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RESEARCH ARTICLE

EVALUATION OF THE AGRO-MORPHOLOGICAL PERFORMANCE OF NEW RICE LINES UNDER SALINITY CONDITIONS

Ibrahima Mbodj[1]*, Omar Ndaw Faye[2] and Bouna BAR

[1]Alioune DIOP University of Bambey, Higher Institute of Agricultural and Rural Training, BP 54 Bambey-Senegal
[2]Senegalese Agricultural Research Institute, Center of Saint-Louis, BP 240 Saint-Louis, Senegal

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ABSTRACT

Soil salinity is one of the major constraints to rice production and constitutes a real challenge for the State of Senegal to meet the population's rice consumption needs and to achieve food self-sufficiency. Thus, a subject was made available to us whose objective of the study is to evaluate the agro-morphological performances of thirteen (13) new varieties of rice tolerant to the salinity under the conditions of culture of the delta of the valley of the Senegal River. The trial was carried out at Ndiol's Serigne Moustapha Bassirou MBACKE station under salt stress conditions of five decis siemens per meter (5ds / m) during the hot off-season with sowing in mid-March. The experimental device chosen was of the "Apha-Lattice" type or incomplete block device with 3 repetitions. Saline stress as well as agro-morphological characteristics such as the number of days at 50% heading, the number of days of sowing at physiological maturity, the number of tillers at harvest, the number of panicules per m2 and the yield have have been analyzed. Agronomically, the analysis of variance reveals that there is a significant difference in the studied traits of yield components with the exception of the weight of 1000 grains and the yield at 14% moisture. However, the two varieties HHZSALT 10, D33-NDIOL-3-LON-1 and the FL 478 tolerant control gave the best yields with respectively 3.532, 3.064 and 3.607T/ha.

INTRODUCTION

Rice is the second most produced food grain in the world, after wheat with nearly 754.6 million tonnes of paddy rice (500.8 million tonnes milled equivalent) (1). According to (1), the annual world consumption per capita was on average 54.3 kilos per person and at the same time the volumes destined for animal feed and other uses (including seeds, post-harvest losses and industrial uses) fell slightly and stood at 17.9 and 79.5 million tonnes respectively. Half of humanity depends on rice for its food, of which 90% of the world's production comes from Asia. China, the world's leading rice producer (30%), is also the leading consumer. Thailand and Vietnam are currently the main rice exporters. Together they account for half of global sales. Still in Southeast Asia, the Philippines are the world's leading importing country. Africa, which barely covers more than 10% of its needs, absorbs a third (1/3) of world imports (3). In West Africa (excluding English-speaking countries and Benin), rice production was 6.227 million tonnes in 2017 for a consumption of 10.223 million tonnes, i.e. a deficit of 3.996 million tonnes.

*Corresponding author: ***Ibrahima Mbodj***
Alioune DIOP University of Bambey, Higher Institute of Agricultural and Rural Training, BP 54 Bambey-Senegal

Faced with the concern to satisfy domestic demand, its countries were obliged to resort to imports of broken rice for a value of 4.315 million tonnes in the same year (3). In Senegal, the production of husked rice was 680 thousand tons for a consumption of 1.725 million tons in 2017 with imports of around 1.1 million tons (4.). Senegal has become one of the biggest importers of broken rice in West Africa, after Nigeria, by positioning itself as a net importer of rice. Thus, the promotion of local rice growing to meet national demand will be a strategic option for the State. Food self-sufficiency has become an objective to be achieved through the agricultural policies initiated, including the Program for the Recovery and Acceleration of the Pace of Senegalese Agriculture (PRACAS) which is one of the structural projects of the Senegal Plan Emerging (PES). PRACAS is a reformulation and consistency of the Government's agricultural development strategies. In the PSE, in 2017, all Senegalese consumption needs for good quality rice were estimated at 1.6 million tonnes of paddy rice (1.08 million tonnes of milled rice). The objective was to meet this demand from local production and with a more balanced contribution from the Senegal River Valley (VFS) of 912,002 tons of paddy rice (5; 6). But soil and water salinity has become one of the most important constraints in rice-growing environments (7) that must first be addressed. Indeed, the surface area of salinized cultivated land should thus increase in Senegal from 78,096 hectares in 2010 to 177,327 hectares in 2100 (8).

