Bangladesh J. Bot. **38**(1): 1-6, 2009 (June)

EFFECTS OF ALUMINIUM (Al^{3+}) ON SEED GERMINATION AND SEEDLING GROWTH OF WHEAT (*TRITICUM AESTIVUM* L.)

A.N.M. Alamgir and Sufia Akhter

Department of Botany, University of Chittagong, Chittagong-4331, Bangladesh

Key words: Aluminium stress, Seedling growth, Tolerance index, Wheat, *Triticum aestivum*

Abstract

Effects of different concentrations of aluminium (Al^{3+}) on seed germination of high yielding varieties of wheat (*Triticum aestivum* L.) were investigated. Al^{3+} at 500 ppm had inhibitory effect on seed germination, seedling growth and its dry matter. Relatively higher root and shoot dry matter in Sonlika, Fang-60 and lower in Baw-923 and Protiva were found. Root growth of Fang-60 and shoot growth of all except Akbar, Gourab and Protiva were stimulated at low concentration (10 ppm). Root growth was more susceptible to Al^{3+} stress than that of shoot.

Introduction

Al^{3+} stress associated with low soil pH affected soils and there are more than one million ha of land with low pH in Bangladesh. On world-wide basis there are nearly 2.6 billion ha of strongly acid soils with Al^{3+} toxicity (Dudal 1976). Acid soil, by increasing Al^{3+} solubility increases its concentration at the rhizosphere. Al^{3+} toxicity inhibits plant growth by interfering with the regulatory process of root growth and development (Foy 1988, Taylor 1988, Kochian 1995). To overcome the situation Al^{3+} tolerant wheat germplasm may be helpful for the expansion of its cultivation in the areas of acid soil. In Bangladesh, the tolerance grade of the existing gene pool of wheat against Al^{3+} toxicity is yet to be determined. Thus, the present work was undertaken to determine the tolerance efficiency of some high yielding varieties of wheat against different levels of Al^{3+} stress with respect to seed germination, root and shoot growth, and dry matter yield at seedling stage.

Materials and Methods

Seeds of nine HYV wheat (*Triticum aestivum* L.) varieties were obtained from Bangladesh Agricultural Research Institute (Table 1). One hundred healthy seeds per variety, were placed on filter paper in Pyrex Petri dish containing 10 ml selected solution of 0, 10, 100, 200 and 500 ppm Al^{3+}, prepared in 0.1 mM $CaSO_4$ and incubated in the dark at 25º C in a growth chamber. Seedlings were grown in 0.1 strength Arnon and Hoagland (1940) solution. Seed germination was counted up to six days and seedlings from well germinated seeds of each variety were grown in separate Petri dish up to ten days under artificial light (four florescent tube of 40 W and two incandescent of 60 W) in the growth chamber. Solutions in each case were changed at 24 h interval. Root and shoot lengths were taken after three, five and ten days of exposure from the randomly selected ten seedlings/variety/replication. Root and shoots were then harvested and dried in an oven at 65º C for 12 h to attain constant weight. Tolerance index (TI) of the seedlings was determined following Alamgir *et al.* (1989).

