Original Research Article

An investigation into the effects of organic amendments in a saline environmenton soil chemical characteristics, growth, and yield of rice in the south of Senegal

ABSTRACT

Context of the study: The use of organic amendments could help increase the resilience of lowland rice in Lower Casamance to salinity. The aim of this study was to test the effect of different organic amendments (biochar and compost) on the salinity tolerance of lowland rice in Basse Casamance.
Objective: The aim was to test the effect of different organic amendments on the salinity tolerance of rice in the lowlands of the villages of Selecky and Essyl in Lower Casamance.
Methodology:A split-plot design was adopted with two factors: the type of organic amendment with 4 treatments (biochar, compost, compost + biochar and the control) and salinity with two treatments (salted and unsalted zones). These treatments were repeated 3 times in two consecutive years, 2020 and 2021, at the Selecky and Essyl sites. Physico-chemical characteristics as well as rice growth and production parameters were studied.
Results: In the saline zone, soil amendments significantly increased the number of tillers and the height of rice plants compared with controls ($p<0.05$). Average rice yield and plant biomass were significantly higher in the amended plots at Selecky in both experimental years ($p<0.05$). At Essyl, on the other hand, height, number of tillers, rice yield and plant biomass were lower in the 2nd year of experimentation. Organic amendments had a significant effect ($p<0.05$) on rice production and yield parameters in the salt zone.

Keywords: Salinity, Organic amendments, Yield, Oryza sativa L,

1. INTRODUCTION

Rice (Oryza saliva L.) is the most important food crop in developing countries, feeding more than half the world's population. Its consumption exceeds 100 kg.capita.year^{-1} in many countries [1]. Rice is primarily a self-consumption crop, with global production of 479,200,000,000 kg.year^{-1}[2]. It is also one of the main cereals consumed in West Africa, and in recent years its consumption has seen the strongest increase worldwide, rising from around 30 kg.capita.year^{-1} in 1990 to 45 kg in 2010 [3]. Its production remains insufficient to cover the consumption needs of populations. At the same time, the region's population growth rate is one of the highest in the world. According to an estimate by the Organisation for Economic Co-operation and Development [4] West Africa's population, which stood at around 300 million in 2006, is expected to reach 430 million by 2025, given that rice growing is practiced mainly by family farms, in several production systems (rainfed, lowland, irrigated, mangrove and flottant rice) with particular requirements in terms of agricultural investment. In Senegal, rice consumption reaches even higher levels, between 60 and 70 kg.hab.an^{-1}[5]. This strong domestic demand has prompted the region's agricultural policy to promote local rice growing, which is also reinforced by the uncertainties of the international rice market [3] ; [6]. Casamance, one of the country's main rice-growing areas, has enormous potential for rainfed rice production. However, rice production in this part of the country remains low. According to [7], the main pedoclimatic constraints to lowland rice cultivation in Lower Casamance are mainly linked to soil salinization, iron toxicity and irregular rainfall. These constraints are at the root of the abandonment of rice plots and the decline in rice yields in Lower Casamance. Several strategies have been adopted by farmers to minimize the effect of salt on soil and rice. These strategies are mainly based on the construction of traditional dykes, the use of short-cycle varieties and the application of organic amendments. Organic amendments, with their high nutrient content, could reduce the effect of salt on the soil and improve rice yields. According to [8], the addition of organic matter to the soil increases water retention capacity, cation exchange capacity and provides nutrients to plants. Several studies have shown that organic amendments improve crop yields in salt-affected soils. Thus, the use of organic matter such as biochar and cashew compost could be an alternative to reduce the effects of salt in salt-affected rice fields. The aim of this study is to test the effect of different organic amendments (biochar and compost) on the salinity tolerance of rice.

2. MATERIAL AND METHODS

2.1. Presentation of the study area

Our study was carried out in the localities of Selecky (12° 31'37" North, 16° 27'56" West) and Essyl (12° 31'10" North, 16° 25'34" West) located in south-western Senegal, in Basse-Casamance in the department of Ziguinchor, Ziguinchor region (Fig. 1). These villages are bounded to the north by the Casamance River and to the south by a tributary of the same river [9]. The climate is of the coastal South Sudanian type [10], dominated by two seasons: a dry season from November to May, and a rainy season from June to October, during which agricultural activities are carried out. The average annual temperature is 27°C, with a maximum (35°C) in April and a minimum (15°C) in December [10].

