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Morphological and Physiological Basis of Salt Resistance in Different Rice Genotypes

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Abstract

Salt stress is one of the major abiotic stresses limiting profitable crop production. This study was conducted to evaluate the morphological and physiological basis of salinity tolerance in rice genotypes. Six rice genotypes (IR74099-3R-5-1-K3, FL 478, GAORI, DONGJINBYEO, RYKUU 15 and CHING-YUEH 1) were sown in germination trays filled with artificial rice soil formulated and then transferred to iron containers after germination. Salinity (100 m*M* NaCl) was imposed in equal increments of 25 m*M* per day. Salt stress caused substantial decrease in shoot length, leaf area and leaf fresh weight, specific leaf area (SLA) and seedling fresh and dry weights of all rice genotypes; although the genotypes varied in their response. However, root length of tested rice genotypes increased with salt stress except genotype DONGJINBYEO. A substantial decrease in K^+/Na^+ ratio was observed in all genotypes under salt stress due to substantial increase in Na^+ contents, but genotypes behaved differently. Salt stress also enhanced polyphenols in genotypes IR74099-3R-5-1-K3, FL 478 and GAORI while flavonoids increased in all genotypes except RYKUU15. Rice genotypes IR74099-3R-5-1-K3 and FL 478 had minimum decrease in seedling fresh and dry weights, and higher leaf area and SLA under salt stress. Genotypes IR74099-3R-5-1-K3 and FL 478 also had 6.33 and 13.73% higher anti-oxidant activity. In conclusion, although salinity decreased the growth of all tested rice genotypes; genotypes IR74099-3R-5-1-K3 and FL 478 were more resistant to salt stress, than other genotypes, owing to higher buildup of polyphenols and flavonoids, and decrease in Na^+ uptake and better K^+/Na^+ ratio, which helped to maintain higher leaf area, SLA and growth. Physiological traits like polyphenols and flavonoids, and K^+/Na^+ ratio may be used for mass screening of rice genotypes for salt tolerance.

Keywords: Salt stress; Rice genotypes; Total polyphenols; Na^+ contents; Leaf area

Introduction

Accumulation of soluble salts or exchangeable sodium in the rhizosphere or on the soil surface up to toxic levels, which affects agricultural productivity, is termed as soil salinity. Salinity is one among the major abiotic stresses limiting profitable crop production worldwide (Kumar *et al*., 2010; Tavakkoli *et al.*, 2011). Over 800 million hectares (Mha) land is salt affected either by containing excessive soluble salts (397 Mha) or exchangeable sodium (434 Mha) worldwide (FAO, 2005; Munns, 2005). Hyper-salinization is a severe threat to the crop production in arid and semi-arid regions due to limited precipitation and higher evaporation rate (de Azevedo Neto *et al*., 2006; *Ahmad et al., 2012*). For that reason, it is a general perception that salinity arises predominantly in arid to semi-arid regions of the world but in truth not a single climatic zone of this globe is free from it (Bhutta *et al*., 2004; Rengasamy, 2006).

Elevated osmotic stress, ions toxicity (due to over accumulation of Na^+ in particular), imbalance nutrition and salinity-induced oxidative damage are the principal causes to hamper plants growth under salinity (Pitman and Lauchli, 2002; Munns *et al*., 2006). Higher buildup of ions in soil solution leads to salinity-induced osmotic stress, while specific ion effect and imbalance nutrition is related with the accretion of Na^+ and Cl^- ions at toxic levels lowering the absorption availability of other elements like calcium (Ca^{2+}) and potassium (K^+) etc., (El-Bassiouny and Bekheta, 2001; Munns *et al*., 2006). Higher tissue Na^+ contents may damage the membranes and organelles leading to growth diminution and unusual development prior to plant mortality (Davenport *et al*., 2005; Quintero *et al*., 2007; Saqib *et al*., 2012). Na^+ ion also interferes with K^+ uptake and may disturb stomatal oscillations (Fortmeier and Schubert, 1995; Sümer *et al*., 2004; Shahzad *et al*., 2012). According to bi-phasic model of salinity-induced growth reduction, osmotic stress during 1st phase and ion toxicity during 2nd phase is responsible for growth reduction in cereals (Munns, 1993).

