Research Article

Chemical and Morphological Responses of Several Rice Varieties Against Spraying With Potassium and Irrigation With Saline Water

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Abstract | Salt stress is one of the major physical factors affecting the growth and productivity of rice, which is known to be a salt-sensitive crop. Rice is one of the most important cereal crops in Asia and is a staple food for more than half of the world's population. To evaluate the effects of salinity on rice growth and yield components, this study was conducted to evaluate the response of 5 rice cultivars, Anber 6, Anber 33, Jasmine, Furat, and salt-tolerant cultivar Pokkali, to three salinity levels: 2, 4 or 6 dS^{-1} in combination with foliar 500 ppm K. The 2 dS^{-1} treatment represents irrigation with river water (control), and the saline water treatment started after seed germination. The results showed that irrigation with saline water and spraying with potassium were superior to the control, recording the highest average for dry weight and panicle length, 79 g $plant^{-1}$ and 17.832 cm, respectively. While the variety Anber 33 recorded the highest leaf area and panicle length, 83.33 cm^2 and 22.49 cm, respectively. The treatment S2 had the most active tillers, the most grains per plant, and the most organic yield (44.6 panicle plants per plant, 23.502 g per plant, and 11.88 tonnes ha^{-1}). With a harvest score of 45.39% and a grain yield of 5.20 tonnes ha^{-1}, trait S1 was the best. Pokkali had the most, with an average grain yield of 5.10 tonnes ha^{-1} and an average vegetable yield of 16.43 tonnes ha^{-1}. The amount of NPK in the leaves changed a lot when salt water was used to water them, and potassium was used to wash them. In Treatment S1, these leaves had the most NPK: 1.21, 0.22, and 1.62, in that order. The amount of nitrogen in the leaves of different types of plants was different. The leaves of the Furat type had 1.21 times more nitrogen than those of other kinds. The Jasmine type leaves had 1.21 times more P and 1.73 times more K than they should have had. The interaction treatment between the two factors (Jasmine × S1) also recorded the highest average for the leaf content of N, P and K as it reached 1.54, 0.32 and 3.40, respectively. It can be summarised that potassium treatment at 500 ppm can be effective in improving rice production, vegetative growth traits and nutrient absorption in saline water irrigated soil.

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Introduction

A lot of people grow rice because Asia eats more than 80% of the world's rice (Kaur and Pati, 2017). If everyone eats the same amount of rice now, the market for it will grow to 607 million tonnes by 2050 (Bandumula, 2018). The amount of rice grown has gone down over the last 20 years, and it will keep going down because of climate change and the ease with which things like salt can hurt rice (Fu *et al.*, 2023). Therefore, breeding salt-tolerant rice can effectively enhance its cultivation and production, contributing to addressing current and potential food crises (Ismail *et al.*, 2021). It was indicated (Grattan *et al.*, 2002) that rice is a sensitive crop with growth and productivity affected by salinity, and its sensitivity threshold to salinity does not exceed 3 dS m^{-1}. It can affect most of its metabolic and physiological processes, starting from the entry of water into the seed and ending with the process of photosynthesis and the accumulation of dry matter, while Munns (1993) considered rice to be a moderately tolerant crop as its productivity decreases by 50% at a threshold of 10.3 dS m^{-1}. More than 3.0 dS m^{-1} of salt in the soil slowed plant growth and decreased grain production by reducing leaf area, inflorescence length, seed formation rate, 1000-seed weight, number of effective inflorescences, number of grains per inflorescence, and grain yield (Mumtaz, 2018; Al-Jana, 2021). When there were 6.0 dS m^{-1} of EC in the soil, the yield of rice grains was cut in half. (Djaman, 2020). In (Zheng, 2023), it says that salt stress cut the amount of grain that was made by -64.52% (95% CI: -66.49% to -62.44%). This was because there were not as many grains, seeds, or flower groups that worked per panicle. K+ can't get into the body when there is a lot of Na+ there. K+, which is an important part of many biochemical and biological processes (Horie, 2007), changes the quality, growth, and stress-strength of all plants. lIn turn, this hurts plant growth and makes less food. lPlants grow more slowly when there is 40 mmol of NaCl. lWhen the sodium level goes above 100 mmol, plants that are sensitive to salt, like rice, may die (Almeida, 2017). Salt stress makes plants' cytoplasm have too much sodium (Hao *et al.*, 2021). They need to make sure it has a lot of potassium (Hao *et al.*, 2021).

