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Identification of sodicity-tolerant banana varieties to harness the salt-affected ecosystem

A. Nithya Devi[1], K. Kumanan[2]*, K. Indhumathi[3], S. Sheeba Joyce Roseleen[4] & J. Auxcilia[5]

[1]Dr. M. S. Swaminathan Agrl. Coll. & Res. Inst., TNAU, Eachangkottai, Thanjavur, Tamil Nadu – 614 902, India
[2]Agricultural College & Research Institute, TNAU, Kudumiyanmalai, Pudukkottai, Tamil Nadu – 622 104, India
[3]ICAR - Krishi Vigyan Kendra, Papparapatti, Dharmapuri, Tamil Nadu – 636 809, India
[4]Horticultural College & Research Institute for Women, TNAU, Tiruchirappalli, Tamil Nadu – 620 027, India
[5]Horticultural College & Research Institute, TNAU, Coimbatore – 641 003, India

*Email: kumanan@tnau.ac.in

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Abstract

"Salt Affected Soils" (SAS) refers to a category of soils that contain either an excess of soluble salts or exchangeable sodium. Soils are divided into four categories: normal, saline, sodic and saline-sodic, based on the electrical conductivity (EC), pH and exchangeable sodium percentage (ESP) measurements. At the Horticultural College and Research Institute for Women in Tiruchirappalli, fifteen genotypes of bananas were assessed for growth, yield and physiological parameters in a saline-sodic environment. Four replications of the field experiment were set up in RBD and evaluated for three years. The growth physiological and biochemical characters were recorded in the seventh month after planting (MAP) and the bunch characters were recorded at harvest time. FHIA -1 (83.4%), Saba (81.0%) and Karpooravalli (78.0%) had the highest relative water content. The highest yield was recorded in FHIA -1 (23.5 kg), Saba (22.2 kg), Udhayam (22.5 kg) and Karpooravalli (22.0 kg). The sodicity injury symptoms in the leaves were evaluated using a scoring technique and the genotypes FHIA -1(1.0) and Saba recorded the lowest score for sodicity damage. A significant negative correlation was observed between salt injury degree and leaf K^+/Na^+ ratio. So, the varieties that maintain higher K^+/Na^+ ratio in leaf and root are salt tolerant. The general ranking of the banana varieties for salt tolerance was FHIA -1 > Saba > Karpooravalli > Bangrier > Ash Monthan > Veneetu Mannan > Udhayam. A comparative field trial for the 15 banana varieties showed that Saba, FHIA -1 and Karpooravalli could withstand sodic conditions in the field in terms of bunch characteristics, biochemical parameters and plant growth. Grand Naine, Rasthali and CO 1 were vulnerable to sodicity stress. Regardless of cultivar, sodicity stress increased the days needed for shooting and harvest.

Keywords

Banana; genotypes; salt affected ecosystem; sensitivity; sodicity; tolerance

Introduction

Worldwide, 1.1 billion hectares of land are impacted by rising salt levels. Sixty percent of such lands are covered by saline soils, twenty-six percent by sodic soils, and fourteen percent by saline-sodic soils (1). In India, almost 120 million hectares of land are degraded in one way or another. Specifically, soil acidity (17.94 M ha), soil erosion (94.9 M ha), salinity and sodicity (6.74 M ha) and other stresses (1.07 M ha) (2). Six states, *viz*., Gujarat, Uttar Pradesh, Maharashtra, West Bengal, Rajasthan and Tamil Nadu contribute 80% of the nation's salty and sodic soils out of all the areas affected by salt (3). The distribution of India's territory damaged by salt is shown in Fig. 1. High ESP (>15) weakens the structure, obstructs air and water flow, lowers the amount of water that can be absorbed and hinders root penetration in sodic soils.

Abiotic stresses are thought to be the primary cause of about 70% of crop plant yield loss globally. In recent years, significant obstacles to agricultural productivity have been seen, including decreased availability of irrigation water and issues brought on by increased salt concentrations in soil and water. Salt stress is one of the main abiotic stresses that impact a plant's physiology and biochemistry on practically all levels and lowers its yield (4). The physical, chemical and biological characteristics of sodic soils are gradually improved by growing several tree species in the sodic soil (5). Since agroforestry trees yield comparatively lower yields, efforts have been made to cultivate more lucrative fruit crops in sodic soils. India is the world's biggest producer, with a 25.7% share of worldwide banana output. An area of 8.84 lakh hectares is predicted to produce 30.80 million metric tonnes of bananas in India. Andhra Pradesh is the most productive state in India, producing 50.03 lakh tonnes on 0.88 lakh hectares of land. India's other major banana-producing states are Tamil Nadu, Kerala, Karnataka, Gujarat and Maharashtra (6).

