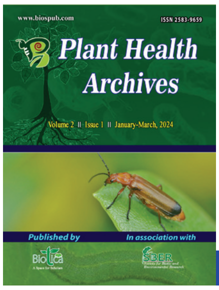

DOI: 10.54083/PHA/2.1.2024/18-25

Plant Health Arch., 2024, 2(1):18-25

Plant Health Archives

e-ISSN: 2583-9659

January-March, 2024

Article ID: PHA036

Research Article

Synergic Effects of Salinity and *Rhizoctonia solani* (Kuhn) Infection on Growth and Yield Attributes of Rice (*Oryza sativa* L.)

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Open Access

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Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Mustapha, T., Kutama, A.S., Auyo, M.I., *et al*., 2024. Synergic Effects of Salinity and *Rhizoctonia solani* (Kuhn) Infection on Growth and Yield Attributes of Rice (*Oryza sativa* L.). *Plant Health Archives* 2(1), 18-25. DOI: 10.54083/PHA/2.1.2024/18-25.

Abstract

Salinity stress and *Rhizoctonia solani* pose significant threats to global rice production; however, their interactive effects on rice plants remain underexplored. This study aimed to determine the combined effects of different salt (NaCl) levels and *R. solani* (Kuhn) infection on selected growth and yield attributes of *O. sativa*. Faro44, Faro52 and *Jamila* rice varieties were subjected to varying NaCl concentrations and *R. solani* infection under screen house conditions, utilizing a Completely Randomized Block Design (CRBD) and Two-Way ANOVA was employed for data analysis. The results revealed that higher NaCl concentrations and *R. solani* infection retarded plant height, with the number of tillers and leaves being significantly affected. The lowest mean values occurred at a salinity level of 8 dS m^{-1}; whereas highest values occurred at 4 dS m^{-1} and 6 dS m^{-1}. The 100 seed weight varied depending on the NaCl concentration, with the lowest seed weight observed at 8 dS m^{-1} and 6 dS m^{-1} in Faro44 and the highest seed weight observed at 4 dS m^{-1}. The grain length was found to be at its minimum when exposed to 8 dS m^{-1}, while grain diameter exhibited its smallest size at 8 dS m^{-1} of salt levels. Variations in NaCl concentrations significantly influenced the number of panicles and length of panicles (NP and LP), and number of grains panicle^{-1}. The lowest values were recorded at 8 dS m^{-1}, whereas the highest values were observed at 0 dS m^{-1} and 2 dS m^{-1}. The study found that, in rice plants infected by *R. solani*, growth and yield are further diminished under saline conditions, emphasizing the complex interaction between abiotic and biotic stressors in rice.

Keywords: Growth, Rice, Salinity, Sheath Blight, Yield

Introduction

Rice (*Oryza sativa* L.) remain an essential and fundamental basic crop playing a pivotal function in ensuring and upholding global food security, acting as the primary and predominant source of sustenance for over 50% of the total global population. Despite the economic importance of this crop, the cultivation of rice encounters a multitude of challenges, encompassing both abiotic and biotic stresses. Salinity stress and the infection caused by the fungus *Rhizoctonia solani* are particularly damaging and harmful, leading to substantial and noteworthy reductions in crop productivity and posing a grave and significant threat to food security in regions that heavily rely on rice products (Effendi *et al.*, 2023; Senguttuvel *et al.*, 2023). In order to address and surmount these challenges, effective strategies are imperative to mitigate their impact and ensure the sustainable and enduring production of rice. Exploring a deeper apprehension of the mechanisms of rice response to diverse stress factors can serve as a foundational basis for the improvement of rice cultivars endowed with heightened tolerance to stressors (Usman *et al.*, 2023). Furthermore, concerted efforts have been directed towards enhancing the nutritional profile and value of rice through the process of biofortification, which aims to reverse the deficiencies of micronutrient and ameliorate human health (Al-hashimi, 2023). By tackling these challenges and implementing sustainable and enduring practices, the cultivation of rice can persist in its contributions to global food security.