It has discovered that adding salt to different types of rice changed how they looked and, in some ways, helped them grow (Hilal *et al.*, 2021). K+ played a big role in these changes. A lot more rice was grown, and dry matter was made after 60 days when potassium was added to salty seaside soils (Banerjee *et al.*, 2018). Also, there was 116% more potassium in the oats than there was before. When there is enough potassium, the stage where the grains are being filled with nitrogen moves more nitrogen to them. This helps the plants take in nitrogen and phosphorus more easily. Also, when they take in a lot of potassium, it lessens the bad effects of taking in sodium (Liu *et al.*, 2024; Alwan *et al.*, 2025; Talib *et al.*, 2025). When potassium was added to rice that was grown in salty soil, the grain yield went up by 49% compared to the control group. It also helped the plant take in more nutrients, like nitrogen, phosphorus, and potassium, and made 19.13% more leaves. 1 But rice wasn't able to use its own nitrogen and potassium as well (Akter *et al.*, 2023).

The objective of the present study is to determine the effect that potassium supplementation has on rice growth and nutrient uptake under salt stress conditions. More specifically, the study aims to observe and record any influenced changes in grain yield, dry matter production, and major nutrients (nitrogen and phosphorus) uptake by rice in a saline soil condition. Potassium is assumed, or rather hypothesised, to play a key role in reducing negative effects manifested through excessive sodium accumulation within a rice plant itself.

Materials and Methods

The field study was undertaken in a farmer's field in Babylon Governorate (Iraq) during the summer season of 2024 to evaluate the chemical and morphological response of five rice varieties (Anber 6, Anber 33, Jasmine, Furat, and Pokkali) to irrigation with saline water at three levels: 2, 4 dS^{-1} + 500 ppm K and 6 dS^{-1} + 500 ppm K, which are denoted by S0, S1, S2 respectively. In the 2 dS^{-1} process, river water is used to test and to water the plants. Once the plants had grown from the first soak, salt water was used to water them. This was done with an RCBD stochastic full block pattern that had three copies. K+ was put on the plants twice early in the morning. After 45 days, a 2-litre hand washer was used for the first time. Two weeks after the first spraying, it was done again. The outside is 2 m2, and there is 1.5 m between each unit. It looked dirty. lHere is a table that shows how it was broken down into its real and chemical parts (Table 1). The seeds were planted on 6/18/2024 at a quantity of 120 kg ha^{-1}, and fertilisation was carried out according to the recommendations (Abu Dahi *et al.*, 2009). And at the maturity stage, the plants were harvested on 12/12/2024. Growth and yield traits and their components (plant height cm, flag leaf area cm^2, number of active branches $plant^{-1}$, panicle length cm, number of grains per panicle, weight of 1000 grains g^{-1}, grain yield kg^{-1}, biological yield) were calculated, and some elements (N, P, K) as well as the leaves' content of chlorophyll and carbohydrates were analyzed according to the protocol followed by (Walsh, 1971) and (Allen *et al*., 1970). To look at the trait data in a scientific way, they used Genstat Discovery 4. There was a 5% chance that the LSD test would show that the means were not the same (Al-Rawi and Khalaf Allah, 2000).

Table 1: *Some chemical and physical properties of the field soil before planting.*

Results	Unit	Properties
2	ds m^{-2}	Ece
7.8	--	pH
1.3	mg kg^{-1}	O.M
8.8	mg kg^{-1}	N
11.4	mg kg^{-1}	P
132	mg kg^{-1}	K
80	mg kg^{-1}	Sand
320	mg kg^{-1}	Silt
600	mg kg^{-1}	Clay
silty clay		Soil texture

Table 2: *The effect of irrigation with saline water and spraying with potassium on the weight of leaf area and their interaction*

L.S.D	Average	S2	S1	S0	Variety
N0.524	79.67	83.00	82.00	74.00	Anber 6
L.S.D	83.33	76.00	109.00	65.00	Anber 33
V0.956	72.00	85.00	58.00	73.00	Pokkali
L.S.D	36.33	42.00	34.00	33.00	Furat
N×V 1.656	33.00	28.00	42.00	29.00	Jasmine
		62.8	65	54.8	Average

Results and Discussion

Effect of irrigation with NaCl and spraying with K^+ on growth traits Leaf area

As shown in Table 2, the best average area was 65 cm² for the way where salt water was used to water the plants and potassium S1 was put on them. It should have been 54.8 cm² for treatment S0, but this was bigger than that. One type of plant, Anber 33, had 83.33 cm² of leaf area, while another type, Jasmine, had only 33.00 cm². This might be because the genes of the types that were looked at changed. Flag plants have flag leaves that are different sizes because their genes have changed. The interaction treatment area (Anber 33 — S1) was 109.9 cm², but the interaction treatment area (Jasmine S2) was only 28.00 cm².

