

December 31, 2025



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DOI: [10.5281/zenodo.17840632](https://doi.org/10.5281/zenodo.17840632)

## Motorized Tillage Effects on Rice Growth and Yield in the Senegal River Valley: The Case of the Ndiaye Mberess and Lampsar Rice Fields

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### Author Contributions

This work was carried out in collaboration between all the authors. Authors Cheick Atab Mane and Ibrahima Boubacar FALL collected the data and drafted the manuscript. Authors Siré Diédhiou, Arfang Ousmane Kémo Goudiaby and Niokhor Bakhom contributed to editing and proofreading the manuscript. Authors Guillaume Gillet and Mohamed SALL helped proofread the final document. All authors read and approved the final manuscript.

Received Date: 28-Oct-2025

Accepted Date: 30-Nov-2025

Published Date: 31-Dec-2025

### Abstract

*The modernization of rice-growing in Senegal, particularly in the river valley, through the use of agricultural machinery, has made it possible to reduce tillage, increase cultivated areas and improve yields. Nevertheless, the suitability of the machinery used and its effect on rice cultivation remain unknown. Then, the aim of this work was to determine the effects of different motorized tillage on rice growth and yield in field conditions. The study was carried out using a nested experimental design with a primary factor (tillage modality) and a nested secondary factor (tillage depth) and was installed at 2 sites (Ndiaye Mbéress and Lampsar) over 2 successive years. Minimum tillage or offsetting with depths 5 cm (Off5), 10 cm (Off10) and 15 cm (Off15) and conventional tillage or ploughing with depths 20 cm (Lab20), 30 cm (Lab30) and 40 cm (Lab40) were carried out. Thus, 6 treatments, repeated 4 times, were applied in 10 x 10 m plots. The results showed that there was significant variation ( $P=2.99e-10$ ) in rice height and rooting depth according to treatment. The highest rice height was obtained at Ndiaye Mberess in year 2 ( $P< 2e-16$ ) for Lab20 (108.7 cm), Lab30 (107.6 cm) and Lab40 (106.4 cm). The Lab40 treatment significantly ( $P=0.00815$ ) improved rice rooting depth. There were no significant differences between sites, treatments or years in terms of rice yield ( $P=0.95$ ) with an averaged from 10 to 17.5 kg ha<sup>-1</sup>.*

**Key words:** ploughing, offsetage, irrigated rice, river valley, yield

## Introduction

In Senegal, the lack of agricultural infrastructures as well as the low level of both input use and adequate mechanization represent the main constraints to the development of the agricultural sector and rice growing in particular (Sarr, 2013). The use of mechanization and/or motorization for agricultural work could be an important factor for improving agricultural production and then a catalyst for rural development. Indeed, agricultural motorization has become an indispensable tool for making cultivation efficient and productive, and would enable farmers to improve their income. It could help as well to increase the cultivated area, and to overcome the time constraints associated with double-cropping per year by a rapid intervention. In the Senegal River valley, the use of agricultural motorization is relatively old; the first machines were introduced after the Second World War (Kanté, 1995). Since, motorization utilization has continued to increase. The motorized operations include pumping, tilling, harvesting, threshing and processing. Most of these operations involve rice growing, the main cereal crop grown in the area. Tillage is generally carried out in the dry, mainly by ploughing (conventional tillage), offsetting (minimum tillage) or ridging (Kanté, 1995). Despite these major advances, rice yields, which had been successful over the years, have been falling. Thus, for the 2019 season, paddy rice production was down 4.2% (ANSD, 2019). Several causes could explain this shortfall including the non-modernization or timid modernization of working tools, the loss of soil fertility, the use of inadequate seeds, but also the appearance and presence of invasive weeds. Indeed, the type of tillage (with or without turning, deep or shallow, with trailed or driven implements) determines the vertical distribution of weed seed stocks, that of mineral elements with low mobility in the soil, and that of crop residues or amendments (Estrade et al. 2020). Even if tillage is not necessarily directed against the flora, it will disrupt the weed community by eliminating plants, modifying the position of seeds in the soil and promoting the germination of new seeds (Chauvel et al., 2018). Numerous studies have shown the appearance of dead soil following inappropriate cultivation practices (Blanchart et al., 2021). Then, poor farming practices and factors such as weeds (Bassène et al., 2012; Mballo et al., 2018) complicate this situation. In the Senegal River valley, weed management in rice plots is generally carried out using chemical herbicides such as Propanil, Weedone and Londax (FAO, 2012), which are harmful to health and the environment. This is partly due to the arduous nature of manual tillage and its inefficiency in some cases. Time spent on weeding accounts for 20-60% of cultivation time (Bassène et al., 2014). However, agricultural motorization could also have adverse effects on soil preservation. Indeed, the phenomenon of soil erosion has increased on farmland, necessitating some actions to limit their impact. The development of motorization and the emergence of increasingly heavy machinery have accentuated the effects of agricultural soil degradation. Changes in farming practices, including mechanized tillage, are leading to soil compaction, organic matter depletion and erosion (Dahou et al, 2018). The efficient and sustainable use of these motorized tools, in particular tillage tools, to improve rice yields while preserving the soil by finding a suitable motorized tillage method to improve rice productivity becomes necessary. Therefore, the aim of this study was to determine the effects of motorized tillage on rice growth and yield.

## 1. Material and methods

### 1.1. Area of study

Our study was carried out in Dagana department in the Senegal River valley, located in the north of Senegal. The area is characterized by its irrigated rice-growing system and is rich in agricultural potential, with rice cultivation taking place over two periods: the winter season and the off-season, as hydro-agricultural facilities have been installed (Figure 1).

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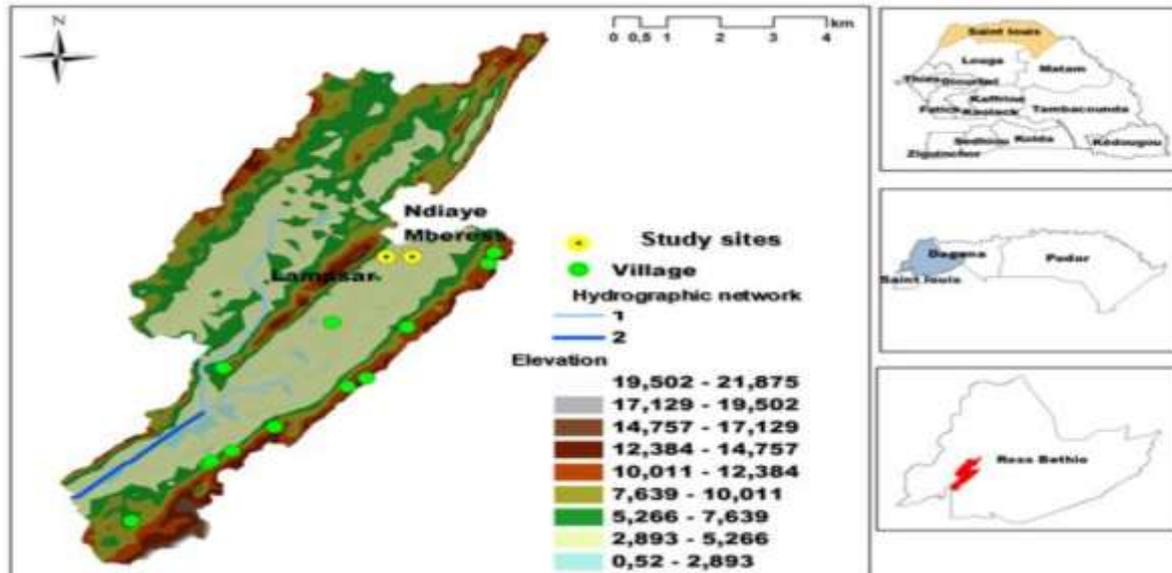


Figure 1: Map of the experimental area

The climate is arid Sahelian, characterized by warm, dry continental trade winds (Harmattan) and maritime trade winds to the west (Dieye, 1994). The continental zone has high temperatures almost all year round, sometimes exceeding 40°C in Podor department. However, the softening influence of the sea to the west is favorable for vegetable production (ANSD, 2021). The dry season is marked by the harmattan, a warm, dry, dust-laden wind (GRDR, 2014).

Rainfall is fairly low between 330 to 400 mm yr<sup>-1</sup> (Figure 2) with a rainy season period from mid-July to mid-October, high temperatures, intense evaporation, and high luminosity (GRDR, 2014).

