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# Effects of oxen yoke and donkey collar on traction force and their consequences on sorghum production in the northern Burkina Faso

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## ABSTRACT

The realization of mechanized zaï with draft animal encounters the weakness of hitch traction capabilities. To overcome this issue, a study was conducted in three villages in the northern Burkina Faso with the aim at evaluating the effect of improved yoke and improved collar respectively with oxen and donkey harnessing on the traction force delivered. The experimental design was a simple randomized bloc comparing improved yoke to classic yoke and improved collar to classic collar. The results showed that the improved yoke allows oxen harness to get 57% more traction force compared with the harness of classic yoke which was 53 daN ($P < 0.0001$). For the donkey harness there was no statistical difference between the improved collar and the classic one (24 daN and 23 daN). Tillage quality was better with the improved yoke and generates more soil roughness index. This led to increase in sorghum grain yield by 60% (694 $kg.ha^{-1}$) and sorghum straw yield increase by 91% (2688 $kg.ha^{-1}$). The improved yoke increases oxen traction force, dry soil tillage efficiency and sorghum production. These results showed that improved yoke can contribute to an increase in sorghum yield in the northern Burkina Faso.


**Keywords:** Sahel, animal, harness, traction, force, sorghum.

## INTRODUCTION

In many regions of Africa, draft animal is an essential part of farming systems (FAO, 2008; Lhoste et al., 2010). In the Sahelian zone where drought is an important constraint on crop production, farmers often used dry soil tillage to be able to have earlier moisture for sowing. That is the case in the northern Burkina Faso, where zaï is used for sorghum and millet cropping (Sawadogo et al., 2008). To alleviate the labor time for people, the manual zaï have been mechanized (Barro et al., 2005). But the draft force delivered by the most common animals (oxen and donkeys) used for work remains weak (Lëtzebuerger, 2004). The sowing period and plant growth stage are very important in the rainfed production, because it largely determines the success of the production. In the northern Burkina Faso, the rains settle down late and that leads to a delay in the crops establishment (Zougmoré et al., 2004). The droughts of the 70s have led authorities and the international community to implement water management

 
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practices in the watershed by the systems of rock bunds and grass strips (Zougmoré et al., 2004; Kiéma et al., 2012) and in the plot level by zaï, half-moons, mulching, etc. Water management led to an improvement of the production which can only be maintained if their suitable combination is made with adequate fertilization for poor soil mineral elements. Thus, production techniques involving the management of water and nutrients across the land have been developed, improved and disseminated in the central and the northern region of Burkina Faso (Zougmoré et al., 2002). Zaï association with mineral fertilization by micro dose led to an increase in sorghum grain and straw production (Palé et al., 2009; Barro et al., 2011; Kate et al., 2016).

However, the use of animal traction for mechanized zaï realization during the dry season is facing several constraints, including weak traction capacity of oxen and donkeys because of their bad harnessing.

To overcome this limiting factor, a study of oxen and donkeys harnessing was conducted from 2008 to 2010 in the northern part of Burkina Faso to identify the better harnessing that improve draft capacity for oxen and donkeys. This study compared a classic yoke to an improved one for oxen, and a classic collar to an improved one for donkeys. The draft force for dry soil tillage was measured. Sorghum straw and grain yields were also evaluated.

## MATERIALS AND METHODS

### Experimental sites

The studies have been conducted in the northern Burkina Faso in three villages (Salla, Kibilo and Pougyango). The village of Salla is in Lorum province (Titao), whose coordinates are 13°47'36.83" N; 2° 6'5.16"W; the village of Kibilo is in Zondoma province (Gourcy), at 13°12'38.33"N; 2°15'32.81"W, and the village of Pougyango is in Passoré province (Yako). It is located at 12°58'35.82"N; 2°09'55.82"W. The average annual rainfall varied from 600 mm in the North (Salla) to 700 mm in the South (Yako) (Figure 1).

### Soils and vegetation

The major type of soil is ferric lixisol (FAO, 2006). This soil covers an important part of the country (Zougmoré et al., 2008). The soil is not deep; in average it is 50 cm depth. The slope is low (0.8%) and in general soil texture is sand and loam (Table 1). In this study, there are three major types of soil texture. The moisture measurement was made on the layers 0-10 and 10-20 cm (Table 2).

