plow may also be used, each ridge being constructed by two passes of the implement. In-depth studies need to be made concerning the compaction effects. These occur in the furrow bottom and also at the base of the ridge, under the loose soil where a previous scarifying has not been done. Studies are also required as to the most advantageous position to sow: in the furrow bottom, on one or other side of the ridge or on top.

Résumé

Bien qu'il existe au Niger plusieurs ateliers capables de produire des équipements de culture attelée, la production de ce type de matériel est actuellement très limitée. Cette situation s'explique par les politiques successives de crédit et la présence d'un stock important de cultivateurs Arara. Plusieurs projets recherchent des équipements adaptés à leurs besoins et susceptibles d'être fabriqués localement.

Parmi eux, le Projet recherche, production et formation pour l'utilisation du matériel agricole en zone sahélienne a pour objectifs principaux : la production d'équipements agricoles, la formation des utilisateurs de ces équipements, la recherche-développement, et l'évaluation de matériels adaptés aux zones pluviales. Le projet a testé en station et en conditions paysannes diverses méthodes de culture attelée du mil en zone de terres sèches. Les essais ont été réalisés sur des sols dunaires et des sols de glacis (argileux dégradés, récupérés par sous-solage et terrassement). Les travaux de préparation du sol incluaient labour, billonnage, diverses dents, et la méthode de culture traditionnelle sans préparation du sol. Le projet a aussi étudié des méthodes de semis du mil sur sols dunaires, l'efficacité de plusieurs outils de labour en bande, les interactions entre différents systèmes de labour et l'apport de résidus de récoltes, d'engrais chimiques et divers outils aratoires encore au stade de prototype.

Toutes les techniques utilisées en sols dunaires et de glacis ont permis une augmentation des rendements de grain et de paille par rapport aux méthodes traditionnelles. Bien que la charrue à versoir augmente la production, sa lenteur s'ajoute à des risques accrus d'érosion. La scarification était plus rapide, permettant de labourer et de semer en une seule journée. Le labour en bande est satisfaisant, mais demande davantage de travail technique et d'équipements. Le billon-

nage peut convenir aux sols dunaires. L'étude de ces équipements et techniques continue.

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