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Effects of deep urea placement and variety on agromorphological performance of rice (*Oryza sativa* L.) in lowland rice production in Essyl (Enampore commune, Lower Casamance)

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Abstract

This study evaluates the effectiveness of localized application of super granular urea on lowland rice production compared to the farmer practice (FP). To this end, a two-factor Split Plot design was implemented: the practice factor with two modalities, Farmers' Practice (FP) and Deep Urea Placement (DUP), and the variety factor with two modalities, Sahel 108 and Tox 728-1. It was found that the most important height and plants collar diameter were obtained with the practice of deep placement of urea with respectively 68.10 cm and 4.02 cm. A significant effect of variety on growth parameters was also found. Indeed, the variety Tox 728-1 had the greatest height (63.63 cm) and the variety Sahel 108, the largest diameter at the collar (3.81 cm). Overall, the best performance in terms of growth is recorded with the practice of deep placement of urea regardless of variety. Heading was earlier with the variety Sahel 108 under deep urea placement. As for tillering and the number of panicles produced, they are statistically more important with the variety Sahel 108 under deep urea placement with 45±6.61 tillers/m^2 and 192±10.69 panicles/m^2 respectively. Considering the grain yield, it is more important with the DUP whatever the variety. It is 3055±148.39 kg/ha for the variety Sahel 108 and 2877.5±339.12 kg/ha for the variety Tox 728 -1 with this practice. These results indicate that, overall, DUP has a positive effect on the agromorphological parameters of rice in Lower Casamance.

Keywords: Rice; Deep urea placement; Farmer practice; Super granular urea; Essyl

1 Introduction

Rice is one of the most consumed cereals in the world. Since the mid-1990s, it has been the most consumed cereal ahead of millet and corn. However, consumption needs are estimated at between 1.7 and 1.8 million tons (white rice equivalent), or an average annual consumption of about 90 kg/per capita [1].

Rice has a prominent place in the consumption habits of Senegalese populations. Moreover, population growth and increasing urbanization have significantly increased the consumption needs of this commodity, leading Senegal to resort to massive imports. The latter reached a net value of 189, 27 billion FCFA in 2016 or 966,498 tons imported [2], with an average consumption of 80 kg/year per capita, making Senegal one of the largest consumers of rice in Africa. In the Ziguinchor region, the area sown was around 44,900 ha with a production of 139,004 tons and a yield of 3,096 kg/ha in 2019 [3]. In the rainfed system, rice cultivation is generally of the family type, with low yields (1.5 to 2 tons/ha), in contrast to the river valley, where the average is around 6 to 8 tons/ha. As a result, there is an urgent need to implement soil fertility management strategies to improve the yields of this cereal, which is so widely consumed by the population. It is in this context that the final evaluation report of DUNDËL SUUF, executed by the International Fertilizer

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Development Center (IFDC), with funding from USAID, launched a program to disseminate an efficient technology for fertilizer use, namely the Deep Placement of Urea (DUP). It is in this perspective that the National Agency for Agricultural and Rural Consulting (ANCAR) in collaboration with the Department of Agroforestry of the Assane SECK University initiated this study. This study aims to evaluate the influence of deep urea placement on the agromorphological performance of rice compared to the farmers' practice.

Thus, the objective of this study was to evaluate the effects of Deep Urea Placement (DUP) technology on the growth and yield parameters of two rice varieties (Sahel 108 and Tox 728-1).

2 Material and methods

2.1 Presentation of the study area and the experimental site

The study was conducted in the village of Essyl, belonging to the commune of Enampore, arrondissement of Nyassia, department and region of Ziguinchor. This locality belongs to the Lower Casamance, located at latitude 12°33' North and longitude 16°16' West (Figure 1).

