

# Influence of Organic and Mineral Fertilizer on Soil Properties and Performance of Rice (*Oryza sativa*) in Casamance, Senegal

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**How to cite this paper:** Diedhiou, P.C.C., Sokhna, P.S., Sambou, A. and Sissoko, S. (2025) Influence of Organic and Mineral Fertilizer on Soil Properties and Performance of Rice (*Oryza sativa*) in Casamance, Senegal. *Journal of Agricultural Chemistry and Environment*, **14**, 132-146.  
<https://doi.org/10.4236/jacen.2025.141009>

**Received:** December 21, 2024

**Accepted:** February 22, 2025

**Published:** February 25, 2025

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## Abstract

Chemical fertilizers are a source of soil degradation. In order to mitigate soil degradation and to face the negative impacts of climate change, the use of organic fertilizers, accessible to small farmers can maintain the productivity of cereals including rice. The objective of this experiment is to study the effect of organo-mineral fertilizers on soil chemical properties, growth and physiology parameters and yield of rice. For this purpose, a completely randomized block design with three replications was adopted. Different organic (Fertinova, Organova and Fertinova + Organova) and mineral (NPK + Urea) fertilizers were applied to cultivate the NERICA L19 variety of rice. The soil chemical properties (pH), germination rate, growth, yield and physiological (chlorophyll content) parameters were assessed. The results revealed a germination rate of the grains varying between 87.5 and 100%. Fertinova and Fertinova + Organova had the highest germination rates. Soil pH decreased significantly from initial ( $6.71 \pm 0.01$ ) to final ( $5.73 \pm 0.04$ ) with the development cycle of the rice. Organo-mineral fertilizers influenced significantly ( $p = 5.36e-09$ ) soil chemical properties by increasing pH (4%) compared to Control. Analysis of variance on growth and yield parameters, yield and chlorophyll content revealed a significant difference ( $p < 0.05$ ) between fertilizers. Growth and yield parameters and yield were significantly higher in NPK and Fertinova + Organova than in Fertinova, Organova and Control. For the biomass the NPK + Urea recorded significantly highest biomass ( $488.28 \pm 60.83$  g). Leaves chlorophyll content varied significantly according to the daytime and the status of leaf development. The higher chlorophyll content was recorded at noon ( $27.96 \pm 0.32$  SPAD value) and with young leaves ( $30.21 \pm 0.35$  SPAD value). NPK + Urea ( $29.36 \pm 0.45$  SPAD value) and Fertinova ( $27.78 \pm 0.40$  SPAD value) favored

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more chlorophyll content in the rice leaves. Rice performed better in NPK + Urea and Fertinova + Organova fertilizers.

### Keywords

Fertilizers, Soil pH, Rice, Growth, Yield, Chlorophyll

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## 1. Introduction

Rice is a staple food in Africa. From 2008 to 2018, rice production in Sub-Saharan Africa doubled, while consumption continued to rise exponentially [1]. Senegal is the third largest importer of rice in Africa, behind Nigeria and South Africa [2]. The calorific intake of rice is estimated at 31%, while production covers only 28% of the country's needs, exposing the country to vulnerability and food insecurity [3] [4]. Despite the government's efforts to increase the area under cultivation and improve production, yields are still low to meet the demand of an ever-growing population [5]. Most of the production of the most consumed crop depends largely on the quality of the soil and especially on the availability of nutrients in the soil. This availability has been ensured for many years by the application of chemical fertilizers. An insufficient application of nutrients and poor soil management, combined with harsh climatic conditions and other factors, have contributed to soil degradation, including soil fertility depletion [6]. However, the continued use of chemical fertilizers leads to the degradation of the chemical and physical properties of the soil, biological activities [7]. In addition, nutrients supplied exclusively from chemical sources, while initially improving yields, lead to unsustainable productivity over time. All these factors, combined with the high cost of chemical fertilizers and the low financial accessibility of small farmers, constitute the main obstacle to the use of chemical fertilizers, without taking into account the environmental pollution they generate.

The current energy crisis, with rising prices and the lack of an adequate supply system for inorganic fertilizers, requires more efficient use of organic fertilizers, green manures, crop residues and other sources to maintain yield levels and facilitate access for small-scale farmers [8]. The application of organic fertilizers has been demonstrated to improve crop growth by providing nutrients to plants as well as the physical, chemical and biological properties of the soil, creating a better environment for root development by improving soil structure [9]. However, improving soil quality to maintain agricultural yields will not be achieved without additional effort [10]. Organic fertilizers and optimized crop rotations foster the accumulation of organic matter in the soil [11] which in turn improves soil characteristics such as its infiltration and water retention capabilities [12]. According to [13] climate change is expected to negatively impact at least 22% of the cultivated areas of the world's important crops, notably wheat and rice, one of the major contributors to food security. Since rice is a staple food for more than half of

the world's population [14], its productivity needs to be maintained by reducing yield gaps [15] to ensure the survival of populations in sub-Saharan Africa, particularly in Senegal, where its consumption is estimated at 90 kg/inhabitant/year [16] for a demand that is only met at 28% in the country. To cover this gap, it is crucial to transform our production systems and move towards agriculture capable of adapting to climate change while preserving soil quality and improving farmers' livelihoods through the valorization of organic fertilization. The aim of this study is to assess the effect of organo-mineral fertilizers on soil chemical properties, rice development parameters and physiological and yield parameters.

## 2. Material and Methods

### 2.1. Study Area

The study was conducted in the experimental farm of the Agroforestry Department of Assane SECK University in Ziguinchor region. The experimental farm of Agroforestry Department is located at 12° 32'54.88" North latitude and 16° 16'40.89" West longitude (Figure 1). Ziguinchor region is characterized by an average annual rainfall of 1322.66 mm between 1984 and 2015 with a rainy season that extends from June to October and a Sudano-Guinean type of climate [17] and an average temperature of 27.10°C.

