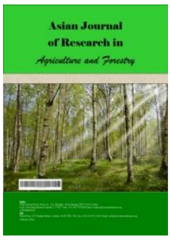

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Evaluation of Traditional Know-How for the Cultivation of Muskuwaari Transplanted Sorghum in a Context of Climate Change (Mayo-Danay and Mayo-Kani, Far North Cameroon)

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Authors' contributions

This work was carried out in collaboration among all authors. Author PAAVN designed the study, performed the statistical analysis. Author DDB wrote the protocol. Author Tchobsala wrote the first draft of the manuscript. Authors DND and IA managed the analyses of the study. Author SM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Sorghum is a staple food crop and accounts for more than half of cereal production in the Far North region. It is ranked among the seven most important agricultural products in the CEMAC zone. Approximately 12% of this dry season sorghum, known as transplanted sorghum, is used extensively in the population's diet.

Study Design: The study conducted from 2017 to 2019 aims to assess the adopted techniques for better exploitation of Muskuwaari in the Far North region of Cameroon in a context where climate change has a strong influence on agricultural yield.

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Methodology: The evaluation of Muskuwaari cultivation techniques is based on farmer surveys and direct field observations. A total of 390 people were surveyed in six different villages in the two regions.

Results: Cultivation lasts from July to April, for a period of 10 months. Several activities were identified: primary preparation of the field from July to August, setting up nurseries from August (This activity is poorly represented in Kalfou (16.92% on both types of soil) and in Kaélé (18.46% on clay soil and 13.85% on hydromorphic soil), preparation of the field from September (The most common techniques used today are spraying and transplanting (Technique 6): 34.92% in Guidiguis, 52.31% in Touloum, 50.77% in Kaélé, 62.50% in Kalfou, 35.38% in Doukoula, 55.38% in Tchatibali on average for the clay type soil and 40,63% in Guidiguis, 47.69% in Touloum, 56.92% in Kaélé, 52.46% in Kalfou, 47.62% in Doukoula, 46.77% in Tchatibali on average for the hydromorphic type soil), transplanting from September, weeding from November and harvesting from January. These activities vary according to the type of soil used and the villages.

Conclusion: The analysis of these Muskuwaari cultivation techniques showed a slight shift in relation to the cultivation calendar described in the past by other authors. This shift is caused by the change in climate that shortens and/or extends the rainy season from one year to the next.

Keywords: Transplanted sorghum; Muskuwaari; cultivation techniques; climate change Far North; Cameroon.

1. INTRODUCTION

African states spend several billion CFA francs annually to cover food deficits, but demand has always exceeded supply [1], since the challenges of agriculture in Central Africa remain. Population growth has led to an increase in food demand that can only be met by intensifying agricultural activity [2]. Cereals remain the main source of energy for more than 962 million people in this part of the world and are therefore essential for food security [3]. Although it has decreased from 33% in 1990-92 to 23% in 2014-16, the percentage of undernourished people remains the highest in the developing world [4]. Statistics provided by FAO [5] on agricultural production in the CEMAC countries for the year 2008 show that the seven most important productions in this zone are: cassava, plantains, maize, taros and other colocases, yams, sorghum, and dessert bananas. Among these foodstuffs, more than 12% of sorghum is grown in the dry season and is known as transplanted sorghum. As a cereal, it plays an important role in the agricultural production system of the savannah zones of Cameroon [6]. However, the strong dynamics of transplanted sorghum cultivation techniques have led to profound changes in agrarian systems and natural resource management. However, current cropping practices characterized by systematic clearing before cultivation and the almost non-existence of fallows (10 to 15 years in continuous cultivation) have inevitable repercussions on the sustainable management of agropastoral areas and in particular of woody resources [7]. Thus, the techniques for the establishment of Muskuwaari cultivation are in perpetual evolution over time since the rainfall cycle changes every year. This work is in line with the fact that today the use of chemical inputs and the alteration of plant biodiversity are very advanced in the exploitation of Muskuwaari sorghum, while the yield decreases over time (source: survey).

2. MATERIALS AND METHODS

2.1 Description of the Study Area and Rationale for Selecting the Area

The study area is located in the Departments of Mayo-Kani and Mayo-Danay in the Far North of Cameroon. The capital of Mayo-Kani is Kaélé, with an area of 5,033 km^2 and 338,448 inhabitants. As for Mayo-Danay, its chief town is Yagoua, with an area of 5,303 Km^2 and 522,782 inhabitants [8]. The studied site covers a total of six areas in two regions. In Mayo-Kani, we have Guidiguis, Touloum and Kaélé. In Mayo-Danay we have Kalfou, Doukoula and Tchatibali. There is no precise delineation of these plains, but the most important part has been used in this work.

The physical characteristics of the region include ferruginous and ferralitic soils resulting from the intensity of leaching affecting this area [9]. The soils are very diversified and Brabant & Gavaud [10] distinguish different types, namely, Vertisols, alluvial soils, hydromorphic soils, planosols, tropical leached soils, ferruginous soils, ferralitic soils and lithosols. The Far North region is attached to the Sahelian climate with sub-desert

