International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 375-386, 2022; Article no.IJPSS.95216
ISSN: 2320-7035

Screening of Rice Genotypes against Sodicity in Relation to Physiological and Biological Traits

Ajay Kumar Upadhay [a*] and Vipin Kumar [a]

[a] Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar-848125, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242653

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/95216

Original Research Article

Received: 18/10/2022
Accepted: 26/12/2022
Published: 28/12/2022

ABSTRACT

The study aimed to screen the rice genotypes against sodicity in relation to physiological and biological traits to identify the tolerant and susceptible genotypes. The field experiment was carried out at the Research Farm of Dr. Rajendra prasad central agricultural university, Pusa, Samastipur, Bihar during *Kharif* season of 2019-2020. The experiment was based on randomized block design with 30 plots in each of 3 replications where each replication consists of 30 rice genotypes. A total of 30 rice genotypes were screened of which 25 are exotic and 5 are indigenous. The exotic genotypes are GPV 1, GPV 2, GPV 3, RMS 1, RMS 2, RMS 3, RMS 4, RMS 5, RMS 6, RMS 7, RMS 8, SRL 1, SRL 2, SRL 3, CNN 1, CNN 2, KRH 4, PVP 221, MTU 1010, VR 181, PS 344, MTP 1, Vardhan, Rasi, CSR 23 (Check) while Prabhat, R. Sweta, R. Bhagwati, R. Mahsuri and Rajshree are the indigenous ones. The physiological and biological traits were evaluated at tillering and pre-flowering stages and their inter-relationship among various physiological parameters are established. The genotypes such as SRL 1, GPV 1, GPV 2, GPV 3, and Rajendra Mahsuri show the highest chlorophyll content, SPAD value, peroxidase and catalase activity, proline content, RLWC

**Corresponding author: E-mail: ajpusasoil.339@gmail.com;*

content, and MSI percentage, and the lowest was found in Prabhat, Rasi, and Rajendra Bhagwati. Based on response with regard to SPAD value, RLWC, and MSI the genotypes such as SRL 1, GPV 1, GPV 2, GPV 3, and Rajendra Mahsuri show positive increase compared to CSR 23 (Check). The inter-relationship concerning to various physiological parameters shows a strong significant and positive correlation among each other at tillering and pre-flowering stages. However, Total chlorophyll at the tillering stage was found to bear a highly significant correlation with all the physiological parameters except relative water content and membrane stability index. The genotypes such as SRL 1, GPV 1, GPV 2, and GPV 3, Rajendra Mahsuri possess better potential in sodic soil than the rest of the genotypes taken in the experiment with regard to various physiological parameters (taken as salt indices) by counteracting or minimizing the sodicity effect of sodium ion. The greater synthesis of antioxidant enzymes like catalase and peroxidase plays an important role in plant adaptation which effectively support to withstand and perform well in sodicity conditions hence SRL 1, GPV 1, GPV 2, GPV 3, and Rajendra Mahsuri categorized as salt tolerant genotypes which have great potential to boost up the rice production in sodic soil condition while Prabhat, Rasi and Rajendra Bhagwati categorized as salt susceptible genotypes. Thus, this study will be helpful for the identification of tolerant and susceptible genotypes through screening and pave way for the development of stable and high-yielding genotypes for the improvement of rice production under sodic soil.

Keywords: Oryza sativa; rice genotypes; salt stress; antioxidant or enzyme; proline; chlorophyll; SPAD; RLWC; MSI.

1. INTRODUCTION

Globally, rice is one of the foremost and pre-dominant cereal crops after wheat. Over half of the world's population depends on rice as a staple food crop or one in every three persons depends on rice for more than half of their daily food requirement [1]. In Asian and African countries rice itself emerges as the principal agricultural commodity throughout the year where it is solely cultivated and consumes more than 90% of the world's rice [1]. The world population is rapidly mounting with every passing year and there will be a need to produce 87% more of what we are producing today, especially cereal crops like rice by 2050 (Kromdijk and Long, 2016). Since Asian countries largely depend on rice cultivation for their sustenance, livelihood, and as a source of income, therefore rice holds significant agricultural and economic importance. Therefore, it is also considered as the model of cereals [2].

In most of the countries, crops are mainly raised under field conditions or open environments which are often exposed to biotic as well as abiotic stress. Abiotic stresses like climatic catastrophes like fluctuation of temperature, rainfall, drought, flood, sodicity, salinity, acidity in tropics, temperate, arid, or semi-arid regions which influence plant metabolism directly or indirectly, thereby affecting plant growth development and finally their production. Among these abiotic stresses, soil sodicity is one of the most destructive ones, is a global problem in arid and semi-arid regions because of erratic rainfall which is insufficient to leach soluble salts from the soil, which threatens and limits the production of cereal crops, especially rice (Sagar and Patil, 2018). For this reason, millions of hectares of land are left uncultivated or generally are grown crops with very low yields [3].