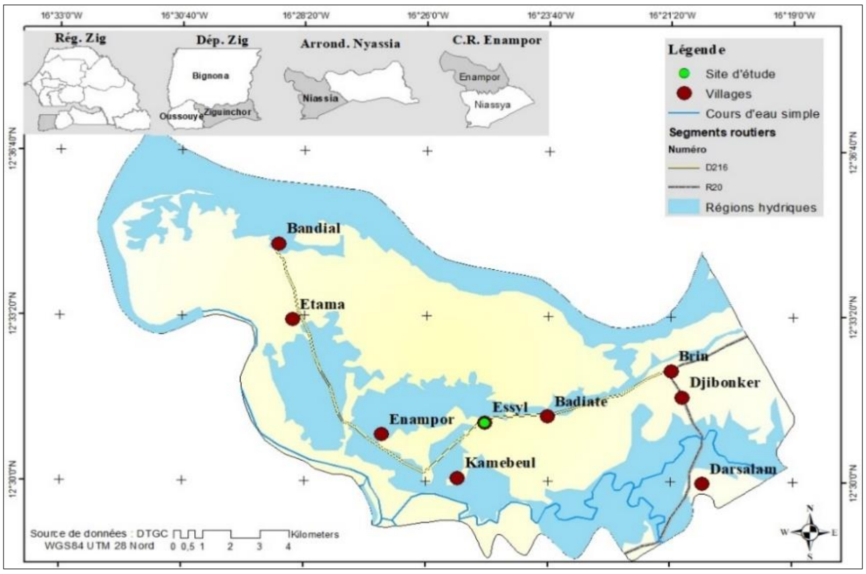


Figure 1 location map of the experimental site

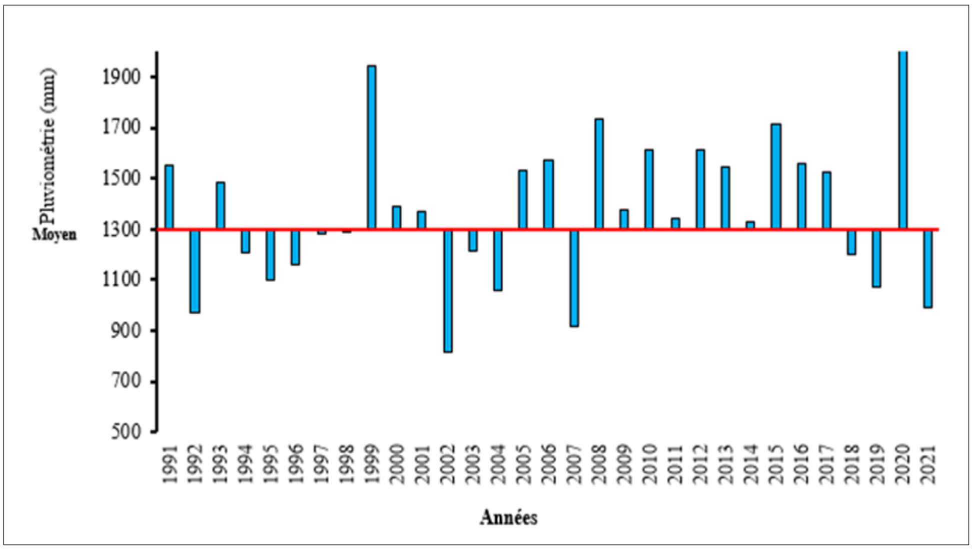


Figure 2 Variation in rainfall from 1991 to 2021 in Lower Casamance recorded at the Ziguinchor regional weather station

This area is influenced by a coastal South Sudanese type climate [4]. The average annual rainfall over the 1991-2021 series is 1300 mm (Figure 2).

The relatively flat terrain of Lower Casamance has several types of soils divided into two main areas: the continental shelf, and the floodplains ([5] ; [6] and [7]). The soils are rich in organic matter. The presence of mineral elements is not homogeneous, some of which are in excess such as iron, which causes iron toxicity [8].

2.2 Plant material

The plant material consists of two varieties of rice (*Oryza sativa* L.) whose seeds were provided by the Agence Nationale du Conseil Agricole et Rural (ANCAR). These varieties are : SAHEL-108 (breeder ISRA-Africa Rice; maturity cycle 105 JAS in wintering and 117 JAS in the off-season) and TOX-728-1 (breeder IITA; maturity cycle 105JAS).

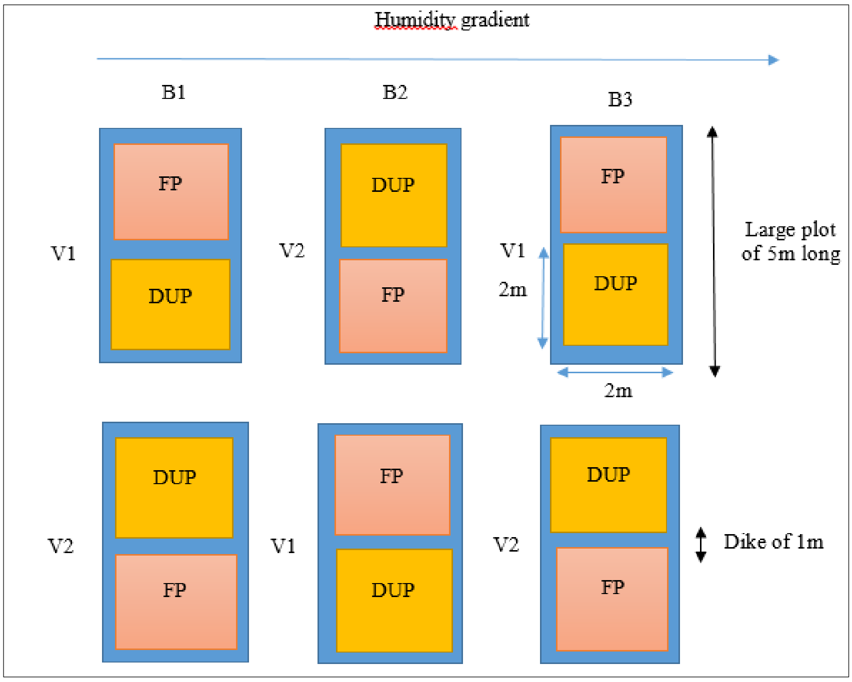
2.3 Methods used

2.3.1 Experimental design

The experimental design used in this study is a split plot with two factors: the variety factor and the practice factor. The variety factor corresponds to the main factor with two modalities (V1 or Sahel 108 and V2 or Tox 728-1). The secondary factor corresponds to the practice with two modalities, namely Deep Urea Placement (DUP) and Farmer Practice (FP).

