Screening of Rice Genotypes against Sodicity inRelation to Physiological and Biological Traits

Abstract

The present study was conducted to screen the rice genotypes against sodicity in relation to physiological and biological traits.The field experiment was carried out at research farm of Dr. Rajendra prasad central agricultural university, pusa, samastipur, Bihar. Among the 30 rice genotypes, 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 and GPV 3 shows the highest chlorophyll content and SPAD value, Peroxidase and catalase activity, proline content, RLWC content and MSI percentage and the lowest were found in Prabhat, Rasi and Rajendra Bhagwati. The inter-relationshipwith regard to various physiological parametersshows a strong significant and positive correlation among each other at tillering and pre-flowering stages. However, Total chlorophyll at tillering stage was found to bear highly significant correlation with all physiological parameters except relatve water content and membrane stability index.Thegenotypes such as SRL 1, GPV 1, GPV 2 and GPV 3 seems to possess better potential in sodic soil than rest of the genotypes carried out in experiment with regard to various physiological parameters (taken as salt indices)by counteract or minimize the sodicity effect of sodium ion and boost up the rice production in sodic soil condition. Thus, screening of genotypes is one of the important procedure to identify the tolerant as well as susceptible genotypes under various stress condition.

Comment [A1]: The sentence structure in the abstract needs to be rearranged: Aims, study design, place and duration of study, methodology, results, and conclusion

Key words: Oryza sativa, Rice genotypes, salt stress, antioxidant or enzyme, SPAD, chlorophyll, proline, RLWC and MSI.

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 (Khush and Virk, 2000). In Asian and African countries rice itself emerges as the principal agricultural commodities throughout the year where it is solely cultivated and consume more than 90% of the world's rice (Khush and Virk, 2000). World population is rapidly mounting by every passing year and there will be 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 depends 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 (Eckardt, 2000).

In most of the countries crops are mainly raised under field conditions or open environment which are often exposed to biotic as well as abiotic stress. Abiotic stresses like climatic catastrophe like fluctuation of temperature, rainfall, drought, flood, sodicity, salinity, acidity in tropics, temperate, arid or semi- arid regions which influences 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 one, is a global problems in arid and semi-arid region because of erratic rainfall which is insufficient to leach soluble salts from the soil, that 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 yield (IRRI. 2006).

All over the world, cultivable lands are decreasing because of urbanization and 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 lands 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 lands 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, and it has been predicted that half of the cultivable terrains will be lost due to salt by the middle of the 21st century (Munns and Tester, 2008). In india, 6.73 mha area is salt affected in which sodic soil comprises 3.77 mha which is about 56% of total salt affected area (Singh *et al*., 2010) and holds third position after former Soviet union and China in terms of salt affected area in Asian countries (ICARDA, 2002). Soils having 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 excess of sodium ion near or in the rhizospheric region causes sodicity stress (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 levels reaches 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 affect the plant growth and thereby one of the obvious manifestation could be associated with the physiological and biological attributes and absence or presence of nature and type of ion in soil as well as its equilibrium and uptake by plants.

Crop genotypes or varieties and their lines do differ for their inherent capabilities to modify various physiological and biological processes in response to salt stress. Though numerous physiological and biological changes take place under altered salt stress environment but only few of them change very significantly and also contribute a lot to 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 (Zhu, 2001: Sairam and Tyagi, 2004). The changes occur in plants controls the solute and water balance (Relative water content) and their distribution on 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 process 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, the one of the obvious sign of the plant is the reduction of leaf area which is one of the first reaction of plant (Alam *et al.*, 2004). An initial and rapid response of the plants to the salt stress is the movement of soil water potential towards 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.2007). Reduction of leaf area leads tovariation in chlorophyll content and Soil plant analysis development (SPAD) value signaling the physiological and biological manifestation under salt stress condition. Obviously greater upsurge of polyphenol or enzymatic antioxidants in plant systems play an imperative and vital physiological role in ion-induced oxidative damage with the purpose of reducing the detrimental effect of salt which causes injury to cell membrane and enhanced membrane leakage in salt – sensitive genotypes (Meloni *et al*., 2003).

In sodium saturated sodic soil, the elevated pH and supremacy of Na^+ ion restricts the evenly going activities, process 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; Mehrotra and Agarwal,1979).Generally rice crop shows variability in sensitivity towards excess sodicity at various developmental stages during its life cycle. It is considered relatively tolerant to salt stress at germination stage and early reproductive stage while pollination are the most sensitive stages towards salt stress which directly affect the plants.

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 for their potential of salt resistance. However, current developments in the field of different aspects of soil science and molecular biology has opened up new and innovative possibilities in understanding the physiology of abiotic stresses (Bennet and Khush, 2003; Eynard *et al.*, 2005; Ismail *et al*., 2007).

As all these traits are independently or weekly associated, none of the known salt tolerant genotypes combine more than 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.

