Oryza Vol. 53 No.3, 2016 (309-315)

Effect of Arsenic - induced toxicity on germination parameters of rice (*Oryza sativa* L.) varieties

Pankaj Singh* and Nidhi Kumari

Rajendra Agricultural University, Pusa, Samastipur-848125, Bihar

****Corresponding author e-mail: nscpasoil@gmail.com***

Received : 21 January 2015 Accepted : 20 December 2016 Published : 23 December 2016

ABSTRACT

An experiment was conducted to study the response of four rice varieties (Richharia, Swarna-Sub1, Rajendra masuri and Rajendra suvasini) to various levels of arsenic concentration (0, 5, 10, 15, 20, 25, 30 ppm) on different germination parameters. The germination study was conducted on moist filter paper placed in Petri plates under laboratory conditions with 70% relative humidity. The seeds were surface sterilized with 0.1% mercuric chloride solution and thoroughly washed with distilled water. The germination count was done on 7th day. Percent germination, germination index and relative germination rate decreased significantly over control with increasing concentration of arsenic. None of the varieties recorded germination at 30 ppm concentration. The arsenic - induced injury was higher in Richharia. Rajendra masuri, Swarna-Sub 1 and Rajendra suvasini recorded more than 50% reduction over control at 10 ppm. Swarna-Sub 1 recorded germination upto 25 ppm. Richharia and Rajendra suvasini were found susceptible after 20 ppm, while Rajendra masuri recorded germination only upto 15 ppm arsenic concentration. Among four varieties, Swarna-Sub 1 was comparatively more tolerant to arsenic injury.

Key words: *Arsenic, rice, toxicity, germination index*

The problem of water pollution is getting greater dimension day by day in India. Water is mostly polluted by the industrial wastewater released from various industries. Since heavy metals are the main constituent of many industrial effluents, therefore, the industrial, agricultural and municipal wastes are the key sources of these toxic heavy metals in the wastewater (Kirupalakshmi 2004). Groundwater contamination with arsenic is reported from many parts of the world, the extent of severity being higher in Bangladesh, West Bengal of India, China and Taiwan (WHO 2001). In Bihar, groundwater of 15 districts is reported to be contaminated with arsenic (CGWB, Ministry of water Resources, GOI, 2010). One of the major concerns is the accumulation of arsenic in edible parts of crops creating hazards to animal and human health. In Asian countries, the people consuming and using arsenic contaminated drinking water and groundwater for irrigation purposes suffer from arsenicosis (Chakravarty and Das 1997). In recent times, the impact of irrigation with high arsenic contaminated groundwater on soil and crop has now drawn more attention due to transfer of arsenic to the food chain via groundwater-plant-soil system (Das *et al*. 2004 and Rahaman *et al*. 2008). The bioaccumulation of arsenic in different crop plants including cereals, beans, vegetables and fruits has huge negative impact for public health both in rural and urban population (Katz and Salem 2005) and this is of great environmental concern.

Presence of arsenic in irrigation water or in soil at an elevated level could hamper normal growth and development of plants. Plants can develop toxicity symptoms such as, inhibition of seed germination (Liebig 1966) and reduction in root and shoot growth (Carbonell -Barrachina *et al*. 1998). Hence, the present investigation was conducted to find out the effect of different concentration of arsenic on seedling emergence of different rice cultivars.