There are 4 main soil types in the area. The chromic vertisols soils (hollaldé) represent 36% of irrigable potential, these soils are suitable for rice cultivation, but are difficult to work due to their high clay content (50 to 75%) and poor drainage. The eutric fluvisols soils (faux-hollaldé) account 31% of irrigable potential, these soils are suitable for rice cultivation and other crops; they contain 30 to 50% clay, have no structure and poor drainage. The Eutric fluvisols (fondés) with 33% of irrigable potential, and are suitable for all crops except rice; these silty-clay soils have a clay content of 10 to 30% and average drainage. The eutric regosols soils (Diéri) contain 80 to 90% sandy deposits, and can support all crops other than rice (GRDR, 2014).

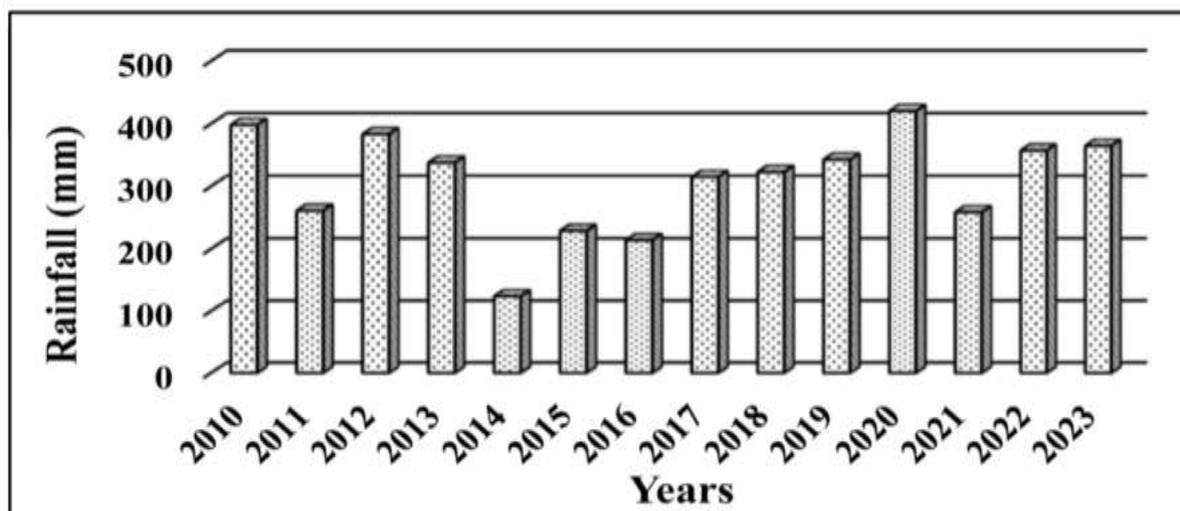


Figure 2. Annual rainfall variation in the Saint-Louis region from 2010 to 2023

Vegetation depends essentially on soil type, available water and topography (Dirk ,1993). Several species are found from the south to the north of the Senegal River valley: *Sterculia setigera* Del., *Combretum glutinosum* Perr. Ex DC, *Sclerocarya birrea* A. Rich. Rich, *Boscia senegalensis* Pers, *Acacia senegal* (L.) Wild, *Cenchrus biflorus* Roxd.), *Euphorbia balsamifera* Ait, *Commiphora africana* (A. Rich.) Endl.), *Acacia nilotica* (L.) Wild. Ex Delile, *Mimosa pigra* L., *Echinochloa colona* (L.) Link and *Aeschynomene ssp* L. (Van Lavieren et al., 1988).

### 1.2. Experimental design

A complete randomized block design with a single factor (tillage) was set up at each of the two sites (Ndiaye Mbéress and Lampsar) with 6 treatments and 4 replications: Two tillage modalities were selected, with 3 depths for each modality: minimum tillage (Off5 = offsetting or minimum tillage at 5 cm depth, Off10 = offsetting or minimum tillage at 10 cm depth and Off15 = offsetting or minimum tillage at 15 cm depth) and conventional tillage (Lab20 = ploughing or conventional tillage at 20 cm depth, Lab30 = ploughing or conventional tillage at 30 cm depth and Lab40 = ploughing or conventional tillage at 40 cm depth). The minimum tillage consisted of offsetage or offsetting, which involves working the soil without turning it over, superficially mixing the organic matter. Conventional tillage involved ploughing with a share plough, based on cutting and turning a strip of land. Each of the 6 treatments was applied to a 10\*10 m square plot randomly distributed in each sub-block for each of the 2 sites (figure 5). The sub-blocks and treatments were spaced by 1 m apart to limit external influences from one plot to another. The total surface area of the blocks is therefore 0.48 ha, or 0.24 ha for each site. In total, 6\*4=24 plots were installed at each site.

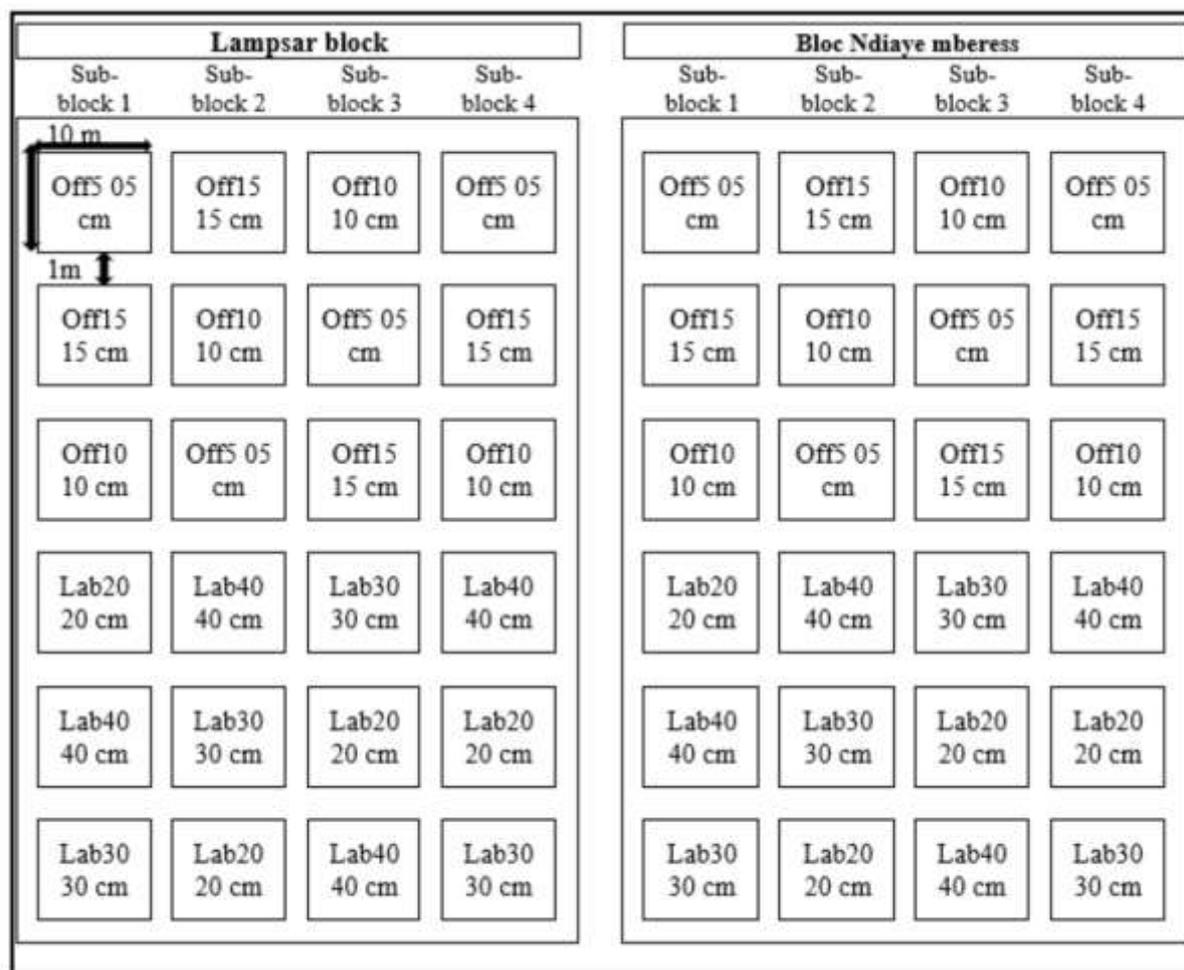


Figure 3: Complete randomized block experimental design

### 1.3. Agricultural equipment

A trisoc plough was hitched to an agricultural tractor for conventional tillage or ploughing to a depth of between 20 and 40 cm for the Lab20, Lab30 and Lab40 treatments. For the Off5, Off10 and Off15 treatments, an offset sprayer was attached to the same farm tractor for minimum or superficial tillage between 5 and 15 cm depth.