Both abiotic and biotic stresses account for most of the bananas' production constraints. Abiotic stresses in bananas have not received as much study attention as biotic stresses. Although the productivity of these salt-affected soils is poor, they have much promise for agricultural production with proper management. Plant tissues are under many stressors due to salinity. Salt stress involves cellular and metabolic mechanisms comparable to those in plants impacted by drought (7, 8). Excessively significant sodium (Na) levels in their cation exchange capacity are characteristic of sodic soils.

Compared to saline soils, sodic soils typically have poor physical and chemical qualities that cause soil instability, which can significantly affect plant growth (9). The banana plants could have marginal chlorosis and necrosis of older leaves, reduced root multiplication and a roughly thirty percent decrease in yield as a result of the salinity and sodicity of the soil. Applying 0.5 kg of gypsum plus 15 kg of FYM and 100% of the necessary potassium per plant will resolve this issue. The land's drainage system needs to be modified to minimize the excess salt and sodium in the water (10). As bananas are susceptible to salt stress, the yield declined by half in salt-stress conditions and the plant height decreased by around 75% (11, 12). Although sodicity impacts a broader range of environments than salinity, less is known about how bananas tolerate sodicity. This is because testing for sodicity tolerance in glasshouses or labs is challenging, necessitating the use of numerous accessions under carefully monitored field studies (13).