The natural vegetation was bush Savanah with the following species *Combretum spp.* and *Vitellaria paradoxa* Gaertn. f. The herbaceous layer is composed mainly of *Loudetia togoensis* (Pilger) C.E. Hubb. and *Schoenfeldia gracilis* Kunth. In the South, the natural vegetation is degraded because of human activities. Now the savanna is composed of trees and shrubby. We can find there, *Vitellaria paradoxa* Gaertn. f, *Faidherbia albida* Del, *Parkia biglobosa* (Jacq.) Benth., *Tamarindus indica* Linn., *Lannea acida* A. Rich. and *Lannea microcarpa* Engl. and K. Krause *Bombax costatum* Pellegr and Vuillet, etc. The herbaceous layer is mainly constituted of *Andropogon gayanus* Kunth, *Pennicetum pedicelatum* Trin, *Loudetia togoensis* (Pilger) C.E. Hubb, which are annual (Arbonnier, 2002).

### Material of study

#### *Yokes and collars*

The improved yoke is a material of hitch that allows a pair of oxen to have a better traction force. The forms of this harnessing tool are rounded and the contact with the animal is ensured by cushions (Figure 2). The cord allows adjustment on the neckline of the animals so that there is no strangulation. The classic yoke is round or parallelepiped timber perforated at the sides of oxen neckline position. In the holes of the timber is set an iron bars or cords adjustable to the neckline of animals, and sometimes the wood is summarily pruned and has acute angles. However, there is never a cushion on the classic yoke (Figure 3).

Donkey improved collar and donkey classic collar are presented on Figures 4a and 4b. The donkey improved collar is a wood support, adapted to the neckline of the donkey and covered with a cushion on the sides (Figure 4a). The donkey classic collar has a support wrapped or not, by rags (Figure 4b).

The tool used is oxen plow frame. On this frame, a tine IR12 for dry soil tillage has been assembled by a shore. The mechanized zaï is done by the method described by Barro et al. (2005). The tool for realization of the mechanized zaï is drawn by oxen or donkeys harness. For plots having received the mineral fertilization (14 N-23 P-14 K) by micro dose, the level is 2 g/pit (65 $kg.ha^{-1}$), 14 days after the emergence.

***Crop and experimental design***

The plant material used in this study was *Sorghum bicolor* L. Moench. with Kapèlga (SCHV 168), an improved local variety, with short cycle (90 days).

The experimental design was a simple randomized bloc with two replications by site. The plot is 30 m length and 10 m width. The sowing was made at 80 cm intervals between rows and 40 cm between planting holes in a row. The thinning was done at two plants per hole around 14 days after emergence.

**Data collected**

***The traction force***

The traction effort was measured using a mechanical dynamometer with maxima mounted between the soil tillage tool and oxen or donkeys at the rate of 30 repetitions by treatment. The texture of the soil was determined by Robinson method with three samples of each site in 0-20 cm layer. Soil moisture content was measured by taking samples in 0-10 and 10-20 cm layers. Three replications were made in the plots before tillage.

***The soil roughness***

Soil roughness was measured by the method of the chain (Jester et al., 2005). The chain is laid on the soil surface so that it follows soil micro-relief. The chain was 1.045 m length (L). The measurements were done cross the zaï pits. The vertical projection of the chain (lo) is then measured with 30 replications. The roughness index (Irug) is the ratio L/lo.

***The pits sizes and sorghum yield***

The size of zaï pits was measured using a rigid meter at the rate of 30 repetitions by treatment. The pits were chosen randomly on the whole plot except the borders pits. The width of the pit was measured on the axis passing through the center and making 45° with each furrow and the depth was also measured. Sorghum grain and straw yields were measured on each plot.

The regression model and variance analysis of XLSTAT software, version 2015.17.6 (Addinsoft 2015), were used for data analysis.


**Figure 1**: Map of the study areas (Guinko 1995 cited by http://ornithologieetbetta.free.fr/ornitho/ornitho_burkina_pays.php, 2010).

