Effect of Arsenic Contaminated Irrigation Water on Growth, Yield and Nutrient Accumulation of *Vigna radiata*

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Abstract

A pot experiment was conducted to study the effects of arsenic containing irrigation water on growth, yield and nutrient accumulation of *Vigna radiata* (mung bean) in two different soils – one is non calcareous and non saline (Sara soil series) and the other is calcareous and slightly saline (Barisal soil series). The levels of arsenic used in irrigation water were 0, 1, 2, 5 and 10 ppm. Root and shoot growth parameters, yield and nutrient accumulation were studied to assess the effect of arsenic. All the growth parameters responded better at 2ppm concentration in both soils. The parameters of growth and yield studied, almost all showed to be drastically affected by 10ppm treatment. Accumulation of all the studied nutrients in shoot decreased while accumulation of iron increased with increasing arsenic concentrations.

***Key words*:** Arsenic, *Vigna radiata*, concentration, shoot and root.

1. Introduction

About 33 percent of total arable lands of Bangladesh are now brought under irrigation facilities (BBS, 1996). Most of the lands are irrigated with ground water which comes from deep tube well and shallow tube well. Most of ground waters of irrigated areas of Bangladesh are contaminated with arsenic (Khan *et al.*, 1998). In recent years, it has been reported that the concentration of arsenic in the groundwater in many areas of Bangladesh especially in the Gangetic belt exceeds limit value manifold. Its concentration were found to vary up to 3 mgL^{-1} water, while in irrigated agricultural sols this concentration increased up to 83 μgg^{-1} soils in Comilla and 50 μgg^{-1}soils in Faridpur. Continual use of Arsenic contaminated irrigation water will inevitably increase As concentration in soil which in turn will affect crop quality and human health through entering the food chain. Like other heavy metals arsenic is toxic to plant (Martin *et al.,* 1993). Numerous greenhouse studies by a number of researchers have revealed that an increase in As in cultivated soils leads to an increase in the levels of As in edible vegetables with many complex factors bioavailability, accumulation and phytotoxicity of As (Carbonell-Barrachina *et al.,* 1999).Studies by Meharg *et al.,* (2002) and Huq *et al.,* (2001) demonstrate significant accumulation of As by rice and a range of vegetable crops commonly grown in Bangladesh. In general, ordinary crop plants do not accumulate enough as to be toxic to man. Instead, growth reductions and crop failure are the main consequences. Twenty percent loss of crop production due to high concentration (20 ppm) of arsenic in plant body was reported in a research study (Abedin *et al.,* 2002b). The people of Bangladesh, as like other parts of the world, consider plants as cheap vital sources of vitamins and minerals. Green gram (*Vigna radiate)* is a protein rich staple food belongs to the family Leguminoseae. It contains about 25 percent protein, which is almost three times that of cereals. It supplies protein requirement of vegetarian population of the country. In many parts of the country mungbean is cultivated in As contaminated areas. The study was conducted in a view to observe the effect of arsenic contaminated irrigation water on growth and yield of mungbean and on bacterial population in the rhizosphere.

2. Materials and Methods

A pot experiment was conducted with green gram or mung bean as a test crop. Two different soil series –Sara (geographic location $23^o 12''$ N and $89^o 15''$ E) and Barisal (geographic location $22^o 48''$ N and $89^o 32''$ E) were selected for the experiment. Sara soil belongs to non calcareous and non saline and Barisal belongs to calcareous and slightly saline conditions. Bulk soil samples representing 0-15 cm depth were collected from the selected sites on the basis of composite sampling method as suggested by the Soil Survey Staff of the USDA (1951). The experiment was laid out in a Completely Randomized Design (CRD) with three replications. Different concentrations [0ppm (T_0), 1ppm (T_1), 2ppm (T_2), 5ppm (T_3) and 10ppm (T_4)] of arsenic (sodium Meta arsenate) were taken as the treatments of the study. Seeds of green gram (0.5gram/pot) were sown and the pots were kept moist applying irrigation five times to complete the experiment. The crop was harvested at full maturity. Shoots and roots were collected carefully and washed thoroughly with distilled water to remove soil particles and adhering ions. Data of different growth and yield parameters were recorded. The collected data were analyzed for variance by using MSTAT-C program. The test of significance of different treatment means was computed by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