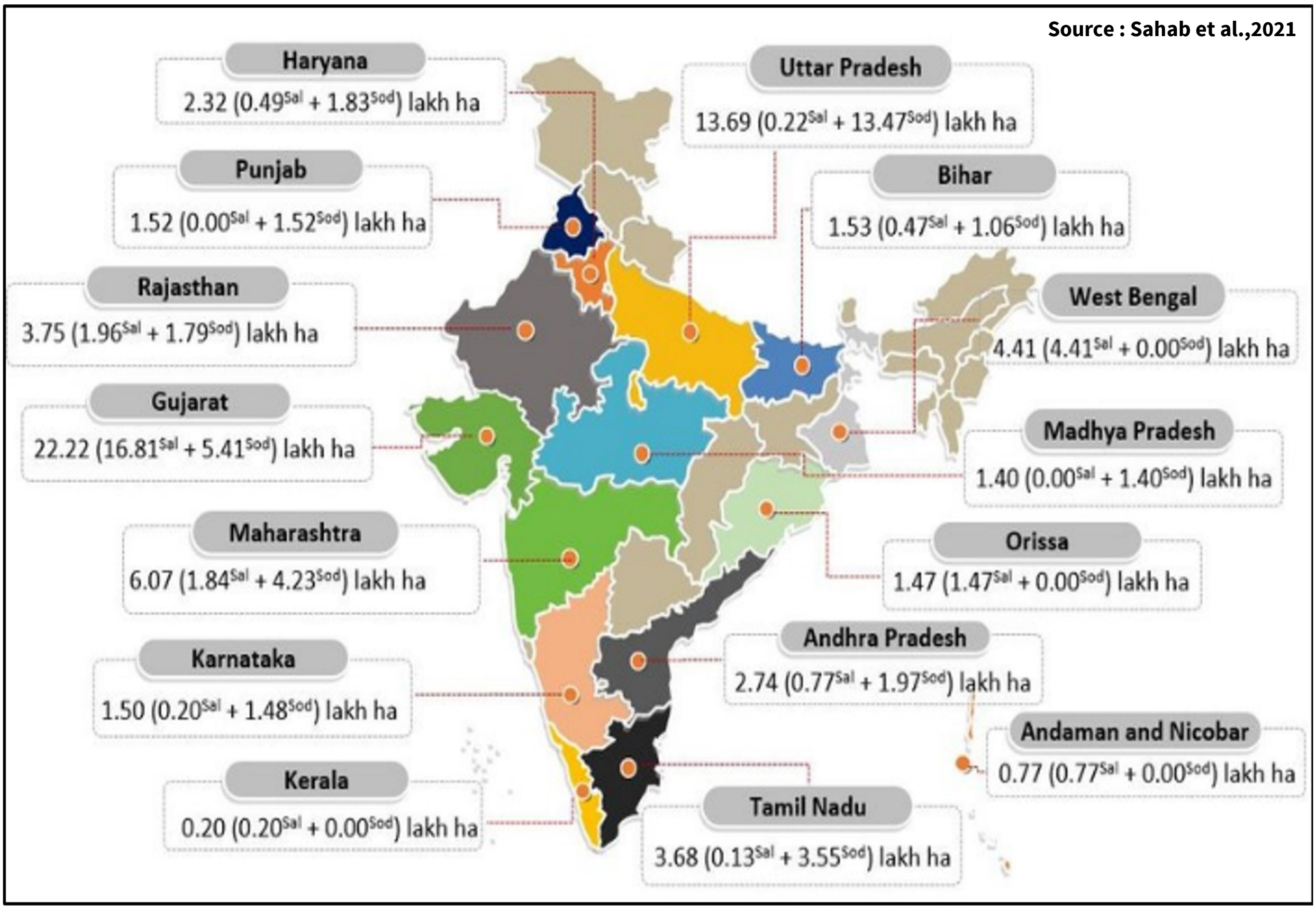

Fig. 1. Distribution of salt-affected land in India

Finding genotypes and cultivars that are tolerant to stress is essential to managing or overcoming salt stress, particularly in Tamil Nadu. Salt tolerance is a complicated trait that incorporates many genes and adaptive physiological and biochemical pathways (14). It's essential to determine possible sources of resistance before trying to breed stress resistance. Therefore, varietal screening is the primary technique for identifying tolerant genetic resources, which needs further manipulation. By increasing the effectiveness of empirical selection, applying physiological selection criteria can raise the likelihood of success (15). Given this context, this work aimed to screen and identify the genotypes of bananas that are sodicity tolerant based on growth, physiological and biochemical parameters and comprehend the overall effects of salt stress on the growth and development of banana accessions.

Materials and Methods

The main goal of the present investigation was to assess the sodicity tolerance of fifteen different banana varieties and to comprehend the physiological, biochemical and morphological mechanisms behind sodic stress tolerance under field conditions. At the Horticultural College and Research Institute for Women, Tiruchirappalli, fifteen genotypes of bananas were evaluated for growth, yield and physiological parameters under the prevalent saline-sodic conditions. For the screening experiments, healthy corms weighing 1.5 ± 0.1 kg belonging to the fifteen banana varieties listed below were utilized. The genotypes were collected from the in-situ field gene bank maintained at ICAR - National Research Centre for Banana, Tiruchirappalli. Disease-free healthy corms from fifteen varieties were collected from the healthy mother plants. One diploid and fourteen triploids are among the fifteen varieties. The varieties were selected to represent either *Musa acuminata* genome (A) alone or the bispecific hybrid genomic attribute involving *Musa acuminata* and *Musa balbisiana* (A and B).

The field experiment was conducted in RBD with four replications and assessed for three years. The soil exhibits an ESP of 15%, an EC of 1.4 dSm-1 and a pH of 8.9. The irrigation water recorded an EC of 1.87 dSm-1, pH of 8.4 and RSC of 12%. Under field evaluation, growth, physiological and biochemical characters were recorded in the seventh month after planting (MAP) and bunch characters were recorded at harvest time in this study on screening for tolerance to sodic stress. The plant height or pseudostem height was measured at the 7th month after planting from the base of the plant to the axil of the youngest leaf and expressed in cm. The pseudostem girth was measured 15 cm above the ground level and expressed in centimetres.

Table 1. List of banana varieties used in the study

Sl.No.	Varieties	Genome
1	Ney Poovan	AA
2	Grand Naine	AAA
3	Karpooravalli	ABB
4	Poovan	AAB
5	Rasthali	AAB
6	FHIA 1	AAAA
7	Nendran	AAB
8	Monthan	ABB
9	Robusta	AAA
10	CO 1	AAB
11	Saba	ABB
12	Ash Monthan	ABB
13	Udhayam	ABB
14	Bangrier	ABB
15	Veneetu Mannan	ABB

The total leaf area was calculated using a non-destructive method (16) by multiplying the length and breadth of the third leaf with the factor 0.8 and the number of leaves expressed as m^2. Quantification of leaf relative water content (RWC%) in the plant samples was measured according to the method suggested by Barrs and Weatherley and presented as percentage (17). The leaves were collected from the plants and fresh weight (FW) was measured immediately after sampling. Then, the leaves were immersed in distilled water for 8 h at room temperature (25 ± 2 °C). The leaves were then blotted to dry, and the leaf turgid weight (TW) was taken before drying in an oven at 75 °C for 72 h. After the incubation period, the leaf dry weight (DW) was noted. The leaf RWC was calculated using the following formula:

$$\text{RWC (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

The plant samples' potassium (K^+) and sodium (Na^+) contents were examined. Each plant sample's total sodium and potassium contents were estimated for each genotype, and the K^+/Na^+ ratio was computed by dividing the potassium values by the sodium values. Using a Flame photometer, sodium and potassium were assessed (18). Flame photometry estimated sodium and potassium content (%) in leaf samples to be in the ionic state. For determination of Na^+ and K^+ content in plant samples, 1g of the plant samples were first digested in 15 ml of tri-acid mixture (HNO_3:H_2SO_4: $HClO_4$ in 9:2:1 ratio), then made up the volume to 100ml. The flame photometer was calibrated by feeding the K^+ standards. Introduce the triple acid extract in the flame photometer, get the concentration of K^+ at 768 nm red filter and express it in percentage. For estimation of Na^+ content, 1 g of leaf sample was digested using an acid mixture consisting of nitric acid, perchloric acid and sulphuric acid at the ratio of 8:1:1. The extract was fed to a flame photometer after adjusting the flame photometer to read zero with distilled water. The calibration was done with Na^+ standards, and the extract was measured at 589 nm and expressed as Na^+ percentage.

