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Economic and Operational Evaluation of the Use of Two Manual Rotary and Cono Weeders in an Intensive Rice Cultivation System (SRI) in the Central Zone of Burkina Faso

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice, the Burkina Faso's fourth most important cereal in terms of surface area, production and annual per capita consumption, is a staple food. The high demand for rice is far from being met by national production. Several constraints, including weeds, are causing huge yield losses. The aim of this study is to assess the economic impact of innovative mechanical weed management technologies, with a view to increasing the productivity of irrigated rice in Burkina Faso. The Boulbi irrigated paddy field was used for experimentation. The evaluation was carried out on the farm using a completely randomized Fisher block design in a 4-repeat SRI. The performance of three weeders, two designed (rotary (T2) and cono (T3)), was evaluated with the Africa Rice model (T1), compared with weeding with a hand hoe (T0). Data were collected on performance and yield parameters. They were recorded with XLSTAT Version 2016.02.27444 and subjected to descriptive analyses. Results showed that weeding with weeders reduced labor time for the three weeding operations by 55% with T1, 65% with T2 and 70% with T3 compared with T0. The yield increase was 37.20% with T3, 32% with T2 and 22% with T1 compared with T0. The operating account results show additional gains of 386,250 FCFA with T3, 319,417.8 FCFA with T2 and 223,583.9 FCFA with T1 compared to T0.

Keywords: Mechanization; weeds; weeders; performance; weeding; yield.

1. INTRODUCTION

Rice has long held a low position in Burkina Faso's cereal economy. In the 1960s, rice was considered an insignificant plant, only to be found on festive tables and in urban centers [1]. But today, rice has become a strategic product, playing an important role in food security and the local economy. Indeed, rice became part of the population's eating habits during the French administration, which paved the way for massive imports of cheap broken rice from Asian colonies. The low cost of processing and cooking, and the popularity of street vendors for their rice-based dishes, led to a growing preference for this cereal among urban consumers [2].

As a result, rice consumption continues to grow from one year to the next, and to extend to all socio-economic strata [3]. From an insignificant level in the early 1960s, rice consumption in Burkina Faso grew at an annual rate of 11% [4]. Annual per capita consumption rose from 4.5 kg in 1960 to 18.2 kg in 1999 and 35 kg in 2013 [5-6]. In large cities such as Ouagadougou and Bobo-Dioulasso, this annual per capita consumption is around 50 kg [7]. Rice production has been estimated at 350,392 tons in 2019 [8], but with an estimated deficit of 393,816 tons. To make up the shortfall in consumption needs, Burkina Faso resorts to massive imports. Thus, rice remains Burkina Faso's main cereal import load, with an expenditure of 69,252.6 million FCFA in 2019 [9]. Another powerful argument is that Burkina Faso consumers, like other African consumers, are turning away from traditional cereals in favor of rice and corn. It is likely that, in time, rural consumers will also increase their rice consumption.

Despite its predominant role in the national economy, Burkina Faso's rice-growing industry faces a number of constraints that are hampering its development. Among these constraints, weeds are considered the most formidable. They cause enormous yield losses, and their management requires the mobilization of a large workforce. Indeed, in all regions, crop pests, particularly weeds, cause major yield losses. Crop weeding represents a high demand for manpower during the relatively short peak period when cultivation operations follow one another: ploughing, sowing and first weeding of the various crops. This labor requirement represents a bottleneck in the technical production itinerary, which is particularly acute in regions with low rainfall.

Weeds therefore have a definite cost in a country's economy, potentially causing huge financial losses. Losses were estimated per year by $137 billion in the United States, and $7 billion in South Africa [10]. More than 33% of the expenses generated by rice production are devoted to weeding activities, which reduces producers' share of profit [11]. The drop in yield due to weeds alone is estimated at between 30% and 60% depending on crop and area [12].

In rice cultivation, weeding is the most tedious, laborious and time-consuming operation. It is

estimated that one-third to one-half of the labor used in rice cultivation is devoted to weed control, with an average of 30-40% of labor-day/ha [13]. The overall yield loss induced by weeds is of the order of 10% of actual yield [14]. Yield losses range from 10 to 50% for transplanted rice and from 50 to 90% for upland rice, depending on the level of weed infestation [14]. According to [15], weed-related losses are estimated at 15% for irrigated rice and 30% in lowlands.