The system consists of three (3) blocks or replicates. Each block consists of two large plots corresponding to the modalities of the main factor (variety) in which the two modalities of the secondary factor (practice) are randomized. This means a total of 4 elementary plots per block and 12 elementary plots for the whole experimental set-up.

The large plots are 5m long and 2m wide. As for the elementary plots, they have a dimension of 2m×2m, i.e. 4m^2, and are separated by a 1m wide dike (Figure 3).



Legend: V1: Sahel 108 variety and V2: Tox 728-1 variety; FP: Farmer's Practice and DUP: Deep Urea Placement

Figure 3 Diagram of the experimental device

2.3.2 Conduct of the trial

The crop was planted after a 21-day nursery for both varieties. The plots were ploughed twice with a tractor and then a third ploughing was done with a "kadjandou" before transplanting the plants.

The seedlings from the nursery were then transplanted at a distance of 20 cm between plants at the plot level at a rate of one plant per cluster. The plots were then delimited in these plots using string and stakes.

For the farmer practice (FP), farmers use NPK 15-15-15 fertilizer at a rate of 150 kg/ha and Urea at a rate of 50kg/ha which they broadcast.

For the practice of Deep Placement of Urea (DPU), a first application of DAP 18-46-0 fertilizer at the rate of 150 kg/ha was made just after transplanting. Then, 7 days after transplanting, Super Granular Urea (SGU) was placed deep between four rice clumps (Figure 4) at a rate of 113 kg/ha over the entire plot.

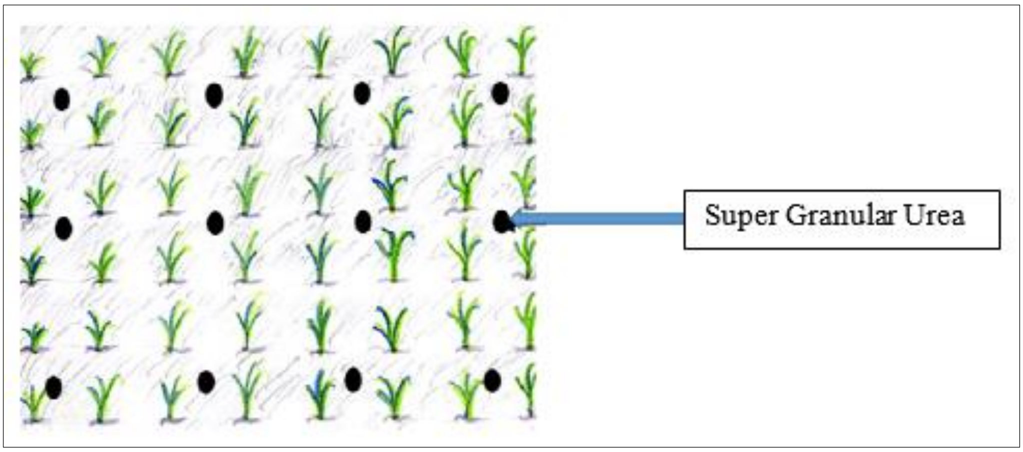


Figure 4 How super granular urea is used [9]

Weeding is done regularly to prevent the spread of weeds.

2.3.3 Observations and measurements

Observations and measurements were made on the agromorphological parameters.

- Morphological parameters of rice

Number of tillers produced
The number of tillers/m2 was assessed at 60 days after sowing by counting the number of tillers produced in 4 randomly selected clusters in each elementary plot;

Height and plant collar diameter
The height and plants collar diameter at 35, 50, 65 and 80 days after sowing were measured on 4 randomly selected clusters in each elementary plot.

The height was determined using a tape measure (Figure 5b) and the diameter at the plant collar using a caliper (Figure 5a).

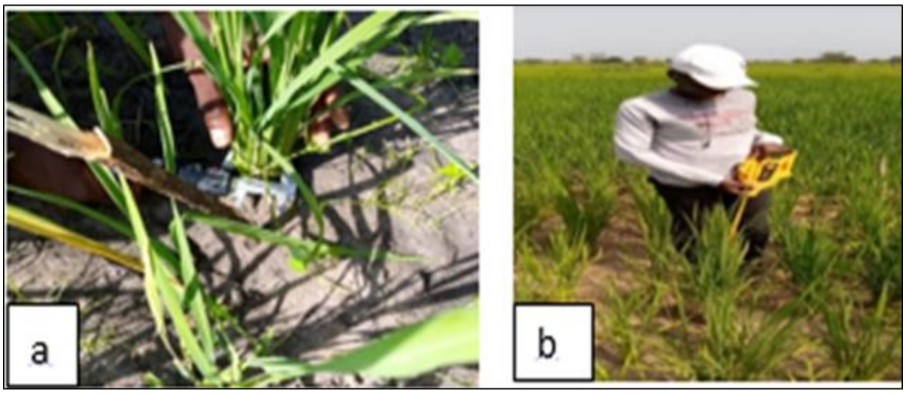


Figure 5 Measurement of the height (a) and plants collar diameter (b)

- Production parameters

50% heading date
It corresponds to the number of days after transplanting when 50% of the plants have produced ears in each elementary plot.

