**Dry soil tillage tines RS8 and IR12: two efficient tools for zaï technique mechanisation in the Sahel**

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**Abstract**

In the semiarid and arid sahelian zone, the zaï practice is a well-known efficient method for the rehabilitation of degraded bare and crusted soils. It consists in digging pits (20-40 cm width, 10-15 cm depth) in which organic amendments are added. The realisation of this traditional practice requires for a man about 300 hours ha\(^{-1}\). For many smallholders, this time labour remains a big constraint to the large diffusion of the technique. The alternative local solution consists in using animal traction force (cattle drawn) with the tine set on a frame, to create pits in the crossing points of perpendicular furrows. The experiment was conducted in two sites: Saria village (12° 16’ N and 2° 9’ W) in the North soudanian climate (800 mm), and Pougyango village (12° 59’ N and 2° 9’ W) in the sahelian climate (600 mm). The experimental design consisted in 5 treatments with 3 repetitions. Two treatments of mechanised zaï were compared to traditional zaï, scarifying, and zero tillage. Soil texture was sandy-clay type at Saria and sandy loamy type at Pougyango. RS8 tine was used for Saria soils and IR12 for Pougyango soils.

The tractive effort with RS8 tine at Saria was 115 kg. Pit sizes obtained with RS8 tine was 9 ± 2 cm depth and 28 ± 2 cm in diameter. At Pougyango village, with the IR12 tine, tractive effort was 100 kg and the pits sizes was 10 ± 1 cm depth and 39 ± 3 cm in diameter. Soil resistance to penetration at Pougyango, was better in mechanised zaï treatments than in traditional zaï ones, mostly between the pits. Plant gathering reached 80% in mechanised zaï plots without earth extirpation from the pit (MZ), 40% in mechanised zaï plots with earth extirpation from the pit (MZE) and 30% in manual zaï plots (MnZ). At Pougyango site, sorghum grain yield in treatment MZE was 35% greater that obtained with the two other treatments. Labour time was 66 hours ha\(^{-1}\) per man for MZ and 132 hours ha\(^{-1}\) per man for MZE. Cost analysis showed that the total cost for MZ was 39.258 f cfa ha\(^{-1}\), 51.158 f cfa for MZE and 55.000 f cfa ha\(^{-1}\) for MnZ. Mechanised zaï has improved soil physical characteristics and hence, soil moistening. Zaï mechanisation appeared less costly. Moreover, it induced a better sorghum crop production and could be well spread if the animal tractive force available to farmers wasn’t limited by factors like low alimantation, bad health and bad harnessing of animals.

**Keywords:** dry soil tillage, zaï mechanisation, crusted soil, rehabilitation, Sahel
Introduction

The North of Burkina Faso a sahelian land of West Africa has low rainfall moving from 400 to 700 mm y⁻¹. In this region farmers are confronted with rainfall irregularity and topsoil encrusting inducting the sterile areas which are not permeable to water (Casenave and Valentin, 1992; Ambouta et al., 1999). Those sterile areas locally called “zipellé” are traditionally tilled by manual zaï technique (Ouedraogo and Kaboré, 1996). This soil regeneration and water conservation method is manually used with picks and mattocks. Manual labour time is to long (300 h man⁻¹ ha⁻¹) and tillage in the hot and dry season is arduous for farmers. Despite soil rehabilitation and interesting sorghum grain yield (600 to 800 kg ha⁻¹) and straw yield (2600 kg ha⁻¹); the practice diffusion to farmers is slowed by those factors:

- the tillage is painful for farmers during the hot and dry season,
- the high labour time makes required a lot of person for the manual zaï practice (Wedum et al., 1996).

To perfect this practice which can be assimilated to the farmers production intensification, and to make easier his application to large areas, dry soil tillage tines RS8 and IR12 was used with cow traction force to make zaï holes (Sédogo et al., 1998).

This research purpose is to evaluate the mechanisation of zaï holes making and labour time reduction, the efficiency of the tools for mechanised zaï practice, the comparative cost of mechanised and manual zaï, and the effect of this method on sorghum grain and straw yield production.