The problem of weed management is therefore acute. To minimize losses caused by weeds, agricultural plots, both perennial and food crops, need to be weeded regularly, in accordance with the technical itineraries of the concerned crops. This should be done more or less frequently, depending on the age and/or type of crop, to prevent weeds from invading and leading to plot abandonment. In West Africa, and more particularly in Burkina Faso, agriculture is very little mechanized, so weeding is done manually, with a hoe and/or by spraying herbicides. Manual weeding absorbs 20-50% of total work, from soil preparation to harvesting [16]. However, mechanical and chemical controls are costly and financial resources are not always available. With this in mind, it is more than necessary to introduce innovative technologies (manual weeders) that are accessible and that take into account producers' purchasing power and respect for the environment, for healthy, sustainable production.

The overall goal of this study is to assess the economic profitability of locally manufactured hexagonal and conical roller hand weeders used for weed management.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted on the Boulbi irrigated paddy field. It is located in central Burkina Faso, in the rural commune of Komsilga, 25km south of Ouagadougou. The commune of Komsilga is one of six (06) communes in the Centre region. Located in the province of Kadiogo, it is bordered to the east by the commune of Koubri, to the west by the communes of Komki-Ipala and Tanghin-Dassouri, to the north by arrondissements 7 and 12 of the commune of Ouagadougou and to the south by the communes of Saponé and Kayao (province of Bazèga). The geographic coordinates are precisely 1° 35' 38'' and 12° 16' 45'' West longitude, 12° 03' 43'' and 12° 16' 45'' North latitude [17].

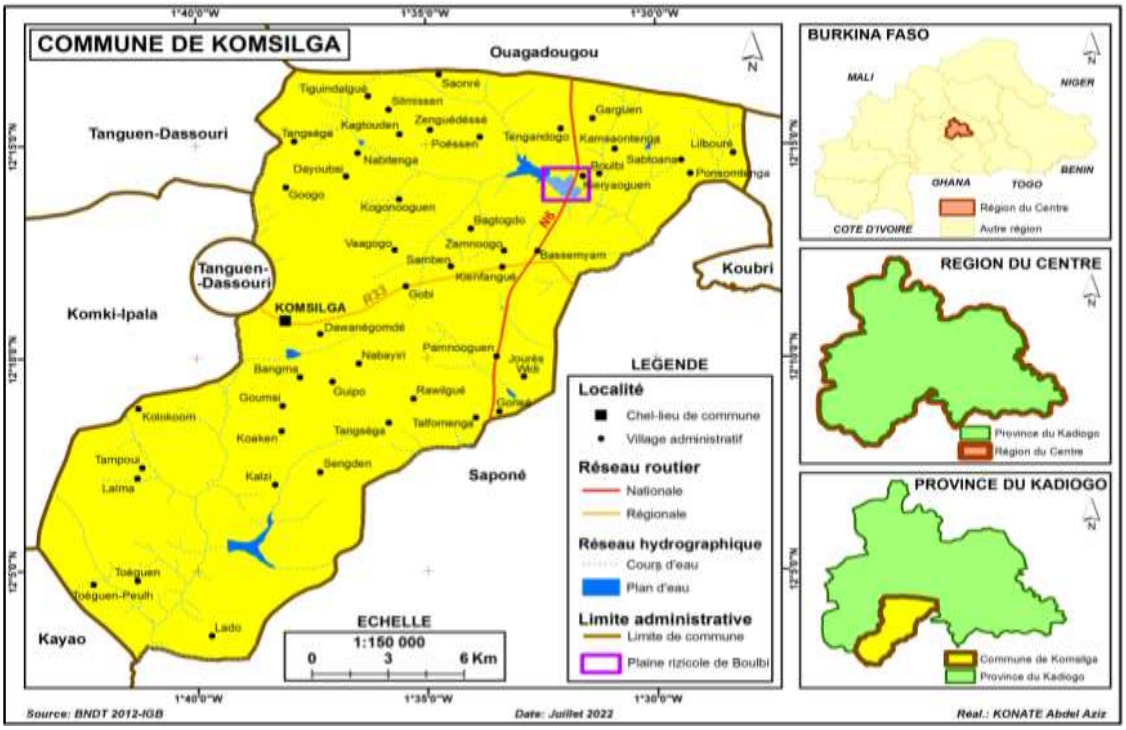

Fig. 1. Geographic location of study site [17]

2.2 Experimental Design

The trial was carried out on the farm using a completely randomized Fisher block design in an SRI system consisting of 4 treatments. The design was randomly repeated in 4 blocks of farms out of the 7 blocks on the Boulbi irrigated plain, to obtain 4 replicates per treatment. One farmer was randomly selected from each of the four blocks among those practicing SRI to conduct the trials.