100% heading date
It corresponds to the number of days after transplanting after which 100% of the plants have produced ears in each elementary plot.

Straw and panicle biomass
In each elementary plot, the rice plants were cut flush with the ground (Figure 6a), and the straw and panicles were separated and weighed on the spot to determine the fresh weight. The straw was then oven-dried (Figure 6b) for 3 days at 70°C and the panicles were sun-dried for 15 days and weighed (Figure 6c) to determine dry weight.

Grain weight
The weight of grains/m^2 was evaluated by weighing the grains with an electronic scale (Figure 6e) obtained after harvesting and ginning the panicles at the level of the elementary plot.

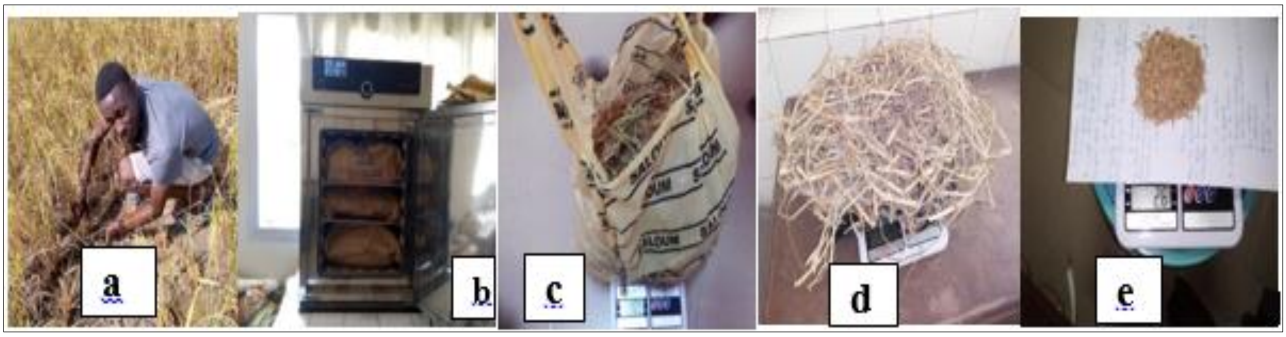


Figure 6 Rice harvest (a), straw drying (b) and weighing of panicles (c), straw (d), and grains (e)

Panicle production
The number of panicles/m2 was evaluated by counting panicles on all plants at each elementary plot.

Sterility rate
The sterility rate was evaluated by counting the empty grains in a batch of 100 grains taken from each elementary plot.

1000-grain weight
The 1000-grain weight was determined by evaluating the average weight of three 1000-grain batches at the working plot level of each elementary plot.

Harvest index
The rice harvest index is calculated using the following formula:

$$IR=Grain\ Yield/Grain\ Yield + Straw\ Yield$$

2.3.4 Data processing and analysis

The collected data were entered with the Excel spreadsheet and then subjected to an analysis of variance (ANOVA) with XLSTAT software (2014). The Student-Newman-Keuls (SNK) test was applied for the comparison of means for each parameter at the 5% significance level. Then a Principal Component Analysis (PCA) was used to graphically identify the practice and variety that gave the best results for the agromorphological parameters studied.

3 Results

3.1 Growth parameters of rice

3.1.1 Plant height

Statistical analysis revealed a very highly significant effect of practice ($p < 0.0001$) and highly significant effect of variety ($p = 0.009$) on plant height.

Indeed, considering the practice, the plant height recorded with the Deep Urea Placement (DUP) is statistically greater (68.10 cm) than that obtained with the farmer practice (52.52 cm) (Figure 5A).

For the variety factor, the greatest rice plant height was obtained with the variety Tox 728-1 (63.63 cm) compared to a height of 57 cm for the variety Sahel 108 (Figure 7B).