#### **1.4. Plant material**

The rice variety Sahel 108, suitable for the irrigated Sahelian zones of West Africa, was used. Sahel 108 has low ginning and a potential yield of 10 t ha<sup>-1</sup>. Production increases by almost 11% in the rainy season (WARDA, 1998).

#### **1.5. Crop management**

##### ***-Sowing***

Broadcast sowing was carried out at a water depth of 5 cm. Thus, for each experimental unit, 1 kg of certified seed of the sahel 108 variety was used representing 80 to 120 kg ha<sup>-1</sup>, i.e. an average of 100 kg ha<sup>-1</sup>. It should be noted that the seeds were first soaked in water for 24 hours to lift the dormancy.

##### ***-Irrigation***

Water management in the plots followed the method adopted by SAED (Lage et al. 1996) in the Senegal River valley, which takes into account the development phases of the rice plants. This involved maintaining a 5 cm water gap during the vegetative phase; a 10 cm water gap during the reproductive phase; and finally, total drainage of the plot at the doughy stage, leaving a dry soil for rice maturation. The method has been adapted to allow herbicide application as well as urea application.

##### ***-Fertilization***

Fertilization was carried out in two ways: as bottom dressing and as top dressing. The base fertilizer consisted of 100 kg ha<sup>-1</sup> of ammonium phosphate (DAP) 18-46-0, applied during tillage, i.e. 1 kg of DAP per experimental unit (SAED, 2001). Urea was applied as a cover dressing in three applications averaging 275 kg ha<sup>-1</sup>. Each treatment unit received a dose of 2.75 Kg of urea. The following proportions were applied during the study: 40% as the first application (at the start of tillering), i.e. 1.1 Kg per experimental unit; 40% as the second application (at panicle initiation), i.e. 1.1 Kg per experimental unit and 20% as the third application (at bolting), i.e. 0.55 Kg per experimental unit.

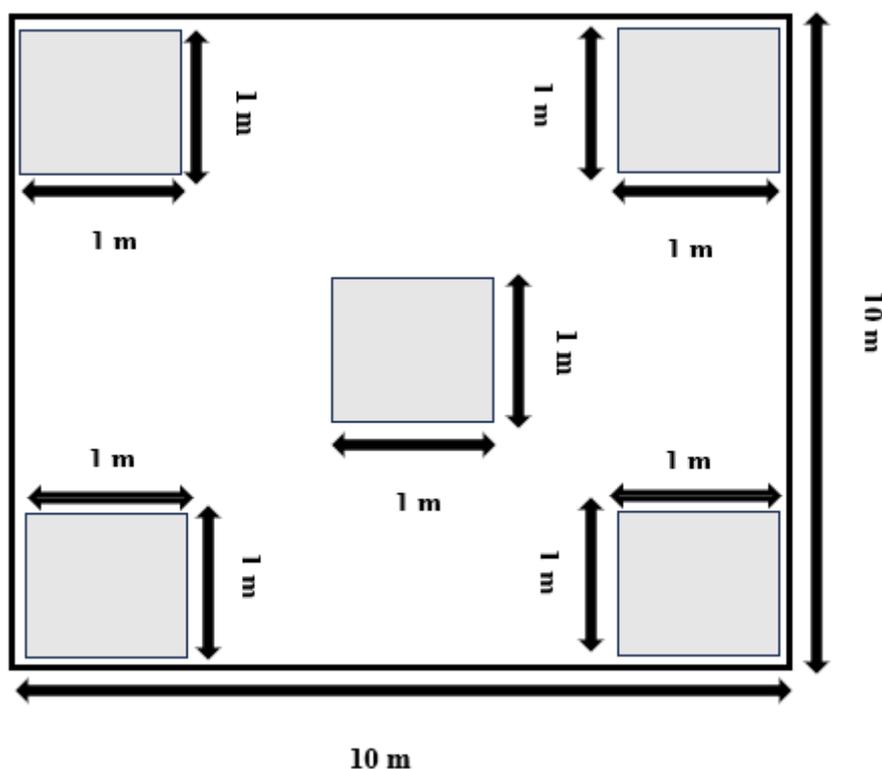
##### ***-Phytosanitary treatments***

To control weeds, rice plots were treated on the 40th day after sowing with systemic herbicides such as Propanil combined with Weedone at a dose of 8 to 10 L ha<sup>-1</sup> and 11 L ha<sup>-1</sup>, respectively (SAED, 2001).

#### **1.6. Data collection**

##### **1.6.1. Agromorphological parameters of rice**

The collection of agromorphological data for rice involved measurements and/or estimates of parameters during the vegetative phase at 15 days after sowing (DAS), reproductive phase at 50 DAS and mature phase at 80 DAS. The following parameters were determined: height, rooting depth, number of roots per plant, total root length. Measurements were taken on 10 plants selected randomly from each experimental unit. For data collected at maturity, 5 yield squares measuring 1 m x 1 m were set up in each elementary plot (Figure 4).



**Figure 4.** Yield square diagram at elementary plot level

Manual harvesting was then carried out in the yield squares for each experimental unit. The above-ground and root biomass, number of plants, number of panicles per plant, number of grains per panicle, number of full and infertile grains, mass of 1000 grains and yield were evaluated in each yield square.

#### **1.6.2. Plant height**

The height of the rice plants was measured from the collar of the rice plants to the top of the longest leaf on 10 plants randomly selected by UE at 15 JAS, 50 JAS and 80 JAS. The average height was then calculated.

#### **1.6.3. The number and length of roots**

On 10 randomly selected plants, the number and length of all roots per plant were determined and averages calculated. The total root length per plant was then deduced.

#### **1.6.4. Rooting depth**

Rooting depth per plant was determined by measuring the depth of the longest root from the collar.

#### **1.6.5. Aboveground and root biomass**

Above-ground and root biomass were determined after air-drying. Dry matter was then weighed using a 0.01 precision balance.

#### **1.6.6. The number of plants and tillers**

The number of tillers was measured after rice harvest at 80 days after sowing (DAS).

#### **1.6.7. The average number of panicles per plant**

The average number of panicles per plant was obtained by dividing the number of panicles per yield square by the number of plants in the square.

#### **1.6.8. The weight of 1000 grains**

The 1000-grain weight was determined in the laboratory using the Numigral seed counter. The seeds were weighed on a 1/1000 precision balance. They were then averaged to obtain the average weight of 1000 grains per treatment. This weight is expressed in grams (g).

#### **1.6.9. Rice yield**

The grains collected in each square were weighed to obtain the yield per square. Subsequently, the yield per hectare (ha) was obtained by extrapolating the average yield of the squares in each treatment. Grain yield is expressed in kilograms per hectare,  $\text{kg ha}^{-1}$  (Ovono et al., 2013; Karambiri, 2016).

$$\text{Rendement (kg/ha)} = \frac{\text{Poids du produit des carrés de rendement (kg)}}{\text{m nombre de carrés (m}^2\text{)}} \times 10\,000 \text{ m}^2$$

## 1.7. Statistical analysis

Data obtained from plant growth and yield were statistically analysed using one way Analysis of variance (ANOVA) with R software version 4.4.1. The Student–Newman–Keuls range test ( $P < 0.05$ ) was performed to indicate the level of differences between the means.