As distribution and dispersion of salt affected land is not uniform since it depends on various factors such as climate, concentration of salts, topography of land etc. Current challenges of global food security can only met if destroyed productive land is made cultivable again, to identify tolerant or susceptible genotypes, changes the growing environment and make it suitable for normal growth of plant. Worldwide research is going on to combat and overcome 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 crop. Hence, the present study was undertaken to screen the rice genotypes against sodicity with respect to physiological and biological traits.

Material and Methods

Comment [A2]: Material and Methods With subtitle : area study, experimental design, data collection methods/measurement of research results, data analysis

The study was conducted at Research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur,Bihar in which a total of 30 rice genotypes were taken with 5 indigenous and 25 are exotic for this region. CSR 23 used as a check genotype to assess the positive and negative percent response of sodicity tolerance with respect to different physiological and biological traits. This research was carried out with 3 replication and a total of 90 plots (each replication contains 30 plots with 30 genotypes) based on the randomized block design (RBD) in open environment or field condition. Initial properties of soil were analysed in laboratory to know the chemical status and sodium concentration in soil which are shown in table 2. 30 genotypes were transplanted in the main field having pH- 9.61 after 25 days of old seedlings at a spacing of 20 x 15 cm (P-P & R-R) with the individual plot of 10 m^2. Plant samples (Leaf) 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.The genotypic details of rice used in this experiment are presented in table 1.

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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 rest of the above 25 genotypes are exotic for 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

Physiological and Biological attributes

SPAD value

A hand held device was used in order to know the Soil Plant Analysis Development value, 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 red region (650 nm) and infrared (940 nm) regions of the electromagnetic spectrum.

Chlorophyll content

The procedure described by Anderson and Bordman (1964) was used to estimate the chlorophyll content quantitatively. The chlorophyll content ('a', 'b' and total)was estimated in flag leaf at both the stages and expressed as µg ml^{-1}on fresh weight basis.

Assay of enzyme

Catalase

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

Peroxidase

The method described by Palmiano and Juliano (1973) was used to determine the assay of peroxidase activity in flag leaf of rice and expressed as unit mg^{-1} protein of flag leaf on fresh weight basis.

Proline content

The amino acid proline content was estimated in fully expanded leaf at flowering stage following the method of Bates *et al*. (1973) and expressed as mg^{-1} fresh weight of flag leaf.

Membrane stability index (MSI)

The procedure explained by Premchandra *et al*. (1990), modified by Sairam (1994) was used to determine Membrane stability index and expressed as percentage.

Relative water content (RWC)

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

Data Analysis

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

Result and Discussion

In the present study, attempts were made with the main objective of finding is 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 pre-flowering stages would definitely help in order to find out the tolerance and susceptible nature.

SPAD value and Chlorophyll Content

The results of the study show that SPAD values increased with the age of the crop from tillering to pre-flowering stage are presented in Table3.The SPAD values varies significantly among genotypes in which highest value was observed in GPV 1 at tillering stage and Rajendra Mahsuri at pre-flowering stage. The minimum value was observed in Rasi at tillering stage and prabhat at pre-flowering stages.Based on percent,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 the stages. While the results pertaining to chlorophyll, its content (chll.a, chll.b and total content) significantly varies in both the stages.

Rajendra Mahsuri contains highest chll.a at tillering stage and GPV 1 contains highest chll.a at pre-flowering stages. In case of chll.b, highest content was observed in SRL 1 at tillering stageand Rajendra Mahsuri has highest at 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 each other while the lowest content was observed in Prabhat which is similar with Rasi. This might be due to highsodium accumulation in the shoots and low accumulation of calcium, magnesium and potassium in shoots. Salt stress decreases the amount of chlorophyll in the leaves by degrading or inhibiting the chlorophyll synthesis (Ashraf and Harris, 2013) with the increase in chlorophyllase enzyme activity (i.e.enzyme having ability to degrade chlorophyll). The another reason might be because of oxidative stress under salt stress which decreases the number and size of chloroplasts and destroy it (Santos, 2004; Khafagy *et al.* 2009).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, 2001.

Enzyme Content

Peroxidase and Catalase activity

Among the genotypes, peroxidase activity differ significantly where Rajendra Mahsuri recorded maximum enzyme activity and statistically significant over rest of the genotypes but at par with GPV 1, SRL 1, GPV 2 and Rajshree. Similarly catalase activity was 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 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, 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 in order to detoxify reactive oxygen species, especially, hydrogen peroxide (H_2O_2) through its breakdown into water molecule. These results are in accordance with the findings of Caverzan *et al.*, 2016.