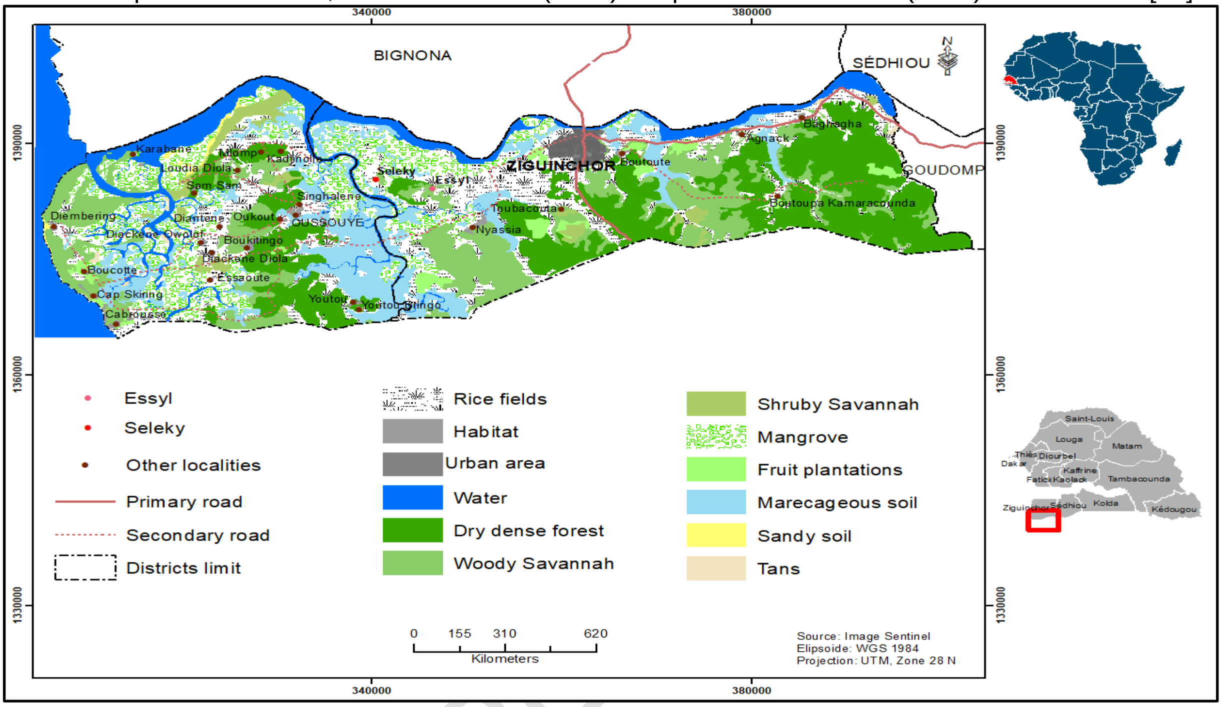


Fig. 1: Location of study sites

2.2. Plant and organic material

The WAR77 variety of the Oryza genus was used as planting material. This variety is adapted to lowlands and is resistant to salinity. Two types of organic amendment were used in this study. These were cashew nut compost (C) and biochar (B). The chemical composition of these amendments is shown in Table 1.

Table 1: Chemical composition of organic soil improvers: biochar and cashew nut compost

	Biochar	**Compost d'anacarde**
pH eau 1/ 2.5	7.5	6
CE 1/ 10 µs/Cm	173	148
%C	5.56	8.98
MO %	9.58	15.48
N %	0.56	0.84
C/N	10	11
Ca^{2+}meq/100g	13.5	1.425
Mg^{2+}meq/100g	3.75	1.2
Na^{+}meq/100g	0.073	0.050
K^{+}meq/100g	3.32	0.74
P ppm	14.17	15.71
S meq/100g	20.64	3.42
CEC meq/100g	9	11
T %	229	31
PSE %	0.8	0.5

EC (Electrical Conductivity); pH (Hydrogen Potential); MO% (Percentage of Organic Matter); %C (Percentage of Carbon); N % (Percentage of Nitrogen); P (Phosphorus); K+ (Potassium); S (Sulfur);

CEC (Cation exchange capacity); C/N (Carbon-Nitrogen ratio); Na+ (Sodium); T% (Base saturation rate); PSE% (Percentage sum of exchangeable bases); Mg (Magnesium); Ca (Calcium)

2.3. Experimental design

A split-plot experimental design with 2 factors was set up in both villages: the type of organic amendment with 4 treatments (biochar, compost, compost + biochar and the control) and the salinity of the area with 2 treatments (salted and Unsalted). For the amendment factor, a random level was determined and repeated 3 times for a total of 24 experimental units per site (fig. 2). In total, we have 48 elementary plots for the 2 study sites.

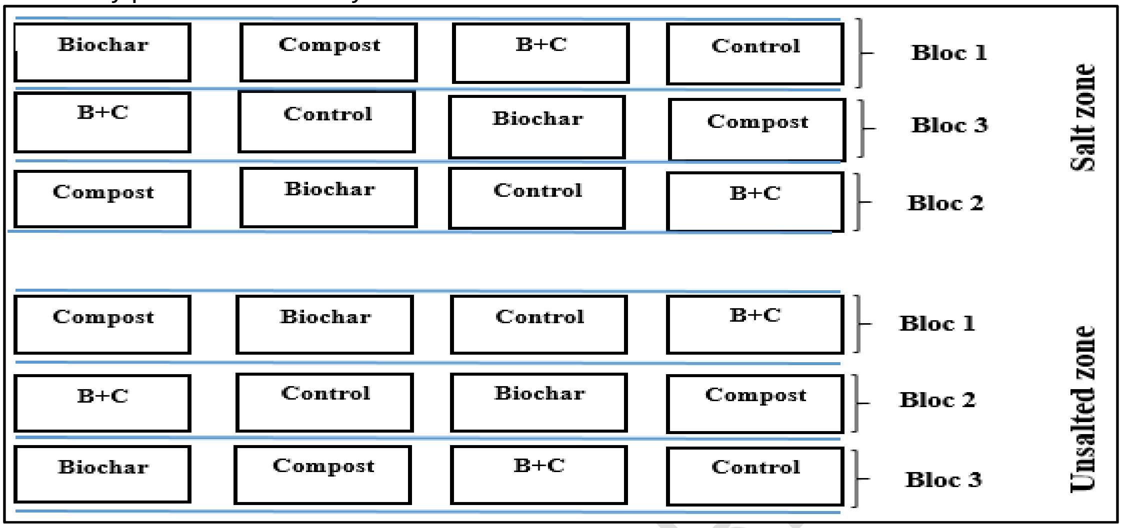


Fig. 2: Experimental design in a real environment

2.4. Development of ricepaddies

The seedlings were nursed for 21 days before being transferred to the rice fields, where a split-plot experimental design was adopted in both the saline and non-saline zones. Amendments were applied one week before transplanting at a rate of 10 $kg.m^{-2}$ in each rice bin. The rice seedlings were transferred to the ridges with a spacing of 20 cm between seedlings along the length and width of the ridges and at a rate of 1 seedling per poquet, i.e. a density of 33 $seedlings.m^{-2}$.

2.5. Agro-morphologicalparameterscollected

Number of tillers, average height, number of panicles per plant, average panicle mass, dry plant biomass, 1000-grain mass and yield were determined on rice. These parameters were measured or collected after rice harvest, with the exception of the number of tillers, which was determined at 60 days after transplanting (DAR).

2.5.1. Plant survival rate

Survival rates were assessed at 15 DAR, 60 DAR and 90 DAR. This was a count of the number of plants that survived after transfer to the various experimental racks.

2.5.2. Number of plant tillers

The number of tillers was counted at 60 DAR. This involved 10 plants per treatment in the 2 study areas.

2.5.3. Average plant height

Plant height was measured on 10 individuals per treatment and per zone at 90 DAR, the day before harvest. Height was measured with a ruler from the plant collar to the tallest panicle.

2.5.4. Number of panicles per plant

This parameter was determined by counting panicles on 10 plants for each treatment, per zone and per site at 90 DAR.

2.5.5. Average panicle mass, above-ground and root dry biomass

Panicle mass and above-ground and root dry biomass at maturity were determined by summing the average plant mass per treatment and per zone. The biomasses collected were weighed after oven-drying at 70°C for 72 h, using a 10^{-4} precision balance.

2.5.6. The mass of 1000 grains

A total of one thousand (1000) seeds were collected at maturity and weighed on 10 plants per treatment.