3. Results and Discussion

3.1. Plant height

Plant height varied significantly among the treatments in Barisal soil series and varied insignificantly in Sara series. The mean plant height varied from 15.72±0.48 cm to 17.00±1.73 cm in Sara soil series and 12.00±0.00 cm to 19.00±0.00 cm in Barisal soil series (Table 1). In both the soil series the highest plant height was obtained at 2ppm arsenic treatment. Sushant and Ghosh (2010) reported that growth of onion plants were significantly increased with the increasing concentration of Arsenic in irrigated water and soil but the present study showed that plant height increased up to 2ppm and decreased at higher concentration arsenic treatments - 5ppm and 10ppm. When plants are exposed to excess arsenic either in soil or in solution culture, they exhibits toxicity symptoms such as: inhibition of seed germination (Abedin *et al.,* 2002a); decrease in plant height (Abedin *et al.*, 2002b; Jahan *et al.*, 2003).

3.2. Root length

Root length varied significantly among the treatments in Barisal soil series but varied insignificantly in Sara soil series. In Barisal soil series, root length varied from 38.99 ±7.13 cm to 92.95±2.58 cm and the lowest root length was observed with 5 ppm and the highest root length was observed at 2ppm arsenic treatment which was statistically similar to 1ppm and 10ppm As treatment and significantly varied with 5ppm. In Sara soil series, root length varied from 31.07±5.77 cm to 63.42±0.87 cm and the highest root length was observed at 10ppm arsenic treatment (Table 1). A study of Carbonell *et al.* (1997) suggested that root length decreased with increasing arsenic concentration but the present study showed no regular pattern of variation in root length in Barisal soil series while in Sara series an increasing trend of root length was observed up to 5 ppm showed and decreased thereafter.

3.3. Fresh weight of shoot

Arsenic concentrations exhibit significant differences in biomass production of mung bean in both the soils. The fresh weight of shoot varied from 2.5±0.5 g to 8.43±2.5 g in Sara soil series and 3.26±0.5 g to 11.4±1.01 g in Barisal soil series (Table. 1). In both the soil series fresh weight of shoot decreased with increasing arsenic treatments with minor exception with 2 ppm in case of Barisal soil series. The fresh weight of shoot (11.4±1.01 g) in Barisal soil series was found highest at 2ppm while in Sara soil series treatments decreased fresh weight of shoot with increasing concentration of arsenic provided that 0ppm produced highest fresh weight of shoot (8.43±2.5 g). Mahmud *et al,* (2006) reported that increased rate of soil arsenic concentration is beneficial for castor oil plant biomass but not for common buckwheat. Sushant and Ghosh (2010) suggested that the leaf biomass increases with the increasing arsenic concentration in water and soil.

3.4. Dry weight of shoot

In both the soils dry matter yield of shoot differed significantly by the levels of Arsenic. In both the soils dry weight of shoot was decreased with increasing levels of As treatments with minor exception with 2 ppm in case of Barisal soil series. The highest weight of plant (1.98±0.26 g) was observed in Sara soil series at 0ppm arsenic concentration whereas the lowest weight of shoot (0.75±0.05 g) was observed at 10ppm arsenic concentration. However, in Barisal soil the highest weight (2.94±0.07 g) was observed at 2ppm and the lowest weight of shoot (0.76±0.07 g) was observed at 10 ppm arsenic concentration (Table. 1). Carbonell *et al.* (1997) stated that root, stem and leaf dry biomass productions of tomato and bean plants were increased with increasing As(III) concentrations in the nutrient solution but this experiment showed that shoot dry weight increased up to 2ppm in Barisal soil series and decreased thereafter while in Sara soil series it decreased with increasing As concentration.