All over the world, cultivable lands are decreasing because of urbanization, millions of hectares of land are affected by sodicity, and day by day area is expanding because of salt accumulation. Salt stress is a widespread problem, affecting around 831 Mha of land that include 397 and 434 Mha of saline and sodic soils, respectively (Teakle and Tyerman, 2010). It is undesirable that every year around 1.5 Mha of land are being taken out of production by excessive salt, and it has been predicted that every year around 1.5 Mha of lands are being taken out of production by excessive salt with half of the cultivable terrains will be lost due to salt by the middle of the 21st century [4]. In India, 6.73 Mha area is salt affected in which sodic soil comprising.77 Mha which is about 56% of the total salt-affected area [5] and holds the third position after the former Soviet Union and China in terms of salt-affected areas in Asian countries [6]. Soils having an excess of sodium ion on the exchangeable sites of clay complex and high concentrations of free carbonate and bicarbonate of sodium with electrical conductivity (EC) of saturation extracts < 4 dS m^{-1}, exchangeable sodium percentage (ESP) > 15 and having pH > 8.5 are regarded as sodic soil. Due to presence

of an excess of sodium ions near or in the rhizospheric region causes sodicity stress (a kind of salt stress) in such a way that it disrupts the natural growth and plant metabolism. Salt causes two major stresses, first an osmotic stress and later an ionic stress. The osmotic stress affects plants when the salts reach above a threshold level which depends on the species and its genotypes while the ionic stress starts when the salt accumulation reaches toxic levels in soil and older plant tissue. Extreme high salt stress kills the plant but moderate to low salt stress affects the plant growth and thereby one of the obvious manifestations could be associated with the physiological and biological attributes and absence or presence of nature and type of ion in the soil as well as its equilibrium and uptake by plants.

Crop genotypes or varieties and their lines do differ in their inherent capabilities to modify various physiological and biological processes in response to salt stress. Though numerous physiological and biological changes take place under an altered salt stress environment but only a few of them change very significantly and also contribute a lot to the salt tolerance mechanism. These significant changes *viz* multigenic response exhibited by plants towards salt stress, such as osmotic and ionic homeostasis, and cell or tissue detoxification with the stimulation of antioxidant defense mechanism [7,8]. The changes that occur in plants control the solute and water balance (Relative water content) and their distribution on a whole plant and tissue basis. Changes in enzymatic pattern, accumulation of non-toxic compatible organic solutes, increase in amino acids like proline, increase the level of Reactive Oxygen Species (ROS), increase in membrane stability index (MSI) as well as relative leaf water content (RLWC).

As one of the universal processes of plant physiology is strongly affected by salt is none other than it's a Photosynthesis which is controlled by various factors *viz*. salt concentration, genotypes or variety, growth stage, and environmental conditions. Due to the excess salt concentration, one of the obvious signs of the plant is the reduction of leaf area which is one of the first reactions of plants [9]. An initial and rapid response of the plants to the salt stress is the movement of soil water potential towards a more negative value which demote the normal plant water absorption and its movement. Stomatal closure may be due to low water potential, Na^+ within the plant system (root system and guard cells of the leaves, Moradi and Abdelbagi [10]). Reduction of leaf area leads to variation in chlorophyll content and Soil plant analysis development (SPAD) value signaling the physiological and biological manifestation under salt stress conditions. An obvious upsurge of polyphenol or enzymatic antioxidants in plant systems plays an imperative and vital physiological role in ion-induced oxidative damage to reduce the detrimental effect of salt which causes injury to the cell membrane and enhanced membrane leakage in salt-sensitive genotypes [11].

In sodium-saturated sodic soil, the elevated pH and supremacy of Na^+ ion restrict the evenly going activities, processes, and functions of soil and plant as excess sodium imparts adverse physical properties to soils leading to poor air-water-plant relationships by affecting the SPAC system viz. Soil- Plant- Atmosphere- Continuum (Acharya and Abrol, 1975); [12] Generally, rice crop shows variability in sensitivity towards excess sodicity at various developmental stages during their life cycle. It is considered relatively tolerant to salt stress at germination and early reproductive stage while pollination is the most sensitive stage towards salt stress which directly affects the plants [13,14].

Mass screening and physiological characterization of rice genotypes may help in improving resistance against salt stress as it was previously hypothesized that rice genotypes differ in their potential for salt resistance. However, current developments in the field of different aspects of soil science and molecular biology have opened up new and innovative possibilities in understanding the physiology of abiotic stresses (Bennet and Khush, 2003); [15]; (Ismail et al. 2007).

As all these traits are independently or weekly associated, none of the known salt tolerant genotypes combine more than a few of them favorably, hence pyramiding of these traits at both the stages (*i.e.* tillering and booting stages) is much needed for developing salt tolerant and salt susceptible genotypes [16,17].

As distribution and dispersion of salt-affected land are not uniform since it depends on various factors such as climate, the concentration of salts, the topography of the land, etc. Current challenges of global food security can only be met if destroyed productive land is made cultivable again, to identify tolerant or susceptible

genotypes, changes the growing environment, and make it suitable for the normal growth of the plant [18,19]. Worldwide research is going on to combat and overcome the sodicity problem with different approaches like genetic engineering, crop breeding, soil amelioration process, screening procedure, etc. The success of any screening program depends on understanding the interrelationship of physiological and biological attributes at different growth stages of the crop. Hence, the present study was undertaken to screen the rice genotypes against sodicity with respect to physiological and biological traits.

