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Universidad Nacional Autónoma de Tayacaja Daniel Hernández Morillo

Preliminary agronomic evaluation of rice *(Oryza sativa L.)* genotypes under saline soil conditions of Yaguachi, Ecuador

Evaluación agronómica preliminar de genotipos de arroz (Oryza sativa L.) en condiciones de suelo salino de Yaguachi, Ecuador

Reina Medina Litardo
Universidad de Guayaquil, Ecuador
reina.medinal@ug.edu.ec
Manuel Carrillo Zenteno
Instituto Nacional de Investigaciones Agropecuarias, Ecuador
manuel.carrillo@iniap.gob.ec
Luís Acosta Velazco
FRUTADELI S.A., Ecuador
luiguiacosta14@gmail.com
Iris Pérez- Almeida
Universidad Tecnológica ECOTEC, Ecuador
iperez@ecotec.edu.ec
Christian Duran-Mera
Universidad de Guayaquil, Ecuador
christian.duranm@ug.edu.ec
Pedro José García Mendoza
Universidad Nacional Autónoma de Tayacaja Daniel Hernández Morillo, Perú
pedrogarcia@unat.edu.pe

ABSTRACT

Soil salinity is considered one of the main abiotic stresses that affect rice cultivation throughout the world. The main objective of this study was to carry out the preliminary agronomic evaluation of five commercial rice varieties (INIAP11, INIAP14, SFL-011, INIAP-FL-Arenillas and Fedearroz-60) under saline soil conditions in Yaguachi, Guayas, Ecuador.

A completely randomized block design was used to estimate the agronomic response of the materials by quantifying grain yield t.ha-1 (Yield), number of tillers.m-2 (TN), plant height at harvest (PH), number of panicles.m-2 (NPM), panicle length (PL), number of grains/panicle (NGP), number of filled grains/panicle (NFG), number of vain grains (NVG), weight of 1000 grain (P1000) and content of chlorophyll at 30 (C30D) and 60 (C60D) days.

The analysis of variance reflected a high phenotypic diversity among the varieties studied, showing adequate adaptation to the level of salinity contained in the soil used for the study. The INIAP-FL-Arenillas, INIAP14, INIAP11 and FEDEARROZ-60 varieties were the genotypes with the best responses under the study conditions, expressed in higher productivity levels.

The results also suggest the need to continue evaluating these varieties with and without saline stress conditions, to discriminate the effect of genotype by environment interaction and confirm the level of tolerance to saline stress present in these genotypes, optimizing the selection of the appropriate germplasm in breeding programs, aiming to obtaining genotypes tolerant to saline soils.

Keywords: Electrical conductivity, genotypes, salinity, soils, yield.

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RESUMEN

La salinidad del suelo se considera uno de los principales estreses abióticos que afectan al cultivo del arroz en todo el mundo. El objetivo principal de este estudio fue realizar la evaluación agronómica preliminar de cinco variedades comerciales de arroz (INIAP11, INIAP14, SFL-011, INIAP-FL-Arenillas y Fedearroz-60) en condiciones de suelo salino en Yaguachi, Guayas, Ecuador.

Se utilizó un diseño de bloques completamente al azar para estimar la respuesta agronómica de los materiales mediante la cuantificación del rendimiento de grano t.ha-1 (Rendimiento), número de macollos.m-2 (TN), altura de planta a la cosecha (PH), número de panojas.m-2 (NPM), longitud panícula (PL), número de granos/panícula (NGP), número de granos llenos/panícula (NFG), número de granos vanos (NVG), peso de 1000 granos (P1000) y contenido de clorofila a los 30 (C30D) y 60 (C60D) días.

El análisis de varianza reflejó una alta diversidad fenotípica entre las variedades estudiadas, mostrando una adecuada adaptación al nivel de salinidad contenido en el suelo utilizado para el estudio. Las variedades INIAP-FL-Arenillas, INIAP14, INIA-11 y FEDEARROZ-60 fueron los genotipos con mejores respuestas bajo las condiciones de estudio, expresadas en mayores niveles de productividad.