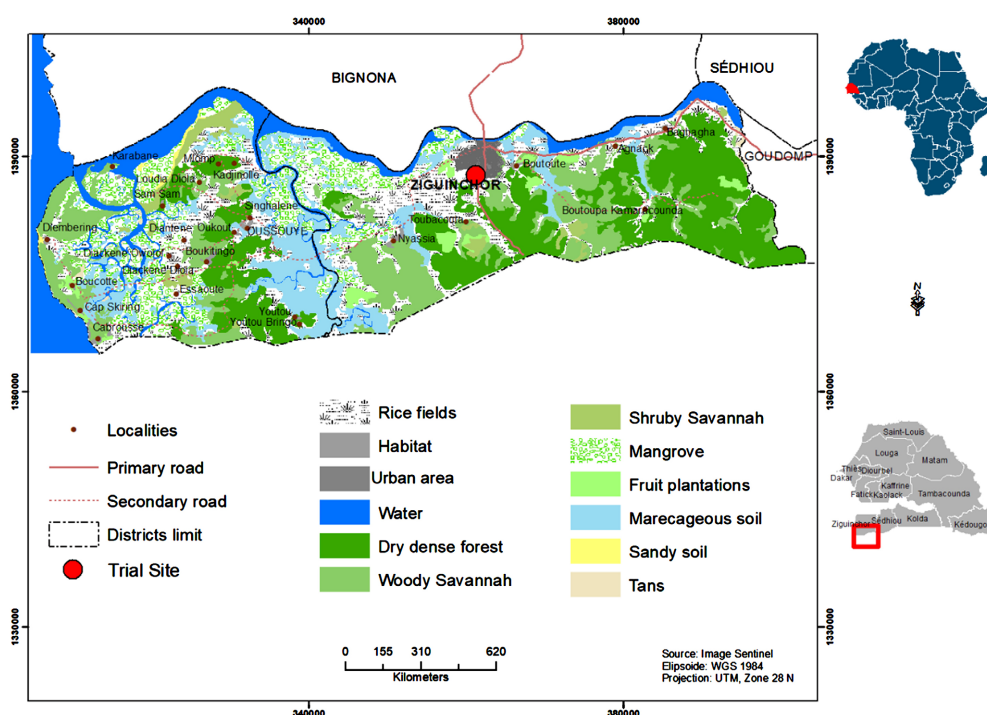


Figure 1. Localization of trial and collected samples.

### 2.2. Vegetal Material

The plant material used in this study was the lowland rice variety Nérica L19,

which had the dual advantage lacking in both parents (*O. sativa* and *O. glaberrima*). It combines the hardiness of the African species *Oriza glaberrima* with the productivity of the Asian species [18]. The development cycle of the variety is between 70 and 100 days after sowing and can reach a yield of 5T per hectare [19].

### 2.3. Fertilizer and Experimental Design

The fertilizers used were organic (Fertinova, Organova and Fertinova + Organova), mineral (NPK + Urea) and Control (without fertiliser). Fertinova is an organic fertilizer manufactured by the group “EléphantVert” and obtained by drying and sanitation poultry droppings which is rich in organic matter, macro and micro-nutrients. It is used as a foliar fertilizer. The 4-3-3 Fertinova formula was used, including 4% Nitrogen (N), 3% Potassium (K) and Phosphoric Anhydride (P205), 26% organic matter for a C/N of 12 and 20% moisture. Organova, mainly composed of 30% Organic Matter and 35% Moisture 35% is an organic fertilizer resulting from the composting of plant residues, livestock effluents and agro-industry co-products and developed by the group [20].

Organova and Fertinova were applied during the sowing phase with respectively 16 and 6 g. Fertinova + Organova was a combination composed by Organova (8 g/pot) and Fertinova (3 g/pot). For NPK + Urea, the 15-15-15 formula with 1.25 g/pot and Urea (0.9 g/pot) were use (Table 1).

**Table 1.** Composition of fertilizers.

Fertilizers	Composition			
	Fertinova (g/pot)	Organova (g/pot)	NPK (g/plot)	Urea (g/pot)
Fertinova	16			
Organova		6		
Fertinovat organova	8	3		
NPK + Urea			1.25	0.9
Control	0	0	0	0

A randomized complete block design with three replications was used in this experiment. A total of 15 elementary plots were carried out. The experimental design was 15 m long and 4.5 m wide with 67.5 m<sup>2</sup>. The blocks were separated from each other by alleys of 0.5 m.

Each block represented a repetition and included five elementary plots. The dimensions of the elementary plots were 2.25 m long and 1 m wide with 2.25 m<sup>2</sup>. Within each elementary plot, five pots were dug for better moisture conservation [21]. Eight seeds of Nerica L19 were sown in each pot. A direct sowing was carried out for 08 seeds of Nerica L 19 per pot. A thinning was done after germination to leave only one plant per pot.

## 2.4. Germination, Soil pH, Growth and Yield Parameter, Yield and Chlorophyll Content Were Measured

Germination, soil pH, growth and yield parameter, yield and chlorophyll content were measured.

### Germination

Germination was obtained by direct counting of the number of emergences. The germination rate [22] was using the following formula:

$$\text{Germinate rate} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} * 100.$$

### Soil pH

Soil samples were taken at a depth of 10 cm depending on the fertilizers according to the duration for the initial, 15 and 35 days after sowing (DAS) and final phase of the rice cultivation. The soil samples were analyzed for soil pH using a pH meter.

### Growth and yield parameters

The height of plants was measured using a centimeter and the number of tillers was counted at 60 DAS. The number of spikelets was obtained by direct counting at the phase of maturity.

### Yield

The yield was calculated using the Lacharme formula [23]. The fresh plants were collected during the flowering phase and further dried at 60°C in the oven for three days to obtain the weight of dry biomass. The 1000 grains and the dry biomass were weighed with an electronic precision balance (0.0001 g).

### Chlorophyll content

The chlorophyll content of leaves was measured using a SPAD-502 Plus at the flowering stage of rice. Measures were taken in the morning at 07:00 am and the noon at 12:00 pm and were repeated for seven days on young, medium and old leaves.

## 2.5. Data Processing and Analysis

Collected data were processed and analyzed using R software [24] to evaluate the differences between the fertilizers. Analysis of variance (ANOVA) was done, and Tukey's test was used to make multiple mean comparisons and detect the significant differences between the characteristics (fertilizers, duration, daytime, and stages of leaf development). Statistical significance was fixed at 0.05. All data were expressed as overall mean  $\pm$  SE. Clustering based on Euclidian ecological distance, principal components analyses and correlations were done to study the relationships between soil pH, growth and yield parameters, yield and chlorophyll content and fertilizers.