This state of affairs constitutes a real constraint for the production of irrigated rice, leading to a considerable reduction in crop yields. Soil management is therefore considered to be one of the priority themes for ensuring the sustainability of production methods and concerns not only environmental protection but also concerns related to production and product quality (9). To remove this threat of salinity, it is therefore necessary to create new varieties tolerant to salt stress. It is in this context that ISRA, through the STRASA project (Stress Tolerant Rice for Africa and South Asia) funded by the Bill and Melinda Gates Foundation, has been carrying out a rice varietal improvement activity for salinity tolerance since 2009. The objective of this work is to evaluate the agro-morphological performances of the new lines under salinity conditions at 5dS/m.

MATERIAL AND METHODS

Plant Material : The plant material is composed of thirteen lines of rice (Table 1) from various origins (AfricaRice, IRRI, CASS, CRA Saint Louis) and two selected controls are: the tolerant control (FL 478) and the sensitive control Sahel 108, most cultivated variety in the Senegal River Valley with a short cycle and high yield.

Methods

Experimental apparatus: The experimental device is in Alpha Lattice with 3 incomplete blocks each containing 5 lines. The lineage constitutes the factor to be studied with 15 levels. The number of repetitions is 3. The dimension of each experimental unit (Figure 1) or elementary plot is: (5 m x 4 m) i.e. 20 m^2 with spacings of 50 cm between the experimental units as well as between the blocks. The salinity was maintained at a single level (EC= 5ds/m) on all the elementary plots.

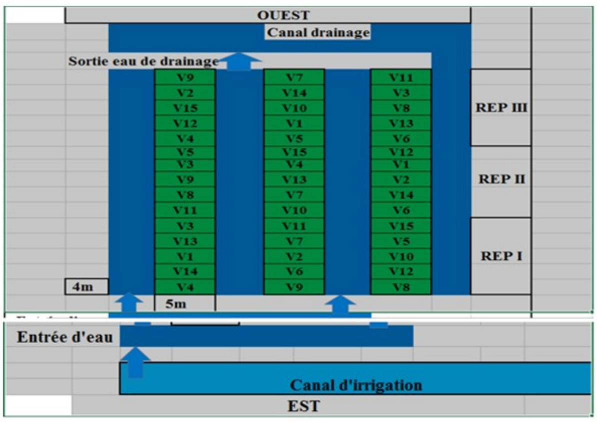

Figure 1. Plan of the experimental device

Cultivation management : The test was conducted at the Ndiol station (Saint Louis du Senegal) in the hot off-season from February to July 2018.

- **Setting up the nursery :** The seeds were first winnowed, sorted, and then put in labeled bags bearing the name of each line, the number of the block and the plot to be sown. Sorting consists of removing empty or damaged grains and impurities.
- **Dipping :** It consists of rehydrating reconditioned seeds in jute bags by soaking them in water for 24 hours.
- **Incubation:** The seeds are soaked in water for 24 hours then removed from the water and left to dry in the ambient air for 15 minutes before incubation. Incubation was done under straw. The operation lasted 24 hours after which we observed the appearance of stems and rootlets.
- **Land preparation:** At the start, we carried out pre-irrigation to trigger the appearance of the first weeds and regrowth and to moisten the soil to facilitate plowing with a tiller. And to obtain a good seedbed, manual harrowing and leveling were carried out.
- **Sowing:** After 24 hours of incubation, the seeds, sufficiently pre-germinated, are sown on muddy beds in the nursery with a low water depth, covered with a thin layer of sand and a tarpaulin to facilitate uprooting and speed up the germination process.