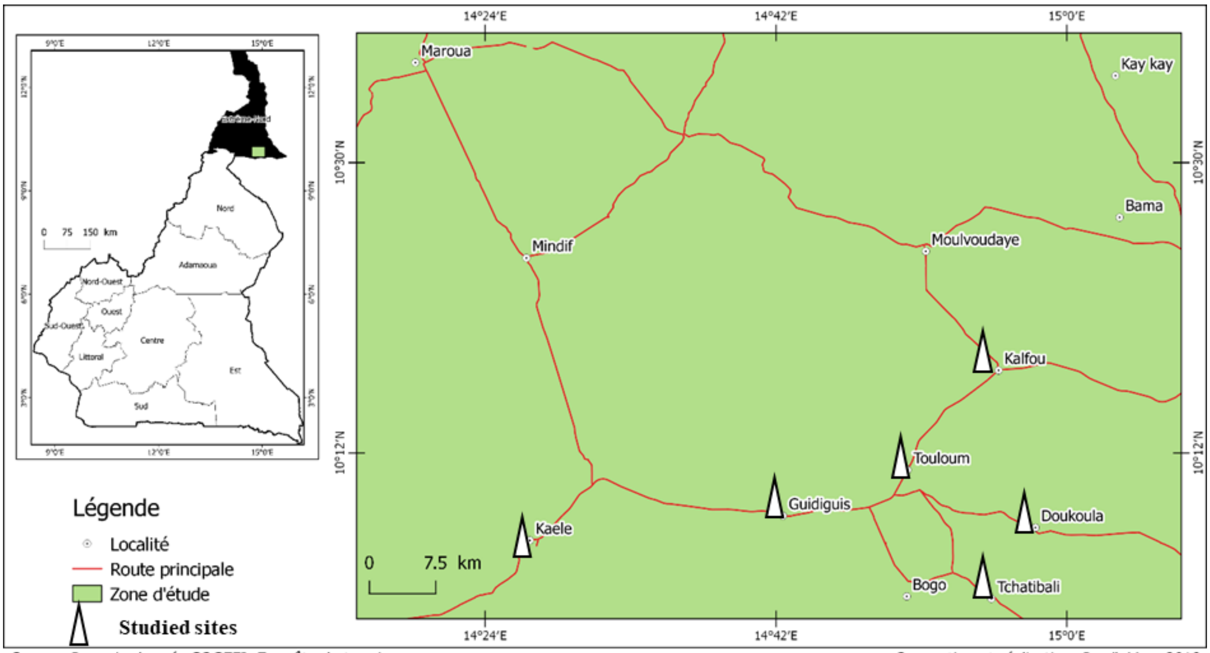

Fig. 1. Map of the study area

nuances, a Sudano-Sahelian climate prevails on the plain (with six months of rainfall from May to October) and during this season the vegetation is green [11]. It consists of highlands and plains. To the north and east are the Chadian basin and plains. The altitude varies from 280 to 550 m. In the southwest, the Mandara Mountains with steeply sloping massifs and sharp peaks form the highlands of the region (MINTOUR, 2011). The most widespread vegetation types are those of shrub and tree savannahs with plant species that are dominated by *Anogeissus leiocarpus, Balanites aegyptiaca, Guiera senegalensis, Piliostigma thonningii, Acacia seyal, A. albida, A. nilotica, A. senegal, Ziziphus mauritiana* [12]. This zone presents an ecological fragility, the increase of the aridification of the environment and the increase of the mortality of the woody species lead to a decrease of the biodiversity [13].

2.2 Methods

Two methods were used for this study: surveys of farmers and field observations, i.e., in the Karal fields during cultivation activities.

2.2.1 Socio-economic surveys

The type of interview used was the so-called semi-structured interview with closed (yes/no), open (deliberately answered from one's own perspective), and guided (with some answers offered to the respondent) questions [14]. The respondents were all transplanted sorghum farmers. Surveys were conducted at farm sites and in households in the surrounding villages. Only those involved in muskuwaari farming were surveyed. These surveys were carried out using a questionnaire previously established in the forms according to the objectives sought. The surveys focused on one main area: the techniques used to farm sorghum and alternative measures for sustainable and ecological farming of transplanted sorghum. A total of 390 farmers were surveyed in the selected area, including 65 farmers per village.

2.2.2 Field observation

Direct observation is a means of collecting data from an individual or group of individuals through direct observation by the researcher in the field, who, using an observation grid, notes and describes the behavior of the actor, but also the course of events observed around him [15]. Direct observation was therefore chosen as a complementary method for data collection because it allows the researcher to verify the activities carried out by the actor himself. It consists of going to the field during sorghum production from the beginning of work to the end, in order to see all the activities carried out for the crop. Soil preparation techniques, seedling placement, transplanting, weeding and harvesting techniques were noted in a field notebook. The information obtained here complements and confirms the information obtained from the questionnaires.

2.3 Data Analysis

The data collected during this study was recorded in an Excel sheet and analyzed by software Statgraphic Plus version 5.0, which allowed comparison of the data collected using ANOVA and the DUNCAN test for comparison of means and Ki-squares ($\chi 2$) for rate comparison. Excel was also use for histograms construction, averages and percentage determination.

3. RESULTS

3.1 Crop Cycle of *Muskuwaari* Transplanted Sorghum in the Study Area

Table 1 summarizes the different activities carried out during the harvesting of Muskuwaari transplanted sorghum. All of these activities are dependent on rainfall during the year, since muskuwaari farming is strongly rain-dependent. Muskuwaari cultivation is largely practiced on floodable soils during the rainy season. It is the receding of the flood that marks the beginning of harvesting and for this reason soil preparation and transplanting takes place over three months (September, October and November). Flooding does not occur at the same time everywhere, but rather depends on the type of soil and the source of origin. Many farmers did not transplant sorghum in 2017 in Mayo-Kani and Mayo-Danay because of the lack of flooding. The cropping cycle remains the same in the six villages of the two Departments with just a few days difference depending on the soil types. Soils that are saturated with water (hydromorphic) are transplanted last, since the water withdraws a little later (end of October to November) than hard soil, which is harvested in September because the soil dries out quickly.

3.2 Primary Field Preparation Activities According to Soil Types and Villages

During primary preparation, a great deal of work is carried out: the construction of bunds, the demarcation of plots, and the stumping and pruning of plant species (Fig. 2). Stump removal activities are carried out in all six villages, and are most common in Guidiguis (43.08% on clay soil) and Touloum (35.38% on hydromorphic soil). This activity is poorly represented in Kalfou (16.92% on both types of soil) and in Kaélé (18.46% on clay soil and 13.85% on hydromorphic soil). The removal of a woody tree leads to the permanent disappearance of the individual or species concerned, and since there is no reforestation in the karal for the time being, this makes the field a treeless space. A selective pruning or trimming would be more appreciated given the current state of the kare vegetation where in one hectare there are less than two trees. The demarcation of plots takes place almost every year before the start of exploitation, since plots are either rented to other farmers without plots or divided among family members. This activity takes place in all six villages. Boundaries are often the subject of major conflicts. Primary field preparation activities vary according to soil type; hardened soils require bunds to retain water for proper wetting and are also practiced throughout the zone. Pruning is not practiced much since the fields are almost devoid of trees (a maximum rate of 24.62% is observed in Doukoula on hydromorphic soil).