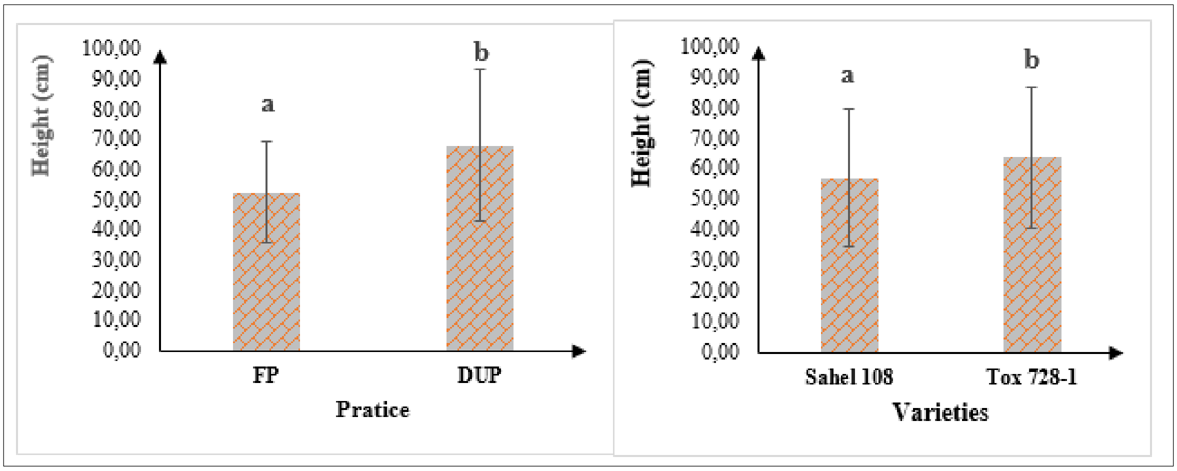


Figure 7 Variation in rice plant height by practice (A) and variety (B)

Analysis of the table below indicates that there is no significant difference in plant height between treatments at 35th (p=0.24) and 50th (p=0.79) days of age. However, there was a significant effect of treatments on rice plant height at 65th (p=0.025) and 80th (p=0.009) days.

Indeed, at the 65th and 80th DAS, the variety Tox 728-1 with Deep Urea Placement (DUP) gave the best result with 80±6.76 cm and 107.83±5.10 cm respectively (Table 1).

Table 1 Variation in plant height (cm) according to treatments and number of days after sowing

Treatments	Days after sowing			
	35 JAS	50 JAS	65 JAS	80 JAS
Sahel 108_PP	29.91±7.52a	44.58±9.43a	57.166±6.48a	70.9±8.49a
Sahel 108_PPU	32.08±8.53a	55.83±10.88a	71.25±11.78ab	94.25±17.76ab
Tox 728_1 PP	34.08±6.08a	44.25±1.63a	63.16±0.94ab	76.09±0.38a
Tox 728_1 PPU	45.83±2.98a	57.75±2.88a	80±6.76b	107.83±5.10b
Moyenne	35.47±2.41	50.6±4.62	67.89±4.42	87.27±7.34
P-value	0.24NS	0.79NS	0.025*	0.009N**

In the same column, values with identical letters are not significantly different. *: significant; **: highly significant; ***: very highly significant; NS: not significant

3.1.2 Plants collar diameter

Statistical analysis revealed a highly significant (P<0.0001) effect of practice and significant effect of variety on the rice plants collar diameter.

Indeed, it appears that rice plants collar diameter is significantly larger with the Deep Urea Placement (4.02 cm) compared to that recorded with the Farmer's Practice (FP), which is 3.11 cm (Figure 8 A).

Considering variety, the largest rice plant collar diameter (3.81 cm) was recorded with the variety Sahel 108 (Figure 8B).

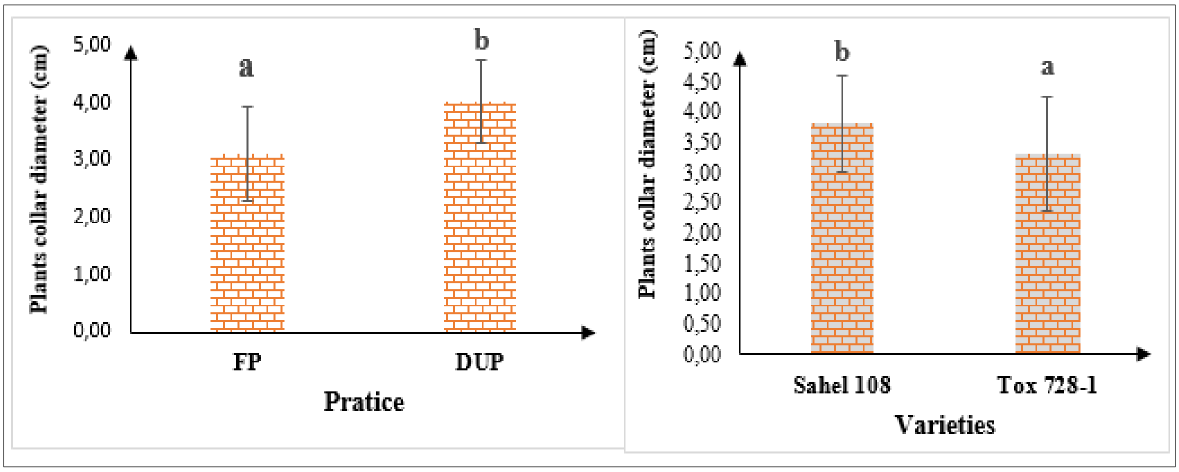


Figure 8 Variation in rice plants collar diameter by practice (A) and variety (B)

It appears from the analysis of Table 2 that the treatments did not induce any significant difference in the rice plants collar diameter at 35 and 65 days after the harvest. However, at 50 and 80 days of age, there was a significant difference in the mean of plant collar diameter between treatments.

Indeed, at 50th DAS, the mean of rice plants collar diameter of the variety Tox 728-1 with FP (2.66±0.39 cm) is statistically lower than that recorded for the same variety with PPU (4.46±0.84 cm). This mean rice plant collar diameter is also significantly lower than that obtained for the variety Sahel 108 regardless of practice (Table 2).