•**Establishment of the experimental plot :** Preparation of the soil of the experimental plot: Shallow mechanical cross-plowing was carried out with the aim of burying weeds, loosening the soil and aerating it. It was followed by harrowing to crush the clods of earth raised by the discs during ploughing. Then, the blocks were delimited by bunds and the irrigation network installed.

•**Transplanting :** Transplanting took place three weeks after sowing in the nursery, following a spacing of 20 cm x 20 cm at the rate of two plants per pocket.

Cultivation maintenance

•Irrigation: It was done as needed to maintain a good layer of water depending on the stage of development. Irrigation was alternated with series of drainage on demand. During the vegetative phase, a low layer of water is maintained at 5cm. A 10 cm water slide is maintained until the start of the pasty stage. Complete drainage was carried out on each plot between the pasty stage and maturity.

•**Fertilization:** 100 kg of DAP (18-46-00)/ha were applied as basal fertilizer during the preparation of the plots and 100 kg of KcL/ha on the 15th day after transplanting. 46-0-0 was applied at a dose of 300 kg per hectare in three additions: 120 kg per hectare at the start of tillering, 120 kg per hectare at panicle initiation (and 60 kg at per hectare uphill.

•**Weed management and phytosanitary treatments:** Chemical weeding was carried out 15 days after transplanting (DAR) by applying Bensulfuron-methyl (Londax 60 Df) at a dose of 75g/ha, under a 5 cm water slide followed by some manual weeding at whenever necessary. Preventive treatments with Decis at a dose of 1l/ha were carried out every 15 days against mites and insects in the reproduction phase. From flowering to harvest, the protection of crops against birds is ensured by two guards against the invasion of seed-eating birds.

•**Electrical conductivity measurements:** Salinity was monitored by electrical conductivity measurements using a conductivity meter, and maintained at 5 deci-siemens per meter (5 dS/m). The measurement process requires prerequisites. A small drop of wetting solution (moistening solution) serving as a pre-treatment was put on the electric plate, 10 minutes later, water was poured before starting. Once the device is running, a standard solution (model Y071L) allowing to play a calibration role whose value is 1.41ms/cm is used. With a pipette, we took from each elementary plot a small quantity of water which gave the level of salinity in deci-siemens per meter.

•Evolution of electrical conductivity

•The evolution of electrical conductivity is illustrated in figure 2.

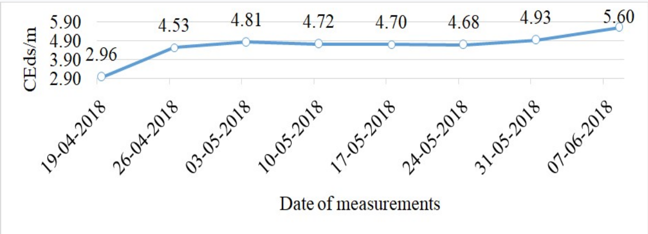

Figure 2.Evolution of electrical conductivity

Regarding the first measurement, the electrical conductivity is below 3 dS/m. From the second week, it fluctuates between 4.53 and 5.60 dS/m. Our lines were placed in a saline environment.

- **Harvest and post-harvest :** Harvesting took place when the grains reached physiological maturity. To assess the production potential of each line, a useful area was calculated and harvested.
- **Observations and measurements :** Observations and measurements relate to the following parameters:
- **Agro morphological parameters**
- **Observing 50% DAF :** Observations on all the elementary plots were made to determine the duration of the "sowing-flowering" cycle. This duration corresponds to the number of days between sowing and flowering of 50% of the plants of each line.
- **Observing 50% DAE:** Number of days at 50% heading, i.e. the number of days from sowing to heading of 50% of the plants of a variety on a given plot.
- **Number of mature tillers:** A count of the total number of tillers per pocket is carried out in the lab after harvest.
- **Panicle length at harvest :** The average panicle length was obtained by averaging the length of ten randomly selected panicles from each plot. A double decimeter was used to measure the distance from the base of the panicle to the last branch.
- **Yield components:** Four (4) plots of 0.25 m2 were placed at 4 different locations within each useful plot. The evaluation focused on the number of total pockets, the total number of tillers, the number of panicles per m2, the total weight of panicles, the number of full and empty grains and the weight of 1000 grains.
- **Data processing and analysis:** Data processing was carried out by Microsoft Office 2013 software for data entry (Word) and tables and graphs (Excel). In addition, the ARIS software was used for the variance analyses.