Los resultados sugieren la necesidad de continuar evaluando estas variedades en condiciones con y sin estrés salino, para discriminar el efecto de la interacción genotipo por ambiente y confirmar el nivel de tolerancia al estrés salino presente en estos genotipos, optimizando la selección del germoplasma apropiado en programas de mejoramiento, con el objetivo de obtener genotipos tolerantes a suelos salinos.

Palabras clave: Conductividad eléctrica, genotipos, salinidad, suelos, rendimiento.

Introduction

The problem of salinity affects an area between 900 and 1060,1 million ha worldwide (FAO and ITPS 2015). Ivushkin et al. (2019) placed the global distribution of soils affected by salinity at 1000 million ha; in Latin America 31 million ha have this problem (FAO & ITPS 2015).

On the Ecuadorian coast there are saline soils with a dS.m-1 > 4, PSI < 15 and pH < 8.5, where the condition of water deficit favors the edaphic concentration of basic cations and anions in toxic degrees for plants. Some 337,613 ha (8.01 %) of Manabí, Guayas and El Oro show salinity problems, in several degrees: light (175,107 ha); average (59,247 ha); high (72,806 ha) and very high (30,453 ha) (Pozo et al. 2010).

Rice (Oryza sativa L.) is the second most cultivated cereal worldwide, with economic, environmental, and social importance in Ecuador. It is located mostly in the coastal region, with the highest production (90,59 %) in Guayas and Los Ríos (INEC 2022b). The most obvious effects of salinity are poorly developed, chlorotic, poorly tillered plants. The first symptom of salinity stress in rice in the vegetative stage is the white tip of the leaf; in flowering high infertility and poor grain filling are observed, generating negative effects directly on crop yield (Dobermann & Fairhurst 2012; Cobos et al. 2021). High salinity eventually leads to plant death.

The region of Guayas represents about 40 % of the irrigation areas in Ecuador, which are characterized by being made up of vertisol soils, with accumulation of salts on the surface, possibly due to the use of water for irrigation with the presence of salts and aggravated by drainage deficiencies in the soils.

In the dry season of 2019, an experiment was planned under saline soil conditions in that region, with the main objective of carrying out the preliminary agronomic evaluation of rice genotypes, to contribute to the identification of cultivars with satisfactory adaptation to saline soil conditions, which may in the future be recommended to rice producers in those areas with similar soil conditions to where the study was carried out (Yaguachi area, Ecuador), as well as to identify genotypes that could be used as references in subsequent studies where the tolerance of commercial rice varieties to saline soil conditions is evaluated.

Materials and methods

Experimental material: In this study, five commercial rice varieties (INIAP-FL-Arenillas, SFL011, INIAP14, INIAP11 and FEDEARROZ-60) were evaluated, these are used by farmers in the region where the study was carried out. The varieties INIAP-FL-Arenillas, SFL011 and FEDEARROZ-60 are genotypes that have their origin in the program of the Latin American Fund for Irrigated Rice (FLAR), being

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FEDEARROZ-60 produced by the National Federation of Rice Growers of Colombia, while INIAP11 and INIAP14 were originated by the National Institute of Agricultural Research (INIAP) of Ecuador. These are varieties widely tested by farmers but have not been evaluated under saline soil conditions.

Location of the trial: The research was conducted on a farm of the Guajala Association, San Jacinto de Yaguachi canton, Ecuador, during the dry season from August to December 2019 (Medina et al. 2022).

Test soil characteristics: The soil is a vertisol, with an electrical conductivity (EC) of 7.44 dS m-1 and pH of 6.79, whose texture, and other physical and chemical characteristics were previously reported in Medina et al. (2022). These chemical characteristics of EC and pH allow classifying this soil as a saline soil (USSLS 1954, Shaygan & Baumgartl 2022)

Agronomic management: Fertilization was based on the results of soil analysis and the demand for the varieties used in the study (Medina et al. 2022). Irrigation management, weed control, insect pests and diseases were previously specified by Medina et al. (2022).