## 3. Results

### 3.1. Germination

There was no significant difference ( $p = 0.485$ ) between fertilizers. The overall germination rate was 98%. It varied between  $87.5 \pm 0.3$  and  $100 \pm 0.0\%$  depending on the fertilizer. In absolute value, the Fertinova ( $100 \pm 0.0$ ) and Fertinova +

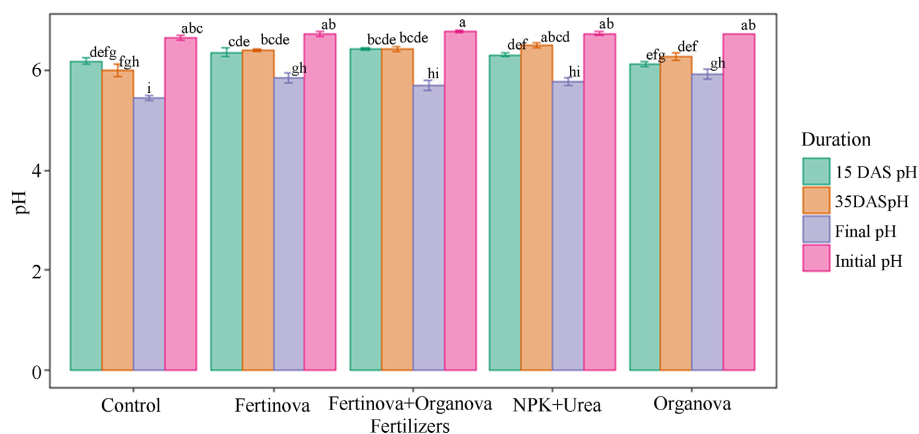
Organova ( $100 \pm 0.0$ ) fertilizers had the highest germination rate (**Table 2**).

**Table 2.** Variation of the germination rate according to fertilizers.

Fertilizers	Germination rate (%)
Fertinova	$100 \pm 0.0^a$
Fertinovat oganova	$100 \pm 0.00^a$
NPK	$87.5 \pm 0.42^a$
Organova	$87.5 \pm 0.42^a$
Control	$87.5 \pm 0.30^a$
P	<b>0.48</b>

### 3.2. Soil pH

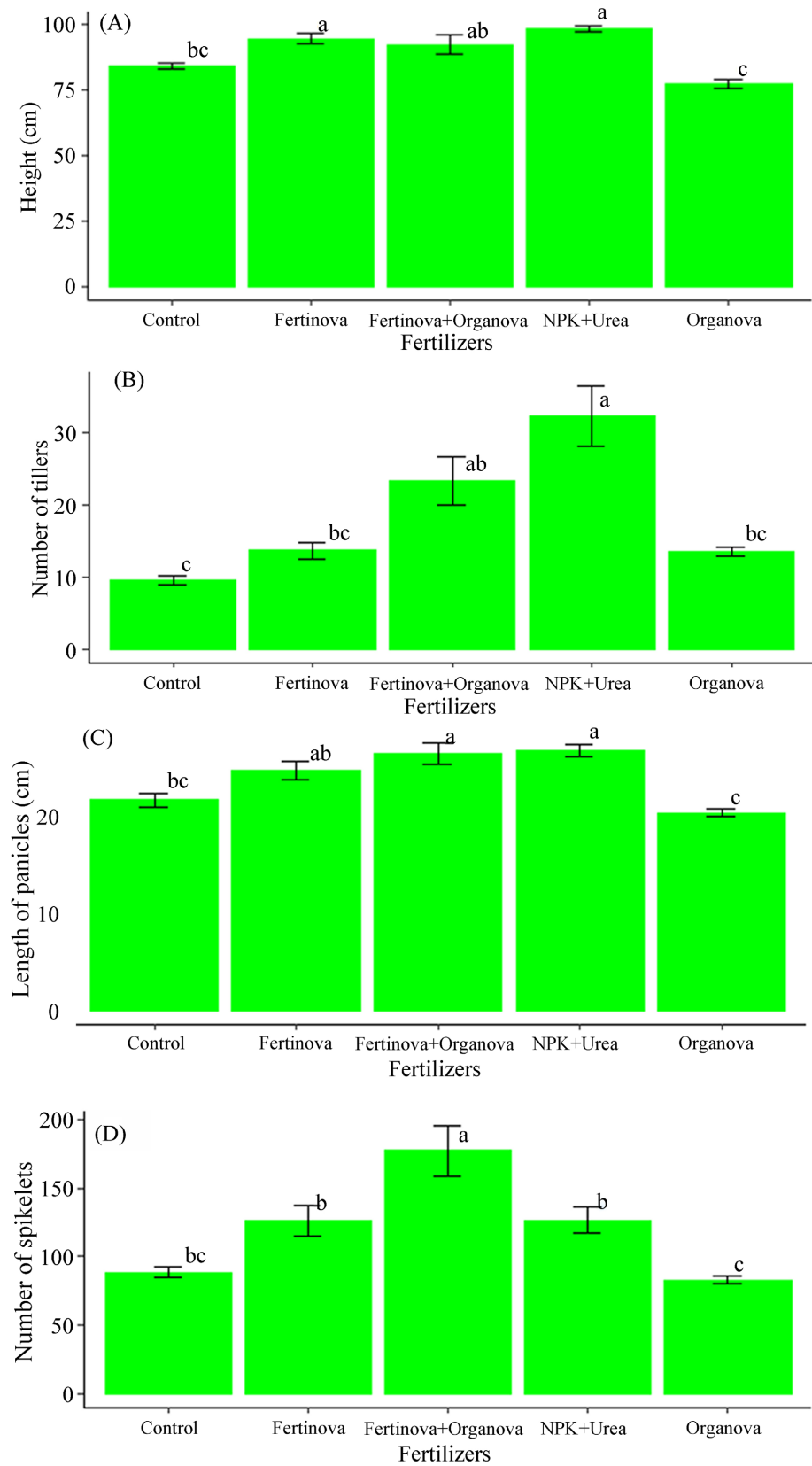
The evolution of pH over time revealed a significant decrease from initial ( $6.71 \pm 0.01$ ) to final ( $5.73 \pm 0.04$ ). The analysis of pH variance revealed a significant difference ( $p = 2e-16$ ) between fertilizers. The highest pH was obtained with Fertinova + Organova and Fertinova ( $6.32 \pm 0.05$ ), followed by NPK + Urea ( $6.31 \pm 0.05$ ) and Organova ( $6.25 \pm 0.05$ ). The Control recorded the lowest soil pH ( $6.06 \pm 0.07$ ). The interaction fertilizers \* duration influenced significantly ( $p = 0.000691$ ) the soil pH variation. Fertinova + Organova obtained the highest pH ( $6.41 \pm 0.03$ ) at 15 DAS followed by Fertinova ( $6.34 \pm 0.09$ ). At 35 DAS, an increase in pH was observed in all fertilizers. At the end of the experiment, a decrease in pH was recorded for all fertilizers. Organova ( $5.92 \pm 0.10$ ) and Fertinova ( $5.84 \pm 0.09$ ) recorded the highest pH. The lowest pH ( $5.44 \pm 0.06$ ) was obtained with Control (**Figure 2**).