Although rice (*Oryza sativa* L.) is considered somewhat salt resistant but the yield of rice, in particular

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Asian rice (*sativa*), is largely sensitive to salt stress (Munns and Tester, 2008) leading to sizeable decline in productivity under salinity (Kumar *et al*., 2008). Na^+ and Cl^- are the principal ions in majority of salt affected soils, which mainly affect plants growth. The roots of rice plants readily absorbed Na^+ due to its small sized molecules which are distributed in all plant organs to pose ion damage, osmotic stress and imbalance nutrition (Siringam *et al*., 2009, 2011). Over accumulation of Na^+ and elevated lipid peroxidation is well reported in salt sensitive rice cultivars under high salinization (Dionisio-Sese and Tobita, 1998). Therefore small accrual of Na^+ ions in resistant rice genotypes under salt stress may explain the basis of NaCl tolerance of rice varieties than sensitive ones (Dionisio-Sese and Tobita, 1998). Kumar *et al*. (2009) reported that salt resistant rice cultivars generate larger biomass than sensitive ones irrigated with NaCl dominated water.

Salinity may also cause oxidative stress due to over-production of reactive oxygen species (ROS) leading to alteration in plant metabolism. The ROS thus produced may damage DNA, proteins, lipids, carbohydrates and membranes (Menezes-Benavente *et al*., 2004; Hichem*et al*., 2009). Meloni *et al*. (2003) reported comparatively higher injury to cell membranes in salt-sensitive rice cultivars under salt stress. However, salt resistant genotypes regulate the ion and water movements and also uphold better antioxidant defense system to counteract the ROS (Rout and Shaw, 2001). Higher accumulation of flavonoids and polyphenols in plants under salt stress may help the plants to alleviate the salinity-induced oxidative stress (Wahid and Ghazanfar, 2006; Hichem *et al*., 2009). Recently, Danai-Tambhale *et al*. (2011) quoted significantly higher buildup of total polyphenols in tolerant rice cultivar than sensitive one under salinity stress.

Massive genetic diversity for salt resistance had been reported in crops like wheat (Jafar *et al*., 2012), maize (Akhtar *et al*., 2003), sunflower (Hussain *et al*., 2012), canola (Farhoudi *et al*., 2012) and rice (Kumar *et al*., 2008, 2009; Quinet *et al*., 2010) etc. Nonetheless, rice is not only the leading cereal crop of the world but also a staple diet of more than half of the world population (IRRI, 2011). Therefore, tailoring of salt resistant genotypes of rice will help in feeding the escalating world population. Mass screening and physiological characterization of rice genotypes may help in tailoring salt resistant rice genotypes. This study was conducted to evaluate the performance of different rice genotypes under salt stress on morphological and physiological basis with the hypothesis that rice genotypes differ for their salt resistance potential.

Materials and Methods

Site Description and Experimental Details

This experiment was conducted in a phytotron (with 26 and 18ºC for 16 and 8 h light and dark period, respectively) at Crop Science Section, Rural Development Administration, Suwon and analytical work was conducted in Functional Plant Bioresearch Laboratory, Department of Crop Science and Biotechnology, Dankook University, Cheonon Campus, South Korea.

Sprouted seeds (25 in number) of six rice genotypes IR74099-3R-5-1-K3, FL 478,GAORI, DONGJINBYEO, RYKUU 15 and CHING-YUEH 1 were sown in germination trays (5 seeds in one hole) filled with artificial rice soil. Experimental soil comprised vermiculite, diatomaceous earth, clay, coco peat, charcoal and water-soluble humic acid having moisture contents 25±8%, bulk density 0.50±0.10 Mg m^{-2}, pH 5.4, EC (2 dS m^{-1}, ammonia nitrogen (NH_4-N) 350 ppm, and available phosphorous (P_2O_5) 350 ppm. After achieving the constant emergence count, 15 rice seedlings were maintained in each replicate with three seedlings per hole. Germination trays were shifted in iron containers having 25 m*M* NaCl solution (salt stress) or tap water (control). Solution concentration was increased to 50, 75 and 100m*M* NaCl on 16, 17, 18th day after sowing, respectively in salt stress treatment. The experiment was conducted under completely randomized design (CRD) with factorial arrangement and replicated four times.

Observations

Plants were harvested on 23rd day after sowing to record root and shoot lengths, leaf fresh weight and seedling fresh weight of ten seedlings selected at random from each replicate were taken immediately after harvest and then averaged. The samples were put in an oven at 70°C for 72 h to record seedling dry weight. Leaf area of rice seedlings was measured at harvesting with a leaf area meter (Area Meter AM-200 ADC Bio-scientific limited). Specific leaf area (SLA) was computed as ratio of leaf area to leaf dry weight.

