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Impact of Different Arsenic Concentrations on Key Morphological and Physiological Parameters in Wheat Genotypes (*Triticum aestivum* L.)

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ABSTRACT

An experiment was carried out in the Laboratory of the Department of Plant Physiology to determine the effects of various arsenic concentrations on the morphological and physiological parameters in wheat genotypes. Four genotypes of wheat viz., Sonalika, HUW-234, HUW-669 and DBW-187 were taken for this experiment with four different concentrations of sodium arsenate, i.e., T_1 - 50 µM, T_2 - 100 µM, T_3 - 150 µM and T_4 - 200 µM. When the concentration of arsenic rose, there were significant variations observed across the genotypes, with each genotype recorded a decline in performance with respect to physiological parameters including percent germination, germination rate, radicle length, plumule length, seedling vigour index, fresh weight and dry weight, except percent difference from control. However, among genotypes DBW-187 and HUW-669 did not show steep decline in each parameter, but drastic reduction was observed in HUW-234 and particularly in Sonalika genotype. As a result, DBW-187 and HUW-669 genotypes of wheat were found to be more tolerant to the harmful effects of arsenic than HUW-234 and Sonalika in all treatments.

Key words: Wheat, Arsenic toxicity, Heavy metal, Phytochelatin complex

Arsenic (As) is a metal contaminant and considered as a major environmental concern to the agricultural system. A recent study by [1] showed that arsenic was an emerging source of carcinogenic risk in humans. Uncontaminated soils typically have arsenic concentrations below 0.5 mg kg^{-1}, although depending on the soils constituents, these concentrations can rise to considerable levels. Although, Arsenic is a non-essential element for agricultural plants, but it is readily absorbed by plants growing in arsenic-contaminated soils, entering the food chain and harming both plants and human beings. On the other hand, the pesticides based on inorganic arsenic groups such as copper aceto-arsenite and calcium arsenite have also been applied in agricultural soils and related to negative impacts on the growth of crops [2]. Arsenic accumulation affects the absorption of nutrients from minerals, particularly phosphate, and hinders stomatal opening and closing. It also alters internal metabolism and reduces crop production. It is well reported that arsenic availability in soil triggers a substantial reduction in the growth and productivity of plants. This might be because roots are usually the primary organ to be in contact with arsenic, where this metalloid results in root lignification, the disintegration of microtubules, discoloration of cells, and increase of root diameter [3-4]. Arsenic toxicity have been reported to alter many morphological and physiological parameters in crop plants which leads to significant reduction in yield potential of crop plants.

MATERIALS AND METHODS

The experiment was conducted in the Laboratory of the Department of Plant Physiology, Institute of Agricultural Sciences, Banaras Hindu University. Healthy seeds of wheat varieties i.e., HUW-669, HUW-234 and DBW-187 were collected from Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University and Sonalika variety was procured from Department of Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University. Different concentrations of sodium arsenate ($Na_2HAsO_4.7H_2O$) were used to induce the heavy metal stress to selected wheat genotypes. Sodium arsenate was dissolved in double distilled water and four different concentrations i.e., T_1 - 50 µM, T_2 - 100 µM, T_3 - 150 µM, T_4 - 200 µM of salts were prepared. Fresh, clean, air-dried Petri plates (10 cm diameter) were taken and filter paper according to base size was carved out and placed. The filter paper discs were spiked with different treatments of sodium arsenate solution. Each petri plate contained 10 seeds. 15 Petri plates of each variety viz., Sonalika, HUW-669, HUW-234, and DBW-187 were prepared in replicated form. All

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morphological and physiological parameters were recorded following standard protocols. Statistical analysis and ANOVA table was prepared using two factorial CRD utilizing OPSTAT software.

RESULTS AND DISCUSSION

Many plants are susceptible to environmental variables during the seed germination and seedling phases. As a result, decrease in percent germination and germination rate was seen at each stage of treatment. However, drastic reduction in percent germination was observed at 200 µM concentration of sodium arsenate i.e., 68% reduction as compared to control, while germination rate was reduced by 67.76% in case of Sonalika genotype (Table 1). DBW-187 and HUW-669 genotypes were less susceptible to arsenic stress. Aksakal *et al.* [5], Duncan *et al.* [6] has documented similar negative effects of arsenic on percent germination and germination rate in *Triticum aestivum* L. seedlings.