**Table 1**: Soil texture in the studies sites (%).

| Sites | Clay | Silt | Sand | Soil type |
|---|---|---|---|---|
| Salla | 46.1 | 23.0 | 30.9 | clayey |
| Kibilo | 5.5 | 6.5 | 88.0 | sandy |
| Pougyango | 24.8 | 44.3 | 30.9 | Loam clay-sandy |

**Table 2**: Soil moisture at tillage period (%).

| Sites | Soil layer (0-10 cm) | Soil layer (10-20 cm) |
|---|---|---|
| Pougyango | 1.24 | 1.81 |
| Salla | 1.53 | 2.05 |
| Kibilo | 1.70 | 1.87 |

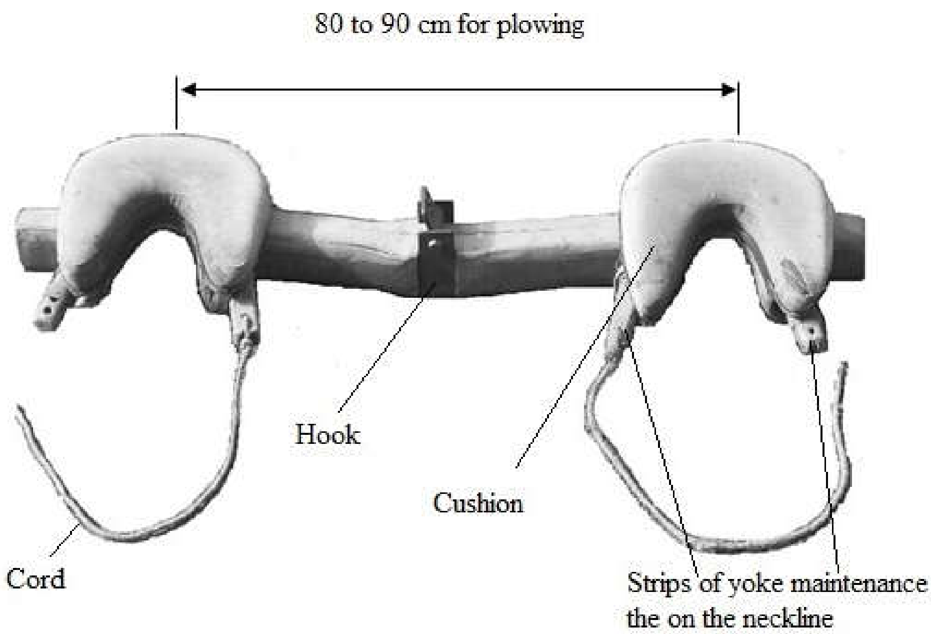



**Figure 2**: Improve yoke (photo Barro 2005).

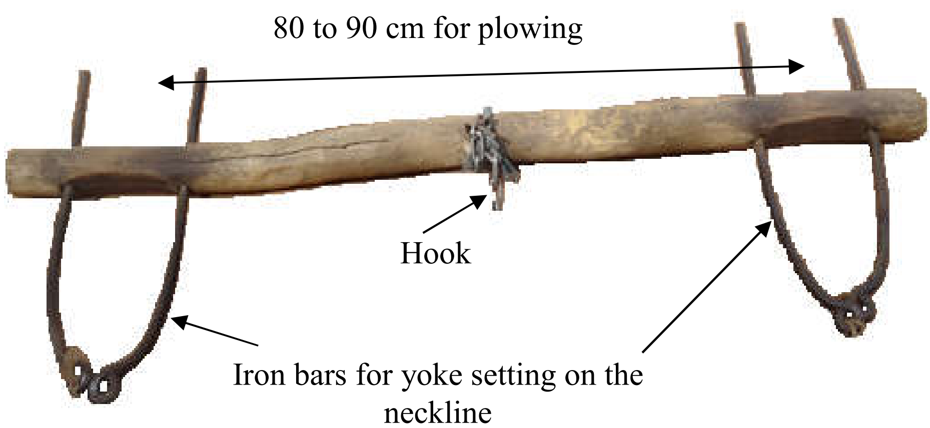