Article History

RECEIVED on 02nd December 2023 RECEIVED in revised form 11th March 2024 ACCEPTED in final form 18th March 2024

Salinity stress emerges and manifests when an excessive and disproportionate accumulation of salts takes place in both the soil and irrigation water, consequently exerting a significant and notable impact on rice production in coastal as well as inland areas. The presence of elevated levels of salt disrupts the delicate and intricate equilibrium of osmotic and ionic processes within plant cells, thereby precipitating a diverse array of physiological disorders, impeded growth and reduced yields (Munns and Tester, 2008). Salinity stress exerts a deleterious and adverse effects on critical physiological processes in rice plants, including but not limited to photosynthesis, nutrient absorption, water relations and hormonal regulation, thereby exacerbating the detrimental impact (Abu-Ria *et al.*, 2023). Numerous studies have provided valuable contributions towards understanding the effects of salinity on rice plants, elucidating the reduction in various growth indices, presence of Na^+ at toxic levels, decrease in K^+ as well as K^+/Na^+ ratio, malondialdehyde buildup, electrolyte leakage in addition to alterations of osmolytes content and antioxidant defense system (Abu-Ria *et al.*, 2023; Al-hashimi, 2023; Chakrobortty *et al.*, 2022; Mustapha *et al.*, 2022b; Muthuramalingam *et al.*, 2022).

Rhizoctonia solani AGIA is a significant threat to rice cultivation, causing diseases like root rot and sheath blight, leading to reduced growth and grain yield; the pathogen primarily infects the roots and lower portions of rice plants, hindering nutrient absorption and water uptake, as well as impeding root elongation and nutrient transport (Chen and Nahar, 2023; Liyanapathiranage *et al.*, 2023). Soil salinity impacts plant tolerance to biotic stress such as sheath blight disease in rice, leading to reduced immunity to pathogens, weakened defense signaling proteins and enhanced pathogen development and multiplication (Mustapha *et al.*, 2022a). However, Salinity can alter plant-pathogen interactions, affecting plant health (Bidalia *et al.*, 2019). Salt stress also causes physiological effects on plants, such as restriction of water absorption, nutrient deficiency and oxidative stress, which significantly affect the occurrence of plant disease (Mustapha *et al*., 2022b).

Rice (*O. sativa*) cultivation encounters significant obstacles, encompassing both abiotic and biotic pressures, which present hazards to global food security. Among these challenges, the damaging effects of salt stress and fungal pathogens on crop productivity are well-documented, notably in regions heavily reliant on rice products. However, a noticeable void in knowledge persists regarding the interactive repercussions of these two stressors on growth and yield. Hence, this investigation endeavors to bridge this knowledge gap by examining the combined effects of salinity stress and *R. solani* infection on crucial growth parameters and yield components across diverse rice varieties. The findings will be instrumental in ensuring food security globally and agricultural sustainablity in the face of environmental challenges (Abu-Ria *et al.*, 2023; Guigard *et al.*, 2023; Taha *et al.*, 2023).

Materials and Methods

Experimental Design and Growth Conditions

Screen house experiment was performed in the Department of Plant Biology Botanical garden, at Federal University Dutse, Nigeria. The experimental site was located at the geographical coordinates of 11°42′20″ N and 9°22′13″ E. Completely Randomized Block Design (CRBD) was used, with tree replications. The experiment was carried out between March-August, 2022.

Plant Material and Seed Sowing

Seeds from three varieties of rice namely Faro44, Faro52 and *Jamila* were obtained from A.P. Leventes Agricultural Institute, Panda, Kano state, Nigeria. Prior to seed sowing in pre-nursery, seed sorting was carried out to separate the light seeds from heavier ones, which were regarded as viable seeds. Briefly, heavier seeds were separated from light ones by soaking in 12% NaCl solution for about 2 minutes; seed germination rate was also determined before sowing (Kamai *et al.*, 2020). Viable seeds were sown and allowed to germinate for transplanting. After 2 weeks of seed sowing, seedlings of the three respective varieties were transplanted at a rate of 2 seedlings pot^{-1} maintaining a plant spacing of 30×30 cm (Kamai *et al.*, 2020). Transplanting was carried out in late evening and water was applied immediately to minimize transplanting shock. Water was applied twice a day, early morning and late evening as part of agronomic practices.