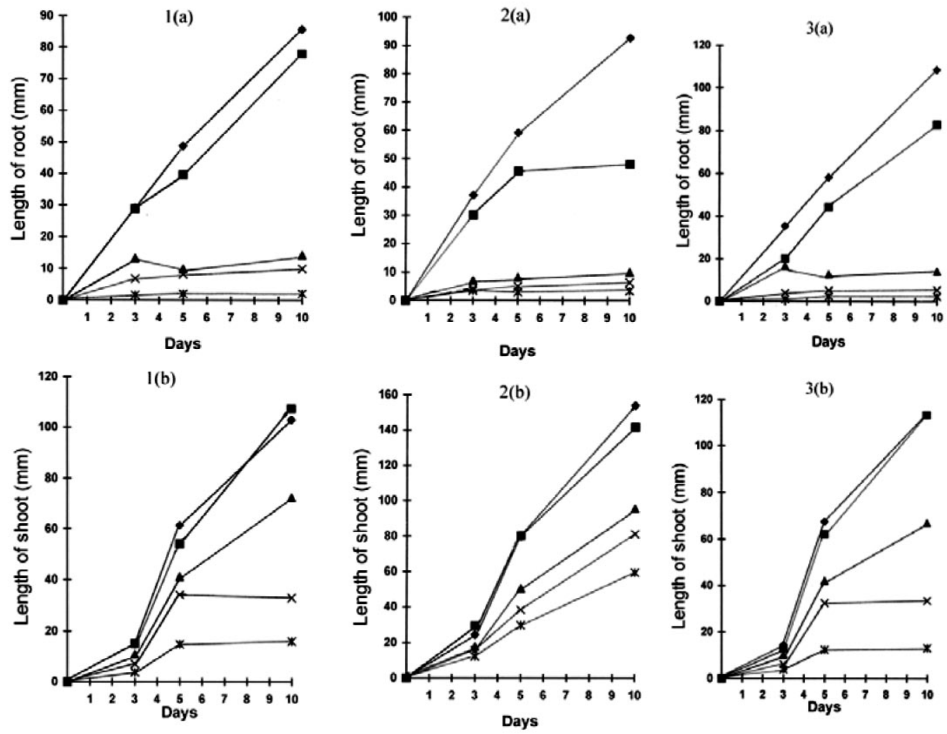
Results and Discussion

Aluminium affected seed germination of different varieties of wheat (*Triticum aestivum* L.), and the inhibitory effect increased with the increase of Al^{3+} concentration (Table 1). The inhibitory sequence of different varieties at 500 ppm Al^{3+} was: Fang-60 > Protiva > Aghrahani > Sonalika > Sourab > Akbar > Kanchan > Gourab > Baw-923. Fang-60 had the lowest percentage of seed germination while Baw-923 had the highest. It has been reported that Al^{3+} at different concentrations showed differential inhibitory effect on seed germination of white spruce (Nosko *et al.* 1988), pigeon pea (Narayanan and Syamala 1989) and wheat (Lima and Copeland 1990). Germination tolerance index (TI) at different Al^{3+} concentrations were variable and Gourab had relatively higher germination TI in most of the concentrations, but Akbar and Kanchan had relatively higher TI under high stress. In spite of the inhibitory effect of Al^{3+} the seed germination, however did not fall below 48% under stress. Lima and Copeland (1990) while working with different germplasms of wheat reported that seed germination was less sensitive to Al^{3+} than the seedling growth.

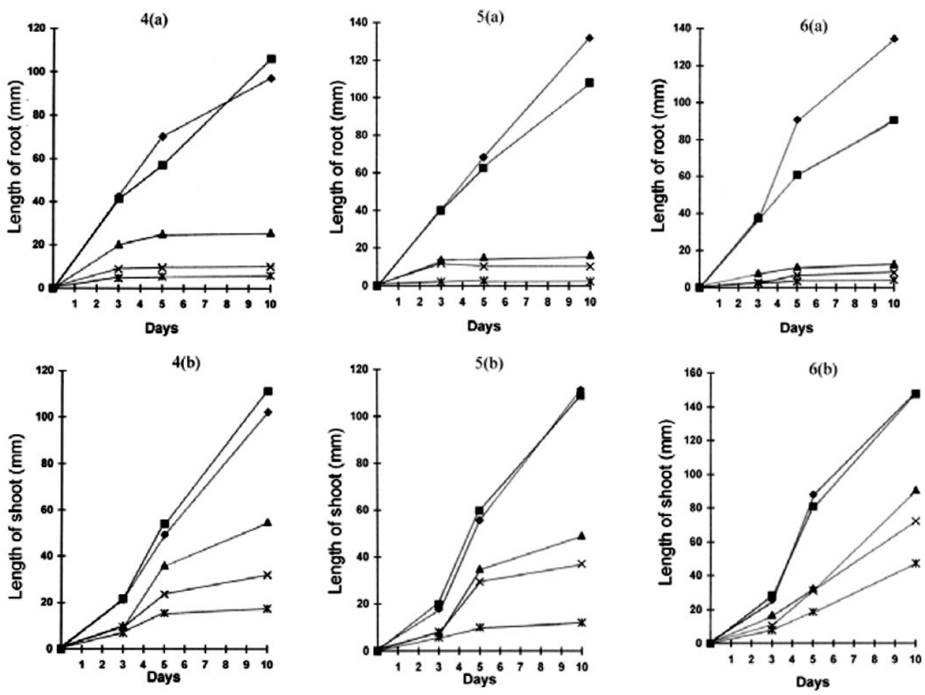
Table 1. Effects of aluminium on percentage of seed germination and TI of different wheat varieties. ± standard error.