At 80 days before harvest, the largest mean rice plant collar diameter was observed for the variety Sahel 108 under PPU (4.41±0.55 cm). This plant collar diameter is statistically larger than that recorded with the variety Tox 728-1 subjected to PP (2.7±0.56 cm) (Table 2).

Table 2 Variation of the mean of rice plants collar diameter (cm) according to the treatments and the number of days after sowing

	Number of days after sowing			
Treatments	**35 JAS**	**50 JAS**	**65 JAS**	**80 JAS**
Sahel 108_PP	2.60±1.12a	3.85±0.71b	4.058±0.39a	3.59±0.49ab
Sahel 108_PPU	3.23±0.44a	4.23±0.35b	4.475±0.31a	4.41±0.55b
Tox 728-1_PP	2.23±0.36a	2.66±0.39a	3.13±0.79a	2.7±0.56a
Tox 728-1_PPU	3.91±0.69a	4.46±0.84b	4.125±0.90a	3.3±0.63ab
Moyenne	2.99±0.33	3.80±0.24	3.947±0.29	3.50±0.057
P-value	0.238NS	0.02*	0.468NS	0.02*

In the same column, values with identical letters are not significantly different.; *: significant; **: highly significant; ***: very highly significant; NS: not significant

3.2 Production parameters

3.2.1 Earliness of rice heading

Statistical analysis showed that the treatments significantly influenced the 50% and 100% heading dates of rice. Indeed, the variety Tox 728-1, subjected to FP showed a later heading with 130±3 JAS and 140±6c JAS respectively for the 50% and 100% heading dates (Table 3). The earliest heading was recorded with the variety Sahel 108 subjected to DUP with 95±2 JAS and 106±2 JAS for 50% and 100% heading dates respectively (Table 3).

Table 3 Variation in earliness of rice heading according to treatments

Treatments	50% heading date	100% heading date
Sahel 108_PP	103±2.31b	113±4.04a
Sahel 108_PPU	95±2a	106±2a
Tox 728-1_PP	130±3d	140±6c
Tox 728-1_PPU	115±2.31c	124±2.08b
Moyenne	111±0.42	121±1.897
P-value	0.026*	0.0001***

In the same column, values with identical letters are not significantly different.; *: significant; **: highly significant; ***: very highly significant; NS: not significant

3.2.2 Yield components

The analysis of Table 4 showed that there was a significant difference in the number of tillers/m^2 (NT/m^2), the number of panicles produced/m^2, the weight of panicles produced/m^2. The sterility rate and thousand kernel weight (MGW) did not vary significantly between treatments (Table 4).

The highest number of tillers produced per m^2 (NT/m^2) was recorded with the variety Sahel 108, regardless of the practice to which it was subjected. It produced 45±6.61 and 45±4.33 tillers/m^2 for PPU and PP respectively (Table 4).

The number of panicles produced/m^2 was statistically higher for the variety Sahel 108 under UIP (192±10.69 panicles/m^2) than for the same variety under CP (119±36.02 panicles/m^2). As for the variety Tox 728-1, it did not present any significant difference in terms of panicle production between the practices even though in absolute value it recorded the highest results with the PPU (Table 4).

Table 4 Variation of rice yield components with treatments

Treatments	Yield components				
	NT/m^2	nb panicules/m^2	Taux stér. (%)	Pds Pan. (g/m^2)	PMG
Sahel 108_PP	45±4.33b	119±36.02a	34±7.94a	144.92±55.91a	22.66±0.88a
Sahel 108_PPU	45±6.61b	192±10.69b	20±11.59a	339.67±36.01b	22.89±1.02a
Tox 728-1_PP	29±7.64a	104±1.73a	27±11.15a	220.42±38.72ab	24.66±0.34a
Tox 728-1_PPU	37±3.82ab	130±38.97a	28±7.23a	321.62±106.97b	26.33±173a
Moyenne	39±1.82	136±18.47	27±2.21	256.67±32.91	24.14±0.58
P-value	0.02*	0.01**	0.245^{NS}	0.02*	0.346^{NS}

In the same column, values with identical letters are not significantly different.; *: significant; **: highly significant; ***: very highly significant; NS: not significant; Legend: NT: number of tillers; pds Pan: panicle weight; PMG: thousand grain weight; Sterility rate: sterility rate

The highest weight of panicles produced/m^2 was obtained with the variety Sahel 108 subjected to PPU (339.67±36.01 g/m^2) followed by the variety Tox 728-1 subjected to PPU (321.62±106.97 g/m^2) (Table 4).

Although the rate of grain sterility did not vary significantly between treatments in absolute value, it was lower with the variety Sahel 108 subjected to PPU (20±11.59%) (Table 4).

Overall, it appears that the variety Sahel 108 subjected to PPU gave the best results in terms of number of tillers produced/m², number of panicles/m², sterility rate and panicle weight.

3.2.3 Rice yields and harvest index

Analysis of Table 5 reveals significant variation in grain yield and straw yield between treatments with probabilities of 0.001 and 0.04 respectively. As for the harvest index (HI), it does not vary significantly between treatments (P= 0.38).