RESULTS

Our results on the agro-morphological characteristics of the lines evaluated and the parameters of the yield components are recorded in Table 2. They concern the number of days at 50% heading, the number of days at 80% maturity, the length of the panicles at harvest, number of mature tillers per square metre, number of mature panicles per square metre, 1000 grain weight and yield at 14% moisture content.

Agro-morphological parameters

•Number of days at 50% heading: The number of days at 50% heading is in an interval of 120 to 138 days, concerning lines ARS756-1-1-3-B-2-2 and D14 respectively with an average of 129. Two lines, ARS756-1-1-3-B-2-2 and HK122-NDIOL-1-1, are earlier than Sahel 108, the best control which records 125 d. The analysis of variance does not show a significant effect at the 5% threshold between the varieties tested (Pr=0.904). Our results are shown in Figure 3.

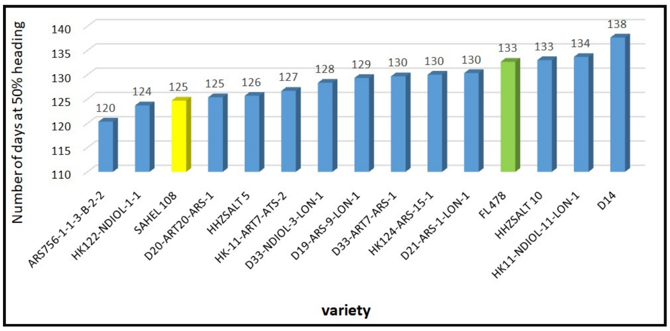

Figure 3. Variation in the number of days at 50% heading depending on the variety

•**Number of days at 80% maturity:** The maturity cycle varies from 155 to 163 days with an average of 160 days after sowing. From seeding to harvest, line ARS756-1-1-3-B-2-2 had the shortest number of days and HK11-NDIOL-11-LON-1 had the longest number of days. Sahel 108, the earliest control recorded 156 cycle d, which is similar to that of HK11-NDIOL-11-LON-1.

The analysis of variance shows that there is no significant effect at the 5% threshold between the varieties tested (Pr =0.784). Our results are shown in Figure 4.

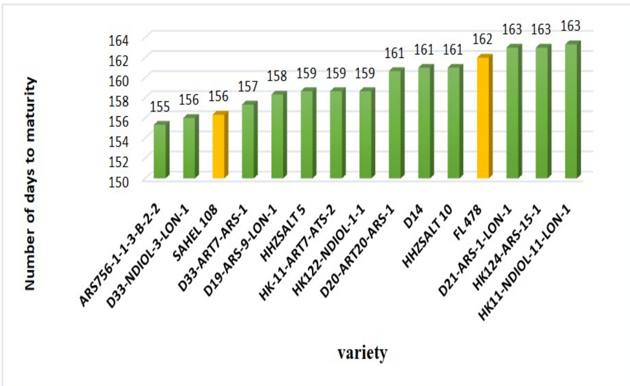

Figure 4. Variation du nombre de jours à 80 % maturité en fonction des variétés

- **Panicle length at harvest:** The measurements taken at the level of the panicles showed a minimum of 17.38 cm and a maximum of 24.57 cm corresponding respectively to the lines D19-ARS-9-LON-1 and D20-ATR20-ARS-1 with an average of 21 .43 cm (figure 5). The analysis of variance shows that there is no significant effect at the 5% threshold between the varieties tested (Pr =0.491).