2. MATERIALS AND METHODS

The study was conducted at Research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar in *Kharif* season of 2019-2020. A total of 30 rice genotypes were taken with 5 indigenous and 25 exotica for this region. CSR 23 was used as a check genotype to assess the positive and negative response of sodicity tolerance with respect to different physiological and biological traits. This research was carried out with 3 replications and a total of 90 plots (each replication contains 30 plots with 30 genotypes) based on the randomized block design (RBD) in an open environment or field condition. The genotypic details of rice used in this experiment are presented in Table 1. The Initial properties of the soil were analyzed in the laboratory to know the chemical status and sodium concentration in the soil which is shown in Table 2. After 25 days of old seedlings 30 genotypes were transplanted in the main field having pH- 9.61 at a spacing of 20 x 15 cm (P-P & R-R) with the individual plot of 10 m^2. Plant samples (Third Leaf from apex) were collected at tillering and pre-flowering stages to know about the physiological attributes such as SPAD value, chlorophyll content, catalase & peroxidase (antioxidant/ enzyme), proline (amino acid), relative water content (RWC), membrane stability index (MSI) and its relationship among them.

3. PHYSIOLOGICAL AND BIOLOGICAL ATTRIBUTES

3.1 SPAD Value

A handheld device was used to know the Soil Plant Analysis Development value, which ranges from 0.0 to 50.0 known as SPAD – 502 meter based on light-emitting diodes and a photo receptor (silicon made) that measures transmittance from the leaf in the wavelength of the red region (650 nm) and infrared (940 nm) regions of the electromagnetic spectrum.

Table 1. Details of 30 rice genotypes

Sl. no.	Genotypes	Sl. no.	Genotypes
1	GPV 1	16	RMS 3
2	GPV 2	17	R. BHAGWATI
3	GPV 3	18	MTU 1010
4	SRL 3	19	CNN 1
5	RMS 4	20	CNN 2
6	PRABHAT	21	VR 181
7	RMS 5	22	RMS 2
8	VARDHAN	23	RAJSHREE
9	KRH 4	24	SRL 1
10	RASI	25	RMS 1
11	SWETA	26	PS 344
12	RMS 6	27	MTP 1
13	RMS 7	28	SRL 2
14	RMS 8	29	R. MAHSURI
15	PVP 221	30	CSR 23

(Indigenous genotypes: Prabhat, Sweta, Rajendra Bhagwati, Rajshree, Rajendra Mahsuri, and the rest of the above 25 genotypes are exotic for the Samastipur region of Bihar.)

Table 2. Initial soil properties of the experimental field

Sl. No.	Property	Value
1	Soil pH	9.61
2	EC (dS m^{-1})	0.42
3	Organic carbon (g Kg^{-1})	4.1
4	Available nitrogen (Kg ha^{-1})	209.5
5	Available phosphorus (Kg ha^{-1})	19.41
6	Available potassium (Kg ha^{-1})	102.14
7	Available sodium (meq l^{-1})	56.2

3.2 Chlorophyll Content

The procedure described by Anderson and Bordman [20] was used to estimate the chlorophyll content quantitatively. The chlorophyll content ('a', 'b', and total) were estimated in flag leaf at both stages and expressed as µg ml^{-1} on a fresh weight basis.

3.3 Assay of Enzyme

Catalase

The activity of catalase was determined by the method described by Euler and Josephson (1927) in the flag leaf of rice and expressed as unit mg^{-1} protein of flag leaf on a fresh weight basis.

Peroxidase

The method described by Palmiano and Juliano [21] was used to determine the assay of peroxidase activity in the flag leaf of rice and expressed as unit mg^{-1} protein of flag leaf on a fresh weight basis.

3.4 Proline content

The amino acid proline content was estimated in a fully expanded leaf at the flowering stage following the method of Bates et al. [22] and expressed as mg^{-1} fresh weight of flag leaf.

3.5 Membrane Stability Index (MSI)

The procedure explained by Premchandra et al. (1990), modified by Sairam [23] was used to determine the Membrane stability index and expressed it as a percentage.

3.6 Relative Water Content (RWC)

The procedure explained by Weatherly et al. (1950) was used to determine Relative water content and expressed it as a percentage.

3.7 Data Analysis

Statistically, Analysis of variance is used to analyze the recorded data for different physiological attributes during the itinerary of the research. The comparison of significance was tested and a 5% of probability of error difference of significant values was computed. Wherever the variance ratio was found significant, CD values were computed for comparison among genotypes (taken as treatment).

4. RESULTS AND DISCUSSION

In the present study, attempts were made with the main objective of finding the response of rice genotypes against sodicity in relation to physiological and biological traits. The variation in physiological attributes against sodicity for different rice genotypes at tillering and the pre-flowering stages would definitely help to find out the tolerance and susceptible nature.