Evaluated variables: Information was registered about yield (t.ha-1) (Yield); number of tillers.m-2 (TN); plant height at harvest (cm) (PH); number of panicles.m-2 (NPM); panicle length (cm) (PL); number of grains per panicle (NGP); number of filled grains (NFG), number of vain grains (NVG), weight of 1000 grains (g) (P1000); chlorophyll content at 30 (C30D) and 60 (C60D) ddt (%), based on the Standard Evaluation System for rice (SES) (IRRI 2002), as described by Medina et al. (2022).

Experimental design and statistical analysis: a random complete blocks design was used, with five treatments (varieties), four replications, and experimental units of 6 m2.

For the analysis of the variables, the average obtained per variable in each experimental unit was used, according to the established experimental design. For the separation of the values, Duncan's mean test was used at 5 % probability. To aid in the separation of means between the productivity levels of the varieties, orthogonal contrasts were applied. In addition to mean tests, confidential intervals were constructed for the population mean, according to Walpole et al. (2012).

RESULTS

The analysis of variance determined highly significant ($p \leq 0.01$) or at least significant ($p \leq 0.05$) differences for the effect of varieties in all the variables analyzed, except for the number of vain grains (NVG) (table 1), suggesting sufficient phenotypic diversity among the varieties included in the study. The coefficients of variation (CV) and determination (R2) observed in all the variables analyzed, can be considered appropriate for this type of studies, except that observed with the NVG variable, which obtained a relatively high CV and an R2 of 0.50, which suggests that about 50 % of the variability shown by this variable could not be explained by the model used. However, even when the data transformation was carried out, achieving a much smaller CV, no significant differences were detected. A Friedman test, equivalent to parametric ANOVA for two factors, was also performed, but no statistically important differences were detected.

Table 1

Mean squares of the ANOVA of 11 variables evaluated in five rice varieties, under saline soil conditions

Sources of variation	DF	Mean Square										
		Yield	TN (x10^2)	PH	NPM (x10^2)	PL	NGP (x10^2)	NFG (x10^2)	NVG	P1000	C30D	C60D
Blocks	3	0.06	28,02	26,73	22,26	3,07	3,63	3,26	0,40	0,06	4,57	3,08
Varieties	4	1.29*	132,01**	111,50**	134,07**	10,03*	13,08*	12,03*	2,51	6,66**	13,52**	11,64*
FLAR VARIETIES	2	0.737	170.00	60.25*	1.09	11.66*	1.50	1.65	0.86	2.23	16.56**	13.91*
INIAP VARIETIES	1	0.001	648.00	4.50	6.13	3.78	2.27	2.00	3.00	0.001	1.81	0.01
FLAR vs INIAP	1	3.387**	512.80**	242.00**	521.65**	15.40*	46.75**	42.05**	7.70*	17.70**	0.001	0.11
Error	12	0.27	14,89	10,07	14,33	2,16	2,88	3,09	0,94	0,70	2,16	3,01
Total	19											
	CV (%)	7,04	9,88	3,36	9,85	5,71	13,70	14,65	25,02	3,03	3,15	3,54

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R^2	0,62	0,77	0,81	0,78	0,66	0,65	0,61	0,50	0,76	0,72	0,61
Mean	7.438	390,50	94,50	384,15	25,74	123,88	120,02	3,88	27,51	46,65	49,01

** and ** indicate significant differences at 5 % and 1 %, respectively. I-FL-A = INIAP-FL-Arenillas. TN, PH, NPM, PL, NGP, NFG, NVG, P1000, C30D and C60D mean, respectively, number of tillers.m-2, plant height, number of panicles.m-2, panicle length, number of grains. panicle-1, number of filled grains, number of vain grains, weight of 1000 grains, chlorophyll content at 30 days and chlorophyll content at 60 days.*

Source: Authors.

Yield (t. ha-1)

The varieties INIAP-FL-Arenillas, INIAP14 and INIAP11 achieved the highest levels of average productivity, significantly surpassing SFL011, which obtained the lowest average productivity (table 2). Average levels of productivity analysis between the cultivars of FLAR origin regarding the local group of INIAP origin carried out through the means test showed significant differences between both groups, as demonstrated by the contrast test (table 1).

