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Rice variety-specific characteristics of rice variety stress from water and salt

Dhwani Bartwal[1]*, Balraj Singh[2] and Jyoti Saini[3]

[1]Parul University, PO Limda, Vadodara, Gujarat, India
[2]Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India
[3]Vivekananda Global University, Jaipur, India.

Abstract

Rice is the most critical provisions cause in support of more than the world's population (Oryza sativa L.). Globally, 678.7 million tonnes of rice are produced annually on 161 million hectares. Drought and salinity are two significant abiotic variables because of the size of their impacts and the prevalence of their occurrence. The current study assessed different rice varieties' capacity to survive salt and water stress during germination and the first stages of seedling growth. The seeds of three different types of rice were collected and then placed in storage with four levels of varying water stress and six levels of varying salt stress. The seed vigor, dry weight, seed germination rate, seedling size, and other factors were noted. According to the findings, all cultivars' germination was inhibited and delayed as water stress increased, going from 68.8% in control to 4.4% at the point of maximum pressure (-15 bar). All rice varieties saw a decrease in the "dry weight of shoot and root, shoot and root length, and fresh weight of stem and root as water stress" increased. Hybrid 312 could not germinate in water stress conditions, but Narendra 1 and Sabarmati fared well. The rising salt burden considerably decreased every quantifiable attribute in all organisms. Under control conditions, seed germination was 100%; under the highest (10 ds/m) salt stress level, it was only 65%. The highest germination rate (100%) was seen with Hybrid 224 in all salt-stress situations. These findings aid in selecting the tolerant types that need additional research and use in real-world settings.

Keywords: Seed vigor, Water stress, Salt stress, Relative water content, Salt tolerance, Seed germination

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1. Introduction

Rice supplies many as 50% of the world's food needs. The irrigation method of choice in Egypt is continuous flooding, a significant water user for the rice crop. In the conventional flooded system, rice plants in Egypt's 700000 ha rice-covered region need more than 20,000 m3 ha-1 of irrigation water, which is more than three to four times what they need for biological purposes [1]. Abiotic stressors like drought, salt, waterlogging, and extreme temperatures significantly impact plant development and productivity and cause yearly crop losses. Such forces significantly reduce crop productivity and negatively impact many photosynthetic components. In 2020, wheat was anticipated to cover more than 200 million hectares, making it the second-largest crop in the world. The area used for growing rice is expected to remain constant in 2030 [2]. Abiotic stressors originate in unfavorable environmental conditions and hinder all stages of plant development, including "germination, seedling establishment, vegetative growth, flower initiation, panicle enlargement, grain filling, and production." Examples include heat or temperature stress, submersion, dehydration, and inadequate nutrition. These features negatively impact rice production, grain quality, crop establishment, and plant growth. Specific abiotic difficulties in locations where rice is grown promote the development and infection of causative biotic agents, compounding productivity and grain quality losses [3]. The largest of the three rainfed rice ecosystems, rainfed lowland covers 7.0 million ha, or 65% of the rice-growing area (upland, lowland, and deep water). The northeast (5.0 million acres) and north of Thailand are home to most of its rain-fed lowland lands (2.0 million ha).

