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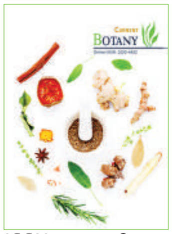

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Morphological screening of rice varieties growing in Assam resistance to aluminium toxicity

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ABSTRACT

When plants are exposed to low pH levels, aluminium, which is unnecessary for plant growth, can be harmful. This experiment was conducted to study the aluminium toxicity induced responses among the 100 rice varieties growing in Assam, India. The rice seeds were grown hydroponically in Hoagland's solution and 10 day old seedlings were subjected to 50 and $100 \mu M AlCl_3$ treatment for 7 days and various growth parameters (viz., root length, shoot length, root fresh weight, shoot fresh weight, root dry weight, shoot dry weight) were recorded. Based on the overall morphological parameters, the aluminium Stress Response Index (SRI) was calculated. Again, iPASTIC software is also used to calculate various tolerance indices. Our experiment identified the Al-tolerant and Al-sensitive rice varieties based on the growth performance. Our findings lead us to conclude that both the Stress Response Index and iPASTIC can be used as a useful method for sorting among a wide range of rice cultivars to assess each variety's resistance to a particular abiotic stress.

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INTRODUCTION

Assam and most of Northeast India and Southeast Asia, including Bangladesh, Myanmar, and portions of China, have severe problems with acid soils. Aluminium (Al) toxicity is considered to be one of the main factors limiting plant growth in acid soils worldwide (Shandilya & Tanti, 2019). Aluminum-hydroxy cations, $Al(H_2O)_6^{3+}$ and Al^{3+}, the most hazardous chemical species of aluminium, are released by aluminosilicate clays and aluminium hydroxide minerals when soil pH falls below 5.5, which causes threat to plants. (Rahman & Upadhyaya, 2020). Root cells are the primary target site of Al^{3+}. Rapid suppression of root extension is the first and most noticeable sign of Al toxicity. Inhibition of root and shoot growth, as well as leaf curling, chlorosis, and necrosis, as well as swelling, thickening, and discoloration of the root are the immediate morphological alterations of plants induced by the Al toxicity (Alvarez *et al.*, 2012; Rosmaninho *et al.*, 2019). Like other abiotic stresses, Al also induces the production of reactive oxygen species (ROS) which causes membrane damages and disturbs the other physiological processes. Al ions attach to the lipid component of the plasma membrane, stiffening the membrane, changing ion fluxes through the membrane, namely the uptake of Ca^{2+} and Al can also bind to DNA firmly, which hinders cell division (Ali *et al.*, 2008).

The most important cereal crop on earth is rice, which is consumed regularly by the majority of people. Roughly half of the global population consumed rice as a staple diet (Rasheed *et al.*, 2021). In order to meet the growing need from a rapidly expanding global population, rice output will increase day by day. Previous studies have shown that rice plants are considerably more Al-tolerant than other minor cereal crop species, despite the fact that they are not completely immune to Al phytotoxicity (Pradhan *et al.*, 2023). Many studies have reported that Al toxicity reduced the length of primary root, decreased the number of lateral roots and root surface area in rice (Samad *et al.*, 2021). According to the study of Mishra and Dubey (2008) Al^{3+} toxicity inhibits the activities of the enzyme amylase and starch phosphorylase, which hydrolyze starch, disrupting the metabolism of starch and sugars in developing rice seedlings. Al^{3+} has a strong detrimental effect on the upland rice plants' mineral nutrition, particularly in the roots. The interaction between Al and Ca leads to a drop in Ca content in the plant tissue. The intake of iron (Fe) and manganese (Mn) is most impacted by Al^{3+} among the micronutrients (de Freitas *et al.*, 2017). The rice plant has identified mechanisms for both outward exclusion and internal tolerance in response to Al toxicity. The main defense of rice plants against the entry of Al^{3+} is the increased secretion of organic acids (malate, citrate, etc.), which is part of the external exclusion mechanism. Al-responsive genes (OsSTAR1, OsSTAR2, OsNRAT1, OsALS1, OsFRDL4, OsMGT1, and OsCDT3) have a significant internal function in the tolerance to Al toxicity (Yan *et al.*, 2021; Pradhan *et al.*, 2023).

Since rice is a crop that is frequently farmed in Assam, plant scientists must identify viable rice varieties that may thrive under Al toxicity. In this study, we looked at the different morphological impacts of 100 rice (*Oryza sativa* L.) varieties grown in Assam to Al stress in an effort to ascertain the cultivars' susceptibility or tolerance to the stress. This can open the door for the evolution of an Al-tolerant rice crop plant by exploiting various modern technologies.

MATERIALS AND METHODS

Plant Material and Experimental Conditions

Seeds of 100 rice varieties were collected from Regional Rainfed Lowland Rice Research station (RRLRRS), Gerua, Hajo, Assam and RARS, Akbarpur, Karimganj, Assam. The seeds were first surface sterilized using 0.1% $HgCl_2$ solution and incubated for 4 days at 25±3 °C in an incubator for germination. Germinated seeds were then transferred to Hoagland solution for 5 days at 25-28 °C in a photoperiod-controlled chamber (16 hr light to 8 hr dark). After acclimatization, 50 and 100 μM of $AlCl_3$ along with 500 μM $CaCl_2$ treatment was given to the growing seedlings and grown for another 7 days under similar growing conditions and growth parameters were measured. Three replicates were maintained for each Al concentration, and untreated plants were treated as the control.

Growth and Biomass Measurement

The lengths of the roots and shoots, their fresh weights, and their dry weights were used to measure the growth of the plants. Using a metric scale, the lengths were measured in centimetres. Using an electronic balance, the fresh weight was calculated in grams. The root and shoot tissues were heat-dried for 72 hours at 80 °C in a hot air oven, and the dry weight was then determined by weighing them again.

Aluminium Stress Response Index (SRI)

Aluminium Stress Response Index was calculated by using growth parameters such as root and shoot length, fresh and dry biomass of the root and shoot adopting formula as mentioned by Kalita and Tanti (2020).

$$E_R = C_P/R_{CP},$$

where E_R = relative effect of stress on a parameter, C_P = percentage change in parameter value and R_{CP} = range of CP in the parameter among all cultivars. The mean of the E_R values of all parameters of a cultivar under 100 μm $AlCl_3$ treatment was considered as the "stress response index (SRI)" of the cultivar at that treatment.

Statistical Analysis

This study employed a completely randomized design with three replicates for each experiment. The mean±SE was computed for each result. ANOVA was performed to compare the means in SPSS 20.

Screening of Al-tolerant and Sensitive Cultivar through iPASTIC Analysis

The Plant Abiotic Stress Index Calculator (iPASTIC) is used to calculate yield-based stress tolerance and susceptibility indices for various crop traits including the tolerance index (TOL), relative stress index (RSI), mean productivity (MP), harmonic mean (HM), yield stability index (YSI), geometric mean productivity (GMP), stress susceptibility index (SSI), stress tolerance index (STI), and yield index (YI). This program also estimated an average sum rank (ASR) for all indices. In our experiment, Yp (dry biomass yield of per plant in control) and Ys (dry biomass yield of per plant in 100μm Al stress condition) have been considered to calculate all the indices.

RESULTS

Measurement of Growth in Response to Al

The name and morphology of the 100 rice varieties were noted and mentioned in Table 1. Al treatment led to morphological changes and growth inhibition in rice seedling. It had been noticed that both 50 and 100 μM Al treatments affected the shoot and root lengths of the seedlings. The measure of all the growth parameters of 100 rice cultivars at 50 and 100 μM Al treatments was noted in Table 2. Among the 100 rice varieties, 85 varieties had shown reduction in root growth and 15 varieties had shown increase in root growth when compared with the control. Figure 1 shows the difference in root length between control and plant treated with 100 μm $AlCl_3$ solution. At 100 μm Al treatment the highest reduction in root length was recorded in the variety 'Dusari'(G22), 39.28% reduction followed by varieties 'Basudev'(G57), 29.20%, Piyolee 28.12%, Jaymati 27.1% and Satyabhama 26.6% reduction. However, the variety Moinagiri (G91) showed 22% increase in root length, followed by Kalangi (G80), 11.27% increment. Most of the rice varieties did not show toxicity symptoms in shoot growth. The most reduction in shoot length was shown by Rupohi (G85), 36.17%, followed by Burimakra (G100), 18.33%. Highest shoot growth was observed in variety Moinagiri (G91) and CR Dhan 909(G68) which showed 37% increase in shoot length (Figure 2).

Fresh and Dry Weights

Al stress adversely affected the fresh root biomass in most of the cultivars. Highest reduction in fresh root weight was shown by 'Satayabhama' (G25), 41.95% reduction followed by 'Dusari' (G22), 40.17% reduction. However, in tolerant varieties root fresh biomass was found to be increased under Al stress. 'TN-1' (G72) showed 32.81% increase in root fresh weight followed by 'Moinagiri' (G91) with 31.75% increase. Highest reduction in

Table 1: Name, code and morphology of collected rice varieties

Code	Name of rice variety	Morphology of rice seed			
		Seed shape	Seed colour	Length (cm)	Breath (cm)
G1	Savita	Medium bold (Slight elongated)	Straw yellow	0.9	0.3
G2	T-141	Medium bold	Straw yellow (Dark)	0.7	0.2
G3	SBG 44	Medium bold	Straw yellow	0.9	0.3
G4	SR-70	Medium bold	Straw yellow	0.72	0.3
G5	SR-100	Medium bold	Raddish yellow	0.6	0.3
G6	Bahadur	Medium bold	Straw yellow	0.85	0.3
G7	Varsadhan	Medium bold	Straw yellow	0.9	0.3
G8	SBG33	Medium bold	Straw yellow	0.89	0.3
G9	Binadhan 17	Medium bold	Straw yellow	0.8	0.3
G10	BRRI75	Medium bold	Straw yellow	0.8	0.3
G11	Pooja	Medium bold	Straw yellow	0.7	0.28
G12	C R DHAN 802	Medium bold	Straw yellow	0.8	0.3
G13	IR-64	Medium bold	Straw yellow	0.8	0.3
G14	MATU	Medium bold	Straw yellow	0.72	0.3
G15	Maudamini	Medium bold	Straw yellow	0.8	0.3
G16	Jaya	Medium bold	Straw yellow	0.8	0.3
G17	PUSA-1121	Medium bold	Straw yellow	0.8	0.3
G18	Sugandha	Medium bold	Straw yellow	0.8	0.3
G19	Tengre	Long bold	Straw yellow	0.92	0.35
G20	Surrendra	Medium bold	Straw yellow	0.85	0.3
G21	Savitri	Small bold	Straw yellow	0.6	0.3
G22	Dusari	Medium bold	Straw yellow	0.85	0.3
G23	Joymati	Medium bold	Straw yellow	0.8	0.3
G24	C R DHAN 311	Medium bold	Straw yellow	0.8	0.3
G25	Satyabhama	Medium bold	Straw yellow	0.8	0.3
G26	Abhishek	Medium bold	Straw yellow (light)	0.8	0.3
G27	C R DHAN 310	Medium bold	Straw yellow (light)	0.8	0.3
G28	Dumai	Medium bold	Brown	0.74	0.34
G29	Borbagoonigutia	Medium bold	Straw yellow	0.72	0.3
G30	Baismuthi	Medium bold	Straw yellow	0.8	0.3
G31	Rangai	Medium bold	Pale Straw yellow	0.7	0.2
G32	Dudratia	Medium bold	Straw yellow	0.7	0.26
G33	Mayamati	Medium bold	Pale Straw yellow	0.84	0.21
G34	Kosalu	Medium bold	Straw yellow	0.68	0.2
G35	Kablabadam	Medium bold	Straw yellow	0.72	0.3
G36	Aus jhoria	Medium bold	Red	0.7	0.3
G37	Assamukosaloth	Medium bold	Yellow with black spot	0.74	0.28
G38	Kosaloth	Medium bold	Straw yellow	0.66	0.24
G39	Kola joha	Small bold	Black	0.6	0.2
G40	Bongobandhu	Medium bold	Straw yellow	0.72	0.3
G41	Lal Aus	Medium bold	Red	0.66	0.26
G42	Sadakara	Medium bold	Straw yellow	0.8	0.3
G43	Terabali	Medium bold	Straw yellow	0.8	0.3
G44	Beribhog	Small bold	Blackish	0.6	0.2
G45	Luit	Medium bold	Straw yellow	0.8	0.3
G46	Gopal Bhog	Medium bold	Straw yellow	0.72	0.3
G47	Balighungoor	Medium bold	Straw yellow with red Spot	0.82	0.2
G48	Kataktara	Medium bold	Straw yellow with red Spot	0.66	0.26
G49	Loskos	Small bold	Brown	0.6	0.2
G50	Dhoria Aus	Medium bold	Reddish Yellow	0.67	0.24
G51	Grem Dhan	Medium bold	Straw yellow	0.72	0.21
G52	Bora	Medium bold	Brownish yellow	0.8	0.3
G53	Boka	Medium bold	Straw yellow	0.72	0.3
G54	Ronga Bora	Long bold	Reddish Yellow	1	0.3
G55	Ranjit	Medium bold	Straw yellow	0.8	0.3
G56	Aijung	Medium bold	Straw yellow	0.8	0.2
G57	Basudev	Medium bold	Straw yellow	0.8	0.3
G58	Piolee	Medium bold	Straw yellow (Light)	0.8	0.3
G59	Kolong	Medium bold	Straw yellow	0.8	0.3
G60	Sorutengaguri	Slender	Straw yellow	0.8	0.2
G61	Bortengaguri	Medium bold	Straw yellow	0.8	0.2
G62	Biboi Sali	Medium bold	Straw yellow	0.72	0.3
G63	Kumrikata	Medium bold	Straw yellow (light)	0.8	0.3
G64	Surajmukhi	Medium bold	Straw yellow	0.72	0.3
G65	Parijat	Long bold	Straw yellow	0.9	0.2

(*Contd...*)

Table 1: (*Continued*)

Code	Name of rice variety	Morphology of rice seed			
		Seed shape	Seed colour	Length (cm)	Breath (cm)
G66	Naveen	Medium bold	Straw yellow	0.8	0.3
G67	Anjali	Medium bold	Straw yellow	0.8	0.3
G68	C R DHAN 909	Medium bold	Straw yellow	0.8	0.3
G69	CR DHAN601	Medium bold	Straw yellow	0.8	0.3
G70	Chandrama	Medium bold	Straw yellow	0.7	0.3
G71	Khaijhoria	Medium bold	Straw yellow	0.72	0.3
G72	TN1	Medium bold	Straw yellow	0.8	0.3
G73	Jeng Bao	Medium bold	Straw yellow	0.7	0.3
G74	Shahbaghi Dhan	Medium bold	Straw yellow	0.72	0.3
G75	SR-25	Medium bold	Straw yellow	0.72	0.2
G76	Sathi	Medium bold	Straw yellow	0.72	0.3
G77	Chanda	Medium bold	Straw yellow	0.72	0.3
G78	Kalti Sali	Medium bold	Straw yellow	0.8	0.3
G79	Prosad Bhog	Medium bold	Straw yellow	0.72	0.3
G80	Kalingi	Medium bold	Straw yellow	0.8	0.3
G81	Kanchan	Medium bold	Straw yellow	0.7	0.2
G82	Disang	Medium bold	Straw yellow	0.8	0.3
G83	Mashuri	Medium bold	Straw yellow (Dark)	0.7	0.3
G84	Swarna	Medium bold	Straw yellow	0.8	0.3
G85	Rupohi	Medium bold	Straw yellow	0.7	0.3
G86	Ranjit Sub-1	Medium bold (elongated)	Straw yellow	0.8	0.2
G87	Swarna Sub-1	Medium bold	Straw yellow	0.72	0.3
G88	Monoha	Medium bold	Straw yellow	0.72	0.28
G89	Biroi	Medium bold	Straw yellow	0.8	0.3
G90	Jol depha	Medium bold	Straw yellow	0.7	0.3
G91	Moinagiri	Medium bold	Red	0.74	0.26
G92	Kakua	Medium bold	Brown	0.7	0.3
G93	CR-309	Medium bold	Straw yellow	0.8	0.3
G94	Tora Bau	Medium bold	Straw yellow	0.72	0.3
G95	Bokul Joha	Small bold	Straw yellow	0.6	0.2
G96	Keteki Joha	Small bold	Straw yellow (light)	0.6	0.2
G97	Baraguta	Medium bold	Straw yellow	0.74	0.3
G98	Konjoha	Small bold	Brown with black tips	0.44	0.2
G99	Tapswini	Medium bold	Straw yellow	0.8	0.3
G100	Burimakra	Medium bold	Brown	0.74	0.26