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Proline Content

In this study the maximum accumulation of proline was observed in Rajendra Mahsuri which was statistically significant over 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 with Rajenda Bhagwati.Under salt stress, it is generally believed that accumulation of compatible solutes (proline,glycine,betaine,pinnitol etc) are involved in cellular osmotic balance (Valliyodan and Nguyen, 2006).This might be due to 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 contains higher proline in its cells or tisues, the plants will be more resistant towards salt stress. This finding were consistent with Neo *et al*.2004; Ghosh *et al.* 2011. There is a existence of relationship between degree of salt tolerance and proline concentration (Igarashi *et al.* 1997). Proline is used as 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 acclimatizations. Besides this, proline also acts as a source of carbon and nitrogen for stress recovery in later stages, sometimes as a energy sink to regulate redox potential and also help in protection of protein against denaturation (Saha *et al*.2010; Fariduddin *et al*. 2013).

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Relative Water Content

Among the genotypes, the percentage of relative leaf water content (RLWC) significantlyvaries at both tillering and pre-flowering stages. The highest relative water content (RWC) 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 percent, 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 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 leaf. These results were in accordance with the finding of Neo *et al.*2018.

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Membrane Stability Index

Among the genotypes, the percentage of membrane stability index (MSI) significantly varies at both tillering and pre-flowering stages. The highest MSI was observed in GPV 2 and the lowest one was Rasi at both tillering and pre-flowering stages. Based on percent 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 presence of excess salts. This findings were in accordance with the results of Kumar *et al.*2015.

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Inter-relationship among physiological parameter of rice

With regard to interrelationship among salt tolerance indices of physiological parameters, membrane stability index (Tillering and preflowering stages) were found to bear highly and positive relationship with total chlorophyll (tillering and preflowering stages), peroxidase activity, catalase activity, proline content and relative water content (tillering and preflowering stages).Relative Water Content at preflowering stages was significantly correlated with total chlorophyll at tillering stage (r =0.41*), total chlorophyll (preflowering stage) (r = 0.812*), peroxidase activity (r = 0.722**), catalse activity (r = 0.782**), proline content (r = 0.839**) and relative water content at tillering stage (r = 0.979**). Similar pattern of significant relationship was observed with relative water content with at tillering stage while correlation coefficient of proline content with total chlorophyll content at tillering and preflowering stage, peroxidase and catalase activity were 0.504**, 0.904**, 0.903** and 0.959**, respectively. The correlation coefficient betweencatalase and total chlorophyll at tillering stage and preflowering stage (r = 0.527** and 0.988**) and catalase with peroxidase activity (r = 0.900**) were highly significant. Total chlorophyll at tillering stage was found to bear highly significant correlation with all physiological parameters except relatve water content and membrane stability index. These results are in corroboration with findings of Chunthabure *et al*. (2016). The antioxidant enzymes like catalase and peroxidase play an important role in plant adaptation in stress condition (Mishra and Gupta, 2006). In plants, chloroplast, mitochondria and peroxisomes are responsible for the conversion of H_2O_2 to water molecule (Anderson *et al.*, 1995).

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Conclusion

The genotypes SRL 1, GPV 1, GPV 2 and GPV 3 possesses significantly highest physiological and biological value against sodicity as well as significantly strong positive correlation exist among physiological parameters. Based on percent, the positive response is also observed among these potential genotypes with regard to SPAD value, Relative water content and membrane stability index. Genotypes having highest SPAD and chlorophyll content, enzymatic (peroxidase and catalase) activity, antioxidants or amino acids like proline content as well as relative water content and membrane stability index percent possesses 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 is observed in

Prabhat, Rasi and Rajendra Bhagwati. Therefore, it can be concluded that SRL 1, GPV 1, GPV 2 and GPV 3 can effectively withstand and perform well under sodic soil. Hence, thesegenotypes can be further utilized in improvement of rice crop for its production and productivity and can be grouped into salt tolerant nature.

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Table 3: Effect of salt stress on SPAD value in 30 rice genotypes at tillering and preflowering stage.

Genotypes	Tillering stage	Preflowering 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

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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 preflowering stage

Genotypes	Tillering stage			Preflowering stage		
	Chl a	Chl b	Total	Chl a	Chl b	Total
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

Comment [A11]: Unit....g or mg or.....

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
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 preflowering stage

Genotypes	Relative water content (%)		Membrane stability index (%)	
	Tillering stage	Preflowering stage	Tillering stage	Preflowering 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

Comment [A12]: units

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

Parameters	Total Chlorophyll (Prefloweering Stage)	Peroxidise activity	Catalase activity	Proline content	Relative Water Content (Tillering Stage)	Relative Water Content (Prefloweering Stage)	Membrane Stability Index (Tillering Stage)	Membrane Stability Index (Prefloweering Stage)
Total Chlorophyll (Tillering Stage)	0.680**	0.468**	0.527**	0.504**	0.402*	0.410*	0.379*	0.402*
TotalChlorophyll (Prefloweing 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 (Prefloweing Stage)							0.857**	0.870**
Membrane Stability Index (Tillering Stage)								0.966**