**Figure 3**: Farmer's classic yoke (photo Barro 2005).

**a**: improve collar **b:** classic collar

**Figure 4**: a) improve collar for donkeys; b) classic collar for donkeys (photo Barro 2005).

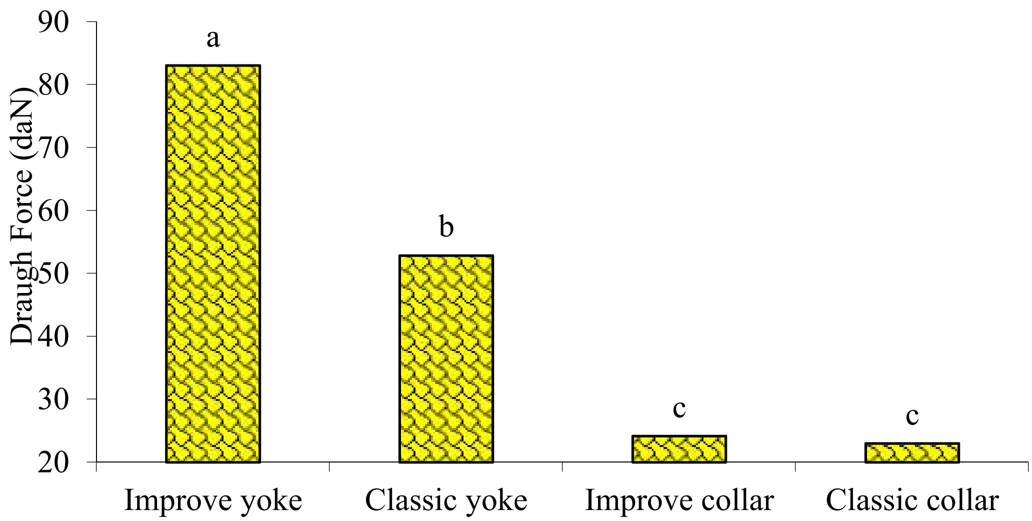



**Figure 5**: Traction force variation according the type of harnessing. N and K test: a, b, c, are groups of means significantly different at α = 0.05 level.

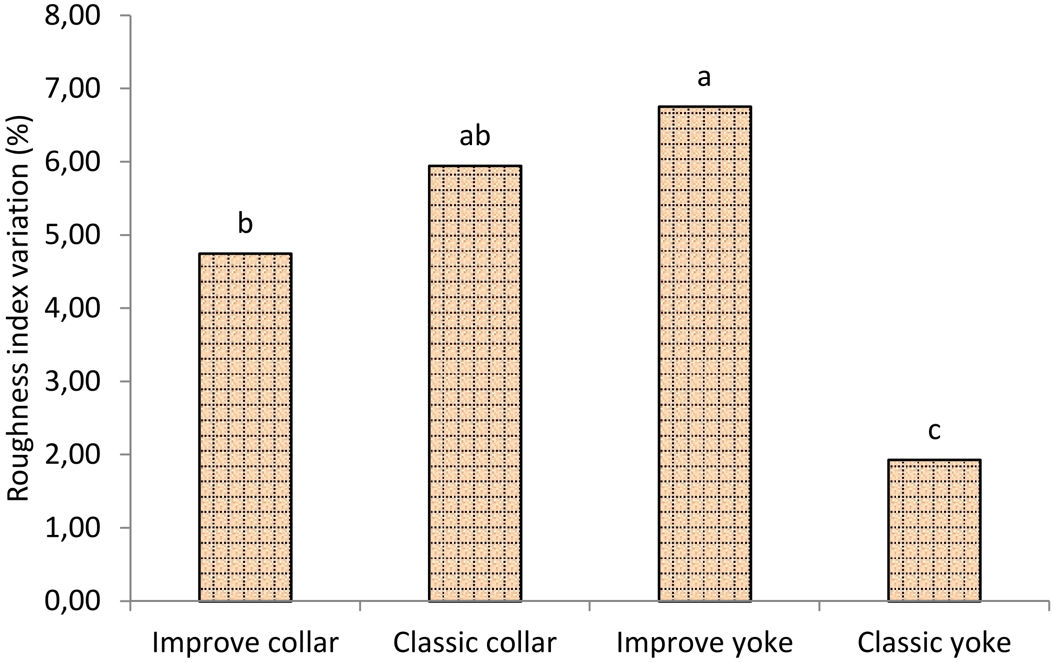



**Figure 6**: Soil roughness index variation after the tillage. N and K test: a, ab, b, c, are groups of means significantly different at α = 0.05 level.