To evaluate the foliar symptoms caused by salt-affected soils, plants exhibiting no symptoms were scored as 1 and those with the most significant amount of foliar damage were scored as 5, as indicated below (a minor modification of 19, 20). By visually assessing the genotypes and allocating a damage score based on the degree of damage inflicted by the salt-affected soil, five categories were identified to evaluate the impact of salt-affected soils on the health of the plants, as detailed below.

Scale	Extent of damage	Score
Scale 1	No visible damage to leaves	1
Scale 2	Slight damage to leaves - 25% of marginal scorching of leaves	2
Scale 3	Moderate damage to leaves - 50% of scorching and yellowing of leaves	3
Scale 4	High damage to leaves - 75% of scorching, yellowing and drying of leaves	4
Scale 5	Severe damage to leaves; almost all leaves were dying - 100% of drying of leaves	5

The data recorded were subjected to statistical scrutiny by analysis of variance (ANOVA) using the AGRES statistical software (AGRES, 1994). Conclusions were drawn from the results obtained from the package.

Results and Discussion

Conditions of water scarcity and saline soil or salt stress frequently restrict the production of bananas in India. Several factors can negatively impact crop performance, including reduced water availability, increased respiration rate, altered mineral distribution, membrane instability and failure to maintain turgor pressure. However, salinity effects can be somewhat mitigated by using soil amendments, cultivating tolerant crops or varieties and using better irrigation techniques like drip irrigation. Plants respond and adapt to salt at the molecular, cellular, physiological and biochemical levels, making salt tolerance a complicated characteristic (12). Identifying banana genotypes resistant or tolerant to salt stress will benefit the growers to a great extent. Understanding the extent of the impact of these stresses on the crop growth of bananas and identifying possible sources of tolerance to these stresses are, therefore, of great importance in the above context.

Effect of sodicity on plant growth parameters

The results of the field trials showed that at the 7th MAP, the cultivar Saba recorded the highest pseudostem height of 305.2 cm, followed by Ash Monthan (300.4 cm), whereas the lowest height was observed in Grand Naine (178.0 cm). Saba and FHIA 1 recorded the highest pseudostem girth of 76.4 and 74.0 cm, respectively, while CO 1 registered the lowest stem girth of 50.6 cm. The pseudostem girth and height measurements in bananas are directly correlated with growth. In the current investigation, pseudostem height and girth assessments indicated reductions in sodic environments, regardless of the genetic makeup of the screened cultivars. Reduced plastic extensibility of the developing cell walls in the root and leaf expansion zones has frequently been linked to salt-induced growth decreases (21). The accumulation of salt in the older leaves hastened their death, and their removal has reduced the amount of carbohydrates or growth hormones available to meristematic regions, thereby inhibiting growth (22). The same reduction trend was observed in salt-stressed maize plants (23).

The banana cultivars Udhayam, Saba and Poovan recorded a higher number of leaves of 13.5, 13.25 and 12.8, whereas the lesser number was recorded in CO 1 (9.0). Leaf area ranged from 5.1 m^2 $plant^{-1}$ in CO 1 and Grande Naine to 13.3 in cultivar FHIA 1. The leaf area (m^2) in different varieties was high (10 m^2) in the varieties in the order of FHIA 1 > Saba > Karpooravalli > Monthan > Nendran > Bangrier. Varieties like FHIA 1, Saba, Karpooravalli, Ash Monthan and Bangrier recorded low leaf Na^+ and high K^+ content while comparing the relationship between leaf number, leaf area, leaf Na^+ and K^+ content, and salt injury symptoms. The remaining varieties, Grand Naine, Robusta, CO 1 and Nendran, showed lower total leaf areas ranging from 5.10 to 7.10 m^2 and higher leaf Na^+ concentrations of more than 0.50 percent. This indicates that the concentration of Na^+ in banana leaves is diluted by leaf elongation (24). Compared to the varieties with fewer leaves, those with more leaves and greater leaf area showed fewer signs of salt damage. Thus, the cultivars exhibiting greater leaf surface area, increased leaf K^+/Na^+ ratio and less salt injury under sodic soil may be considered tolerant.