Between 1.5 and 2.2 t ha-1 of rice are produced there irregularly. Plant breeding has not significantly increased yield [4]. In the rainfed areas of Asia, plenty of pressure is a complicated occurrence that can happen at any point throughout the growing season and varies significantly between years and locales. Early-stage droughts (germination, seedling, and tillering) delay germination in uplands or lowlands that get rain, resulting in slow development and poor crop establishment. As a result, the quantity of panicles per entity region with their dimension is reduced. Salt is the second-biggest emerging danger to rice output after the drought was suggested. This suggests that salt is the second-biggest emerging danger to rice output after drought. 10% of the world's croplands are predicted to be impacted [5]. Using third-generation sequencing technology, the research [6] examined the gene expression variations in the leaves of three rice types with varying degrees of tolerance following a 6-hour salt stress treatment. The article [7] gathered the most recent peer-reviewed research on how multi-omics approaches can speed up the development of drought-tolerant rice plants to achieve sustainable rice manufacture and global food security. The study [8] showed how rice's free and total amino acids (FAAs) changed based on the milling speed. To comprehend the changes in the A.A. content of milled rice and the associated brand, Pachchaperumal and Bg 406 were given three degrees of milling (4%, 7%, and 12%). The article [9] used the stochastic frontier (S.F.) production function to evaluate how saltwater intrusion has affected the technical efficacy (T.E.) and productivity of rice farms in Central Vietnam. The research [10] looked at 30 different rice types and discovered a lot of variation in how photosynthetic performance responded to salt stress throughout the reproductive stage, which eventually reduced yield components after recovery. The paper [11] used cost-effective land reclamation and crop management methods combined with salt-tolerant rice varieties to study the interaction between adaptation and mitigation strategies. The research [12] compared the agronomic features of Thai rice varieties to a type resistant to salinity stress at the tillering stage to ascertain how salinity from sodium chloride (NaCl) impacts them. Comparing the responses of the four commonly used indigenous aromatic rice varieties—Tulaipanji (T.P.), Radhunipagal (R.P.), Kalonunia (K.N.), and Gobindobhog—with those of IR-64, a non-aromatic rice cultivar, will help researchers better understand how the aforementioned common metabolites are channeled for aroma formation and salt stress relief in the chosen rice cultivars (G.B.) [13]. The research [14] investigated the genes causing and the molecular basis of rice's low light resistance. Researchers examined transcriptome profiling under low light stress. The study [15] highlighted the importance of various omics techniques, like genomes, transcriptomics, proteomics, metabolomics, phenomics, metabolomics, genomics, and interactomics, in creating the climate-resistant rice range to provide for the world's increasing population.

The following sections of the article are organized: The materials and techniques are summarized in Section II; Section III presents the recommended results and discussion in more depth. Section IV concludes the study and offers suggestions for more research.

2. Materials and methods

Water stress experiment: Using mannitol solution and the method provided by Helmericls and Pfeifer, some level of external water pressure (-5, -10, with 15 bars) was produced in this study (1954).

$$water\ stress = \frac{1}{-25} \times molality/\psi_p \qquad (1)$$

Experiment on salt stress

The seeds used to establish the Narendra1, Sabarmati, and Hybrid 312 rice varieties, which are grown in the Bhabhar area of the Nainital region, were produced by the (GB Pant University of Agriculture and Technology in Pantnagar). All sound and uniform seeds were surface sterilized before being rinsed using distilled water.According to the instructions for the salt stress experiment and the water stress experiment, the seedlings waslocated in sterile Petri dishes lined with two sheets of clean Whatman Number. 1 filter paper and 5 ml of distilled water or the appropriate test results Figure 1. Each treatment had three replicates and ten seeds per petri plate.A 12-hour light/dark cycle, the minor temperature at $140°C$, with the highest temperature of$24\,°C$, was these conditions represented in the germination test. When Ψ_p is the mannitol solution's osmotic potential (also known as water stress), a control water stress level of 0 bars was maintained. The seed was considered to have germinated when its radicle reached a length of 2 mm. The number of sources that sprout each day determines the germination percentage. We measured the fresh and dry weights, the roots and shoots' heights, and the young seedlings' sizes on the fifteenth day.The shoot and root's dry weights were measured after a 48-hour drying time in an oven heated to 60° C. SPSS version 16 was used to complete the statistical analysis.

Following the final count, the germination rate (G.R.) and germination percentage were calculated using the following formulas (G.P.).

$$Gp = (no\ of\ total\ germinated\ seeds\ ) / (total\ number\ of\ sources\ tested \times 100 \qquad (2)$$

$$GR = \frac{Number\ of\ germinated\ seeds}{Day\ of\ first\ count} + - + \frac{Number\ of\ germinated\ seeds}{Day\ of\ final\ count} \qquad (3)$$

After separating the shoots from the roots, the fresh weights were calculated, and the dry weights were measured immediately after being baked for 24 hours at 60 °C. The following formulas were used for every salt conduct to determine the regulated new in addition to dry weights in percent.