Varieties	Control (0.0 ppm)	Germination (%) and TI at different Al^{3+} concs.							
		10 ppm	TI	100 ppm	TI	200 ppm	TI	500 ppm	TI
Aghrahani	100.00 ± 0.00	95.00 ± 0.98	95.00	99.00 ± 0.82	99.00	72.00 ± 1.69	72.00	56.00 ± 1.69	56.00
Akbar	100.00 ± 0.00	100.00 ± 0.00	100.00	94.00 ± 2.00	94.00	73.00 ± 1.39	73.00	66.67 ±2.08	66.00
Baw-923	98.00 ± 0.80	98.00 ±0.80	100.00	80.00 ± 1.70	82.00	68.00 ± 0.47	69.00	68.00 ± 1.25	69.00
Fang-60	100.00 ± 0.00	100.00 ± 0.00	100.00	84.00 ± 1.00	84.00	56.00 ± 0.47	56.00	48.00 ± 2.49	48.00
Gourab	100.00 ± 0.00	96.00 ± 0.00	96.00	96.00 ± 1.37	96.00	94.00 ± 1.88	94.00	68.00 ± 1.41	68.00
Kanchan	100.00 ± 0.00	93.00 ± 1.00	93.00	90.00 ± 1.39	90.00	72.00 ± 1.04	72.00	67.00 ± 1.18	67.00
Protiva	80.00 ± 2.04	67.00 ± 0.80	84.00	53.00 ± 3.45	66.00	47.00 ± 2.08	59.00	50.00 ± 2.62	63.00
Sonalika	100.00 ± 0.00	100.00 ± 0.00	100.00	88.00 ± 2.16	88.00	72.00 ± 1.25	72.00	60.00 ± 1.28	60.00
Sourab	100.00 ± 0.00	92.00 ± 1.04	92.00	90.00 ± 1.39	90.00	72.00 ± 0.50	72.00	60.00 ± 1.25	60.00