**Figure 2.** Soil pH evolution over time according to fertilizer.

### 3.3. Growth Parameters

The growth parameters (height, number of tillers and spikelets and length of panicles) varied significantly ( $p < 0.05$ ) between fertilizers (**Figure 3**). NPK + Urea ( $98.6 \pm 1.33$  cm), Fertinova ( $94.73 \pm 1.97$  cm) and Fertinova + Organova ( $92.4 \pm 3.78$  cm) recorded significantly the highest plant height than Control ( $84.33 \pm 1.39$  cm) and Organova ( $77.53 \pm 1.65$  cm).



**Figure 3.** Variation of plant height (A), number of tillers (B), length of panicles (C) and number of spikelets (D) according to fertilizers.

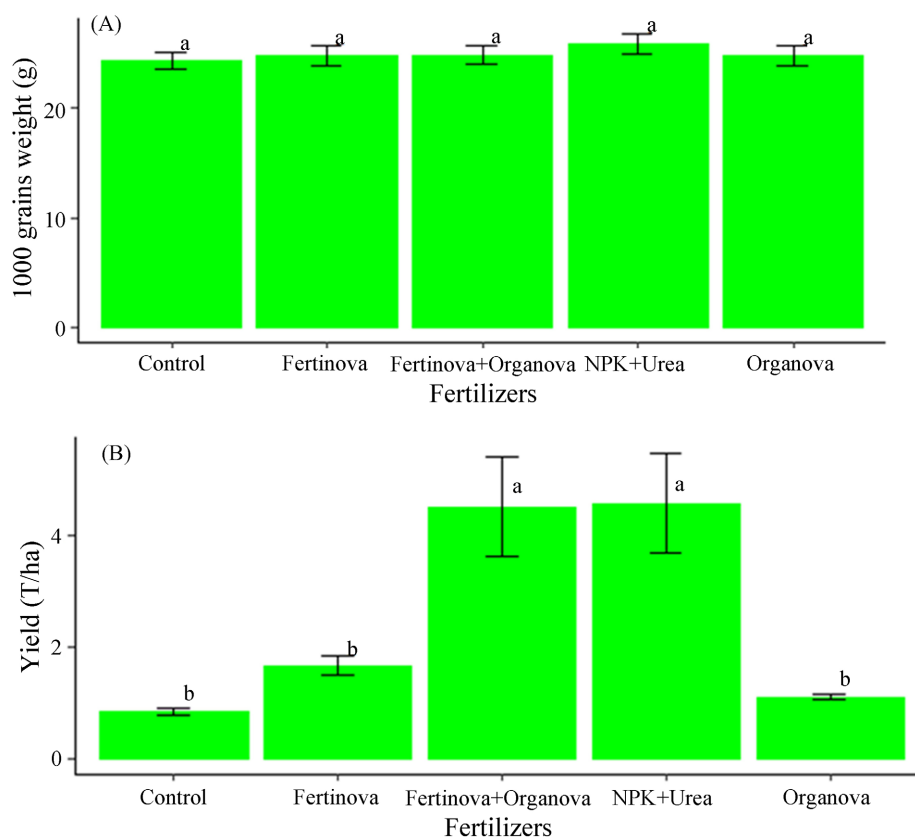
The highest numbers of tillers were recorded on NPK + Urea ( $32.27 \pm 4.19$  cm) and Fertinova + Organova ( $23.27 \pm 3.29$  cm). However, the lowest number of tillers ( $9.60 \pm 0.56$  cm) was obtained on the Control. For the length of panicles, NPK + Urea ( $26.8 \pm 0.60$  cm) and Fertinova + Organova ( $26.46 \pm 1.14$  cm) recorded significantly larger panicles than organova ( $20.33 \pm 0.38$  cm) and Control ( $21.66 \pm 0.71$  cm).

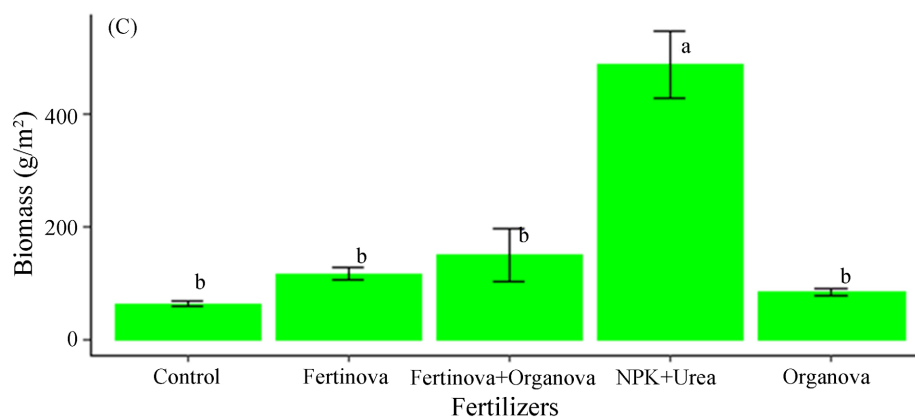
Indeed, the number of spikelets under Fertinova + Organova ( $177 \pm 18.76$  cm) was significantly higher compared to NPK + Urea ( $126.67 \pm 9.83$ ), Fertinova ( $126.13 \pm 10.99$ ), Control ( $88.8 \pm 4.27$ ) and Organova ( $82.93 \pm 2.57$ ).

### 3.4. Yield

The analysis of 1000 grains weight showed no significant difference ( $p = 0.802$ ) between fertilizers. However, NPK + Urea ( $25.84 \pm 0.98$  g) recorded the highest weight in absolute value compared to the other. The fertilizers influenced significantly ( $p < 0.05$ ) the yield (Figure 4). The NPK + Urea ( $4.57 \pm 0.90$  tones  $\text{ha}^{-1}$ ) and Fertinova + Organova ( $4.51 \pm 0.89$  tones  $\text{ha}^{-1}$ ) recorded the highest yields. The lowest yields were observed at the Control ( $0.85 \pm 0.05$  tones  $\text{ha}^{-1}$ ).