MATERIALS AND METHODS

The effect of different concentrations of arsenic on seedling emergence of rice varieties was evaluated. The experiment was conducted during two consecutive *kharif* seasons 2011 and 2012 in three replicates at 70% relative humidity in Petri plates. The treatment comprised of six arsenic concentrations i e., control (No arsenic), 5, 10, 15, 20, 25 and 30 ppm, and four rice varieties *i.e.*, Rajendra masuri, Swarna sub-1, Rajendra suvasini and Richharia popularly grown in Bihar. Healthy and uniform-sized seeds of these varieties having 96% germination were used. Arsenic 1000 ppm solution was used as arsenic source for present study. From this standard solution, different concentrations (5, 10, 15, 20, 25 and 30 ppm) were prepared and used for germination studies. Prior to germination, all seeds were surface sterilized with 0.1% mercuric chloride solution for 60 seconds and washed thoroughly with tap water and then by distilled water for 30 minutes. The seeds were placed equispacially in sterilized petri-plates lined with filter paper (Whatman No.1). Two pieces of filter paper (9.0 cm disks) were placed on 10 mm dia Petri plate and moistened with aqueous solution (10 ml) of different concentrations of Arsenic. The seeds moistened with distilled water were treated as control. Twenty five seeds of each variety was placed in each Petri plate, covered by the lid, and incubated at room temperature (28 ± 2^0C) under diffused sunlight. The number of germinated seeds in each treatment was counted and calculated on 7 days after sowing. Seeds were considered germinated when both the plumule and radical were extended to more than 2mm from their junction. Germination percent, germination index, relative germination rate and relative arsenic injury rate were determined using following formula of Li (2008) with some modifications for the present materials:

$$\text{Germination percentage} = \frac{\text{No.of seeds germinated}}{\text{No.of seeds taken for germination}} * 100$$

$$\text{Germination index(GI)} = \frac{\text{Total no.of germinated seed}}{\text{Total no.of germination days required}}$$

$$\text{Germination index(GI)} = \frac{\text{Total no.of germinated seed}}{\text{Total no.of germination days required}}$$

$$\text{Relative arsenic injury rate} = \frac{(\text{Germination percentage in controle - Germination percentage in arsenic treatment})}{\text{Germination percentage in controle}}$$

The tolerance to arsenic was determined by calculating arsenic response index (ARI) = [(value from salt treatment) / (value from control)] x 100 for each treatment.

RESULTS AND DISCUSSION

The germination percent varied significantly from 93.18% to 6.67% at different arsenic concentrations from 0 to 25 ppm (Table 1). Germination percent of rice varieties was the highest under control (no arsenic) and it decreased with increasing concentration of arsenic. Among the four varieties, Rajendra suvasini recorded significantly higher germination percent (93.18%) under control followed by Rajendra masuri (85.26%) whereas, Swarna-Sub 1 (80.19%) and Richharia (80.34%) were at par to each other. As the arsenic concentration increased from 0 to 5 ppm, variety Richharia recorded a sharp decline (66.7%) in germination whereas, the other three varieties Rajendra masuri, Swarna-Sub1 and Rajendra suvasini also recorded similar reduction (>50%) at 10 ppm arsenic concentration as compared to control and were at par to each other. At 5 ppm concentration the performance of Rajendra suvasini was significantly superior followed by Rajendra masuri & Swarna-Sub 1 which were at par to each other. As compared to control, the maximum decline in germination percent was recorded at10 ppm by Richharia (86.2%) followed by Rajendra masuri (70.6%), Rajendra suvasini (64.2%) and Swarna-Sub1 (56.3%). The germination percent of Richharia recorded at 10, 15 and 20 ppm arsenic concentration were statistically at par to each other and lowest among all varieties. All the varieties recorded a gradual decrease in germination percent as the concentration

Table 1. Effect of arsenic concentration on germination percent of different varieties of rice

As Conc. (ppm)	Germination Percentage			
	Rajendra Masuri	Swarna sub-1	Rajendra Suvasini	Richharia
Control	85.26^{b}	80.19^{bc}	93.18^{a}	80.34^{bc}
5	75.14^{d}	65.09^{d}	80.80^{bc}	26.71^{e-h}
10	25.02^{e-h}	35.03^{e}	33.38^{ef}	11.12^{ij}
15	20.02^{g-i}	15.01^{g-j}	30.11^{e-g}	8.89^{ij}
20	0.00	15.00^{g-j}	20.07^{f-i}	6.67^{i}
25	0.00	11.67^{ij}	0.00	0.00
CD			6.35	