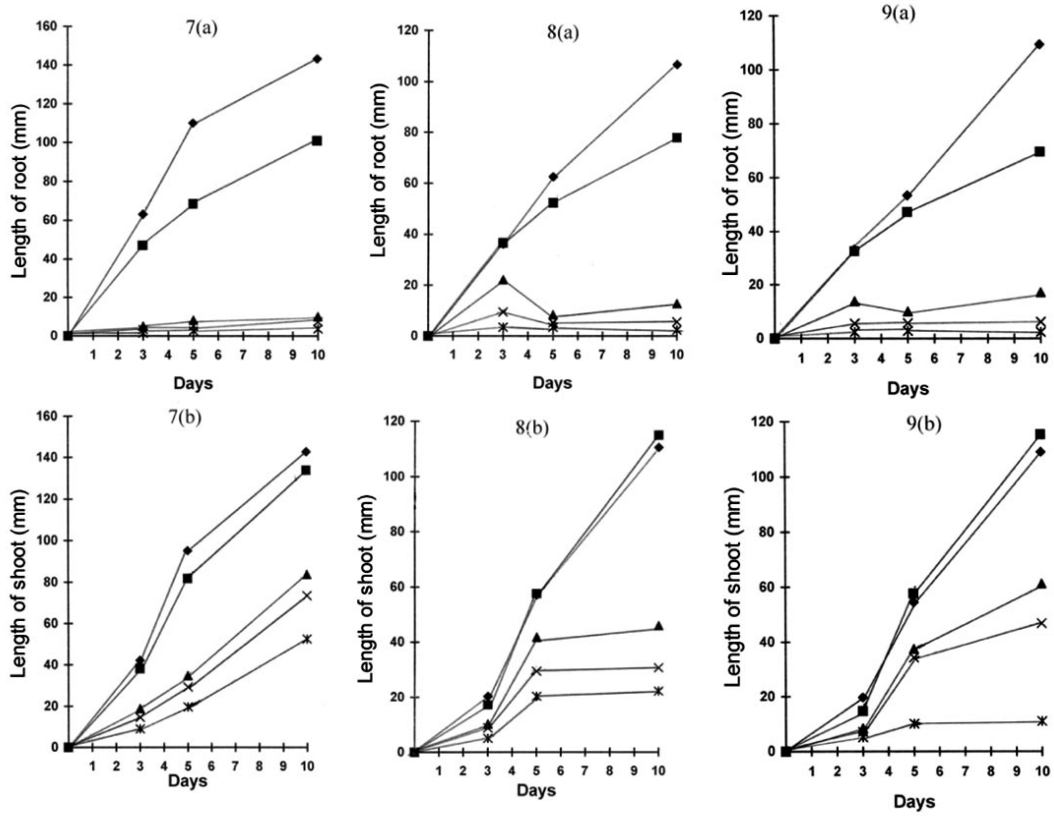
Root-shoot growth measured after three, five and ten days of Al^{3+} treatment were inhibited in most cases and the results are shown in Figs. 1a,b to 9a,b. At a relatively lower concentration of Al^{3+} stimulatory effect on root and/or shoot growths of the seedlings were noted. After ten days inhibition of shoot growth of Baw-923 was negligible at low concentration (Fig. 3a,b). Root growth under Al^{3+} stress in different cultivars of wheat was reported to be different but low concentrations, in some cases, revealed stimulatory effect (Samuels *et al.* 1997). The observed root-shoot growths at 100 ppm were highest in Sourab and Akbar while the lowest was in Protiva and Sonalika at 200 ppm in Gourab and Akbar, Sonalika and Fang-60 and at 500 ppm in Fang-60 and Aghrahani, Akbar and Sourab, respectively. Fageria (1985) noted differential responses of rice to different levels of Al^{3+} while Delhaize *et al.* (1991) as well as Petterson and Strid (1989) reported significant inhibitory effect on root growth in Al^{3+} sensitive wheat. On the other hand, Purcell *et al.* (2002) observed inhibitory effect on water uptake, growth and grain yield in soybean. In the present work, root growth was affected more than that of shoot and as observed by others, the inhibition of root elongation was the first visible symptom of Al^{3+} toxicity and the effect on shoot was the delayed and indirect response to Al^{3+} toxicity (Fageria 1985, Narayana and Syamala 1989).



Figs. 1a,b - 3a,b: Effect of Al^{3+} on root length and shoot height (mm) of seedlings. 1a,b: var. Aghrahani, 2 a,b: var. Akbar. 3a,b. var. Baw-923. Control ♦, 10 ppm ■, 100 ppm ▲, 200 ppm ×, 500 ppm x.



Figs. 4a,b - 6a,b: Effect of Al^{3+} on growth of root length and shoot height (mm) of seedlings. 4 a,b: var. Fang-60. 5a,b: var. Gourab. 6 a,b: var. Kanchan. Control ♦, 10 ppm ■, 100 ppm ▲, 200 ppm ×, 500 ppm x.



Figs. 7a,b - 9a,b: Effect of Al^{3+} on root length and shoot height (mm) of seedlings. 7a-b: var. Protiva. 8 a,b: var. Sonalika. Control ♦, 10 ppm ■, 100 ppm ▲, 200 ppm ×, 500 ppm x.