Salinity Levels Preparation and Treatment Application

Different salinity levels comprising of 0, 2, 4, 6 and 8 dS m^{-1} including control were used; these salinity levels were prepared through determination of the EC value of the NaCl solution (Hardie and Doyle, 2012). Treatment application was commenced two weeks after transplanting when the transplanted seedlings were acclimatized. About 500 mL of NaCl solution from each of the prepared NaCl concentrations were applied to each pot according to the treatment groups in each experimental unit; treatments were applied once in a week. To maintain constant salinity levels, soil EC was assessed through the technique of soil water extraction (1:5 ratio of soil to distilled water) after each treatment application of the varying NaCl concentrations (Hardie and Doyle, 2012).

Fungal Inoculum and Pathogenicity Test

Pure isolate of *R. solani* AG1 IA was procured from Plant Pathology Laboratory, Bayero University, Kano, Nigeria. The isolate was sub-cultured adopting direct plate method on an autoclaved Potato Dextrose Agar (PDA) augmented with 3 drops of acetic acid to check bacterial growth and incubated at room temperature until full mycelial growth was obtained. Mycelial balls were prepared by incubating 5 mm mycelial blocks in Potato Dextrose Broth (PDB) and allowed to grow at room temperature for five days on orbital shaker (Park *et al.*, 2008; Senanayake *et al.*, 2020). Pathogenicity test was carried out at late tillering stage of the rice varieties using the incubated mycelil balls. Briefly, a mycelial ball was carefully inoculated in to the rice sheath and covered with

Aluminium foil (Park *et al.*, 2008). This is to maintain constant temperature and humidity for successful infection by the pathogen. Pathogenicity test was done at late evening hours and observed after 3 days for disease establishment. This method inoculation was used to inoculate the rice varieties involved in this study.

Determination of Vegetative Growth Parameters

Vegetative growth characteristics particularly height of the plant (PH), leaf number (NL) and tillers plant^{-1} (NT) were considered (Soares *et al.*, 2021). The height was measured, recorded and expressed in centimeters using transparent meter rule, likewise the leaf and tillers number were counted and expressed as numbers respectively. All vegetative growth parameters were recorded at every two weeks' interval in any case (Zhang *et al.*, 2022).

Determination of Yield Parameters

The length and number of panicle pot^{-1} represented as LP and NP, the grains panicle^{-1} (NGP), seed length (SL), seed diameter (SD) and 100-seed-weight (HSW) were regarded as the yield parameters. The PL was measured using calibrated metre rule and recorded, NP and NSP were directly counted and values recorded. The SL and SD were determined using a digital caliper and expressed in millimeter, the HSW was determined using digital weighing balance (SciChem CLS501) (Zhang *et al.*, 2022).

Statistical Analysis

The data obtained in this research were subjected to factorial analysis of variance (ANOVA), for P-value ≤ 0.05; Duncan Multiple Range Test (DMRT) was used to compute the mean significant differences within the treatments. SPSS Statistical software at P≤0.05 was used for the analysis.

Results and Discussion

Synergic Effects of R. solani Infection and Salinity Levels on Growth

Effects of Different NaCl Levels and R. solani Infection on Plant Height of Rice

Figure 1 depicts the impact of NaCl concentration on mean height of Faro-44, Faro52 and *Jamila* rice cultivars. The tallest plant height was observed at 6 dS m^{-1} at 2WAT. The lowest mean plant height was observed at 4 WAT at 6 dS m^{-1}, while the highest was observed at 4 dS m^{-1}. At 6 WAT, the plant height was highest at 2 dS m^{-1} and 4 dS m^{-1}. At 8 WAT, the average plant height was lowest at 8 dS m^{-1} and highest at 2 dS m^{-1}. In Faro44, the lowest mean plant height was recorded at 2 WAT at 6 and 8 dS m^{-1}, while the highest was observed at 4 dS m^{-1}. At 4 WAT, the least mean height was recorded at 8 dS m^{-1}, and highest mean was observed at 4 dS m^{-1}. At 6 WAT, the least mean height was recorded at 8 dS m^{-1}, while the highest was observed at 2 dS m^{-1}. At 8 WAT, the meant height was lowest at 8 dS m^{-1} and highest at 4 dS m^{-1}. For *Jamila*, the least mean height was recorded at 8 dS m^{-1} at 4 WAT, while the highest was observed at 2 and 4 dS m^{-1}. At 4 WAT, the least mean plant height was observed at 8 dS m^{-1}, while the highest was observed at 4 dS m^{-1}. At 6 WAT, mean height was at its least value at 8 dS m^{-1}, while the highest was recorded in the control group. At 8 WAT, the lowest mean plant height was recorded at 8 dS m^{-1}, while the highest was observed at 4 dS m^{-1}. The NaCl concentrations and *R. solani* infection significantly influenced the plant height of all three varieties.