Panicle length

In treatment S2, the average flower length was 17.832 cm, which is longer than the average flower length in treatment C (16.6 cm (Table 3. lNumber 33 had the highest average at 22.49 cm, and number 10 had the lowest average at 10.60 cm. It's important to know that types with high output breed new types with long panicles. This raises the number of grains and the number of whole grains. One thing that these genes need to be checked for is the long panicle trait (Peng *et al*., 2008). Two groups needed to work together. The average length of the Number 33 S1 interaction treatment was 24.17 cm, and the average length of the Yasmine S2 interaction treatment was 9.63 cm.

Table 3: *The effect of irrigation with saline water and spraying with potassium on the weight of panicle length and their interaction*

L.S.D	Average	S2	S1	S0	Variety
NN.S	19.40	20.53	18.66	19.00	Anber 6
L.S.D	22.49	22.30	24.17	21.00	Anber 33
V0.943	20.42	21.60	20.66	19.00	Pokkali
L.S.D	13.70	15.10	13.00	13.00	Furat
N×V1. 633	10.60	9.63	11.17	11.00	Genotype 14
		17.832	17.532	16.6	Average

Table 4: *The effect of irrigation with saline water and spraying with potassium on the weight of the number of inactive tillers and their interaction.*

L.S.D	Average	S2	S1	S0	Variety
N0.4395	10.333	12.000	0.000	19.000	Anber 6
L.S.D V	4.000	1.000	0.000	11.000	Anber 33
0.8023	5.333	2.000	2.000	12.000	Pokkali
L.S.D	3.667	1.000	3.000	7.000	Furat
N×V1. 3897	3.000	7.000	0.000	2.000	Genotype 14
		4.6	1	10.2	Average

Number of inactive tillers

Table 4 shows that the S1 group had the fewest plantlets (1 panicle plant per plant), while the control group had the most (10.2% of the plants were useless). The Jasmine variety only had 3,000 panicles per plant on average, while the Amber 6 variety had an average of 10.333 panicles per plant. This could be because

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of how weak different types are naturally, even if everything else is the same. The interaction treatment (Anber 6× S0) recorded the highest average of 19.000 panicles plant^{-1}, while the interaction treatment (Jasmine× S1) and (Anber 6× S1) recorded the lowest average of 0.000 panicles plant^{-1}.

Dry weight

The S2 treatment had the most impact, at 79 g plant^{-1}. Whereas the S1 treatment had the least, at 64.2 g plant^{-1}. That number was 113.33 g plant^{-1} for the Pokkali variety and 27.00 g plant^{-1} for the Jasmine variety. Potassium is good for plants and helps them improve their health. It also helps the plant turn the dry matter that the green parts make into food better. It was also found that up to 10% of the plant's dry weight is potassium. This matches what [9] found. The average of the two methods showed that (Pokkali × S2) had the most plants (148.00 g plant^{-1}), while (Jasmine × S1) had the fewest plants (21.00 g plant^{-1}) (Table 5).

Table 5: *The effect of irrigation with saline water and spraying with potassium on the weight of dry weight and their interaction.*

L.S.DN 0.525	Average	S2	S1	S0	Variety
	76.67	73.00	76.00	81.00	Anber 6
L.S.DV 0.959	85.67	91.00	60.00	106.00	Anber 33
	113.33	148.00	105.00	87.00	Pokkali
L.S. DN×V 1.661	43.67	49.00	59.00	23.00	Furat
	27.00	34.00	21.00	26.00	Jasmine
		79	64.2	64.6	Average

