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Faqiha PH
Department of Crop Physiology,
Assam Agricultural University,
Jorhat, Assam, India

Ranjan Das
Department of Crop Physiology,
Assam Agricultural University,
Jorhat, Assam, India

Ujjal Baruah
Department of Crop Physiology,
Assam Agricultural University,
Jorhat, Assam, India

Sangita Das
Department of Crop Physiology,
Assam Agricultural University,
Jorhat, Assam, India

Growth study of rice genotypes to varying levels of aluminum

Faqiha PH, Ranjan Das, Ujjal Baruah and Sangita Das

Abstract
The investigation was carried out to study the growth of seven rice genotypes (*Oryza sativa* L.) under different levels of aluminum in the stress physiology laboratory, Department of Crop Physiology, Assam Agricultural University. Results obtained from the investigation revealed that higher levels of aluminum significantly influenced the growth of the genotypes. However, some tolerant genotypes *viz.* Rajamani and Rene Nepung Aam showed a better performance than the other genotypes by maintaining the Leaf area index, Specific leaf weight, Root biomass accumulation and other yield attributing characters (Panicle weight, Harvest index). Considering all these characters Rajamani and Rene Nepung Aam may be considered as tolerant genotypes under high aluminium conditions.

Keywords: aluminum, leaf area index, specific leaf weight, panicle weight, harvest index

Introduction
Rice (*Oryza sativa* L) is one of the world's most important crops, supplying staple food for nearly half of its population, especially in Asia. Rice is not only the principal food crop of India but it also occupies the largest area under cultivation. In most of the rice producing regions of the world, acid soil is one of the most limiting factors for its production. About 13% of global rice production occurs in acidic soils. Acid soils that limit crop production have extended for more than 40% of the world's potentially arable soils (Pariasca-Tanaka *et al.,* 2009) [9]. In acidic soils, poor crop productivity and low soil fertility are mainly due to the combination of aluminium and manganese toxicities coupled with nutrient deficiencies (P, Ca, Mg and K). Among these problems, aluminium toxicity has been identified as a major growth limiting factor in acidic soils (Alvim *et al*., 2012; Pandey *et al.,* 2013) [1, 7]. Aluminium toxicity is a serious problem in low pH acidic soils. Aluminium affects about 40–70% of the world's arable land, which has potential for production of food crops. Aluminium is a light metal that makes up 7% of the earth's crust, and is the third most abundant element after oxygen and silicon (Ma *et al*. 2001) [11]. The soil pH is the single most important factor controlling the amount of Al^{3+} available for plant uptake in the soil solution. There is no evidence that Al is essential for plant growth, although it is beneficial for some plant species (Pilon-Smits *et al*., 2009) [11]. Aluminum can cause harmful effects on plant growth both directly and indirectly. The most direct and obvious effect of Al toxicity on plant growth is the inhibition of root elongation. Even micro molar concentrations of aluminum in the soil solution can rapidly inhibit the root growth of many species (Wissuwa and Ae, 2001; Wissuwa, 2005) [16, 17]. In response to aluminum stress, roots become stubby and brittle. The root tips and lateral roots thicken and turn brown. Effect of Al stresses is not the same in all plants, even within the same species. The roots of the plants is mostly sensitive to Al-toxicity. Binding of Al to the pectin matrix, plasma membrane and other constituents of cell wall causing alteration of cell wall properties and leads to decreased extensibility (Tabuchi and Matsumoto, 2001) [14] cell wall permeability resulting in reduced root growth (Schmohl and Horst, 2000) [13].

Materials and Methods
Experimental site
The experiment was conducted in the Experimental field, Stress Laboratory and PG laboratory of the Department of Crop Physiology, Assam Agricultural University, Jorhat, Assam.

Corresponding Author:
Ranjan Das
Department of Crop Physiology,
Assam Agricultural University,
Jorhat, Assam, India

The experimental site is situated at 26°45′ N latitude, 94°12′ E longitude having an elevation of 87 m above mean sea level.