Table 2

Average values for grain yield (Yield), number of tillers.m-2 (TN), plant height (PH), number of panicles.m-2 (NPM) and panicle length (PL) estimated in five rice varieties evaluated in saline soils.

N°	Varieties	Yield. (t. ha^{-1})	TN	PH (cm)	NPM	PL (cm)
1	INIAP-FL-Arenillas	7.430 a	353.00 b	95.50 b	339.50 b	28.18 a
2	SFL011	6.589 b	354.00 b	103.00 a	349.75 b	25.85 b
3	INIAP14	7.948 a	443.75 a	91.00 bc	438.25 a	23.80 b
4	INIAP11	7.966 a	461.75 a	89.50 c	455.75 a	25.18 b
5	FEDEARROZ-60	7.257 ab	340.00 b	93.50 bc	337.50 b	25.68 b
FLAR VARIETIES		7.092 b	349.00 b	97.33 a	342.25 b	26.57 a
INIAP VARIETIES		7.957 a	452.75 a	90.25 b	447.00 a	24.49 b
Average:		7.438	390.50	94.50	384.15	25.74
Confidence interval (5%):		6.601; 8.276	310.41; 470.59	87.26; 101.74	304.86; 463.44	23.26; 28.21
LSD		0.807	59.45	4.89	58.33	2.26

Values marked with the same letter in each variable do not differ statistically from each other (Duncan α 0.05); LSD means least significant difference.

Source: Authors.

Number of tillers.m-2 (TN)

The rice varieties generated by INIAP, presented the highest number of tillers.m-2, being statistically superior (p≤0.05) to the varieties of FLAR origin (table 2). The difference in the tillers number per area of the varieties of INIAP origin compared to the rest of the evaluated varieties (more than 100 tillers m-2), shows that they had better both, establishment and plants development.

Plant height at harvest (PH)

The SFL011 variety presented the highest average for this variable (table 2), statistically outstanding the other varieties; the INIAP11 variety was the lowest PH, but was statistically equal in PH to the INIAP14 and Fedearroz-60 varieties (table 2). When the PH of both groups of germplasms is analyzed, the mean test shows that the lowest materials were the varieties of INIAP origin. However, regardless of the pH reached by the evaluated varieties, all of them reached heights of suitable plants for irrigated rice cultivation (low growth), since they are less prone to lodging due to strong winds.

Number of panicles.m-2 (NPM)

The INIAP11 and INIAP14 varieties presented the highest number of panicles.m-2, statistically outstanding the other varieties, which is derived from the highest number of tillers.m-2 obtained by them (table 2). In this regard, it can be observed that the evaluated varieties expressed a proportion of effective tillers (tillers with panicles) equal to or greater than 98%, which implies that the difference between the cultivars in terms of number of panicles was directly determined by their establishment and tillering capacity.

Panicle length (cm) (PL)

Regarding this variable, the variety INIAP-FL-Arenillas reached the highest PL, being statistically higher (p≤0.05) than the other varieties included in the study; the lowest PL corresponded to the INIAP14

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variety, whose average PL was statistically equal to that observed in the remaining three varieties (table 2).

Number of grains per panicle (NGP), filled grain (NFG) and vain grain (NVG)

Regarding the NGP trait, the means test separated the varieties into four groups, where the Fedearroz-60 variety showed the highest average values, while INIAP11 obtained the lowest values (table 3). The varieties of FLAR origin expressed on average longer panicles and with a greater number of grains, presenting on average panicles with 136.06 grains, compared to 105.61 grains per panicle in the local varieties of INIAP origin, which represented a superiority of the varieties of FLAR origin of 30.45 grains per panicle.

Table 3

Average values for the N° of grains per panicle (NGP), N° of full grains (NFG), N° of vain grains (NVG), weight of 1000 grains (P1000), chlorophyll content at 30 days (C30D) and at 60 days (C60D) after the transplanting obtained in the evaluation of five varieties of rice in saline soils.