## 2. Results

### 2.1. Effect of motorized tillage on plant height

The height of rice plants was significantly influenced by tillage, irrespective of treatment ( $P=7.28e-07$ ), experimental year ( $P=1.20e-06$ ) and measurement date ( $P=2e-16$ ) at Ndiaye Mberesse. Data in Table 1 showed that there was a significant difference ( $P=7.28e-07$ ) between the Off15 treatment (19.52 cm) and the Lab20 (16.86 cm), Lab30 (16.05 cm) and Lab40 (15.79) treatments at 15 DAS in year 1. A significant variation in plant height was noted in the second year too. The Lab20 treatment (22.07 cm) significantly influenced plant height compared with the Off10 (19.02 cm), Off15 (18.57 cm), Lab30 (19.3 cm) and Lab40 (19.47 cm) treatments. At 50 DAS, plants from the Off5 treatment (55.93 cm) were the tallest compared with the Lab20 (50.92 cm) and Lab40 (50.51 cm) treatments in the first year. In the second year of experimentation, the Off 15 treatment, with a height of 42.81 cm, gave the greatest height compared with the Off10 (36.17 cm), Lab20 (37.55 cm), Lab30 (37.88 cm) and Lab40 (37.32 cm) treatments. However, there was no significant difference at 80 days after surgery ( $P=0.264$ ). At 80 days, the Off5 treatment (86.43 cm) gave the greatest variation in height compared with the Off10 (81.82 cm), Off15 (81.29 cm), Lab20 (80.60 cm), Lab30 (82.69 cm) and Lab40 (81.89 cm) treatments in the first year. In general, the heights were much greater in the second year compared with the first, except those measured at 50 DAS.

At Lampsar, in the first year of experimentation, the height was strongly influenced by the Off15 treatment (21.48 cm) compared with the Lab20 (19.60 cm) and Lab30 (19.62 cm) treatments at 15 days after sowing. At 50 and 80 days, the tallest plants were found in Off5 and Lab40, respectively compared with the other treatments. In the second year, no significant difference ( $P=0.264$ ) in height was noted between treatments during the vegetative phase. At 50 and 80 DAS, the heights obtained in the Off5 (45.70 cm) and Lab20 (109.89 cm) treatments, respectively were the highest compared with the others. Overall, the heights obtained in the first year are much higher than those recorded in the second year, with the exception of those measured during the maturity phase (80 days after planting) (Table 1).

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**Tableau 1.** Variation in rice plants height regarding the tillage, the year and the site

| Treatments            | Plants height (cm)       |                       |                   |                            |                       |                    |                        |                        |                    |
|-----------------------|--------------------------|-----------------------|-------------------|----------------------------|-----------------------|--------------------|------------------------|------------------------|--------------------|
|                       | 15 DAS, Vegetative stage |                       |                   | 50 DAS, Reproductive stage |                       |                    | 80 DAS, Maturity stage |                        |                    |
|                       | Year1                    | Year2                 | Diff(Year2-Year1) | Year1                      | Year2                 | Diff( Year2-Year1) | Year1                  | Year2                  | Diff( Year2-Year1) |
| <b>Ndiaye Mbéress</b> |                          |                       |                   |                            |                       |                    |                        |                        |                    |
| Off5                  | 18,78 <sup>abBC*</sup>   | 20,23 <sup>abAB</sup> | 1,45              | 55,93 <sup>aA</sup>        | 39,80 <sup>abDE</sup> | -16,13             | 86,43 <sup>aB</sup>    | 124,39 <sup>aA</sup>   | 37,96              |
| Off10                 | 18,17 <sup>abBCD</sup>   | 19,02 <sup>bBC</sup>  | 0,85              | 54,85 <sup>abAB</sup>      | 36,17 <sup>bE</sup>   | -18,68             | 81,82 <sup>bC</sup>    | 124,22 <sup>bA</sup>   | 42,4               |
| Off15                 | 19,52 <sup>aB</sup>      | 18,57 <sup>bBC</sup>  | -0,95             | 54,59 <sup>abcABC</sup>    | 42,81 <sup>aD</sup>   | -11,78             | 81,29 <sup>bC</sup>    | 124,70 <sup>aA</sup>   | 43,41              |
| Lab20                 | 16,86 <sup>bcCDE</sup>   | 22,07 <sup>aA</sup>   | 5,21              | 50,92 <sup>bcBC</sup>      | 37,55 <sup>bE</sup>   | -13,37             | 80,60 <sup>bC</sup>    | 126,67 <sup>aA</sup>   | 46,07              |
| Lab30                 | 16,05 <sup>cDE</sup>     | 19,3 <sup>bB</sup>    | 3,25              | 53,75 <sup>abcABC</sup>    | 37,88 <sup>bE</sup>   | -15,87             | 82,69 <sup>bC</sup>    | 124,17 <sup>aA</sup>   | 41,48              |
| Lab40                 | 15,79 <sup>cE</sup>      | 19,47 <sup>bB</sup>   | 3,68              | 50,51 <sup>cC</sup>        | 37,32 <sup>bE</sup>   | -13,19             | 81,89 <sup>bC</sup>    | 124,73 <sup>aA</sup>   | 42,84              |
| <b>Lampsar</b>        |                          |                       |                   |                            |                       |                    |                        |                        |                    |
| Off5                  | 20,68 <sup>abAB</sup>    | 18,49 <sup>aCD</sup>  | -2,19             | 72,28 <sup>aC</sup>        | 45,70 <sup>aD</sup>   | -26,58             | 77,56 <sup>cE</sup>    | 104,22 <sup>abAB</sup> | 26,66              |
| Off10                 | 20,78 <sup>abAB</sup>    | 18,21 <sup>aCD</sup>  | -2,57             | 68,06 <sup>abABC</sup>     | 41,09 <sup>bD</sup>   | -26,97             | 81,61 <sup>bD</sup>    | 102,93 <sup>bB</sup>   | 21,32              |
| Off15                 | 21,48 <sup>aA</sup>      | 18,55 <sup>aCD</sup>  | -2,93             | 64,53 <sup>bC</sup>        | 44,52 <sup>abD</sup>  | -20,01             | 81,02 <sup>bD</sup>    | 105,44 <sup>abAB</sup> | 24,42              |
| Lab20                 | 19,60 <sup>bBC</sup>     | 17,49 <sup>aD</sup>   | -2,11             | 69,10 <sup>abABC</sup>     | 41,84 <sup>abD</sup>  | -27,26             | 77,25 <sup>cE</sup>    | 109,89 <sup>aA</sup>   | 32,64              |
| Lab30                 | 19,62 <sup>bBC</sup>     | 18,31 <sup>aCD</sup>  | -1,31             | 69,52 <sup>abAB</sup>      | 42,65 <sup>abD</sup>  | -26,87             | 77,54 <sup>cE</sup>    | 101,86 <sup>bB</sup>   | 24,32              |
| Lab40                 | 20,18 <sup>abAB</sup>    | 18,51 <sup>aCD</sup>  | -1,67             | 66,08 <sup>bBC</sup>       | 44,75 <sup>abD</sup>  | -21,33             | 84,17 <sup>aC</sup>    | 101,11 <sup>bB</sup>   | 16,94              |

Values in the same column with identical letters are not statistically different at the 5% threshold, Student-Newman-Keuls (SNK) test. DAS: day after sowing; Diff: difference

## 2.2. Effect of motorized tillage on rice root growth

The root system significantly varied across treatments, experimental time and sites ( $P=0.00105$ ). The Off5 treatment significantly increased the number of roots in the first year, compared with the Off10, Lab30 and 40 treatments. The lowest number of roots was noted in the Off5 treatment in year 2 at Ndiaye Mberess.

Root depth was strongly influenced by the Off5 treatment in year 1 compared with the other treatments. However, there was no significant difference between treatments in the second year. A decrease in root number and an increase in rooting depth in year 2 at Ndiaye Mberess.

At Lampsar, no significant influence of the different treatments on root number and root length was noted in the first year ( $P=0.41360$ ). However, the Lab20 treatment (11.90 roots and 70.89 cm) increased these two parameters in the second year ( $P=0.03037$ ). The same trend was noted for root depth. In fact, no significant difference ( $P=0.49548$ ) was obtained in the first year. However, in the second year, it was the Lab40 treatment (10.59) that increased root depth. Generally, these parameters were greater in the second year compared with the data obtained in the first year, with the exception of root number, which was higher in the first year compared with the second (Table 2).