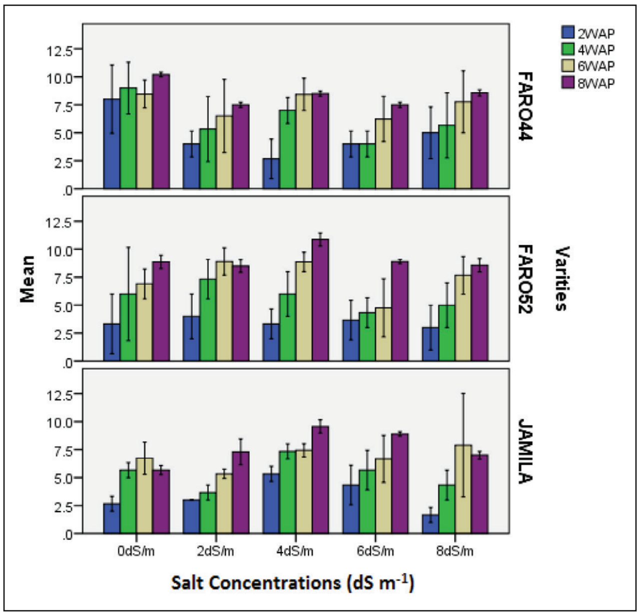

Figure 1: Effects of different NaCl concentrations (dS m^{-1}) on plant height of *R. solani* infected Faro44, Faro52 and *Jamila* at 2, 4, 6 and 8 Weeks after Transplanting (WAT)

Effects of Different NaCl Levels and R. solani Infection on Number of Leaves of Rice (O. sativa)

As represented in Figure 2, at the 4 dS m^{-1} salt level, Faro44 had more leaves (4.0). Lower mean values of 3.4, 3.6, 3.7 and 3.9 were found at salinities of 0, 8, 2 and 6 dS m^{-1}, respectively. At 4 WAT, the mean number of leaves was 3.7 at 8 dS m^{-1} while 3.3 at 2, 4 and 6 dS m^{-1}, with a mean of 4.0 in the control group. At 6 WAT, the average number of leaves was 3.0 at 4 dS m^{-1} and average of 3.7 at 8 dS m^{-1} and 4.0 at 0 dS m^{-1}. Mean number of leaves was 6 dS m^{-1} at

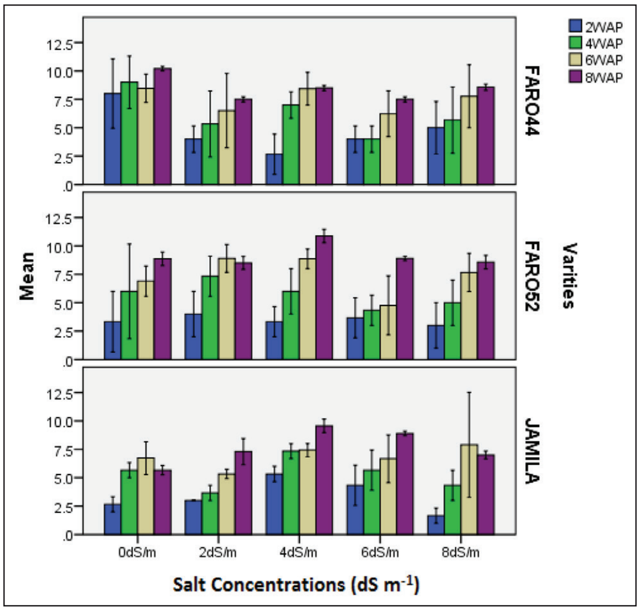

Figure 2: Effects of NaCl concentrations (dS m^{-1}) on number of leaves of *R. solani* infected Faro44, Faro52 and *Jamila* at 2, 4, 6 and 8 Weeks after Transplanting