For the biomass, NPK + Urea recorded the highest biomass ( $488.28 \pm 60.83$  g), followed by Fertinova + Organova ( $149.8 \pm 46.68$  g) and Fertinova ( $117.12 \pm 10.65$  g). However, the lowest biomass production was recorded in Control ( $64.44 \pm 5.63$  g) and Organova ( $84.84 \pm 5.97$  g).





**Figure 4.** Variation of 1000 grains weight (A), yield (B) and biomass (C) according to fertilizers.

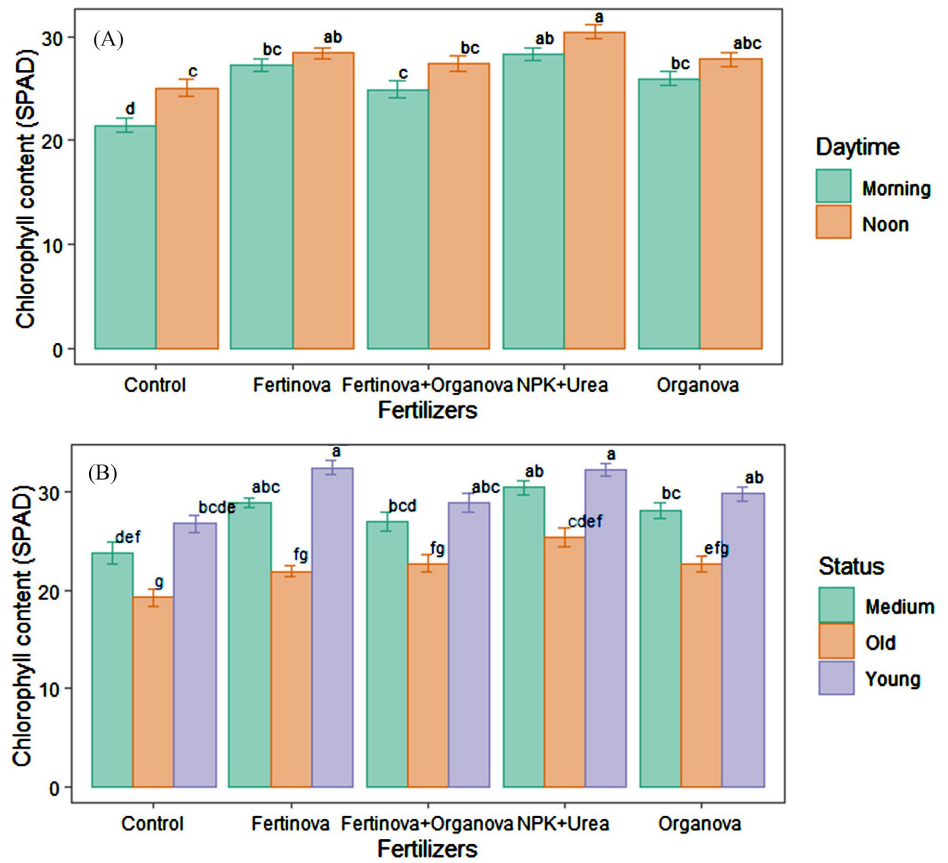
### 3.5. Chlorophyll Content

Fertilizers influenced significantly ( $p < 2e-16$ ) rice leaves chlorophyll content. NPK + Urea registered the highest chlorophyll content ( $29.36 \pm 0.45$  SPAD value), followed by Fertinova ( $27.78 \pm 0.40$  SPAD value), Organova ( $26.88 \pm 0.47$  SPAD value) and Fertinova + Organova ( $26.16 \pm 0.55$  SPAD value). Rice leaves chlorophyll content varied significantly according to daytime and development status. A higher chlorophyll content was observed at noon ( $27.96 \pm 0.32$  SPAD value) than morning ( $25.69 \pm 0.30$  SPAD value). The interaction fertilizers\*daytime influenced significantly ( $p < 0.05$ ) leaves chlorophyll content. However, the highest chlorophyll content was noted on NPK + Urea ( $30.4 \pm 0.6$ ) followed by Fertinova ( $28.4 \pm 0.5$ ) at noon. The lowest chlorophyll content was recorded on Control ( $21.5 \pm 0.73$ ) in the morning (Figure 5). For the leaves development status, young leaves ( $30.21 \pm 0.35$  SPAD value) recorded the highest chlorophyll content than medium ( $27.80 \pm 0.37$  SPAD value) and old ( $22.51 \pm 0.38$  SPAD value) leaves. However, analysis of variance showed a significant ( $p < 0.05$ ) effect of the interaction fertilizers\*leaf status on chlorophyll content. The highest chlorophyll content were recorded on Fertinova ( $32.50 \pm 0.70$  SPAD value) followed by NPK + Urea ( $32.25 \pm 0.61$  SPAD value) in young leaves. The lowest chlorophyll content was recorded on Control ( $19.24 \pm 0.91$  SPAD value) in old leaves (Figure 5).

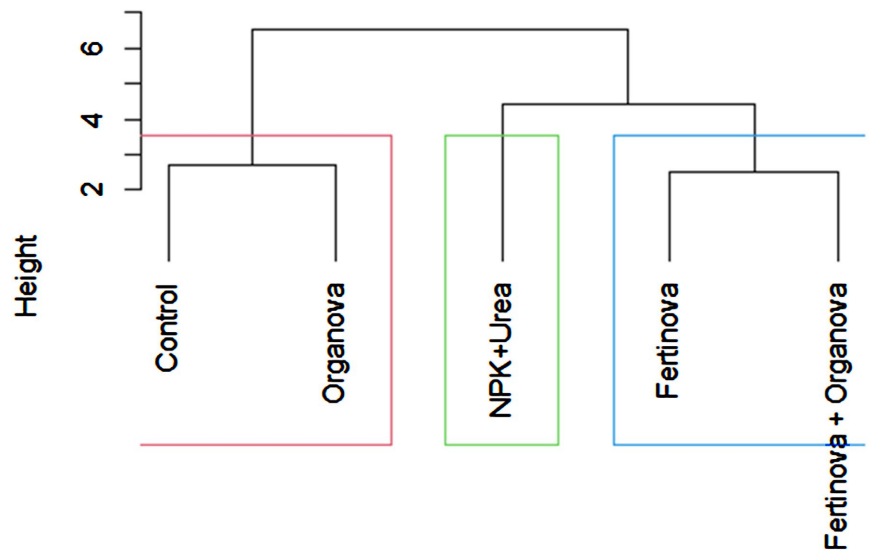
### 3.6. Relation between Fertilizers, Soil pH, Growth and Yield Parameters, Yield and Chlorophyll Content