2.5.7. Yield.

Yield was determined using the formula of Lacharme, (2001)

Yield= NP/ha x NT/P xNpa/T x NG/Pa x PG

Where NP/ha = number of plants/hectare = NP/m² x 10,000
NT/P = number of tillers/foot; NPa/T = number of panicles/tall; NG/Pa = number of grains/panicle; PG = grain weight

2.6. Soil physico-chemical parameters

2.6.1. Soil sampling

Soil samples were taken from each plot before ploughing and during the rice cycle to assess soil texture and chemical parameters (nitrogen, phosphorus, potassium and exchangeable base content). Samples were taken at random from the 0-10 cm and 10-30 cm horizons using an auger. Three samples were taken per treatment to make a composite sample. A total of 96 samples were taken from the two zones (salted and Unsalted). Further samples were taken at 15 DAR, during rice tillering at 60 DAR and on the eve of harvest at 90 DAR. Soil texture was determined using granulometric analyses based on sedimentation. Quantification of mineral elements was carried out in the laboratory at the Institut National de Pedologie (INP) in Dakar. The chemical elements analyzed were: electrical conductivity (EC), pH (water), total carbon (C), total nitrogen (N), total and assimilable phosphorus (P), potassium (K) and exchangeable bases.

3. RESULTS AND DISCUSSION

3.1. Soil texture

Analysis of the results showed that the soil texture was sandy-loam, irrespective of sampling depth and site (Table 2).

Table 2: Physical composition of soil sampled at different depths depending on the salinity of the area at the two sites.

Physicalselements	**Clay (%)**		**Loam fins (%)**		**Loam (%)**	**rough**	**Sand fins (%)**		**Sand (%)**	**moyens**	**Sand rough(%)**	
Zones	0-10	10-30	0-10	10-30	0-10	10-30	0-10	10-30	0-10	10-30	0-10	10-30
Essyl												
Salted	9.5^{de*}	6.75^{e}	8.75^{de}	6^{e}	9.04^{de}	25.14^{bc}	24.37^{bc}	27.78^{bc}	45.14^{ab}	33.13^{ab}	3.19^{f}	1.19^{f}
Unsalted	5^{e}	7.75^{e}	4.75^{e}	5.75^{e}	29.4^{bc}	20.75^{bc}	24.37^{ab}	25.53^{bc}	34.31^{ab}	37.9^{ab}	2.17^{f}	2.31^{f}
Selecky												
Salted	10de	10.5^{de}	14.5^{cd}	14.5^{cd}	84.06^{a}	26.22^{bc}	27.3^{bc}	25.83^{bc}	22.22^{bc}	21.17^{bc}	2.03^{f}	1.76^{f}
Unsalted	23.25^{bc}	28.5^{bc}	11.25^{cd}	9.5^{de}	16.81^{cd}	18.63^{cd}	35.72^{ab}	31.8^{ab}	12.08^{cd}	10.4^{de}	0.88^{f}	1.16^{f}

At each site, treatments with the same letters per column are not statistically different (Fisher test P<0.05).

3.2 Effects of organic amendments on soil chemical properties

Soil pH ranged from 3 to 7 at all sampling depths for all treatments at both sites. Organic carbon (OC) content ranged from 0.7% to 3.7%; organic matter (OM) content from 1.2% to 9.2%. These contents differed significantly according to sampling depth ($p < 0.05$). Soil nitrogen content for the various treatments ranged from 0.07% to 0.46%, with significant differences depending on sampling depth, organic amendments and site ($p>0.05$). Sodium (Na^{+}), potassium (K^{+}) and magnesium (Mg^{2+}) content varied significantly ($p=0.01$) across sampling depths and organic amendments, and across all sites ($p<0.05$). Potassium levels ranged from 0.1 to 0.31 meq.100g^{-1} for all treatments and all sites. Soil Na^{+} content ranged from 0.15 to 0.31 meq.100 g^{-1}, Mg^{2+} values ranged from 0.51 to 0.96 meq.100g^{-1} for all treatments and all sites. Assimilable phosphorus content varied significantly between treatments and sites ($p=0.03$). At Essyl, assimilable phosphorus levels were significantly higher than at other sites. The ANOVA showed a significant difference for CEC regardless of sampling depth and organic amendments for all sites ($p>0.05$). The CEC value was higher at Essyl for all treatments. In summary, these analyses show that the effect of treatments on chemical properties varies from zone to zone and, above all, from site to site (Table 3).

Table 3: Chemical properties of soil sampled at different depths in relation to organic amendments at two sites