8 WAT, with values of 3.7 and 4.5 at 4 dS m^{-1}, while highest mean (5.0) was recorded at 0 dS m^{-1}. At 4 WAT, mean leaf counts in Faro52 was 3.3 at 2 and 8 dS m^{-1}, 3.5 at 6 dS m^{-1} and 3.8 and 3.9 at 0 and 2 dS m^{-1}, respectively. At 4 WAT, the average number of leaves was 3.0 at 2 and 4 dS m^{-1} and 3.3 at 0, 6 and 8 dS m^{-1}. At 6 WAT, the mean number of leaves was lower at 0 and 4 dS m^{-1} (3.3 and 3.7), while at 2, 8 and 6 dS m^{-1}, the mean leaf number was 4.0 and 4.3. At 8 WAT, a mean number of leaves of 4.0 was recorded at NaCl levels of 0 and 4 dS m^{-1}, 4.7 at 2 and 8 dS m^{-1} and 4.6 at 6 dS m^{-1}. Furthermore, the lower average leaf number in *Jamila* at 4 WAT was 3.1 at 6 dS m^{-1}, 3.2 at 8 dS m^{-1} and higher (3.9) at 4 dS m^{-1}. The lower mean number of leaves at 4 WAT was 3.0 at 6 and 8 dS m^{-1} while 3.3 at 0, 2 and 4 dS m^{-1}. The results at 6 WAT show that the lowest mean number of leaves were 3.3 at salinity levels of 0, 2 and 6 dS m^{-1}, with 3.7 at 4 dS m^{-1} and 4.3 at the salinity level of 8 dS m^{-1}. The lower mean at 8 WAT was 3.0 at 8 dS m^{-1} and the higher mean (4.0) at 4 dS m^{-1}. All differences in the effects of the different NaCl concentrations were not significant ($P<0.05$) on all of the varieties tested, according to the statistical test.

Effects of Different NaCl Concentrations and R. solani Infection on the Number of Tillers of Different Varieties of Rice

Figure 3 reveals Faro44 had higher tillers in the control group at 2 WAT, lower at 4, 2 and 6 as well as 8 dS m^{-1}. Control group was fund to have higher tillers at 4 WAT (9.0) and 6 dS m^{-1} had the least average of tillers (4.0). At 8 WAT, 2 and 6 dS m^{-1} had the fewest tillers (7.5), while 4 and 8 dS m^{-1} had 8.5 and 7.7 tillers, less than the control group's mean number of leaves. At 4 WAT, least average of tillers were at 8 dS m^{-1} (3.0), and increased to 3.3 at 0 and 4 dS m^{-1} while highest mean of 4.0 was at 2 dS m^{-1}. At 6 WAT, lower value of tillers was at 6 dS m^{-1} (4.8), and subsequently 7.7 at 8 dS m^{-1} and the highest mean of 8.9 was at 0, 2 and 4 dS m^{-1}. At 8 WAT, 0 and 6 dS m^{-1} had the same mean number of tillers

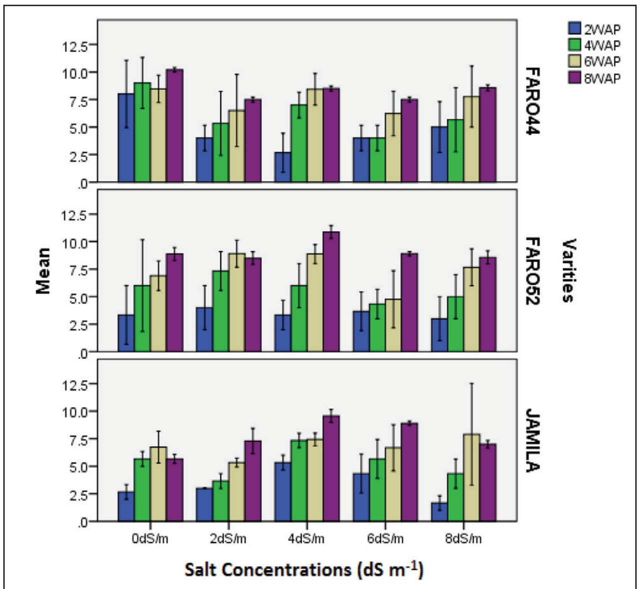

Figure 3: Effects of NaCl concentrations (dS m^{-1}) on number of tillers of *R. solani* infected Faro44, Faro52 and *Jamila* at 2, 4, 6 and 8 Weeks after Transplanting