Effect of sodicity on yield attributes of banana varieties

The impact of sodicity on the total crop duration of the different varieties revealed significant differences (Table 2). Crop duration is the critical trait affected by sodicity that is invariable with the genotypes. Crop duration extended in sodic soil conditions. Among the fifteen varieties evaluated, the total crop duration ranged from 435.5 days in Veneetu Mannan to 510 days in CO 1. The data on bunch yield showed that bunch weight varied significantly among the varieties in the sodic conditions. Among the varieties harvested, FHIA 1 registered the highest bunch weight of 23.5 kg $bunch^{-1}$, followed by Udhayam (22.5 kg $bunch^{-1}$), Saba (22.2 kg $bunch^{-1}$) and Karpooravalli (22.0 kg $bunch^{-1}$). The least bunch weight was recorded by CO 1 (8.5 kg $bunch^{-1}$).

AAA cultivars showed abnormally delayed shooting, suggesting they cannot withstand the saline levels in the experimental field. Choosing cultivars that complete their reproductive stage quickly is essential, particularly under stressful conditions. Veneetu Mannan, Karpooravalli, Saba and FHIA 1 show promise since they showed early shooting and required fewer days to reach maturity and bunch filling. Based on their duration, Udhayam and Bangrier were also rated as tolerant. Though crop duration varies with variety and genomic status, the extension of crop duration due to the influence of salt under sodic soil cannot be eliminated. The extent of delay in shooting, fruiting and harvest varies with its tolerance to sodicity. It may be possible that maintenance of a sufficient number of leaves, higher leaf area and better physiological attributes such as high relative water content and higher K^+/Na^+ ratio in these varieties have led to shooting and harvesting even under sodic conditions. These findings concur with the recognized genetic variation for salt tolerance in numerous crop species (25, 26). The salt stress impacts the development and viability of reproductive organs in annual plants (27). Salt stress reduces the number of florets per ear and alters the flowering time and thus, delays maturity in cereals.

Table 2. Effect of sodicity stress on biometrical and yield traits of banana genotypes under sodic soil condition

S.No	Varieties	Pseudostem height (cm)	Pseudostem girth (cm)	Number of leaves	Leaf area (m^2 $plant^{-1}$)	Crop duration (days)	Bunch weight (kg)
1	Ney Poovan	279.3	66.2	12.2	8.4	490.2	7.5
2	Grand Naine	178.0	52.0	9.7	5.1	482.0	13.2
3	Karpooravalli	288.0	70.8	12.0	11.8	440.6	22.0
4	Poovan	228.2	65.1	12.7	6.9	480.0	14.5
5	Rasthali	179.5	68.4	10.2	7.16	490.2	12.5
6	FHIA 1	230.5	74.0	10.7	13.3	445.0	23.5
7	Nendran	220.0	60.0	10.5	11.0	490.0	9.5
8	Monthan	280.5	58.0	9.7	11.5	483.0	15.5
9	Robusta	180.0	52.2	10.5	7.1	495.0	11.0
10	CO 1	180.8	50.6	9.0	5.05	510.8	8.5
11	Saba	305.2	76.4	13.2	12.3	445.0	22.2
12	Ash Monthan	300.4	72.8	13.5	9.4	490.0	18.0
13	Udhayam	290.8	68.3	11.2	9.8	450.5	22.5
14	Bangrier	270.5	66.0	10.2	9.3	460.0	18.0
15	Veneetu Mannan	230.2	70.5	12.5	10.6	435.5	12.4
	Mean	242.79	64.75	11.19	9.24	465.87	15.39
	S. Ed	6.48	0.86	0.38	0.28	7.841	0.15
	CD (P=0.05)	3.21	1.73	0.77	0.57	16.26	0.31
	SD	46.27	8.06	1.35	2.48	23.11	5.21

Effect of sodicity on root and leaf K^+/Na^+ content and RWC in banana genotypes

In the present investigation, it is inferred that the varieties like FHIA 1, Saba, Karpooravalli, Monthan, and Bangrier absorbed less Na, Udhayam, Poovan, Ney Poovan, and Veneetu Mannan absorbed moderate Na^+. Grand Naine, CO 1, Robusta, Rasthali, Nendran and Monthan absorbed more Na^+ (Fig. 2). In the present study, the highest leaf K^+/Na^+ ratio of more than six was seen in the order of FHIA 1 > Saba > Karpooravalli > Bangrier > Ash Monthan > Veneetu Mannan > Udhayam. A significant negative correlation was observed between salt injury degree and leaf K^+/Na^+. So, the leaf and root varieties that maintain a higher K^+/Na^+ ratio may be salt tolerant. Based on the above-discussed results, the general ranking of the banana varieties for salt tolerance was FHIA 1 > Saba > Karpooravalli > Bangrier > Ash Monthan > Veneetu Mannan > Udhayam. Many salt-tolerant plants exhibit a more excellent K^+/Na^+ ratio than susceptible plants and a higher K^+/Na^+ ratio is considered a significant salt tolerance adaptation (28-30).