Chimicalseleme nts		pH eau		CE 1/ 10 µs/Cm		%C		MO %		N %		C/N		Ca2+ meq/100g		Mg + meq/100g		Na+ meq/100g		K+ meq/100g		P ppm		CEC meq/100g	
Zones		0-10	10-30	0-10	10-30	0-10	10-30	0-10	10-30	0-10	10_30	0-10	10-30	0-10	10-30	0-10	10-30	0-10	10-30	0-10	10_30	0-10	10-30	0-10	10-30
												Essyl													
Salted	Initial	3.6^{t}	3.6^{t}	490^{d}	410^{j}	3.76^{g}	3.68^{h}	6.49^{g}	6.3^{h}	0.32^{d}	0.32^{d}	12^{ab}	11^{b}	0.23^{v}	0.53^{s}	2.03^{d}	0.38^{r}	0.07^{q}	0.03^{uv}	0.016^{mn}	0.00^{o}	10.88^{c}	9.65^{d}	19^{a}	19^{a}
	Biochar	4.0^{pq}	3.6^{t}	496^{c}	696^{a}	4.53^{d}	2.91^{k}	7.81^{d}	5.01^{k}	0.39^{b}	0.25^{f}	12^{ab}	11^{b}	0.91^{p}	1.65^{h}	2.71^{b}	0.90^{m}	0.081^{p}	0.16^{f}	0.000^{o}	0.01^{no}	2.94^{m}	2.26^{q}	17^{bc}	19^{a}
	Compost	4^{q}	3.6^{t}	246^{q}	352.33^{o}	2.91^{k}	2.91^{k}	5.01^{k}	5.02^{k}	0.25^{f}	0.25^{f}	11.33^{ab}	11^{b}	0.91^{p}	0.45^{t}	0.08^{v}	0.15^{u}	0.17^{e}	0.06^{t}	0.026^{lm}	0.04^{kl}	6.62^{f}	12.32^{b}	16.96^{bc}	19^{a}
	B+C	5.21^{f}	3.71^{s}	337^{p}	373.33^{n}	5.39^{a}	4.62^{c}	9.29^{a}	7.96^{c}	0.46^{a}	0.39^{b}	12.33^{ab}	12^{ab}	0.38^{u}	0.53^{s}	0.08^{v}	0.98^{l}	0.03^{tu}	0.021^{vw}	0.01^{no}	0.01^{no}	2.18^{r}	7.94^{e}	12.36^{jkl}	18^{ab}
	Control	3.9^{r}	4.11^{p}	395.33^{k}	116^{G}	3.59^{i}	3.93^{f}	6.19^{i}	6.78^{f}	0.31^{de}	0.34^{c}	12^{ab}	12^{ab}	0.45^{t}	0.75^{r}	1.21^{j}	0.08^{v}	0.13^{jkl}	0.21^{c}	0.000^{o}	0.01^{o}	2.96^{l}	12.85^{a}	17.16^{bc}	17^{bc}
Unsalted	Initial	4.1^{p}	4.4^{m}	181^{x}	203^{s}	0.77^{y}	0.75^{yz}	1.33^{w}	1.3^{wx}	0.07^{n}	0.07^{n}	11^{b}	11^{b}	0.75^{r}	0.9^{p}	0.15^{u}	0.15^{u}	0.62^{b}	0.02^{w}	0.06^{j}	0.07^{ij}	5.46^{g}	3.29^{k}	17^{bc}	15^{def}
	Biochar	4.21^{o}	4.5^{l}	162.8^{A}	139^{E}	5.21^{b}	1.04^{u}	8.98^{b}	1.81^{t}	0.45^{a}	0.09^{m}	12^{ab}	12^{ab}	0.75^{r}	1.13^{n}	0.15^{u}	0.38^{r}	0.113^{no}	0.02^{w}	0.000^{a}	0.043^{k}	0.84^{D}	2.9^{n}	16.16^{cd}	15^{def}
	Compost	4.3^{n}	4.7^{j}	172^{z}	150^{B}	1.81^{n}	1.8^{n}	3.11^{o}	3.39^{n}	0.16^{i}	0.16^{i}	12^{ab}	12^{ab}	0.88^{pq}	0.38^{u}	0.15^{u}	0.45^{q}	0.03^{tu}	0.04^{t}	0.043^{k}	0.04^{kl}	2.86^{o}	4.14^{i}	16^{cd}	14^{fgh}
	B+C	4.2^{o}	4.6^{k}	202^{s}	143^{C}	1.81^{n}	3.68^{h}	3.11^{o}	6.34^{h}	0.16^{i}	0.32^{d}	12^{ab}	11^{b}	0.91^{p}	0.9^{p}	1.35^{i}	0.67^{p}	0.06^{r}	0.04^{t}	0.07^{ij}	0.06^{j}	5.21^{h}	3.41^{j}	16^{cd}	14^{fgh}
	Control	4.21^{o}	4.8^{i}	184^{v}	143^{C}	3.42^{j}	4.02^{e}	5.90^{j}	6.93^{e}	0.30^{e}	0.35^{c}	12^{ab}	11^{b}	0.75^{r}	0.83^{q}	0.15^{u}	0.3^{s}	0.06^{r}	0.04^{t}	0.103^{h}	0.07^{ij}	2.43^{p}	2.90^{n}	16^{cd}	13^{hijk}
												Selecky													
Salted	Initial	5.81^{b}	5.81^{b}	382^{l}	352^{o}	0.72^{zA}	0.89^{x}	1.24^{wx}	1.53^{v}	0.09^{m}	0.07^{n}	13^{a}	12.33^{ab}	1.95^{f}	1.51^{j}	1.65^{g}	2.03^{d}	0.14^{gh}	0.172^{de}	0.21^{f}	0.243^{e}	0.91^{C}	1.15^{z}	9.1^{n}	9.1^{n}
	Biochar	5.37^{e}	4.81^{i}	441^{g}	542^{b}	2.52^{l}	3.76^{g}	4.39^{l}	6.5^{g}	0.23^{g}	0.32^{d}	11.33^{b}	12^{ab}	2.48^{d}	1.62^{hi}	0.31^{s}	1.35^{i}	0.124^{klm}	0.12^{mn}	0.0133^{mno}	0.183^{g}	0.77^{F}	1.21^{y}	11.33^{lm}	12.33^{jkl}
	Compost	4.96^{h}	5.51^{d}	482^{f}	425^{i}	2.02^{m}	1.54^{p}	3.55^{m}	2.6^{p}	0.18^{h}	0.13^{jk}	11.33^{b}	12^{ab}	3^{b}	0.47st	0.37^{r}	1.06^{k}	0.138^{hij}	0.113^{no}	0.213^{f}	0.073^{ij}	1.59^{w}	0.82^{E}	12.66^{ijk}	10.5^{m}
	B+C	5.31^{e}	4.81^{i}	488^{e}	218^{r}	1.25^{t}	1.25^{t}	2.15^{s}	2.15^{s}	0.11^{l}	0.11^{l}	11.33^{b}	11.33^{b}	1.73^{g}	1.27^{m}	1.71^{f}	2.93^{a}	0.79^{a}	0.18^{d}	0.43^{a}	0.29^{d}	0.47^{H}	0.85^{D}	10.66^{m}	13^{hijk}
	Control	5.61^{c}	7^{a}	375^{m}	430^{h}	1.42^{qr}	1.05^{u}	2.46^{qr}	1.81^{t}	0.13^{jk}	0.11^{l}	11^{b}	11.33^{b}	1.6^{hi}	1.66^{h}	1.81^{e}	1.35^{i}	0.21^{c}	0.14^{hi}	0.313^{c}	0.18^{g}	0.55^{G}	1.02^{B}	10.33^{m}	10.5^{m}
Unsalted	Initial	5.1^{g}	5.31^{e}	182^{wx}	193.3^{u}	0.92^{w}	1.76^{o}	1.6^{uv}	3.03^{o}	0.09^{m}	0.16^{i}	11.66^{ab}	12^{ab}	2.54^{c}	4.28^{a}	1.35^{i}	1.44^{h}	0.133^{ijk}	0.17^{de}	0.213^{f}	0.36^{b}	1.12^{A}	0.47^{H}	13^{hijk}	12^{kl}
	Biochar	4.4^{m}	4.81^{i}	173^{z}	183^{vw}	0.71^{AB}	0.98^{v}	1.22^{wx}	1.71^{tu}	0.07^{n}	0.09^{m}	12.33^{ab}	11.66^{ab}	1.5^{j}	2.17^{e}	0.24^{t}	0.31^{s}	0.05^{s}	0.122^{lmn}	0.063^{j}	0.07^{ij}	2.02^{t}	1.41^{x}	16^{cd}	12.66^{ijk}
	Compost	5.11^{g}	4.61^{jk}	151^{B}	198^{t}	1.4^{r}	1.44^{q}	2.43^{qr}	2.48^{pq}	0.133^{j}	0.12^{kl}	11.66^{ab}	11.33^{ab}	1.51^{j}	0.98^{o}	0.75^{o}	2.33^{c}	0.113^{no}	0.15^{g}	0.08^{i}	0.223^{f}	1.59^{w}	2.05^{s}	12.1^{kl}	13.83^{fghi}
	B+C	4.6^{k}	4.91^{h}	198.5^{t}	178^{y}	1.42^{qr}	1.25^{t}	2.44^{qr}	2.15^{s}	0.133^{j}	0.11^{l}	11.33^{b}	11.33^{ab}	1.58^{i}	1.35^{l}	0.23^{t}	0.15^{u}	0.126^{klm}	0.11^{o}	0.11^{h}	0.063^{j}	1.16^{z}	1.71^{v}	15.33^{de}	13.16^{ghijk}