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**Table 2:** Variation in the rice root system in the vegetative phase (15 days after sowing) regarding the tillage, the year and the site.

| Treatments            | Root number/plant      |                        |                   | Root total length/plant |                         |                   | Root depth           |                      |                    |
|-----------------------|------------------------|------------------------|-------------------|-------------------------|-------------------------|-------------------|----------------------|----------------------|--------------------|
|                       | Yera1                  | Yera2                  | Diff(Yera2-Yera1) | Yera1                   | Yera2                   | Diff(Yera2-Yera1) | Yera1                | Yera2                | Diff(Yera2- Yera1) |
| <b>Ndiaye Mbéress</b> |                        |                        |                   |                         |                         |                   |                      |                      |                    |
| <b>Off5</b>           | 12,35 <sup>aA</sup>    | 8,65 <sup>aDEFG</sup>  | -3,7              | 71,88 <sup>aA</sup>     | 36,45 <sup>aD</sup>     | -35,43            | 4,35 <sup>bD</sup>   | 7,88 <sup>aAB</sup>  | 3,53               |
| <b>Off10</b>          | 10,30 <sup>bBCD</sup>  | 8,15 <sup>abFG</sup>   | -2,15             | 61,52 <sup>aABC</sup>   | 33,68 <sup>aD</sup>     | -27,84            | 5,26 <sup>abCD</sup> | 7,61 <sup>aAB</sup>  | 2,35               |
| <b>Off15</b>          | 11,20 <sup>abAB</sup>  | 7,35 <sup>bG</sup>     | -3,85             | 69,24 <sup>aAB</sup>    | 33,28 <sup>aD</sup>     | -35,96            | 6,47 <sup>aBC</sup>  | 6,47 <sup>aA</sup>   | 0                  |
| <b>Lab20</b>          | 10,80 <sup>abABC</sup> | 8,90 <sup>aDEFG</sup>  | -1,9              | 55,75 <sup>aC</sup>     | 37,41 <sup>aD</sup>     | -18,34            | 5,42 <sup>abCD</sup> | 7,63 <sup>aAB</sup>  | 2,21               |
| <b>Lab30</b>          | 10,15 <sup>bBCDE</sup> | 8,60 <sup>abEFG</sup>  | -1,55             | 57,97 <sup>aBC</sup>    | 36,21 <sup>aD</sup>     | -21,76            | 5,40 <sup>abCD</sup> | 7,87 <sup>aAB</sup>  | 2,47               |
| <b>Lab40</b>          | 9,30 <sup>bCDEF</sup>  | 8,35 <sup>abFG</sup>   | -0,95             | 55,95 <sup>aC</sup>     | 35,86 <sup>aD</sup>     | -20,09            | 6,03 <sup>abC</sup>  | 8,54 <sup>aA</sup>   | 2,51               |
| <b>Lampsar</b>        |                        |                        |                   |                         |                         |                   |                      |                      |                    |
| <b>Off5</b>           | 15,60 <sup>aAB</sup>   | 10,35 <sup>bcCD</sup>  | -5,25             | 74,98 <sup>aABC</sup>   | 60,73 <sup>bcEF</sup>   | -14,25            | 3,96 <sup>aC</sup>   | 9,58 <sup>abAB</sup> | 5,62               |
| <b>Off10</b>          | 14,20 <sup>aB</sup>    | 10,90 <sup>abcCD</sup> | -3,3              | 70,4 <sup>aBCDE</sup>   | 61,64 <sup>bcDEF</sup>  | -8,76             | 4,23 <sup>aC</sup>   | 9,27 <sup>bB</sup>   | 5,04               |
| <b>Off15</b>          | 16,00 <sup>aAB</sup>   | 11,45 <sup>abCD</sup>  | -4,55             | 82,81 <sup>aA</sup>     | 66,32 <sup>abCDE</sup>  | -16,49            | 4,06 <sup>aC</sup>   | 9,48 <sup>bAB</sup>  | 5,42               |
| <b>Lab20</b>          | 14,95 <sup>aAB</sup>   | 11,90 <sup>aC</sup>    | -3,05             | 73,34 <sup>aABCD</sup>  | 70,89 <sup>aABCDE</sup> | -2,45             | 3,58 <sup>aC</sup>   | 9,78 <sup>abAB</sup> | 6,2                |
| <b>Lab30</b>          | 16,40 <sup>aA</sup>    | 9,90 <sup>cD</sup>     | -6,5              | 75,82 <sup>aABC</sup>   | 53,35 <sup>cF</sup>     | -22,47            | 4,70 <sup>aC</sup>   | 9,40 <sup>bAB</sup>  | 4,7                |
| <b>Lab40</b>          | 14,80 <sup>aAB</sup>   | 10,80 <sup>abcCD</sup> | -4                | 81,56 <sup>aAB</sup>    | 66,63 <sup>abCDE</sup>  | -14,93            | 4,06 <sup>aC</sup>   | 10,59 <sup>aA</sup>  | 6,53               |

Values in the same column with identical letters are not statistically different at the 5% threshold, Student-Newman-Keuls (SNK) test. Diff: difference

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The Off10 and Off15 treatments respectively increased root number (129.65; 140.60 roots), root length (1782.25; 1954.65 cm) and root depth (16.48; 15.75) during the reproductive phase (50 DAS) compared with the other treatments in year 1 at Ndiaye Mberess. However, no significant difference was noted in year 2 between treatments for these same parameters ( $P=0,678$ ) and the same site. Essentially, these parameters are much more important in year 1 against year 2 at Ndiaye Mberess.

At Lampsar, the Off5, Off10 and Off15 treatments particularly influenced root number in year 1. No significant difference was noted between treatments in year 2. The same trend was observed for root length in years 1 and 2. In fact, no significant difference was observed between treatments in years 1 and 2 ( $P=0.491$ ). As for root depth, the analysis showed that the Off10 treatment gave the least benefit to root depth during this phase. The best measurements of these parameters were recorded in the second year of experimentation at this site (Table 3).

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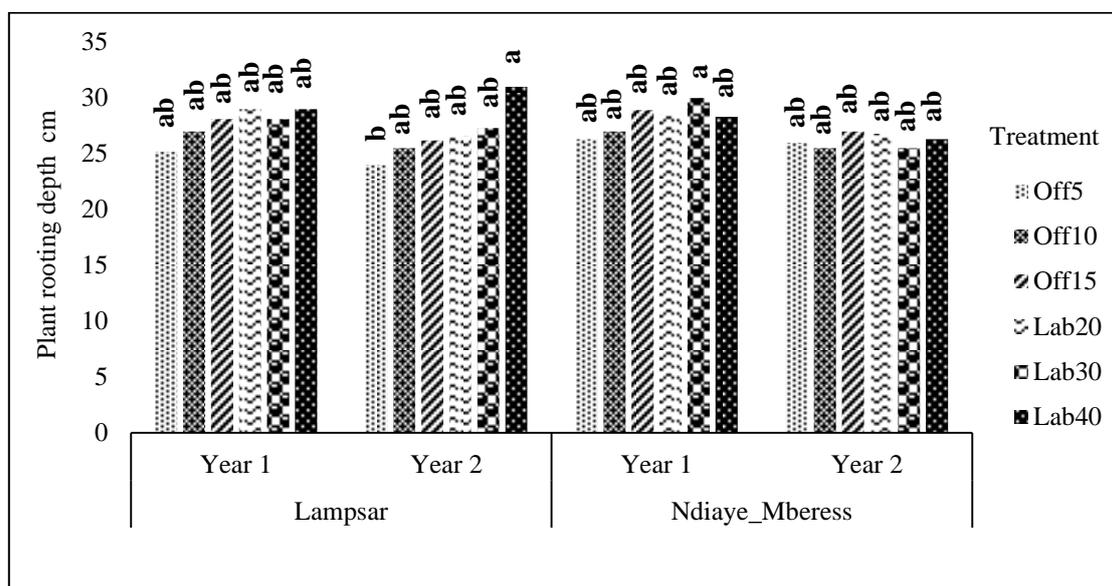
**Table 3:** Variation of rice root system in reproductive phase (50 days after sowing) regarding the tillage, the year and the site