Plant materials

Seven rice genotypes *viz.* Alubari Dhan, Dewri, Ayang Leima, Marin Chatpi, Rene Nepung Aam, Ronga Betguti, and Rajamani genotypes collected from the different places of North East India. Genotypes were grown in pots of plastic pots (10x15''). The soil was treated with different concentration of aluminium 100 µM Al, 200 µM Al, 300 µM Al (www.hill-laboratories.com) along with a control. The following parameters were recorded under the study.

Leaf area index

Leaf area index was taken at 20 and 50 days after sowing and leaf area index was calculated by using following formula. (Watson, 1952) [15].

LAI = Total leaf area/Ground area covered by the plant

Specific leaf weight

It is a measure of leaf weight per unit leaf area. Hence, it is a ratio expressed as $g\ cm^{-2}$ and the term was suggested by Pearce *et al.*, (1968) [10]. More SLW/unit leaf area indicates more biomass and a positive relationship with yield can be expected.

SLW = Leaf weight/Leaf area

Effective tiller number hill^{-1}

The number of tillers per hill was counted on the tagged plants. It was recorded during the maximum vegetative stage.

Root dry weight

Plants were uprooted and roots were separated and dried in an oven at 80 °C for 3 days until a constant weight was attained. Root biomass was recorded at harvest stage using an electronic balance and was expressed in $g\ pl^{-1}$.

Relative stress injury (RSI)

Fresh leaf sample of 0.5g was washed with distilled water and then placed in tube containing 12ml of deionized water which was kept at 27 °C and then its EC_1 was recorded. The same was autoclaved at 10 Pi for 10 min. then cooled to room temperature and EC_2 was recorded. RSI was calculated using the following formula as suggested by Goyal *et al.,* (2001) [4] and the value was expressed in terms of percentage.

Panicle weight

Individual weight of ten panicles was measured; the average was calculated and expressed in gram.

Harvest index

Harvest index percentage was calculated for each plant of different genotypes and treatments using the formula suggested by Nichi Provinch (1967) [6].

HI = Economic yield/Biological yield

Statistical analysis

Statistical analysis of data was done following the method of analysis of variance (ANOVA) given by Panse and Sukhatme (1967) [8]. The critical difference (CD) values were calculated 5% probability level.

Result and Discussion

Leaf area index (LAI) and specific leaf weight (SLW)

In the present study, it was observed that with an increase in the concentration of aluminium the leaf area index and specific leaf weight were significantly reduced (Table 1 & 2). When compared to control, the highest reduction in leaf area index was recorded in the treatment 300 µM Al followed by treatment 200 µM Al and 100 µM Al. Among the genotypes significant variation in leaf area index and Specific leaf weight was also recorded (Fig 1 & 2).

The interaction between treatments and genotypes were non-significant in terms of leaf area index. In SLW variations due to treatment and genotype interaction were observed significantly. The highest reduction was recorded in the higher concentration of aluminium (300 µM Al) in the genotype Marin Chatpi (-30.56%). While the lowest reduction was recorded in Rajamani (-15.79%)

Effective tiller number

The effective tiller number per hill was recorded to be reduced significantly as the concentration of aluminium increased as compared to control. The reduction in effective tiller number was recorded highest in the treatment 300 µM Al (-27.87%) followed by treatment 200 µM Al (-21.64%) and 100 µM Al (-12.23%) as compared to control.

Among the genotypes the effective tiller number per hill was recorded highest in the genotype Rongabetguti (6.64) followed by Rajamani (6.29) which was at par with Rene Nepung Aam (6.28). A non-significant variation was noticed due to interaction between treatment and genotypes.

Root dry weight

The root dry weight was reduced significantly in all the treatments as compared to normal. There was significant variation amongst the genotypes. On an average, the root dry weight among the genotypes was recorded highest in Rajamani (14.62 g) followed by Rene Nepung Aam (14.28 g). Significant variation was observed due to treatment and genotype interaction. The lowest reduction in the treament 300 µM Al was recorded in Rajamani (-25.92%) followed by Rene Nepung Aam (-26.98%) and Alubari Dhan (-29.77%) while the reduction was recorded highest in Marin Chatpi (-41.53%) in the same treatment. Decrease in root growth in some genotype could be correlated with lower leaf area index and SLW. But some genotype such as Rajamani and Rene Nepung Aam showed higher LAI and SLW which might have been a contributing factor for higher root dry weight.