Control	4.7^{j}	4.91^{h}	141^{D}	135^{F}	1.36^{s}	0.68^{B}	2.34^{r}	1.18^{x}	0.12^{kl}	0.06^{n}	12^{ab}	11.66^{ab}	1.43^{k}	1.58^{i}	0.76^{c}	0.83^{n}	0.08^{p}	0.17^{e}	0.07^{ij}	0.06^{j}	1.75^{u}	2.18^{r}	14.33^{efg}	13.33^{ghij}

At each site, treatments with the same letters per column are not statistically different (Fisher test P<0.05). C%= Percentage of Carbon. MO%= Percentage of organic matter. N%= Nitrogen percentage. Na= Sodium. Ca= Calcium. K= Potassium. P= Assimilable phosphorus. Mg= Magnesium. CEC= Cation exchange capacity.

3.3. Effects of organic amendments on rice plant growth parameters

3.3.1. <u>Seedlingsurvival rate</u>

Survival rates varied between sites, sampling dates, zones and amendments ($p<0.05$). At 15 DAR, the survival rate was 100% for all treatments regardless of zone ($p>0.05$). At 60 DAR and 90 DAR, there was a significant decrease ($p=0.001$) in the survival rate at Essyl in the salted zone for all treatments. This decrease was greater in year 2 for all treatments. However, the highest survival rates were noted with treatments B+C (81.67; 66.67%) and compost (81.67; 60.55%) in the 1st and 2nd years of experimentation respectively. On the other hand, at Selecky, no reduction in the number of plants was noted, with the exception of the control, where a reduction was noted in the 1st year of testing.

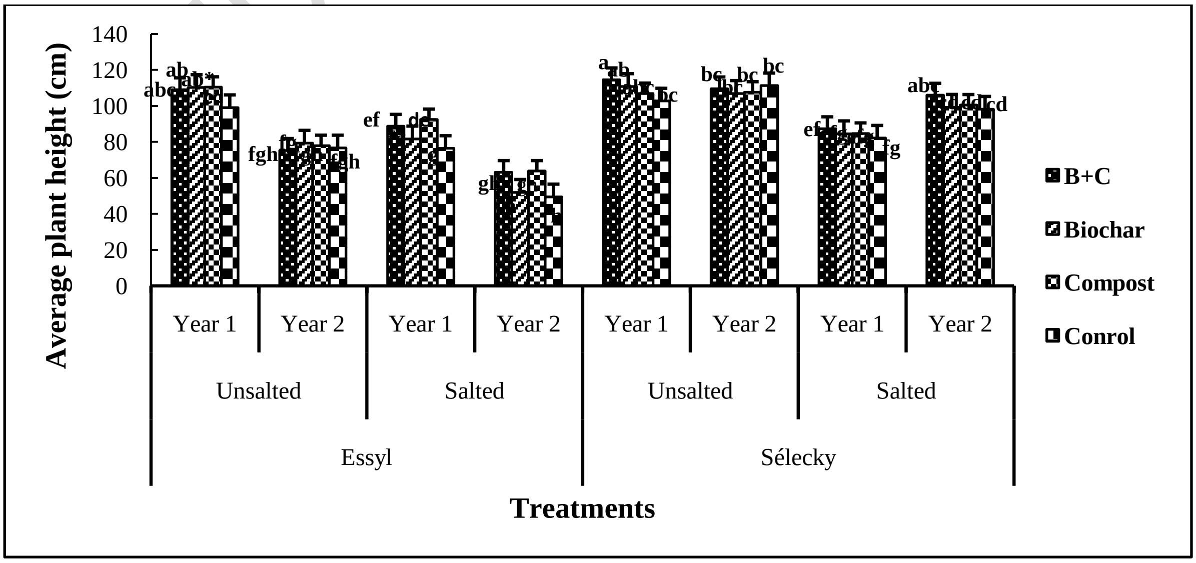
Table 4: Plant survival rates according to different treatments, sampling dates and years

Treatments		Biochar		Compost		B+C		Control	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Essyl									
Unsalted	15DAR	100^{a*}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
	60DAR	100^{a}	86.67^{ab}	100^{a}	86.67^{ab}	100^{a}	86.67^{ab}	100^{a}	80^{bc}
	90DAR	100^{a}	83.33^{bc}	100^{a}	81.66^{b}	100^{a}	76.67^{bc}	100^{a}	73.33^{bcd}
Salted	15DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
	60DAR	66.67^{cd}	61.67^{cd}	80^{b}	48.33^{ef}	81.67^{b}	58.33^{de}	53.33^{de}	40^{f}
	90DAR	58.33^{de}	43.33^{ef}	65^{cd}	33.33^{f}	75^{b}	41.67^{ef}	40^{f}	33.33^{f}
Selecky									
Unsalted	15DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
	60DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
	90DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Salted	15DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
	60DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	96.67^{a}	100^{a}
	90DAR	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	88.33^{ab}	100^{a}

**At each site, treatments with the same letters per column are not statistically different (Fisher test P<0.05).*

3.3.2. <u>Variation in average plant height</u>

Average plant height varied significantly between the salted and Unsalted zones at each site ($p<0.05$). In fact, the greatest heights were measured in the non-salted zone on both sites for all the organic amendments used, compared with the control (fig. 3). At Essyl, the lowest heights were measured in the 2nd year of experimentation, irrespective of the organic amendments used (fig. 3).