N°	Varieties	NGP	NFG	NVG	P1000 (g)	C30D	C60D
1	INIAP-FL-Arenillas	134.13 ab	129.38 ab	4.75 a	27.98 b	45.63 b	49.83 a
2	SFL011	128.88 ab	124.20 abc	4.18 a	29.40 a	49.63 a	50.80 a
3	INIAP14	110.93 bc	107.68 bc	3.83 ab	26.30 c	46.08 b	49.08 a
4	INIAP11	100.28 c	97.68 c	2.60 b	26.33 c	47.03 b	49.13 a
5	FEDEARROZ-60	145.18 a	141.15 a	4.03 ab	27.53 bc	44.88 b	46.23 b
FLAR VARIETIES		136.06 a	131.58 a	4.32 a	28.30 a	46.71 a	48.95 a
INIAP VARIETIES		105.60 b	102.68 b	3.21 b	26.31 b	46.55 a	49.10 a
Average		123,88	120,02	3,88	27,51	46,65	49,01
Confidence interval (5%)		95,71; 152,04	92,26; 147,77	2,52; 5,23	25,82; 29,19	43,89; 49,40	46,28; 51,74
LSD		26,14	27,09	1,49	1,29	2,27	2,67

Values with the same letter in each variable do not differ statistically from each other (Duncan α=0.05). LSD = least significant difference

Source: Authors.

Weight of 1000 grains (g) (P1000)

The SFL011 variety showed the highest average value for P1000, statistically outstanding (p≤0.05) the rest of the evaluated varieties, while the INIAP11 and INIAP14 varieties resulted in the lightest grains (table 3). For the environmental conditions where the study was carried out, the group of varieties of FLAR origin expressed grains with a greater weight (28.30 gr) compared to the INIAP materials (26.31 gr) (table 3).

Chlorophyll content at 30 and 60 ddt (C30) (C60)

The SFL011 variety presented the highest content of C30, surpassing the remaining varieties, which showed statistically equal values. However, the C60 content determined that the varieties INIAP-FL-Arenillas, SFL011, INIAP14 and INIAP11 obtained chlorophyll concentrations statistically equal, but higher than the value observed in the Fedearroz-60 variety (Table 3). No significant differences (p>0.05) were found between the means of these characters observed for both groups of genotypes.

DISCUSSION

The orthogonal contrast test determined highly significant differences (p≤0.01) between the varieties of FLAR origin and the INIAP varieties, for all studied variables, except for the chlorophyll content at 30 (C30D) and 60 (C60D) days after transplanting, where both groups presented statistically equal values (p>0.05) and for the panicle length (PL) and number of vain grains (NGV) traits, whose differences between both groups of genotypes were only significant (p≤0.05) (table 1). Another important aspect to highlight was what was observed with the block effect, which was not significant for all the variables analyzed. These results suggest a high spatial uniformity in the conditions of the terrain where the experiment was carried out, which was most likely favored by the low number of materials included in the test and the use of a lot of land with adequate leveling.

Yield (t. ha-1)

The varieties INIAP-FL-Arenillas, INIAP14 and INIAP11 achieved the highest levels of average productivity, significantly surpassing SFL011, which obtained the lowest average productivity (table 2). These results were to be expected, since the local materials come from the region, which implies that they must have genetic factors that allow them to adapt adequately to the environment. This situation is also a reflection of the complexity of grain yield, influenced by many environmental, genotypic factors and their interaction (Hallauer et al. 2010).

Salinity is considered one of the main abiotic factors that affects different phenological stages of the crop, reflected in lower productivity (Dobermann & Fairhurst 2012). Several studies have found significant reductions in grain yield in rice due to stress generated by saline soils, which can vary, under conditions of soils with high levels of salinity and sodicity, between 28 to 97% (Krishnamurthy et al. 2016), variation that will depend on the genotype and its interaction with the environment where the crop is grown. Zeng and Shannon (2000) reported significant effects of salinity on grain yield, grain/plant weight, grain/panicle weight, and spikelet/panicle number.