$$FWPR\ \% = 100 \times [1 - (fresh\ weight_{salt\ stress}/ fresh\ weight_{contorl})] \qquad (4)$$

$$DWPR\ \% = 100 \times [1 - (dry\ weight_{salt\ stress}/ dry\ weight_{contorl})] \qquad (5)$$

Relative water content (RWC)

The fresh weight's extra water was estimated using the methods outlined below.

$$RWC\ (\%) = 100 \times [(FW - DW)/FW] \qquad (6)$$

Seed vigor (S.V.)

$$Strong\ seed\ index = \{germination\ percentage \times means\ of\ seedling\ length\ (Root + Shoot)/100 \qquad (7)$$

This index was calculated using the equation below:

Salt Tolerance Index (STI):

$$STI = 100 \times (Total\ DW_{salt\ stress}/Total\ DW_{control}) \quad (8)$$

It is measured using the ratio of the overall dehydrated mass beneath salt pressure, represented in the prescribed value (%).

3. Results and Discussions

Water stress's effects

Rice seed germination and seedling development are significantly impacted by the types and severity of drought stress (Table 1). In this experiment, as the water stress grew, the amount of germination decreased (Figure 2). All types' germination was entirely hindered at -10 and -15 bar levels. Compared to the other two types (Narendra 1 and Sabarmati), the Hybrid 312 variety was the most susceptible to drought stress since germination was entirely suppressed at all water stress levels (-5, -10, and -15 bar). Sabarmati, one of the three rice cultivars, performed better under water stress.

Effects on the proportion of germination

Here the testing, the germination percentage declined as the water pressure grew (Figure 2). Compared to the other two types (Narendra 1 and Sabarmati), the Hybrid 312 variety was the most susceptible to drought stress since germination was entirely suppressed at all water stress levels (-5, -10, and -15 bar). Sabarmati, one of the three rice cultivars, performed better when exposed to water pressure.

Although the degree of the response and the effect of the stress varies by variety, the current investigation has found that drought stress has a considerable detrimental impact on seed germination (Table 2). Drought stress impedes seed germination, plant growth, and plant development. Sabarmati, one of the kinds, had the highest seed germination rate (70.7%), while Hybrid 312 had the lowest rate (5%). Water stress decreased seed germination by 53.6%, from 68.8% to 4.4%.

Effects on germination rate

When the drought stress severity rose, the germination rate dropped. Under drought stress, the control had the highest germination rate, whereas the -15 bar level had the lowest. At the -5 bar level, Narendra 1 and Sabarmati (2.36) had a higher germination rate; however, when drought stress rose to the -15 bar level, the germination rate fell. Drought stress affected the Hybrid 312 variety's germination rate on all levels.

Effects on the Start and Finish of Germination

Different rice cultivars need various amounts of time to start and finish germination. All three kinds took at least six days to initiate at the control level and 12 days to complete. Yet, emergence time also increased as water stress rose. Under drought stress, Sabarmati demonstrated excellent start and completion, although Hybrid 312's seedling growth was hampered at -10 with a bar in Table 3.

Impact on the roots and the shoot's length

Water stress significantly impacted the height of the different rice kinds. The root and the shoot had the most significant drought stress and extensive length (Fig 3). In Narendra 1, the most extended nodes were discovered (4.22cm). In comparison to the Hybrid 312 variety (0.70 cm), which generated the shortest roots at all levels of drought, Sabarmati (0.79 cm) and Narendra 1 (1.49 cm) produced noticeably longer seeds (Figure 8).

Effects on the seedlings' fresh and dried weight

Dry shoot weight has a bad association with water stress. Shoot dry weight decreased for the Narendra 1 and Sabarmati varieties as water stress increased; however, the dry mass of all levels of water stress fully repressed the hybrid 223 variety, demonstrating this variety's sensitivity to water stress. Two germination traits especially at risk from drought stress are seed vigor index and seedling length. Drought pressure significantly reduced seedling length and weight in the current study.