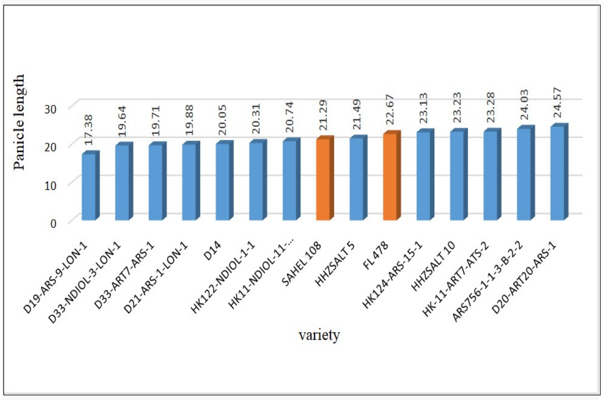

Figure 5. Variation in panicle length depending on the variety

Parameters of performance components

- **Number of mature tillers per square meter (/m2):** The number of tillers at maturity varies between 159 (HK11-NDIOL-11-LON-1) to 296 (Sahel 108) for an average of 230 tillers. Lines D33-ART7-ARS-1, D20-ART20-ARS-1 and D19-ARS-9-LON-1 have the highest number of tillers with 264, 278 and 284 tillers respectively, just behind the control Sahel 108 and before the tolerant control FL 478. Figure 6 illustrates our results. The analysis of variance reflects a very highly significant difference at the 5% threshold between the lines studied (Pr=0.0000104).

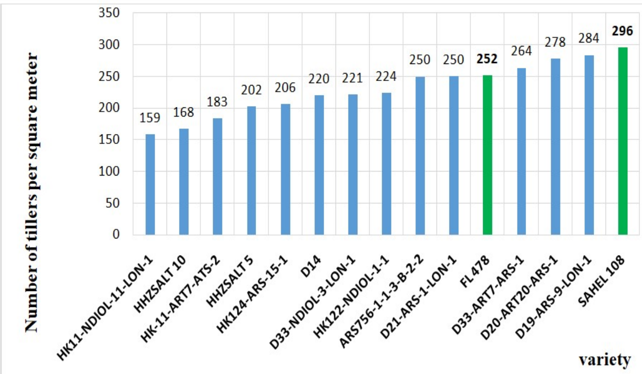

Figure 6. Variation in the number of tillers per square meter depending on the variety

- **Number of mature panicles per square meter (/m2):** The number of mature panicles per square meter varies between 157 and 281 with an average of 225 panicles per square meter. Line D19-ARS-9-LON-1 has the highest number of panicles followed respectively by susceptible tolerant control Sahel 108, lines D20-ART20-ARS-1, D33-ART7-LON-1 and D21- ARS-LON-1. On the other hand, line HK11-NDIOL-11-LON-1 shows a smaller number of panicles. Figure 7 illustrates our results. The analysis of variance reveals a very highly significant effect at the 5% threshold between the rice lines tested (Pr=0.0001067).

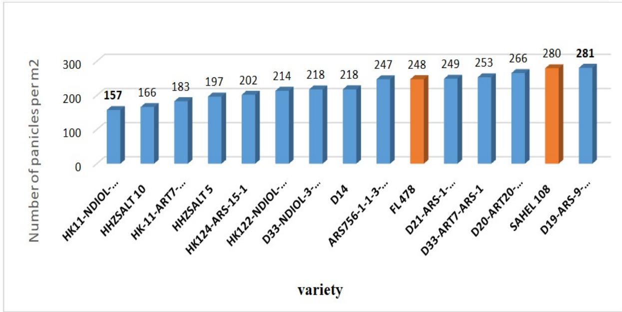

Figure 7. Variation in the number of panicles per square meter depending on the variety

- The 1000 grain weight varies between 17.69 to 26.95 g with an average of 21.60 g. ARS756-1-1-3-B-2-2 has the best PMG and HK124-ARS-15-1 has the lowest. The D20-ART20-ARS-1, D33-ART7-ARS-1 and ARS756-1-1-3-B-2-2 lines have a PMG greater than that of FL 478, the best control which has an average of 23.58 g. Lines D21-ARS-1-LON-1, HHZSALT 10 and HK124-ARS-15-1 have a lower PMG than Sahel 108 (19.2 g). Figure 8 illustrates our results.The analysis of variance shows that there is no significant effect at the 5% threshold between lines tested (Pr = 0.490).