Yield and its components lNo. Of active tillers

The results shown in Table 6 reveale the effect of irrigation with saline water and spraying with potassium on the yield and its components. The third level S2 recorded the highest average for the No. Of active shoots, which amounted to 44.6 panicle lplant^{-1}, while the second level S1 recorded the lowest level, which amounted to 40.2 panicle plant^{-1}. The best number was 48.67 panicles per plant for the Jasmine type. Altogether, 34.33 panicles grew on each Anber 33 plant, which was the worst. Different genetic structures have different grain weights. These weights depend on things like the area of the flag leaf, the number of active tillers per unit area, and the grain's area and chemical make-up (Hussien *et al.*, 2014). The method that did this (Jasmine S2) had the best average, with 59.0 panicles per plant. This shows how the two things affected each other. After being treated with both Anber33 S1 and S2, most of the panicles were lost, on average, 32.00 per plant.

Table 6: *The effect of irrigation with saline water and spraying with potassium on the number of active tillers and their interaction.*

L.S.D N	Average	S2	S1	S0	Variety
0.504	38.67	32.00	46.00	38.00	Anber 6
L.S.D V	34.33	32.00	32.00	39.00	Anber 33
0.920	43.00	48.00	44.00	37.00	Pokkali
L.S.D N×V	47.67	52.00	43.00	48.00	Furat
1.593	48.67	59.00	36.00	51.00	Jasmine
		44.6	40.2	42.6	Average

Weight of 1000 grains

Twenty-five hundred-grain weight trait was 23.502 g for the third level, S2 (as highlighted in Table 7). It was the people in the control group who weighed the least, at 21.8002 g on average. Most of the time, the Anber 33 variety weighed 19.592 g, and the Furat variety weighed 25.538 g. The type that was given was better because it had more grains, and the grains got bigger when potassium was added (Table 6). It went the way (Al-Jana, 2021) said it would. The best way was to mix Jasmine and S2, which gave it a weight of 26.860 g. This method helped people lose the most weight (number 33, s2). 1A mean of 19.150 g was lost.

Table 7: *The effect of irrigation with saline water and spraying with potassium on the weight of 1000 grains and their interaction.*

L.S.D N0.3609	Average	S2	S1	S0	Variety
	23.019	23.240	23.150	22.667	Anber 6
L.S.D V0.6589	19.592	19.150	19.960	19.667	Anber 33
	21.296	22.410	21.810	19.667	Pokkali
L.S.D N ×V1.1413	25.538	25.850	26.430	24.333	Furat
	24.842	26.860	25.000	22.667	Jasmine
		23.502	23.27	21.8002	Average

Grain yield

Near level S1, which was the second level, 5.20 tonnes of grain were grown every day. On the other hand, 3.04 tonnes of grain grew when level C1 was used. In general, the Pokkali variety gave rise to 5.10 tonnes ha^{-1}, while the Jasmine variety gave rise to 2.33 tonnes ha^{-1}. Based on Table 6, this type of wheat had high means for both the number of tillers that worked and the grain weight. This could be one reason, as shown in Table 7. It also helped by lowering the effects of salt stress, which made it possible for more grains to grow. This is where Mumtaz (2018) and Al-Jana (2021) talked about how different types can make different amounts of grains. It had an average of 9.50 tonnes ha^{-1}, which was the most of any treatment (Anumber 6 × S1). The treatment that mixed jasmine and S0 had the lowest average, at 20 tonnes ha^{-1}(Table 8).

Table 8: *The effect of irrigation with saline water and spraying with potassium on the grain yield and their interaction.*

L.S.D N	Average	S2	S1	S0	Variety
0.4649	4.93	2.80	9.50	2.50	Anber 6
L.S.D V	4.83	5.50	5.00	4.00	Anber 33
0.8488	5.10	5.30	5.50	4.50	Pokkali
L.S.D N×V	3.06	3.50	3.50	2.20	Furat
1.4702	2.33	2.50	2.50	2. 00	Jasmine
		3.92	5.20	3.04	Average

Biological yield

That's 11.82 tonnes ha-1 more for treatment S2, as shown in Table 9. The average organic yield for the control treatment, on the other hand, was only 9.52 tonnes ha^{-1}. Pokkali types gave the most food (16.43 tonnes ha^{-1}), while Jasmine types gave the least (5.03 tonnes ha^{-1}).

This could be because each type has a different growing rate, grain yield, leaf area, and dry matter weight. This agrees with what Djaman (2020) found, which is that genes' organisation has a big effect on what cells do. The best yield (20.10 tonnes ha^{-1}) was seen when Porkkali and S2 were put together. When Furat and S0, Jasmine and S0, and Jasmine and S1 were mixed, the yield was only 4.60 tonnes ha^{-1}.