Clustering analysis revealed three groups according to the fertilizers. The first group was composed of Control and Organova, and characterized by very low chlorophyll content, growth and yield parameters and yield. The second group is constituted of NPK + Urea and favored high chlorophyll content, height, biomass and number of tillers. However, the last group composed of Fertinova and Fertinova + Organova and was characterized by higher yield, panicle length, number of spikelets and soil pH (Figure 6 and Figure 7). Principal component analysis (PCA) showed an overall positive correlation between agrophysiological parameters and yield. Yield was positively correlated with plant height, number of tillers,

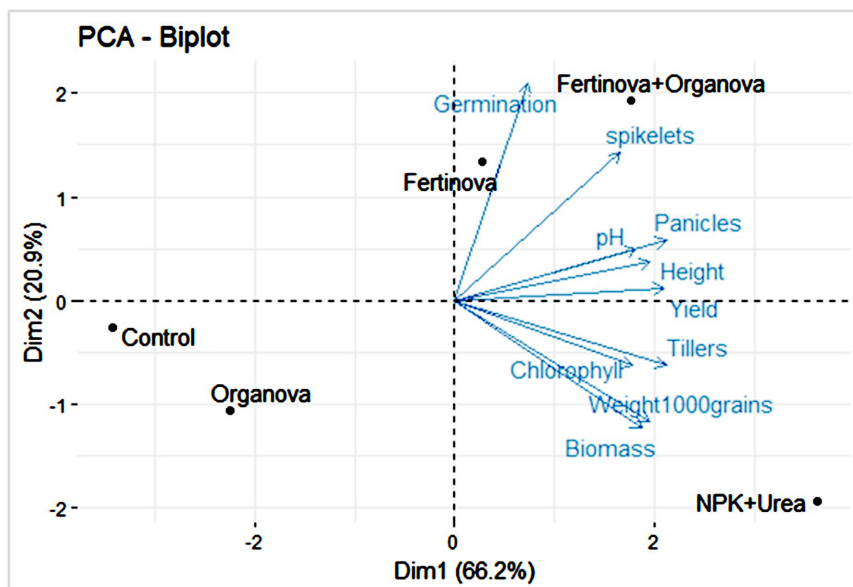
number and length of panicles, number of spikelets and 1000-grain weight, biomass and chlorophyll content. The number of tillers was also correlated with all



**Figure 5.** Change in Chlorophyll content of rice leaves in responses to daytime (A), status of leaves development and fertilizers (B).



**Figure 6.** Cluster dendrogram of agrophysiological parameters between fertilizers of 1000 grains weight (A), yield (B) and biomass (C) according to fertilizers.



**Figure 7.** Principal component analysis of physiological parameters, yield parameters and fertilizers.

agrophysiological parameters except germination, where the correlation was zero. Chlorophyll content was strongly and positively correlated with biomass, pH, 1000 grain weight, plant height and number of spikelets. pH was positively correlated with all yield parameters and yield (**Figure 8**).

## 4. Discussion

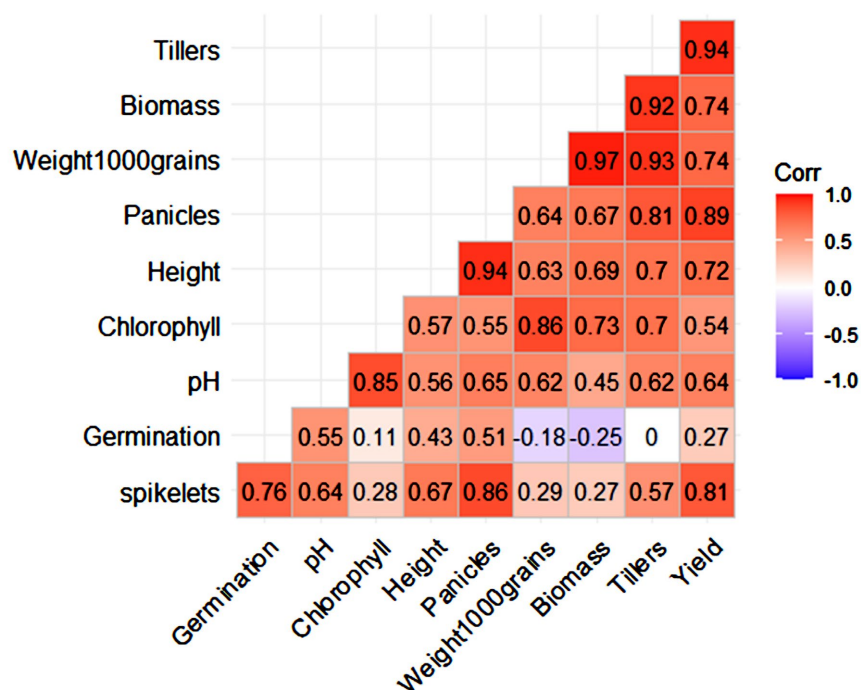
### Influence of fertilizer on soil pH

The results showed a significant variation in pH depending on the fertilizer used. This variation was observed during the development of the rice. Fertinova and Fertinova + Organova fertilizers recorded the highest pH while the lowest was noted for Control. Following the evolution of pH over time, an overall decrease in pH was noted from the beginning to the end of the experiment, except on day 35, when we noted a slight increase in pH for all fertilizers, excluding the Control. This could be explained by the reaction of the fertilizers some days after their application, coinciding with the release of nutrients for plants. This variation in pH, close to neutrality between the start of the experiment and 35 days, which is correlated with the development phase of the rice, favors good plant growth. Indeed, a pH close to neutrality is an asset for better nutrient uptake by the roots [25]. The relative decrease in pH from 6.4 to 5.2 can be explained by the waterlogging due to irrigation, which consequently generated acidification due to alternating flooding and drying [26]. Organic amendments increase soil pH compared to mineral fertilizers. The long-term addition of organic amendments increases the pH of acidic soils [27]. The application of Urea decreased the soil pH [28].