Effects of salt stress

Effect on germination percentage

At all degrees of salt stress, Hybrid 223 had the highest germination rate compared to other cultivars Figure 5. All cultivars' germination percentages significantly decreased due to the rising levels of salt stress. The sensitivity between the types revealed a sizable variation in response to salt stress. The average effects of various salt concentrations on the rate and percentage of germination are compared (Table 4). The 20 ds/m salt stress level had the lowest germination rate (66.6%), while the control site had the most significant (100%). According to Hakim et al. (2010), higher salt concentrations decrease the medium's water potential, hindering seeds from absorbing water and preventing germination. This Hybrid 223 was the first to germinate at a saline level of 20 ds/m, followed by Sabarmati and Narendra 1, in addition to the negative impacts of particular ions. The variance in salinity tolerance across rice cultivars has been reported in these germination percentages. The osmotic salinity-induced effects are the main factor impeding seed germination.

Effect on germination rate

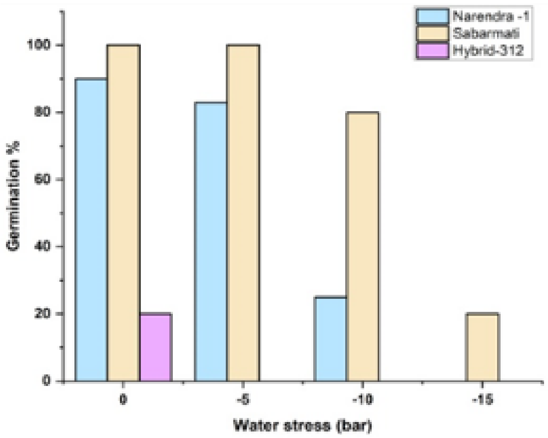
As the salinity stress rose, the rate of germination dropped. With a 4.4 germination rate in Narendra 1 and a 4.1 germination rate in Sabarmati, hybrid 223 outperformed the other two types. According to data, Hybrid 223 is supplementary elastic towards salt pressure.

Impact on the start and finish of germination

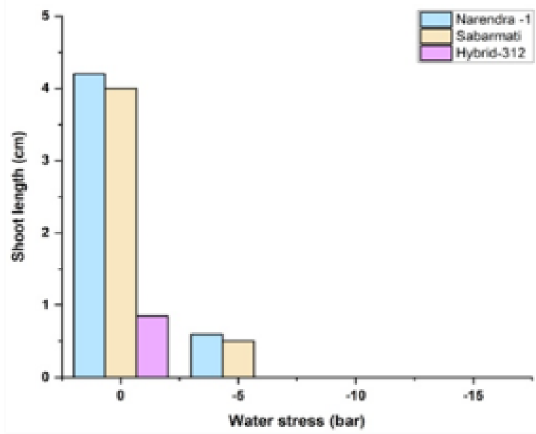
Under all stress circumstances, Hybrid 223 required 5 to 21 days, while Narendra 1 and Sabarmati required 7 to 21 days for emergence to start and end (Table 5).

Impact on the length of the root and shoot

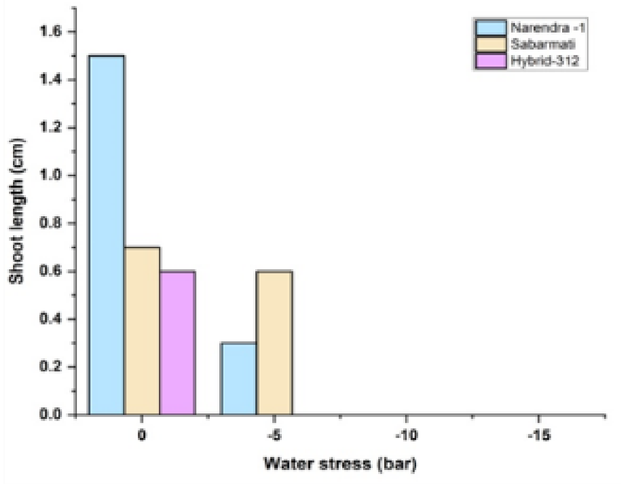
When saline stress rose, plant height decreased, and Sabarmati showed incredible sensitivity. At all salinity levels, the hybrid 312 (3.3cm) variety outperformed the other two types (Figure 6). Salinity stress rose like how the length of the roots decreased. At each salt concentration level, salinity significantly reduced root length more than shoot length. Longer roots were seen in the Narendra 1 variety (5.83cm) (Figure 7). Salt stress considerably impacted the sources' size and shot at a 0.05% probability level (Table 4). Many crop plants commonly exhibit shorter seedlings while growing in salty environments. A key predictor of how plants will respond to salt stress is the growth of the nodes and roots. As shown by the negative trend in the root and shoot length of seedlings cultured in salt solutions, salt stress impacted seedling growth and germination.