Materials and Methods

Plots locations

The research is done in 2000, on tow villages located in Sudanian regions: Saria (12° 16’ N, 2° 9’ W) and Pougyango (12° 59’ N, 2° 16’ W). The annual rainfall average is 800 mm at Saria and 600 mm at Pougyango. It is not regular, little periods of draught often occurred.

The majority of soils are a Ferric lixisol (FAO-UNESCO, 1989). The topsoil texture is sandy-loamy type in Saria and loamy type in Pougyango. Soil depth varied from 30 to 50 cm. The most important difference in the tow types of location, is the crusty topsoil at Pougyango reducing water infiltration and plants growing. Topsoil is not crusty in Saria but the soil is more compact than Pougyango soil because of clay. The experimentations are done in both cases on sterile plots called “zipellé”.

Experimental design

Tow techniques of mechanised zaï practice (mechanised zaï with earth extirpation: MZE, and mechanised zaï without earth extirpation: MZ) were compared with manual zaï: MnZ and usual tillage practice of scarifying with animal traction force and manual soil preparation with dig or zero tillage. The effect of plots is evaluated with the principal crop of this zone. The experimental design is a Fisher bloc with 5 treatments and 3 replications. The treatments were those:

(1) Control plot: Manual tillage with dig (GRT) has done by farmers in Saria zone. In Pougyango zone the control plot is a zero tillage plot.
(2) Scarifying plot with cow traction force with “houe manga” (SCA). This tillage is useful in the major area in the Central and North region of the country because of the lowest of the traction force, the swiftness, and the earliness of is application.
(3) Manual zaï plot (MnZ). The zaï pits are making by manual picks like farmers done.

(4) Mechanised zaï with earth extirpation (MZE). Zaï pits are making by dry soil tillage tine RS8 in Saria or IR12 in Pougyango. After mechanised tillage, earth extirpation is realised manually by men at the cross of tines tillage. The earth is putting backsides pits like moon crescent.

(5) Mechanised zaï without earth extirpation (MZ). It is only realised by dry soil tillage tools RS8 or IR12. Cow manure is used at the level of 160 g pits⁻¹ with correspond to 5 t ha⁻¹

The crop
The crop used is local sorghum ecotype (Nongomsoba) in Saria and (Sariasso 12) which have a short vegetative stage at Pougyango.

Observations and measurements
Soil resistance measurement is realised on the horizon (0-20 cm). This factor is useful to appreciate the traction force of soil tillage. It is done with a percussion penetrometer describe by ORSTOM (1993). Tools effect is evaluated by deep and larger measurement by a meter and a graduate bar. The traction force is measured by mechanical dynamometer. Labour time has been measure by a chronometer. After soil tillage the moisture deep progression is evaluated at the end of important rainfall. Sorghum rising is measured by counting pits in each plot. Sorghum grains and straw production are wetting after dry period of 14 days at the end of growth period.

Results and Discussion
Tine RS8 and IR12 efficiency for mechanised zaï pits realisation
Table 1 presented dry soil tillage factors (labour time, holes dimensions, and traction force) for mechanised and manual zaï application in Saria and Pougyango. MZ is the most rapid technique. It’s need only 64 h man⁻¹ ha⁻¹. Doing MZE increase the labour time to 132 h man⁻¹ ha⁻¹. The tow-mechanised techniques are better than the manual one which takes 300 h man⁻¹ ha⁻¹.

Table 1 Comparison between tools effect in mechanised and manual zaï.