### Influence of fertilizers on rice performance

The yield parameters (tillers, spikelets, panicles and panicle length and 1000 grain weight), dry biomass and paddy yield varied significantly according to fer-

tilizers. NPK + Urea and Fertinova + Organova recorded the highest performance of rice. The agro-morphological parameters of the rice and yields are improved with the application of Urea [29]. However, the combination of Fertinova and Organova was a good alternative for soil improvement. Organova and Fertinova was used as a base and foliar fertilizers respectively. The combination of organic amendments played an important role by supplying required nutrients to the plant, particularly during the tillering and flowering phases. The application of Fertinova and Organova produced higher yields of tomato variety [21]. In addition to being easily accessible to smallholders, organic fertilizers ensured long-term sustainable rice production by preserving soil physicochemical parameters [30]. Indeed, organic amendments acted on soil structure by improving the soil's retention capacity and consequently the balanced use of nutrients by plants [31].



**Figure 8.** Correlation matrix for agro-physiological parameters, fertilizers and rice yields.

### Influence of fertilizers on rice leaves Chlorophyll content

Results showed a substantial variation in chlorophyll content depending on the daytime and leaf status. The chlorophyll content observed at noon was significantly higher than in the morning. According to leaf status, chlorophyll content was highest in young leaves, followed by medium leaves and old leaves. A higher chlorophyll content on medium leaves of cucumber was recorded compared to old and young leaves [32]. The content of chlorophyll in leaves can be influenced by many factors such as leaf age, leaf position, and environmental factors such as light, temperature and water availability [33]. For the analysis also revealed that the highest chlorophyll content was recorded on NPK + Urea and Fertinova. The improvement in photosynthetic activity observed in NPK + Urea, Fertinova

+ Fertinova and Organova revealed the importance of mineral element availability on plant metabolism and physiology. The chlorophyll content in addition can be also influenced by cultivation practices and the nitrogen amount available for plants [34].

### Conclusion

Increasing rice yields in the current context of climatic variability and degradation of agricultural soils required effective application of fertilizers. The results of our study revealed that soil chemical properties and rice performance were influenced by fertilizers. Organic fertilizers increased significantly soil pH. NPK + Urea and Fertinova + Organova recorded the best rice performance development and chlorophyll content. The chlorophyll content varied according to daytime and leaf status. The highest chlorophyll content was recorded at noon and in young leaves of rice. The application of fertilizers was an important element in improving soil pH and rice performance, the efficiency of fertilizer on rice yield.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

### References

- [1] Otsuka, K., Mano, Y. and Takahashi, K. (2023) The Rice Green Revolution in Sub-Saharan Africa: Issues and Opportunities. In: Otsuka, K., Mano, Y. and Takahashi, K., Eds., *Rice Green Revolution in Sub-Saharan Africa*, Springer, 3-24. [https://doi.org/10.1007/978-981-19-8046-6\\_1](https://doi.org/10.1007/978-981-19-8046-6_1)
- [2] FAO (2021) FAOSTAT Online Database. <http://www.fao.org/faostat/en/#data>
- [3] FAO (2010) The Rice Crisis. Markets, Policies and Food Security. In: Dawe, D., Ed., *Food and Agriculture Organization and Earthscan*, WHO, 133.
- [4] Diagne, M., Demont, M., Seck, P.A. and Diaw, A. (2012) Self-Sufficiency Policy and Irrigated Rice Productivity in the Senegal River Valley. *Food Security*, **5**, 55-68. <https://doi.org/10.1007/s12571-012-0229-5>
- [5] MAER (2021) Ministère de l'Agriculture et de l'Équipement Rural. Programme National D'autosuffisance en Riz (PNAR). <https://agriculture.gouv.sn/projets-programmes/programme-national-dauto-suffisance-en-riz-pnar/>
- [6] Goulding, K., Jarvis, S. and Whitmore, A. (2007) Optimizing Nutrient Management for Farm Systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **363**, 667-680. <https://doi.org/10.1098/rstb.2007.2177>
- [7] Mahajan, A., Bhagat, R.M. and Gupta, R.D. (2008) Integrated Nutrient Management in Sustainable Rice Wheat Cropping System for Food Security in India. *SAARC Journal of Agriculture*, **6**, 29-32.
- [8] Sathish, A., Govinda Gowda, V., Chandrappa, H. and Nagaraja, K. (2011) Long Term Effect of Integrated Use of Organic and Inorganic Fertilizers on Productivity, Soil Fertility and Uptake of Nutrients in Rice & Maize Cropping System. <https://www.semanticscholar.org/paper/LONG-TERM-EFFECT-OF-INTEGRATED-USE-OF-ORGANIC-AND-%26-Sathish-Gowda/a42f584ec0ef9a7c948e8e08ff7bab6a1766f98e>
- [9] Joshi, N.V., Vesey, A.T., Williams, M.C., Shah, A.S.V., Calvert, P.A., Craighead,