3.3 Techniques for Setting Up Nurseries According to the Villages and the Type of Soil

Two techniques are used to establish nurseries: spreading and seeding (Table 2). The most popular technique in the zone is spreading (Guidiguis 76.19%, Touloum 79.69%, Kaélé 71.88%, Kalfou 83.08%, Doukoula 76.58%, Tchatibali 73.44%). Spreading is carried out after clearing or plowing the surface with a plow or hoe, then the seeds are buried in the soil with a hoe or with a pile of thorns dragged over the spread seeds. Sowing nurseries is less popular than spraying, but many also practice it (17.19% in Touloum, 20.31% in Kaélé, and 18.75% in Doukoula). Other farmers practice both (spreading and sowing) and are also representative, 12.50% in Tchatibali, 11.11% in Guidiguis and 7.81% in Kaélé. The nurseries are calibrated on several types of soil, but the most popular are those around the termite mounds because these soils are more fertile even for transplanting. The calibration is done over time with time intervals ranging from two to seven days since transplanting can last several weeks and this allows to have plants available at any time. The nurseries last 3 to 6 weeks and the plants are pulled out and placed in water overnight or two and then transplanted. The techniques for setting up nurseries have evolved.

Table 1. Production cycle of transplanted sorghum according to soil type

Types of soil	Activities	January	February	March	April	May	June	July	August	September	October	November	December
Clay soil (SA)	Primary field preparation												
	Spreading of seeds for nursery												
	Soil preparation for transplanting												
	Transplanting												
	Weeding												
	Harvest												
Hydromorphic soil (SH)	Primary field preparation												
	Spreading of seeds for nursery												
	Soil preparation for transplanting												
	Transplanting												
	Weeding												
	Harvest												

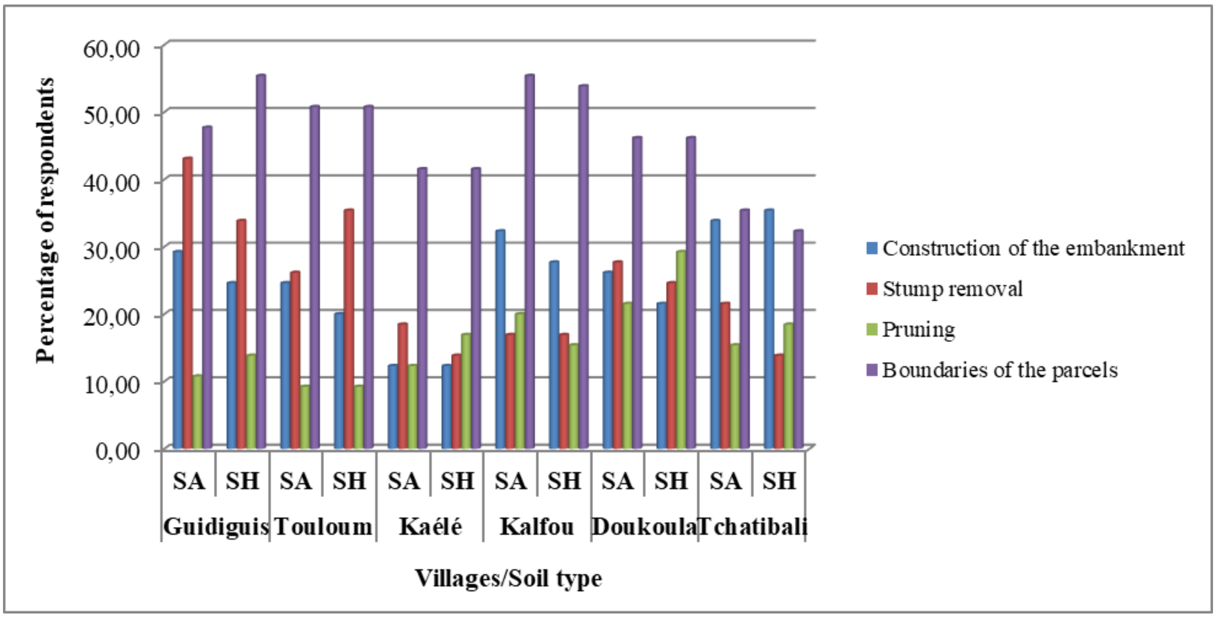

Fig. 2. Primary field preparation activities according to soil types and villages

Table 2. Techniques (%) for setting up nurseries according to villages

Techniques	Guidiguis	Touloum	Kaele	Kalfou	Doukoula	Tchatibali
Spreading	76,19	79,69	71,88	83,08	76,56	73,44
Seedlings	12,70	17,19	20,31	10,77	18,75	14,06
Spreading and seeding	11,11	3,13	7,81	6,15	4,69	12,50

(χ2: 37.65; DDL: 25; P: 0.0001 where χ2 (k-two) is the comparison rate; DDL is the degree of freedom and P is the P-value)

The techniques for setting up the nursery do not vary according to soil type. Rather, it is the seed varieties that are chosen based on soil type. Statistical analysis reveals that there is a highly significant difference between villages at the 0.001 level.