3.5. Fresh weight of root

As concentration in irrigation water significantly affected the fresh weight of root in both the soils. The mean fresh weight of root varied from 0.38±0.07 g to 1.09±0.16 g in Sara soil series and 0.5±0.04 g to 1.22±0.08 g in Barisal soil series (Table 1). The highest fresh weight of root (1.22±0.08) was observed in Barisal soil series at 2ppm arsenic treatment which was statistically similar to 0, 1 and 10ppm whereas the lowest weight of root (0.5±0.04 g) was observed at 5 ppm arsenic concentration. In Sara soil series the highest weight (1.09±0.16 g) was observed at 0ppm arsenic treatment which was statistically similar to 1ppm whereas the lowest weight of root (0.38±0.07 g) was observed at 10ppm arsenic treatment that was statistically similar to 2 and 5ppm. Mahmud *et al.* (2006) reported that the root yield of buckwheat decreased (0.16±0.01 to 0.12±0.01 g) with 100ppm of soil, whereas the dry matter weight of root in castor oil plant increased (1.01±0.03 to 1.07±0.02 g) significantly with increasing level of soil As.

3.6. Dry weight root

Dry weight of root affected significantly among the treatments in Barisal soil series and was affected insignificantly in Sara soil series. The mean weight of root varied from 0.22±0.03 g to 0.51±0.02 g in Sara soil and 0.23±0.03 g to 0.47±0.03 g in Barisal soil (Table 1). In Barisal soil the highest weight of root (0.47±0.03 g) was observed at 2ppm arsenic concentration whereas the lowest weight of plant (0.23±0.03 g) was observed at 10 ppm arsenic concentration. Again, in Sara soil the highest weight (0.51±0.02 g) was observed at 0ppm arsenic concentration and the lowest weight of root (0.22±0.03 g) was observed in Sara soil

Table 1: Effect of As containing irrigation water on agronomic parameters of Mungbean.

Soil	As treatment	Height	Root length	Fresh weight of shoot	Dry weight of shoot	Pod number	Seed number	Number of nodule	Fresh weight of root	Dry weight of root
Barisal	0	14.31± 0.39^{bc}	55.35± 15.08^{bc}	6.163 ± 2.01^{b}	1.23 ± 0.16 ^{b}	5.33 ± 2.08^{b}	22.66± 8.33^{b}	7.33± 4.04^{b}	0.75 ± 0.12^{ab}	0.33± 0.07^{a}
	1	14.75± 1.58^{bc}	82.18± 10.38^{ab}	5.17 ± 0.14^{b}	1.073± 0.31^{b}	5.667± 1.15^{b}	16.76± 7.16^{b}	10.00 ± 0.00 ^{b}	0.76 ± 0.32 ^{ab}	0.29± 0.02^{a}
	2	19.00± 0.00 ^{a}	92.95 ± 2.58^{a}	11.43± 1.01^{a}	2.94 ± 0.07 ^{a}	15.00 ± 0.00^{a}	43.3 ± 2.89 ^{a}	34.83± 22.14^{a}	1.22 ± 0.08 ^{a}	0.47 ± 0.03 ^{a}
	5	15.50± 0.50 ^{b}	38.99 ± 7.13^{c}	4.20 ± 0.39^{b}	0.763± 0.23 ^{b}	5.33± 0.58 ^{b}	16.08± 4.45 ^{b}	10.00 ± 0.00 ^{b}	0.50 ± 0.04^{b}	0.33 ± 0.11^{a}
	10	12.00± 0.00 ^{c}	59.70 ± 4.08^{abc}	3.267± 0.53^{b}	0.80 ± 0.18 ^{b}	1.33 ± 0.58^{b}	2.66 ± 0.58 ^{b}	0.00± 0.00^{b}	0.65 ± 0.05 ^{ab}	0.23± 0.03^{a}
	se	0.44	5.22	0.61	0.12	0.65	3.15	5.81	0.09	0.04
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Sara	0	16.24± 0.22	47.53± 16.11	8.43 ± 2.05^{a}	1.98 ± 0.26^{a}	1.46 ± 0.19	5.25 ± 0.86^{b}	2.30± 1.04	1.09± 0.16^{a}	0.51± 0.02^{a}
	1	16.94± 0.19	57.96± 12.92	4.99 ± 0.03^{ab}	1.14 ± 0.80^{ab}	1.93 ± 0.95	11.66 ± 1.64^{a}	8.33± 6.66	1.02± 0.08^{a}	0.41 ± 0.04^{a}
	2	17.00± 1.73	63.42± 0.87	5.11 ± 1.12^{ab}	0.82 ± 0.33^{b}	3.25 ± 0.43	8.91 ± 1.53^{ab}	10.00± 5.00	0.44± 0.11^{b}	0.25 ± 0.00^{b}
	5	16.49± 0.65	55.34± 22.07	3.26 ± 0.29^{b}	0.79 ± 0.07^{b}	3.00 ± 1.73	4.00 ± 0.14^{b}	3.33 ± 5.77	0.38± 0.07^{b}	0.26 ± 0.06^{b}
	10	15.72± 0.48	31.07± 5.77	2.50 ± 0.50^{b}	0.75 ± 0.05^{b}	1.20 ± 0.35	3.88 ± 2.45^{b}	0.66 ± 1.15	0.38± 0.04^{b}	0.22 ± 0.03^{b}
	se	0.50	7.95	0.62	0.26	0.53	0.86	2.65	0.06	0.02
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series at 10ppm arsenic concentration. Mahmud *et al.* (2006) reported that dry matter weight of root in castor oil plant increased significantly with increasing level of soil As but this experiment showed that shoot dry weight increased up to 2ppm in Barisal soil series and decreased thereafter while in Sara soil series it decreased with increasing arsenic concentration.