Relative stress index (RSI)

The relative stress injury increased significantly in all the treatments as compared to control. On an average, the RSI among the genotypes was recorded lowest in Rene Nepung Aam (30.88) followed by Rajamani (32.04) which, whereas the highest RSI value was recorded in the genotype Marin Chatpi (33.76) followed by Dewri (33.19).

A significant variation was observed due to interaction between treatment and genotype interaction. The increase in RSI was recorded highest in 300 µM Al treatment in the genotype Marin Chatpi (32.83%) while the increased in RSI was recorded lowest in Rajamani (16.86%) followed by Rene Nepung Aam (18.96%) and Alubari Dhan (23.20%) in the same treatment as compared to control. Aluminium toxicity led to decrease in membrane stability index which may be due to leakage of plasma membrane and directly related with the loss of membrane integrity due to aluminium. Aluminium

toxicity and having low membrane stability index ultimately results in higher relative stress injury. The genotypes Marin Chatpi recorded with higher relative stress injury. Premchandra *et al.* (1992) [12] reported that cell membrane stability has been widely used to express stress tolerance in plants and higher membrane stability is correlated with stress tolerance.

Panicle weight

The panicle weight was significantly reduced in all the treatments as compared to normal. On an average the panicle weight was recorded highest in Rene Nepung Aam (5.97) followed by Rajamani (5.84) and Dewri (5.78) while the lowest was recorded in the genotype Rongabetguti (5.02) followed by Marin Chatpi (5.26).

Significant variations due to genotype and treatment interaction were also observed. The reduction was recorded highest in Alubari Dhan (-36.92%) in the higher concentration of aluminum. i.e., 300 µM Al. But in the same treatment the lowest reduction was recorded in Rajamani (-23.06%) followed by Rene Nepung Aam (-24.60%). Increase in grain weight also attributed to good panicle length, higher panicle weight due to less number chaffy grain. In tolerant genotypes like Rajamani and Rene Nepung Aam as copmpared some other genotype like Marin Chatpi has higher panicle weight.

Harvest index

With the increase in the concentration of applied aluminium the harvest index of the crop was reduced significantly as compared to control. Increasing aluminium concentration reduced the harvest index proportionately.

Chikuta and Mwala, (2012) [2] reported that harvest index contribute effectively to high yielding (resistant) sorghum genotypes in low pH soil with high aluminium. In the present study highest harvest index was showed by Rajamani followed by Rene Nepung Aam whereas the lowest was recorded in the genotype Dewri followed by Marin Chatpi under varying concentration of Al. Per cent reduction in harvest index was highest in genotype Marin Chatpi and lowest per cent reduction was observed in the genotypes Rajamani followed by Rene Nepung Aam. According to Freitas *et al.*, (2016) [3], reduced number of panicles per plant, grain production, shoots dry matter and harvest index of upland rice cultivars were higher in sensitive cultivars than in tolerant cultivars when grown in soil containing higher amount of alumnium.

According to our study, genotypes *viz.* Rajamani and Rene Nepung Aam showed better partitioning capability with sufficient amount of assimilates and their by maintaining the better HI even under stressful condition.

Table 1: Effect of aluminium on leaf area index (LAI)