3.4 Steps for Preparing the Field for Transplanting According to Soil Types and Villages

Fig. 3 shows the eight field preparation techniques for *Muskuwaari* transplanting identified in the study area. The most common techniques used today are spraying and transplanting (Technique 6): 34.92% in Guidiguis, 52.31% in Touloum, 50.77% in Kaélé, 62.50% in Kalfou, 35.38% in Doukoula, 55.38% in Tchatibali on average for the clay type soil and 40,63% in Guidiguis, 47.69% in Touloum, 56.92% in Kaélé, 52.46% in Kalfou, 47.62% in Doukoula, 46.77% in Tchatibali on average for the hydromorphic type soil (Table 3). Followed by spraying-burning-planting (Technique 5): 39.68% in Guidiguis, 29.23% in Touloum, 24.62% in Kaélé, 21.88% in Kalfou, 41.54% in Doukoula 32.26% in Tchatibali on average for the clay type soil and 32,81% in Guidiguis, 30.77% in Touloum, 29.23% in Kaélé, 24.59% in Kalfou, 36.51% in Doukoula, and 32.26% in Tchatibali on average for the hydromorphic soil type (Table 3). Technique 6 is the most widely used because of the lack of manpower in recent years for mowing, the low cost of herbicides (1,200 to 1,500 CFA francs for glyphosate), and the time saved since 5 to 7 days after spraying, transplanting can begin even if the grass is not yet dry. The other techniques are less practiced; technique 8, which consists of direct transplanting, is practiced only in Guidiguis (1.59% on SA and 3.13% on SH), Doukoula (1.54% on SA and 1.59% on SH) and Tchatibali (1.61% on SA). This is due to the fact that this technique requires plots that are entirely free of grass or have little grass and are easy to mow or plow during weeding. Some farmers spray after clearing (Technique 3: varying from 1.54 to 7.69%) to destroy as much grass as possible and reduce weeding. Today, it has become essential for the exploitation of transplanted sorghum. Fig. 3 shows a ploughed and transplanted plot (A), a sprayed, burned and transplanting plot, a farmer practicing manual mowing (C), and the burning of a sprayed plot (D). For muskuwaari, it is preferable for the farmer not to treat systematically every year, and to do so at the recommended rate when really needed [16] since repeated treatment year after year has significant consequences on health and vegetation. Statistical analysis reveals that there is a highly significant difference between villages at the 0.001 level.

3.5 Techniques and Stages of Transplanting of Muskuwaari According to the Villages

Three transplanting techniques were noted (Table 4): Technique 1 (Trouaison - insertion of seedlings into hole and water supply), Technique 2 (Trouaison - water supply and insertion of seedlings into hole), and Technique 3 (Hoe transplanting). These three techniques vary according to soil type (Table 4). Technique 1 (17.46% in Guidiguis) is practiced on sandy-clay soils because the water supply must occur after the seedlings are inserted into the hole, since if the water arrives before the seedlings, the sand will block the hole. Technique 2 is practiced on hydromorphic, hardpan and clay soils over 85% (Table 4). Technique 3 (only 1.59% in Doukoula and Guidiguis) is poorly represented because this method was observed in farmers whose plants already had "very large" internodes. These plants are generally not suitable for transplanting, since even a light wind can break them, but this transplanting was successful. Technique 2 is the most practiced because sandy-clay soil is encountered in only a few sites. Holes are made with a sharp-tipped crowbar or a sharp-tipped stake, and there are usually two plants per hole, with the spacing between holes varying from grower to grower. Most farmers no longer burn the grass cover because it conserves soil moisture. This is a recent practice, which emerged with the advent of herbicide treatment. Photos 5 A and B also show the bottom of a cultivation area almost devoid of trees. Transplanting techniques have not evolved over time. However, the standard technique has remained the drilling of the hole, the supply of water to the hole and the insertion of two seedlings into the hole (Technique 2). Statistical analysis reveals that there is a highly significant difference between villages at the 0.001 level.