The experimental average productivity was 7.438 t/ha, which when compared with the productivity of rice cultivation in Ecuador during 2019, both nationally (4.274 t/ha), and in Guayas (5.140 t/ha) (INEC 2022a), it can be inferred that the varieties used in this study had normal growth and development, despite the soil salinity conditions; this suggests that they have suitable adaptation to this type and level of abiotic stress. On the other hand, despite the good behavior shown by the varieties, the study shows that there is a difference according to their origin; in this particular case, the varieties of the national program (INIAP) were superior in productivity to those of FLAR origin, reaching a difference of 0.865 t/ha, which was statistically significant ($p \leq 0.05$), suggesting that this group has a better adaptation to the particular soil conditions used in this study. In summary, the higher productivity of the INIAP-FL-Arenillas, INIAP14 and INIAP11 varieties could indicate their adequate adaptation to the soil and climate conditions where the study was carried out.

Number of tillers.m-2 (TN)

The rice varieties generated by INIAP, presented the highest number of tillers.m-2, being which is indicative that the INIAP Ecuador breeding program for rice cultivation has been efficient in obtaining varieties with adequate adaptation to abiotic stress conditions, such as those generated by saline soils, despite the fact that said program was not focused in developing materials for saline soils. All this has been possible because the cultivars are being generated in the environmental conditions typical of the region of production.

Plant height at harvest (PH)

Under saline soil conditions, Cristo et al. (2012), observed a substantial reduction in plant growth, because of osmotic stress, imbalance of specific ions and toxic effects caused by excessive accumulation of ions. Also, Ashraf and Harris (2004), indicated that salinity in soils produces different types of stresses, which affect germination, vegetative growth, flowering, among other phenological processes of the plant. All of these types of effects could end up negatively affecting the PH.

Number of panicles.m-2 (NPM)

In this regard, it can be observed that the evaluated varieties (table 2) expressed a proportion of effective tillers (tillers with panicles) equal to or greater than 98%, which implies that the difference between the cultivars in terms of number of panicles was directly determined by their establishment and tillering capacity.

Panicle length (cm) (PL)

When the materials are observed according to their origin (table 2), the varieties of FLAR origin expressed, under the environmental conditions of the experiment, a greater panicle length (26.57 cm) compared to the local varieties of INIAP origin (24.49 cm), representing this an average difference between both groups of 2.08 cm

Number of grains per panicle (NGP), filled grain (NFG) and vain grain (NVG)

For the number of filled grains per panicle (NFG), the behavior of the varieties was similar to that expressed in the NGP trait, where the variety Fedearroz-60 showed the highest mean values, whereas the variety INIAP11 resulted with the lower values for this trait. The FLAR varieties origin expressed an average of 131.58 full grains per panicle in comparison with the local varieties of INIAP origin that managed to

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produce, under the experimental conditions, 102.68 full grains per panicle, which meant a difference of 29 GFP between both groups of genotypes.

For the number of vain grains (NVG) no significant differences were detected between the varieties, which was due to the great similarity of the values reached by them, even though in the contrast analysis differences were detected when comparing the varieties by their origin (table 1), where the varieties of FLAR origin surpassed the varieties of INIAP origin in the NVG (table 3). However, the percentage of vain grains reached by the varieties was less than 4%, despite the abiotic stress conditions generated by the saline soil, which suggests that the genotypes had a normal grain filling process under the environments conditions where the study was carried out. The results reveal that these cultivars could have tolerance to the level of salts contained in the soils where the study was carried out, since it is known that although rice is relatively tolerant to salinity in the germination stage, it is sensitive in the panicle initiation and flowering stages (Khatun & Flowers 1995; Zeng et al. 2001). In susceptible rice cultivars, the vanishing of the grains due to the effect of high concentrations of salts in the soil is due to the fact that fertilization of the ovule is not achieved or causes the unviability of the pollen (Cristo et al. 2012).

Weight of 1000 grains (g) (P1000)

Zeng & Shannon (2000) report that one of the measurable or visible effects of salinity on plants can include significant reductions in yield components, one of them being the weight of 1000 grains; therefore, the normal filling of grains (table 3) occurred in the varieties evaluated in this study (values in accordance with those observed in irrigated rice cultivars), indicate that they have tolerance in the reproductive stage to the salinity conditions of the soils used in this study.