3.7. Number of pods

The number of pods varied from 1.46±0.19 to 3.25±0.43 in Sara soil series and 1.33±0.58 to 15±0.00 in Barisal soil series (Table. 1). The highest number of pods (15±0.00) was observed in Barisal soil series at 2ppm arsenic treatment whereas the lowest number of pod (1.33±0.58) was observed at 10ppm which was statistically similar to 0, 1, and 5ppm. In Sara soil series the maximum number of pods (3.25±0.43) was observed at 2ppm arsenic concentration and the minimum numbers of pod (1.46±0.19) were observed at 0 ppm arsenic concentration. However, As treatments significantly affected the number of pods of green gram in Barisal soil series and the variation found statistically insignificant in Sara soil series.

3.8. Number of seeds

In Sara soil number of seeds varied from 3.88±2.45 to 11.66±1.64 and 2.66±0.58 to 43.3±2.89 in Barisal soil series (Table. 1). 2ppm arsenic treatment produced the highest number of seeds (43.3±2.89) while 10ppm arsenic concentration produced the lowest number of seeds (2.66±0.58) in Barisal soil. In Sara soil the highest number of seeds (11.66±1.64) was produced at 1ppm arsenic concentration and the lowest number of seeds (3.88±2.45) was produced at 10ppm arsenic concentration. Arsenic treatments significantly affected the number of seeds in both soils. Carbonell-Barrachina *et al. (*1998) and Gulz (1999) reported that yield increases for com, potatoes, rye and wheat due to small additions of As.

3.9. Number of nodule

Number of nodule significantly varied among the treatments in Barisal soil and varied insignificantly in Sara soil. In Barisal soil, number of nodule varied from 0.00±0.00 to 34.83±22.14 and at 2ppm As concentration the number of nodule was found superior to other treatments. In Sara soil series, number of nodule varied from 0.66±1.15 to 10.00±5.00 and the highest number of nodule was observed with 2ppm arsenic treatment (Table 1). Santi *et al*. (2011) reported that arsenic produced a drastic effect in nodule number in early stage of nodulation. Toxic effects of metals on nitrogen fixing area in root nodules of soybean plants have been reported earlier by Chen *et al.* (2003).