## RESULTS

### Traction force

The variance analysis on the traction forces measured on the yokes and collars showed a highly significant difference between means ($P < 0.0001$). The greatest traction force is provided by oxen harness with improved yoke (83 daN). It is followed by oxen harness with the classic yoke which has a traction force means of 53 daN. The high traction force delivered by improved yoke is 57% more than those provided by the oxen harness with the classic yoke (Figure 5). The means of traction forces of donkey harness are lower than those of oxen harness. Between the donkey harness with classic collar and those with the improved one, there is no significant difference (23 and 24 daN).

The analysis of soil roughness after tillage showed significant differences between the hitches (Figure 6). The effect of these traction forces on the soil roughness indicates that plots having tillage by oxen harness with improved yoke have presented the most roughness increase (6.76%). The plots having tillage by donkey harness with the improved collar have more great roughness increase (5.95%) than those of donkey harness with the classic collar (4.75%). The lowest roughness increase value is observed on the plot having tillage with oxen harness by classic yoke (1.93%).

### Roughness index and pits sizes

Pits sizes variance analysis shows that there is a significant difference between the means of the widths and depths of pits for the four treatments (Table 3). The greatest width and depth are obtained after the tillage with improved yoke harness. The improved donkey collar tillage gives pits depth identical to that of the classic collar, but the width of the zaï pit which is 4 cm lower is given by the classic yoke. The classic yoke tillage generates similar pits width to that of the improved yoke, but the depth is 1 cm lower. The working depth has a strong relationship with roughness index increase. The probability is 0.01 at $\alpha = 0.05$ level with a linear regression (Figure 7 a). The value of the regression slope (1.6) is positive. The depths of 9 to 10 cm correspond to the high value of roughness index increase. The roughness index increase after the tillage is also linked to the pits width (Figure 7 b) with a probability of 0.03 at $\alpha = 0.05$ level. The regression is slightly positive (slope = 0.37). The values of 30 to 35 cm of pits width correspond to the high roughness index increase.