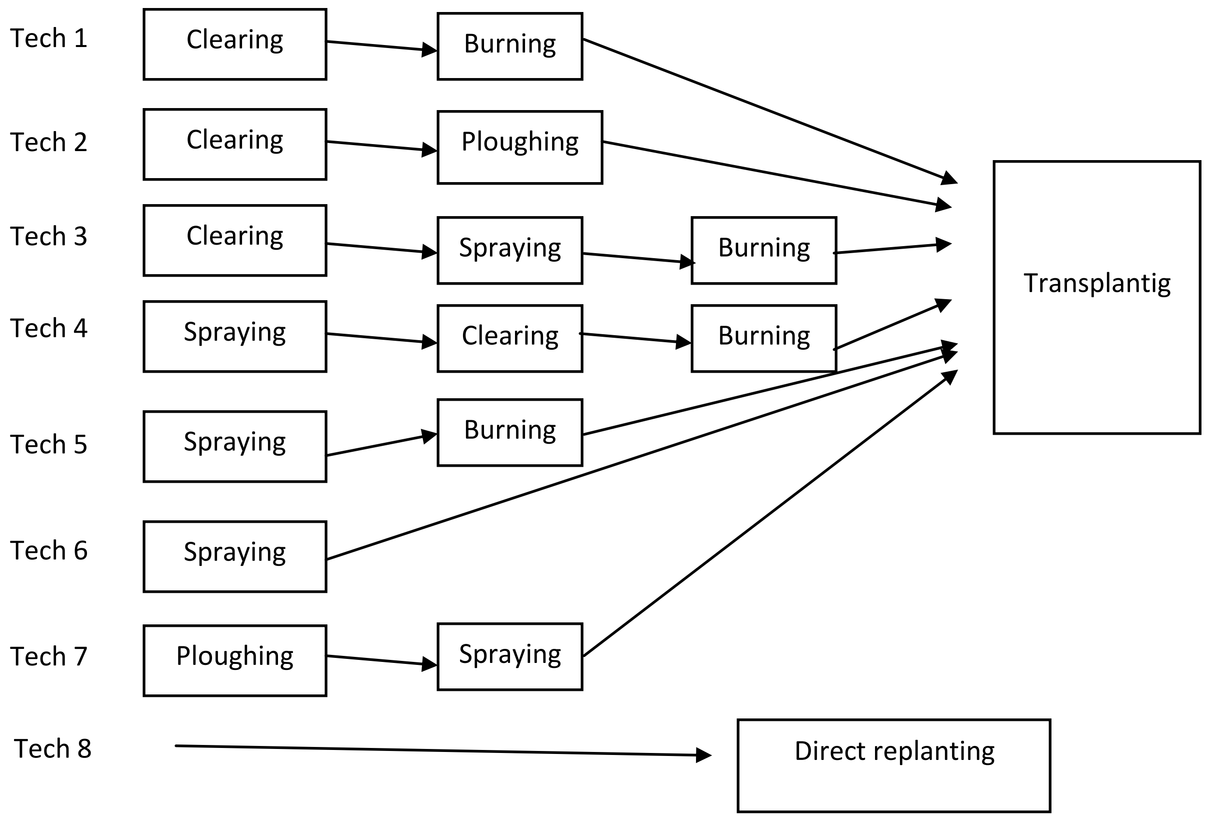

Fig. 3. Steps in preparing the field for transplanting; Tech = technique

Table 3. Field preparation techniques (%) by village and soil type

Techniques	Guidiguis		Touloum		Kaele		Kalfou		Doukoula		Tchatibali	
	SA	**SH**	**SA**	**SH**	**SA**	**SH**	**SA**	**SH**	**SA**	**SH**	**SA**	**SH**
Tech 1	11,11	12,50	9,23	7,69	10,77	6,15	12,50	14,75	9,23	6,35	4,62	8,06
Tech 2	3,17	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,08	0,00	0,00	0,00
Tech 3	1,59	1,56	0,00	0,00	7,69	1,54	1,56	1,64	1,54	3,17	3,08	1,61
Tech 4	3,17	3,13	6,15	4,62	1,54	3,08	0,00	3,28	3,08	1,59	1,54	3,23
Tech 5	39,68	32,81	29,23	30,77	24,62	29,23	21,88	24,59	41,54	36,51	30,77	32,26
Tech 6	34,92	40,63	52,31	47,69	50,77	56,92	62,50	52,46	35,38	47,62	55,38	46,77
Tech 7	4,76	6,25	3,08	7,69	4,62	3,08	1,56	3,28	4,62	3,17	4,62	6,45
Tech 8	1,59	3,13	0,00	0,00	0,00	0,00	0,00	0,00	1,54	1,59	0,00	1,61

(χ2: 37.65; DDL: 25; P: 0.0001 where χ2 (ki-two) is the comparison rate; DDL is the degree of freedom and P is the P-value)

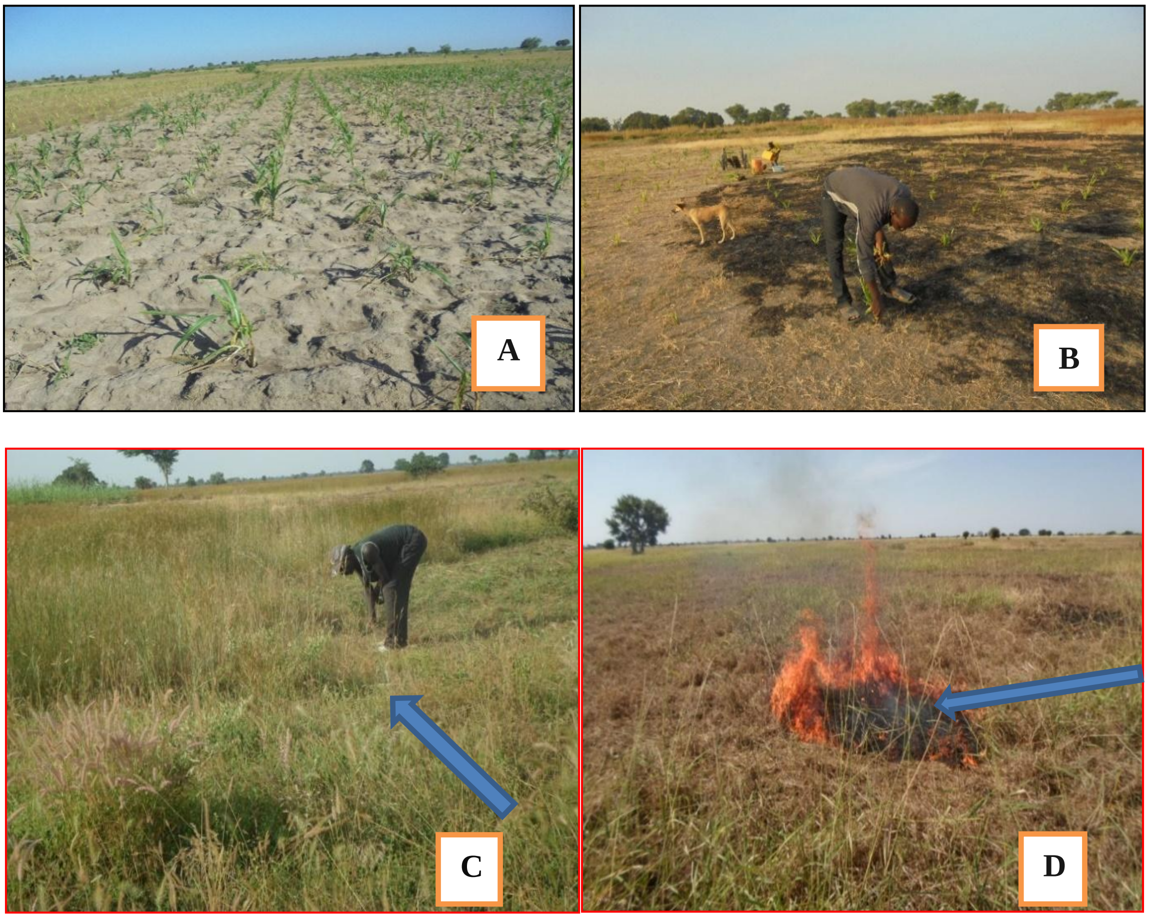

Plate 1. Soil preparation techniques: (A)- Clay soil (SA) plowed and transplanted; (B)- SA pulverized, burned and transplanted in Doukoula; (C) - SA mowed manually; (D)- Burning of grass cover after spraying of a hydromorphic Soil (SH)

Plate 2. Water supply to holes and seedling insertion (B) after drilling (A) in Guidiguis on clay soil with and without fire

Table 4. Proportion of transplanting techniques according to village and soil type