One gram plant sample was dissolved in 10 mL of 80% methanol to prepare extract to estimate total polyphenols, flavonoids and antioxidant activities. Total polyphenols were determined by reacting phenolic compounds with phosphomolybdate blue using Folin–Ciocalteu procedure (Shen *et al*., 2009). Colorimetric assay described by Zhishen *et al*. (1999) was used to determine total flavonoids contents. Diluted methanolic extract (1 mL), catechin standard solutions (as blank) and 5% $NaNO_2$ (0.3 mL) were added to 4 mL of distilled water. After 5 min, 10% $AlCl_3$ (0.3 mL) was added, 2 mL 1 M NaOH was added after 6 min, and volume was made up to 10 mL with distilled water. The absorbance was determined at 510 nm against an appropriate blank. Antioxidant activities of the extracts were measured by scavenging the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radicals in a process guided by its discoloration (Lee and Lee, 2004). Sample stock solutions (0.50 mg mL^{-1}) were diluted to final concentrations of 100 µg mL^{-1}, 33 µg mL^{-1} and 11 µg mL^{-1}

in methanol; 150 µ*M* DPPH methanol solution (150 µL) was added to 100 µL of sample solutions, and allowed to react at room temperature. After 30 min, absorbance values were taken at 518 nm using microplate reader to estimate IC_{50} value (concentration need to inhibit activity of free radical below 50%).

Dried ground 0.5 g plant sample was digested in 100-ml polystyrene bottle by adding 25 mL of 1 N for 24 h, filtered through Whatman No. 1 filter paper and collected in a 100 mL polystyrene bottle. At the same time, 25 mL 1 N HCl blank was also prepared using the same procedure. Sodium (Na^+) and potassium (K^+) contents (mg g^{-1} dry weight) of seedlings was determined from digested sample with flame photometer (Jenway PFP-7). After that K^+/Na^+ ratio was also computed.

Statistical Analysis

The collected data were statistically analyzed according to Fisher's analysis of variance technique under completely randomized design (CRD) with factorial arrangement; and least significant test (LSD) at 0.01 probability level was used to compare treatments means (Steel *et al*., 1997).

Results

All the tested rice genotypes indicated substantial increase in root length except DONGJINBYEO under salt stress compared with control; and maximum increase (38.04%) was noted in RYKUU 15. Salinity caused substantial reduction in shoot length of all genotypes; however, the tested genotypes varied greatly in this regard. Genotypes CHING-YUEH 1 and FL 478 indicated a minimum (5.29 and 8.18%, respectively) while GAORI showed a maximum (20.42%) decrease in shoot length under salt stress (Table 1).

Salinity substantially reduced the leaf area and leaf fresh weight of all genotypes with varying degree (Table 2). Genotypes FL 478 and IR74099-3R-5-1-K3 indicated the least (36.73 and 42.62%, respectively) decrease in leaf area while all other genotypes indicated more than 70% decrease in leaf area under salt stress (Table 2). Likewise, genotypes FL 478 and IR74099-3R-5-1-K3 showed lesser and RYKUU 15 indicated more decline in leaf weight under salt stress (Table 2). Salt stress also caused drastic reduction in specific leaf area (SLA) of all genotypes, and genotypes FL 478 indicated minimum (10.92%) and DONGJINBYEO observed maximum (57.82%) decline in SLA under salt stress (Table 2).

Salt stress significantly decreased the seedling fresh and dry weights of all genotypes, although genotypes behaved differently in this regard. Genotypes IR74099-3R-5-1-K3 and FL 478 indicated the minimum (5.48 and 7.14%) while RYKUU 15 and DONGJINBYEO showed the maximum (41.42 and 34.91%) decrease in seedling fresh weight under salt stress (Table 3). Likewise, genotypes FL 478 and IR74099-3R-5-1-K3 observed the least (10.53 and 16.67%) while RYKUU 15 and DONGJINBYEO indicated the most (29.41 and 23.51%) decrease in dry weight under saline conditions than control (Table 3).