4.1 SPAD Value and Chlorophyll Content

The results of the study show that SPAD values increased with the age of the crop from tillering to the pre-flowering stage are presented in Table 3. The SPAD values vary significantly among genotypes in which the highest value was observed in GPV 1 at the tillering stage and Rajendra Mahsuri at the pre-flowering stage. The minimum value was observed in Rasi at tillering stage and Prabhat at the pre-flowering stage. Based on percent, a positive increase to CSR 23 (check) was observed in Rajendra Mahsuri, GPV 1, GPV 2, GPV 3, CNN 2, SRL 1, KRH 4, and RMS 8 at both stages. While the results pertaining to chlorophyll are presented in Table 4 in which the chlorophyll content (chll.a, chll.b, and total content) significantly varies in both stages. Rajendra Mahsuri contains the highest chll.a at the tillering stage and GPV 1 contains the highest chll.a at pre-flowering stages. In case of chll.b, the highest content was observed in SRL 1 at the tillering stage and Rajendra Mahsuri has the highest at the pre-flowering stage. On critical analysis, the total chll. was observed highest in Rajendra Mahsuri followed by SRL 1, GPV 1, GPV 3, RMS 8, and GPV 2 while the lowest was observed in VR 181 genotypes at tillering stage. At pre-flowering stages, significantly higher total chll.a was observed in Rajendra Mahsuri followed by GPV 1, GPV 3, SRL 1, and RMS 8 were at par with each other while the lowest content was observed in Prabhat which is similar to Rasi. This might be due to high sodium accumulation in the shoots and low accumulation of calcium, magnesium, and potassium in the shoots. Salt stress decreases the amount of chlorophyll in the leaves by degrading or inhibiting the chlorophyll synthesis [24] with the increase in chlorophyllase enzyme activity (i.e. enzyme having the ability to degrade chlorophyll). Another reason might be because of oxidative stress under salt stress which decreases the number and size of chloroplasts and destroy it [25,26]. Hence, variation in the chlorophyll and SPAD value can be used as a stress indicator (Naumann et al.

2008). The result of the research was in accordance with the findings of Ashraf and Ali, 1998; Mandal and Singh, [27].

4.2 Enzyme Content

4.2.1 Peroxidase and catalase activity

The results on peroxidase and catalase as influenced by sodicity stress at tillering and pre-flowering stages are presented in Table 5. Among the genotypes, peroxidase activity differs significantly where Rajendra Mahsuri recorded maximum enzyme activity and was statistically significant over the rest of the genotypes but at par with GPV 1, SRL 1, GPV 2, and Rajshree. Similarly, catalase activity also varies significantly in which the highest activity was observed in Rajendra Mahsuri which was at par with GPV 1, GPV 2, SRL 1, SRL 3, GPV 3, and RMS 8. This might be due to the detrimental effect of salt like sodium and chloride which triggers the physiological systems of the plant to release the peroxidase enzyme (POD enzyme) in order to minimize the activity of free radical as well as reactive oxygen species (ROS). Peroxidase plays a key role in the metabolism of reactive oxygen species, and biosynthesis of plant cell walls by enhancing the terminal stage of the synthesis of lignin and suberin (Quiroga et al. 2000). While the increase in catalase activity under salt stress is also induced by salt to detoxify reactive oxygen species, especially, hydrogen peroxide (H_2O_2) through its breakdown into a water molecule. These results are in accordance with the findings of Caverzan et al. [28].

4.3 Proline Content

In this study, the maximum accumulation of proline was observed in Rajendra Mahsuri which was statistically significant over the rest of the genotypes but at par with GPV 1, GPV 2, SRL 1, and SRL 3. The lowest value was observed in Prabhat which is similar to Rajendra Bhagwati. The obtained data pertaining to proline are presented in Table 5. Under salt stress, it is generally believed that the accumulation of compatible solutes (proline, glycine, betaine, pinnitol, etc) are involved in cellular osmotic balance [29]. This might be due to the breakdown of the existing protein molecule into constituent amino acids with proline being dominant and the loss of turgor due to salt stress triggers proline accumulation in plants. Based on this study, it is said that the genotypes which contain higher proline in their cells or tissues, the plants will be more resistant to salt stress. This finding was consistent with Neo et al. 2004; Ghosh et al. 2011. There is an existence of a relationship between the degree of salt tolerance and proline concentration [30]. Proline is used as a stress indicator and will increase in the plants with the increase in salt concentrations (salinity or sodicity conditions) to adjust the osmotic potential of the cells in order to better acclimatization. Besides this, proline also acts as a source of carbon and nitrogen for stress recovery in later stages, sometimes as an energy sink to regulate redox potential and also help in the protection of protein against denaturation [31] (Fariduddin et al. 2013).