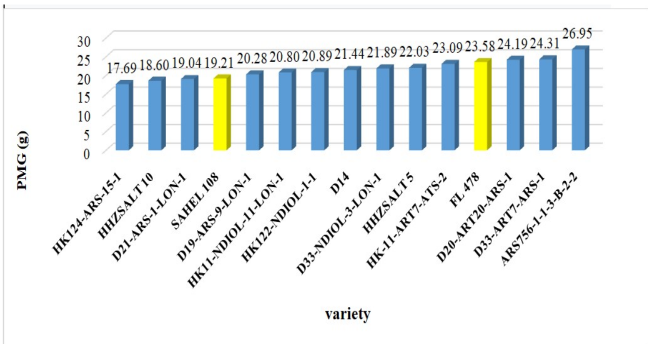

Figure 8. Variation in 1000 grain weight depending on the variety

- **Yield at 14% humidity:** The yield at 14% humidity varies between 1.50 to 3.61 T//ha with an average of 2.26 T/ha. The best yield is obtained by the control FL 478. Seven lines (07), (HHZSALT 5, D14, D21-ARS-1-LON-1, HK122-NDIOL-1-1, D19-ARS-9-LON-1, HK11-NDIOL-11-LON-1 and HK-11-ART7-ATS-2) have a lower yield than that of Sahel 108 which records 2.09 T/ha. Figure 9 illustrates our results.The analysis of variance shows that there is no significant effect at the 5% threshold between the lines studied (Pr = 0.069).

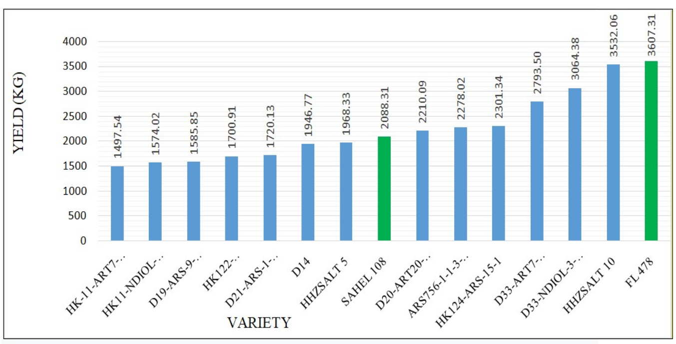

Figure 9. Variation in yield at 14% humidity depending on the variety

Table 1. List of lines and controls used

Numbers	Name of Varieties and Lines
1	HK124-ARS-15-1
2	D14
3	HK11-NDIOL-11-LON-1
4	ARS756-1-1-3-B-2-2
5	D20-ART20-ARS-1
6	D33-ART7-ARS-1
7	HK-11-ART7-ATS-2
8	D33-NDIOL-3-LON-1
9	D21-ARS-1-LON-1
10	D19-ARS-9-LON-1
11	HK122-NDIOL-1-1
12	HHZSALT 5
13	HHZSALT 10
14	SAHEL 108
15	FL 478