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

Fig. 3: Variation in plant height according to treatments

3.3.3. Variation in the number of tillers on rice plants

The number of tillers varied from site to site, zone to zone, year to year and amendment type to amendment type. The highest number of tillers (p=0.03) was obtained at Selecky in both zones (Salted and Unsalted) and for both years. At Essyl, it was highest in the unsalted zone in the 1st year of experimentation. The same Essyl site recorded the lowest number of tillers in the 2nd year of experimentation. However, the various organic amendments applied did not have a positive impact on the number of tillers at either site (fig. 4).

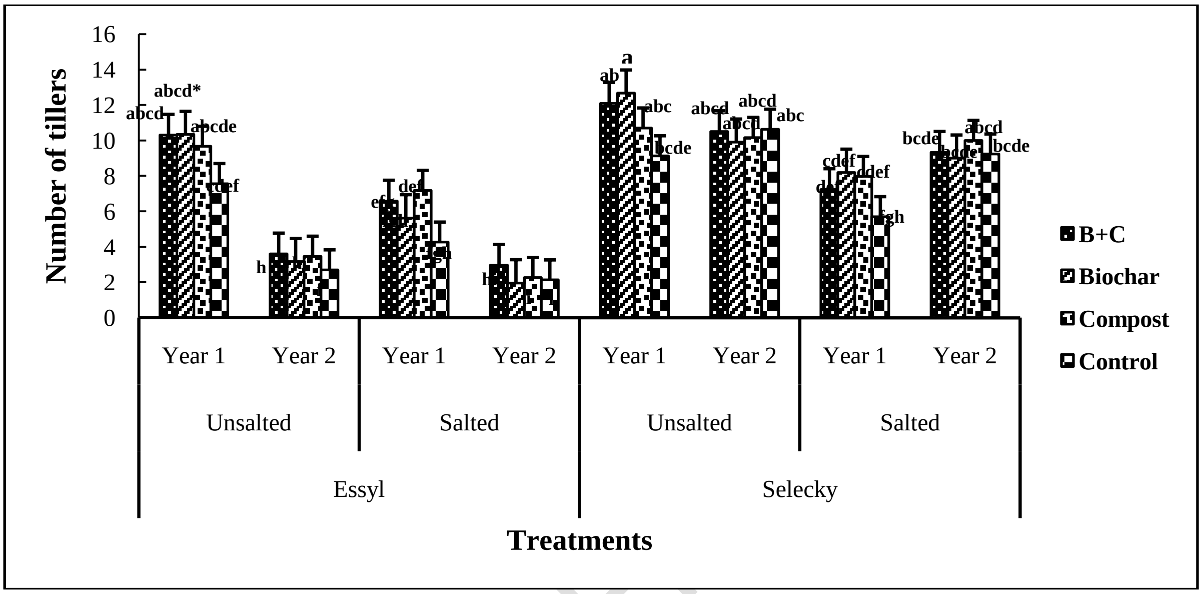


Fig. 4: Variation in the number of talles as a function of treatments

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

3.3.4. Effects of organic amendments on rice production and yield parameters

There was a significant difference between treatments across zones and sites (p<0.05). Production parameters are significantly (p<0.05) higher at Selecky, particularly in the Unsalted zone. Production parameters were higher for the biochar and B+C treatments compared with the control. The same finding was noted at Essyl for both zones. For both sites, however, production was lower in year 2 (p<0.05) than in year 1 (Table 5).

Table 5: Effect of organic amendments on production parameters in salted and unsalted areas for both sites

		Essyl					
Treatments		Numberpanicle		Panicleweight (g)		Paddy weight (g)	
		Year 1	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
Unsalted	Biochar	10^{cd*}	3^{mn}	13.93^{abcd}	2.28^{hi}	12.46^{abc}	2.56^{hi}
	B+C	10^{cd}	3^{mn}	14.48^{abcd}	1.26^{i}	10.95^{abcd}	3.23^{ghi}
	Compost	9^{cde}	3^{mn}	11.75^{bcde}	0.9^{i}	9.48^{bcdef}	2.63^{hi}
	Control	7^{ghij}	2^{mn}	9.2^{defg}	1.15^{i}	7.5^{cdefgh}	2.3^{i}
Salted	Biochar	5^{kl}	2^{mn}	6.51^{efghi}	0.58^{i}	4.91^{efghi}	1.73^{i}
	B+C	6^{ijk}	3^{mn}	7.68^{efgh}	0.85^{i}	6.35^{defghi}	2.8^{hi}
	Compost	7^{ghij}	2^{mn}	7.58^{efgh}	0.48^{i}	5.91^{defghi}	1.8^{i}
	Control	4^{lm}	2^{mn}	4.08^{ghi}	0.36^{i}	3.03^{hi}	1.66^{i}
		Selecky					
Unsalted	Biochar	13^{ab}	9^{cde}	16.73^{ab}	8.53^{efg}	13.9^{ab}	9.26^{bcdef}

	B+C	12^{ab}	10^{cd}	17.58^{a}	11.23^{cdef}	14.86^{ab}	9.76^{bcdef}
	Compost	11^{bc}	10^{cd}	15.11^{abc}	10.75^{cdef}	12.05^{abc}	9.46^{bcdef}
	Control	9^{cde}	10^{cd}	15.58^{abc}	10.95^{cdef}	11.86^{abc}	10.16^{bcde}
Salted	Biochar	8^{defgh}	8^{defgh}	7.86^{efgh}	5.43^{fghi}	6.11^{defghi}	8.06^{cdefg}
	B+C	7^{ghij}	9^{cde}	7.98^{efgh}	4.41^{ghi}	6.21^{defghi}	9.03^{bcdef}
	Compost	8^{defgh}	9^{cde}	6.23^{efghi}	4.63^{ghi}	4.81^{fghi}	9.5^{bcdef}
	Control	5^{kl}	8^{defgh}	7.4^{efgh}	5.78^{efghi}	6.05^{defghi}	8.83^{bcdef}

**At each site, treatments with the same letters per column are not statistically different (Fisher test P<0.05).*

3.3.5. <u>Variation of performance parameters.</u>

Yields increased significantly for treatments with organic amendments in the saline and non-saline zones for both sites ($p<0.05$; Table 6). Treatments with biochar, compost and B+C gave the highest biomass at Essyl and Selecky in both zones. In terms of paddy rice yield, the biochar and B+C treatments gave the highest yields at all sites and in both zones (Table 6).