Means with the same letter are not significantly different increased from 10 to 15 ppm. Among four varieties, Swarna-Sub 1 was found to be comparatively more tolerant to increasing concentration of arsenic. At 20 ppm arsenic concentration only three varieties i.e., Swarna-Sub1, Rajendra suvasini and Richharia recorded germination which were at par to each other. Among the four rice varieties, only Swarna-Sub1 recorded 11.67% germination at 25 ppm arsenic concentration. On the other hand, none of the varieties recorded germination at 30 ppm arsenic concentration. The inhibition of germination at higher concentration of arsenic was also reported in wheat (Panda and Patra 1997), pea (Chugh and Sawhney 1996), *T.* f*oenum-graecum* and *L. sativus* (Mumthas *et al*. 2010). The reduction in germination percentage may be attributed to the interference of metabolic process of germination by arsenic (Sankar Ganesh 2008).

The germination index (GI) of rice varieties varied significantly at different arsenic concentrations (Table 2). The GI was highest under control which decreased with increasing concentration of arsenic. The lowest GI was recorded for variety Richharia at 15 ppm arsenic concentration. The performance of Rajendra masuri and Swarna-Sub 1 was comparatively better than Rajendra suvasini and Richharia. Among the four rice varieties, Richharia recorded more than 50% reduction in GI as the arsenic concentration increased from 0 to 5 ppm, while the other varieties recorded similar reduction at 10 ppm arsenic concentration. The decrease in GI was very sharp for Rajendra masuri, Swarna-Sub 1 and Rajendra suvasini as the arsenic concentration increased from 5 to 10 ppm. The GI of Swarna-Sub1 was significantly higher over all other varieties at 10 ppm concentration, while GI of Rajendra masuri, Swarna-Sub 1 and Rajendra suvasini were at par to each other at 15 ppm. The data of GI at 15 ppm arsenic concentration revealed a percent reduction of 89.0, 81.2, 76.3 and 66.6 for Richharia, Swarna-Sub 1, Rajendra masuri and Rajendra suvasini, respectively. Arsenic-induced toxicity in leguminous plants also led to similar results (Talukdar 2011).

Similarly, the relative germination rate (RGR) was maximum in control and it decreased significantly with increasing concentration of arsenic in all the four varieties (Table 2). At 5 ppm arsenic concentration, the RGR of Rajendra masuri, Swarna-Sub 1 and Rajendra suvasini were statistically similar. At 10 ppm concentration, except Richharia all the three varieties recorded more than 50% reduction in RGR whereas, Richharia recorded same reduction at 5 ppm. Further, in comparison to other varieties Richharia recorded maximum reduction at all concentrations of arsenic from 5 to 15 ppm. At 15 ppm the RGR of Richharia was at par to Swarna-Sub 1 which was at par to Rajendra masuri. Rajendra suvasini recorded significantly higher RGR at 15 ppm arsenic concentration indicating better tolerance as compared to other varieties. RGR has been reported to reduce with increasing concentration of arsenic in Green gram (Mumthas *et al*. 2010). Smith *et al.* (1998) reported that rice, bean and oats exhibit phytotoxic symptoms at 20 ppm in soil, while maize and radish at 100 ppm.

Relative arsenic injury rate calculated on the basis of germination percentage in each of the four varieties was zero in control, but the rate of injury increased significantly with increasing concentration of arsenic in all the four varieties (Table 2). In comparison

Table 2. Effect of arsenic concentration on germination index (GI), relative germination rate (RGR) and relative arsenic injury rate (RAIR)

Varieties	Germination Index (GI)				Relative Germination Rate (RGR)				Relative Arsenic Injury Rate (RAIR)			
	Arsenic concentration (in ppm)											
	Control	5	10	15	Control	5	10	15	Control	5	10	15
Rajendra Masuri	2.83a	2.50b	0.83f	0.67fg	1.00a	0.88b	0.29ef	0.23fg	0.00h	0.12g	0.71cd	0.76bc
Swarna Sub-1	2.67ab	2.17c	1.17e	0.50gh	1.00a	0.81b	0.43c	0.19gh	0.00h	0.19g	0.56f	0.81ab
Rajendra Suvasini	1.50d	1.33de	0.56g	0.50gh	1.00a	0.89b	0.38cd	0.33de	0.00h	0.11g	0.62ef	0.67de
Richharia	2.00c	0.67fg	0.28hi	0.22i	1.00a	0.33de	0.14h	0.11h	0.00h	0.67de	0.86a	0.89a
CD			0.13				0.04				0.04	