Transplanting techniques	Guidiguis		Touloum		Kaele		Kalfou		Doukoula		Tchatibali	
	SA	SH	SA	SH	SA	SH	SA	SH	SA	SH	SA	SH
T_1	17,46	0	0	0	0	0	0	0	0	0	0	0
T_2	80,95	100	100	100	100	100	100	100	98,41	100	100	100
T_3	1,59	0	0	0	0	0	0	0	1,59	0	0	0

(χ2: 37.65; DDL: 25; P: 0.0001 where χ2 (ki-two) is the comparison rate; DDL is the degree of freedom and P is the P-value)
T = Technical; SA = Clay soil; SH = Hydromorphic soil

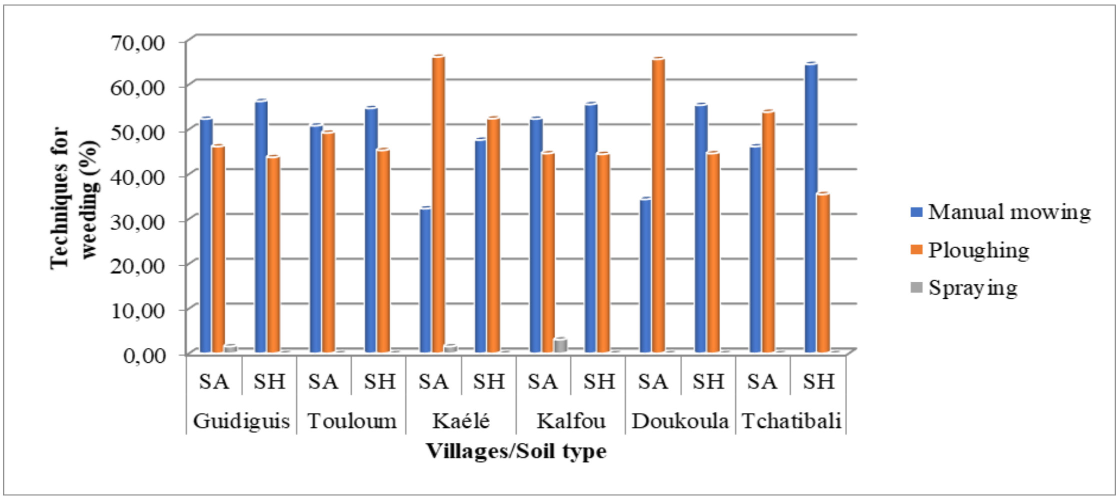

Fig. 4. Weeding techniques (%) by village and soil type

3.6 Weeding Techniques of the Field According to the Type of Soil and the Villages

Three methods of weeding *Muskuwaari* fields were identified: manual mowing, hoeing, and spraying with herbicides. Spraying is not highly valued by farmers (1% in Guidiguis and Kaele and 2% in Kalfou) because poor application of herbicides could destroy the crop. Selective herbicides are very rare. Manual mowing with a bifurcated blade (*wiikordu* in Fulfulde) is practiced more in Tchatibali (64.52% in SH) and Guidiguis (56.25% in SA) than in the other villages (Touloum: 50.79% SA and 59.64% SH, Kaele: 32.31% SA and 47.62% SH, Kalfou: 52.31% SA and 55.56% SH and Doukoula: 33.38% SA and 55.38% SH). Some farmers practice plowing more than spraying and mowing with a bifurcated mower. Once spraying for soil preparation is successful in eliminating "weeds", there will be little or no weeding, which encourages muskuwaari farmers to use herbicide treatments. These weeding techniques do not vary much by soil type, but by farmer.

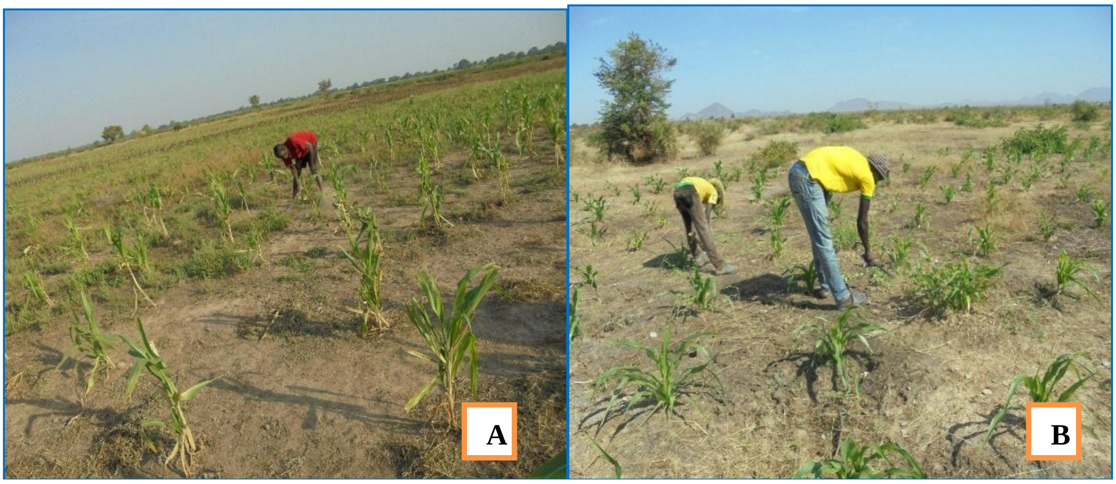

Plate 3. Weeding techniques in Doukoula (A: on clay soil) and in Kaele (B: on hydromorphic soil)