Table 9: *The effect of irrigation with saline water and spraying with potassium on the biological yield and their interaction.*

L.S.D	Average	S2	S1	S0	Variety
N0.4498	12.60	10.10	17.10	10.60	Anber 6
L.S.D V	13.40	14.60	11.00	14.60	Anber 33
0.8213	16.43	20.10	16.00	13.20	Pokkali
L.S.D N×V	7.46	8.40	9.40	4.60	Furat
1.4225	5.03	5.90	4.60	4.60	Jasmine
		11.82	11.62	9.52	Average

Harvest index

Table 10 shows that the average number for this trait was 45.39% for the second level S1 and 35.16% for the third level S2. Most of the time, the Pokkali variety had an average of 31.61%, while the Jasmine variety had an average of 46.72%. This could be because potassium helps the body work better, and sodium has less of an effect. The better type found it easy to turn the dry matter that the plant parts made into grains, which increased the rate of production. More than half of the dry matter that was grown could be turned into grains with this mix. This matches what Djaman (2020) found about how the harvest index trait changed between types. With 55.56% of the votes, number 6 (S1) was the best way to engage. With a score of 23.58%, Number 6 S0 was the worst way to get in touch.

Table 10: *The effect of irrigation with saline water and spraying with potassium on the harvest index and their interaction.*

L.S.D N	Average	S2	S1	S0	Variety
0.510	35.62	27.72	55.56	23.58	Anber 6
L.S.D V	36.84	37.67	45.46	27.40	Anber 33
0.930	31.61	26.37	34.37	34.10	Pokkali
L.S.D N×V	42.26	41.68	37.23	47.87	Furat
1.611	46.72	42.36	54.33	43.46	Jasmine
		35.16	45.39	35.282	Average

Effect of irrigation with saline water and potassium spraying on leaf macronutrient content (NPK) and their interaction

Treatment S1 had a lot more of the three things (NPK) in its leaves (Table 11). These things had means of 1.21, 0.22, and 1.62. They were 0.98, 0.11, and 0.81 for each factor in Treatment S2, which was the worst. In its leaves, the Furat type had 1.21 mg/m2, which was the most of any type. On the other hand, the leaves of the Jasmine type had 1.21 mg/m2 of phosphorus and 1.73 mg/m2 of potassium. For this reason, the extra potassium might have reduced the bad effects of sodium chloride and made it easier for the plant to take in phosphorus and nitrogen ions, which led to more of these ions. Ali found it too. He said that potassium changed the way plants looked and worked, as well as the way chemicals moved through them and how photosynthesis worked.

Because of this, plants grew, changed, and made more (Nieves-Cordones *et al*., 2016; Horie, 2007).

Regarding the interaction between the two factors, the results of the same table showed that the treatment (Jasmine × S1) achieved the highest average of leaf content of nitrogen, phosphorus and potassium, reaching 1.54, 0.32 and 3.40 respectively, while the interaction treatment (Anber33 × S0) recorded the lowest average of 0.84 and 0.09 for each of the nitrogen and phosphorus elements, while the treatment (Jasmine × S2) recorded the lowest average of leaf content of potassium, reaching 0.60.

Table 11: *The effect of irrigation with saline water and spraying with potassium on the N, P, and K content of leaves and their interaction.*

N					
Variety	S0	S1	S2	Average	L.S.D
Anber 6	1.32	1.12	0.98	1.14	N0.016
Anber 33	0.84	1.12	1.12	1.02	
Pokkali	1.12	1.05	0.70	0.95	V0.023
Furat	1.33	1.26	1.05	1.21	
Jasmine	0.77	1.54	1.05	1.12	N×V 0.041
Average	1.01	1.21	0.98		
P					
Variety	S0	S1	S2	Average	L.S.D
Anber 6	0.13	0.253	0.09	0.159	N 0.0024
Anber 33	0.09	0.13	0.12	0.12	
Pokkali	0.15	0.16	0.11	0.14	V 0.0034
Furat	0.13	0.25	0.10	0.16	
Jasmine	0.15	0.32	0.11	0.19	N×V0.0058
Average	0.13	0.22	0.11		
K					
Variety	S0	S1	S2	Average	L.S.D
Anber 6	1.80	1.12	0.76	1.22	N 0.033
Anber 33	1.11	0.93	0.72	0.92	
Pokkali	0.62	1.49	1.08	1.06	V 0.047
Furat	1.01	1.19	0.89	1.03	
Jasmine	1.19	3.40	0.60	1.73	N×V 0.081
Average	1.14	1.62	0.81		