(8.6), the lowest was at 2 dS m^{-1} and highest when increased to 4 dS m^{-1} (10.9). At 4 WAT, the highest mean of tillers (5.3) was at 4 dS m^{-1} and decreased to 1.7 when the salinity level increased to 8 dS m^{-1}. Leaves attained a maximum value of 7.3 at 4 dS m^{-1} NaCl level and the declined to 3.7 at 2 dS m^{-1} NaCl level. No significant difference observed between 0 and 6 dS m^{-1}; having an average tillers of 6.7. The lowest value was 5.3 at 2 dS m^{-1}, while maximum numbers of tillers were 7.9 at 8 dS m^{-1}. At 8 WAT, lowest average of tillers (7.0) was at the maximum level salinity representing 8 dS m^{-1}, while 8.9 tillers were observed at salt level of 4 and 6 dS m^{-1} respectively. Significant mean difference between the treatment effects on different rice cultivars were observed at Probability level of 0.05.

Synergic Effects of Different NaCl Levels and R. solani Infection on Panicle Characteristics

Table 1 depicts the influence of varying NaCl concentrations on panicle characteristics in Faro44, Faro52 and *Jamila*. Control groups consistently exhibited the highest panicle numbers, with Faro44 showing the lowest mean at the highest NaCl concentration (9.33) and Faro52 at 8 dS m^{-1} (17.33). In *Jamila*, the highest salinity (8 dS m^{-1}) resulted in the fewest panicles. Panicle numbers for Faro44, Faro52 and *Jamila* were highest at 2 dS m^{-1} (26.00, 36.00 and 28.67, respectively) compared to controls.

Regarding panicle length, control groups had longer panicles, while Faro44 and Faro52 exhibited the shortest lengths at 4 and 8 dS m^{-1}. Panicle length in *Jamila* variety was most affected at 8 dS m^{-1}, with 24.33cm when the salt level is 6 dS m^{-1}. However, 2 dS m^{-1} yielded most grains panicle^{-1} in Faro44, whereas higher salinity levels resulted in the lowest mean grains panicle^{-1}. Faro52 showed the greatest mean at 0, 2 dS m^{-1} and in *Jamila* variety particularly the untreated group. The statistical significance of NaCl levels on rice cultivars was evident, impacting panicle numbers, lengths and grains panicle^{-1}.

Table 1: Effects of NaCl concentrations (dS m^{-1}) on the number of panicle (NP), length of panicle (LP) and number of grains panicle^{-1} (NGP) of *R. solani* infected Faro44, Faro52 and *Jamila* rice varieties

Treatments		Panicle Characteristics		
		NP (cm)	LP (cm)	NGP
Concentrations (dS m^{-1})	0	26.33^{a}	23.97^{a}	103.22^{a}
	2	24.00^{b}	23.00^{a}	96.44^{a}
	4	23.56^{b,c}	21.28^{b}	93.78^{a}
	6	21.00^{d}	21.83^{b,c}	79.33^{b}
	8	15.89^{e}	21.83^{b,d}	71.00^{b,c}
Varieties	Faro44	18.27^{a}	21.13^{b}	134.60^{a}
	Faro56	25.13^{b}	20.63^{c}	80.33^{b}
	Jamila	23.07^{c}	25.40^{a}	51.33^{c}

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of DMRT

Synergic Effect of NaCl Levels and R. solani Infection on Grain Attributes of Different Rice Cultivars

The impact of different NaCl concentrations on seed weight, grain length and grain diameter (Table 2) was analyzed. The results showed that seed weight varied depending on the NaCl concentration. Faro44 had the lowest seed weight at 8 dS m^{-1} and 6 dS m^{-1}, and in comparison, the average seed weight increased to the maximum value at lower NaCl level of 4 dS m^{-1}. Similar trends were observed in the other varieties. Grain length also varied with NaCl concentration, with Faro44 having the lowest grain length at 4 dS m^{-1} and the control group, having the highest. Faro52 had the shortest and longest grain length at 8 dS m^{-1} and 4 dS m^{-1}, and *Jamila* had the least grain length when the NaCl increased to 8 dS m^{-1}.