Similar results were observed in case of radicle length and plumule length at greater doses of sodium arsenate. In each variety, radicle length was more inhibited than plumule length, while Sonalika genotype showed greater inhibition at higher levels of arsenic concentration. At the concentration of 200 µM sodium arsenate, radicle length and plumule length was decreased by 78.33% and 71.04% respectively in case of Sonalika genotype (Table 2), however HUW-669 and specially DBW-187 genotypes has longer radicle and plumule length at each treatment and percent reduction was not steep, which shows that DBW-187 and HUW-669 genotypes of wheat are more tolerant to arsenic toxicity than other genotypes. In another study, Hossain *et al.* [7], Sil *et al.* [8] found that arsenic treatment harmed root growth than shoot growth in wheat seedlings [9].

Table 1 Impact of different arsenic concentrations on percent germination (%) and germination rate (%) in wheat genotypes

	Percent germination (%)						Germination rate (Days)					
Treatment / Variety	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
Sonalika	83.3	76.6	66.6	53.3	26.6	61.3	2.73	2.55	2.22	1.77	0.88	2.04
HUW-234	93.3	83.3	76.6	60	36.6	70	3.11	2.77	2.55	1.99	1.22	2.33
HUW-669	96.6	86.6	83.3	63.3	40	74	3.22	2.88	2.77	2.11	1.33	2.46
DBW-187	100	93.3	86.6	70	46.6	79.3	3.33	3.11	2.88	2.33	1.55	3.97
Mean	93.3	85	78.3	61.6	37.5		3.11	2.83	2.61	2.05	1.24	
ANOVA	SEm ±			C.D. at 5%			SEm ±			C.D. at 5%		
V	2.028			5.801			0.068			0.195		
T	2.267			6.483			0.076			0.218		
V × T	4.534			13			0.151			0.434		

Where (T_0 - Control / Distilled water, T_1 - 50 µM, T_1 - 100 µM, T_2 - µM, T_3 - 150 µM, T_4 - 200 µM)

Table 2 Impact of different arsenic concentrations on radicle length (cm) and plumule length (cm) in wheat genotypes

	Radicle length (cm)						Plumule length (cm)					
Treatment / Variety	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
Sonalika	3.97	2.75	1.84	1.02	0.86	2.09	4.8	3.6	2.12	2	1.39	2.78
HUW-234	4.1	3.22	2.45	1.7	0.98	2.49	5.98	4.63	3.83	2.71	1.91	3.81
HUW-669	4.61	3.9	3.43	2.82	2.12	3.37	6.85	6.24	5.72	4.52	3.9	5.44
DBW-187	5.27	4.32	3.85	3.01	2.51	3.79	7.4	6.8	6.01	4.8	4	5.8
Mean	4.48	3.55	2.89	2.13	1.62		6.26	5.32	4.42	3.07	2.8	
ANOVA	SEm ±			C.D. at 5%			Sem ±			C.D. at 5%		
V	0.031			0.089			0.05			0.144		
T	0.035			0.1			0.056			0.161		
V × T	0.07			0.2			0.112			0.323		

Where (T_0 - Control / Distilled water, T_1 - 50 µM, T_1 - 100 µM, T_2 - µM, T_3 - 150 µM, T_4 - 200 µM)

Table 3 Impact of different arsenic concentrations on seedling vigour index and percent difference from control (%) in wheat genotypes

	Seedling vigour index						Percent difference from control (%)				
Treatment / Variety	T_0	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
Sonalika	400	276	141	106	37.2	192	7.87	20.37	35.64	68.05	32.98
HUW-234	558	385	294	163	70.3	294	10.37	17.77	35.92	61.1	31.29
HUW-669	661	540	477	287	155	424	10.37	13.33	34.81	58.88	29.35
DBW-187	740	636	522	362	185	489	6.66	8.81	30	53.33	25.83
Mean	590	460	358	229	112		8.81	16.2	34.09	60.34	
ANOVA	SEm ±			C.D. at 5%			Sem ±			C.D. at 5%	
V	2.68			7.69			2.367			6.93	
T	3.81			10.93			2.734			8.026	
V × T	5.22			14.98			4.735			13.902	