The spacing between bunches and between rows was 25 x 25 cm respectively. The surface area of each elementary plot was 30 m^2 (10 m x 3 m), spaced 1 m apart with a lane bund. The surface area of the block was 176 m^2 (22 m x 8 m).

Four tools were used during the weeding operations that made up the treatments:

- weeding with the hand hoe (T0);
- weeding with the Africa Rice model weeder (T1);
- weeding with the rotary weeder (T2);
- weeding with the cono weeder (T3).

Weeding frequency took place on the 15th day after transplanting (15 DAT), at 30 DAT and 45 DAT. Fig. 2 below illustrates the experimental set-up of the study.

Fig. 3 and 4 below illustrate the two types of weeders manufactured locally.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1 Yield

The highest yield was obtained in treatment T3, while the lowest yield was recorded in treatment T0, with 5,716.67 kg/ha for T3, 5,500 kg/ha for T2, 5,083.33 kg/ha for T1 and 4,166.67 kg/ha for T0 respectively. Yields for the various treatments are shown in Table 1.

3.1.2 Weeding cost

Weeding costs were estimated in Man/day at 3,000 FCFA/Man/day. The cost of weeding/ha varied between 60,000 and 18,000 FCFA. The highest cost for the three weeding operations combined was recorded with the manual hoe, and the lowest with the manual weeder with conical wheels. These were respectively 156,000 FCFA for weeding with the manual hoe, 69,000 FCFA for the Africa Rice weeder, 54,000 FCFA for the hexagonal roller hand weeder and 48,000 FCFA for the conical roller hand weeder. Fig. 5 below shows the evolution of weeding costs at 15 days after transplanting (JAR), 30 JAR and 45 JAR.

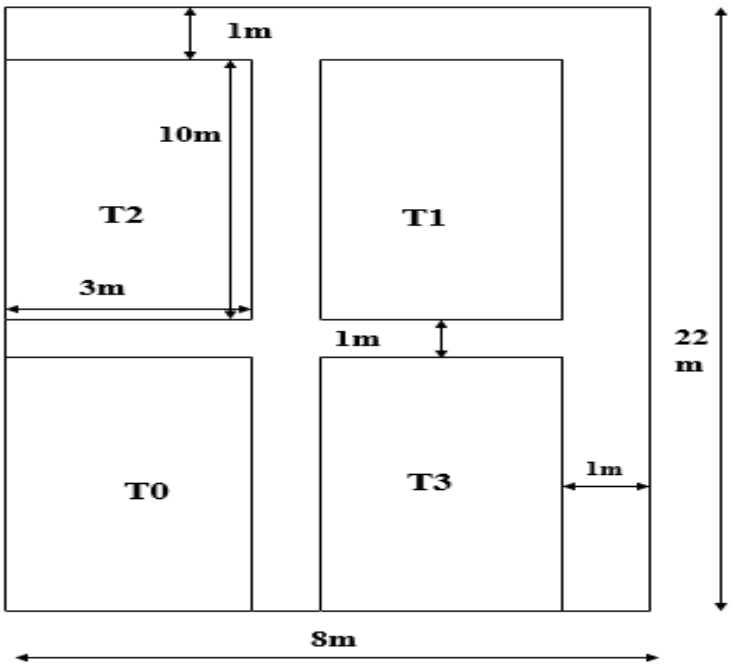

Fig. 2. Experimental design

Fig. 3. Rotary weeder

Fig. 4. Cono weeder

Table 1. Average yield (kg/ha) by treatment

Treatments	Average yield
T0	4166.67a
T1	5083.33b
T2	5500.00b
T3	5716.67b
Pr > F	0.001
Signification	HS