The grain diameter result indicated that different NaCl concentrations had a significant impact on 100 grain weight, grain length and grain diameter. A NaCl level of 2 dS m^{-1} resulted in the least average diameter of 1.7 mm in Faro44, followed by 6 and 8 dS m^{-1} showing 1.9 mm. At 4 dS m^{-1}, a grain diameter of 2.0 mm was measured, with the control group having the largest diameter. Faro52 yielded a comparable result, with the smallest diameter of 1.8mm measured at NaCl concentrations of 6 and 8 dS m^{-1}. NaCl level of 4 dS m^{-1} resulted in a diameter of 2.0 mm, while 2 dS m^{-1} yielded an average grain diameter of 2.3 mm, with the control group having the largest diameter. *Jamila* had the smallest diameter of 1.3 mm at 8 dS m^{-1}, followed by 2.0 mm at 2 and 6 dS m^{-1}. NaCl at EC level of 4 dS m^{-1} yielded 2.3 mm of diameter, while the control group yielded the largest diameter of 2.7 mm.

Table 2: Effects of NaCl concentrations (dS m^{-1}) on grain yield of *R. solani* infected Faro44, Faro52 and *Jamila* rice varieties

Treatments		Grain Yield Parameters		
		100 SW (g)	GL (mm)	GD (mm)
Concentrations (dS m^{-1})	0	2.7^{a}	12.60^{a}	2.42^{a}
	2	2.12^{b}	8.63^{b}	1.91^{b}
	4	$2.01^{c,b}$	$8.76^{c,b}$	$2.13^{a,b}$
	6	1.41^{d}	$8.83^{d,b}$	$1.91^{c,b}$
	8	0.99^{e}	7.93^{e}	$1.70^{e,b}$
Varieties	Faro44	2.30^{a}	10.03^{a}	1.94^{a}
	Faro56	1.32^{b}	9.55^{b}	2.04^{a}
	Jamila	1.96^{c}	8.47^{c}	2.07^{a}

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of DMRT

Synergic Effects of Salinity and R. solani Infection on Growth

The investigation conducted in this study has successfully brought to light the interconnected impact of different levels of NaCl and the sheath blight disease on the growth characteristics of three distinct varieties of rice. The growth of plants, which serves as a key indicator of their overall health and vitality, is inherently influenced by a multitude of factors such as number of leaves they possess, the abundance of branches stemming from their main stem and the number of tillers they generate. These growth parameters are directly tied to essential biological processes that are fundamental to the development and sustenance of plant life, such as cell division, expansion and maturation. The findings of this study discovered a notable retardation in the aforementioned growth parameters, particularly when plants are subjected to the dual stressors of high salt concentrations and the presence of sheath blight disease. Hence, the observed retardation of these parameters, especially under the influence of salt stress and sheath blight disease, is in harmony with Chalbi *et al*. (2021).

However, biotic and abiotic stresses have common impacts, which encompass diseases as well as soil salinity in this study, can exert a profound influence on growth and yield attributes of plants. Specifically, the stress caused by salinity has a capacity to disrupt a multitude of vital metabolic activities, impede the absorption of nutrients and interfere with the vital pathways responsible for hormone signaling. The findings presented in this study serve to highlight the significant relationship between the concentration of NaCl, the sheath blight disease and the duration of treatment on the overall height of plants. It becomes evident that the detrimental effect on plant height is amplified at higher NaCl levels and lengthier periods of treatment, potentially due to the disruption of nutrient equilibrium, the adjustment of metabolic activities and the alterations induced by pathogens (Mustapha *et al*., 2022a).

Moreover, it is crucial to highlight within this research the temporal aspect of the influence, wherein the initial reaction to these stressors could be recognized to encompass an antioxidant enzymes liberation and osmoprotectant molecules. It is worth noting, however, that prolonged exposure ultimately weakens the capacity of the plant to withstand stress. This decline in stress tolerance can potentially be attributed to the interference caused by salinity and sheath blight disease on fundamental metabolic processes, resulting in a diminishing anabolic activity and compromised cellular formation (Anwar *et al.*, 2022; Nawaz *et al.*, 2022; Krishnamoorthy *et al.*, 2022).