Table 2. Agro-morphological characteristics of lines

Varieties	Number of tillers at harvest/m^2	Total number of panicles/m^2	Number of days at 50% heading	Number of days at 80% maturity	Panicle length at maturity	PMG g	Rdt kg/ha
ARS756-1-1-3-B-2-2	250	247	120	155	24,03	26,95	2278,02
D14	220	218	138	161	20,05	21,44	1946,77
D19-ARS-9-LON-1	284	281	129	158	17,38	20,28	1585,85
D20-ART20-ARS-1	278	266	125	161	24,57	24,19	2210,09
D21-ARS-1-LON-1	250	249	130	163	19,88	19,04	1720,11
D33-ART7-ARS-1	264	253	130	157	19,71	24,31	2793,5
D33-NDIOL-3-LON-1	221	218	128	156	19,64	21,89	3064,38
FL 478	252	248	133	162	22,67	23,58	3607,31
HHZSALT 10	168	166	133	161	23,23	18,6	3532,06
HHZSALT 5	202	197	126	159	21,49	22,03	1968,33
HK-11-ART7-ATS-2	183	183	127	159	23,28	23,09	1497,54
HK11-NDIOL-11-LON-1	159	157	134	163	20,74	20,8	1574,01
HK122-NDIOL-1-1	224	214	124	159	20,31	20,89	1700,91
HK124-ARS-15-1	206	202	130	163	23,13	17,69	2301,34
SAHEL 108	296	280	125	156	21,29	19,21	2088,31
Moyenne Générale	230	225	129	160	21,43	21,6	2257,9
CV	46.64	43	9.68	5.2	2.1	3.06	931
Pr	0,0000104	0,00001067	0,904	0,784	0,491	0,49	0,069

DISCUSSION

This experiment carried out in the ISRA station in Ndiol made it possible to evaluate the morpho-agronomic performance of rice varieties tolerant to salinity under the growing conditions of the delta of the Senegal River Valley.

• **Evaluation on morphological characters:** In view of the results obtained on the number of days at 50% heading, the analysis of variance shows that there is no significant difference between the lines tested. The ARS756-1-1-3-2-2 line has a shorter number of days at 50% heading with 120 days while that D14 has the longest number of days after sowing with 138 days. Indeed, the hot dry season was marked by low temperatures from January to March, thus leading to a delay in the transplanting date. This delay is due to the time taken in the nursery for the different lines studied. This lengthening of the sowing-heading cycle is caused by the slowdown in the growth of plants at the seedling stage. This will eventually influence the cycle at maturity. The sensitive Sahel 108 control, which has a short cycle in a non-saline environment, sees its cycle at physiological maturity at 156 DAS. The delay in the date of heading is also part of the harmful effects of salinity (10). Concerning the length of the panicles at harvest, the analysis of variance shows that there is no significant difference between the varieties tested even if, arithmetically, there is a difference between the means and the controls; therefore all varieties behave in the same way.

The capacity for salt tolerance between lines could be linked to variations in genetic potential resulting in variable physiological responses to the salt content of the study medium.

• **Assessment of performance components:** Regarding the number of tillers at harvest, the analysis of variance shows that there are significant differences between the varieties tested. The sensitive control Sahel 108 has the highest number of tillers with 296 whereas the HK11-NDIOL-11-LON-1 has the lowest number with 159 tillers. Indeed, these results confirm those of (11), according to which salinity affects the rice plant during tillering and are not consistent with those of (12) which showed that the different levels of salinity have no significant effect on the number of tillers. The stress linked to the presence of salt could lead to difficulty in absorbing water due to the difference in osmotic pressure between the external environment and the internal environment of the plant, with the consequence of water stress which can be severe depending on the degree of salt concentration. One of the strategies to reduce the effects of salt could consist in reducing the aerial parts, but also in closing the stomata in order to reduce the amount of water transpired. This could reduce the absorption of CO2. During the tillering period, the rice plant needs energy to develop tillers, and the closure of the stomata would reduce the photosynthetic capacity of the plant, thus leading to a decrease in energy and consequently the reduction in the tillering capacity of the plants. rice lines.