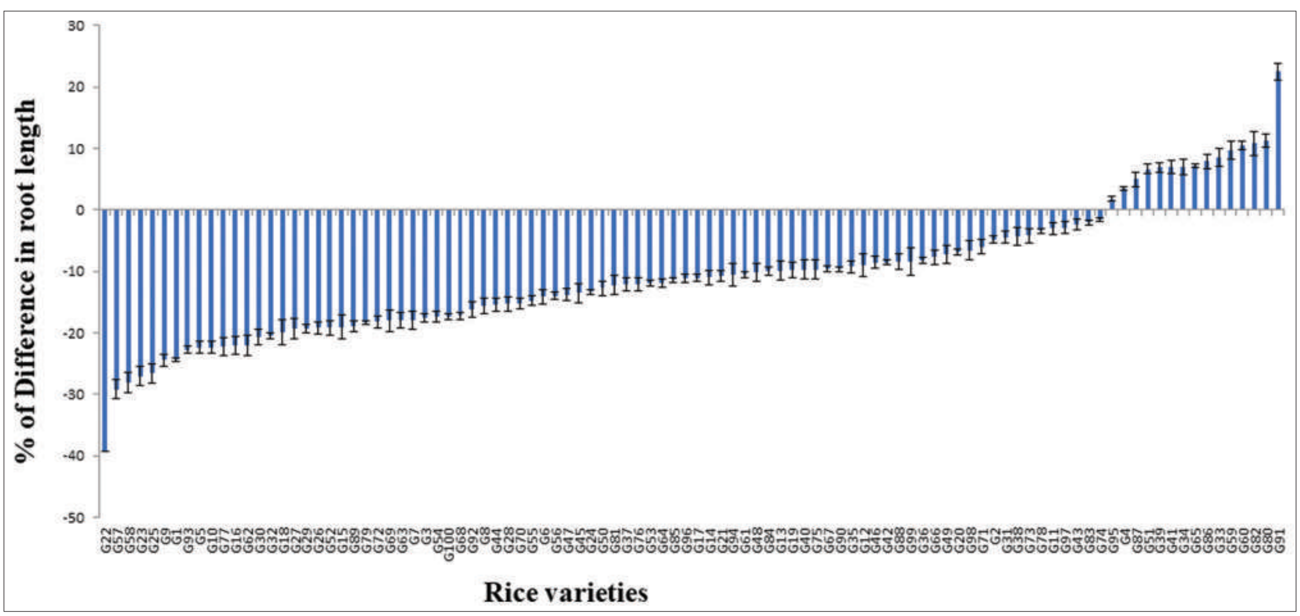


Figure 1: The values of the graph are the differences in root length between the control and 100 μM Al treatment. Data presented are mean±SE (n=3)

shoot fresh weight was recorded in Gopal bhog (G46), 40.48% reduction followed by Abhisek (G26) with 23.61% reduction. 32.12% increase in SFW was shown by Moinagiri (G91) followed by CR dhan 909 (G68) with 28. 36% increase.

Table 2: Measures of all the growth parameters of 100 rice cultivars at 50 and 100 μM $AlCl_3$ treatments. Data are presented as±SE. * indicates that the mean difference is significant at the 0.05 level

Rice variety	Treatment (μm)	RL (cm)	SL (cm)	FRW (mg/plant)	FSW (mg/plant)	DRW mg/plant	DSW (mg/plant)
G1	0	10.40±0.65	19.21±0.97	0.0214±0.009	0.0662±0.011	0.0048±0.001	0.0135±0.001
	50	8.62±0.49*	20.8±1.19	0.0246±0.014	0.0764±0.03	0.0059±0.005*	0.0175±0.003*
	100	7.87±0.47*	21.33±1.23	0.0206±0.009*	0.0799±0.005	0.0056±0.001*	0.0178±0.003
G2	0	7.89±0.22	14.98±0.49	0.0181±0.006	0.0699±0.01	0.0035±0	0.0203±0.004
	50	7.65±0.33*	13.48±0.07	0.0136±0.006	0.0739±0.027	0.0032±0.001*	0.022±0.004*
	100	7.5±0.11*	14.12±0.63	0.0152±0.006*	0.0806±0.004	0.0029±0.001*	0.0254±0.008
G3	0	8.58±0.25	14.55±0.2	0.0117±0.004	0.0687±0.062	0.0027±0	0.0117±0.002
	50	7.27±0.31*	15.78±0.63	0.01006±0.001	0.0776±0.067	0.0033±0.002*	0.0119±0.001*
	100	7.08±0.31*	13.83±0.23	0.0098±0.003*	0.0744±0.078	0.0025±0*	0.011±0.003
G4	0	8.62±0.59	15.32±0.99	0.0137±0.005	0.0511±0.033	0.0021±0.001	0.0113±0.011
	50	8.19±0.27*	16.53±0.8	0.0111±0.013	0.0565±0.011	0.0015±0.001*	0.0105±0.009*
	100	8.91±0.58*	16.8±0.95	0.0155±0.006*	0.0587±0.038	0.0025±0.001*	0.0143±0.014
G5	0	9.56±1.07	12.41±0.41	0.0139±0.009	0.0484±0.024	0.0032±0.002	0.0137±0.002
	50	7.15±0.07*	12.46±1.51	0.01006±0.006	0.0474±0.033	0.0029±0.004*	0.0139±0.011*
	100	7.46±1*	14.52±0.38	0.009±0.005*	0.0545±0.021	0.0025±0.002*	0.0157±0.002
G6	0	10.89±1.1	12.33±0.09	0.0136±0.013	0.0479±0.003	0.0025±0.002	0.0101±0.002
	50	7.90±0.78*	11.33±0.24	0.01366±0.007	0.0489±0.002	0.0029±0.004*	0.0109±0.007*
	100	9.35±0.91*	10.95±0.16	0.0122±0.012*	0.0454±0.004	0.0024±0.003*	0.0093±0.002
G7	0	8.28±0.62	14.03±1.49	0.0304±0.009	0.0501±0.02	0.0037±0.003	0.0109±0.005
	50	7.15±1*	15.6±1.04	0.0194±0.005	0.0513±0.014	0.0028±0.003*	0.0121±0.005*
	100	6.81±0.6*	15.7±1.51	0.0204±0.004*	0.0557±0.016	0.003±0.003*	0.0123±0.005
G8	0	6.97±0.13	13.27±0.15	0.0194±0.009	0.0503±0.005	0.0021±0	0.0104±0.004
	50	5.49±0.83*	12.91±0.58	0.0165±0.003	0.0519±0.039	0.0021±0.001*	0.0114±0.003*
	100	5.89±0.26*	13.73±0.12	0.0156±0.005*	0.0543±0.002	0.0018±0*	0.0109±0.003
G9	0	12.35±63	14.58±0.53	0.0194±0.009	0.0519±0.01	0.0022±0.002	0.0093±0.001
	50	9.72±48*	13.64±0.08	0.0146±0.002	0.0561±0.017	0.0019±0.001*	0.0111±0.002*
	100	9.33±53*	13.56±0.35	0.0144±0.006*	0.0597±0.004	0.0017±0.001*	0.0108±0.001
G10	0	12.99±1.13	14.08±0.16	0.0205±0.007	0.0546±0.019	0.0022±0.001	0.009±0.003
	50	9.95±0.91*	13.52±0.85	0.0169±0.002	0.0559±0.018	0.002±0.001*	0.0104±0.005*
	100	10.02±0.51*	15.23±0.38	0.0161±0.006*	0.0627±0.014	0.0021±0*	0.0113±0.004
G11	0	11.77±1.29	13±1.59	0.0172±0.006	0.0457±0.018	0.0021±0	0.0091±0.001
	50	11.15±1.44*	13.23±1.75	0.0174±0.014	0.0471±0.011	0.002±0.001*	0.0094±0.001*
	100	11.45±1.41*	13.29±1.51	0.0149±0.005*	0.0447±0.018	0.0017±0.001*	0.0087±0.001
G12	0	10.79±0.14	11.14±0.38	0.0122±0.008	0.0403±0.02	0.0015±0.001	0.0072±0.003
	50	9.93±0.27*	11.58±0.17	0.0099±0.002	0.0429±0.008	0.0014±0.001*	0.008±0.002*
	100	9.83±0.33*	10.03±0.58	0.0086±0.005*	0.0345±0.014	0.001±0.001*	0.0068±0.003
G13	0	13.24±1.5	11.26±2.03	0.0223±0.011	0.0481±0.019	0.0023±0.001	0.0082±0.008
	50	10.43±0.96*	10.66±1.62	0.0172±0.011	0.0487±0.014	0.0019±0.001*	0.0079±0.005*
	100	11.99±1.6*	11.6±2.07	0.0184±0.011*	0.0564±0.02	0.0022±0.001*	0.0097±0.009
G14	0	11.31±0.42	10.53±0.23	0.01513±0.005	0.0401±0.012	0.0019±0*	0.0085±0.001*
	50	9.76±0.99*	10.3±0.4	0.0116±0.003*	0.0446±0.011	0.0013±0*	0.0088±0.003
	100	10.05±0.17*	9.25±0.05	0.0120±0.003	0.0422±0.01	0.0013±0	0.0089±0
G15	0	12.21±1.5	13.8±0.46	0.0185±0.009	0.0586±0.013	0.0022±0.001*	0.0111±0.003*
	50	9.39±1.6*	11.5±1	0.0123±0.002	0.0464±0.013	0.0015±0*	0.0097±0.003
	100	9.94±1.4*	11.86±0.59	0.01413±0.009*	0.0485±0.008	0.0015±0	0.0097±0.001
G16	0	12±1.7	13.26±0.72	0.0202±0.006	0.0653±0.009	0.0023±0	0.012±0.003
	50	8.69±0.36*	11.83±0.42	0.0239±0.004	0.0521±0.005	0.0028±0*	0.0101±0.002*
	100	9.34±0.30*	12.16±0.62	0.0228±0.004*	0.0513±0.01	0.0027±0*	0.0104±0.002
G17	0	12.74±2.01	12.43±0.41	0.0286±0.02	0.0613±0.005	0.0029±0.002	0.0099±0.004
	50	11.78±1.78*	11.13±0.75	0.0205±0.02	0.0519±0.009	0.0021±0.002*	0.0093±0.005*
	100	11.28±1.68*	11.23±0.15	0.0196±0.013*	0.0529±0.006	0.0022±0.001*	0.0088±0.003
G18	0	12.72±0.40	15.9±0.25	0.0174±0.002	0.0527±0.006	0.0023±0	0.0104±0.002
	50	10.98±0.51*	16.33±0.44	0.0167±0.002	0.0494±0.01	0.0022±0.001*	0.0103±0.002*
	100	10.17±0.26*	14.66±0.18	0.0147±0.003*	0.0455±0.01	0.0022±0.001*	0.0096±0.002
G19	0	13.28±0.64	13.33±0.2	0.0262±0.004	0.0752±0.022	0.0027±0.001	0.0136±0.003
	50	11.47±1.27*	12.86±0.67	0.0245±0.011	0.0771±0.006	0.0025±0.001*	0.0131±0.004*
	100	11.94±0.37*	11.85±0.3	0.0232±0.003*	0.0707±0.019	0.0029±0.001*	0.0129±0.004
G20	0	11.94±1.09	10.43±1.1	0.0273±0.017	0.0511±0.01	0.0025±0.001	0.0097±0.003
	50	8.64±0.90*	8.83±0.85	0.0204±0.009	0.0469±0.014	0.0019±0.001*	0.0082±0.005*
	100	11.08±0.74*	9.56±1.18	0.0212±0.016*	0.0497±0.012	0.0023±0.001*	0.0093±0.003
G21	0	9.68±0.72	10.92±0.39	0.0208±0.021	0.0501±0.025	0.0021±0.002	0.0097±0.003
	50	8.8±0.67*	11.1±0.45	0.0204±0.021	0.0506±0.019	0.0021±0.001*	0.0092±0.001*
	100	8.6±0.30*	9.43±0.34	0.0161±0.016*	0.0425±0.019	0.0017±0.001*	0.0081±0.003

(*Contd...*)

Table 2: (*Continued*)