Aluminium affected dry weight of root and shoot at varietal and treatment levels, and generally decreased with the rise of Al^{3+} concentration (Table 2). Root dry weight was inhibited in all cases excepting three varieties, shoot dry weight in others was stimulated at 10 ppm Al^{3+}. Sourab and Protiva had the highest root-shot dry weight and the lowest was in Kanchan and in Gourab, respectively whereas under similar stresses the lowest root dry weight was in Sourab and that of shoot in Akbar and Sonalika, respectively where as under similar stress the lowest root dry weight was in Protiva and Akbar and shoot in Sonalika and Protiva, respectively. At 500 ppm, dry weight was further decreased with the sequence: Sonalika > Kanchan > Gourab > Aghrahani > Sourab > Akbar > Fang-60 > Protiva > Baw-923 and that of shoot was: Fang-60 > Kanchan > Sonalilka > Protiva > Gourab > Aghrahani > Sourab > Baw-923 > Akbar for shoot. R/S dry weight ratio was decreased with stresses indicating that the effect on root was more than that of shoot. Narayanan and Syamala (1989) noted proportionate decrease of dry matter of *Cajanus cajan* with the rise of Al^{3+}, but marked distinct variation among the genotypes. Relative shoot weight (RSW) could be the best parameter in determining the Al^{3+} tolerance in rice and wheat or RSW alone could be an acceptable indicator (Jan and Patterson 1989, Foy 1997). In the present work, root of Sonalika and shoot of Fang-60 revealed relatively higher growth efficiency at 500 ppm Al^{3+}. Length and weight of root and also those of the above ground parts of wheat could be the best criterion for selecting Al^{3+} tolerant varieties (Macuha and Rychtarik 1999). Tolerant varieties should definitely reveal higher rate of growth activities under stress.

Table 2. Effects of Al^{3+} on dry weight (µg/seedling) of root and shoot after ten days growth of seedlings of different wheat varieties. ± standard error.

Varieties	Dry wt. (µg/seedling) of roots and shoots and their ratio														
	Control (0.0 ppm)			10 ppm			100 ppm			200 ppm			500 ppm		
	Root	Shoot	R/S	Root	Shoot	R/S	Root	Shoot	R/S	Root	Shoot	R/S	Root	Shoot	R/S
Aghrahani	5.22 ± 0.14	6.96 ± 0.08	0.75	4.59 ± 0.44	8.22 ±0.16	0.56	3.56 ± 0.24	5.42 ± 0.06	0.66	2.17 ± 0.03	5.79 ± 0.32	0.37	0.42 ± 0.06	2.14 0.13	0.20
Akbar	7.50 ± 0.99	15.83 ± 0.55	0.47	6.35 ± 0.93	11.97 ±0.72	0.53	2.79 ± 0.15	10.41	0.27	0.60 ± 0.03	6.69 ± 0.19	0.09	0.31 ± 0.06	0.42 ± 0.03	0.74
Baw-923	6.85 ± 0.54	7.90 ± 0.20	0.87	6.37 ± 0.74	7.60 ±0.02	0.84	5.46 ± 0.31	6.43 ± 0.21	0.85	2.45 ± 0.4	4.00 ± 0.08	0.61	0.23 ± 0.02	0.93 ± 0.02	0.25
Fang-60	7.06 ± 0.26	7.73 ± 0.41	0.91	6.49 ± 0.02	8.16 ±0.04	0.80	5.41 ± 0.02	6.84 ± 0.14	0.79	2.64 ± 0.07	5.37 ± 0.13	0.49	0.30 ± 0.02	4.47 ±0.02	0.07
Gourab	7.39 ± 0.01	7.68 ± 0.03	0.96	5.78 ± 0.01	6.75 ±0.01	0.86	4.03 ± 0.02	5.20 ± 0.21	0.78	2.36 ± 0.01	4.68 ± 0.03	0.50	0.55 ± 0.08	2.44 ± 0.01	0.23
Kanchan	3.63 ± 0.14	7.19 ± 0.20	0.50	3.91 ± 0.17	10.56 ±0.87	0.37	2.97 ± 0.46	5.14 ± 0.18	0.58	2.29 ± 0.26	6.93 ± 0.54	0.33	0.74 ± 0.08	4.19 ± 0.06	0.16
Protiva	4.52 ± 0.17	10.96 ± 0.68	0.42	4.83 ± 0.59	12.07 ±0.12	0.40	2.46 ± 0.17	6.58 ± 0.13	0.37	2.23 ± 0.56	3.11 ± 0.78	0.72	0.24 ± 0.06	2.56 ± 0.04	0.09
Sonalika	6.55 ± 0.10	8.98 ± 0.3	0.73	6.18 ± 0.15	10.32 ±0.09	0.60	4.22 ± 0.07	4.66 ± 0.11	0.91	2.75 ± 0.18	7.51 ± 0.05	0.37	0.91 ± 0.02	3.65 ± 0.07	0.25
Sourab	7.35 ± 0.02	7.60 ± 0.09	0.97	6.91 ± 0.01	8.14 ±0.04	0.85	6.15 ± 0.12	5.63 ± 0.02	1.09	2.80 ± 0.03	5.03 ± 0.00	0.56	0.34 ± 0.02	2.02 ± 0.18	0.17