Three genotypes (IR74099-3R-5-1-K3, FL 478 and GAORI) indicated increase, while other three genotypes (DONGJINBYEO, RYKUU 15 and CHING-YUEH 1) observed slight decrease in total polyphenols accumulation under salt stress (Table 4). Moreover, genotypes IR74099-3R-5-1-K3 and FL 478 indicated 77.84 and 56.42% higher flavonoids contents under salt stress than control, whereas RYKUU 15 observed 22.13% decrease in flavonoids buildup in saline environment (Table 4). Likewise, genotypes IR74099-3R-5-1-K3 and FL 478 indicated higher anti-oxidant activity as evident from 6.33 and 13.73% decrease in IC_{50} value under salinity than control while all other genotypes indicated decrease in anti-oxidant activity under salt stress with maximum reduction in RYKUU 15 (Table 4).

A significant increase in seedling Na^+ contents on the expense of seedling K^+ contents was noted under salt stress, although the genotypes behaved differently in this regard (Table 5). Genotypes IR74099-3R-5-1-K3 and CHING-YUEH 1 respectively indicated minimum (13.39%) and maximum (44.04%) decrease in K^+ contents under salt stress (Table 5). Moreover, IR74099-3R-5-1-K3 indicated the least (299.15%) and DONGJINBYEO indicated the most (1050.27%) increase in Na^+ contents under saline conditions (Table 5). Salt stress substantially decreased the K^+/Na^+ ratio of all genotypes, with varying degree, and genotype IR74099-3R-5-1-K3 indicated the minimum decrease in this regard (Table 5).

Discussion

Results of this study elaborated that salt stress significantly decreased the growth of all tested rice genotypes; however, rice genotypes behaved differently in this regard (Tables 1-3). Kumar *et al*. (2009) quoted that salt resistant rice cultivars generate larger biomass than sensitive ones irrigated with NaCl dominated water. Decreased shoot length and leaf area might be due to impaired cell division and elongation due to salinity induced osmotic stress. Drastic reduction in leaf area under salt stress might be associated with salinity-induced decrease in seedling fresh and dry weights as leaves are the units of assimilatory system (Tables 2-3). Higher seedling fresh and dry weights recorded in genotypes IR74099-3R-5-1-K3 and FL 478 under salinity might be associated with their higher leaf area (Tables 2-3). Salt-induced osmotic stress (Bandeoglu *et al*., 2004), altered metabolism, inability of apoplastic acidification and lack of turgor seems the possible reasons of salinity-induced decrease in rice growth (Munns and Tester, 2008); increase in Na^+ uptake also contributed for that (Munns *et al*., 2006; Table 5).

Applied salinity caused an increase in Na^+ contents at the expense of K^+ contents in all rice genotypes under

Table 1: Effect of salinity on root and shoot length of different rice genotypes

Rice genotypes	Root length (cm)			Shoot length (cm)		
	Control	Salinity	Increase over control (%)	Control	Salinity	Decrease over control (%)
IR74099-3R-5-1-K3	14.06±0.55 h	18.89±1.13 de	34.35	26.65±0.66 g	23.53±0.73 h	11.71
FL 478	18.24±0.47 de	19.15±0.71 cde	4.99	29.60±0.51 f	27.18±0.63 g	8.18
GAORI	17.69±0.35 ef	20.46±0.86 bc	15.66	39.11±0.98 a	31.11±1.07 ef	20.46
DONGJINBYEO	21.480.94 ab	18.20±0.71 de	-15.27	32.67±0.82 cd	27.96±0.53 g	14.42
RYKUU 15	16.30±0.57 fg	22.50±0.45 a	38.04	39.59±0.95 a	34.90±1.05 b	11.85
CHING-YUEH 1	15.46±1.37 gh	19.72±0.91 cd	27.55	32.91±0.76 c	31.17±0.56 de	5.29
LSD (p 0.01)	1.55			1.52		

Table 2: Effect of salinity on leaf area and fresh weight and specific leaf area of different rice genotypes