<table>
<thead>
<tr>
<th></th>
<th>MZ</th>
<th></th>
<th>MZE</th>
<th></th>
<th>MnZ</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep (cm)</td>
<td>Larger (cm)</td>
<td>Deep (cm)</td>
<td>Larger (cm)</td>
<td>Effort (kgf)</td>
<td>Deep (cm)</td>
</tr>
<tr>
<td>Saria</td>
<td>7.3</td>
<td>25.4</td>
<td>29.5</td>
<td>9.5</td>
<td>115</td>
<td>11.9</td>
</tr>
<tr>
<td>Pougyango</td>
<td>10.6</td>
<td>39.4</td>
<td>39.3</td>
<td>10.3</td>
<td>101</td>
<td>11.3</td>
</tr>
<tr>
<td>Labour time</td>
<td>64 h ha⁻¹</td>
<td>132 h ha⁻¹</td>
<td>300 h man⁻¹ ha⁻¹</td>
<td>#</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#: No data have been measured
MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage
Dry soil tillage tine RS8 and IR12 used is based fundamentally on Herblot (1984) then Barro (1988) research, which exposed that in the Central area of the country broking dry soil increase soil permeability and water storage. Dry soil tillage must be done when the soil has a hard consistency. Broken hard consistency soil induced cracks in soil and clods in the topsoil. Clods protect on topsoil from crusting. So we can easily imagine that the effect of the tines on soil will depend on its type in the way of traction force and holes dimensions (Table 1). Saria soil is compact and sandy clay. Nicou (1975) explains that in the dry season this kind of soil become hard. The moisture is less at Saria (1.05 %) than Pougyango (2.92 %). Pougyango soil is clay loamy. That explains difference of traction force and dimension of holes in the two regions.

Moisture deep evolution after tillage is shown on graphics A) and B) of Figure 1. In zaï holes (manual or mechanised), moisture deep is about (15 to 35 cm) and (5 to 17 cm) on the odder plots.

Manual zaï, broke crusty topsoil from place to place and water infiltration is located. The using of dry soil tillage tine RS8 and IR12 broke soil on all the area over tillage deep. Water infiltration and storage is better (Lethiec, 1990; Barro, 1997; Sédogo et al., 1998). The hole creating by the crossing of tillage can be used for zaï. It can receive manure and runoff water. This hole is the future pits of the crop. Sorghum gets there in hydrous and mineral food. More than water storage which is an important factor in Sahel, other interesting points of zaï must be considered.

We observe that zaï practice decrease topsoil resistance (Figure 2) comparatively to scarifying or zero tillage on “zipellé”. This is a favourite factor for the soil rehabilitation. The low soil resistance have been observed on “zipellé” in the North of Burkina Faso (Zombré et al., 1999).
The difference of the traction force depends of soil cohesion (Caquot and Kérisel, 1966) and moisture. The traction force is low (101 kgf) at Pougyango and height at Saria (115 kgf). Despite difference, hole deep at Saria is lower than Pougyango’s (Table 1). The raison is the difference of soil texture and moisture in those two regions.

For mechanised zaï it is only necessary for man to drive harnessing. Roose et al. (1993); Ouedraogo and Kaboré (1996), measured 300 h man\(^{-1}\) ha\(^{-1}\) for manual zaï labour time. Or results confirm it. Mechanisation of zaï allow farmer to work 80 % more quickly than manual zaï. The cost analysis showed that manual zaï (MnZ) need 55000 Fcfa ha\(^{-1}\). Mechanised zaï with earth extirpation (MZE) is evaluated to 51158 Fcfa ha\(^{-1}\). It is not really different of the manual one. This high cost is related to the manual extirpation witch is so long (68 h man\(^{-1}\) ha\(^{-1}\)). Mechanised zaï is 30 % lowest than the manual zaï (39258 Fcfa ha\(^{-1}\)).

Considering the positive results of tillage factors and holes dimensions, the trail show that zaï practice can be mechanised. This mechanisation makes the practice easer. Tools actions on soil depend on soil type. It is more important in sandy loamy-soil. Research pursuit will give more precisions on zaï mechanisation.

**Sorghum rising and production**

Observations were done on sorghum rising and results are presented on Figure 3. Manual zaï (MZ) get the better rising. It is low on the odder plots. Soil moisture is the essential reason. Sowing are done on 25\(^{th}\) June. At this period the moisture is important in the pits of zaï (20 to 30 cm deep) (Figure 1 A) and very low on no-tillage and scarifying plots (5 cm deep) (Figure 1 B). In low rainfall conditions all pits of manual zaï can’t be humid because water is not sufficient for going over upwards slope pits. So, down slope pits can’t be moist. Statistical analysis and Newman–Keuls classification

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**Figure 2** Topsoil resistance in horizon (0-5 cm).