Table 6: Effect of organic amendments on yield parameters in salted and Unsalted areas for both sites

Treatments		Total biomass (g)		Aerialbiomass (g)		Rootbiomass (g)		Weight 1000g		paddy yield (t/ha)	
		Year 1	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
						Essyl					
Unsalted	Biochar	26.38^{bcde*}	17.06^{de}	19.75^{bcde}	11.26^{de}	6.63^{cd}	1.8^{gh}	27.30^{abc}	24.14^{cdefgh}	2.49^{abcde}	0.77^{ghi}
	B+C	26.83^{bcde}	11.93^{e}	18.76^{cde}	9.58^{de}	8.06^{c}	2.35^{fgh}	27.4^{ab}	21.41^{fghi}	2.19^{cdefg}	0.57^{hi}
	Compost	22.83^{cde}	12.1^{e}	16.28^{cde}	10.56^{de}	6.55^{cd}	1.53^{h}	28.28^{a}	23.85^{defgh}	1.89^{cdefgh}	0.31^{i}
	Control	22.38^{cde}	12.93^{e}	16.5^{cde}	11.03^{de}	5.88^{cde}	1.9^{gh}	27.19^{abc}	25.04^{abcde}	1.5^{defghi}	0.41^{i}
Salted	Biochar	3.88^{e}	7.95^{e}	2.96^{e}	6.36^{e}	0.91^{h}	1.59^{h}	24.56^{bcdefg}	21.5^{fghi}	0.983^{fghi}	0.25^{i}
	B+C	14.65^{e}	10.06^{e}	11.28^{de}	8.71^{de}	3.36^{defgh}	1.35^{h}	24.66^{bcdef}	21.33^{ghi}	1.2^{efghi}	0.38^{i}
	Compost	6.18^{e}	6.86^{e}	4.21^{e}	5.74^{e}	1.96^{gh}	1.11^{h}	25.98^{abcd}	19.92^{i}	1.183^{efghi}	0.24^{i}
	Control	5.33^{e}	3.61^{e}	4.25^{e}	3^{e}	1.08^{h}	0.61^{h}	21.98^{efghi}	19.93^{i}	0.607^{hi}	0.13^{i}
						Selecky					
Unsalted	Biochar	20.06^{cde}	35.6^{abcd}	17.6^{cde}	31.87^{abc}	2.46^{fgh}	3.73^{defgh}	28.01^{a}	27.45^{ab}	2.78^{abcd}	2.95^{abc}
	B+C	21.15^{cde}	41.93^{ab}	18.35^{cde}	36.37^{a}	2.8^{efgh}	5.56^{cdef}	27.63^{ab}	27.76^{ab}	2.973^{abc}	3.72^{a}
	Compost	18.2^{de}	44.35^{ab}	15.86^{cde}	38.8^{a}	2.33^{fgh}	5.55^{cdef}	27.73^{ab}	27.32^{abc}	2.41^{bcdef}	3.59^{ab}
	Control	19.9^{cde}	38.95^{abc}	17.5^{cde}	34.05^{ab}	2.4^{fgh}	4.9^{defgh}	28.12^{a}	28.22^{a}	2.373^{bcdef}	3.17^{abc}
Salted	Biochar	12.96^{e}	53.18^{a}	9.36de	34.01^{ab}	3.6^{defgh}	19.16^{a}	21.04^{hi}	21.77^{fghi}	1.223^{efghi}	2.13^{cdefg}
	B+C	12.33^{e}	48^{a}	8.88de	28.98^{abc}	3.45^{defgh}	19.01^{a}	23.39^{defgh}	25.48^{abcd}	1.243^{efghi}	2.05^{cdefg}
	Compost	11.33^{e}	45.08^{ab}	8.55de	26.03^{abcd}	2.78^{efgh}	19.05^{a}	21.15^{hi}	23.67^{defgh}	0.963^{fghi}	1.91^{cdefgh}
	Control	11.56^{e}	41.4^{ab}	8.15de	25.91^{abcd}	3.41^{defgh}	15.48^{b}	21.85^{efghi}	23.67^{defgh}	0.963^{fghi}	2.05^{cdefg}

**At each site, treatments with the same letters per column are not statistically different (Fisher test at $p<0.05$).*

3.3.6. Correlation between soil physico-chemical elements and rice parameters at the two sites as a function of organic amendment application.

The combination of the two principal component analysis (PCA) axes explains 72.92% of the variance. Depending on the axes. Fig. 5 can be subdivided into three (3) groups. Parameters such as Mg^{2+} Na^{+}, PSE, S, K^{+}, pH, Ca^{2+}. Clay, fine silts and fine sand located on the positive abscissa side (axis 1) are more correlated with the combined biochar and compost treatment. B+C (Fig. 5). This means that the values of these parameters are higher for this treatment than for the other treatments. These treatments gave the highest root biomass values. The same applies to carbon, soil phosphorus. C/N ratio, CEC, organic matter (OM) and nitrogen (N), all of which are located on the negative abscissa side and are more correlated with the biochar-only and compost-only treatments. However, despite their importance, these parameters did not improve rice plant growth. It should also be noted that the EC (electrical conductivity) characterizing the saline zone is closer to the y-axis. Salinity has negative effects on rice growth and yield. Finally, all the agro-morphological parameters (height, number of tillers. survival rate, number of panicles, paddy mass, 1000-seed mass and yield) were greater in the Unsalted zone of the Selecky site.