| Treatments            | Root number/plant       |                       |                    | Root total length/plant   |                        |                    | Root depth              |                         |                    |
|-----------------------|-------------------------|-----------------------|--------------------|---------------------------|------------------------|--------------------|-------------------------|-------------------------|--------------------|
|                       | Year1                   | Year2                 | Diff(Year2- Year1) | Year1                     | Year2                  | Diff(Year2- Year1) | Year1                   | Year2                   | Diff(Year2- Year1) |
| <b>Ndiaye Mbéress</b> |                         |                       |                    |                           |                        |                    |                         |                         |                    |
| Off5                  | 97,92 <sup>bcC</sup>    | 95,30 <sup>aC</sup>   | -2,62              | 1317,67 <sup>bcCD</sup>   | 1172,31 <sup>aD</sup>  | -145,36            | 14,50 <sup>bcCD</sup>   | 20,43 <sup>aA</sup>     | 5,93               |
| Off10                 | 129,65 <sup>abAB</sup>  | 94,80 <sup>aC</sup>   | -34,85             | 1782,25 <sup>abAB</sup>   | 1181,62 <sup>aD</sup>  | -600,63            | 13,55 <sup>cD</sup>     | 21,02 <sup>aA</sup>     | 7,47               |
| Off15                 | 140,60 <sup>aA</sup>    | 107,3 <sup>abC</sup>  | -33,3              | 1954,65 <sup>aA</sup>     | 1300,38 <sup>aCD</sup> | -654,27            | 16,48 <sup>abBC</sup>   | 21,22 <sup>aA</sup>     | 4,74               |
| Lab20                 | 103,33 <sup>abcBC</sup> | 94,40 <sup>aC</sup>   | -8,93              | 1320,92 <sup>abcACD</sup> | 1093,70 <sup>aD</sup>  | -227,22            | 15,75 <sup>abcBCD</sup> | 20,20 <sup>aA</sup>     | 4,45               |
| Lab30                 | 83,75 <sup>cC</sup>     | 90,70 <sup>aC</sup>   | 6,95               | 1110,44 <sup>cD</sup>     | 1182,62 <sup>aD</sup>  | 72,18              | 15,60 <sup>abcCD</sup>  | 20,76 <sup>aA</sup>     | 5,16               |
| Lab40                 | 103,00 <sup>bcBC</sup>  | 99,90 <sup>aC</sup>   | -3,1               | 1720,70 <sup>abABC</sup>  | 1177,96 <sup>aD</sup>  | -542,74            | 17,45 <sup>aB</sup>     | 20,14 <sup>aA</sup>     | 2,69               |
| <b>Lampsar</b>        |                         |                       |                    |                           |                        |                    |                         |                         |                    |
| Off5                  | 113,29 <sup>aAB</sup>   | 116,60 <sup>aA</sup>  | 3,31               | 1403,34 <sup>aA</sup>     | 1446,32 <sup>aA</sup>  | 42,98              | 16,78 <sup>aDE</sup>    | 20,93 <sup>bABC</sup>   | 4,15               |
| Off10                 | 104,25 <sup>aAB</sup>   | 104,93 <sup>aAB</sup> | 0,68               | 1113,35 <sup>aA</sup>     | 1293,8 <sup>aA</sup>   | 180,45             | 11,83 <sup>bG</sup>     | 19,85 <sup>bcBCD</sup>  | 8,02               |
| Off15                 | 100,95 <sup>aAB</sup>   | 123,40 <sup>aA</sup>  | 22,45              | 1363,63 <sup>aA</sup>     | 1342,92 <sup>aA</sup>  | -20,71             | 15,53 <sup>aEF</sup>    | 19,86 <sup>bcABCD</sup> | 4,33               |
| Lab20                 | 65,42 <sup>bc</sup>     | 111,60 <sup>aAB</sup> | 46,18              | 1358,5 <sup>aA</sup>      | 1372,09 <sup>aA</sup>  | 13,59              | 15,15 <sup>abEF</sup>   | 21,58 <sup>abAB</sup>   | 6,43               |
| Lab30                 | 88,42 <sup>abBC</sup>   | 108,80 <sup>aAB</sup> | 20,38              | 1155,44 <sup>aA</sup>     | 1294,56 <sup>aA</sup>  | 139,12             | 17,03 <sup>aDE</sup>    | 18,69 <sup>cCD</sup>    | 1,66               |
| Lab40                 | 101,80 <sup>aAB</sup>   | 100,40 <sup>aAB</sup> | -1,4               | 1162,45 <sup>aA</sup>     | 1391,85 <sup>aA</sup>  | 229,4              | 14,15 <sup>abFG</sup>   | 23,09 <sup>aA</sup>     | 8,94               |

Values in the same column with identical letters are not statistically different at the 5% threshold, Student-Newman-Keuls (SNK) test. Diff: difference

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During the maturity phase, root depth varied significantly ( $P=0.00667$ ) between the Lab40 and Off5 treatments in the second year of experimentation at the Lampsar site. However, no significant difference ( $P=0.83516$ ) was observed between treatments at Ndiaye Mberess. The deepest roots of around 30 cm were observed on the Lampsar site in the second year of experimentation with the Lab40 treatment (Figure 5).



**Figure 5:** Variation in plant rooting depth as a function of tillage, year and site at maturity (80 days after sowing).

Treatments assigned the same letter are not statistically different at the LSD threshold of 5% according to Fisher's test.

### 2.3. Effect of motorized tillage on rice root biomass

Results recorded in Table 4 reveals a significant difference between treatments ( $P=0.00105$ ) and years of trialling ( $P=0.02909$ ). The Off5, Off15, and Lab20 treatments yielded the highest rice root biomass in year 1 compared to the other treatments. In year 2, the Off5 and Off15 treatments recorded the highest rice root biomass in Ndiaye Mberess. The highest biomass was recorded in year 1 against year 2. The same tendency was observed in Lampsar, the Off5 treatment in year 1 and, the Off5 and Off10 treatments in year 2 produced the highest root biomass. Generally, the biomass obtained in the first year was much higher than in the second year.

### 2.4. Effect of motorized tillage on rice shoot biomass

In Ndiaye Mberess, the Lab20 treatment significantly influenced the above-ground biomass of rice in the first year. In the second year, the treatment that had the least influence on biomass was Lab40. However, no difference was noted in the first year between the treatments in Lampsar. The smallest variation was obtained with the Lab30 treatment. This aboveground biomass varies significantly from one year to the next ( $p=3.75e-05$ ). The highest biomass was observed at Lampsar in the first year with the experiment with the Off15, Lab20, and Lab40 treatments, 246.63, 294.32, and 260.57 g of above-ground biomass, respectively (Table 4).

### 2.5. Effect of motorized tillage on rice packing

The number of tillers varied depending on the site ( $P=0.000404$ ), the year of experimentation ( $P=2.99e-10$ ), and the treatments ( $P=0.001169$ ). The Lab20 and Off10 treatments improved rice tillering compared to the others in the first and second years at Ndiaye Mberess, respectively. In general, the number of tillers was higher in the second year than in the first year.

In Lampsar, a significant difference was noted between the Off15 and Lab30 treatments and the other treatments in the first year. In the second year, the Lab40 treatment resulted in the best variation in the

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number of tillers compared to the others. The number of tillers varied depending on the year. The highest number of shoots was noted at the Lampsar site, more in year 1 (14.64 shoots) than in year 2 (12.35 shoots) (Table 4).

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**Table 4:** Variation in number of tillers, root and shoot biomass of rice as a function of tillage, year and site