Indeed, for both grain and straw yields, the best results were obtained with the variety Sahel 108 subjected to PPU with 3055±148.39 kg/ha and 922.5±95.78 kg/ha respectively (Table 5). The lowest yields were recorded with the same variety subjected to PP with 1325±141.86 kg/ha and 333.55±60.18 kg/ha respectively (Table 5).

The harvest index was not influenced by the treatments. And the values of this index greater than 0.5 for all treatments indicate that regardless of the treatment, grain production is higher than straw production.

Table 5 Variation of yields and harvest index according to treatments

Treatments	**Yields**		**Harvest index (IR)**
	Grain yield (kg/ha)	**straw yield (kg/ha)**	
Sahel 108 PP	1325±141.86a	333.55±60.18a	0.806±0.04a
Sahel 108 PPU	3055±148.39b	922.5±95.78b	0.77±0.026a
Tox 728-1 PP	2012.5±160.22ab	431.45±2.43ab	0.82±0.027a
Tox 728-1 PPU	2877.5±339.12b	663.95±131.16ab	0.819±0.028a
Moyenne	2371.5±94.79	587.86±54.91	0.804±0.006
P-value	0.01**	0.04*	0.375NS

In the same column, values with identical letters are not significantly different; *: significant; **: highly significant; ***: very highly significant; NS: not significant

3.3 Relationship between the treatments and the parameters studied

The inertia and eigenvalues of the different factorial axes of the Principal Component Analysis (PCA) are presented in Table 6. The eigenvalues are higher for the first two axes with 6.97 and 3.74 respectively for the F1 and F2 axes. These first two axes represent respectively 58.12% and 31.19% of inertia, i.e. a cumulative inertia of 89.31%. The factorial plane constituted by these two axes F1 x F2 thus allows a good representation of the information contained in the matrix.

Table 6 Distribution of eigenvalues and inertia along the PCA factorial axes

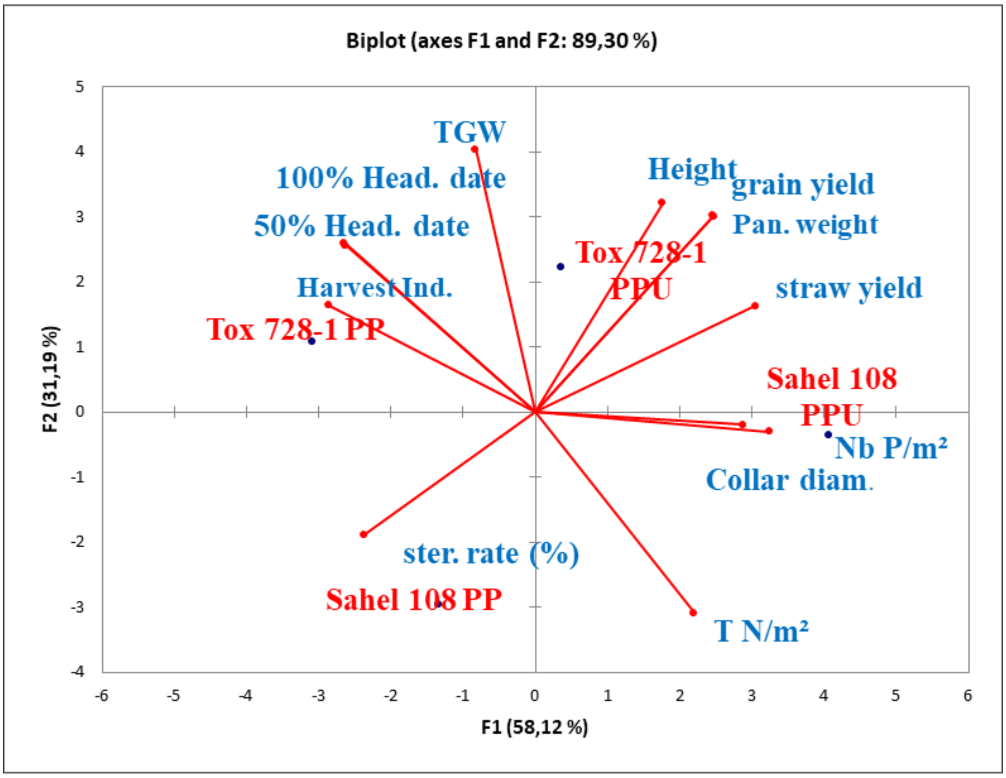
	F1	**F2**	**F3**
Eigenvalues	6.97	3.74	1.28
Inertia (%)	58.12	31.19	10.70
Cumulative inertia (%)	58.11	89.31	100

The analysis of Figure 9 allowed us to distinguish three (3) groups:

- the group represented by the varieties Tox 728_1 and Sahel 108 subjected to the practice of Deep Urea Placement (DUP). This group is characterized by high plant height, high grain and straw yields, high weight and number of panicles produced/m², high Tousand Grains Weight, high plant collar diameter and low grain sterility rate;
- the group represented by the variety Sahel_108 under the farmers' practice (FP). This group is characterized by high tillering, high sterility rate, low grain and straw yields and low height;

- and finally the group represented by the variety Tox 728-1 subjected to the farmer's practice (FP) which is characterized by a high harvest index, a late heading.