4.4 Relative Water Content

Among the genotypes, the percentage of relative leaf water content (RLWC) significantly varies at both tillering and pre-flowering stages are presented in Table 6. The highest relative water content (RLWC) was observed in GPV 2 and SRL 3 at tillering and pre-flowering stages while the lowest value was observed in Prabhat at tillering stages and Rasi at pre-flowering stages respectively. Based on the response, a positive increase was found highest in GPV 2 at tillering stages SRL 3 at pre-flowering stages w.r.t CSR 23 (check). This might be due to variation in the osmotic pressure of the cytoplasm as sodium ion within the leaf tissue is accompanied by the absorption and synthesis of osmolytes which ultimately enhance or reduce the water content in the leaf. These results were in accordance with the finding of Neo et al. 2018.

4.5 Membrane Stability Index

Among the genotypes, the percentage of membrane stability index (MSI) significantly varies at both tillering and pre-flowering stages are presented in Table 6. The highest MSI was observed in GPV 2 and the lowest one was Rasi at both tillering and pre-flowering stages. Based on the response, the highest positive increase was observed in GPV 2 w.r.t CSR 23 (check). This might be due to membrane damage and oxidative stress by lipid peroxidation because of the presence of excess salts. This finding was in accordance with the results of Kumar et al. [32].

5. INTER-RELATIONSHIP AMONG PHYSIOLOGICAL PARAMETERS OF RICE

The correlation coefficient among different physiological parameters of rice at tillering and pre-flowering stages are presented in Table 7. With regard to the interrelationship among salt

tolerance indices of physiological parameters, membrane stability index (Tillering and Pre-flowering stages) was found to bear highly and positive relationship with total chlorophyll (Tillering and Pre-flowering stages), peroxidase activity, catalase activity, proline content and relative water content (Tillering and Pre-flowering stages). Relative Water Content at pre-flowering stages was significantly correlated with total chlorophyll at the tillering stage (r =0.41*), total chlorophyll (pre-flowering stage) (r = 0.812*), peroxidase activity (r = 0.722**), catalase activity (r = 0.782**), proline content (r = 0.839**) and relative water content at tillering stage (r = 0.979**). A Similar pattern of significant relationship was observed with relative water content at the tillering stage while the correlation coefficient of proline content with total chlorophyll content at the tillering and pre-flowering stage, peroxidase, and catalase activity were 0.504**, 0.904**, 0.903** and 0.959**, respectively. The correlation coefficient between catalase and total chlorophyll at the tillering stage and pre-flowering stage (r = 0.527** and 0.988**) and catalase with peroxidase activity (r = 0.900**) were highly significant. Total chlorophyll at the tillering stage was found to bear a highly significant correlation with all physiological parameters except relatve water content and membrane stability index. These results are in corroboration with the findings of Chunthabure et al. (2016). Antioxidant enzymes like catalase and peroxidase play an important role in plant adaptation to stress condition [33]. In plants, chloroplast, mitochondria, and peroxisomes are responsible for the conversion of H_2O_2 to a water molecule [20].

Table 3. Effect of salt stress on SPAD value in 30 rice genotypes at tillering and pre-flowering stage

Genotypes	Tillering stage	Pre-flowering stage
GPV 1	43.1	40.4
GPV 2	42.2	38.5
GPV 3	42.4	40.2
SRL 3	41.7	38.0
RMS 4	39.1	37.1
PRABHAT	35.6	31.6
RMS 5	40.3	37.0
VARDHAN	40.1	32.9
KRH 4	41.4	38.3
RASI	35.3	32.1
R.SWETA	40.5	37.6
RMS 6	38.2	34.6
RMS 7	39.3	36.9
RMS 8	41.6	39.0
PVP 221	40.5	36.0
RMS 3	38.5	34.5
R.BHAGWATI	36.9	33.6
MTU 1010	39.5	37.3
CNN 1	39.5	34.1
CNN 2	41.8	39.9
VR 181	36.3	32.6
RMS 2	38.9	36.2
RAJSHREE	40.0	36.9
SRL1	42.5	39.2
RMS 1	39.4	34.0
PS 344	41.3	34.2
MTP 1	36.8	33.1
SRL 2	40.4	36.5
R. MAHSURI	42.5	40.5
CSR 23**(Check)**	40.7	37.7
Mean	**43.2**	**36.4**
SEm±	1.17	0.96
CD (P=0.05)	3.31	2.73
CV%	5.08	4.59

Table 4. Effect of salt stress on chlorophyll a, chlorophyll b and total chlorophyll (µg ml^{-1}) in 30 rice genotypes at tillering and pre-flowering stage