- F.H.M., *et al.* (2014) <sup>18</sup>F-Fluoride Positron Emission Tomography for Identification of Ruptured and High-Risk Coronary Atherosclerotic Plaques: A Prospective Clinical Trial. *The Lancet*, **383**, 705-713. [https://doi.org/10.1016/s0140-6736\(13\)61754-7](https://doi.org/10.1016/s0140-6736(13)61754-7)
- [10] Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., *et al.* (2012) Enhanced Top Soil Carbon Stocks under Organic Farming. *Proceedings of the National Academy of Sciences of the United States of America*, **109**, 18226-18231. <https://doi.org/10.1073/pnas.1209429109>
- [11] Zeiger, M. and Fohrer, N. (2009) Impact of Organic Farming Systems on Runoff Formation Processes—A Long-Term Sequential Rainfall Experiment. *Soil and Tillage Research*, **102**, 45-54. <https://doi.org/10.1016/j.still.2008.07.024>
- [12] Lorenz, K. and Lal, R. (2016) Environmental Impact of Organic Agriculture. *Advances in Agronomy*, **139**, 99-152. <https://doi.org/10.1016/bs.agron.2016.05.003>
- [13] Campbell, S.G. and Campbell, K.S. (2011) Mechanisms of Residual Force Enhancement in Skeletal Muscle: Insights from Experiments and Mathematical Models. *Biophysical Reviews*, **3**, 199-207. <https://doi.org/10.1007/s12551-011-0059-2>
- [14] Muthayya, S., Sugimoto, J.D., Montgomery, S. and Maberly, G.F. (2014) An Overview of Global Rice Production, Supply, Trade, and Consumption. *Annals of the New York Academy of Sciences*, **1324**, 7-14. <https://doi.org/10.1111/nyas.12540>
- [15] Dossou-Yovo, E.R., Vandamme, E., Dieng, I., Johnson, J. and Saito, K. (2020) Decomposing Rice Yield Gaps into Efficiency, Resource and Technology Yield Gaps in Sub-Saharan Africa. *Field Crops Research*, **258**, Article ID: 107963. <https://doi.org/10.1016/j.fcr.2020.107963>
- [16] Fall, A.A. (2016) Synthèse des études sur l'état des lieux chaîne de valeur riz en Afrique de l'ouest: Bénin, Burkina Faso, Mali, Niger et Sénégal. Rapport Final, ROPPA, 83.
- [17] Sagna, P. (2005) Dynamique du climat et son évolution récente dans la partie ouest de l'Afrique occidentale. Master's Thesis, Université Cheikh Anta Diop de Dakar.
- [18] Akassimadou, F.E., Hien, M.P., Bouadou Oi, F.B., Bolou Bi, E.B., Bongoua, J.A., Ettien, J.D., *et al.* (2017) Efficiences Des Nutriments P Et K En Riziculture Irriguée Dans Un Bas-Fond Secondaire En Zone De Savane Guinéenne De La Côte d'Ivoire. *European Scientific Journal, ESJ*, **13**, 432-453. <https://doi.org/10.19044/esj.2017.v13n36p432>
- [19] Sié, M. (2008) Biodiversité et amélioration génétique du riz en Afrique subsaharienne. Agropolis International.
- [20] Coulibaly, A., Ouédraogo, J., Nacro, S.R. and Serme, I. (2022) Effets des fertilisants organiques sur la production de la tomate et les paramètres chimiques du sol au Centre Nord du Burkina Faso. *Afrique Science*, **21**, 10-27.
- [21] Vidotto, F. and Ferrero, A. (2000) Germination Behaviour of Red Rice (*Oryza sativa* L.) Seeds in Field and Laboratory Conditions. *Agronomie*, **20**, 375-382. <https://doi.org/10.1051/agro:2000134>
- [22] Kabuyaya, D. (2001) Le Protocole «PRERP». La mise en place d'un essai et la collecte des données. Coopération Agricole Italienne à la RDC, At. C/PNR, Kinshasa.
- [23] Lacharme, M. (2001) Le plant de riz Données morphologiques et cycle de la plante. Mémento Technique de Riziculture, 22.
- [24] Team, R.C. (2015) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. <https://www.R-project.org>
- [25] Ognalaga, M., Odjogui, P.I.O., Lekambou, J.M. and Poligui, R.N. (2016) Effet des écumes de canne à sucre, de la poudre et du compost à base de *Chromolaena odorata*

- (L.) King R.M. & H.E. Rob sur la croissance de l'oseille de Guinée (*Hibiscus sabdariffa* L.). *International Journal of Biological and Chemical Sciences*, **9**, 2507-2519. <https://doi.org/10.4314/ijbcs.v9i5.22>
- [26] Yameogo, P.L., Traore, A. and Arzouma, B.A. (2021) Influence des modes de gestion de l'eau et de la fumure minérale sur quelques paramètres chimiques du sol et le rendement du riz à la Vallée du Kou au Burkina Faso. *Journal of Applied Biosciences*, **165**, 17099-17110.
- [27] Walker, B., Holling, C.S., Carpenter, S.R. and Kinzig, A.P. (2004) Resilience, Adaptability and Transformability in Social-Ecological Systems. *Ecology and Society*, **9**, Article 5. <https://doi.org/10.5751/es-00650-090205>
- [28] Badiane, A., Faye, B.A., Sambou, A., Ba, I., Diop, K., Diallo, M., *et al.* (2023) Cultural Mode and Organo-Mineral Amendment Effect on Growth and Yield of Rice (*Oryza sativa* L.) and Soil Chemical Properties in Sulfated Acid Soils of Basse-Casamance. *Heliyon*, **9**, e18830. <https://doi.org/10.1016/j.heliyon.2023.e18830>
- [29] Bamba, B., Coly, I. and Guèye, M. (2022) Effects of Organo-Mineral Fertilization on Plant Growth and Grain Yield of an Upland Rice Variety (NERICA 14) in Lower Casamance (South-West Senegal). *International Journal of Scientific Research Updates*, **4**, 303-311.
- [30] Song, W., Shu, A., Liu, J., Shi, W., Li, M., Zhang, W., *et al.* (2022) Effects of Long-Term Fertilization with Different Substitution Ratios of Organic Fertilizer on Paddy Soil. *Pedosphere*, **32**, 637-648. [https://doi.org/10.1016/s1002-0160\(21\)60047-4](https://doi.org/10.1016/s1002-0160(21)60047-4)
- [31] Bayu, T. (2020) Review on Contribution of Integrated Soil Fertility Management for Climate Change Mitigation and Agricultural Sustainability. *Cogent Environmental Science*, **6**, Article ID: 1823631. <https://doi.org/10.1080/23311843.2020.1823631>
- [32] Diouf, S. and Sambou, A. (2023) Agro-Morphological Characterization of Four Varieties of Cucumber from *Cucumis sativus* L. and *Cucumis metuliferus* E. Mey. Ex Naudin in Senegal. *Journal of Horticulture and Postharvest Research*, **6**, 131-144.
- [33] Hikosaka, K., Ishikawa, K., Borjigidai, A., Muller, O. and Onoda, Y. (2005) Temperature Acclimation of Photosynthesis: Mechanisms Involved in the Changes in Temperature Dependence of Photosynthetic Rate. *Journal of Experimental Botany*, **57**, 291-302. <https://doi.org/10.1093/jxb/erj049>
- [34] Hidayati, N., Triadiati, and Anas, I. (2016) Photosynthesis and Transpiration Rates of Rice Cultivated under the System of Rice Intensification and the Effects on Growth and Yield. *HA YATI Journal of Biosciences*, **23**, 67-72. <https://doi.org/10.1016/j.hjb.2016.06.002>