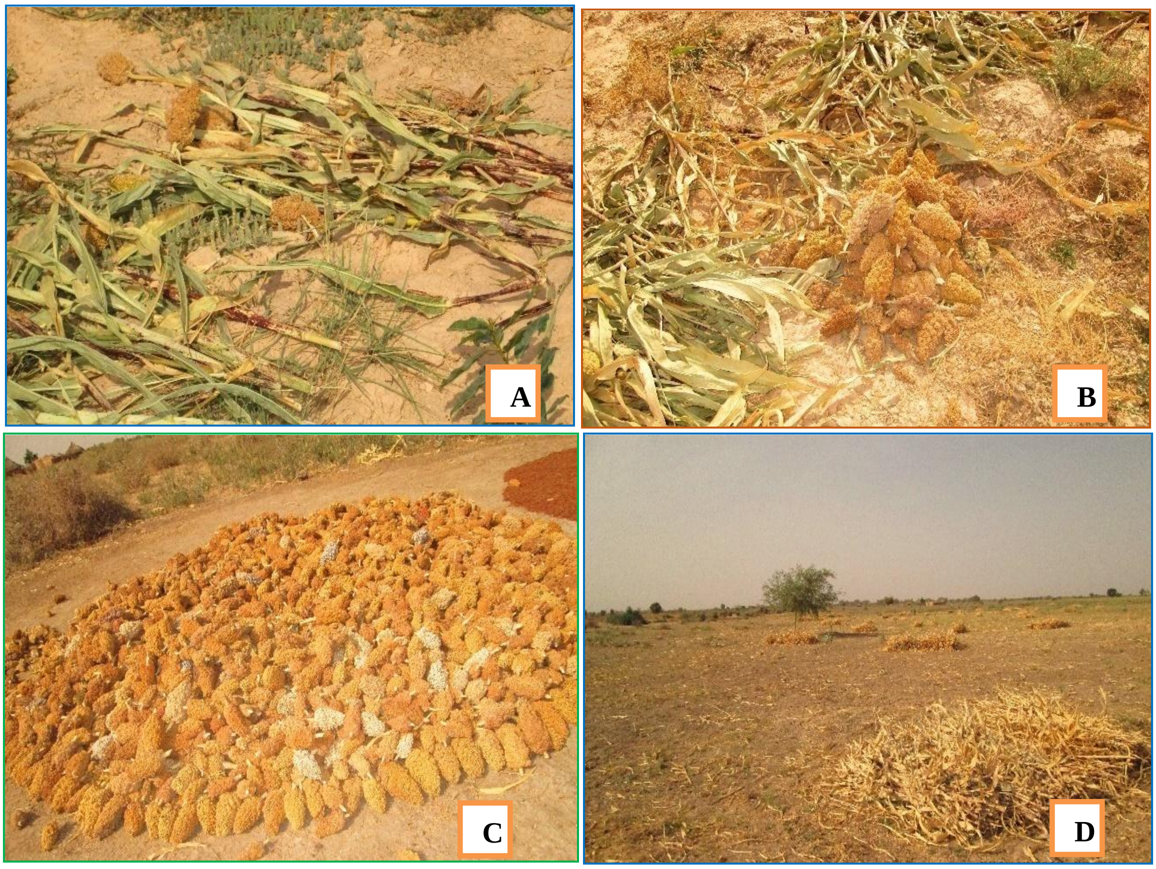

Plate 4. (A) Fully cut sorghum plant; (B) Spikes separated from stems; (C) Spikes piled; (D) Stems alone piled

3.7 Harvesting Steps and Techniques of Muskuwaari in the Study Area

In the two departments and six villages, the harvesting steps and techniques are the same and do not vary or depend on soil type. Initially, the entire plant is cut flush with the ground. After a few days of drying, the panicles are separated from the stems, and then the panicles are transported and piled up at the threshing site. After threshing and winnowing, the seeds are put into the bags for easy transport home. The stalks are finally tied and are either transported for fodder for the farmer's animals or sold locally in the field or transported and sold in town. Panicle debris is not spared; it is also bagged and taken home for the animals. The means of transport vary according to the farmers. They use rickshaws, motorcycles, tricycles, donkeys or horses and all-terrain vehicles. The price of transport varies according to the distance, but generally,- a bag is transported at a cost of 500 F CFA and a bundle of stems at 50 to 100 F CFA. Once the crop is home, the sorghum is either consumed by the producer or a portion is sold to meet other needs. After all these activities, the herdsmen and the shepherds pass by with their animals to consume the remaining debris.

3.8 Crop Yields by Village and Soil Type for the Years 2017, 2018, and 2019

The average yield in tons per farmer for the last three years (2017, 2018, and 2019) in the six villages is summarized in Table 5. The average yield of muskuwaari harvested on the hydromorphic soil type is higher than that on the clay soil type in four of the six villages (Guidiguis, Kaélé, Kalfou, and Tchatibali). In Touloum and Doukoula, it is the clay-type soil that exceeds in yield (0.48 t/ha on SA and 0.41 t/ha on SH in Touloum; 0.80 t/ha on SA and 0.61 t/ha on SH in Doukoula) In general, the area of clay-type karal soil is greater than that of hydromorphic soil everywhere and every year, but it is the hydromorphic soil that has a higher average yield in the villages. A small area of cultivated land and a higher average yield found on the hydromorphic soil type show that it has a more productive arable area than the clay soil type. The study found that yield and harvested area decreased from 2017 to 2018 across both departments for both soil types. An increase in harvested area and an increase in yield in 2019 were also noted across the board. Thus, muskuwaari cultivation in 2018 experienced a decline in both harvested area and average yield

Table 5. Yields of muskuwaari sorghum in the last three years by village and soil type