Genotypes	Tillering stage			Pre-flowering stage		
	Chl a (µg ml^{-1})	Chl b (µg ml^{-1})	Total (µg ml^{-1})	Chl a (µg ml^{-1})	Chl b (µg ml^{-1})	Total (µg ml^{-1})
GPV 1	3.03	2.43	5.46	3.30	2.58	5.88
GPV 2	2.93	2.34	2.27	3.05	2.35	5.40
GPV 3	2.98	2.42	5.40	3.16	2.48	5.64
SRL 3	2.90	2.27	5.17	3.02	2.31	5.33
RMS 4	2.55	1.95	4.50	2.82	2.05	4.87
PRABHAT	2.01	1.53	3.54	2.35	1.78	4.13
RMS 5	2.58	1.95	4.53	2.86	2.09	4.95
VARDHAN	2.06	1.55	3.61	2.43	1.89	4.32
KRH 4	2.62	2.02	4.64	2.75	2.11	4.86
RASI	2.02	1.50	3.52	2.38	1.75	4.13
R.SWETA	2.60	2.01	4.61	2.82	2.13	4.95
RMS 6	2.44	1.89	4.34	2.65	1.98	4.63
RMS 7	2.52	1.88	4.40	2.88	2.09	4.97
RMS 8	3.01	2.35	5.36	3.08	2.50	5.59
PVP 221	2.42	1.96	4.39	2.72	2.01	4.73
RMS 3	2.35	1.89	4.24	2.48	1.96	4.44
R.BHAGWATI	2.15	1.73	3.88	2.42	1.84	4.26
MTU 1010	2.75	2.14	4.89	2.76	2.25	5.01
CNN 1	2.32	1.73	4.04	2.50	2.08	4.58
CNN 2	2.42	1.82	4.24	2.55	2.13	4.68
VR 181	2.05	1.45	3.50	2.36	1.78	4.14
RMS 2	2.45	1.83	4.28	2.68	1.98	4.66
RAJSHREE	2.46	1.85	4.31	2.75	2.22	4.97
SRL1	2.95	2.52	5.47	3.15	2.47	5.62
RMS 1	2.30	1.75	4.05	2.65	2.14	4.79
PS 344	2.45	1.92	4.37	2.73	2.22	4.96
MTP 1	2.13	1.56	3.69	2.45	1.82	4.27
SRL 2	2.50	1.89	4.39	2.82	2.18	5.00
R. MAHSURI	3.07	2.45	5.52	3.25	264	5.89
CSR 23 **(Check)**	2.65	1.98	4.64	2.78	2.02	4.80
Mean	**2.52**	**1.95**	**4.48**	**2.75**	**2.13**	**4.88**
SEm±	0.084	0.069	0.11	0.087	0.047	0.13
CD (P=0.05)	0.24	0.18	0.32	0.24	0.13	0.38
CV%	5.80	5.61	4.34	5.45	3.87	4.77

Table 5. Effect of salt stress on peroxidase activity, catalase activity, and proline content in 30 rice genotypes

Genotypes	Peroxidase activity (unit mg^{-1} protein of Flag leaf)	Catalase activity (unit mg^{-1} protein of Flag leaf)	Proline content (mg g^{-1} fresh wt. of Flag leaf)
GPV 1	162.3	90.2	31.6
GPV 2	155.7	89.1	31.3
GPV 3	147.0	85.8	29.5
SRL 3	148.0	86.5	30.5
RMS 4	140.2	70.0	26.2
PRABHAT	128.7	60.5	22.3
RMS 5	142.7	69.0	24.6
VARDHAN	142.0	66.7	24.8
KRH 4	146.6	74.4	25.9
RASI	133.3	58.6	22.8
R.SWETA	142.5	72.6	26.1
RMS 6	140.5	68.7	24.4
RMS 7	145.5	77.4	26.4
RMS 8	146.5	83.5	27.6
PVP 221	143.1	75.4	25.8
RMS 3	140.5	66.4	23.5

Genotypes	Peroxidase activity (unit mg^{-1} protein of Flag leaf)	Catalase activity (unit mg^{-1} protein of Flag leaf)	Proline content (mg g^{-1} fresh wt. of Flag leaf)
R.BHAGWATI	135.6	64.5	22.3
MTU 1010	146.3	78.3	26.5
CNN 1	145.3	79.8	25.7
CNN 2	148.7	81.4	27.2
VR 181	141.6	67.6	23.8
RMS 2	143.4	72.3	25.3
RAJSHREE	151.6	78.4	27.4
SRL1	157.6	87.5	30.7
RMS 1	138.6	67.4	24.2
PS 344	149.6	80.5	26.9
MTP 1	144.4	66.7	23.8
SRL 2	143.7	68.4	24.5
R. MAHSURI	165.1	93.0	32.3
CSR 23**(Check)**	147.2	76.5	26.9
Mean	**145.5**	**75.2**	**26.4**
SEm±	4.35	1.97	0.93
CD (P=0.05)	12.32	5.58	2.64
CV%	5.18	4.54	6.13

Table 6. Effect of salt stress on relative water content and membrane stability index (%) in 30 rice genotypes at tillering and pre-flowering stage