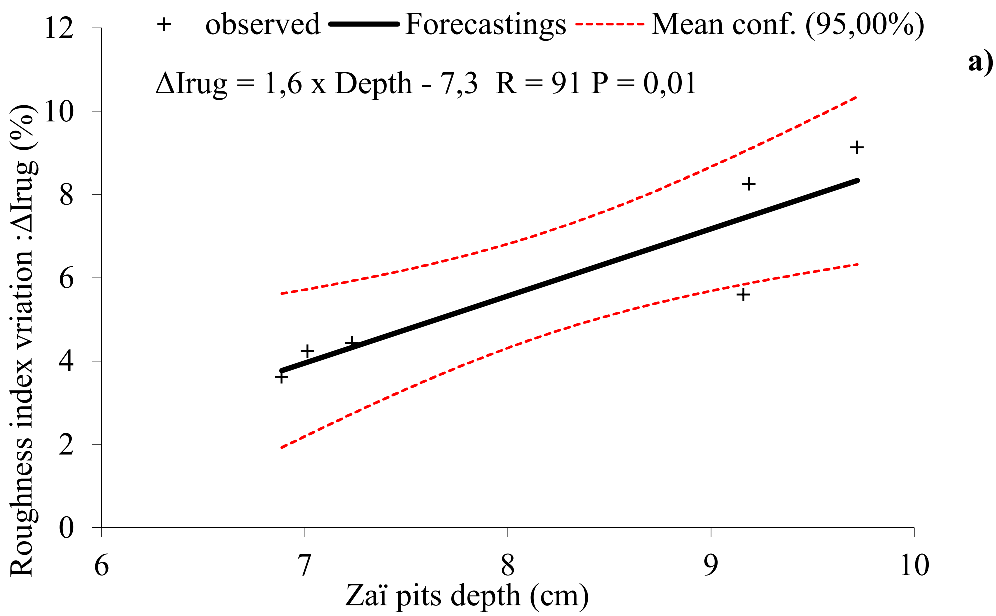
**Sorghum yield**

The sorghum grain and straw production measured on plots treated with the improved yoke and the classic yoke showed highly significant different means ($P < 0.0001$) according to the presence or not of mineral fertilizers by micro dose (Figures 8 a and 8 b). With NPK mineral fertilizer by micro dose, the use of harness with the improved yoke gave an average grain yield of 1835 $kg.ha^{-1}$ against 1141 $kg.ha^{-1}$ for the classic yoke. In the absence of mineral fertilizer by micro dose, the use of the harness with the improved yoke and classic yoke gave respectively 1165 $kg.ha^{-1}$ and 704 $kg.ha^{-1}$ of grain yield. The sorghum grain yield obtained with the improved yoke harness without micro dose is statistically similar to the classic yoke with micro dose. The straw production follows the same trends. With micro dose fertilization, the straw production level of the plots having improved yoke tillage is practically the double of those obtained by classic yoke (5646 and 2958 $kg.ha^{-1}$).

**Table 3**: Zaï pits sizes (width and depth) by harness system.

| Treatments | width (cm) | depth (cm) |
|---|---|---|
| Improve yoke | 32.9 a | 9.9 a |
| Classical collar | 29.4 a | 8.2 b |
| Improve collar | 25.2 b | 7.7 b |
| Classical yoke | 23.3 b | 6.5 c |
| Probability | <0.0001 | <0.0001 |

N and K test: a, b, c, are groups of means significantly different at $\alpha = 0.05$ level



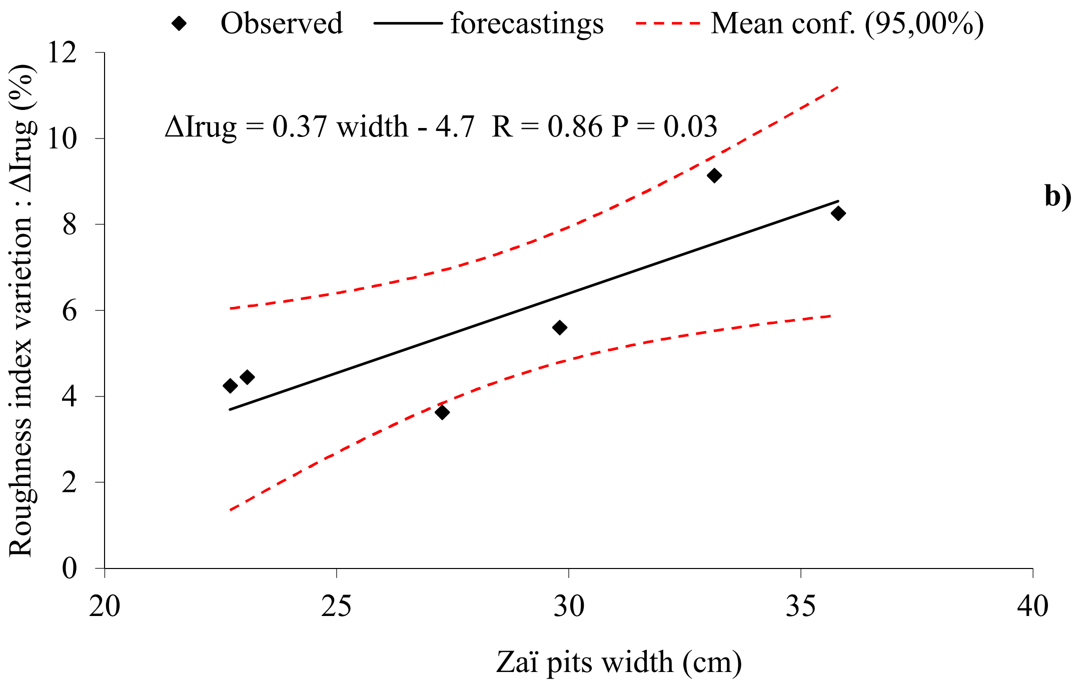




**Figure 7**: Roughness increase according to the pits depth (a); Roughness increase according to the pit width ( b). ΔIrug: roughness index variation, R: regression coefficient, P: probability.