		Quantity (t/prs)		Area (ha/prs)		Yield (t/ha)	
	Soil type/Year	**SA**	**SH**	**SA**	**SH**	**SA**	**SH**
Guidiguis	**2017**	0,26	0,19	0,58	0,27	**0,45**	**0,7**
	2018	0,23	0,15	0,47	0,2	**0,49**	**0,75**
	2019	0,4	0,17	0,5	0,2	**0,8**	**0,85**
	Average	***0,3***	***0,17***	***0,52***	***0,22***	***0,58***	***0,77***
Touloum	**2017**	0,31	0,16	0,67	0,42	**0,46**	**0,38**
	2018	0,29	0,12	0,6	0,3	**0,48**	**0,4**
	2019	0,37	0,18	0,72	0,4	**0,51**	**0,45**
	Average	***0,32***	***0,15***	***0,66***	***0,37***	***0,48***	***0,41***
Kaele	**2017**	0,27	0,25	0,49	0,38	**0,55**	**0,66**
	2018	0,21	0,22	0,46	0,4	**0,46**	**0,55**
	2019	0,46	0,3	0,6	0,43	**0,77**	**0,7**
	Average	***0,31***	***0,26***	***0,52***	***0,4***	***0,59***	***0,64***
Kalfou	**2017**	0,26	0,29	0,46	0,36	**0,57**	**0,81**
	2018	0,2	0,22	0,44	0,4	**0,45**	**0,55**
	2019	0,3	0,34	0,45	0,48	**0,67**	**0,71**
	Average	***0,25***	***0,28***	***0,45***	***0,41***	***0,56***	***0,69***
Doukoula	**2017**	0,36	0,15	0,47	0,23	**0,77**	**0,65**
	2018	0,3	0,11	0,4	0,2	**0,75**	**0,55**
	2019	0,42	0,18	0,48	0,28	**0,88**	**0,64**
	Average	***0,36***	***0,15***	***0,45***	***0,24***	***0,8***	***0,61***
Tchatibali	**2017**	0,38	0,35	0,6	0,44	**0,63**	**0,8**
	2018	0,23	0,27	0,56	0,36	**0,41**	**0,75**
	2019	0,42	0,32	0,6	0,39	**0,7**	**0,82**
	Average	***0,34***	***0,31***	***0,59***	***0,4***	***0,58***	***0,79***

Prs: *Person**; t:** ton**; ha:** hectare* per farmer. These variations would be due to climatic conditions with variations in rainfall and temperatures as the success of *karal* depends largely on these two parameters. Many farmers did not harvest muskuwaari in the year 2017-2018 due to the absence of flooding and the rapid departure of soil moisture, which prevented the establishment of the crop and the unavailability of nurseries.

4. DISCUSSIONS

4.1 Crop Cycle of Muskuwaari Transplanted Sorghum

Cutting and clearing of trees is a necessary condition for crop establishment, in order to reduce competition for water and to limit the presence of perches for granivorous birds and woody plants [17]. But this remains a problem for biodiversity and soil at the same time, leading in the most extreme cases to desertification.

Muskuwaari has been exploited since the 19th century . The techniques of its exploitation have remained almost the same from the beginning until today. Its cropping cycle has remained stable, but a slight shift is often observed due to the rainy season, which does not follow a precise calendar. Mathieu [17] obtained almost the same result on the cultural cycle with a slight difference; the harvest according to him occurs in January and February whereas in the present study it is in March and April.

4.2 Primary Field Preparation

In his document entitled, *Une démarche agronomique pour accompagner le changement technique*, Cas de l'emploi du traitement herbicide dans les systèmes de culture à sorgho repiqué au Nord-Cameroun (*An agronomic approach to accompany technical change, the* case of the use of herbicide treatment in transplanted sorghum cropping systems in North Cameroon), Mathieu [17], in the context of the primary preparation of the field, lists only the construction of bunds. Activities such as plot delimitation, pruning, stump removal, or pruning of woody species are not mentioned, yet apart from plot delimitation, these other activities are even those that are at the root of irreversible changes in the soil and vegetation cover in the karal.

4.3 Setting up the Nurseries

The techniques for setting up nurseries have evolved. From the spreading of seedlings described by Bretaudeau et al. [18], it is now also practiced to sow and spread the seeds on a soil previously plowed by hand or plow followed by the burial of the seeds in the soil with the help of a pile of thorns pulled by oxen or by man.

4.4 Soil Preparation

For the preparation of the soil, several techniques are used, among which, the use of herbicide treatment comes in the first position. The intensification of the use of the herbicide treatment does not date more than 15 years. Today, it has become essential for the exploitation of transplanted sorghum. For muskuwaari, it is preferable for the farmer not to treat systematically every year, and to do so at the recommended rate when really needed [16] since repeated treatment year after year has significant consequences on health and vegetation. Repeated use of the same herbicide product can lead to flora selection, with a population of species on which the active ingredient is not or less effective [19]. This work is consistent with that of Donfack and Seignobos [20] on indicator plants in an agrosystem that includes fallow and that of Seignobos et al. [21] on land saturation in *Muskuwaari.*

4.5 Transplanting and Weeding of Muskuwaari Sorghum

Transplanting techniques have not evolved over time. However, the standard technique has remained the one described by Mathieu [17], which consists of digging a hole, supplying water to the hole and inserting two seedlings into the hole. The other two techniques described in this work are not well known but are also used by a handful of farmers.

Bretaudeau et al. [18] on *recessional sorghum cultivation in West and Central Africa,* describes sorghum weeding methods, but the use of herbicide treatment, although not very significant, was not mentioned, even though it is practiced by some farmers in an effort to reduce weeding and labor. According to the surveys, by 2002, the use of herbicides in muskuwaari cultivation was not well developed. What has remained unchanged over the years is harvesting; the techniques have remained the same.

Seignobos [22] found in his research work that the yield of muskuwaari sorghum generally varies from 0 to 3 tons per hectare. But the present results are more in agreement with those of Yakouba et al. [23] who found in 2017 a yield hovering around 0.6 t/ha in Laf, Guividig and Mindif in the same region. These results are not in agreement with those of Raimond [6] who found that the yield ranged from 3 to 4 tons/hectare where there was a yield of 7 t/ha in the Salamat plain of Chad. This difference would be due to the degradation of arable soils over time 20 years later (1999 to 2019).

5. CONCLUSION

The different techniques and methods of cultivation used by farmers in Far North Cameroon are almost the same as those used in other *Muskuwaari* regions of North Cameroon, the Lake Chad Basin and Nigeria, with the same cropping cycles (from July to April in this case) but with different average yields, as this depends strongly on soil type, rainfall, year and temperature, and the mastery of cultivation techniques. The activities carried out during the cropping cycle vary from one farmer to another, with the use of herbicide treatments, the clearing of woody plants, burning, the construction of bunds, the digging or repair of pits, mowing and plowing. These different activities, which are indispensable in most cases, have led to changes in the *Kare* with annual variations in species, the invasion of fields by crop weeds, the denudation of the soil after harvesting, the disappearance of biodiversity, soil erosion and the advance of the desert. The results of the study confirm the need to develop and apply alternative measures for sustainable *Karal* exploitation.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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