(a)



(b)



(c)

Figure 1: (a) Effect of water stress on germination % of three rice varieties, (b) Impact of water stress on three different rice cultivars' shoot lengths, and (c) Root length of three different rice cultivars as a result of water stress

Table 1: ANOVA for trait variance was used to compare the three rice types' responses to shortages stress

Parameter		Mean square					
	df	SL(cm)	GP (%)	RDW(g)	SDW(g)	RL(cm)	GR
Varieties(N-1,S,H-312)	2	9.227*	11969.44 *	0.163^{ns}	0.330^{ns}	0.456^{ns}	9.257*
Waterstresslevels	3	61.85*	8266.667 *	0.000^{ns}	0.063^{ns}	6.476*	14.423*

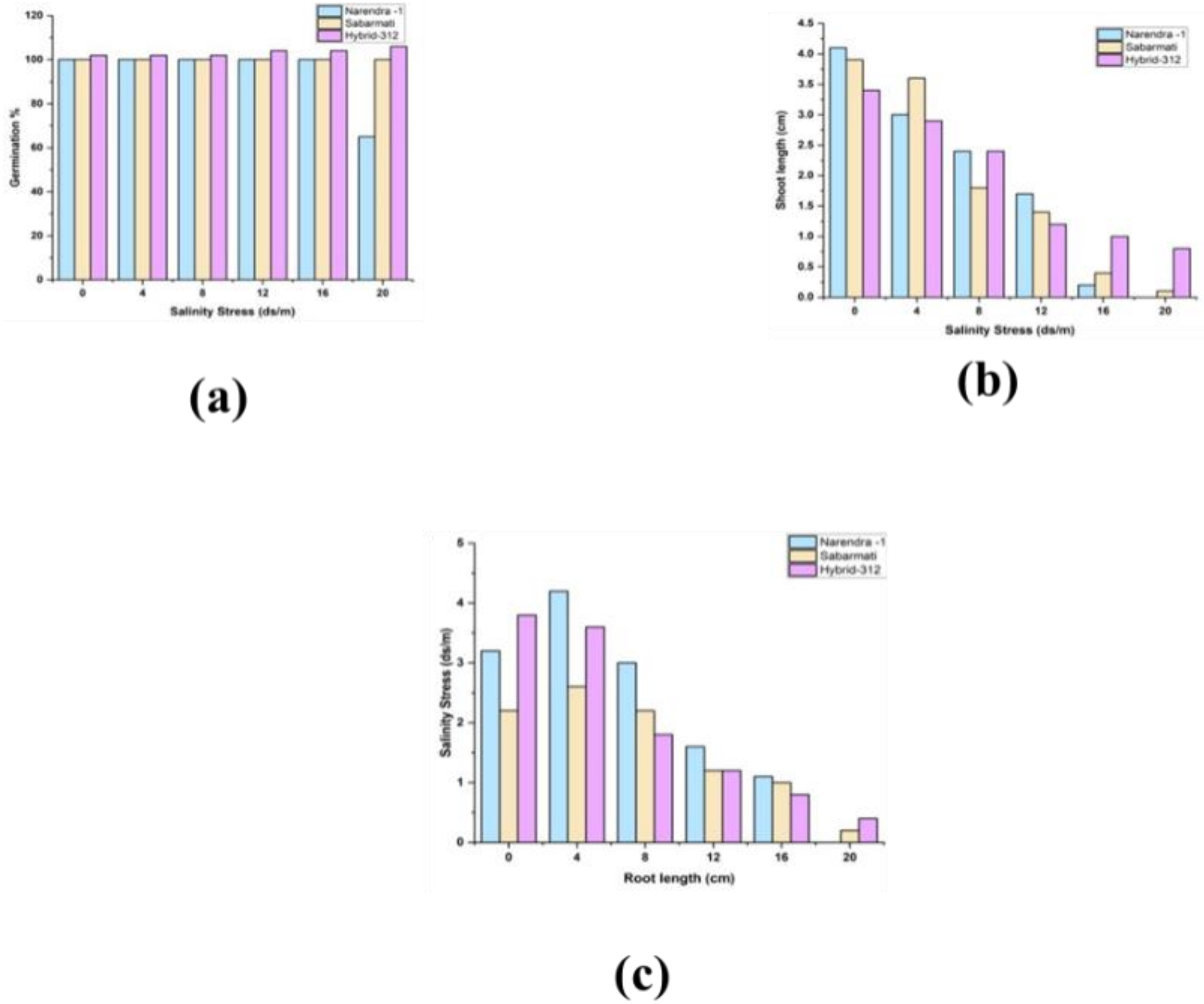


Figure 2: (a) The influence of salt stress on the germination rates of three types of rice (b) Impact of salt stress on three different rice types' shoot lengths (c) Root length of three different rice types as a result of salt stress

Table 2: Comparison of varieties, water stress levels, and interactions between these factors and the attributes under study

Variety	R .L. (cm)	G.P. (%)	TDW (g)	S.L. (cm)
Hybrid 312	0.175 ± 0	5.00 ± 00		0.20 ± 0
Sabarmati	0.337 ± 0.20	70.78 ± 19.72	0.011 ± 0 .009	1.12 ± 0.963
Narandra 1	0.447 ± .354	49.05 ± 22.17	0.020 ± .018	1.20 ± 1.015
Treatment(bar)				
–10		33.3 ± 22.67		
–5	0.28 ± 0.163	59.96 ± 30.22	0.003 ±0.001	0.36 ± 0.184
–15		4.44 ± 0		
0	0.99 ± 0.24	68.86 ± 24.10	0.038 ±0 .021	3.01 ± 1.09

Table 3: Water stress' effects on the start and finish of seed germination in three different varieties of rice (I = beginning in days, C = finishing in days)