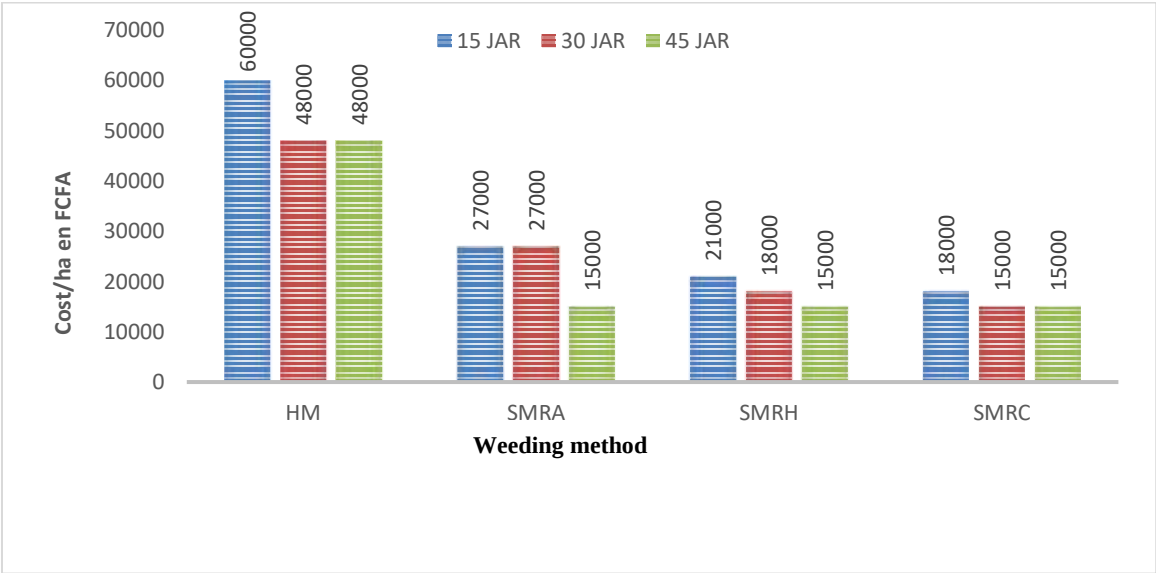

Fig. 5. Weeding costs evolution at 15 JAR, 30 JAR et 45 JAR

Legend: HM: Hand hoe; SMRA: Africa Rice weeder; SMRH: Rotary weeder; SMRC: Cono weeder

Table 2. Operating account of one hectare of rice production

Weeding with hand hoe				**Weeding with Africa Rice weeder**			
Expenses	**Amount (FCFA)**	**Products (Kg)**	**Amount (FCFA)**	**Expenses**	**Amount (FCFA)**	**Products (kg)**	**Amount**
Cost of the hand hoe	750			Weeder depreciation cost / 3 years	25, 000		
Plowing	30,000			Plowing	30,000		
Mudding + leveling	40,000	4,166.66	708,332.2	Mudding + leveling	40, 000	5,083.33	864,166.1
Organic manure	24,000	Rice straw	70, 000	Organic manure	24 000	Rice straw	80,000
Seed	4,800			Seed	4,800		
Urea	24,000			Urea	24,000		
Weeding	156,000			Weeding	69,000		
Harvesting	30,000			Harvesting	30,000		
Threshing + winnowing	40,000			Threshing + winnowing	40,000		
Packaging	30,000			Packaging	30,000		
Transport	15,000			Transport	20,000		
Total expenses	394,550	Total products	778,332.2	Total expenses	336 800	Total products	944,166.1
Gross margin			383,782.2	Gross margin			607,366.1

Weeding with rotary weeder				**Weeding with cono weeder**			
Expenses	**Amount (FCFA)**	**Products (kg)**	**Amount (FCFA)**	**Expenses**	**Amount (FCFA)**	**Products (kg)**	**Amount**
Weeder depreciation cost / 3 years	25,000			Weeder depreciation cost / 3 years	25,000		
Plowing	30,000			Plowing	30,000		
Mudding + leveling	40,000	5,500	935,000	Mudding + leveling	40,000	5,716.66	971,832.2
Organic manure	24,000	Rice straw	95,000	Organic manure	24,000	Rice straw	100,000
Seed	4,800			Seed	4,800		
Urea	24,000			Urea	24,000		
Weeding	54,000			Weeding	48,000		