NaCl concentrations that surpass the threshold of 4 dS m^{-1} have most significant effects on the height of plants during various weeks after the transplanting process. This observation is in accordance with the established threshold for salinity levels specifically pertaining to rice, as stated by Soares *et al*. (2021). The number of leaves displayed notable variations in response to the presence of sheath blight disease and heightened salinity, indicating the existence of significant interactions between these stressors and the different stages of plant development. The statistical analyses conducted on the result further highlighted a significant synergy between the different varieties of rice and the concentrations of NaCl, thus underscoring the complexity inherent in these relationships (Soares *et al*., 2021).

Contrarily, when comparing the findings of Soares *et al*. (2021) to this study, it was observed that the influence of salinity on the number of leaves in *R. solani*-infected rice varieties was determined to be minimal. This phenomenon could potentially be attributed to the inherent tolerance of the tested varieties towards a NaCl concentration of up to 8 dS m^{-1}. Additionally, it could be as a result that the specific experimental conditions, such as the soil type utilized, contribute to this outcome. Notably, the number of tillers, a crucial factor affecting rice yield, displayed significant variations under varying NaCl concentrations and sheath blight disease stress, particularly during the prolong period of treatment. Furthermore, it is worth mentioning that Faro44 exhibited the highest capacity for tillering, which aligns with the findings of Kamai *et al*. (2020).

Synergic Effects of Different NaCl Levels and R. solani Infection on Rice Yield

Salinity, which refers to the amount of dissolved salts in soil or water, represents a noteworthy environmental limitation that greatly influences the vegetative development and yield of rice crops. To gain a comprehensive understanding of the relationship between salinity and sheath blight disease, which is a fungal infection causing significant damage to rice plants, a detailed investigation was conducted to examine their combined impact on various yield attributes. Through a rigorous analysis of the experimental data, it was revealed that when rice varieties were simultaneously exposed to these two stressors, their growth and productivity were severely compromised. Specifically, the number and length of panicles, which are the reproductive structures of the rice plant, were significantly reduced. Additionally, the number of grains panicle^{-1}, which directly contributes to overall rice yield, was also negatively affected. These findings highlight the detrimental consequences of the simultaneous occurrence of salinity and sheath blight disease on rice crops and present the urgent need for effective practice of mitigating the adverse impacts of these stressors in order to ensure sustainable rice production.

Different rice varieties exhibited diverse levels of vulnerability to soil salinity, ultimately affecting the production and length of their panicles. The susceptibility of Faro44 to salinity was notably higher compared to Faro52 and *Jamila*, as evidenced by the lower number of panicles it produced. This discrepancy in susceptibility can be related to the genetic differences that exist between these varieties. The findings from this study corroborate previous observations that have established a connection between salt stress and the sterility of panicles, consequently leading to a reduction in overall yield (Soares *et al*., 2021).

The pronounced impact on grain characteristics, such as weight, length and diameter, was observed at NaCl concentrations that were higher than 4 dS m^{-1}, thereby indicating a significant influence of stress due to salinity on these traits. Moreover, susceptibility shown by different rice varieties to this stress was evident, as Faro52 and *Jamila* exhibited a higher susceptibility in terms of grain weight. These findings challenge the existing conventional threshold for salt stress in rice, as proposed by Razzaq *et al*. (2020). Consequently, this study indicates that the presence of sheath blight disease, coupled with salinity levels exceeding 4 dS m^{-1}, could result in substantial damaging effect on the vegetative growth and yield attributes of rice plants infected by *R. solani*.

Conclusion

This investigation underscores the substantial impact of *R. solani* infection and NaCl stress on different varieties *O. sativa*. Notable effects on plant height, tiller numbers, panicle characteristics and grain attributes were observed. The effects were found to be more severe when NaCl levels increased, suggesting an importance of managing salt stress in rice cultivation. This study contributes valuable insights into the interactions between salt stress due to NaCl exposure and sheath blight disease in Rice, providing a basis for further research to enhance rice crop resilience and productivity under challenging conditions.

Acknowledgments

The authors wish to extend their thanks to the Plant Pathology Laboratory at Bayero University, Kano, Nigeria for supplying the pure and identified isolate of *R. solani* that was utilized in this research. Additionally, we would like to acknowledge the invaluable contribution of the Biology Lab at the science Laboratory Department of Jigawa State Polytechnic for proving maximum support.

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