Water stress levels (bar)	Varieties					
	Sabarmati		Hybrid 312		Narendra 1	
	I	C	I	I	I	C
0	6	12	8	8	6	12
-5	6	12	10	10	6	14
-10	6	14				
-15	10	18				

Table 4: The reactions of the three typesrice to salinity stress were compared using an ANOVA for trait variance

Salinity Levels (ds/m)	Varieties					
	Sabarmati		Narendra 1		Hybrid 312	
	I	C	I	C	I	C
0	4	6	4	10	4	6
4	4	6	4	10	4	6
8	4	8	4	12	4	6
12	4	8	6	10	4	6
16	6	10	6	12	4	8
20	6	14	6	12	4	10

Table 5: The impact of salt stress on the onset and progression of rice seed germination across three cultivars.

Parameters	df	Mean Square			
		G.P. (%)	RL(cm)	TDW(g)	SL(cm)
Salinity Stress Level (ds/m)	3	1352.223*	33.657*	0.002*	79.754*
Varieties (N 1, S, H 312)	2	272.23 ns	5.179 ns	0.017 ns	85.589*

Table 6: Impact of salt stress on various rice seed germination

Varieties/salt Stress Level	FWPR (%)	DWPR(%)	RWC(%)	SVI(%)	STI(%)
0 ds/m					
Narendra 1	00	00	87	7.16	
Sabarmati	00	00	87	6.01	
Hybrid 312	00	00	85	21.26	
4 ds/m					
Narendra 1	20	31	88	7.0	
Sabarmati	10	11	87	6.06	
Hybrid 321	4	14	86	19	
8 ds/m					
Narendra 1	45	64	91	5.21	
Sabarmati	67	58	86	3.73	
Hybrid 321	30	57	90	12.1	
12 ds/m					
Narendra 1	48	72	93	2.86	
Sabarmati	68	72	89	2.14	
Hybrid 321	69	98	99	6.5	
16 ds/m					
Narendra 1	50	91	97	1.24	
Sabarmati	70	95	95	1.2	
Hybrid 321	68		100	3.8	
20 ds/m					
Narendra 1	99				
Sabarmati	96			3.4	
Hybrid 321	78	98		2.9	

Table 7: Compares different salinity stress levels and how they affect the investigated attributes.