Excess salinity lowers the growth rate, postpones flowering, raises the Na^+ content in roots with a considerable reduction in K^+ uptake (31) and lowers crop production (9). K^+/Na^+ ratios are found to be less than one in the majority of crops grown on saline, sodic soils; nevertheless, K^+/Na^+ ratios of greater than one are crucial for bananas. According to Heiman's thief-watchman hypothesis of antagonism, the tolerant crop plants grown in saline-sodic soils typically absorb more K^+ to compensate for the highly concentrated Na^+ in the soil.

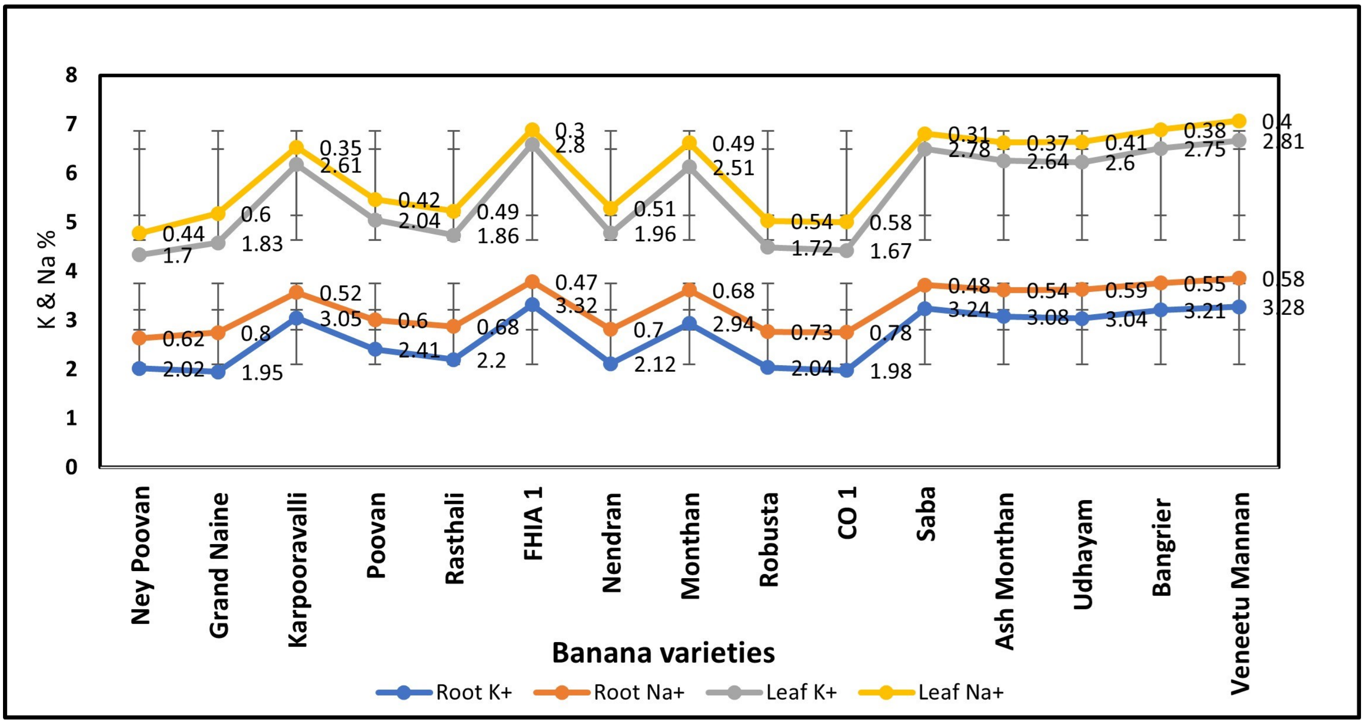

Fig. 2. Effect of sodicity stress on K^+ & Na^+ content of banana varieties under sodic soil

Table 3. Effect of Sodicity Stress on physiological traits of banana genotypes under sodic soil condition