This observation is consistent with that of (13) which explains that salinity affects the physiological activity of the leaf, and more particularly photosynthesis, which constitutes the main cause of the reduction in plant productivity. These physiological considerations could explain the behavior of the different lines tested with respect to the presence of salt. Lines D19-ARS-9-LON-1, D20-ART20-ARS-1 and D33-ART7-ARS-1, apart from Sahel 108, with their respective tiller numbers of 284, 278 and 264 per square meter, are more tolerant to salinity. The same difference was observed on the number of panicles due to the negative effect of salinity; this phenomenon is more visible during the reproduction phase than during the heading-flowering stage.

These results are in line with those of (14) which explains that throughout the rice cycle, morphological symptoms due to stress caused by salinity can be observed, in particular numerous dead leaves at the base of the foot, a number of reduced green leaves, abandoned panicle branches. We then observe white panicle branches bearing sterile flower buds (15). Indeed, during the flowering phase, salinity causes a reduction in photosynthesis, which leads to an increase in the number of empty spikelets; thus, the number of full grains/panicle decreases (16). At the reproductive stage, salinity decreases the number of full grains, fertile tillers and grain weight (17). Salinity reduces yield by reducing the number of filled grains per panicle. The reduction in the number of filled grains may possibly be due to a decrease in pollen viability or a decrease in stigma surface receptivity or both (18). The negative effect of salinity on yield is the result of a significant reduction in spikelet number, branching and panicle weight (19).

Also, sterile flowers affect a priori the 1000 grain weight; on this, the analysis of variance showed no significant difference between the lines tested and the controls, but arithmetically there is a difference between the means. The ARS756-1-1-3-B-2-2 line has the largest weight with 17.69 g while the HK124-ARS-15-1 comes with 26.95 g, so all varieties behave in the same way. All the new varieties were able to resist in the EC= 5 ds/m environment, the analysis of variance showed no significant difference in the yields obtained. Severe inhibitory effects of salt on fertility may be due to differential carbohydrate competition during vegetative growth and constrain its distribution to developing panicles, while others are likely related to reduce pollen viability under vegetative conditions. stress, leading to failure of seed formation (20). According to the scale of (21), the maximum degree of salinity that rice can withstand without considerable loss of yield corresponds to an electrical conductivity of 3 dS/m, from this critical threshold, salt stress is felt and can have drastic consequences on performance. In this logic, under our conditions of 5 dS/m, the yields must be low. This was confirmed by our results as more than 60% had a yield of less than 2000 kg/ha. Nevertheless, despite the very high salinity conditions, some lines have shown themselves to be a little less efficient with yields of more than 3T/ha which compare well with the average yield in the Senegal River valley which is 6000 kg/ha (22) under normal conditions. These are the two lines HHZSALT 10 and D33-NDIOL-3-LON-1 which gave yields which exceeded more than three tonnes per hectare (3T/ha) after the tolerant control FL 478. lines D33-ART7-ARS-1, HK124-ARS-15-1, ARS756-1-1-3-B-2-2 and D20-ART20-ARS-1 record yields of more than 2 T/ha.

CONCLUSION

This study conducted in Ndiol made it possible to evaluate the morphological and agronomic behavior of thirteen (13) new varieties of rice tolerant to salinity in the growing conditions of the delta of the Senegal River valley.

- The analysis of variance did not show any significant effect on the characters studied except for the number of tillers and panicles at harvest per m2;
- Lines D19-ARS-9-LON-1, D20-ART20-ARS-1 and D33-ART7-ARS-1, with their respective number of tillers of 284, 278 and 264 per m2 are more tolerant to salinity than Witness FL 478;
- Salinity and cold have shown an effect on increasing the maturity cycle of rice, this is the case of Sahel 108;
- The three varieties FL 478, HHZSALT 10 and D33-NDIOL-3-LON-1 gave better yields with more than 3 T/ha;
- Varieties D33-ART7-ARS-1, HK124-ARS-15-1, ARS756-1-1-3-B-2-2, D20-ART20-ARS-1 and control Sahel 108 obtained average yields with more than 2 T/ha despite the salinity level of 5 ds/m;

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