Varieties	SL (cm)	TDW (g)	GP (%)	SV	RL (cm)	RWC (%)
Narendra 1	1.84 ±.65	.019 ±.007	77.4 ±16.15	3.94 ± 1.25	2.10 ±0.64	76 ±15.28
Sabarmati	1.82 ±.64	.36 ± .329	97.77± 1.12	3.24 ±0.99	1.47 ±0.37	77± 11.55
Hybrid 312	1.84± .45	.018 ±.008	101	10.92±3.21	1.87 ±0.58	71 ±15.76
Treatment (dS/m)						
0	3.75 ±.24	0.044 ±0.002	100	11.48± 4.90	2.99 ±.48	86.34± .66
4	3.14 ±.29	0.036 ±.002	100	10.76 ±4.12	3.39 ±.49	77 ±10.60
8	2.07± .29	0.018 ±.001	100	7.02±2.57	2.24 ±.33	89 ±1.53
12	1.22± .22	0.008 ±.003	97.76 ±1.12	3.84± 1.34	1.22 ±.089	93.66± 3.90
16	0.51 ±.30	0.009			0.66 ±.67	
	86.66 ±11.18	2.08± .96			97.33 ±1.55	
20	0.27± .21	0.003	65.97 ±32.37	1.09 ±.91	0.25 ±.16	6.66± 6.76

The seed's capability for synthesis and the seedlings' ability to produce dry matter were affected. The amount of salt substantially impacts the length of the shoot and root.

Impact on the dry weight of the root and shoot

In particular, at higher salt concentrations, shoot dry weight is less sensitive than root dry weight and is inversely associated with salt stress. Narendra 1 and Sabarmati exhibited minor reductions in dry shoot weight (0.006g and 0.01g, respectively), whereas Hybrid 312 had the most extensive (0.31g) (0.01g). The shoot dry weight of Sabarmati was far less affected by the increasing salt concentrations. Shoots lost less fresh and dry weight percentage-wise than roots did throughout time. Reduced seedling development due to salt stress has been seen in a number of different species. Salinity's osmotic and specific ionic effects on seedlings.

Effect on relative water content

Salinity concentrations have a significant impact on relative water content. At 12 dS/m, the relative water content was at its highest. Sabarmati performs better when exposed to salinity pressure (Table 6).

Modification of the salt tolerance index (STI)

The salt tolerance index decreased as salt stress rose. In comparison, Narendra 1 (69%) and Hybrid 312 (56%), and Sabarmati (89%) had the highest STI rate. All varieties showed the lowest salt tolerance at 16 ds/m salinity stress (Table 6). Influence on seed vitality. The seed vigor index decreased as salt content rose. Strong seed vigor was evident in the hybrid 312 variety (21.6) (Table 6). When seedlings were subjected to salt stress, a drop from 9.5 to 9.9 was seen in the vigor index (Table 7). The sticky substance of seedlings affects several physiological activities, including growth. Also, it has been shown that salt restricts the absorption of vital minerals like P and K, which may harm seedling growth and vigor. According to Prisco and Vieira, water intake reduces during imbibitions and seedling development under stressful conditions (1976). Then, ion uptake while under salt stress might come next. As a result, seeds and seedlings' anabolic and catabolic organs undergo physiological and biochemical alterations.

4. Conclusion

As a result, rice types were much more vulnerable to drought than salinity stress. The current study's findings also imply that all rice varieties suffered unfavorable effects of increasing water/salt stress on germination and early plant development. All physiological indicators, including germination rate, fresh and dried shoot and root weight, and a lifespan of shoot and root varietal variations, showed the greatest difference at greater stress levels. Sabarmati outperformed Narendra 1 regarding germination in response to water stress, while Sabarmati outperformed Narendra 1 regarding seedling length and weight. Hybrid 312 had an improved response in salinity stress gradient.

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