References

Alamgir, A.N.M., Q.A. Baset and J.S. Acharjee. 1989. Effect of salinity on growth, leaf pigments, nutrient levels and yield attributes of rice (*Oryza sativa* L.). Chittagong University Studies. Part II. **13**(1): 87-98.

Arnon, D.I. and D.R. Hoagland. 1940. Crop production in artificial culture solutions and in soil with special reference to factors influencing in yields and absorption of inorganic nutrient. Soil Sci. **50**: 463-483.

Delhaize, E., T.J.U. Higgins and P.J. Randall. 1991. Aluminium tolerance in wheat: analysis of polypeptides in the root apices of tolerant and sensitive genotypes. *In*: Plant soil interactions at low pH. R.T.Wright ***et al.*** (Eds.). pp. 1071-1079.

Dudal, R. 1976. Inventory of the major soils of the world with special reference to mineral stress hazards. *In*: Plant adaptation to mineral stress problem soils. Proceedings workshop, M.J.Wright (Ed.). pp. 3-13. Beltsville Cornell University Press, Ithaca, NY.

Fageria, N.K. 1985. Influence of aluminium in nutrient solution on chemical composition in two rice cultivars of different growth stages. Plant Soil **85**: 423-429.

Foy, C.D.1988. Plant adaptation to acid, aluminium toxic soils. Commun. Soil Sci. Plant Anal. **19**: 959-987.

Foy, C.D.1997. Tolerance of duram wheat lines to an acid, aluminium-toxic subsoil. J. Plant Nutri. **19**: 1381-1394.

Jan, F. and S. Pettersson. 1989. Varietal diversity of upland rice in sensitivity to aluminium. J. Plant Nutri. **12**(9): 973-993.

Kochian, L.V. 1995. Cellular mechanisms of aluminium toxicity and resistance in plants. Annu. Rev. Plant Physiol. Plant Mol. Biol. **46**: 237-260.

Lima de, M.L. and L. Copeland. 1990. The effect of aluminium on the germination of wheat seeds. J. Plant Nutr. **13**(12): 1489-1497.

Macuha, P. and J. Rychtarik. 1999. Evaluation of varieties and hybrids of winter wheat tolerance and sensibility to acid environment and Al^{3+} ions. J. Agri. Sci. **45**(1): 16-28.

Narayanan and Sayamala. 1989. Response of pigeon pea (*Cajanus cajan* L.) genotypes to aluminium toxicity. Indian J. Plant Physiol. **32**: 17-24.

Nosko, P., P. Brassard, J.R. Kramer and K.A. Kershaw. 1988. The effect of aluminium on seed germination and early seedling establishment, growth and respiration of white spruce (*Picea glavca*). Can. J. Bot. **66**: 2305-2310.

Pettersson, S. and H. Strid. 1989. Aluminium toxicity in two cultivars of wheat (*Triticum aestivum* L.) with different sensitivity to Al as affected by the level of nutrient supply. Swedish J. Agril. Res. **19**(4): 189-191.

Purcell, L.C., T.C. Keisling and C.H. Sneller. 2002. Soybean yield and water extraction in response to deep tillage and high soil aluminium. Commun. Soil Sci. Plant Analysis **33**(19-20): 3723-3735.

Samuels, T.D., K. Kucu Kakyuz and M. Rincon-Zachary. 1997. Al partitioning patterns and root growth as related to Al sensitivity and Al tolerance in wheat. Plant Physiol. **113**(2): 527-534.

Taylor, G.J. 1988. Mechanism of aluminium tolerance in *Triticum aestivum* L. nitrogen nutrition, plant induced pH and tolerance to aluminium: correlation without causality. Can. J. Bot. **66**: 694-699.

(Manuscript received on 8 February, 2006; revised on 11 April, 2007)