Rice variety	Treatment (μm)	RL (cm)	SL (cm)	FRW (mg/plant)	FSW (mg/plant)	DRW mg/plant	DSW (mg/plant)
G22	0	21.28±3.08	15.54±2.02	0.0244±0.011	0.0597±0.016	0.0028±0.001	0.0117±0.005
	50	16.46±1.96*	14.9±1.2	0.0238±0.01	0.0585±0.013	0.0025±0.002*	0.0117±0.009*
	100	12.73±1.27*	12.66±1.47	0.0145±0.005*	0.0516±0.01	0.0017±0*	0.0092±0.004
G23	0	12.34±1.59	10.92±1.14	0.0172±0.002	0.0461±0.02	0.0019±0.001	0.007±0.003
	50	8.53±0.36*	12.93±2.16	0.0159±0.005	0.0565±0.021	0.0019±0.001*	0.0089±0.005*
	100	8.96±1.06*	9.46±0.87	0.0142±0.001*	0.0488±0.028	0.0016±0.001*	0.0079±0.004
G24	0	13.43±0.49	10.87±0.73	0.0190±0.001	0.0469±0.012	0.0022±0.001	0.0083±0.003
	50	12.10±0.55*	11.92±0.74	0.0187±0.01	0.0603±0.026	0.0022±0.002*	0.0077±0.019*
	100	11.62±0.37*	12.23±0.67	0.0168±0.002*	0.0562±0.007	0.0019±0.001*	0.0098±0.004
G25	0	15.16±1.08	14.50±1.52	0.0343±0.012	0.0695±0.033	0.0035±0.001	0.0109±0.003
	50	12.43±0.94*	11.94±0.79	0.02286±0.01	0.0598±0.02	0.0026±0.001*	0.01±0.005*
	100	11.08±0.50*	11.88±1.29	0.0198±0.003*	0.057±0.025	0.0023±0.001*	0.01±0.004
G26	0	14.93±0.98	10.23±0.74	0.02753±0.02	0.0583±0.024	0.0029±0.002	0.0089±0.004
	50	9.19±0.28*	7.97±0.7	0.01993±0.01	0.0409±0.012	0.0021±0*	0.0079±0.005*
	100	12.04±0.74*	8.46±0.43	0.02006±0.016*	0.0443±0.011	0.0025±0.001*	0.0075±0.003
G27	0	12.62±0.29	8.76±1.39	0.0185±0.008	0.0415±0.017	0.0019±0	0.0065±0.002
	50	9.54±0.37*	9.95±1.27	0.0162±0.008	0.0497±0.015	0.0017±0.001*	0.0076±0.002*
	100	10.17±0.11*	9.53±1.47	0.0149±0.005*	0.0455±0.017	0.0017±0*	0.0075±0.001
G28	0	21.01±1.6	15.96±0.38	0.0136±0.001	0.0484±0.015	0.0019±0	0.009±0.003
	50	18.13±1.05*	15.7±0.61	0.0118±0	0.049±0.017	0.0017±0*	0.0095±0.002*
	100	17.77±1.29*	13.63±0.3	0.0112±0.001*	0.0521±0.016	0.0017±0*	0.0089±0.003
G29	0	11.73±0.54	10.8±0.71	0.0110±0.003	0.0383±0.005	0.0017±0	0.008±0.002
	50	9.72±0.74*	11.98±0.44	0.00953±0.004	0.0415±0.008	0.0015±0.001*	0.0081±0.002*
	100	9.46±0.45*	8.9±0.44	0.0087±0.003*	0.0337±0.003	0.0015±0*	0.007±0.002
G30	0	15.86±1.51	13.88±1.39	0.0112±0.012	0.0513±0.019	0.0019±0	0.01±0.002
	50	12.43±0.19*	13.46±1.92	0.0099±0.015	0.0474±0.019	0.0018±0.001*	0.0108±0.004*
	100	12.56±1.07*	12.06±1.45	0.0090±0.009*	0.0451±0.012	0.0018±0.001*	0.009±0.003
G31	0	12.03±0.41	11.14±0.43	0.0062±0.001	0.0359±0.011	0.0013±0.001	0.0068±0.003
	50	11.67±0.23*	12.66±0.41	0.0072±0.003	0.0383±0.008	0.0015±0*	0.008±0.001*
	100	11.48±0.28*	11.8±0.32	0.0065±0.001*	0.0395±0.006	0.0015±0.001*	0.0079±0.003
G32	0	16.93±0.43	20.76±1.05	0.0103±0.004	0.0679±0.004	0.0021±0.001	0.0127±0.001
	50	13.16±0.63*	18.36±0.49	0.0090±0.004	0.0569±0.015	0.0019±0.001*	0.0118±0.002*
	100	13.43±0.37*	18.63±0.52	0.0076±0.002*	0.0576±0.013	0.0019±0.001*	0.0113±0.001
G33	0	13.76±0.12	14.4±0.15	0.0076±0.002	0.0447±0.008	0.0017±0	0.0097±0.001
	50	14.75±0.44*	15.26±0.72	0.0066±0.002	0.0441±0.016	0.0019±0*	0.0093±0.002*
	100	14.94±0.42*	15.1±0.38	0.0059±0.001*	0.0481±0.003	0.0019±0.*001	0.0101±0.002
G34	0	16.16±1.26	12.53±2.03	0.0046±0.002	0.0304±0.032	0.0015±0	0.0083±0.003
	50	18.83±0.81*	13.53±1.12	0.005±0.002	0.0329±0.017	0.0017±0.001*	0.0094±0.004*
	100	17.29±1.32*	14.06±2.05	0.0043±0.001*	0.0331±0.035	0.0017±0*	0.0093±0.004
G35	0	12.94±0.63	13.18±1.03	0.0143±0.006	0.0539±0.015	0.0019±0	0.0115±0.004
	50	12.65±1.01*	13.76±0.19	0.01293±0.004	0.0461±0.012	0.0017±0*	0.0123±0.002*
	100	11.70±0.33*	13.57±0.95	0.0118±0.005*	0.0457±0.011	0.0015±0*	0.0109±0.003
G36	0	21.44±0.63	17.8±0.51	0.0117±0.002	0.0519±0.013	0.0017±0.001	0.0103±0.004
	50	23.96±0.5*	19±0.44	0.0096±0.006	0.0581±0.028	0.0019±0*	0.0113±0.002*
	100	19.68±0.72*	18.06±0.47	0.0107±0.003*	0.0567±0.016	0.0019±0.001*	0.0113±0.003
G37	0	18.1±1.76	16.86±1.19	0.0126±0.002	0.0707±0.029	0.0023±0.001	0.0143±0.006
	50	17.53±1.34*	18.56±1.3	0.0149±0.009	0.0775±0.034	0.0022±0.002*	0.0164±0.008*
	100	15.87±1.42*	18±1.47	0.0146±0.002*	0.076±0.027	0.0025±0.001*	0.0155±0.005
G38	0	14.31±1.12	15.33±0.57	0.0108±0.004	0.0433±0.006	0.0023±0.001	0.0107±0.003
	50	12.44±1.16*	14.56±1.23	0.0096±0.001	0.0404±0.022	0.0015±0.001*	0.0112±0.001*
	100	13.65±0.83*	16.5±0.25	0.0121±0.004*	0.0479±0.003	0.0018±0.001*	0.0119±0.004
	0	10.84±0.29	14.48±1.24	0.0073±0.001	0.0343±0.009	0.0007±0	0.0061±0.001
G39	50	11.24±0.17*	15.4±0.53	0.0072±0.003	0.0365±0.004	0.0009±0*	0.0065±0.001*
	100	11.60±0.53*	16.68±1.09	0.0077±0.001*	0.0365±0.006	0.0009±0*	0.0064±0.002
G40	0	12.63±0.24	14.95±0.23	0.01246±0.003	0.063±0.01	0.0016±0	0.0097±0.002
	50	12.2±0.64*	14.28±0.56	0.0126±0.001	0.0629±0.011	0.0017±0*	0.0109±0.001*
	100	11.42±0.58*	14.36±0.32	0.0112±0.002*	0.0617±0.009	0.0014±0*	0.0095±0.002
G41	0	17.88±1.16	14.5±0.79	0.0129±0.013	0.0419±0.03	0.0015±0.001	0.0069±0
	50	18.78±1.56*	14.71±1.32	0.0132±0.019	0.0435±0.025	0.0013±0.001*	0.0068±0.001*
	100	19.09±1.01*	15.83±0.73	0.0140±0.014*	0.0463±0.03	0.0017±0.001*	0.0085±0.001
G42	0	11.30±1.36	16.08±0.63	0.0054±0.001	0.0309±0.005	0.0009±0	0.0069±0.006
	50	10.30±0.83*	14.08±1.75	0.0040±0.003	0.0261±0.028	0.0007±0*	0.0058±0.005*
	100	10.33±1.2*	13.75±0.25	0.0042±0.001*	0.0257±0.003	0.0007±0*	0.0059±0.004
G43	0	10.09±0.29	11±1.37	0.0084±0.005	0.0309±0.006	0.0011±0	0.0077±0.002
	50	9.14±0.23*	11.53±1.18	0.0078±0.006	0.0295±0.007	0.0009±0*	0.0071±0.001*
	100	9.85±0.26*	12.4±1.81	0.0072±0.005*	0.0287±0.008	0.0009±0*	0.0063±0.002

(*Contd...*)

Table 2: (*Continued*)

Rice variety	Treatment (μm)	RL (cm)	SL (cm)	FRW (mg/plant)	FSW (mg/plant)	DRW mg/plant	DSW (mg/plant)
G44	0	13.61±1	12.74±0.69	0.0074±0.002	0.0273±0.005	0.0013±0	0.0059±0.001
	50	11.3±1.44*	10.70±0.53	0.0039±0.001	0.0187±0.007	0.0009±0.001*	0.0056±0.003*
	100	11.53±1.01*	14.07±0.79	0.0063±0.001*	0.0223±0.005	0.0011±0*	0.0065±0
G45	0	9.87±1.34	14.1±0.44	0.0104±0.006	0.0441±0.005	0.0016±0.001	0.0081±0.004
	50	8.94±0.75*	12.4±0.87	0.0099±0.007	0.0407±0.009	0.0015±0.001*	0.0089±0.005*
	100	8.54±1.16*	12.43±0.54	0.0086±0.004*	0.0385±0.003	0.0014±0.001*	0.0075±0.003
G46	0	7.16±0.74	10.08±0.87	0.005±0.002	0.0233±0.012	0.0012±0.001	0.0043±0.002
	50	5.34±0.34*	8.72±0.47	0.0054±0.001	0.0195±0.012	0.0007±0.001*	0.0043±0.001*
	100	6.54±0.63*	8.23±0.63	0.0044±0.001*	0.014±0.01	0.0007±0*	0.0037±0.001
G47	0	14.34±0.3	17.63±0.54	0.0153±0.01	0.0599±0.008	0.0019±0.001	0.0091±0.003
	50	11.62±0.6*	17.4±0.46	0.01786±0.006	0.0663±0.02	0.0019±0.001*	0.0111±0.003*
	100	12.35±0.29*	14.86±0.35	0.0136±0.007*	0.0639±0.006	0.0017±0.001*	0.0108±0.002
G48	0	23.58±1.06	16.83±0.72	0.0258±0.003	0.0516±0.014	0.0037±0.004	0.0121±0.004
	50	19.27±1.5*	13.56±1.33	0.0231±0.017	0.0447±0.035	0.0027±0.002*	0.0104±0.004*
	100	21.16±0.64*	15±0.4	0.022±0.006*	0.0431±0.005	0.0024±0.002*	0.0104±0.002
G49	0	22.17±1.13	14.2±0.92	0.0152±0.004	0.0439±0.004	0.0019±0.001	0.0111±0.002
	50	18.56±1.26*	14.26±0.59	0.0125±0.007	0.0455±0.008	0.0017±0*	0.0094±0.001*
	100	20.54±0.86*	15.3±0.9	0.0146±0.004*	0.0518±0.004	0.0017±0.001*	0.01±0.002
G40	0	12.63±0.24	14.95±0.23	0.01246±0.003	0.063±0.01	0.0016±0	0.0097±0.002
	50	12.2±0.64*	14.28±0.56	0.0126±0.001	0.0629±0.011	0.0017±0*	0.0109±0.001*
	100	11.42±0.58*	14.36±0.32	0.0112±0.002*	0.0617±0.009	0.0014±0*	0.0095±0.002
G41	0	17.88±1.16	14.5±0.79	0.0129±0.013	0.0419±0.03	0.0015±0.001	0.0069±0
	50	18.78±1.56*	14.71±1.32	0.0132±0.019	0.0435±0.025	0.0013±0.001*	0.0068±0.001*
	100	19.09±1.01*	15.83±0.73	0.0140±0.014*	0.0463±0.03	0.0017±0.001*	0.0085±0.001
G42	0	11.30±1.36	16.08±0.63	0.0054±0.001	0.0309±0.005	0.0009±0	0.0069±0.006
	50	10.30±0.83*	14.08±1.75	0.0040±0.003	0.0261±0.028	0.0007±0*	0.0058±0.005*
	100	10.33±1.2*	13.75±0.25	0.0042±0.001*	0.0257±0.003	0.0007±0*	0.0059±0.004
G43	0	10.09±0.29	11±1.37	0.0084±0.005	0.0309±0.006	0.0011±0	0.0077±0.002
	50	9.14±0.23*	11.53±1.18	0.0078±0.006	0.0295±0.007	0.0009±0*	0.0071±0.001*
	100	9.85±0.26*	12.4±1.81	0.0072±0.005*	0.0287±0.008	0.0009±0*	0.0063±0.002
G44	0	13.61±1	12.74±0.69	0.0074±0.002	0.0273±0.005	0.0013±0	0.0059±0.001
	50	11.3±1.44*	10.70±0.53	0.0039±0.001	0.0187±0.007	0.0009±0.001*	0.0056±0.003*
	100	11.53±1.01*	14.07±0.79	0.0063±0.001*	0.0223±0.005	0.0011±0*	0.0065±0
G45	0	9.87±1.34	14.1±0.44	0.0104±0.006	0.0441±0.005	0.0016±0.001	0.0081±0.004
	50	8.94±0.75*	12.4±0.87	0.0099±0.007	0.0407±0.009	0.0015±0.001*	0.0089±0.005*
	100	8.54±1.16*	12.43±0.54	0.0086±0.004*	0.0385±0.003	0.0014±0.001*	0.0075±0.003
G46	0	7.16±0.74	10.08±0.87	0.005±0.002	0.0233±0.012	0.0012±0.001	0.0043±0.002
	50	5.34±0.34*	8.72±0.47	0.0054±0.001	0.0195±0.012	0.0007±0.001*	0.0043±0.001*
	100	6.54±0.63*	8.23±0.63	0.0044±0.001*	0.014±0.01	0.0007±0*	0.0037±0.001
G47	0	14.34±0.3	17.63±0.54	0.0153±0.01	0.0599±0.008	0.0019±0.001	0.0091±0.003
	50	11.62±0.6*	17.4±0.46	0.01786±0.006	0.0663±0.02	0.0019±0.001*	0.0111±0.003*
	100	12.35±0.29*	14.86±0.35	0.0136±0.007*	0.0639±0.006	0.0017±0.001*	0.0108±0.002
G48	0	23.58±1.06	16.83±0.72	0.0258±0.003	0.0516±0.014	0.0037±0.004	0.0121±0.004
	50	19.27±1.5*	13.56±1.33	0.0231±0.017	0.0447±0.035	0.0027±0.002*	0.0104±0.004*
	100	21.16±0.64*	15±0.4	0.022±0.006*	0.0431±0.005	0.0024±0.002*	0.0104±0.002
G49	0	22.17±1.13	14.2±0.92	0.0152±0.004	0.0439±0.004	0.0019±0.001	0.0111±0.002
	50	18.56±1.26*	14.26±0.59	0.0125±0.007	0.0455±0.008	0.0017±0*	0.0094±0.001*
	100	20.54±0.86*	15.3±0.9	0.0146±0.004*	0.0518±0.004	0.0017±0.001*	0.01±0.002
G50	0	13.64±0.49	11.26±0.82	0.0114±0.006	0.0454±0.012	0.0017±0.001	0.0075±0.005
	50	11.006±1.2*	10.88±0.21	0.0097±0.001	0.0408±0.001	0.0013±0*	0.0083±0.002*
	100	11.92±0.75*	12.31±0.88	0.0101±0.005*	0.0459±0.012	0.0015±0*	0.0083±0.005
G51	0	11.52±0.67	16.28±0.54	0.0146±0.001	0.0485±0.011	0.0016±0	0.0077±0.001
	50	11.01±1.52*	13.36±1.22	0.0126±0.005	0.0426±0.024	0.0015±0.001*	0.0073±0.002*
	100	12.30±0.82*	14.2±0.12	0.0153±0.002*	0.0423±0.009	0.0014±0*	0.0078±0.001
G52	0	15.04±1.29	13.28±0.29	0.0246±0.015	0.0621±0.004	0.0027±0.003	0.0109±0.001
	50	13.2±1.25*	11.06±1.07	0.0189±0.014	0.0507±0.018	0.0021±0.001*	0.0094±0.005*
	100	12.07±0.61*	13.96±0.58	0.0187±0.009*	0.0595±0.001	0.0023±0.002*	0.0103±0.001
G53	0	10.94±1.36	15.06±2.37	0.0145±0.009	0.0515±0.01	0.0016±0.001	0.0076±0.002
	50	8.60±0.7*	13.7±2.35	0.0131±0.005	0.0459±0.018	0.0014±0.001*	0.007±0.003*
	100	9.66±1.3*	12.93±1.92	0.0103±0.004*	0.0403±0.002	0.0013±0*	0.0075±0.002
G54	0	16.26±1.59	11.43±0.87	0.0271±0.008	0.0657±0.029	0.0034±0	0.0135±0.001
	50	12.50±0.09*	10.4±0.97	0.0247±0.032	0.0637±0.061	0.003±0.003*	0.0123±0.001*
	100	13.4±1.17*	10.4±0.86	0.0229±0.009*	0.0583±0.029	0.0027±0*	0.0125±0.001
G55	0	13.28±0.64	7.34±0.38	0.0119±0.002	0.0256±0.003	0.0013±0	0.0047±0.002
	50	11.58±0.16*	8.59±0.32	0.0125±0.004	0.0313±0.004	0.0012±0*	0.0053±0.001*
	100	11.3±0.41*	8.4±0.52	0.0109±0.002*	0.0309±0.003	0.0011±0*	0.005±0.002