Weeding with rotary weeder				**Weeding with cono weeder**			
Expenses	**Amount (FCFA)**	**Products (kg)**	**Amount (FCFA)**	**Expenses**	**Amount (FCFA)**	**Products (kg)**	**Amount**
Harvesting	30,000			Harvesting	30,000		
Threshing + winnowing	40,000			Threshing + winnowing	40,000		
Packaging	30,000			Packaging	30,000		
Transport	25,000			Transport	30,000		
Total expenses	326,800	Total products	1,030,000	Total expenses	301,800	Total products	1,071,832.2
Gross margin			703,200	Gross margin			770,032.2

3.1.3 Operating account

Analysis of the operating account for one hectare of rice shows a higher gross margin with the cono weeder, compared with a lower gross margin with the hand hoe. These are respectively 770,032.2 FCFA with the cono weeder, 703,200 FCFA with the rotary weeder, 607,366.1 FCFA with the Africa Rice weeder and 383,782.2 FCFA with the hand hoe. The Table 2 below shows the results of the operating account.

4. DISCUSSION

Crop yield is the production of dry matter per unit area, expressed in quintals/ha, t/ha or kg/ha. Its quality depends on the quality of the various yield components. The number of tillers, panicles and average weight of 1,000 grains are all characteristics that influence yield. Yields evaluated ranged from 5,716.67 kg/ha to 4,166.67 kg/ha. Weeding with manual weeders produced yields in excess of 5,000 kg/ha, compared with 4,166.67 kg/ha for hand hoe weeding. This corresponds to yield increases of 37.20% for weeding with the cono weeder, 32% for weeding with the rotary weeder and 22% for weeding with the Africa Rice weeder. These results corroborate those of [18], who showed that Nepalese rice farmers who adopted SRI and mechanization achieved a 55% increase in production per hectare and 58% higher profits. The action of the thumbs on the manual weeders on wheels aerates the soil, allowing water and air to circulate. Burying weeds improves soil fertility once they have decomposed.

Weeding with weeders reduced labor time for the three weeding operations combined by 55% with the Africa Rice manual weeder with wheels, 65% with the manual weeder with hexagonal wheels and 70% with the manual weeder with conical wheels, compared with weeding with the manual hoe. These results corroborate those of [18], who showed that labor requirements were reduced by 60% and the time needed for all the main rice-growing activities by 70% with the use of mechanization.

In terms of financial gains, weeding with the manual weeders on wheels resulted in savings compared to weeding with the manual hoe. For the three weeding operations combined, these savings ranged from 108,000 FCFA to 87,000 FCFA. Savings of 108,000 FCFA were achieved by weeding with the manual weeder with conical wheels, corresponding to a 69.23% reduction in production costs; 102,000 FCFA with the manual weeder with hexagonal wheels, corresponding to a 65.38% reduction in production costs; and 87,000 FCFA, corresponding to a 55.76% reduction in production costs with the manual weeder with wheels, Africa Rice model. The operating account results offer additional gains of 386,250 FCFA, 319,417.8 FCFA and 223,583.9 FCFA with the conical, hexagonal and Africa Rice model manual weeders compared with the manual hoe. These results are in line with those of [18], who showed that rice farmers in Nepal who introduced mechanization into rice production found that they could reduce production costs by 27% and increase profits per hectare by 36%. Adopting the technology of manual weeders on wheels will enable rice growers to minimize the time spent on weeding operations, as well as the cost of rice production. These savings in time and income could be put to good use in income-generating activities.

5. CONCLUSION

The overall goal of this study on the evaluation of wheeled manual weeders in an intensive rice cultivation system (SRI) in the Central zone of Burkina Faso was to contribute to increasing the productivity of irrigated rice in Burkina Faso through the use of innovative mechanical technologies for weed management. In the course of the study, two manual weeders were manufactured. Weeding with weeders reduced working time for the three weeding operations combined by 55% with the Africa Rice weeder, 65% with the rotary weeder and 70% with the cono weeder, compared with weeding with a hand hoe.

With regard to the effect of weeders on rice yields, it should be noted that their use increased yields by 37.20% for weeding with the cono weeder, 32% for weeding with the rotary weeder and 22% for weeding with the Africa Rice weeder, compared with weeding with the hand hoe. The operating account results show additional gains of 386,250 FCFA, 319,417.8 FCFA and 223,583.9 FCFA respectively with the cono, rotary and Africa Rice manual weeders compared with the hand hoe.

The adoption of this manual weeder technology will enable rice growers to reduce the time spent on weeding operations as much as possible, as well as the cost of rice production. These time and income savings could be used for income-generating activities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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