Treatment	Alubari dhan	Dewri	Ayangleima	Marin chatpi	Rene nepung aam	Rongabetguti	Rajamani	Mean
Control	3.89	4.09	3.75	3.74	3.89	3.75	3.79	3.86
100 µM Al	3.31	3.22	3.26	3.00	3.49	3.12	3.41	3.29
200 µM Al	3.04	3.01	2.79	2.62	3.14	2.87	3.07	2.95
300 µM Al	2.70	2.70	2.31	2.21	2.81	2.55	2.89	2.61
Mean	3.23	3.25	3.03	2.89	3.32	3.07	3.29	
		T		G		T×G		
C.D (0.05%)		0.122		0.162		NS		
SEd±		0.059		0.079		0.157		
CV		4.981						
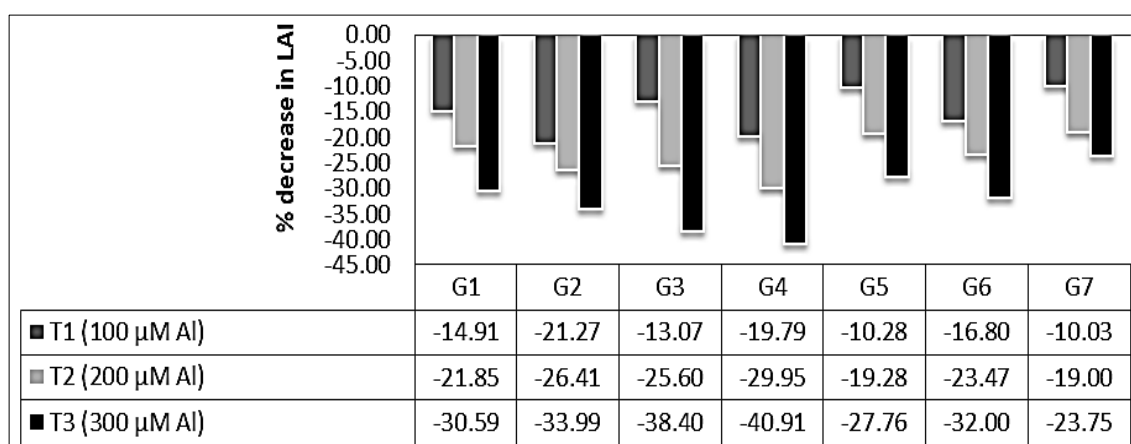
Fig 1: Percent decrease in LAI as compared to control

	G1	G2	G3	G4	G5	G6	G7
T1 (100 µM Al)	-14.91	-21.27	-13.07	-19.79	-10.28	-16.80	-10.03
T2 (200 µM Al)	-21.85	-26.41	-25.60	-29.95	-19.28	-23.47	-19.00
T3 (300 µM Al)	-30.59	-33.99	-38.40	-40.91	-27.76	-32.00	-23.75

Table 2: Effect of aluminium on specific leaf weight (mg cm^{-1})

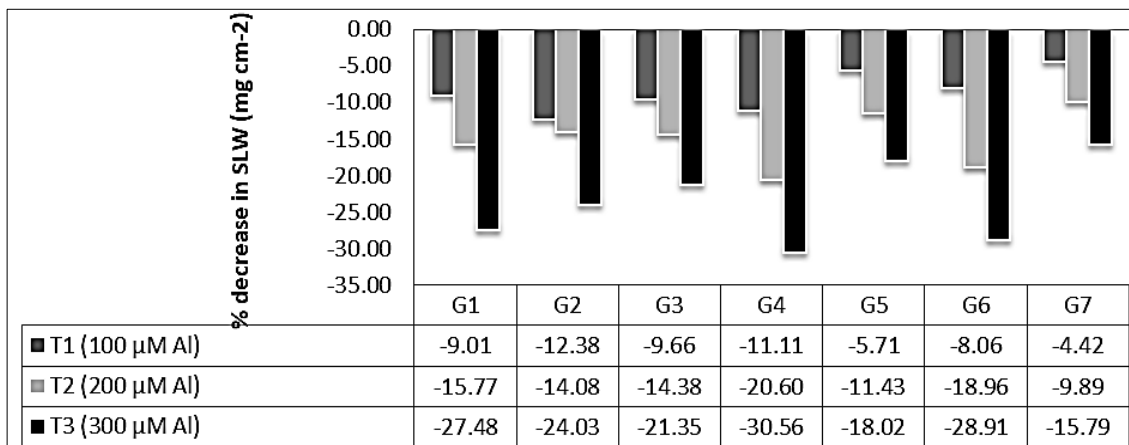| Treatment	Alubari dhan	Dewri	Ayangleima	Marin chatpi	Rene nepung aam	Rongabetguti	Rajamani	Mean
Control	4.44	4.12	4.45	4.32	4.55	4.22	4.75	4.41
100 µM Al	4.04	3.61	4.02	3.84	4.29	3.88	4.54	4.03
200 µM Al	3.74	3.54	3.81	3.43	4.03	3.42	4.28	3.75
300 µM Al	3.22	3.13	3.50	3.00	3.73	3.00	4.00	3.37
Mean	3.86	3.60	3.95	3.65	4.15	3.63	4.39	
		T		G		T×G		
C.D. (0.05%)		0.160		0.121		0.320		
SEd±		0.078		0.059		0.156		
CV		10.12						