(*Contd...*)

Table 2: (*Continued*)

Rice variety	Treatment (µm)	RL (cm)	SL (cm)	FRW (mg/plant)	FSW (mg/plant)	DRW mg/plant	DSW (mg/plant)
G56	0	13.75±0.59	8.7±0.53	0.0185±0.005	0.0315±0.007	0.0016±0.001	0.0053±0.001
	50	11.77±0.72*	8.93±0.43	0.017±0.008	0.036±0.008	0.0017±0*	0.0057±0.003*
	100	11.81±0.42*	9.56±0.47	0.0148±0.007*	0.0349±0.008	0.0013±0*	0.0052±0.001
G57	0	16.56±0.88	11±0.25	0.0174±0.01	0.0466±0.004	0.0017±0.001	0.0065±0.001
	50	11.96±1.14*	9.16±0.41	0.0148±0.001	0.0395±0.02	0.0013±0.001*	0.0062±0*
	100	11.68±0.41*	9.4±0.23	0.0132±0.006*	0.0381±0.007	0.0013±0.001*	0.0059±0
G58	0	15.77±0.06	8.46±0.87	0.0188±0.017	0.0392±0.029	0.0024±0.001	0.0083±0.003
	50	12.13±0.9*	7.94±0.6	0.0155±0.008	0.0404±0.027	0.0021±0.001*	0.0085±0.001*
	100	11.34±0.53*	7.8±0.53	0.0143±0.011*	0.0344±0.023	0.0019±0.001*	0.0077±0.002
G59	0	12.12±0.68	13.73±0.72	0.0154±0.004	0.0606±0.013	0.0021±0	0.0096±0.002
	50	12.26±0.25*	14.66±0.65	0.0163±0.007	0.0637±0.024	0.0022±0.002*	0.0119±0.003*
	100	13.32±0.91*	15.34±0.68	0.0181±0.003*	0.0684±0.022	0.0027±0.001*	0.0121±0.001
G60	0	10.63±0.44	11.83±0.12	0.0147±0.003	0.0388±0.025	0.0016±0.001	0.0087±0.006
	50	11.58±0.7*	12.26±0.22	0.0135±0.004	0.0415±0.024	0.0015±0.001*	0.0093±0.007*
	100	11.72±0.13*	13.16±0.32	0.0131±0.003*	0.0419±0.027	0.0014±0.001*	0.0095±0.007
G61	0	12.95±0.34	19.40±0.3	0.0132±0.003	0.053±0.009	0.0013±0	0.0089±0.001
	50	11.56±0.54*	18.7±0.49	0.0106±0.002	0.0494±0.018	0.0013±0*	0.0077±0.002*
	100	11.61±0.69*	16.86±0.57	0.0113±0.003*	0.0468±0.002	0.0011±0*	0.0081±0.001
G62	0	10.84±0.88	16.6±0.75	0.0108±0.004	0.0419±0.009	0.0011±0	0.0068±0.001
	50	9.47±1.21*	14.63±2.16	0.0102±0.006	0.0427±0.013	0.0013±0.001*	0.0074±0.002*
	100	8.41±0.46*	13.74±0.86	0.0087±0.001*	0.0389±0.009	0.001±0*	0.0058±0.002
G63	0	17.11±0.57	17.98±0.24	0.0151±0.003	0.0579±0.003	0.0019±0.001	0.0111±0.001
	50	14.59±0.33*	16.53±0.43	0.0119±0.003	0.0529±0.006	0.0015±0.001*	0.01±0.002*
	100	14.01±0.16*	17.20±0.38	0.0135±0.002*	0.0505±0.007	0.0015±0*	0.0103±0.001
G64	0	12.43±0.63	14.22±0.41	0.0095±0.002	0.0375±0.008	0.0013±0	0.0055±0.002
	50	9.99±1.3*	14.5±1.15	0.0078±0.003	0.0373±0.02	0.0013±0.001*	0.0061±0.003*
	100	10.95±0.6*	12.83±0.17	0.0075±0.002*	0.0333±0.006	0.0011±0*	0.0054±0.002
G65	0	10.13±0.33	17.46±0.61	0.0137±0.008	0.0513±0.014	0.0016±0	0.0079±0.001
	50	8.08±0.61*	15.93±0.44	0.0124±0.004	0.0522±0.011	0.0015±0.001*	0.0085±0.002*
	100	10.85±0.13*	15.56±0.38	0.0117±0.005*	0.0449±0.01	0.0015±0*	0.0077±0.001
G66	0	10.51±0.52	11.59±0.38	0.0167±0.019	0.0522±0.022	0.0022±0.001	0.0084±0.004
	50	10.39±0.85*	13.89±0.19	0.0181±0.026	0.0683±0.051	0.0028±0.003*	0.0114±0.005*
	100	9.69±0.49*	13.97±0.39	0.0208±0.023*	0.0653±0.026	0.0026±0.001*	0.0107±0.004
G67	0	12.34±0.6	21.21±1.88	0.0338±0.012	0.0883±0.032	0.0033±0.001	0.0143±0.01
	50	12.24±1.23*	19.38±1.71	0.0391±0.018	0.0973±0.041	0.0046±0.004*	0.0159±0.012*
	100	11.14±0.46*	19.57±1.53	0.0388±0.017*	0.0952±0.031	0.0037±0.001*	0.0164±0.009
G68	0	10.54±0.41	11.18±0.61	0.0186±0.009	0.0607±0.001	0.0022±0.001	0.0095±0.001
	50	9.17±0.1*	14.94±1.16	0.0225±0.021	0.0819±0.005	0.0027±0*	0.0119±0.005*
	100	8.7±0.07*	15.35±0.83	0.0209±0.01*	0.0779±0.006	0.0026±0.001*	0.0119±0.001
G69	0	9.52±0.80	11.02±0.56	0.0184±0.006	0.0479±0.016	0.0027±0.001	0.0086±0.005
	50	7.72±0.20*	13.10±1.24	0.0201±0.025	0.0577±0.047	0.0028±0.003*	0.0104±0.009*
	100	7.76±0.43*	13.43±0.51	0.0227±0.007*	0.0577±0.012	0.0029±0.001*	0.0094±0.005
G70	0	10.09±0.37	12.73±0.51	0.0206±0.027	0.0649±0.022	0.0029±0.001	0.0099±0.002
	50	9.27±0.60*	14.83±0.49	0.0223±0.031	0.0773±0.027	0.0033±0.001*	0.0112±0.004*
	100	8.56±0.38*	13.72±0.41	0.0185±0.024*	0.0703±0.021	0.0027±0.001*	0.0111±0.003
G71	0	8.1±0.66	15.89±0.67	0.0172±0.016	0.0549±0.003	0.0023±0	0.0095±0.001
	50	7.49±0.68*	14.35±0.18	0.064±0.22	0.0641±0.01	0.0026±0.001*	0.0471±0.182*
	100	7.61±0.59*	17.33±0.96	0.0168±0.016*	0.0671±0.001	0.0027±0*	0.0119±0.002
G72	0	9.56±1.2	19.02±1.46	0.0148±0.017	0.0729±0.005	0.0041±0.007	0.0141±0.005
	50	7.42±0.33*	17.68±1.99	0.0165±0.029	0.0802±0.044	0.0043±0.006*	0.0159±0.008*
	100	7.73±0.60*	20.55±1.41	0.0197±0.022*	0.086±0.006	0.0052±0.01*	0.0175±0.004
G73	0	7.64±0.21	12.30±0.27	0.0086±0.003	0.0332±0.011	0.0018±0	0.009±0.002
	50	8.1±0.16*	13.12±0.16	0.0108±0.002	0.0467±0.019	0.0023±0.001*	0.0119±0.002*
	100	7.32±0.16*	11.75±0.25	0.0071±0.003*	0.0305±0.008	0.0016±0*	0.0087±0.002
G74	0	8.01±0.51	13.92±0.44	0.0111±0.01	0.0553±0.005	0.0039±0.002	0.0123±0.001
	50	8.12±0.62*	15.09±0.5	0.0115±0.013	0.0641±0.035	0.0031±0.001*	0.0144±0.008*
	100	7.88±0.46*	15.82±0.39	0.0094±0.009*	0.0672±0.005	0.0032±0.002*	0.0155±0.002
G75	0	10.29±0.37	15.08±1.49	0.0171±0.016	0.062±0.027	0.0031±0.001	0.0149±0.003
	50	8.85±0.97*	13.66±1.85	0.0092±0.003	0.0573±0.02	0.0026±0.001*	0.0157±0.004*
	100	9.3±0.40*	12.81±1.21	0.012±0.011*	0.0572±0.017	0.0026±0.001*	0.0153±0.003
G76	0	11.89±0.17	12.88±0.07	0.0118±0.002	0.0457±0.005	0.0025±0	0.0097±0.002
	50	10.58±0.23*	11.98±0.51	0.011±0.002	0.0479±0.003	0.0023±0*	0.0105±0.002*
	100	10.46±0.19*	12±0.12	0.0107±0.001*	0.0447±0.005	0.0021±0*	0.0091±0.001
G77	0	7.94±0.23	9.71±0.16	0.0142±0.015	0.0341±0.004	0.0027±0	0.0091±0.002
	50	6.82±0.65*	11.28±0.37	0.0139±0.011	0.0425±0.009	0.0026±0.001*	0.0099±0.001*
	100	6.17±0.29*	12.04±0.42	0.0135±0.014*	0.0424±0.007	0.0023±0*	0.01±0.002

(*Contd...*)

Table 2: (*Continued*)

Rice variety	Treatment (μm)	RL (cm)	SL (cm)	FRW (mg/plant)	FSW (mg/plant)	DRW mg/plant	DSW (mg/plant)
G78	0	8.55±0.76	8.12±0.11	0.0137±0.001	0.0295±0.004	0.0019±0	0.0071±0.003
	50	8.04±0.47*	8.42±0.19	0.0109±0.001	0.0334±0.006	0.0014±0.001*	0.0078±0.002*
	100	8.26±0.20*	8.71±0.21	0.0117±0.002*	0.0325±0.003	0.0015±0*	0.0077±0.003
G79	0	8.31±0.51	11.07±0.35	0.0151±0.002	0.0464±0.008	0.0027±0.001	0.0101±0.003
	50	7.30±0.37*	11.81±0.68	0.0135±0.003	0.0496±0.007	0.002±0.001*	0.0097±0.002*
	100	6.78±0.39*	10.53±0.33	0.0117±0.003*	0.0441±0.006	0.0019±0.001*	0.0094±0.003
G80	0	9.17±0.27	11.70±0.39	0.0146±0.004	0.0485±0.01	0.0021±0	0.0083±0.005
	50	10.27±0.60*	13.59±2.09	0.0129±0.01	0.0582±0.033	0.002±0.002*	0.0105±0.003*
	100	10.20±0.41*	13.75±0.3	0.0117±0.004*	0.0557±0.009	0.0019±0*	0.0103±0.006
G81	0	7.66±0.44	10.15±0.22	0.0137±0.002	0.0397±0.004	0.0021±0	0.0076±0.002
	50	7.45±0.58*	10.38±0.38	0.0127±0.003	0.0403±0.001	0.0019±0*	0.0074±0.001*
	100	6.73±0.46*	9.58±0.13	0.0113±0.002*	0.0386±0.005	0.0017±0*	0.0073±0.001
G82	0	9.63±0.22	13.02±0.27	0.0131±0.006	0.0835±0.007	0.0028±0.001	0.0126±0.003
	50	9.92±0.87*	14.2±1.38	0.0188±0.03	0.0837±0.005	0.0035±0.002*	0.0142±0.003*
	100	10.69±0.45*	15.55±0.42	0.0166±0.009*	0.0873±0.008	0.0034±0.001*	0.0139±0.002
G83	0	10.52±0.59	12.50±0.38	0.0117±0.005	0.0398±0.014	0.0015±0.001	0.0059±0.001
	50	10.43±0.84*	11.87±0.35	0.0099±0.002	0.0327±0.023	0.0011±0.001*	0.0059±0.001*
	100	10.30±0.56*	11.1±0.5	0.0095±0.004*	0.0331±0.018	0.0012±0.001*	0.0062±0.002
G84	0	11.7±0.57	8.31±0.49	0.0125±0.013	0.0371±0.01	0.0017±0.001	0.0057±0.001
	50	10.28±0.85*	8.23±1.07	0.0135±0.01	0.0371±0.021	0.0015±0.001*	0.0055±0.001*
	100	10.52±0.43*	7.72±0.53	0.0141±0.013*	0.0313±0.007	0.0015±0.001*	0.0059±0.001
G85	0	18.47±0.11	12.2±1.35	0.0259±0.008	0.0481±0.018	0.0038±0.003	0.0075±0.006
	50	16.4±0.81*	10.6±0.64	0.0227±0.004	0.0448±0.023	0.0032±0.001*	0.0083±0*
	100	16.36±0.20*	8.43±0.7	0.0215±0.004*	0.0397±0.011	0.0033±0.002*	0.008±0.006
G86	0	10.82±0.24	7.42±0.23	0.0129±0.003	0.0293±0.006	0.0016±0.002	0.0039±0.001
	50	11.5±0.49*	8.87±0.16	0.0139±0.001	0.0343±0.003	0.0017±0.002*	0.0045±0.001*
	100	11.67±0.25*	7.04±0.19	0.012±0.002*	0.0304±0.005	0.0018±0.002*	0.0047±0.001
G87	0	10.66±0.26	8.89±0.44	0.0121±0.01	0.0322±0.01	0.0015±0.001	0.0056±0.002
	50	11.64±1.3*	10.18±0.35	0.0135±0.007	0.0399±0.005	0.0016±0*	0.0071±0.002*
	100	11.2±0.41*	10.48±0.27	0.0128±0.009*	0.0381±0.012	0.0017±0.001*	0.0067±0.002
G88	0	10.92±0.60	11.48±0.97	0.0151±0.007	0.0479±0.009	0.0016±0.001	0.0081±0.003
	50	9.98±0.97*	10.23±0.67	0.0169±0.001	0.0414±0.019	0.0013±0.001*	0.0071±0.005*
	100	9.96±0.30*	10±0.69	0.0157±0.006*	0.0417±0.017	0.0014±0.001*	0.007±0.003
G89	0	12.08±1.3	9.22±0.470.48	0.011±0.005	0.0291±0.008	0.0015±0	0.0051±0.002
	50	10.38±1.14*	7±0.610.61	0.0095±0.006	0.0247±0.008	0.0011±0.001*	0.0056±0.002*
	100	9.78±0.96*	8.1±0.400.4	0.0097±0.004*	0.0275±0.008	0.0014±0*	0.0055±0.003
G80	0	9.17±0.27	11.70±0.39	0.0146±0.004	0.0485±0.01	0.0021±0	0.0083±0.005
	50	10.27±0.60*	13.59±2.09	0.0129±0.01	0.0582±0.033	0.002±0.002*	0.0105±0.003*
	100	10.20±0.41*	13.75±0.3	0.0117±0.004*	0.0557±0.009	0.0019±0*	0.0103±0.006
G81	0	7.66±0.44	10.15±0.22	0.0137±0.002	0.0397±0.004	0.0021±0	0.0076±0.002
	50	7.45±0.58*	10.38±0.38	0.0127±0.003	0.0403±0.001	0.0019±0*	0.0074±0.001*
	100	6.73±0.46*	9.58±0.13	0.0113±0.002*	0.0386±0.005	0.0017±0*	0.0073±0.001
G82	0	9.63±0.22	13.02±0.27	0.0131±0.006	0.0835±0.007	0.0028±0.001	0.0126±0.003
	50	9.92±0.87*	14.2±1.38	0.0188±0.03	0.0837±0.005	0.0035±0.002*	0.0142±0.003*
	100	10.69±0.45*	15.55±0.42	0.0166±0.009*	0.0873±0.008	0.0034±0.001*	0.0139±0.002
G83	0	10.52±0.59	12.50±0.38	0.0117±0.005	0.0398±0.014	0.0015±0.001	0.0059±0.001
	50	10.43±0.84*	11.87±0.35	0.0099±0.002	0.0327±0.023	0.0011±0.001*	0.0059±0.001*
	100	10.30±0.56*	11.1±0.5	0.0095±0.004*	0.0331±0.018	0.0012±0.001*	0.0062±0.002
G84	0	11.7±0.57	8.31±0.49	0.0125±0.013	0.0371±0.01	0.0017±0.001	0.0057±0.001
	50	10.28±0.85*	8.23±1.07	0.0135±0.01	0.0371±0.021	0.0015±0.001*	0.0055±0.001*
	100	10.52±0.43*	7.72±0.53	0.0141±0.013*	0.0313±0.007	0.0015±0.001*	0.0059±0.001
G85	0	18.47±0.11	12.2±1.35	0.0259±0.008	0.0481±0.018	0.0038±0.003	0.0075±0.006
	50	16.4±0.81*	10.6±0.64	0.0227±0.004	0.0448±0.023	0.0032±0.001*	0.0083±0*
	100	16.36±0.20*	8.43±0.7	0.0215±0.004*	0.0397±0.011	0.0033±0.002*	0.008±0.006
G86	0	10.82±0.24	7.42±0.23	0.0129±0.003	0.0293±0.006	0.0016±0.002	0.0039±0.001
	50	11.5±0.49*	8.87±0.16	0.0139±0.001	0.0343±0.003	0.0017±0.002*	0.0045±0.001*
	100	11.67±0.25*	7.04±0.19	0.012±0.002*	0.0304±0.005	0.0018±0.002*	0.0047±0.001
G87	0	10.66±0.26	8.89±0.44	0.0121±0.01	0.0322±0.01	0.0015±0.001	0.0056±0.002
	50	11.64±1.3*	10.18±0.35	0.0135±0.007	0.0399±0.005	0.0016±0*	0.0071±0.002*
	100	11.2±0.41*	10.48±0.27	0.0128±0.009*	0.0381±0.012	0.0017±0.001*	0.0067±0.002
G88	0	10.92±0.60	11.48±0.97	0.0151±0.007	0.0479±0.009	0.0016±0.001	0.0081±0.003
	50	9.98±0.97*	10.23±0.67	0.0169±0.001	0.0414±0.019	0.0013±0.001*	0.0071±0.005*
	100	9.96±0.30*	10±0.69	0.0157±0.006*	0.0417±0.017	0.0014±0.001*	0.007±0.003
G89	0	12.08±1.3	9.22±0.470.48	0.011±0.005	0.0291±0.008	0.0015±0	0.0051±0.002
	50	10.38±1.14*	7±0.610.61	0.0095±0.006	0.0247±0.008	0.0011±0.001*	0.0056±0.002*
	100	9.78±0.96*	8.1±0.400.4	0.0097±0.004*	0.0275±0.008	0.0014±0*	0.0055±0.003