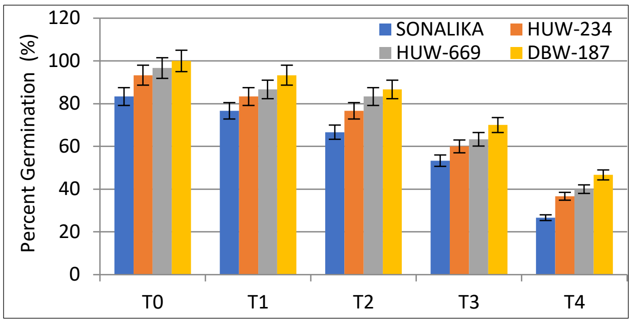
Where (T_0 - Control / Distilled water, T_1 - 50 µM, T_1 - 100 µM, T_2 - µM, T_3 - 150 µM, T_4 - 200 µM)

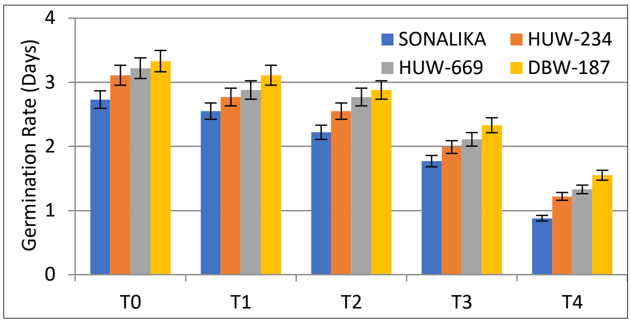
Table 4 Impact of different arsenic concentrations on fresh weight (gm) and dry weight (gm) in wheat genotypes

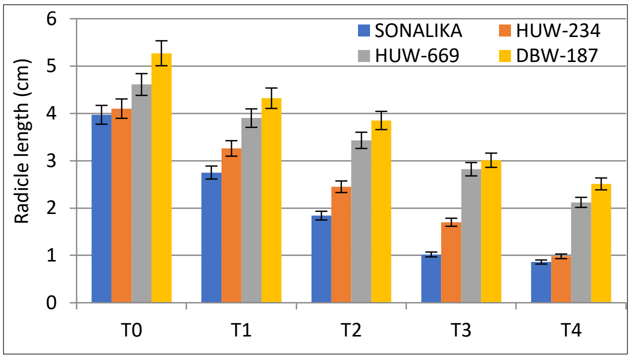
Treatment / Variety	Seedling vigour index						Percent difference from control (%)					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
Sonalika	0.21	0.18	0.14	0.12	0.1	0.15	0.05	0.04	0.04	0.03	0.03	0.04
HUW-234	0.25	0.23	0.2	0.18	0.16	0.2	0.06	0.05	0.04	0.04	0.03	0.05
HUW-669	0.3	0.29	0.23	0.19	0.14	0.23	0.06	0.05	0.05	0.04	0.04	0.05
DBW-187	0.43	0.41	0.37	0.3	0.27	0.36	0.07	0.06	0.05	0.05	0.04	0.06
Mean	0.3	0.27	0.24	0.2	0.17		0.06	0.05	0.05	0.04	0.04	

ANOVA	SEm ±	C.D. at 5%	Sem ±	C.D. at 5%
V	0.004	0.012	0.000	0.000
T	0.005	0.014	0.001	0.004
V × T	0.009	0.027	0.003	0.008

Where (T_0 - Control / Distilled water, T_1 - 50 µM, T_1 - 100 µM, T_2 - µM, T_3 - 150 µM, T_4 - 200 µM)