Table 2: Effect of As containing irrigation water on nutrient accumulation in shoot

Soil	As treatment	P	K	S	Ca	Mg	Fe
Barisal	0	1.43a	5.56	1.38a	1.16a	1.32a	0.29d
	1	1.42a	5.53	1.36ab	0.80ab	1.27a	0.30cd
	2	1.31a	5.50	1.20ab	0.63ab	0.74b	0.31b
	5	1.29a	5.47	1.16bc	0.56ab	0.71b	0.32b
	10	1.07b	5.07	1.01c	0.33b	0.64b	0.35a
		***		**	**	**	***
Sara	0	1.75a	5.44	1.55a	2.06a	1.36a	0.27d
	1	1.74a	5.42	1.52ab	2.00a	1.25a	0.28cd
	2	1.71a	5.39	1.45ab	1.80a	1.16a	0.30bc
	5	1.64a	5.36	1.36ab	1.20b	1.08a	0.31ab
	10	1.47b	5.29	1.20b	0.67b	0.54b	0.33a
		***		**	**	**	***

3.10. Mungbean yield (t ha-1)

Mungbean yield (t ha^{-1}) differed significantly among the treatments in both soil (Fig. 1). In Barisal soil, mungbean yield (t ha^{-1}) varied from 0.05±0.02 to 1.39 ±0.40 t ha^{-1} and the highest yield was observed with 0ppm arsenic treatment which was statistically similar to 1 and 2ppm and the lowest yield was estimated at 10ppm. In Sara soil, yield varied from 0.17±0.00 t ha^{-1} to 1.33±0.28 t ha^{-1} and showed a decreasing trend of yield with increasing As treatment. Carbonell-Barrachina *et al.* (1998) and Gulz, (1999) observed that yield increases due to small additions of As for corn, potatoes, rye and wheat but the present experiment showed that in Barisal soil series yield decreases with increasing As concentration. The same trend was also found in Sara soil series but the treatment 0ppm yielded lower than 1 and 2ppm As concentration. The yield of amaranth was significantly reduced with increasing As levels (Fig.1) (Choudhury *et al.*, 2009).

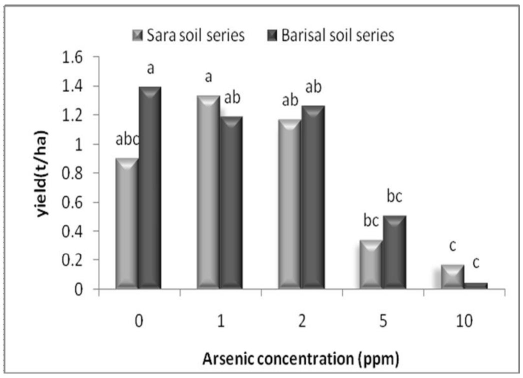

Fig 1: Yield of the green gram plants treated with different concentration of Arsenic

3.11. Nutrients accumulation in Shoot

Nutrient accumulation in shoot differed significantly among the treatments except K accumulation in both Sara and Barisal soil (Table. 2). Phosphorus and potassium concentration showed a decreasing trend with increasing arsenic treatment in both soils. Sulfur accumulation against arsenic treatments 0, 1, 2 and 5ppm showed statistically similar result and the lowest concentration was estimated at 10ppm arsenic in both soils. Calcium accumulation followed exactly similar trend like sulfur accumulation in Barisal soil whereas in Sara soil, calcium accumulation at 0, 1 and 2ppm concentrations were found statistically similar and the lowest value was obtained at 10ppm. Magnesium accumulation showed a decreasing trend with increasing arsenic concentrations in Barisal soil whereas in Sara soil it was statistically similar up to 5ppm and then declined. A dissimilar trend unlike other nutrients was observed with iron accumulation in both the soils; iron accumulation increased with increasing arsenic concentrations.

4. Conclusion

Arsenic accumulation in the plant parts depends on many factors such as plant species, soil type, nutrient supply and pH (Tu and Ma, 2003a), among them plant species is an important factor. The research results revealed that most of the agronomic parameters of mungbean were statistically significant with the arsenic treatments in both the soil except plant height, root length, pod number and numbers of nodule in Sara soil. On the basis of observation, it may conclude that Arsenic positively influenced the entire physiology and growth of mungbean up to 2ppm but finally decreased growth and yield. It also observed that Accumulation of all the studied nutrients in shoot decreased while accumulation of iron increased with increasing arsenic concentrations. So, it may be recommended that As concentration up to 2ppm is not harmful for growth of mung bean pulse and the growth and yield of mung bean showed to be drastically affected by 10ppm treatment.

5. References

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