Despite the fact that the varieties of FLAR origin exceeded the varieties originated by INIAP in the characters PL, NGP, NFG and P1000, the INIAP varieties exceeded those of FLAR origin in average productivity, which was due to the greater capacity of tillering shown by the INIAP varieties, which allowed them to reach a greater number of effective panicles per surface unit. These results demonstrate the importance, in commercial plantings, to use rice cultivars that guarantee an optimal capacity for both, plants establishment and plant development.

Chlorophyll content at 30 and 60 ddt (C30) (C60)

These results seem to indicate that the rice plant is much more sensitive to the effects of soil salinity in the early stages of development. Indeed, soil salinity is considered one of the most important abiotic stresses, which directly affect plant growth and development (Arshad et al. 2012), processes closely linked to photosynthesis. In this sense, Castillejo et al. (2021) found a reduction in net photosynthesis associated with a drop in the rate of electron transport as salinity in the medium increased, a process that articulates the absorption of light energy and its conversion into photoassimilates. That explains why, generally, varieties tolerant to salt stress exhibit a high percentage of chlorophyll. This variable is directly related to salinity tolerance, since the decrease in chlorophyll content affects the process of photosynthesis, plant growth and development (Khairi et al. 2015).

Salinization can be understood as a process of excessive accumulation of soluble salts in soils, by different sources, generating adverse effects on the environment where plants develop and therefore on their productivity (Hussain et al. 2018). Under these conditions, genotypes with the best agronomic responses may reflect a higher level of tolerance to saline soil condition. In this way, INIAP-FL-Arenillas, INIAP14, INIAP11 and Fedearroz-60 would be the genotypes that capitalized on the best responses, observed at higher levels of productivity. However, the SFL011 variety also presented a favorable response in plant height, was among the varieties with the highest NGP, NFG, was the variety with the highest weight of 1000 grains and highest chlorophyll content at 30 and 60 days. These results demonstrate the need to continue evaluating these varieties under conditions of salt stress, as well as in soil conditions without this type of stress, in order to determine the level of tolerance to salt stress present in the genotypes evaluated, because under the conditions in which they were evaluated in this study the results only determine their response to the soil and climate condition where the study was conducted. Despite being results obtained in a single environment, due to logistical and economic limitations that did not allow the placement of other environments, the study is considered very useful to justify the investment in research, in order to continue evaluating these and other varieties of rice under soil conditions with and without stress generated by high levels of salts, as well as for the

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selection of the appropriate germplasm for breeding programs, aiming at obtaining genotypes tolerant to saline soils.

CONCLUSIONS

The present study showed that the commercial rice varieties evaluated have adequate adaptation to the level of salinity contained in the Guayas soils where the study was carried out, having a normal development of the crop and obtaining paddy rice yields that exceeded the average reported for the region in which they were evaluated by more than 2 t/ha, evidencing that they are useful seed technologies capable of enabling profitable productions for farmer rice producer. The INIAP-FL-Arenillas, INIAP-14, INIAP-11 and Fedearroz-60 varieties were the genotypes with better responses under the study conditions, expressed in higher levels of productivity. Even though the SFL-011 variety presented the highest chlorophyll content at 30 and 60 days, influencing a favorable response in plant height and grain weight, its level of productivity was below that of the remaining varieties. The results showed that the FLAR source materials expressed plants with larger panicles, with a greater number of grains and heavier grains, however they were not the ones with the highest yield, due to a deficiency in the number of panicles per area, which implies less capacity for establishment and/or tillering. The results demonstrate the need to continue evaluating these varieties under conditions of salt stress and without stress, to determine the level of tolerance to salt stress present in the genotypes evaluated. All these varieties could also be used as reference witnesses in future studies where it is sought to evaluate new genotypes of rice under conditions with and without salt stress, due to their adequate agronomic response under the study conditions.

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Conflicts of interest

All the authors made equal and significant contributions to the document and agree with its publication and state that there are no conflicts of interest in this study.

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