Means with the same letter are not significantly different to control, the injury rate increased marginally at 5 ppm arsenic concentration except in Richharia which recorded a higher injury at same concentration. However, the injury level was significantly high for all the four varieties at 10 ppm arsenic concentration which further increased at 15 ppm. The maximum injury was recorded in variety Richharia at all concentrations. In addition, the tolerance to arsenic injury at 10 ppm concentration was comparatively higher in variety Swarna-Sub 1 whereas, Rajendra suvasini was more tolerant at 15 ppm arsenic concentration. The injury caused due to 5ppm arsenic was statistically similar for Rajendra masuri, Swarna-Sub 1 and Rajendra Suvasini whereas, Richharia recorded highest injury at this concentration. Except Richharia, all the three varieties recorded a sharp increase in injury level (more than 50%) at 10 ppm arsenic concentration, whereas, similar injury was recorded in Richharia at 5 ppm arsenic concentration. Talukdar (2011) has also reported similar results on leguminous plants.

The cumulative effect of arsenic treatment at different concentrations on germination percentage was manifested by arsenic induced injury rate. The severe effect of arsenic concentration was recorded at 10 ppm for all the three varieties except Richharia which recorded severe effect at 5 ppm arsenic concentration. Significant increase in injury level at 10 ppm arsenic concentration was mainly due to decrease in seed germination percentage. However, the values of arsenic injury rate showed that Rajendra masuri, Swarna-Sub 1 and Rajendra suvasini were tolerant at lower arsenic concentration whereas, Richharia was the most susceptible variety as it recorded significantly higher arsenic induced injury at all concentrations. The increase in injury level at 15 ppm arsenic concentration was marginal in all varieties except Swarna-Sub 1 indicating that it was highly susceptible to arsenic injury at higher concentrations. The result was in corroboration with Talukdar (2011). Relative arsenic injury rate was 0 in control, but the value increased with increase in concentration. The injury rate was marginal at low concentration but increased significantly at higher concentration (Mumthas *et al.* 2010.)

The root and shoot length (Table 3) was maximum under control and decreased with increasing concentration of arsenic for all varieties. However, there was a sharp decrease in root length (more than 50%) at 5 ppm arsenic concentration. The maximum reduction (80%) was recorded in variety Rajendra suvasini followed by Rajendra masuri (58.74%) and Swarna-Sub1 (57.57%). The percent reduction in root length of Richharia with increasing concentration of arsenic was less as compared to other varieties under study.

Reduced root length growth in response to arsenic exposure has been reported by a number of investigators (Snellar *et al.* 1999; Hartley- Whitaker *et al.* 2001). The decrease in root length (Table 3) from 0-10 ppm arsenic concentration was more than 80% in all varieties except Richharia which recorded just more than 50% reduction. The reduction in root length due to increase in concentration from 5 to 10 ppm was maximum (73.0%) in Rajendra masuri whereas, Rajendra suvasini recorded minimum reduction (25.2%). At 15 ppm arsenic concentration the reduction in root length was marginal in all varieties. Inhibition in root elongation is one of the frequently observed symptoms of metal toxicity (Wang *et al.* 2003). The finding is in accordance with the report of significant reduction of root length in arsenic-treated different rice varieties (Dasgupta *et al.* 2004). The inhibition in root growth noticed at higher concentration of arsenic was also reported in wheat (Sankar 2008). The possible reduction in root growth might be due to accumulation of arsenic in tissues and its interaction with their minerals (Banu *et al.* 1997). In general, root length of wet season varieties of rice were adversely affected by arsenic at higher concentration range (Abedin and Meharg 2002). Significant reduction of root length with increasing concentration of arsenic may be due to the fact that plant roots were the first point of contact for the toxic arsenic species in nutrient media. This might lead to lower mitotic activity in the root meristematic zone or to an inhibition of cell enlargement in the elongation zone as a consequence of decreased cellular turgor (Gabbrielli *et al.* 1990)