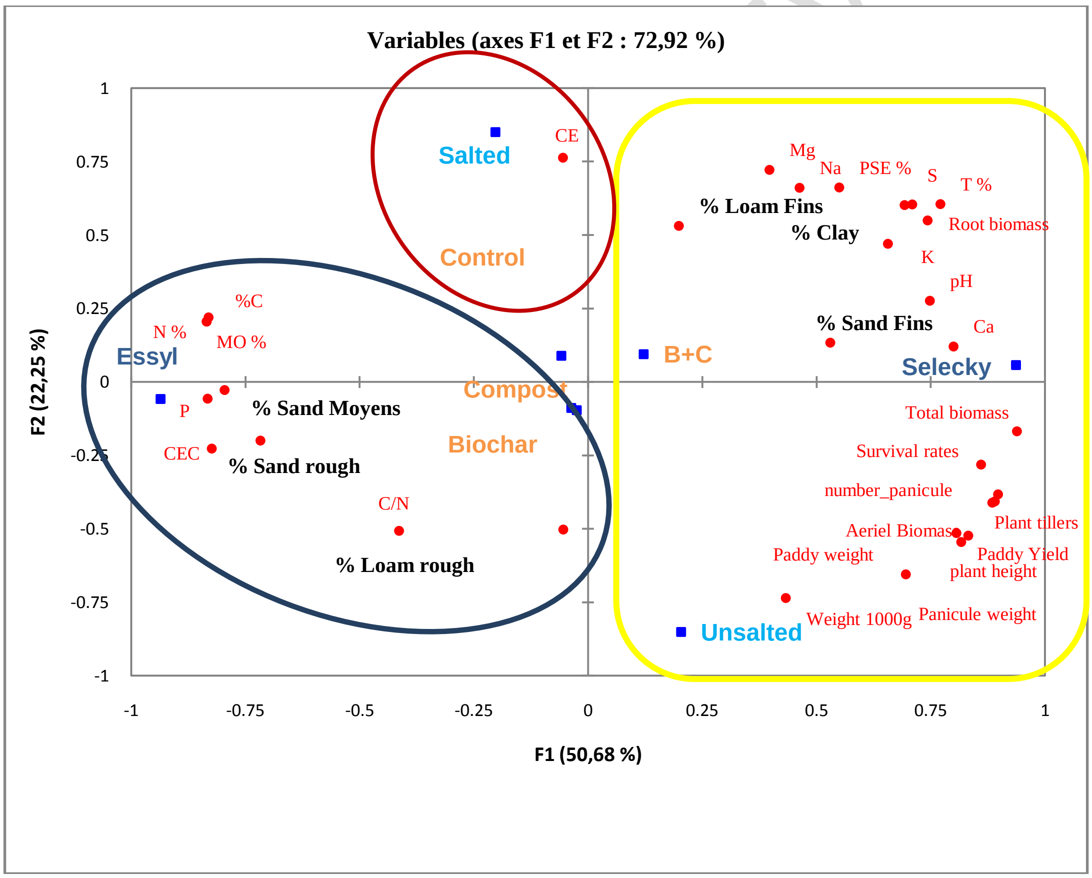


Fig. 5: Correlation between rice parameters, soil parameters (physical and chemical) and organic amendments

3.4. Soil physical characteristics and effects of organic amendments on soil chemical properties

The sandy-loam texture of Essyl soils has been associated with a low content of exchangeable bases, particularly Ca^{2+}, K^{+} and in the case of Selecky clay-loam soils, with a saturation of exchangeable bases (Ca^{2+}, K^{+}, Mg^{+}). According to [12] the low exchangeable base content of soils composed almost exclusively of skeletal sands can be explained by the more advanced maturity of these soils. This phenomenon is more noticeable in the depressions. At Essyl, the soils were sandier than at Selecky. In addition N, P, organic matter, C, C/N ratio, CEC and salinity (EC) levels were highest in soils amended with biochar and compost, compared with Selecky soils. Despite these important elements in saline zones, their influence on plant growth was limited. The work of [13] has shown that excess salt in the soil leads to a drop in nutrient availability for plants. These chemical elements are lower in the lowlands at Selecky.

3.5. Effect of organic amendments on rice plant survival and growth parameters

Overall, salinity had a negative impact on plant survival rates in the salt zone, particularly at Essyl. Indeed, the mortality noted in the saline zone could be due to the unavailability of nutrients for the plants. According to [13] and [14], excess salt in the soil reduces the availability of nutrients to plants, leading to plant mortality. These same results were also obtained by [15]. They noted plant mortality during the tillering stage, but also before harvest. The same finding was also made by [16], who noted a mortality of rice plants at the planting stage following an increase in salt levels in the environment. In most cases, rice becomes particularly sensitive to salinity at the seedling stage [17] ; [18].

3.6. Effect of organic amendments on rice production and yield parameters

Our study showed that for all the parameters studied (growth and yield), the organic amendments used had a significant influence in the non-saline zone. Treatments with biochar, compost and B+C had a significant impact on height, number of tillers and yields for all study sites. This difference could be linked to the availability of nutrients. Organic amendments such as biochar and compost are rich in nutrients. Adding them to soils would improve plant nutrition. Biochar would increase the availability of phosphorus to plants in the soil [19]. According to [20], adding biochar to soils changes their microbiological properties. In fact, biochar is a preferred habitat for soil micro-organisms, and its presence is thought to reduce nitrogen losses [20], which is of great interest for improving tropical soils. Several studies have shown an increase in agricultural yield following the addition of biochar in the short term [21]; [22];[23] and in the long term [24]. It has been suggested that combining compost with biochar could be beneficial for soil fertility. However, an application of 7 $t.ha^{-1}$ of biochar in combination with mineral fertilizer or vermicompost (20 $t.ha.yr^{-1}$) at the foot of the plants did not significantly increase maize yields.

Our results also showed that yield parameters (tillers, panicle weight and plant biomass) were greater in the 1st year of experimentation than in the 2nd, year. This could be due to the high rainfall (2203.6 mm) recorded during the same period. These results corroborate those of [25] who reported that the main limiting factor for rainfed rice production is rainfall. [26], showed that rice yields fell from 2.9 $t.ha^{-1}$ in 2010 to 1.1 $t.ha^{-1}$ in 2013 (a 164% drop) due to the delayed onset of rains and lower rainfall. Climate change generally has a negative effect on lowland rice cultivation in one way or another [27]. The performance noted on rice yield parameters in the 1st year of experimentation may also be attributable to the organic amendments applied at that time. [28] have shown that the long-term fertilizing value of organic fertilizers does not always increase over time, despite the progressive enrichment of soil organic matter in organic fertilizer processes. According to these authors, fertilizing values do, however, vary according to the number of years since the last organic input.

4. CONCLUSION

The study of the effect of organic amendments, biochar and compost on the development and production of Oryza sativa L rice in lowlands affected by salinity revealed that salinity had a negative effect on the survival rate of seedlings for all types of organic amendment in the Essyl zone in the first and second years of experimentation. pHvalueswere generally acidic for all sites and zones in both the first and second years of experimentation. In the salty zone, compost or biochar inputs significantly increased the number of tillers and the height of rice plants compared with controls. The same amendments also increased above-ground biomass in the saline zone in both years. These increases were greater at Selecky in both zones. Plants in the rice fields amended in the saline areas of this site (Selecky) were more tolerant to salinity. Essyl, however, recorded low rice production, mainly due to the salinity observed, but also to the type of soil in the area.

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