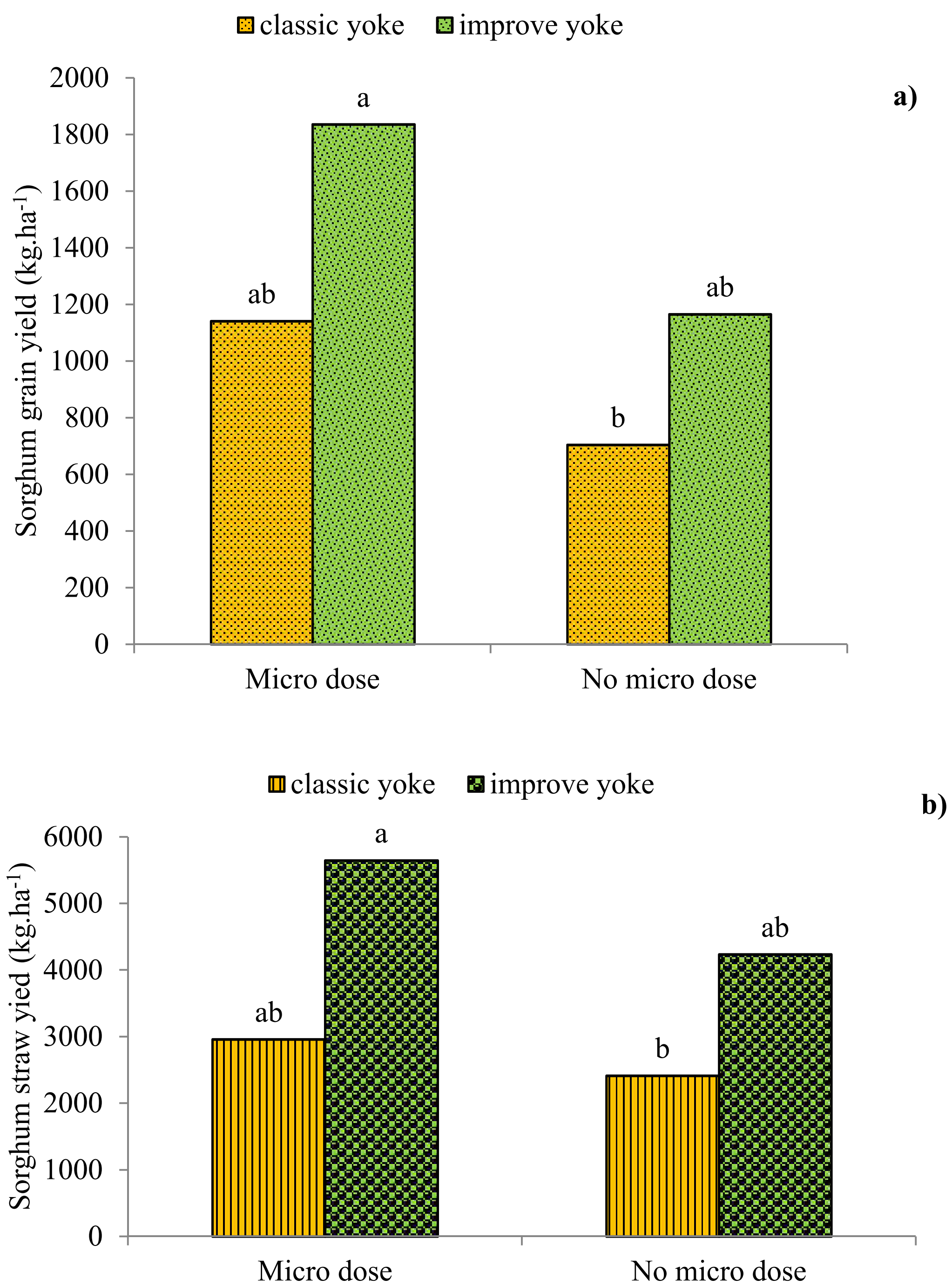



**Figure 8**: Sorghum Grain yield (a); sorghum straw yield (b). N and K test: a, ab, b, c, are groups of means significantly different at α = 0.05 level.