S.No	Varieties	Relative Water Content (%)	Sodicity damage score	Root (%)			Leaf (%)		
				K^+	Na^+	K^+/Na^+	K^+	Na^+	K^+/Na^+
1	Ney Poovan	72.5	4	2.02	0.62	3.26	1.70	0.44	3.88
2	Grand Naine	70.2	5	1.95	0.80	2.44	1.83	0.60	3.05
3	Karpooravalli	78.0	2	3.05	0.52	5.87	2.61	0.35	7.50
4	Poovan	70.5	3	2.41	0.60	4.02	2.04	0.42	4.87
5	Rasthali	74.9	4	2.20	0.68	3.24	1.86	0.49	3.78
6	FHIA 1	83.4	1	3.32	0.47	7.06	2.80	0.30	9.33
7	Nendran	70.2	3	2.12	0.70	3.03	1.96	0.51	3.84
8	Monthan	72.0	3	2.94	0.68	4.32	2.51	0.49	5.11
9	Robusta	66.4	5	2.04	0.73	2.79	1.72	0.54	3.20
10	CO 1	62.5	5	1.98	0.78	2.54	1.67	0.58	2.86
11	Saba	81.0	1	3.24	0.48	6.75	2.78	0.31	8.90
12	Ash Monthan	75.2	3	3.08	0.54	5.70	2.64	0.37	7.20
13	Udhayam	72.0	3	3.04	0.59	5.15	2.60	0.41	6.33
14	Bangrier	73.2	3	3.21	0.55	5.84	2.75	0.38	7.33
15	Veneetu Mannan	69.8	3	3.28	0.58	5.66	2.81	0.40	6.99
	Mean	72.79	3.2	2.66	0.62	4.51	2.28	0.44	5.61
	S. Ed	0.97		0.16	0.07		0.14	0.06	
	CD (P=0.05)	1.95		0.32	0.14		0.28	0.12	
	SD	5.12		0.54	0.10		0.45	0.09	

The K^+/Na^+ ratio in plants and soil is crucial for mitigating the negative impacts of sodicity and salinity. The critical K^+/Na^+ ratios in the soil and banana crops grown in saline-sodic soils were determined to be 1.46 and 5.7 (32). Plant tolerance to salt-related stresses largely depends on the leaf and shoot Na^+ exclusion (33, 8, 34-36). Sensitive crop plants that experience excessive Na^+ absorption and buildup in their tissues experience osmotic and metabolic discomfort. These stresses reduce plant growth, development and productivity (8, 37).

With a Relative Water Content of 83.4 percent, FHIA 1 recorded a higher value, followed by Saba (81.0 percent). The CO 1 and Robusta varieties documented the lowest relative water content of 62.5 and 66.4 percent, respectively (Fig. 3.). Salt-tolerant cultivars may be chosen based on their capacity to sustain a high relative water content throughout the early stages of salt stress (38). Reduced leaf water potential from salinity stress and a drop in relative leaf water content cause turgor loss, which closes stomata and restricts photosynthetic absorption (20). A declining trend in the RWC in salt-stressed rice