(*Contd...*)

Table 2: (*Continued*)

Rice variety	Treatment (μm)	RL (cm)	SL (cm)	FRW (mg/plant)	FSW (mg/plant)	DRW mg/plant	DSW (mg/plant)
G90	0	17.3±0.85	8.65±0.180.19	0.0143±0.006	0.0429±0.004	0.0019±0	0.0089±0.003
	50	14.85±0.59*	9.26±0.270.28	0.0141±0.006	0.0437±0.006	0.002±0.001*	0.0093±0.003*
	100	15.61±0.57*	10.96±0.140.15	0.0154±0.006*	0.0485±0.008	0.0021±0*	0.0095±0.004
G91	0	10.38±0.58	7.16±0.600.6	0.0097±0.001	0.026±0.012	0.0017±0.001	0.0115±0.002
	50	13.48±0.18*	8.88±0.790.8	0.0117±0.007	0.0321±0.004	0.0015±0.001*	0.0122±0.002*
	100	12.69±0.50*	9.8±0.660.67	0.0127±0.001*	0.0343±0.014	0.0019±0.001*	0.0126±0.001
G92	0	18.34±0.22	9.01±0.330.33	0.0263±0.006	0.0441±0.011	0.0029±0.001	0.0083±0.002
	50	17.09±0.36*	8±0.150.15	0.023±0.006	0.0405±0.011	0.0023±0.001*	0.0083±0.002*
	100	15.37±0.59*	8.43±0.270.27	0.0237±0.005*	0.0437±0.01	0.0023±0.001*	0.009±0.002
G93	0	12.57±0.70	14.06±0.060.07	0.0188±0.012	0.0575±0.002	0.0024±0	0.0082±0.002
	50	10.83±0.64*	14.26±1.121.13	0.0209±0.009	0.0648±0.017	0.0027±0.001*	0.0125±0.004*
	100	9.68±0.32*	12.93±0.080.09	0.018±0.012*	0.0501±0.01	0.0021±0*	0.0101±0.001
G94	0	12.08±0.67	13.78±1.151.15	0.0175±0.004	0.0495±0.013	0.0025±0	0.0092±0.002
	50	11.45±0.39*	12.98±0.140.15	0.0163±0.004	0.046±0.004	0.0022±0.001*	0.0086±0.001*
	100	10.8±0.59*	12.03±0.750.75	0.0154±0.002*	0.042±0.006	0.0019±0*	0.0083±0.001
G95	0	7.59±0.95	9.58±0.540.55	0.0059±0.003	0.0268±0.018	0.0007±0.001	0.0052±0.004
	50	6.75±0.93*	10.34±0.110.11	0.0053±0.001	0.0281±0.003	0.0008±0.001*	0.0053±0.002*
	100	7.73±0.98*	10.3±0.330.33	0.0061±0.003*	0.0287±0.015	0.0006±0.001*	0.0049±0.002
G96	0	8.52±0.44	16.14±2.92.98	0.0065±0.001	0.0395±0.028	0.0009±0.001	0.0071±0.002
	50	7.14±0.37*	16.96±2.22.24	0.0061±0.003	0.0419±0.021	0.0009±0.001*	0.0075±0.001*
	100	7.57±0.39*	16.64±2.72.77	0.0068±0.001*	0.043±0.028	0.0007±0.001*	0.0082±0.002
G97	0	11.80±0.47	15.86±0.230.23	0.0147±0.002	0.062±0.017	0.0021±0	0.011±0.001
	50	11.13±0.19*	15.62±0.480.48	0.0141±0.004	0.0669±0.016	0.0019±0*	0.011±0.001*
	100	11.44±0.24*	14.41±0.360.37	0.0125±0.001*	0.0587±0.01	0.0018±0*	0.01±0.002
G98	0	9.08±0.38	11.38±0.200.2	0.0067±0.002	0.0247±0.007	0.0013±0.002	0.0039±0.001
	50	8.72±0.45*	11.54±0.070.07	0.0061±0.003	0.0263±0.01	0.0008±0.001*	0.005±0.003*
	100	8.47±0.26*	11.66±0.240.24	0.0059±0.001*	0.0261±0.005	0.0009±0.001*	0.0041±0.001
G99	0	14.76±2.41	14.90±0.240.24	0.0128±0.007	0.0543±0.044	0.002±0.001	0.0081±0.004
	50	13.74±1.64*	14.68±0.170.17	0.0125±0.006	0.0549±0.033	0.0015±0.002*	0.0084±0.001*
	100	13.49±2.05*	14.22±0.300.3	0.0114±0.005*	0.0593±0.042	0.0017±0.001*	0.0087±0.004
G100	0	8.97±1.03	14.48±0.280.29	0.0063±0.001	0.0429±0.003	0.0011±0	0.0053±0.001
	50	9.08±0.54*	12.37±1.371.37	0.0093±0.004	0.0354±0.011	0.0013±0*	0.0053±0.002*
	100	7.40±0.84*	11.01±0.530.53	0.0065±0.001*	0.0341±0.01	0.0009±0*	0.0038±0.001

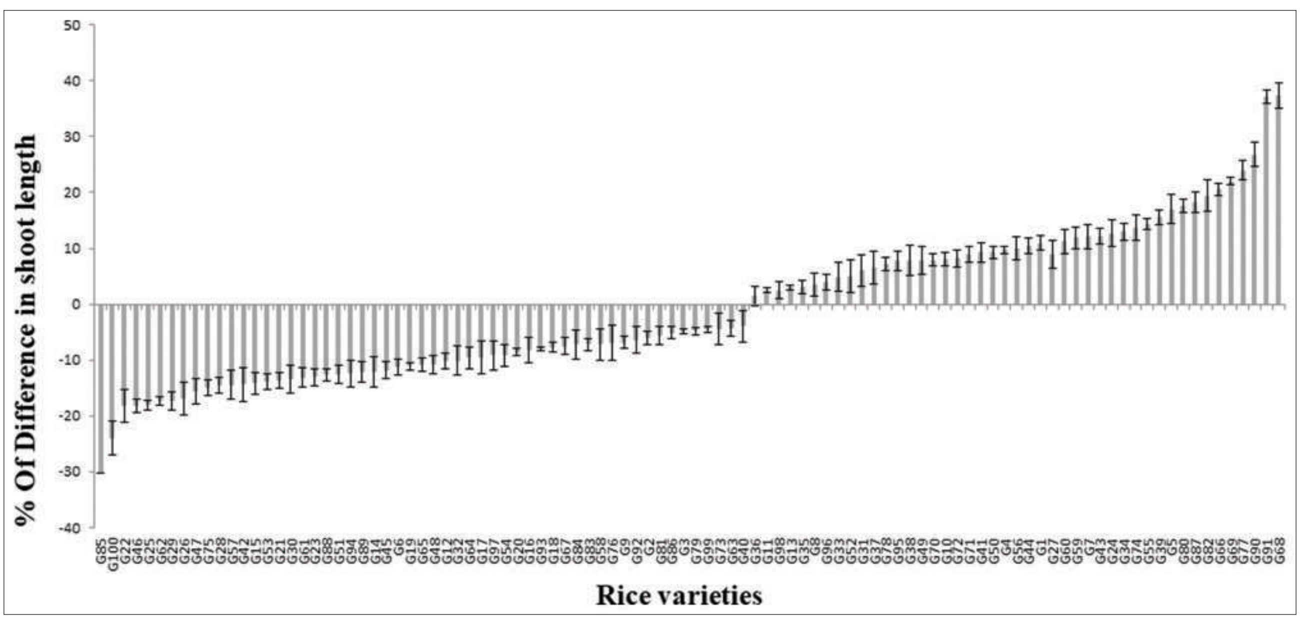


Figure 2: The values of the graph are the differences in shoot length between the control and 100 μM Al treatment. Data presented are mean±SE (n=3)

Al stress reduced the root dry weights also. Maximum reduction in root dry weight was observed in Gopal Bhog (G46) with 44.28% reduction followed by Dusari (G22) showing 40.28% reduction (Figure 3) whereas highest increase in root dry weight was shown by TN-1 (G72) and Kola Joha (G39) with 27.77% increase (Figure 4) Maximum Reduction in shoot dry weight

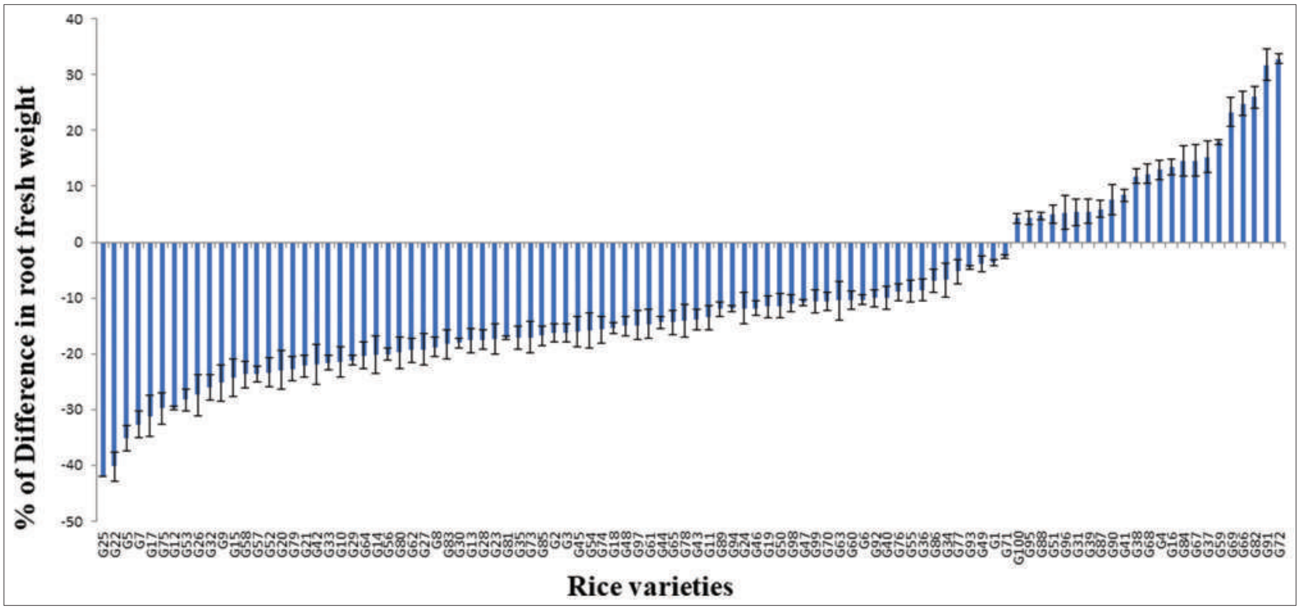


Figure 3: The values of the graph are the differences in root fresh weight between the control and 100 μM Al treatment. Data presented are mean±SE (n=3)