Fig 2: Percent decrease in specific leaf weight (mg cm^{-1})

Table 3: Effect of aluminium on effective tiller number at physiological maturity stage

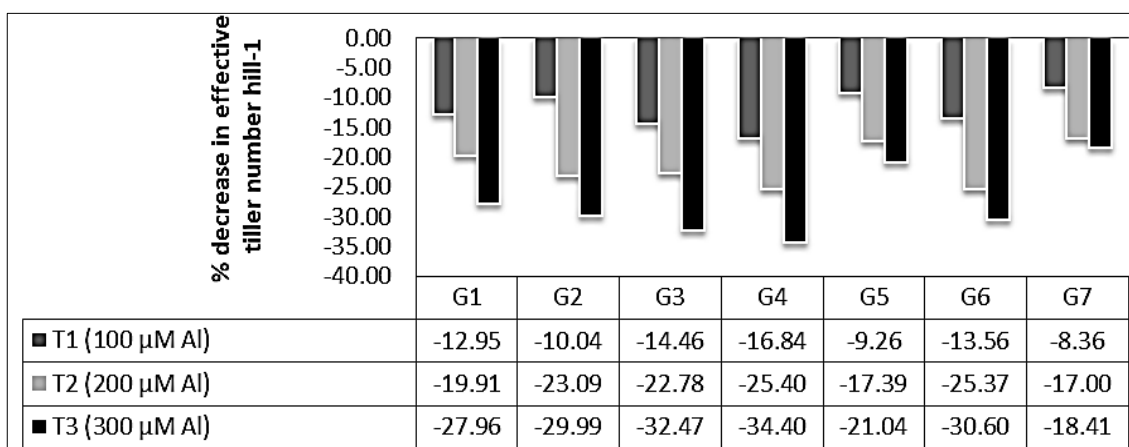| Treatment	Alubari dhan	Dewri	Ayangleima	Marin chatpi	Rene nepung aam	Rongabetguti	Rajamani	Mean
Control	6.33	6.67	7.33	6.89	7.13	8.04	7.06	7.06
100 µM Al	5.51	6.00	6.27	5.73	6.47	6.95	6.47	6.20
200 µM Al	5.07	5.13	5.66	5.14	5.89	6.00	5.86	5.54
300 µM Al	4.56	4.67	4.95	4.52	5.63	5.58	5.76	5.10
Mean	5.37	5.62	6.05	5.57	6.28	6.64	6.29	
		T		G			T×G	
C.D (0.05%)		0.789		1.043			NS	
SEd±		0.393		0.519			1.039	
CV		7.5						

Fig 3: Percent decrease in effective tiller number at physiological maturity stage

Table 4: Effect of aluminium on root dry weight (g plant^{-1}) after harvest

Treatment	Alubari dhan	Dewri	Ayangleima	Marin chatpi	Rene nepung aam	Rongabetguti	Rajamani	Mean
Control	15.72	17.57	17.02	16.95	16.53	15.87	16.90	16.65
100 µM Al	13.98	14.53	14.79	13.41	15.10	13.90	15.12	14.40
200 µM Al	12.57	13.03	12.39	10.82	13.41	12.10	13.95	12.61
300 µM Al	11.04	11.01	10.94	9.91	12.07	11.02	12.52	11.21
Mean	13.33	14.03	13.79	12.77	14.28	13.22	14.62	
		T		G			T×G	
C.D (0.05%)		0.505		0.668			1.336	
SEd±		0.251		0.333			0.665	
CV		5.93						