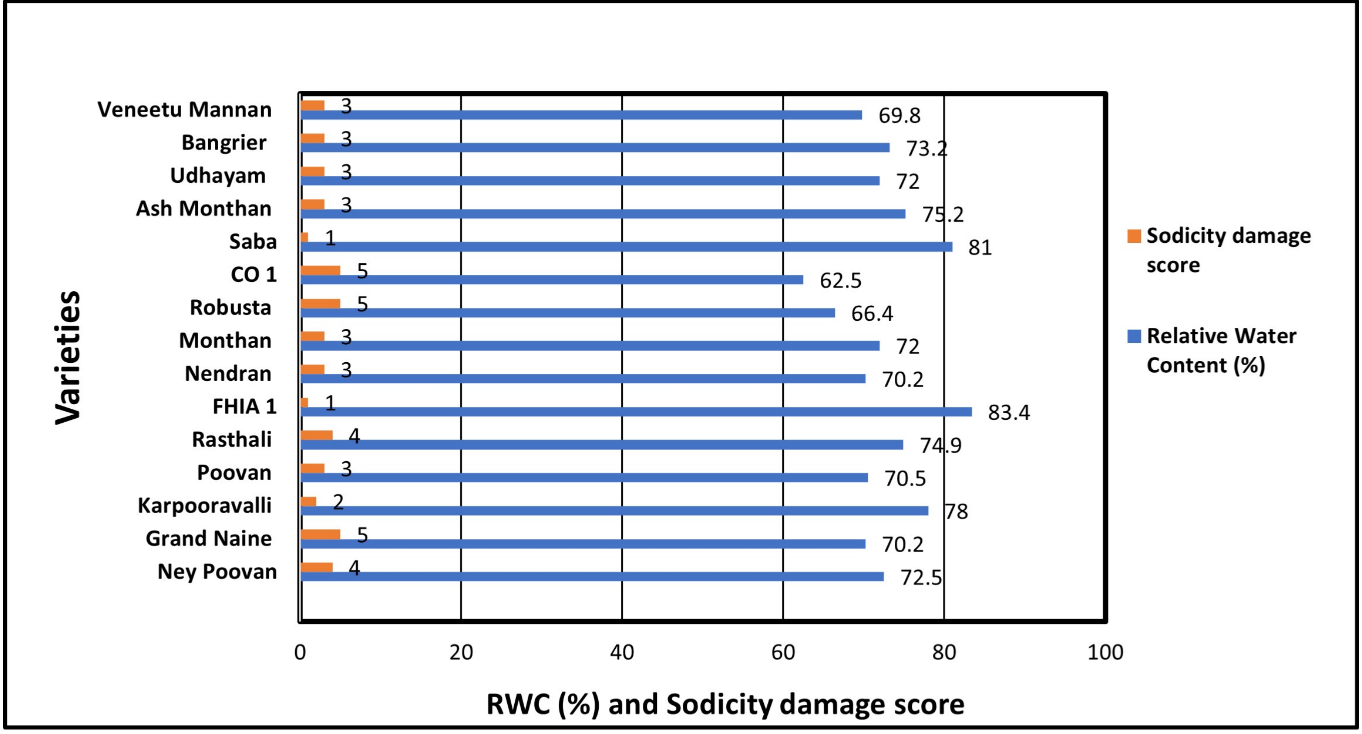

Fig. 3. Effect of sodicity on the RWC (%) and sodicity damage score of banana varieties

seedlings salt was noted (39). The saline stress significantly reduced the amount of chlorophyll and relative water content in maize plants (23).

Effect of sodicity on the salt-induced injury in the banana varieties

The present study on screening banana genotypes clarifies that there are notable varietal differences in sodicity tolerance. The sodicity stress causes leaves to turn yellow, burn, and dry out. This harms plant growth and yield characteristics. Salt injury, which results in external symptoms of marginal chlorosis of leaves and a considerable reduction in production, affects bananas in saline-sodic soils. Since these are comparable values based on plant vigour, chlorosis, necrosis and overall physical health conditions, there is no unit for leaf damage scores. Saba, FHIA 1 and Karpooravalli showed less salt damage in each category than the other cultivars (Fig 3). The cultivars that can maintain a sufficiently high degree of turgidity while retaining a deficient concentration of Na^+ in their roots could be classified as salt-tolerant (40). The anatomical and tissue-based mechanisms might be involved in Na^+ exclusion (41). Even though Ash Monthan and Bangrier excluded Na^+ more at the root level, the leaves showed significant salt injury at score 3. This might be due to the leaves having more compartmentation of Na. The cultivars FHIA 1, Saba (1.0) and Karpooravalli (2.0) showed the least amount of damage, whereas Robusta, Grand Naine and CO 1 (5.0) showed the maximum damage.

Fig. 4. Effect of sodicity on banana varieties under field condition

The ionic stress causes toxicity symptoms like chlorosis, necrosis in mature leaves and premature senescence in older leaves (42). The study's outcome has conclusively demonstrated that breeding can reliably characterize and easily alter the trait in the potential genotypes. Therefore, adjusting the Na^+ concentration in the leaves will enhance the bananas' ability to withstand sodicity in the soil and maximize their utilization of K^+ while preserving agronomic performance, especially in situations with high yields. The adaptive importance of the abovementioned characteristics should be confirmed by putting the tolerant genotypes to the test in soil conditions with increased sodicity levels. Due to the presence of the B genome, varieties with an AAB or ABB genome constitution are said to be more resistant and drought-tolerant (43). While the "B" genome contributes to stress resistance, the present study's diverse response of varieties with the "B" genome suggests that potential genotypes among AAB/ ABB accessions may be selected to enhance salt stress resistance through breeding.

Conclusion

The banana varieties FHIA 1,Saba and Karpooravalli were found to be field tolerant under sodic conditions concerning plant growth, biochemical parameters and bunch features, according to a comparative performance evaluation of the 15 banana varieties in field trials under sodic soil. Grand Naine, Rasthali and CO 1 were identified as cultivars sensitive to sodicity stress. The number of days required for shooting and harvest was prolonged by sodicity stress invariable of the cultivars. This study makes it evident that several variables, including the leaf area, the K^+ and Na^+ concentration in the root and leaf, the K^+/Na^+ ratio, the salt injury symptoms in the leaves and most importantly, yield attributes of banana, should be considered when evaluating the tolerance capacity of the varieties.

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Authors' contributions

AND and KK executed the conceptualization, methodology and supervision. AND, KK, KI and JA conducted the formal analysis and investigation. AND, KI and SJR finalized the preliminary manuscript preparation. KK, KI and SJR performed the last round of editing and review. All authors reviewed and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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