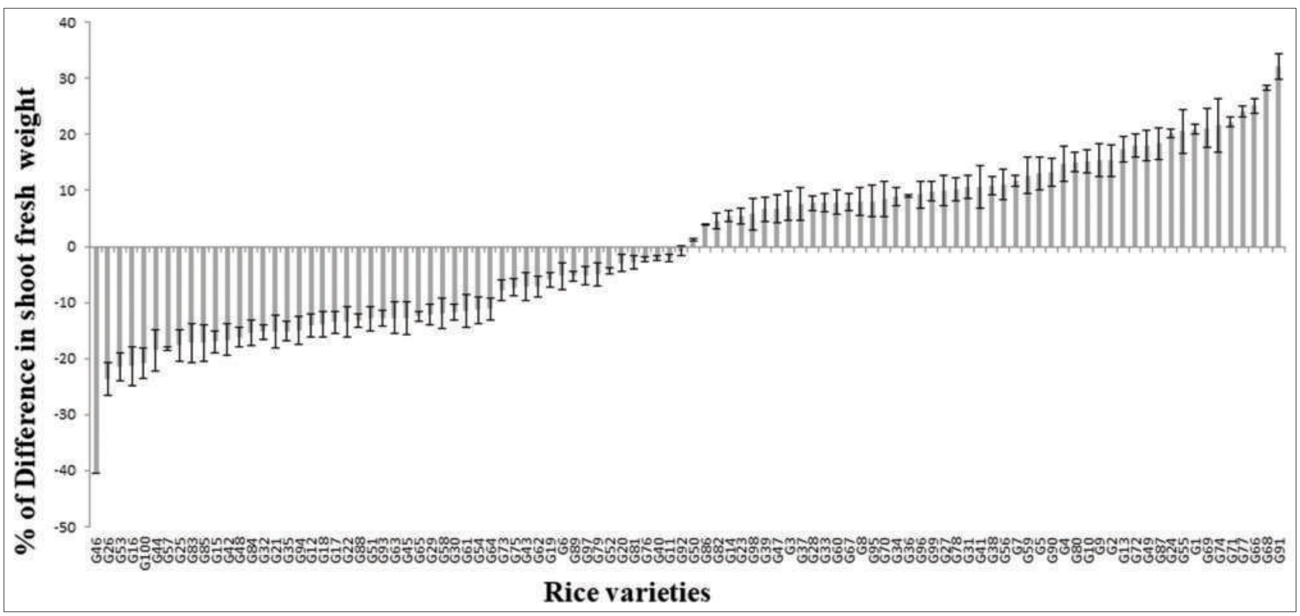


Figure 4: The values of the graph are the differences in shoot fresh weight between the control and 100 μM Al treatment. Data presented are mean±SE (n=3)

was observed in 'Burimakra' (G100), 27.75% reduction followed by Dusari (G22) showing 20.96% reduction (Figure 5). Most of the varieties had shown an increase in shoot dry weights. Savita (G1) showed highest increase in shoot dry weight with 32.13% increase followed by Naveen (G66) showing 28.17% increase (Figure 6).

Stress Response Index (SRI)

The means of the E_R values of all parameters for a particular cultivar under 100 μM $AlCl_3$ gave its stress response index at that concentration. Using this SRI value, as shown in the Figure 7, varieties showing highly positive value were considered to be relatively tolerant whereas highly negative were the most susceptible varieties to aluminium stress.

Screening of Al-tolerant and Sensitive Cultivar through iPASTIC Analysis

Results of the nine yield-based indices due to stress for each rice cultivar, are shown in Table 3. For identifying tolerant genotypes this program estimated an ASR for all indices, which is given in the Table 4. From the results, it was observed that G72 (TN-1), G1 (Savita), G82 (Disang), 67 (Anjali),

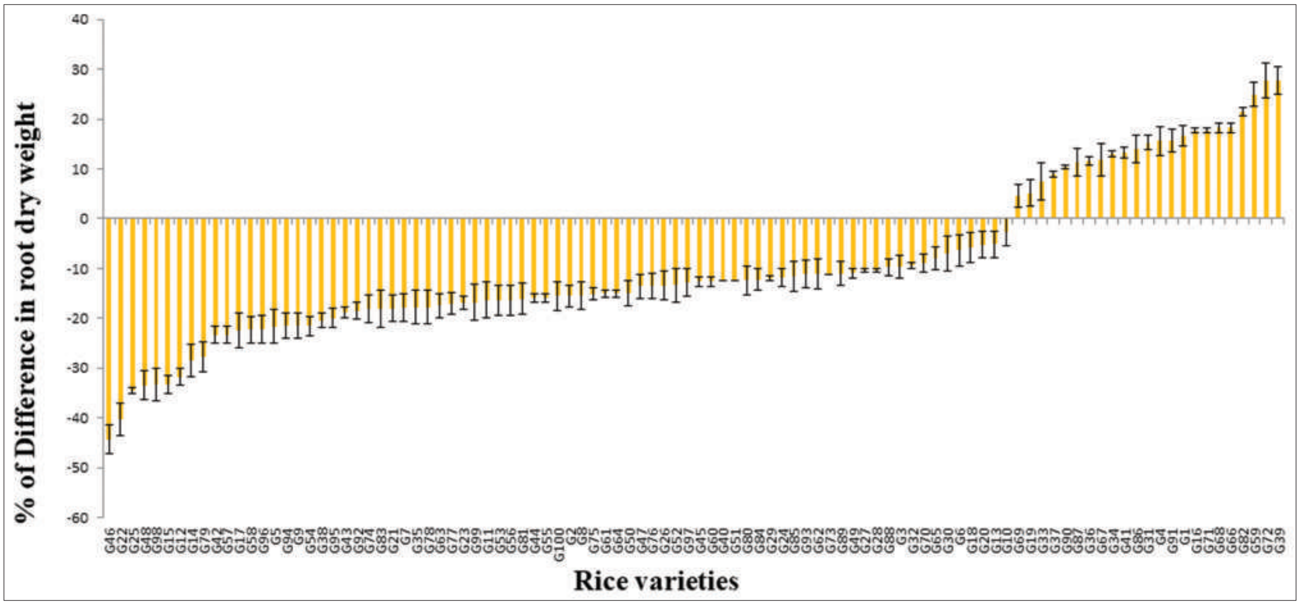


Figure 5: The values of the graph are the differences in root dry weight between the control and 100 μM Al treatment. Data presented are mean±SE (n=3)

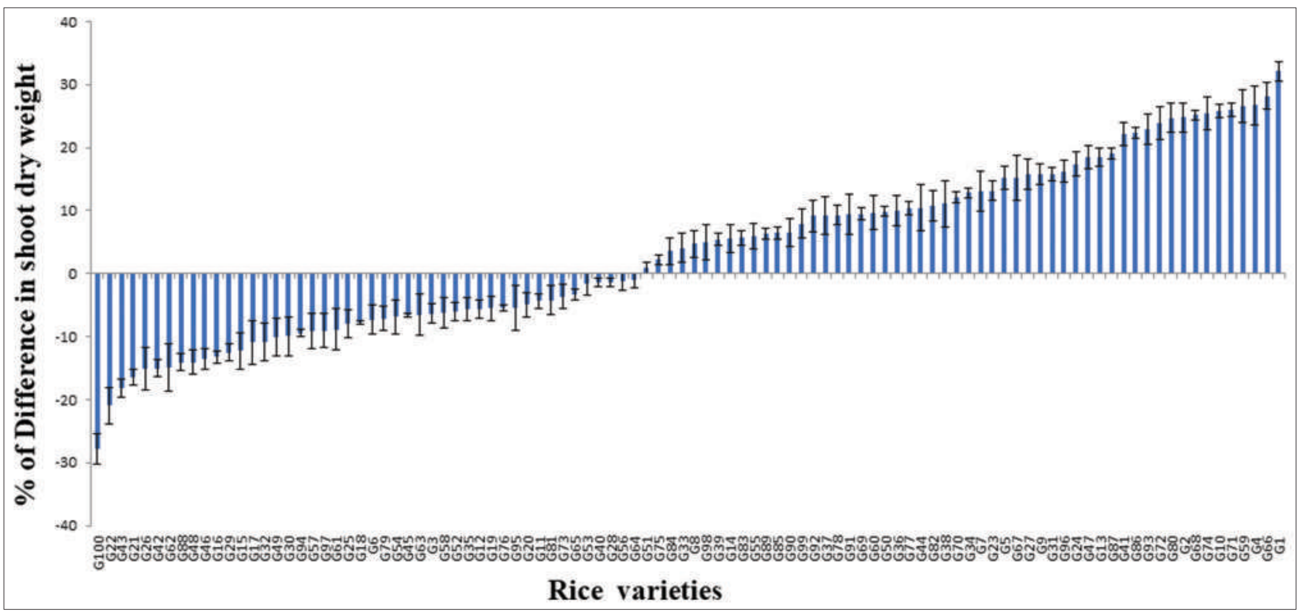


Figure 6: The values of the graph are the differences in shoot dry weight between the control and 100 μM Al treatment. Data presented are mean±SE (n=3)

G16 (Jaya) had the lowest ASR (Figure 8) and G46 (Gopal Bhog), G22 (Dusari), G98 (Kon Joha), G48 (Kataktara), G25 (Satyabhama), G15 (Maudamini) had highest value of SSI as shown in Figure 9. Spearman's correlation coefficients between the tolerance indices and yield in stress and non-stress conditions are shown in Figure 10. Bioplot of 100 rice cultivar and the tolerance indices based on principal component analysis also confirms the result. Principal Component Analysis showing loading factors and eigenvalue are presented in Figure 11.

DISCUSSION

Screening of Rice Cultivars through the Growth Attributes

In acidic soils, Al^{3+} rapidly binds to the cell wall and plasma membrane, causing structural and functional alterations in root systems that led to the reduction of root and overall growth of the plant (Rahman & Upadhyaya, 2021). In our study significant inhibition of root and shoot growth, fresh

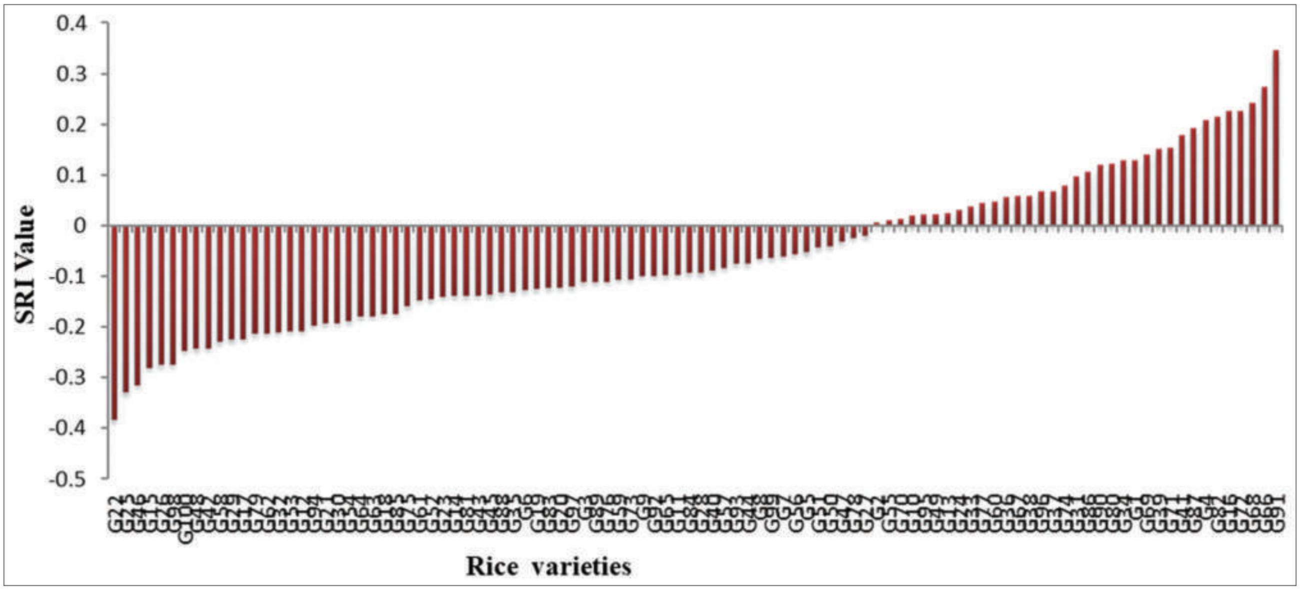


Figure 7: Stress responsive index of 100 rice varieties

Table 3: Yield performance of 100 rice cultivars under control (Y_P) and Al stress (Y_S) conditions along with tolerance and susceptibility indices calculated using iPASCTIC software

Rice variety	Yp	Ys	TOL	MP	GMP	HM	SSI	STI	YI	YSI	RSI
G1	0.0048	0.0056	-0.0008	0.0052	0.0052	0.0052	-1.73	5.88	2.9	1.17	1.29
G2	0.0035	0.0029	0.00053	0.0032	0.0032	0.0032	1.6	2.22	1.52	0.85	0.94
G3	0.0027	0.0025	0.00027	0.0026	0.0026	0.0026	1.01	1.47	1.28	0.9	1
G4	0.0021	0.0025	-0.00033	0.0023	0.0023	0.0023	-1.62	1.15	1.28	1.16	1.28
G5	0.0032	0.0025	0.00073	0.0028	0.0028	0.0028	2.38	1.73	1.28	0.77	0.85
G6	0.0025	0.0024	0.00013	0.0025	0.0025	0.0025	0.55	1.33	1.24	0.95	1.05
G7	0.0037	0.003	0.00067	0.0033	0.0033	0.0033	1.89	2.41	1.55	0.82	0.91
G8	0.0021	0.0018	0.00033	0.002	0.002	0.002	1.62	0.84	0.93	0.84	0.93
G9	0.0022	0.0017	0.00047	0.002	0.002	0.0019	2.2	0.83	0.9	0.79	0.87
G10	0.0022	0.0021	0.00013	0.0021	0.0021	0.0021	0.63	0.99	1.07	0.94	1.04
G11	0.0021	0.0017	0.00033	0.0019	0.0019	0.0019	1.68	0.78	0.9	0.84	0.93
G12	0.0015	0.001	0.00047	0.0012	0.0012	0.0012	3.31	0.32	0.52	0.68	0.75
G13	0.0023	0.0022	0.00013	0.0023	0.0023	0.0023	0.59	1.12	1.14	0.94	1.04
G14	0.0019	0.0013	0.00053	0.0016	0.0016	0.0016	2.97	0.54	0.69	0.71	0.79
G15	0.0022	0.0015	0.00073	0.0018	0.0018	0.0018	3.46	0.71	0.76	0.67	0.74
G16	0.0023	0.0027	-0.0004	0.0025	0.0025	0.0025	-1.83	1.32	1.38	1.18	1.3
G17	0.0029	0.0022	0.00067	0.0025	0.0025	0.0025	2.42	1.38	1.14	0.77	0.85
G18	0.0023	0.0021	0.0002	0.0022	0.0022	0.0022	0.89	1.09	1.1	0.91	1.01
G19	0.0027	0.0029	-0.00013	0.0028	0.0028	0.0028	-0.51	1.71	1.48	1.05	1.16
G20	0.0025	0.0023	0.00013	0.0024	0.0024	0.0024	0.56	1.26	1.21	0.95	1.05
G21	0.0021	0.0017	0.0004	0.0019	0.0019	0.0019	1.95	0.81	0.9	0.81	0.9
G22	0.0028	0.0017	0.00113	0.0022	0.0022	0.0021	4.2	1.02	0.86	0.6	0.66
G23	0.0019	0.0016	0.00033	0.0018	0.0018	0.0018	1.79	0.68	0.83	0.83	0.92
G24	0.0022	0.0019	0.00027	0.0021	0.0021	0.0021	1.26	0.93	1	0.88	0.97
G25	0.0035	0.0023	0.0012	0.0029	0.0028	0.0027	3.6	1.72	1.17	0.65	0.72
G26	0.0029	0.0025	0.0004	0.0027	0.0027	0.0027	1.45	1.55	1.28	0.86	0.95
G27	0.0019	0.0017	0.0002	0.0018	0.0018	0.0018	1.07	0.73	0.9	0.9	0.99
G28	0.0019	0.0017	0.0002	0.0018	0.0018	0.0018	1.07	0.73	0.9	0.9	0.99
G29	0.0017	0.0015	0.0002	0.0016	0.0016	0.0016	1.25	0.53	0.76	0.88	0.97
G30	0.0019	0.0018	0.00013	0.0019	0.0019	0.0019	0.72	0.76	0.93	0.93	1.03
G31	0.0013	0.0015	-0.0002	0.0014	0.0014	0.0014	-1.56	0.45	0.79	1.15	1.27
G32	0.0021	0.0019	0.0002	0.002	0.002	0.002	0.97	0.9	1	0.91	1
G33	0.0017	0.0019	-0.00013	0.0018	0.0018	0.0018	-0.8	0.71	0.97	1.08	1.19
G34	0.0016	0.0018	-0.0002	0.0017	0.0017	0.0017	-1.3	0.63	0.93	1.13	1.24
G35	0.0019	0.0015	0.00033	0.0017	0.0017	0.0017	1.86	0.63	0.79	0.82	0.91
G36	0.0017	0.0018	-0.00007	0.0018	0.0018	0.0018	-0.4	0.68	0.93	1.04	1.15
G37	0.0023	0.0025	-0.0002	0.0024	0.0024	0.0024	-0.92	1.22	1.28	1.09	1.2
G38	0.0023	0.0018	0.00047	0.002	0.002	0.002	2.14	0.89	0.93	0.79	0.88