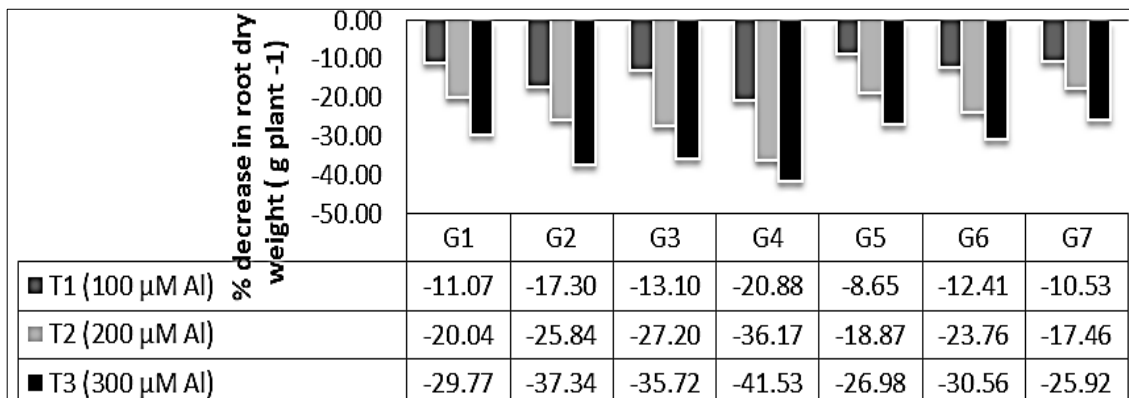|	G1	G2	G3	G4	G5	G6	G7
T1 (100 µM Al)	-11.07	-17.30	-13.10	-20.88	-8.65	-12.41	-10.53
T2 (200 µM Al)	-20.04	-25.84	-27.20	-36.17	-18.87	-23.76	-17.46
T3 (300 µM Al)	-29.77	-37.34	-35.72	-41.53	-26.98	-30.56	-25.92

Fig 4: Percent decrease in root dry weight as compared to control

Table 5: Effect of aluminium on relative stress injury (RSI) at maximum tillering stage

Treatment	Alubari dhan	Dewri	Ayangleima	Marin chatpi	Rene nepung aam	Rongabetguti	Rajamani	Mean
Control	29.22	28.00	27.54	28.66	28.11	28.00	29.00	28.36
100 µM Al	33.03	30.75	31.31	31.88	30.04	30.88	31.55	31.31
200 µM Al	34.27	34.04	34.23	36.44	31.91	33.44	33.71	33.86
300 µM Al	36.00	35.96	35.78	38.07	33.44	36.00	33.89	35.51
Mean	33.13	32.19	32.22	33.76	30.88	32.08	32.04	
		T		G			T×G	
C.D (0.05%)		1.383		1.829			1.383	
SEd±		0.672		0.888			0.672	
CV		7.45						

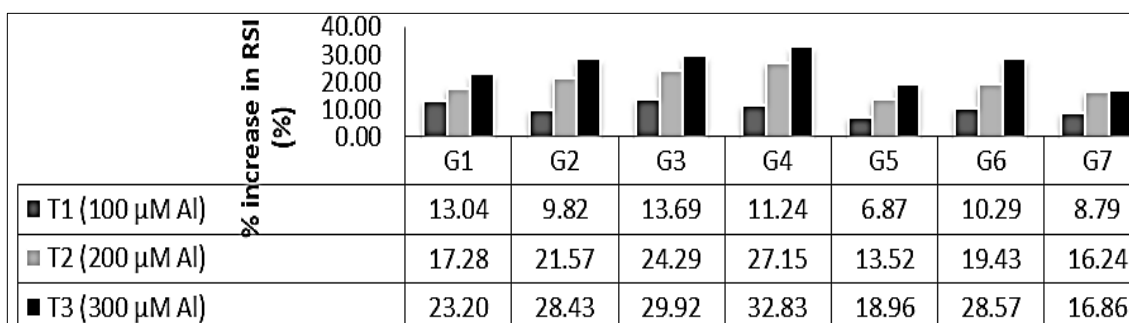|	G1	G2	G3	G4	G5	G6	G7
T1 (100 µM Al)	13.04	9.82	13.69	11.24	6.87	10.29	8.79
T2 (200 µM Al)	17.28	21.57	24.29	27.15	13.52	19.43	16.24
T3 (300 µM Al)	23.20	28.43	29.92	32.83	18.96	28.57	16.86