The Root tolerance Index (RTI) of different varieties decreased with increasing concentration of arsenic. All varieties recorded minimum RTI (Fig.1) at 15 ppm arsenic concentration. However, among the four varieties, Richharia showed better tolerance at all concentration of arsenic while, Swarna-Sub 1 and Rajendra masuri were medium tolerant, and Rajendra suvasini was least tolerant. The Relative shoot height (RSH) (Fig.2) also decreased with increasing

Table 3. Effect of arsenic conc. on root length, shoot length and root-shoot length ratio

Varieties	Root Length				Shoot Length				Root-Shoot Length Ratio			
	Arsenic concentration (in ppm)											
	Control	5	10	15	Control	5	10	15	Control	5	10	15
Rajendra Masuri	4.63b	1.91de	0.47i	0.27i	4.61a	3.11c	2.36ef	2.03g	1.00b	0.61d	0.20ij	0.13j
Swarna	3.30c	1.40f	0.51hi	0.26i	4.25b	2.26efg	1.42hi	1.26i	0.77c	0.62d	0.36fg	0.20ij
Rajendra Suvasini	5.37a	1.07g	0.80gh	0.50i	4.70a	2.42e	2.10fg	1.67h	1.14a	0.44ef	0.38fg	0.30gh
Richharia	2.12d	1.66ef	0.90g	0.50i	3.36c	3.20c	2.80d	2.20efg	0.63d	0.51e	0.32g	0.23hi
CD			0.15				0.15				0.04	

Means with the same letter are not significantly different

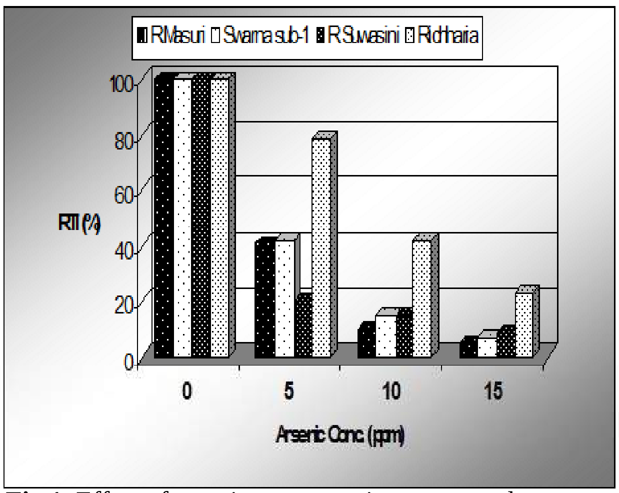

Fig.1. Effect of arsenic concentration on root tolerance index

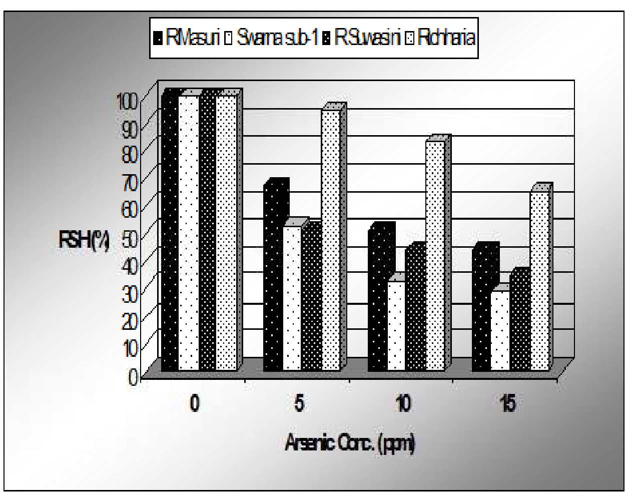

Fig. 2. Effect of arsenic concentration on relative shoot height

concentration of arsenic. Among the four varieties, Richharia recorded higher values of RSH at all concentration of arsenic *i.e.*, its shoot length was less affected due to arsenic, while the shoot height recorded for other three varieties indicated less tolerance to arsenic. Similarly, significant reduction in RSH was observed by Abedin and Meharg (2002) due to increase in arsenic concentrations.