| Treatments            | Number of tillers     |                       |                   | Shoot biomass/m <sup>2</sup> |                       |                   | Root biomass/m <sup>2</sup> |                          |                   |
|-----------------------|-----------------------|-----------------------|-------------------|------------------------------|-----------------------|-------------------|-----------------------------|--------------------------|-------------------|
|                       | Year1                 | Year2                 | Diff(Year2-Year1) | Year1                        | Year2                 | Diff(Year2-Year1) | Year1                       | Year2                    | Diff(Year2-Year1) |
| <b>Ndiaye Mbéress</b> |                       |                       |                   |                              |                       |                   |                             |                          |                   |
| Off5                  | 14,46 <sup>aA</sup>   | 13,35 <sup>aAB</sup>  | -1,11             | 217,21 <sup>bcBC</sup>       | 129,47 <sup>aEF</sup> | -87,74            | 77,39 <sup>abDEF</sup>      | 116,64 <sup>aAB</sup>    | 39,25             |
| Off10                 | 13,06 <sup>abAB</sup> | 11,05 <sup>bcB</sup>  | -2,01             | 169,08 <sup>cDE</sup>        | 138,09 <sup>aEF</sup> | -30,99            | 51,58 <sup>bF</sup>         | 80,90 <sup>bcDEF</sup>   | 29,32             |
| Off15                 | 14,22 <sup>aA</sup>   | 13,00 <sup>aAB</sup>  | -1,22             | 246,63 <sup>abBC</sup>       | 134,77 <sup>aEF</sup> | -111,86           | 76,74 <sup>abDEF</sup>      | 116,29 <sup>aAB</sup>    | 39,55             |
| Lab20                 | 13,92 <sup>aA</sup>   | 10,40 <sup>cB</sup>   | -3,52             | 294,32 <sup>aA</sup>         | 129,29 <sup>aEF</sup> | -165,03           | 93,58 <sup>abCD</sup>       | 126,92 <sup>aA</sup>     | 33,34             |
| Lab30                 | 10,74 <sup>cB</sup>   | 11,55 <sup>bcB</sup>  | 0,81              | 203,77 <sup>bcCD</sup>       | 121,02 <sup>abF</sup> | -82,75            | 61,33 <sup>abEF</sup>       | 119,87 <sup>aAB</sup>    | 58,54             |
| Lab40                 | 11,60 <sup>bcB</sup>  | 11,60 <sup>bcB</sup>  | 0                 | 260,57 <sup>abAB</sup>       | 105,35 <sup>bF</sup>  | -155,22           | 81,87 <sup>abCDE</sup>      | 106,64 <sup>aABC</sup>   | 24,77             |
| <b>Lampsar</b>        |                       |                       |                   |                              |                       |                   |                             |                          |                   |
| Off5                  | 14,64 <sup>aA</sup>   | 12,25 <sup>aBC</sup>  | -2,39             | 237,02 <sup>aC</sup>         | 103,49 <sup>aD</sup>  | -133,53           | 59,93 <sup>bE</sup>         | 83,08 <sup>bcCDE</sup>   | 23,15             |
| Off10                 | 13,53 <sup>abAB</sup> | 12,35 <sup>aBC</sup>  | -1,18             | 272,81 <sup>aABC</sup>       | 110,31 <sup>aD</sup>  | -162,5            | 97,90 <sup>abABC</sup>      | 95,89 <sup>abABC</sup>   | -2,01             |
| Off15                 | 11,53 <sup>cC</sup>   | 11,10 <sup>bc</sup>   | -0,43             | 304,72 <sup>aA</sup>         | 101,84 <sup>aD</sup>  | -202,88           | 117,18 <sup>aA</sup>        | 95,64 <sup>abABCD</sup>  | -21,54            |
| Lab20                 | 12,43 <sup>bcBC</sup> | 11,20 <sup>bc</sup>   | -1,23             | 271,60 <sup>aABC</sup>       | 96,43 <sup>abD</sup>  | -175,17           | 72,86 <sup>bcCDE</sup>      | 91,74 <sup>abABCDE</sup> | 18,88             |
| Lab30                 | 13,49 <sup>abAB</sup> | 11,05 <sup>bc</sup>   | -1,99             | 298,04 <sup>aAB</sup>        | 81,20 <sup>bD</sup>   | -216,84           | 119,34 <sup>aA</sup>        | 90,57 <sup>abABCDE</sup> | -28,77            |
| Lab40                 | 13,44 <sup>abAB</sup> | 11,85 <sup>abBC</sup> | -1,59             | 252,76 <sup>aBC</sup>        | 102,70 <sup>aD</sup>  | -150,06           | 64,47 <sup>bDE</sup>        | 109,82 <sup>aAB</sup>    | 45,35             |

Values in the same column with identical letters are not statistically different at the 5% threshold, Student-Newman-Keuls (SNK) test. Diff: difference

## 2.6. Effect of motorized tillage on rice paddy's weight

The paddy weight varied significantly depending on the treatments. Indeed, the Lab20 and Off15 treatments significantly influenced the paddy weight in years 1 and 2, respectively, in Ndiaye Mberess.

In Lampsar, the Off5, Off10 and Off15 treatments significantly improved the paddy weight in the first year. However, no significant difference was noted in the second year. The paddy weight was generally higher in absolute terms in the second year, regardless of the site. Table 19 shows no significant difference between sites ( $P=0.376$ ) or between years of experimentation ( $P=0.950$ ) (Table 5).

## 2.7. Effect of motorized tillage on rice 1000 grains weight

The analysis of variance revealed a significant difference between treatments ( $P=0.000683$ ). However, no difference was noted between sites ( $P=0.5014$ ). The highest thousand-seed weight was measured in the Lab20 treatment in the first year and in the Off15 treatment in the second year at Ndiaye Mberess. The weight harvested in the first year was higher (Lab20=25.25) than that obtained in the second year. At Lampsar, no significant difference was noted in the first year. However, in the second year, the Lab40 treatment increased the thousand-seed weight (Table 5). Overall, the weight recorded was higher in the second year against the first year.

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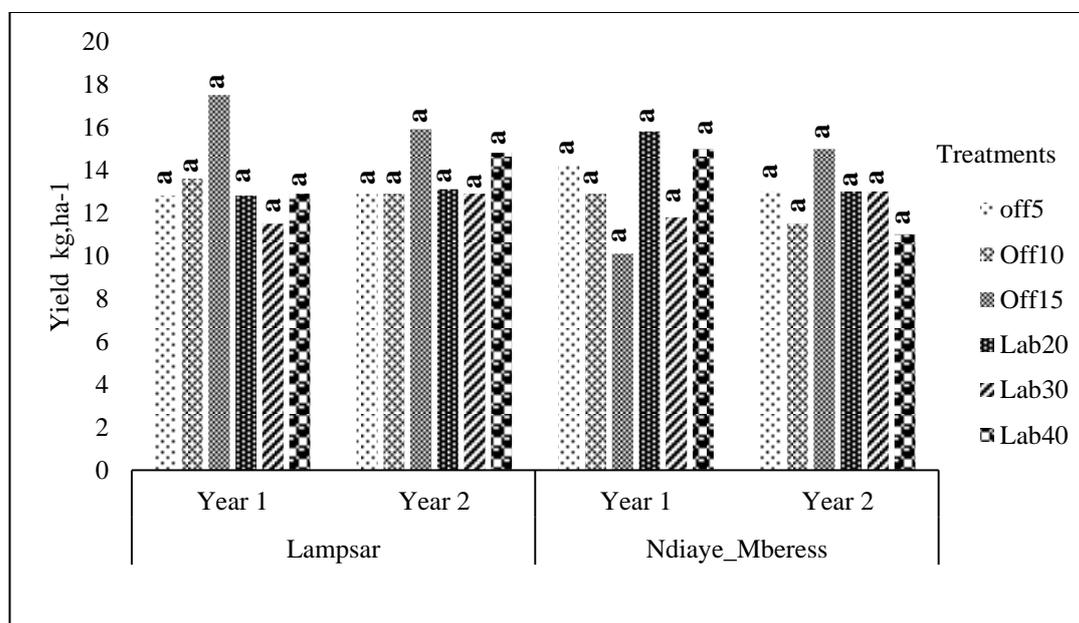
Table 5: Variation in paddy weight (g) and thousand-grain weight (g) depending on soil cultivation, year, and location