Fig 5: Percent increase/decrease in RSI as compared to control

Table 6: Effect of aluminium on panicle weight (g panicle^{-1})

Treatment	Alubari dhan	Dewri	Ayangleima	Marin chatpi	Rene nepung aam	Rongabetguti	Rajamani	Mean
Control	6.83	6.63	7.03	6.64	6.79	6.12	6.59	6.66
100 µM Al	5.90	5.87	5.99	5.47	6.09	5.36	6.00	5.81
200 µM Al	5.37	5.61	5.37	4.73	5.87	4.58	5.74	5.32
300 µM Al	4.31	4.99	4.64	4.21	5.12	4.01	5.03	4.62
Mean	5.60	5.78	5.76	5.26	5.97	5.02	5.84	
		T		G			T×G	
C.D (0.05%)		0.16		0.21			0.41	
SEd±		0.08		0.10			0.20	
CV		4.5						

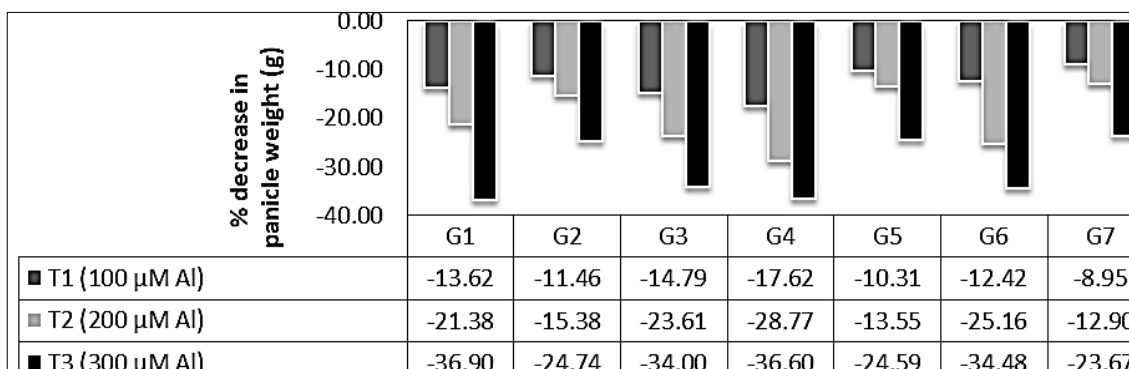|	G1	G2	G3	G4	G5	G6	G7
T1 (100 µM Al)	-13.62	-11.46	-14.79	-17.62	-10.31	-12.42	-8.95
T2 (200 µM Al)	-21.38	-15.38	-23.61	-28.77	-13.55	-25.16	-12.90
T3 (300 µM Al)	-36.90	-24.74	-34.00	-36.60	-24.59	-34.48	-23.67

Fig 6: Percent decrease in panicle weight as compared to control

Summary and Conclusion
The present study gives us a brief knowledge on effect of aluminium on rice. Rice genotypes showed variation in growth under different levels of aluminium. Tolerant genotypes maintained higher growth in all the conditions. Genotype Rajamani followed by Rene Nepung Aam has maintained higher growth under varying levels of aluminium whereas genotype such as Marin Chatpi and Dewri were found to most sensitive. These identified tolerant genotypes could be a gene pool in developing cultivars for aluminium toxic areas. Moreover research on aluminium toxicity in rice was also scanty so this could be a new area for future research in advance level.

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