The data of shoot length recorded (Table 3) showed a decrease with increasing concentration of arsenic as in case of root length. The percent decrease in shoot length was higher with increasing concentration of arsenic, though the decrease in shoot length was variable for different varieties. Among the four varieties, Richharia recorded minimum decrease in shoot length with increasing concentration of arsenic. The maximum percent decrease in shoot length was recorded for variety Swarna-Sub1 followed by Rajendra suvasini and Rajendra masuri. These findings are well supported by RTI and RSH (Fig.2). The root tolerance index of Richharia was comparatively higher at all concentrations of arsenic compared to Rajendra masuri, Swarna-Sub 1 and Rajendra shuvasini. The relative shoot height was also higher for variety Richharia compared to other varieties. The higher RTI and RSH for variety Richharia indicated its capacity to tolerate toxicity to increasing concentration of arsenic after germination. Significant reduction in rice shoot length with increasing arsenic concentration suggest that rice shoot length can also be used as good indicator for arsenic toxicity. Reduced shoot height due to application of arsenic in this study also corroborates with the result of Marin *et al.* (1992). The reduction of shoot height due to arsenic exposure can be an important consideration for rice cultivation as reduced shoot height will decrease rice leaf area, net photosynthesis (Marin *et al.* 1993), and ultimately rice yield.

The root-shoot length ratio of all the four varieties (Table 3) differed significantly with increasing concentration of arsenic. Rajendra suvasini recorded significantly higher root-shoot length ratio followed by

Rajendra masuri, Swarna-Sub 1 and Richharia at 0 ppm concentration. The performance of Richharia in control was statistically at par to Rajendra masuri and Swarna-Sub 1 at 5 ppm concentration. Only Rajendra suvasini recorded more than 50% reduction compared to control in root-shoot length ratio at 5 ppm concentration whereas, the other varieties recorded the same reduction in root-shoot length ratio at 10 ppm arsenic concentration. All the varieties except Richharia recorded a sharp decline in root-shoot length ratio with increasing arsenic concentration indicating a relatively higher tolerance of variety Richharia at higher concentration compared to others.

The present study revealed that the phytotoxic effect of arsenic manifested significant reduction in germination of all the varieties. Considering the 50% reduction in values as compared to control with increasing concentration of arsenic, Richharia was most susceptible to arsenic injury. However, the other three varieties showed better tolerance. The level of 5 ppm was concluded as toxic to Richharia while the limit was 10 ppm for Rajendra masuri, Swarna-Sub1 and Rajendra suvasini. The root and shoot length, as well as RTI and RSH revealed that variety Swarna-Sub 1 was comparatively more tolerant among the three varieties. It is also worth mentioning that only Swarna-Sub 1 seeds recorded germination upto 25 ppm arsenic concentration.

Since, the presence of arsenic in water causes many variations in germination, growth, biochemical and cytological behaviour, hence it may be concluded that arsenic contaminated irrigation water are toxic to crops and should be treated for removal before its application to field crops.

ACKNOWLEDGEMENT

We thank and acknowledge Rajendra Agricultural University for providing financial support to conduct this experiment.

REFERENCES

Abedin MJ and Meharg AA 2002. Relative toxicity of arsenite and arsenate on germination and early seedling growth of rice (*Oryza sativa* L.). Plant Soil 243: 57-66

Banu B, Thangavel P and Subburam V 1997. Toxicity of neolan gray to Vigna radiata CO 3. Poll. Res. 16:25-28.