(*Contd...*)

Table 3: (*Continued*)

Rice variety	Yp	Ys	TOL	MP	GMP	HM	SSI	STI	YI	YSI	RSI
G39	0.0007	0.0009	-0.0002	0.0008	0.0008	0.0008	-2.83	0.15	0.48	1.27	1.41
G40	0.0016	0.0014	0.0002	0.0015	0.0015	0.0015	1.3	0.49	0.72	0.88	0.97
G41	0.0015	0.0017	-0.0002	0.0016	0.0016	0.0016	-1.36	0.58	0.9	1.13	1.25
G42	0.0009	0.0007	0.0002	0.0008	0.0008	0.0008	2.4	0.13	0.35	0.77	0.85
G43	0.0011	0.0008	0.00027	0.0009	0.0009	0.0009	2.6	0.19	0.41	0.75	0.83
G44	0.0013	0.0011	0.0002	0.0012	0.0012	0.0012	1.64	0.3	0.55	0.84	0.93
G45	0.0016	0.0014	0.0002	0.0015	0.0015	0.0015	1.3	0.49	0.72	0.88	0.97
G46	0.0012	0.0006	0.0006	0.0009	0.0008	0.0008	5.19	0.16	0.31	0.5	0.55
G47	0.0019	0.0017	0.00027	0.0018	0.0018	0.0018	1.43	0.7	0.86	0.86	0.95
G48	0.0037	0.0024	0.00127	0.003	0.003	0.0029	3.59	1.93	1.24	0.65	0.72
G49	0.0019	0.0017	0.0002	0.0018	0.0018	0.0018	1.11	0.68	0.86	0.89	0.99
G50	0.0017	0.0015	0.00027	0.0016	0.0016	0.0016	1.6	0.56	0.76	0.85	0.94
G51	0.0016	0.0014	0.0002	0.0015	0.0015	0.0015	1.3	0.49	0.72	0.88	0.97
G52	0.0027	0.0023	0.0004	0.0025	0.0025	0.0025	1.56	1.32	1.17	0.85	0.94
G53	0.0016	0.0013	0.00027	0.0015	0.0015	0.0015	1.73	0.47	0.69	0.83	0.92
G54	0.0034	0.0027	0.00073	0.003	0.003	0.003	2.24	1.98	1.38	0.78	0.87
G55	0.0013	0.0011	0.0002	0.0012	0.0012	0.0012	1.64	0.3	0.55	0.84	0.93
G56	0.0016	0.0013	0.00027	0.0015	0.0015	0.0015	1.73	0.47	0.69	0.83	0.92
G57	0.0017	0.0014	0.00033	0.0016	0.0016	0.0015	2	0.53	0.72	0.81	0.89
G58	0.0024	0.0019	0.00053	0.0021	0.0021	0.0021	2.31	0.98	0.97	0.78	0.86
G59	0.0021	0.0027	-0.00053	0.0024	0.0024	0.0024	-2.6	1.24	1.38	1.25	1.38
G60	0.0016	0.0013	0.00027	0.0015	0.0015	0.0015	1.73	0.47	0.69	0.83	0.92
G61	0.0013	0.0011	0.0002	0.0012	0.0012	0.0012	1.56	0.33	0.59	0.85	0.94
G62	0.0011	0.001	0.00013	0.0011	0.0011	0.0011	1.16	0.25	0.52	0.89	0.98
G63	0.0019	0.0015	0.0004	0.0017	0.0017	0.0016	2.23	0.6	0.76	0.79	0.87
G64	0.0013	0.0011	0.00027	0.0012	0.0012	0.0012	2.08	0.31	0.55	0.8	0.89
G65	0.0016	0.0015	0.00013	0.0015	0.0015	0.0015	0.82	0.52	0.76	0.92	1.02
G66	0.0022	0.0026	-0.0004	0.0024	0.0024	0.0024	-1.89	1.25	1.35	1.18	1.31
G67	0.0033	0.0037	-0.0004	0.0035	0.0035	0.0035	-1.25	2.72	1.93	1.12	1.24
G68	0.0022	0.0026	-0.0004	0.0024	0.0024	0.0024	-1.89	1.25	1.35	1.18	1.31
G69	0.0027	0.0029	-0.00013	0.0028	0.0028	0.0028	-0.51	1.71	1.48	1.05	1.16
G70	0.0029	0.0027	0.00027	0.0028	0.0028	0.0028	0.94	1.71	1.38	0.91	1.01
G71	0.0023	0.0027	-0.0004	0.0025	0.0025	0.0025	-1.83	1.32	1.38	1.18	1.3
G72	0.0041	0.0052	-0.00113	0.0046	0.0046	0.0046	-2.9	4.63	2.69	1.28	1.41
G73	0.0018	0.0016	0.0002	0.0017	0.0017	0.0017	1.15	0.63	0.83	0.89	0.98
G74	0.0039	0.0032	0.00073	0.0036	0.0035	0.0035	1.94	2.75	1.66	0.81	0.9
G75	0.0031	0.0026	0.00047	0.0028	0.0028	0.0028	1.58	1.74	1.35	0.85	0.94
G76	0.0025	0.0021	0.00033	0.0023	0.0023	0.0023	1.4	1.15	1.1	0.86	0.96
G77	0.0027	0.0023	0.0004	0.0025	0.0025	0.0025	1.52	1.4	1.21	0.85	0.94
G78	0.0019	0.0015	0.00033	0.0017	0.0017	0.0017	1.86	0.63	0.79	0.82	0.91
G79	0.0027	0.0018	0.00087	0.0022	0.0022	0.0021	3.38	1.05	0.93	0.67	0.75
G80	0.0021	0.0019	0.00027	0.002	0.002	0.002	1.3	0.87	0.97	0.88	0.97
G81	0.0021	0.0017	0.00033	0.0019	0.0019	0.0019	1.68	0.78	0.9	0.84	0.93
G82	0.0028	0.0034	-0.0006	0.0031	0.0031	0.0031	-2.23	2.08	1.76	1.21	1.34
G83	0.0015	0.0012	0.00027	0.0013	0.0013	0.0013	1.89	0.39	0.62	0.82	0.91
G84	0.0017	0.0015	0.0002	0.0016	0.0016	0.0016	1.2	0.58	0.79	0.88	0.98
G85	0.0038	0.0033	0.00047	0.0036	0.0036	0.0036	1.28	2.77	1.73	0.88	0.97
G86	0.0016	0.0018	-0.0002	0.0017	0.0017	0.0017	-1.3	0.63	0.93	1.13	1.24
G87	0.0015	0.0017	-0.00017	0.0016	0.0016	0.0016	-1.13	0.57	0.88	1.11	1.23
G88	0.0016	0.0014	0.00016	0.0015	0.0015	0.0015	1.04	0.5	0.75	0.9	1
G89	0.0015	0.0014	0.00017	0.0015	0.0014	0.0014	1.13	0.46	0.71	0.89	0.99
G90	0.0019	0.0021	-0.0002	0.002	0.002	0.002	-1.07	0.9	1.1	1.1	1.22
G91	0.0017	0.0019	-0.00027	0.0018	0.0018	0.0018	-1.66	0.7	1	1.16	1.28
G92	0.0029	0.0023	0.00053	0.0026	0.0026	0.0026	1.93	1.46	1.21	0.81	0.9
G93	0.0024	0.0021	0.00027	0.0023	0.0023	0.0023	1.15	1.12	1.1	0.89	0.98
G94	0.0025	0.0019	0.0006	0.0022	0.0021	0.0021	2.53	1.01	0.97	0.76	0.84
G95	0.0007	0.0005	0.0002	0.0006	0.0006	0.0006	2.83	0.09	0.28	0.73	0.8
G96	0.0009	0.0009	0.00007	0.0009	0.0009	0.0009	0.74	0.18	0.45	0.93	1.03
G97	0.0021	0.0018	0.00027	0.0019	0.0019	0.0019	1.34	0.81	0.93	0.87	0.96
G98	0.0013	0.0009	0.00047	0.0011	0.0011	0.0011	3.64	0.25	0.45	0.65	0.72
G99	0.002	0.0017	0.00033	0.0018	0.0018	0.0018	1.73	0.73	0.86	0.83	0.92
G100	0.0011	0.0009	0.00017	0.001	0.001	0.001	1.62	0.21	0.47	0.84	0.93

Table 4: Rank value of different yield-based indices of 100 rice cultivars

Rice variety	Yp	Ys	TOL	GMP	HM	SSI	STI	YI	YSI	RSI	SR	ASR	SD
G1	1	1	2	1	1	1	9	1	1	9	9	36	3.27	3.69
G2	7	8	86	7	7	7	60	7	8	60	60	317	28.82	30.71
G3	19	19	53	18	18	18	34	18	19	34	34	284	25.82	11.5
G4	43	19	10	31	31	31	11	31	19	11	11	248	22.55	11.34
G5	11	19	95	12	12	15	86	12	19	86	86	453	41.18	37.49
G6	25	24	29	25	22	22	24	22	24	24	24	265	24.09	1.97
G7	5	7	92	6	6	6	74	6	7	74	74	357	32.45	36.84
G8	43	45	65	47	46	46	61	46	45	61	61	566	51.45	8.49
G9	37	53	80	46	47	47	82	47	53	82	82	656	59.64	17.83
G10	37	37	29	39	39	37	27	39	37	27	27	375	34.09	5.32
G11	49	53	69	50	50	50	65	50	53	65	65	619	56.27	7.89
G12	85	92	80	87	88	88	93	88	92	93	93	979	89	4.12
G13	31	31	27	33	33	33	26	33	31	26	26	330	30	3.1
G14	59	82	88	73	73	74	92	73	82	92	92	880	80	10.62
G15	37	72	95	53	57	61	95	57	72	95	95	789	71.73	20.67
G16	33	11	5	22	23	23	7	23	11	7	7	172	15.64	9.41
G17	14	31	91	20	21	21	88	21	31	88	88	514	46.73	33.67
G18	31	33	45	37	35	35	31	35	33	31	31	377	34.27	4.13
G19	19	9	21	15	14	12	21	14	9	21	21	176	16	4.82
G20	26	26	31	26	26	26	25	26	26	25	25	288	26.18	1.66
G21	43	53	74	49	49	49	78	49	53	78	78	653	59.36	14.26
G22	17	61	98	36	37	40	99	37	61	99	99	684	62.18	31.37
G23	53	65	65	61	62	62	71	62	65	71	71	708	64.36	5.39
G24	37	38	60	41	41	41	45	41	38	45	45	472	42.91	6.35
G25	7	29	99	11	13	16	97	13	29	97	97	508	46.18	41.25
G26	14	19	74	17	17	17	54	17	19	54	54	356	32.36	21.86
G27	53	53	35	55	53	53	36	53	53	36	36	516	46.91	8.87
G28	53	53	35	55	53	53	36	53	53	36	36	516	46.91	8.87
G29	70	72	35	74	74	73	44	74	72	44	44	676	61.45	15.86
G30	53	45	28	52	52	52	28	52	45	28	28	463	42.09	11.5
G31	87	67	12	85	85	85	12	85	67	12	12	609	55.36	35.08
G32	43	38	35	43	42	42	33	42	38	33	33	422	38.36	4.25
G33	65	41	20	57	56	56	20	56	41	20	20	452	41.09	18.09
G34	72	45	16	63	63	63	14	63	45	14	14	472	42.91	23.88
G35	59	67	71	63	66	66	72	66	67	72	72	741	67.36	4.15
G36	65	45	23	61	60	59	23	60	45	23	23	487	44.27	17.98
G37	33	19	12	30	30	30	19	30	19	19	19	260	23.64	7.02
G38	33	45	80	42	44	44	81	44	45	81	81	620	56.36	19.62
G39	99	93	15	98	98	97	2	98	93	2	2	697	63.36	46.25
G40	72	77	45	78	78	78	48	78	77	48	48	727	66.09	15.06
G41	82	53	12	69	69	69	13	69	53	13	13	515	46.82	28.15
G42	98	98	43	99	99	99	87	99	98	87	87	994	90.36	16.58
G43	95	97	59	95	95	95	90	95	97	90	90	998	90.73	10.85
G44	91	88	35	90	90	90	63	90	88	63	63	851	77.36	18.61
G45	72	77	45	78	78	78	48	78	77	48	48	727	66.09	15.06
G46	93	89	96	97	98	100	97	99	100	100	100	1068	97.09	3.42
G47	53	53	57	58	57	53	58	61	53	53	53	617	56.09	3.24
G48	5	100	9	10	10	96	10	24	96	96	96	480	43.64	42.73
G49	59	45	60	61	60	38	61	61	38	38	38	582	52.91	10.63
G50	65	53	72	72	72	59	72	72	59	59	59	727	66.09	7.3
G51	72	45	78	78	78	48	78	77	48	48	48	727	66.09	15.06
G52	23	77	22	23	23	56	23	29	56	56	56	417	37.91	19.52
G53	72	60	81	81	81	68	81	82	68	68	68	824	74.91	7.89
G54	9	93	9	9	9	84	9	11	84	84	84	412	37.45	38.77
G55	91	35	90	90	90	63	90	88	63	63	63	851	77.36	18.61
G56	72	60	81	81	81	68	81	82	68	68	68	824	74.91	7.89
G57	65	67	75	75	75	79	75	77	79	79	79	823	74.82	4.69
G58	29	85	39	40	39	85	40	41	85	85	85	609	55.36	23.72
G59	43	4	26	29	29	3	29	11	3	3	3	191	17.36	14.2
G60	72	60	81	81	81	68	81	82	68	68	68	824	74.91	7.89
G61	87	35	88	87	87	57	87	87	57	57	57	816	74.18	18.97
G62	94	25	93	93	92	42	93	91	42	42	42	798	72.55	27.99
G63	59	76	68	68	68	83	68	72	83	83	83	800	72.73	7.79
G64	87	51	89	89	89	80	89	88	80	80	80	910	82.73	11.23
G65	72	26	76	76	76	30	76	71	30	30	30	634	57.64	22.81
G66	37	8	26	27	27	5	27	16	5	5	5	199	18.09	11.33