![Graph showing soil resistance with different treatments](image)

a, b : mean that those plots are in the same group (Newman and Keuls classification)

MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage
gave tree categorizes (Figure 3). Photo 1 present scarifying plot and beside a mechanised zaï plot at the rising stage. Mechanised zaï plot has clods and moisture; scarifying plots stay crusty and dry.

![Cow traction scarifying plot](image)

**Photo 1** Mechanised zaï plot compared with a scarifying plot at sorghum rising stage in Pougyango zone.

Results of grains and straw production are presented in Table 2. At Saria we don’t find significant difference between the treatments for grain yield production. «Grattage» plots have the lowest straw production in this region. Zaï and scarifying plots get the same level of production. Water infiltration hasn’t be a limiting factor in this soil if there is tillage by zaï (manual or mechanical) or scarifying. Soil is not crusty and rainfall level is important (800 mm y⁻¹).

![Mechanised zaï plot without earth extirpation](image)

Figure 3 sorghum rising ratio fluctuation in Pougyango plots.
Table 2: Sorghum grains and straw yield at Saria and Pougyango in 2000 (kg ha⁻¹).

<table>
<thead>
<tr>
<th>Plots</th>
<th>Grain yields</th>
<th>Straw yields</th>
<th>Grain yield</th>
<th>Straw yields</th>
</tr>
</thead>
<tbody>
<tr>
<td>MZE</td>
<td>1198 a</td>
<td>3125 a</td>
<td>607 a</td>
<td>2626 a</td>
</tr>
<tr>
<td>MnZ</td>
<td>1520 a</td>
<td>3272 a</td>
<td>433 a b</td>
<td>2015 a b</td>
</tr>
<tr>
<td>MZ</td>
<td>1250 a</td>
<td>3081 a</td>
<td>404 a b</td>
<td>2085 a b</td>
</tr>
<tr>
<td>SCA</td>
<td>1367 a</td>
<td>3168 a</td>
<td>211 b</td>
<td>644 b</td>
</tr>
<tr>
<td>GRT</td>
<td>1176 a</td>
<td>2300 b</td>
<td>167 b</td>
<td>867 b</td>
</tr>
<tr>
<td>Probability</td>
<td>0.1839</td>
<td>0.0260</td>
<td>0.0325</td>
<td>0.0086</td>
</tr>
<tr>
<td>Significance level</td>
<td>NS * * **</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>16.1</td>
<td>13.0</td>
<td>39.7</td>
<td>32.7</td>
</tr>
</tbody>
</table>

NS: Not Significant; *: Significant; ** Highly Significant.
CV (%): Coefficient of variation
a, b: mean that those plots are in the same group (Newman and Keuls classification).
MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage or no tillage

At Pougyango significant difference between plots for grain yield production and highly significant difference for straw yield production. Zaï plots are the better for the production (grains and straw). The worst plots are scarifying and no tillage (GRT). Those practices are not efficient for crop production on crusty soil with low rainfall. The important production on zaï plots is caused by water storage inducted by those techniques. The Photo 2 present scarifying plot beside a mechanised zaï plot at the flower stage. The lower of Pougyango production comparatively to Saria is explain by lowest of rainfall and the shortest of plant growing cycle.

Photo 2: Mechanised zaï plot compared to scarifying plot at sorghum flower stage at Pougyango zone.

Conclusion

Those results show that soil rehabilitation by mechanical zaï practice is possible by using dry soil tillage by tine RS8 or IR12. The mechanical zaï can by used by farmers who have tillage tools (plough, tiller) and animal harnessing (cow or donkey). Labour time is 64 h ha⁻¹. Mechanised zaï is more efficient for soil moisture and 30% lest expensive than manual zaï (39,258 opposed to 55,000 f cfa). Zaï practice (mechanised
or manual) reduces topsoil resistance. His effect is more important in sandy-loamy soil type than sandy-clay soil type. In the two localities, zaï is more productive than tillage usually used by farmers (scarifying and “grattage” or no tillage). We expect that it can be useful for farmers to have the labour time evaluation during mechanical zaï practice with and single cow or donkey. Mechanical zaï, a rapid water conservation and efficient fertilisation technique, will allow Sahelian farmers to enhance the standard living level of people.

Acknowledgement
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References