Carbonell- Barrachina AA, Aarabi MA, Delaune RD, Gambrell RP and Patric WHJr 1998. The influence of arsenic chemical form and concentration on Spartina patens and Spartina alterniflora growth and tissue arsenic concentration. Plant Soil 198: 33-43

Central Ground Water Board (CGWB), GOI, 2010. Arsenic contamination in ground water of Bihar pp. 1-15

Chakravarty AK and Das DK 1997. Arsenic pollution and its environmental significance. J. Interacademicia 1: 262-276

Chugh LK and Sawhney SK 1996. Effect of cadmium on germination amylases and rate of pea respiration of germinating pea seeds. Environ. Poll. 19: 107-124

Das HK, Mitra AK, Sengupta PK, Hossain A, Islam F. and Rabbani GH 2004. Arsenic concentrations in rice, vegetables, and fish in Bangladesh: A preliminary study. Environ. Int. 30: 383-387

Dasgupta T, Hossain S A, Adrew A, Meharg A A and Price A H 2004. An arsenate tolerance gene on chromosome 6 of rice. New phytol. 163: 45-49

Gabbrielli R, Pandolfini T, Verganao O and Palandrii 1990. Comparison of two serpentine species with different nickel tolerance strategies. Plant Soil 122: 27-277

Hartley - Whitakar J, Ainsworth G and Meharg AA 2001. Copper- and arsenate - induced oxadative stress in Holcus lanatus L. clones with differential sensitivity. Plant Cell Environ. 24: 713-722

Katz S A and Salem H 2005. Chemistry and Toxicology of building timbers pressure-treated with chromated copper arsenate: A review. J. Appl. Toxicol. 25: 1-7

Kirupalakshmi S 2004. Biosorption of hexavalent chromium by marine Algae. Poll. Res. 4(23): 737- 739

Liebig-Jr G P 1996. Arsenic. In Dignostic Criteria for Plants and Soils. Ed. H D Chapman. pp 13-23. University of Cailifornia, Division of Agricultural Science, Riverside, CA

Li Y 2008. Effect of salt stress on seed germination and seedling growth of three salinity plants. Pak. J. Biol. Sci. 11:1268 - 1272

Marin AR, Masscheleyn P H and Patrick W H Jr.1992. The influence of chemical form and concentration of arsenic on rice growth and tissue arsenic concentration. Plant soil 139: 175-183

Marin AR, Pezeskhi SR, Masscheleyn PH and Choi H S 1993. Effect of dymethylarsenic acid (DMAA) on growth, tissue arsenic, and photosythesis of rice plants. J. Plant Nutr.16: 865-880

Mumthas S, Chidambaram Al. A, Sundaramoorthy P and Sankar Ganesh 2010. Effect of Arsenic and Manganese on root growth and cell division in root tip cells of green gram (*Vigna radiata* L.) Emir. J. Food Arsenic. 22(4): 285-297

Panda SK and Patra HK 1997. Physiology of chromium toxicity in plants. Rev. Plant Physoil. Biochem. 24(1): 10-17

Rahman MA, Hasegawa H, Rahman MMA and Tasmin A 2008. Arsenic accumulation in rice (Oryza sativa L.): Human exposure through food chain. Ecotoxicol. Environ. Saf. 69: 317-324

Sankar K 2008. Response of paddy cultivers to chromium pollution. Ph.D. Thesis, Department of Botany, Annamalai University, Annamalainagar, Tamilnadu, India

Smith E, Naidu R and Alston A M 1998. Arsenic in the soil environment: a rewiew. Advan. Agron. 64: 149-195

Sneller E F C. Van Heerwaaeden L M, Kraaijieveld-Smit F J L, Ten Bookum W M, Koevoets P L M, Schat H and Verkleij J A C 1999. Toxicity of arsenate in Silene vulgaris, accumulation and degradation of arsenate-induced phytochelatins. New Phytol. 144: 223-232

Talukdar Dibyendu 2011. Effect of Arsenic induced toxicity on morphological traits of Trigonella foenum-graecum L. and Lathyrus Sativus L. during germination and early seedling growth. Current Res. Journal of Biological Sciences 3(2): 116-123

Wang QR, Cui YS, Liu XM, Dong YT and Christie P 2003. Soil contamination and plant uptake of heavy metals at polluted sites in China. J. Environ. Sci. Health Part A Tox. Hazard Subst. Environ. Eng. 38: 823-838

WHO 2001. Arsenic in drinking water URL:http:www.who.int.inffs/en/fact210.html