Genotypes	Relative water content (%)		Membrane stability index (%)	
	Tillering stage	Pre-flowering stage	Tillering stage	Pre-flowering stage
GPV 1	83.4	80.5	83.0	78.3
GPV 2	86.2	83.1	87.7	82.6
GPV 3	84.3	82.5	84.6	80.5
SRL 3	84.6	83.6	84.7	81.3
RMS 4	69.5	62.5	75.5	70.4
PRABHAT	60.3	58.6	71.6	68.4
RMS 5	71.5	68.7	79.7	74.2
VARDHAN	69.5	70.4	80.6	74.4
KRH 4	61.1	60.4	74.7	72.4
RASI	60.7	56.5	71.4	66.5
R.SWETA	73.6	70.5	79.7	73.4
RMS 6	70.2	66.4	72.6	70.6
RMS 7	65.4	64.5	76.2	71.4
RMS 8	84.5	82.6	80.5	76.5
PVP 221	65.4	60.6	79.5	75.2
RMS 3	62.4	58.2	74.5	70.4
R.BHAGWATI	57.1	54.3	71.5	68.6
MTU 1010	69.4	64.4	78.6	75.1
CNN 1	66.4	60.3	75.5	71.3
CNN 2	72.6	68.6	77.6	73.8
VR 181	72.9	68.7	75.6	70.5
RMS 2	72.5	70.7	78.7	76.6
RAJSHREE	75.3	73.6	81.4	75.4
SRL1	79.2	76.4	80.5	77.4
RMS 1	69.3	66.3	75.7	72.6
PS 344	70.4	66.1	76.4	73.5
MTP 1	71.2	64.4	70.5	68.7
SRL 2	71.4	67.4	72.5	69.2
R. MAHSURI	85.4	83.2	86.7	81.3
CSR 23 **(Check)**	70.2	65.9	73.5	69.5
Mean	**71.9**	**68.7**	**77.7**	**73.7**
SEm±	1.89	1.80	1.26	1.92
CD (P=0.05)	5.35	5.11	3.57	5.45
CV%	4.55	4.26	2.81	4.53

Table 7. Relationship (r- value) among physiological parameters of rice

Parameters	Total Chlorophyll (Preflowering Stage)	Peroxidise activity	Catalase activity	Proline content	Relative Water Content (Tillering Stage)	Relative Water Content (Preflowering Stage)	Membrane Stability Index (Tillering Stage)	Membrane Stability Index (Preflowering Stage)
Total Chlorophyll (Tillering Stage)	0.680**	0.468**	0.527**	0.504**	0.402*	0.410*	0.379*	0.402*
TotalChlorophyll (Preflowering Stage)		0.816**	0.881**	0.904**	0.812**	0.812**	0.771**	0.801**
Peroxidise activity			0.900**	0.903**	0.743**	0.722**	0.714**	0.734**
Catalase activity				0.959**	0.796**	0.782**	0.802**	0.844**
Proline content					0.846**	0.839**	0.848**	0.868**
Relative Water Content (Tillering Stage)						0.979**	0.821**	0.837**
Relative Water Content (Preflowering Stage)							0.857**	0.870**
Membrane Stability Index (Tillering Stage)								0.966**

6. CONCLUSION

The genotypes SRL 1, GPV 1, GPV 2, GPV 3, and Rajendra Mahsuri possess significantly the highest physiological and biological value against sodicity as well as a significantly strong positive correlation exists among physiological parameters. Based on response, the positive response is also observed among these potential genotypes with regard to SPAD value, Relative water content, and membrane stability index. Genotypes having the highest SPAD and chlorophyll content, enzymatic (peroxidase and catalase) activity, amino acids like proline content, relative water content, and membrane stability index possess the greater potential to combat or overcome the sodicity, a kind of salt stress and vice-versa. On contrary, the lowest value and its lesser potential are observed in Prabhat, Rasi, and Rajendra Bhagwati. Therefore, it can be concluded that SRL 1, GPV 1, GPV 2, GPV 3, and Rajendra Mahsuri can effectively withstand and perform well under sodic soil and hence, these genotypes can further utilize in the improvement of rice crops for their production and productivity and can be grouped into salt tolerant genotypes while Prabhat, Rasi, and Rajendra Bhagwati can be grouped into salt susceptible genotypes.