Rice genotypes	Leaf area per seedling (cm^2)			Leaf fresh weight (g)			Specific leaf area ($cm^2\ g^{-1}$)		
	Control	Salinity	Decrease over control (%)	Control	Salinity	Decrease over control (%)	Control	Salinity	Decrease over control (%)
IR74099-3R-5-1-K3	13.07±0.34 c	7.50±0.35 f	42.62	0.09±0.00 f	0.06±0.01 g	33.33	151.43±9.40 a	128.79±8.32 b	14.95
FL 478	20.20±0.20 a	12.78±0.59 cd	36.73	0.16±0.01 a	0.11±0.00 e	31.25	126.54±1.09 bc	112.72±2.21 d	10.92
GAORI	11.70±0.59 e	2.55±0.05 h	78.21	0.12±0.00 d	0.05±0.00 h	58.33	98.46±6.56 e	55.30±6.86 hi	43.84
DONGJINBYEO	12.16±0.10 de	2.74±0.27 h	77.47	0.11±0.01 e	0.06±0.01 g	45.45	110.61±2.03 d	46.65±6.66 i	57.82
RYKUU 15	12.60±0.28 cd	3.62±0.26 g	71.27	0.15±0.00 b	0.05±0.01 h	66.67	86.89±2.74 f	75.78±5.27 fg	12.79
CHING-YUEH 1	14.88±0.56 b	3.87±0.23 g	73.99	0.13±0.01 c	0.06±0.01 g	53.85	116.98±6.71 cd	64.98±8.87 gh	44.45
LSD (p 0.01)	0.69			0.006			11.23		

Table 3: Effect of salinity on seedling fresh and dry weights of different rice genotypes

Rice genotypes	Seedling fresh weight (g)			Seedling dry weight (g)		
	Control	Salinity	Decrease over control (%)	Control	Salinity	Decrease over control (%)
IR74099-3R-5-1-K3	0.73±0.04 de	0.69±0.01 ef	5.48	0.12±0.01 e	0.10±0.01 f	16.67
FL 478	1.12±0.01 a	1.04±0.01 bc	7.14	0.19±0.00 a	0.17±0.00 b	10.53
GAORI	1.03±0.02 bc	0.74±0.04 d	28.16	0.16±0.00 c	0.13±0.00 d	18.75
DONGJINBYEO	1.06±0.02 b	0.69±0.02 ef	34.91	0.17±0.00 b	0.13±0.01 d	23.53
RYKUU 15	1.16±0.01 a	0.68±0.01 f	41.42	0.17±0.00 b	0.12±0.00 e	29.41
CHING-YUEH 1	1.01±0.01 c	0.68±0.03 f	32.67	0.16±0.00 c	0.13±0.01 d	18.75
LSD (p 0.01)	0.04			0.009		

Means not sharing the same letter for a trait differ significantly from each other at p 0.01

salt stress leading to decreased K^+/Na^+ ratio (Table 5). The roots of rice plants freely absorbed Na^+ due to its small sized molecules which are finally distributed in all plant organs to pose ion damage, osmotic stress and imbalance nutrition (Siringam *et al*., 2011). However different rice genotypes behaved differently in this regard due to their divergent genetic makeup; and the more salt resistant genotypes IR74099-3R-5-1-K3 and FL 478 maintained higher K^+/Na^+ ratio against the sensitive ones i.e. RYKUU15 and DONGJINBYEO. Over accumulation of Na^+ is well reported in salt sensitive rice cultivars under high salinization and therefore small accrual of Na^+ ions in tolerant rice cultivars under salinity explain the basis of NaCl resistance (Dionisio-Sese and Tobita, 1998).

Minimum decrease in seedling fresh and dry weight was observed in genotypes IR74099-3R-5-1-K3 and FL 478 (Table 3). Moreover, the same genotypes also maintained higher leaf area and SLA (Table 2) and K^+/Na^+ ratio under salinity (Table 5). Higher leaf area might result in superior biomass production due to interception of more radiations as leaves are the units of assimilatory system of plants. Decrease in tissue content of Na^+ and increased one of K^+ is important indicator of salt resistance (Marschner, 1995; Hu and Schmidhalter, 1997). The ability of plants to limit Na^+ transport into shoot is important for the maintenance of growth rates and protection of the metabolic process in elongation cells from the toxic effect of Na^+ (Razmjoo *et al*., 2008).

Nonetheless, salinity leads to oxidative stress due to over-production of ROS and tolerant plant genotypes regulate the ion and water movements and also uphold better antioxidant defense system to counteract the ROS (Rout and Shaw, 2001). Higher accrual of polyphenols in plants subjected to salt stress plays an imperative physiological role to rectify the salinity-induced oxidative stress (Hichem *et al*., 2009). Therefore, higher buildup of total polyphenols and flavonoids observed in tolerant genotypes IR74099-3R-5-1-K3 and FL 478 seemed the adaptive mechanism of plants under salt stress (Table 4). The same tolerant genotypes (IR74099-3R-5-1-K3 and FL 478) also observed higher antioxidant activity under saline environment primarily due to higher buildup of total polyphenols and flavonoids (Table 4). Recently, Danai-