Conclusions

Findings reveal that the effect of irrigation with saline water was remarkably reduced when rice plants were sprayed with potassium. The rice variety Anber 33 was always tolerant to salinity and showed higher growth indicators, including leaf area and panicle length, than other tested varieties, Anber 6, Jasmine, Furat, and Pokkali. Regarding yield and its components, the treatment of saline water at 6 dS-1 in combination with spray with potassium fertiliser at a level of 500 ppm recorded the highest average for the number of active tillers, the weight of 1000 grain and biological yield, especially in the interaction with Amber 33, which was compared to other interaction treatments. It can be concluded that the application of potassium as a spray treatment at 500 ppm can be effective in improving rice growth and production even in soil irrigated with saline water.

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Novelty Statement

The novelty of this study lies in evaluating the effect of potassium on the growth and productivity of rice varieties under salt stress, while improving nutrient absorption and reducing sodium accumulation, and providing updated field data for 2024.

Author's Contributions

Hussein M Shamran, Wafaa N Radhi, Mustafa M Ali and Fuad R Al-Burki: The author carried out all stages of the research, from experimental design to data collection and analysis, and finally, the formulation of the results and references.

Statement of Generative AI and its assistive technologies

Generative AI tools were used to formulate parts of the text and suggest modifications to improve its language. The author confirms that all data and scientific analyses were provided directly by the author, without any intervention from any artificial intelligence in the results or their interpretation.

Conflict of Interest

The author declares that there are no personal or financial conflicts of interest.

References

Abu Dahi, M., S. Al-Jalili, and H. Al-Obaidi.