## DISCUSSION

### Increase of the traction capacity

The study showed the difference that exists between the traction forces provided by using the improved and the classic yoke harness. The improved yoke allows to increase the traction force of the pair of oxen by 57%. This would be due to the characteristics of the yoke: the cushions and rounded corners of yoke allow animals to avoid painful points during the traction and well breathe during tillage. During the traction with the classic yoke, relatively acute angles and the iron bars, create pain either by compression or by the heat. In addition to these points of pain, some classic yokes compress the trachea and the blood vessels of the draft animals, thus limiting their physiological capacity (Phaniraja and Panchasara, 2009) and can induce injuries to animals. For the donkey harness, there was not a significant difference between the traction forces of harness using the improved collar and those using the classic one. Donkey harness is not so comfortable because it does not have cushions but rags (Figures 4 a and 4 b). It is wide enough to allow animals breathing during tillage and does not create painful points at the traction period. The traction forces measured are around 25 daN on average. In fact, this corresponds to the capacity of donkey whom supplies 25% of his weight in continuous tractive effort. The capacity of harness traction force, has direct effects on the tillage quality. The higher the capacity of traction is, the more the surface roughness increases. More efficient tillage with a better quality and roughness can alleviate runoff and erosion on the soil (Garcia Moreno et al., 2008). The width and the depth of the pits are higher (10 cm depth and 33 cm width).

Efficient soil tillage is very important for crops sets in Sahelian regions where the first rains scarcity and their weakness compromise plant growth (Masson et al., 2014). Dry soil tillage induces a better water infiltration in the soil and moisture thus obtained is favorable to an early sowing on the plot tilled (Salé et al., 2014).

### Tool action on soil

The greatest roughness index increase is obtained on improved yoke plots (6.76%). This allows a good infiltration and better water conservation in the soil at the beginning of the rainy season (Lampurlanés and Cantero-Martunez, 2006; Garcia Moreno et al., 2011). The width of zaï pits is linked to the soil roughness by a positive relationship. More the soil roughness is high, more the width of the pit is large. This distinguishes the soils with low cohesion as sands and silts which will have a low pits width during dry soil tillage. Wet soils also will have a similar response because of the low cohesion forces. This is a limitation of the practice of mechanized zaï with tine IR12. It is recommended realizing tillage in dry soil, if not, the pits maybe too small and cannot contain enough compost for the proper plant development. However, for the silty and clayey soils, the water infiltration is often reduced and led to the reduction of the tool effects on roughness and water infiltration of this practice (Barro et al., 2005).

### Sorghum production

The effect of harness with improved yoke led to increase Kapèlga grain yields from

60 to 65%, compared with plots where the harness with classic yoke has been used according the mineral fertilizer application or not. For the straw yields, the production increase is ranging from 74 to 91% according to the mineral fertilizer application or not. This practice is also favorable to soil fertility maintenance (Traoré et al., 2012). Beyond the agricultural production, a good harnessing helps to avoid injuries to the animals and also reduces the veterinary charges; the labor time with animals is also increasing because of their welfare. To increase production is an important factor for farmers in the way of getting income (Sermé et al., 2015); producers can get cash flows to invest in farm management and equipment (Mouazen et al., 2007). According to Gibigaye et al. (2012), the profitability in farms is calculated by taking into account the grain produced in the field; getting more grain yield by using of efficient harnessing is favorable to draft animal development in smallholders' farms.

## Conclusion

As regard to the weakness of the traction force of harness, this study showed that the improved yoke provides a solution of traction force increase of 57% for oxen. The effect of this improved yoke is an increase in sorghum yield from 60 to 91% according the micro dose fertilizer application or not. The increase of the donkey harness, traction force during the dry soil tillage like mechanized zaï, suggests that they must be used in pairs with their classic collar. The improved yoke can be realized by the tradesmen. These tools of harnessing are propitious to the dissemination of mechanized zaï practice associated with a good agricultural practices for sorghum production increase.

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## COMPETING INTERESTS

The authors declare that they have no competing interests.

## AUTHORS' CONTRIBUTIONS

AB has contributed in the all study by choosing the experimental sites, the data collection, analysis and drafting the manuscript; CPK has contributed in variety choice, data analysis and drafting the manuscript; BY has contributed in data collection, analysis and drafting the manuscript.

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