(*Contd...*)

Table 4: (*Continued*)

Rice variety	Yp	Ys	TOL		GMP	HM	SSI	STI	YI	YSI	RSI	SR	ASR	SD
G67	10	5	5	5	5	16	5	3	16	16	16	89	8.09	5.39
G68	37	8	26	27	27	5	27	16	5	5	5	199	18.09	11.33
G69	19	21	15	14	12	21	14	9	21	21	21	176	16	4.82
G70	13	53	14	16	14	32	16	11	32	32	32	244	22.18	13.36
G71	33	5	22	23	23	7	23	11	7	7	7	172	15.64	9.41
G72	2	1	2	2	2	1	2	2	1	1	1	18	1.64	0.5
G73	64	35	63	63	63	40	63	65	40	40	40	601	54.64	12.69
G74	3	93	3	4	4	77	4	6	77	77	77	354	32.18	38.96
G75	12	80	12	11	11	58	11	16	58	58	58	343	31.18	26.38
G76	26	73	31	31	31	52	31	33	52	52	52	445	40.45	14.62
G77	19	77	21	20	20	55	20	26	55	55	55	394	35.82	20.6
G78	59	71	63	66	66	72	66	67	72	72	72	741	67.36	4.15
G79	23	97	35	36	36	94	36	45	94	94	94	635	57.73	29.92
G80	43	51	45	45	45	47	45	41	47	47	47	497	45.18	2.89
G81	49	69	50	50	50	65	50	53	65	65	65	619	56.27	7.89
G82	17	3	8	8	8	4	8	4	4	4	4	72	6.55	4.03
G83	85	60	86	86	86	75	86	86	75	75	75	886	80.55	8.44
G84	65	45	69	69	69	43	69	67	43	43	43	649	59	12.36
G85	4	80	3	3	3	46	3	5	46	46	46	244	22.18	27.27
G86	72	16	63	63	63	14	63	45	14	14	14	472	42.91	23.88
G87	82	19	71	71	71	17	71	60	17	17	17	556	50.55	26.86
G88	72	32	77	77	77	35	77	76	35	35	35	669	60.82	21.13
G89	82	33	84	84	84	39	84	81	39	39	39	730	66.36	22.97
G90	53	16	43	42	42	18	42	33	18	18	18	358	32.55	13.06
G91	70	38	11	57	58	57	10	58	38	10	10	417	37.91	23.72
G92	14	26	86	18	19	19	76	19	26	76	76	455	41.36	29.76
G93	29	33	57	34	34	34	41	34	33	41	41	411	37.36	7.61
G94	26	41	90	38	38	38	89	38	41	89	89	617	56.09	26.59
G95	99	100	43	100	100	100	91	100	100	91	91	1015	92.27	16.84
G96	97	95	24	96	96	96	29	96	95	29	29	782	71.09	34.39
G97	49	45	57	48	48	48	51	48	45	51	51	541	49.18	3.34
G98	87	95	79	92	92	93	98	92	95	98	98	1019	92.64	5.63
G99	52	61	67	53	55	55	67	55	61	67	67	660	60	6.21
G100	95	94	34	94	94	94	62	94	94	62	62	879	79.91	21.19

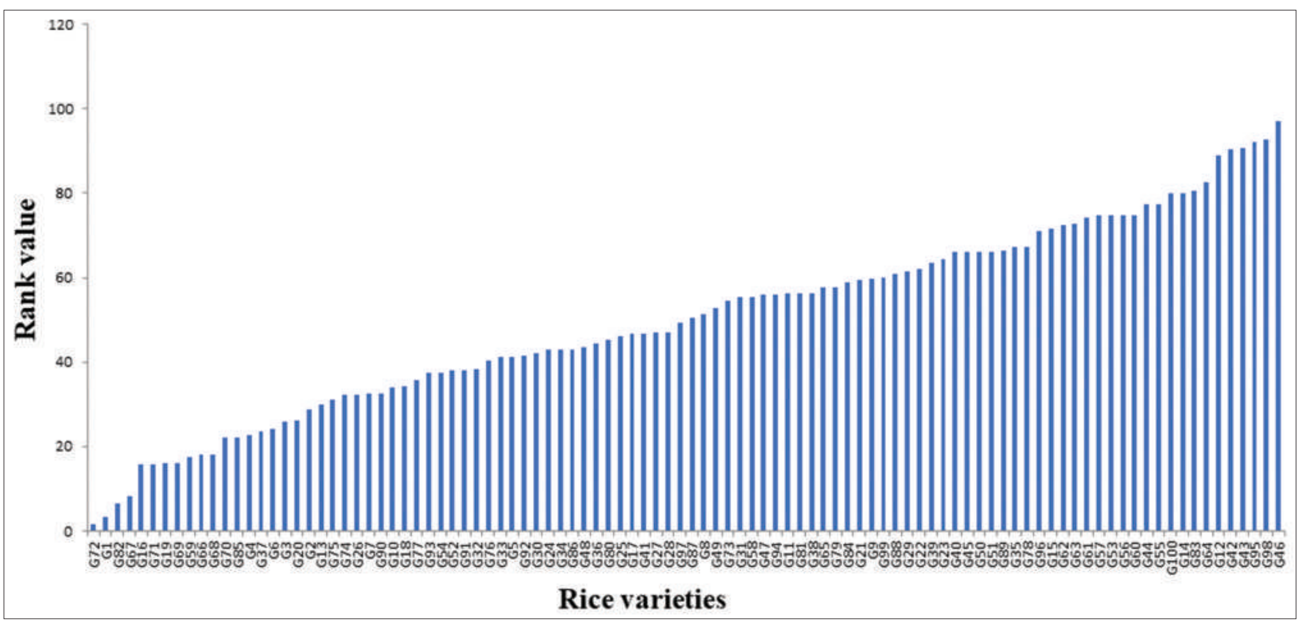


Figure 8: Average Sum Rank Index (ASR)

and dry biomass were seen at both the Al concentrations, with the greatest effect shown at 100 µM. There was a striking resemblance between the toxic symptoms seen and those previously documented in various plants such as rice, mung, pea, etc., however, few cultivars had shown increase in root and shoot length, fresh and dry biomass at both the Al

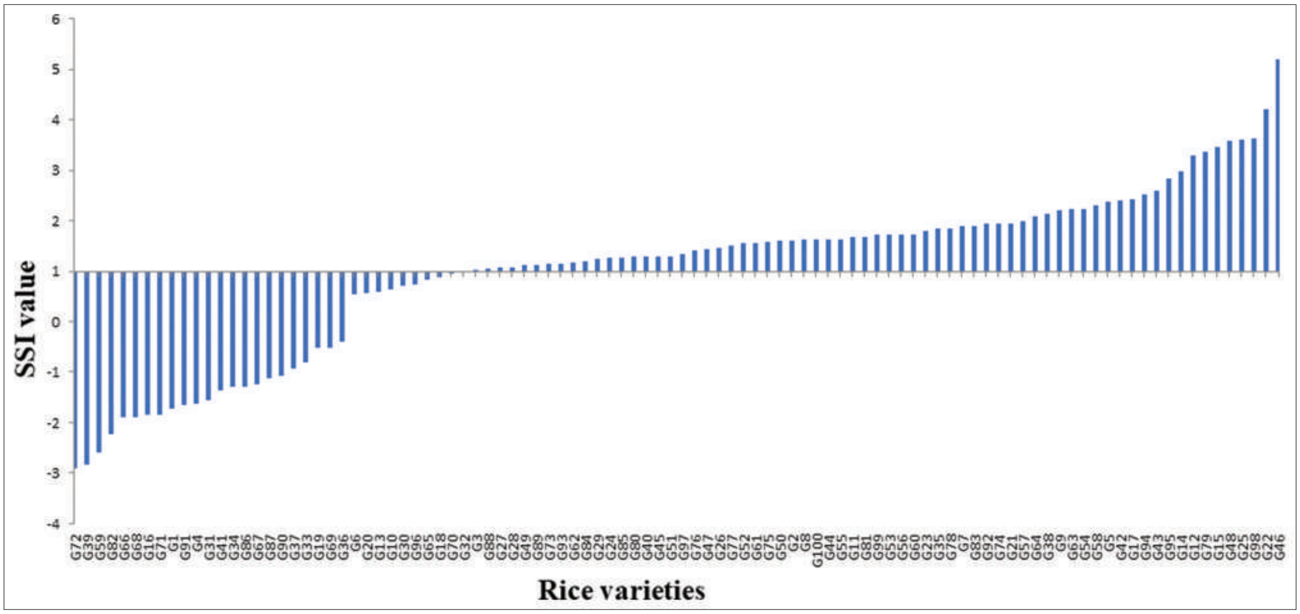


Figure 9: Stress Susceptibility Index (SSI)

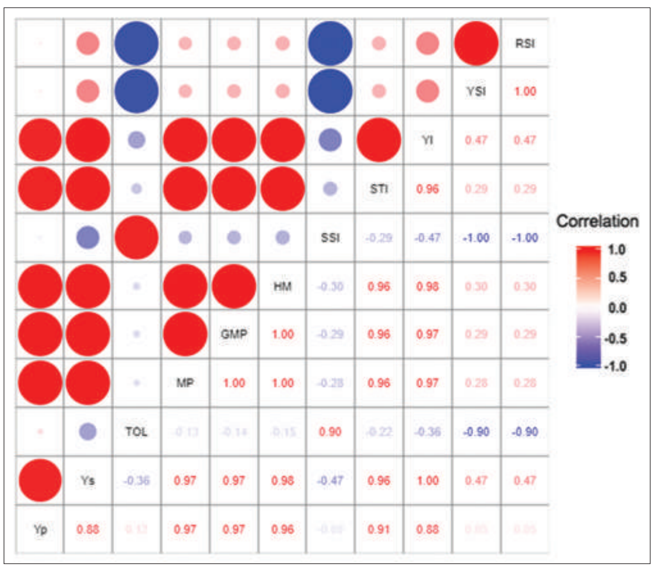


Figure 10: Correlation analysis between the different stress indices

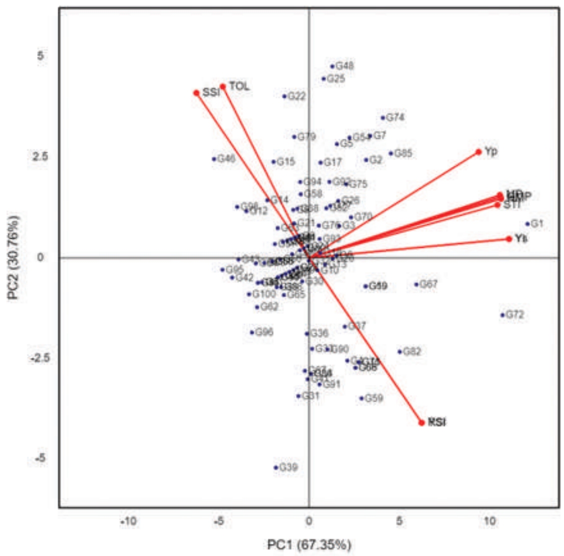
concentrations. It had been reported that for certain native plant species that have adapted to acid soils, Al acted as a beneficial element. It was found that Al^{3+} is indeed necessary for the growth and development of tea roots (Sun *et al.*, 2020). Bressan *et al.* (2021) demonstrated that *Vochysia tucanorum* seedlings exposed to 1110 μM Al displayed enhanced biomass in the roots, stem, and leaves. Our results showed similarity with this previous work. In our experiment growth performance of the rice generated SRI value which identified G91 (Moinagiri), G66 (Naveen), G68 (CR-Dhan909), G72 (TN-1), G16 (Jaya) and G82 (Disang) as relatively tolerant whereas G22 (Dusari), G25 (Satyabhama), G46 (Gopal bhog), G15 (Maudamini), G98 (Konjoha) and G26 (Abhisek) were the most susceptible varieties to aluminium stress.

Screening of Rice Cultivars through iPASTIC Analysis

Pour-Aboughadareh *et al.* (2019) reported that for identifying tolerant genotypes based on a single index could be problematic, so to select potentially superior genotypes, ASR value should be considered. The lower ASR value indicates the superiority of the genotype. In our experiment, varieties G72 (TN-1), G1 (Savita), G82 (Disang), 67 (Anjali), G16 (Jaya) had shown the lowest ASR rank. Among these five varieties, G72, G1, G82, G16 and G59 (Kolong) also showed lower TOL index indicating the highest tolerant Genotype. Genotypes G72, G1, 67 also performed well under non-stress and stressful conditions showing high values for the STI, MP, GMP, and HM indices and will be identified as tolerant. Again, the varieties G72, G59 and G82 also showed high value for RSI index. Similar results were also obtained in other crops including bread wheat (Sardouei-Nasab *et al.*, 2019), durum wheat (Etminan *et al.*, 2019), barley (Khalili *et al.*, 2016), etc.

SSI > 1 indicates above-average susceptibility to stress (Guttieri *et al.*, 2001). The highest SSI indicates the cultivars which performed well in control but showed low yield in Al stress condition hence, those cultivars will be recognized as sensitive ones (Anwaar *et al.*, 2020). In our experiment G46 (Gopal Bhog), G22 (Dusari), G98 (Kon Joha), G48 (Kataktara), G25 (Satyabhama), G15 (Maudamini) showed high value for SSI index. These cultivars have also shown a high value of TOL index which implies that these cultivars are the most low yielding and sensitive in Al stress condition.

Results from the analysis of correlation revealed that positive correlation was found between the biomass yield in the stress (Ys)and non-stress (Yp) conditions with mean productivity (MP), harmonic mean (HM), yield stability index (YSI),



Factors	PC1	PC2
Eigenvalue	7.408724	3.383322
Variability (%)	67.35204	30.75747
Cumulative %	67.35204	98.10951

Figure 11: Biplot based on PC1 and PC2 resulted from the nine indices of 100 rice varieties

geometric mean productivity (GMP), stress tolerance index (STI), relative stress index (RSI), and yield index (YI) indicating that these criteria discriminated the Al- tolerant cultivars with high biomass yield in both stress and non-stress conditions.

The PCA analysis revealed that the first PCA explained 67.35% of the variation. The genotypes with higher values of PC1 are expected to be tolerant cultivars with high yielding. Cultivars G1 (Savita), G72 (TN-1), G82 (Disang), G 67(Anjali) had high values for PC1 and low values for PC2, thus these are identified as tolerant cultivars. Again, the second PCA explained 30.76% of the variability and higher values of PC2 indicate the sensitive one. Varieties G22 (Dusari), G25 (Satyabhama), G48(Kataktara) are the sensitive cultivar showing high value for PC2 (Figure 11).

CONCLUSION

There were notable differences in how the investigated rice cultivars responded to aluminium stress. From this experiment the varieties G1 (Savita), G91 (Moinagiri), G66 (Naveen), G67 (Anjali), G68 (CR- Dhan909), G72 (TN-1), G16 (Jaya) and G82 (Disang) are considered as Al-tolerant and G46 (Gopal Bhog), G22 (Dusari), G98(Kon Joha), G48 (Kataktara), G25 (Satyabhama), G15 (Maudamini), G26 (Abhisek) as Al-sensitive. The identification of this incredibly varied gene pool ought to motivate scientists to investigate important rice progenitor alleles in order to enhance the genetic makeup of current cultivars and create novel Al-tolerant rice variety.

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