2009. Rice cultivation and fertilization recommendations in Iraq. Baghdad: Ministry of Agriculture, Iraq.
Akter, S., M. Rahman, M. Hasan, *et al*. 2023. Enhanced potassium fertilization improved rice (*Oryza sativa*) yield and nutrient uptake in coastal saline soil of Bangladesh. J. Soil Sci. Plant Nutrit., 23(2): 1884-1895. https://doi.org/10.1007/s42729-022-01024-3.
Al-Jana, M. 2021. Morphological, chemical and molecular evaluations for several rice (*Oryza sativa* L.) races grown under salt stress levels. IOP Conference Series: Earth Environ. Sci., 923(1): 012057. https://doi.org/10.1088/1755-1315/923/1/012057.
Allen, S.E., H.M. Grimshaw, J.A. Parkinson, and C. Quarmby. 1970. Chemical analysis of ecological materials. Oxford: Blackwell Scientific Publications.
Almeida, D., F. Silva, R. Oliveira, *et al*. 2017. Regulation of Na+ and K+ homeostasis in plants: towards improved salt stress tolerance in crop plants. Genet. Molecul. Biol., 40(1): 326-345. https://doi.org/10.1590/1678-4685-GMB-2016-0103.
Al-Rawi, K.M., and Khalaf Allah, A. K. 2000. Statistical analysis in agricultural experiments. Baghdad: University of Baghdad Press.
Alwan, M.G., W.H.A. Alqatrani, I.A. Jihad, Q.R. Lahhob, M. Mudhafar, H.A. Alsailawi, and M.A. Zaidan. 2025. Development and in vivo evaluation of recom-binant multi-epitope vaccine (ABOR) with chitin microparticles as adjuvant against brucella abortus. J. Anim. Health Prod., 13(s1): 89–97. https://doi.org/https://dx.doi.org/10.17582/journal.jahp/2025/13.s1.89.97
Bandumula, N. 2018. Rice production in Asia: key to global food security. Proceed. Nation. Academy Sci. India Sect. B., 88: 1323-1328. https://doi.org/10.1007/s40011-018-0961-2.
Banerjee, H., P. Roy, and S. Das. 2018. Optimizing potassium application for hybrid rice (*Oryza sativa* L.) in coastal saline soils of West Bengal, India. Agron., 8(12): 292. https://doi.org/10.3390/agronomy8120292.
Djaman, K. 2020. Rice genotype and fertilizer management for improving rice productivity under saline soil conditions. Paddy Water Environ., 18(1): 43-57. https://doi.org/10.1007/s10333-019-00764-8.
Fu, J., Li, X., Zhang, Y., *et al*. 2023. Extreme rainfall reduces one-twelfth of China's rice yield over the last two decades. Nature Food, 4: 416-426. https://doi.org/10.1038/s43016-023-00749-1.
Grattan, S., M. Shannon, and S. Shafique. 2002. Rice is more sensitive to salinity than previously thought. California Agric., 56(6): 189-195. https://doi.org/10.3733/ca.v056n06p189.
Hao, S., Y. Wang, Y. Yan, Y. Liu, J. Wang, and S. Chen. 2021. A review on plant responses to salt stress and their mechanisms of salt resistance. Hortic., 7(6): 132. https://doi.org/10.3390/horticulturae7060132
Hilal, K., M. Ahmed, and R. Singh. 2021. Growth and yield traits of genetically modified genotypes of rice (*Oryza sativa* L.). Ind. J. Ecol., 48(17): 506-508.
Horie, T. 2007. Rice OsHKT2;1 transporter mediates large Na+ influx component into K+-starved roots for growth. The EMBO J., 26(12): 3003-3014. https://doi.org/10.1038/sj.emboj.7601743.
Hussien, A., A. El-Sayed, and F. Mahmoud. 2014. Genetics of tillering in rice and barley. The Plant Genome., 7(1): 2013-10. https://doi.org/10.3835/plantgenome2013.11.0036.
Ismail, E., H. Farag, and R. Ahmed. 2021. Phenotypic characterization and determination of gene expression of genetically modified rice strains using CRISPR-CAS9 technology with sodium chloride effect. IOP Conference Series: Earth Environ. Sci., 923: 012046. https://doi.org/10.1088/1755-1315/923/1/012046.
Kaur, N., and P. Pati. 2017. Integrating classical with emerging concepts for better understanding of salinity stress tolerance mechanisms in rice. Front. Environ. Sci., 5: 42. https://doi.org/10.3389/fenvs.2017.000
Liu, Y., H. Wang, and X. Zhang. 2024. Effects of phosphorus and potassium supply on photosynthetic nitrogen metabolism, nitrogen absorption, and nitrogen utilization of hydroponic rice. Agron., 14(8): 1726. https://doi.org/10.3390/agronomy14081726
Mumtaz, M. 2018. Genotypic variation in rice for grain yield and quality as affected by salt-affected field conditions. J. Plant Nutrit., 41(2): 233-242. https://doi.org/10.1080/01904167.2017.1375445.
Munns, R. 1993. Physiological processes limiting plant growth in saline soils: some dogmas and

hypotheses. Plant, Cell lEnviron., 16(1): 15-24. https://doi.org/10.1111/j.1365-3040.1993.tb00801.x.

Nieves-Cordones, M., A. Miller, and J. Schroeder. 2016. Roles and transport of sodium and potassium in plants. In: The alkali metal ions: Their role life. pp. 291-324. https://doi.org/10.1016/B978-0-12-802062-6.00013-5.

Peng, S., K. Cassman, and S. Virmani. 2008. Progress in ideotype breeding to increase rice yield potential. Field Crop Res., 108(1): 32-38. https://doi.org/10.1016/j.fcr.2008.04.004

Said, A., Hassan, M. and El-Sharkawy, H., 2025. Biopesticides for sustainable pest management: An eco-friendly approach. J. Agric. Sci. Technol., 27(1): 45–58.

Talib, A.L., R.Y. Rashid, I.A. Jihad, Q.R. Lahhob, M. Mudhafar, H.A. Alsailawi, and A.A. Ayada. 2025. Genetic diversity and evolutionary patterns of avian influenza viruses in poultry and their implications for disease control and vaccine development. J. Anim. Health Prod., 13(s1): 460–469. https://dx.doi.org/10.17582/journal.jahp/2025/13.s1.460.469

Walsh, L.M. 1971. Soil and plant analysis for nutrient content. Madison, WI: Soil Science Society of America.

Zheng, C. 2023. Effect of salinity stress on rice yield and grain quality: A meta-analysis. Europ. J. Agron., 144: 126765. https://doi.org/10.1016/j.eja.2023.126765.