ACKNOWLEDGEMENTS

The author expresses his sincere gratitude and thanks to Dr. Vipin Kumar, Scientist-cum-Assistant Professor and all the supportive member of Department of Soil Science, Dr. Rajendra Prasad Central Agricultural, Pusa, Samastipur, Bihar, India for their valuable and constructive suggestions during the planning and development of the research work and its implementation. The necessary facilities provided by department of soil science and collaboration with other department during the itinerary of research work is highly acknowledge.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khush GS, Virk PS. Rice Breeding: Achievements and Future Strategies. Crop Improv. 2000;27:115-144.
2. Eckardt NA. Sequencing the Rice Genome. Plant Cell Online 12:2011–2017; 2000.
3. IRRI. Standard evaluation system for rice, 4th edn. INGER Genetics Resource Centre, IRRI, Manila. 1996;1–30.
4. Munns R, Tester M. Mechanisms of salinity tolerance. Annu Rev Plant Biol. 2008;59:651–681.
5. Singh RK, Mishra B, Singh KN. Salt tolerant rice varieties and their role in reclamation programme in Uttar Pradesh. Indian Farming. 2004;6–10.
6. ICARDA. International cooperation Highlands's regional program; 2002. Available: URL:http//www.icarda.cgiar.Org
7. Zhu GY, Kinet JM, Lutts S. Characterization of rice (*Oryza sativa* L.) F3 population selected for salt resistance. L. Physiological behavior during vegetative growth. Euphytica. 2001;121:251-263.
8. Sairam RK, Tyagi A. Physiology and molecular biology of salinity stress tolerance in plants. Curr. Sci. 2004;86:407–421.
9. Alam MZ, Stuchbury T, Naylor REL, Rashid MA. Effect of salinity on growth of some modern rice cultivars. J Agron. 2004;3:1–10.
10. Moradi F, Ismail AM. Responses of photosynthesis, chlorophyll fluorescence and ROS-scavenging systems to salt stress during seedling and reproductive stages in rice. Ann Bo. 2007;99:1161–1173.
11. Meloni DA, Oliva MA, Martinez CA, Cambraia J. Photosynthesis and activity of superoxide dismutase, peroxidase and glutathione reductase in cotton under salt stress. Environ Exp Bot. 2003;49:69–76.
12. Mehrotra NK, Agrawala SC. Nutritional composition of rice plants subjected to high alkalinity (SAR) in irrigation waters and soil calcareounesss. Micronutrients in Agriculture. 1979;95-102.
13. Chutipaijit S, Cha-um S, Sompornpailin K. High contents of proline and anthocyanin increase protective response to salinity in *Oryza sativa* L. spp. Indica. Aust. J. Crop Sci. 2011;5(1):191–1198.
14. Zhu JK. Plant salt tolerance. Plant Sci. 2001;6:66-71.
15. Eynard A, Lal R, Wiebe K. Crop response in salt-affected soils. J Sustain Agric. 2005;27:5–50.
16. Munns R. Comparative physiology of salt and water stress. Plant, Cell Environ. 2002;25:239–250.
17. Niu G, Rodriguez DS, Call E, Bosland PW, Ulery A, Acosta E. Responses of eight

Chile peppers to saline water irrigation. Sci Hortic. 2010;126:215–222.
18. Moradi F, Ismail AM, Gregorio G, Egdane J. Salinity tolerance of rice during reproductive development and association with tolerance at seedling stage. Indian J. Plant Physiol. 2003;8:276-287.
19. Munns R, Termaat A. Whole-plant responses to salinity. Aust. J. Plant Physiol. 1986;13:143-160.
20. Anderson MD, Prasad TK, Stewart CR. Changes in isozymes profiles of catalase, peroxidase and glutathione reductase during acclimation of chilling in mesocotyls of maize seedlings. Plant Physiol. 1995;109:1247-1257.
21. Palmiano EP, Juliano BO. Changes in the activity of some hydrolases, peroxidas, and catalase in the rice seed during germination. Plant Physiology. 1973;52(3): V274–277.
22. Bates L, Waldren R, Teare I. Rapid determination of free proline for water-stress studies. Plant Soil. 1973;39:205–207.
23. Sairam RK, Rao KV, Srivastava G. Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration. Plant Sci. 2002;163:1037–1046.
24. Ashraf M, Harris P. Photosynthesis under stressful environments: An overview. Photosynthetica. 2013;51:163–190.
25. Santos VC. Regulation of chlorophyll biosynthesis and degradation by salt stress in sunflower leaves. Sci Hortic. 2004;130:93–99.
26. Khafagy MA, Arafa AA, El-Banna MF. Glycinebetaine and ascorbic acid can alleviate the harmful effects of NaCl salinity in sweet pepper. Aust J Crop Sci. 2009; 3:257–267.
27. Mandal MP, Singh RA. Impact of salt stress on chlorophyll content in rice genotypes. J.of Res. Birsa Agril. Univ. 2001;13(1):61-63.
28. Caverzan A, Casassola A, Brammer SP. Antioxidant responses of wheat plants under stress. Genetics and Molecular Biology. 2016;39(1**)**:1-6.
29. Valliyodan B, Nguyen HT. Understanding regulatory networks and engineering for enhanced drought tolerance in plants. Curr Opin Plant Biol. 2006;9:189–195.
30. Igarashi Y, Yoshiba Y, Sanada Y, Yamaguchi-Shinozaki K, Wada K, Shinozaki K. Characterization of the gene for D1 - pyrroline-5-carboxylate synthetase and correlation between the expression of the gene and the salt tolerance in *Oryza sativa* L. Plant Mol. Biol. 1997;33: 857–865.
31. Saha P, Chatterjee P, Biswas AK. NaCl pretreatment alleviates salt stress by enhancement of antioxidant defense system and osmolyte accumulation in mungbean (*Vigna radiata* L. Wilczek). Indian J Exp Biol. 2010;48:593–60.
32. Kumar V, Shriram V, Nikam TD, Narendra J, Mahadeo GS. Antioxidant enzyme activities and protein profiling under salt stress in indica rice genotypes differing in salt tolerance. Arch Agron Soil Sci. 2009;55:379–394.
33. Mishra N, Gupta AK. Effect of salinity and different nitrogen sources on the activity of antioxidants enzymes and indole alkaloid content in Catharanthus roses seedlings. J. Plant Physiol. 2006;163:11-18.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/95216