Analysis of the correlation between the variables studied reveals a good correlation between plant height and grain and straw yields. This means that rice plants with a high height have high grain and straw yields. There was also an inverse correlation between grain and straw yield and sterility rate, indicating a low sterility rate for plants with good grain and straw yield.



Legend: WTG: Thousand Grains Weight; pan. Weight: weight of panicles; T N: Tillers Number; Ster. rate: Sterility rate, 50% Head. Date: 50% heading date, 100% Head. Date: 100% heading date, Harvest Ind. : Harvest Index

Figure 9 Relationship between the treatments and the parameters studied

4 Discussion

Rice growth parameters showed significant variation by variety and practice. The variety Tox 728-1 showed significantly higher height and crown diameter than the variety Sahel 108. This variation could be related to genetic factors. Indeed, it is accepted by several authors, that variations between varieties could depend on the one hand on environmental effects and on the other hand on genotype-environment interaction effects [10]; [11] . The results obtained also showed that the DUP significantly influenced the growth parameters studied.

Indeed, considering the practice, the plant height recorded with the Deep Urea Placement (DUP) was statistically higher (68.10 cm) than the one obtained with the Farmer Practice (52.52 cm). This could be explained by the greater efficiency of the use of super granular urea by the rice plants compared to the farmer's practice where urea is broadcast with significant losses due to leaching and nitrogen volatilization. These results corroborate those of [9] who testify to the clear importance of supplying urea in the super granular form to the lowland rice crop due to the permanent presence of water in the environment.

Also, statistical analysis showed that the treatments significantly influenced the 50% and 100% heading dates of rice. Indeed, the earliest heading date was obtained with the Sahel 108 variety under deep urea placement (DUP).

For the number of tillers produced, our results showed that tillering is more influenced by variety than by practice. For the same variety, there were no significant differences in tillering according to practice. However, tillering was significantly higher with the variety Sahel 108. This result could be related to the genetic characteristics of the varieties.

These results are in line with those of [12] and [13], according to whom tillering capacity is a genetic trait that allows certain varieties to present an ability to maintain their high water potential. Indeed, the high performance of tillering constitutes according to several authors, a morphological mechanism of drought tolerance, by allowing the plant to cover the soil and reduce evapotranspiration ([14] ; [15]).

The results of this study in terms of panicle production showed that nitrogen fertilization, in the form of urea super granules, provides a higher number of panicles than that obtained with the farmer's practice. Indeed, the highest panicle production was obtained with the variety Sahel 108 under DUP (192±10.69 panicles/m^2) compared to that observed for the same variety under FP (119±36.02 panicles/m^2). This can be explained by the fact that urea application favors the development of fertile tillers, resulting in a highly significant increase in the number of panicles produced/m^2. These results are in line with those of [16] who found that the number of panicles is significantly influenced by the dose and form of nitrogen. Similar results were obtained in Bangladesh by [17] who found variability in panicle number with N source. They are also consistent with [18] who reported that nitrogen dose significantly increases the number of panicles per unit area.

According to [19], varieties that produce more fertile tillers give high yield, this is confirmed with the variety Sahel 108 for both grain and straw yield. Indeed, the variety Sahel 108 subjected to DUP gave higher grain and straw yields with 3055±148.39 kg/ha and 922.5±95.78 kg/ha respectively. The lowest yields were recorded with the same variety subjected to PP with 1325±141.86 kg/ha and 333.55±60.18 kg/ha respectively. The yields obtained with UIP, in this study are close to the upper limit (3.038 t/ha) given in the WARDA report [20]. This reflects the good performance of super granular urea compared to the farmer practice in terms of yield.

The agronomic performance induced by the super granular forms of fertilizer testifies to the suitability of these inputs to the conditions for good rice plant development. In addition, the nutrients contained in urea, particularly nitrogen, ensure that the different phases of plant growth and development evolve well.

The sterility rate, Thousand Grain Weight (TGW), and harvest index (HI) did not vary significantly between treatments. However, in absolute value, the thousand grain weight (TGW) recorded its highest value with the variety Tox 728-1 subjected to DUP (26.33±1.73 g).

5 Conclusion

This study showed that the Deep Urea Placement (DUP) technology induced better agronomic performance compared to the Farmer's Practice (FP) and independently of the variety.

Of the two varieties studied, the variety Tox 728-1 subjected to the DUP technology gave the greatest height. On the other hand, the variety Sahel 108 subjected to the same technology recorded the best results concerning the plant collar diameter, the yields, the tillering and the panicular production.

Thus, with a view to sustainable management of soil fertility and sustainable improvement of upland rice productivity in Lower Casamance, it would be important to :

- promote the deep placement of urea in rice cultivation in the Lower Casamance,
- understand the influence of the interaction of different cultivation techniques used by farmers with the DUP on the nutrient use efficiency and agronomic performance of these two varieties
- to experiment with the technology of deep placement of urea in irrigated rice production in Lower Casamance

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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