| Treatments            | Paddy weight/m <sup>2</sup> |                        |                   | TGW/m <sup>2</sup>     |                         |                   |
|-----------------------|-----------------------------|------------------------|-------------------|------------------------|-------------------------|-------------------|
|                       | Year1                       | Year2                  | Diff(Year2-Year1) | Year1                  | Year2                   | Diff(Year2-Year1) |
| <b>Ndiaye Mbéress</b> |                             |                        |                   |                        |                         |                   |
| Off5                  | 89,87 <sup>abABC</sup>      | 97,97 <sup>abAB</sup>  | 8,1               | 22,36                  | 20,36 <sup>cF</sup>     | -2                |
| Off10                 | 80,97 <sup>abBCD</sup>      | 86,53 <sup>bBCD</sup>  | 5,56              | 22,30 <sup>bcCDE</sup> | 20,91 <sup>cDEF</sup>   | -1,39             |
| Off15                 | 66,36 <sup>bd</sup>         | 112,04 <sup>aA</sup>   | 45,68             | 21,75 <sup>cCDEF</sup> | 23,01 <sup>aBC</sup>    | 1,26              |
| Lab20                 | 100,01 <sup>aAB</sup>       | 97,55 <sup>abABC</sup> | -2,46             | 25,25 <sup>aA</sup>    | 22,93 <sup>abBCD</sup>  | -2,32             |
| Lab30                 | 71,76 <sup>bCD</sup>        | 103,34 <sup>abAB</sup> | 31,58             | 22,34 <sup>bcCDE</sup> | 20,74 <sup>cEF</sup>    | -1,6              |
| Lab40                 | 88,41 <sup>abBCD</sup>      | 96,88 <sup>abABC</sup> | 8,47              | 24,30 <sup>abAB</sup>  | 21,57 <sup>bcCDEF</sup> | -2,73             |
| <b>Lampsar</b>        |                             |                        |                   |                        |                         |                   |
| Off5                  | 73,00 <sup>abBC</sup>       | 101,06 <sup>aAB</sup>  | 28,06             | 20,93 <sup>aD</sup>    | 21,89 <sup>bcBCD</sup>  | 0,96              |
| Off10                 | 102,30 <sup>aAB</sup>       | 103,63 <sup>aAB</sup>  | 1,33              | 21,02 <sup>aCD</sup>   | 21,08 <sup>cCD</sup>    | 0,06              |
| Off15                 | 95,06 <sup>aAB</sup>        | 109,87 <sup>aA</sup>   | 14,81             | 22,21 <sup>aBCD</sup>  | 23,55 <sup>abAB</sup>   | 1,34              |
| Lab20                 | 78,22 <sup>abBC</sup>       | 98,88 <sup>aAB</sup>   | 20,66             | 23,11 <sup>aABC</sup>  | 22,84 <sup>bcBCD</sup>  | -0,27             |
| Lab30                 | 64,21 <sup>bC</sup>         | 95,21 <sup>aAB</sup>   | 31                | 21,01 <sup>aD</sup>    | 23,41 <sup>abAB</sup>   | 2,4               |
| Lab40                 | 101,57 <sup>aAB</sup>       | 114,79 <sup>aA</sup>   | 13,22             | 22,59 <sup>abCD</sup>  | 25,10 <sup>aA</sup>     | 2,51              |

Values in the same column with identical letters are not statistically different at the 5% threshold, Student-Newman-Keuls (SNK) test. Diff: difference; TGW: Thousand grain weight

## 2.8. Effect of motorized tillage on rice yield

Figure 6 showed no significant difference ( $P=0.95$ ) irrespective of site, treatment, or year of experimentation. However, the highest yield of approximately 17.5 kg ha<sup>-1</sup> was recorded in the first year of experimentation at the Lampsar site under treatment Off15.



**Figure 6:** Variation in yield depending on location, trial period, and treatment.

Treatments assigned the same letter are not statistically different at the LSD threshold of 5% according to Fisher's test.

## Discussion

The results of this study show that during the growth phase, the variables used to verify the effects of plowing or offset on rice growth were quite discriminating. Indeed, in view of the results, minimum tillage treatments performed better than deep tillage treatments, particularly for the variables height, number of roots, and total root length. The Off5 and Off15 offset treatments are more prominent from the others. This increase in results with superficial tillage could be explained by the direct effects of minimum tillage (offset) on the growth and development of rice roots, which improves the physical, chemical, and biological properties of the soil for young plants. The upper layers of the soil contain more organic matter in superficial tillage systems than in plowing systems. This is due to the fact that crop residues are not buried in superficial tillage systems. The soil structure influenced by organic matter content is therefore more stable on unplowed soils (Dahou et al., 2018). In soils, organic matter enables agroecosystems to function properly and sustainably by storing and providing the nutrients that plants need. It stimulates biological activities, plays a central role in soil structure, and contributes to its stability against external stresses (rain, compaction, etc). It thus contributes to soil permeability, aeration, water retention capacity and stability. Cultivation techniques promote the maintenance and deterioration of this organic matter in the soil. Surface tillage (direct seeding, minimum tillage) is more suitable than conventional plowing for maintaining organic matter in the soil (Bellemou, 2012). However, for the rooting depth variable, the best performance was obtained with deep tillage treatments, particularly Lab20 and Lab40 plowing treatments. This difference could be linked to the improvement of certain soil parameters, particularly porosity, which promoted good root development. The root growth of cultivated plants is closely related to soil porosity. This effect of porosity on rooting is mainly due to two properties that result from its mechanical resistance to penetration and soil aeration (Chopart, 1980). According to Chopart, plowing improves soil porosity and reduces the mechanical resistance of the soil to root penetration. Dahou et al. (2018) made a comparison of soil physical parameters based on the tillage type and showed that cultivation techniques affect rooting depth. Then, the rooting depth is negatively correlated to the resistance to penetration. The best performance in both sites was achieved with the Lab20 plowing treatment, with 223.6 g m<sup>2</sup> and 107.87 g m<sup>2</sup> for shoot and root biomass, respectively. These results

confirm those obtained for deep tillage treatments in terms of rooting depth, where the best result was obtained with the Lab40 treatment (26.5 cm). This can be explained by the fact that deep tillage improves soil structure, particularly soil porosity, which facilitates root development. Conventional tillage (plowing) therefore promotes better root development compared to minimum tillage and direct seeding (shallow tillage), resulting in better plant rooting depth (Dahou et al., 2018). However, it is interesting to note that only the results of number of tillers and plant height were improved in shallow tillage treatments (Off5): 14.31 and 14.27 of tillers for Ndiaye Mbéress and Lampsar, respectively.

The best performance of grain yield was obtained with shallow tillage using the Off15 treatment. The highest paddy weight and thousand-grain weight per square meter were observed with the Lab20 treatment (100.01 g m<sup>2</sup>, or 1000.1 ha<sup>-1</sup> and 24.09 g m<sup>2</sup>) for the Ndiaye Mbéress site and in the Lab40 treatment (101.57 g m<sup>2</sup>, or 1015.7 kg ha<sup>-1</sup>, and 23.85 g m<sup>2</sup>) for the Lampsar site. This could be explained by the structure of the tilled soils, which promotes better root development and has an impact on yield. According to Bellemou (2012), shallow tillage greatly improves the physical properties of soils, particularly those with a fragile structure.

In addition, these results of this study are consistent with those of Bellemou (2012), who found higher yields on tilled plots compared to those obtained in untilled areas. The same performance of tillage was observed in the researches of Pale et al (2021), where tillage resulted in substantial increases in grain yields of 266 to 635 kg ha<sup>-1</sup> compared to other tillage methods. He was able to clearly demonstrate that tillage, with its beneficial effect of improving soil structure and plant root system development, and therefore productivity, was the best tillage method. All these results highlight the importance of soil cultivation. In addition to cultivation techniques, the depth of cultivation has a decisive impact on crop development. In this study, based on the results for yield parameters, there was a clear difference between the dominance of offset at 15 cm (Off15) and other plowing depths. According to Dahou et al (2018), working depths between 15 and 20 cm are required for good cereal development.

## Conclusion

This study highlighted the effects of tillage on rice growth and yield in the irrigated rice plots of Ndiaye Mberess and Lampsar, located in the Senegal River Valley. Although tillage is effective in improving crop growth and yield, it is crucial to choose the appropriate techniques and use them judiciously to avoid adverse effects. The differences observed between sites and treatments highlight the need for adaptive and site-specific management approaches to achieve long-term results. Thus, comparing minimum tillage (offset) and deep tillage (plowing) methods, deep tillage was found to be the most effective because overall, plowing gave superior results compared to offsetting, in terms of herbaceous plant management. The results of this study showed that there is a significant variation ( $P=2.99e-10$ ) in rice growth parameters between treatments. Thus, treatments Lab20, Lab30, and Lab40 improved rice plant tillers. No significant differences were noted between sites, treatments, and years with regard to the rice yield parameter. Nevertheless, the results revealed that the Off15 treatment at Lampsar and the Lab20 treatment at the Ndiaye Mberess site had the highest rice yields. The highest rice height was obtained at the Ndiaye Mberess site in year 2 of the experiment for treatments Lab20, Lab30, and Lab40. Based on the results obtained in this study, tillage depths between 15 and 20 cm are optimal for promoting the development of rice crops.

Further studies on the optimal cultivation technique and depth of motorised soil tillage for other cereals and cash crops will definitely improve crop productivity and maintain soil fertility.

## Acknowledgements

Authors thank the PEA-PETTAL project/Sine Saloum El Hadji Ibrahima NIASS University, who financially support this work.

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