Table 4: Effect of salinity on seedlings total polyphenols and flavonoids contents and antioxidant activity of different rice genotypes

Rice genotypes	*Total polyphenols (mg GAE g^{-1} DW)			**Total flavonoids (mg CE g^{-1} DW)			***Antioxidant activity (IC_{50}; µg mL^{-1})		
	Control	Salinity	Increase over control (%)	Control	Salinity	Increase over control (%)	Control	Salinity	Decrease over control (%)
IR74099-3R-5-1-K3	126.62±1.62 j	175.09±1.08 d	38.28	21.08±0.55 ef	37.49±1.12 b	77.85	155.23±2.79 a	145.41±4.59 b	6.33
FL 478	150.60±1.45 g	240.20±1.25 a	59.50	21.07±0.78 f	32.95±1.12 c	56.38	143.90±3.24 b	124.14±2.64 e	13.73
GAORI	138.83±0.55 i	183.52±1.12 c	32.19	29.08±0.64 d	29.06±0.70 d	-0.07	160.71±5.54 a	160.30±3.41a	-0.26
DONGJINBYEO	165.41±2.29 e	147.77±1.68 h	-10.66	22.92±1.32 e	27.82±0.81 d	21.38	132.15±2.27 d	141.66±1.34 bc	-7.20
RYKUU 15	188.06±0.71 b	166.27±0.96 e	-11.59	43.19±1.15 a	33.63±1.32 c	-22.13	131.73±2.63 d	157.25±1.51 a	-19.37
CHING-YUEH 1	155.35±0.65 f	147.69±1.20h	-4.93	18.93±1.00 g	19.54±0.53fg	3.22	130.61±2.61 de	135.57±7.87 cd	-3.80
LSD (p 0.01)	2.39		1.85				7.31		

Means not sharing the same letter for a trait differ significantly from each other at p 0.01
*GAE: Gallic acid equivalent, **CE: Catechin equivalent and ***IC_{50} is the concentration needed to inhibit activity of free radical below 50%

Table 5: Effect of salinity on seedling K^+ and Na^+ contents, and K^+/Na^+ ratio of different rice genotypes

Rice genotypes	K^+ contents (mg g^{-1})			Na^+ contents (mg g^{-1})			K^+/Na^+ ratio		
	Control	Salinity	Decrease over control (%)	Control	Salinity	Increase over control (%)	Control	Salinity	Decrease over control (%)
IR74099-3R-5-1-K3	14.26±0.57 f	12.35±0.51 g	13.39	3.53±0.25 d	14.09±0.40 c	299.15	4.05±0.24 d	0.88±0.04 e	78.27
FL 478	22.11±0.31 b	18.36±0.51 d	16.96	2.73±0.22 ef	13.85±0.44 c	407.33	8.14±0.62 c	1.33±0.06 e	83.66
GAORI	24.29±0.94 a	20.63±0.57 c	16.58	2.69±0.21 ef	15.13±0.71 b	481.04	9.09±0.76 b	1.37±0.06 e	84.93
DONGJINBYEO	22.08±0.57 b	18.85±0.56 d	14.63	1.85±0.13 g	21.28±0.61 a	1050.27	11.98±1.04 a	0.89±0.03 e	92.57
RYKUU 15	19.17±0.27 d	15.85±0.57 e	17.32	2.19±0.17 fg	14.18±0.27 c	547.49	8.81±0.80 bc	1.12±0.08 e	87.29
CHING-YUEH 1	25.32±0.57 a	14.17±0.33 f	44.04	3.15±0.11 de	21.59±0.51 a	585.40	8.04±0.30 c	0.66±0.02 e	91.79
LSD (p 0.01)	1.06			0.74			0.94		

Means not sharing the same letter for a trait differ significantly from each other at p 0.01

Tambhale *et al*. (2011) reported a higher buildup of total polyphenols in tolerant rice cultivar than sensitive one under salinity stress.

In summary, although salinity decreased the growth of all tested rice genotypes; genotypes IR74099-3R-5-1-K3 and FL 478 were more resistant to salt stress, than other genotypes, owing to higher buildup of polyphenols and flavonoids, less Na^+ uptake and better K^+/Na^+ ratio, which helped in maintaining leaf area, SLA and growth. Physiological markers like as polyphenols and flavonoids accumulation, and K^+/Na^+ ratio and morphological trait like leaf area may be used for mass screening of rice genotypes for salt resistance.

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