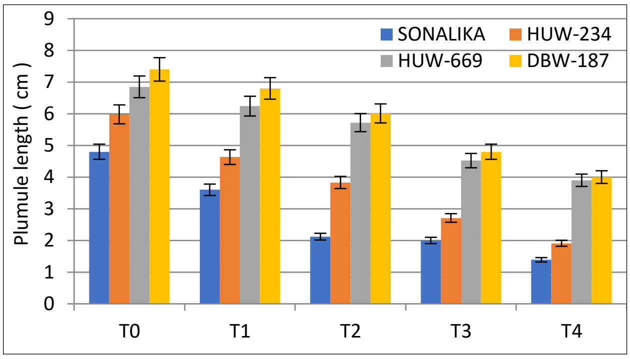


Fig 1

Fig 2

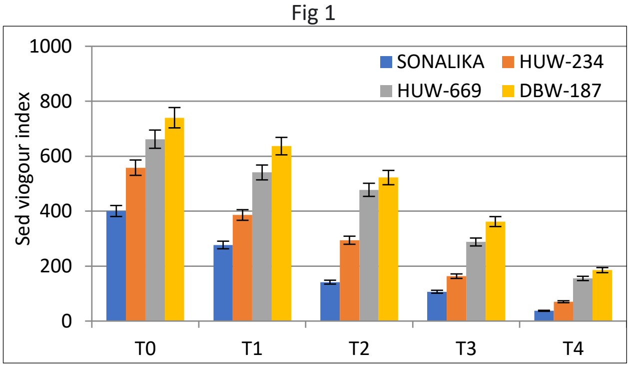


Fig 3

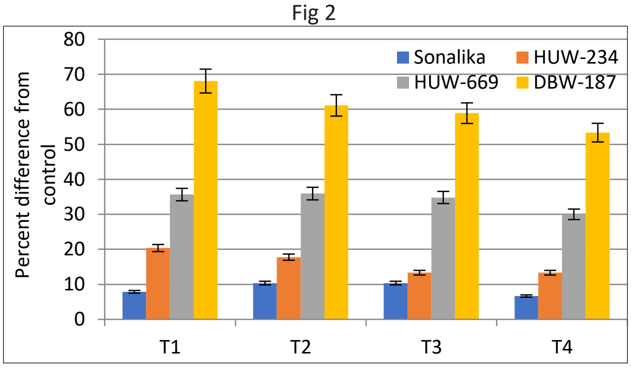


Fig 4

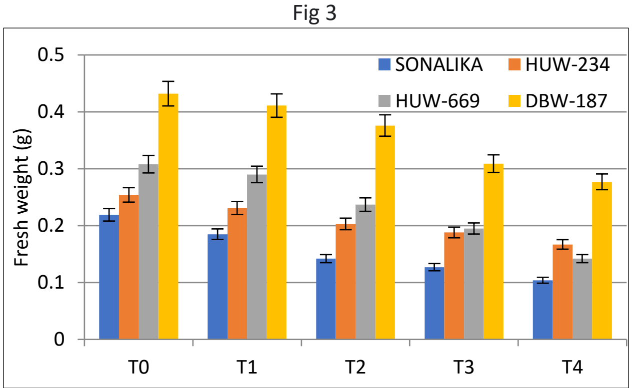


Fig 5

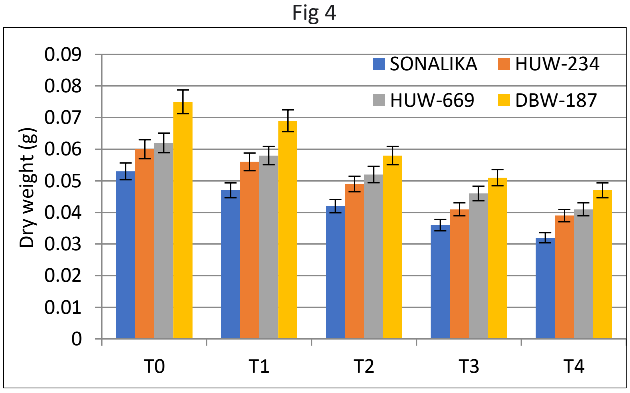


Fig 6

Fig 1-8 Percent germination, germination rate, radicle length, plumule length, seed vigour index, percent difference from control, fresh weight and dry weight respectively

The seedling vigour index (SVI) and percent difference from control are a potential indicator for seed germination and seedling size in the context of metal toxicity and tolerance. With the increasing dosage of arsenic, both the parameters were affected, in which maximum reduction was seen in Sonalika genotype, at the concentration of 150 µM and 200 µM of sodium arsenate, percent reduction was recorded 73.36 and 90.68 respectively. However, there was not any steep reduction observed in case of HUW-234 and DBW-187 genotypes (Table 3). There was direct relationship analyzed between arsenic concentration and percent difference from control. Maximum difference was found in Sonalika genotype i.e., 68.05% in comparison to control at the concentration of 200 µM sodium arsenate. Meanwhile minimum difference was found in DBW-187 genotype i.e., 53.33% which shows that DBW-187 genotype is more tolerant to arsenic toxicity at each treatment [10].

The decrease in the biomass of the crop plants is observed with an increase in the concentration of sodium arsenate. In which, Sonalika genotype was affected severely with the increase in arsenic concentration at each stage. But the drastic reduction was recorded at the concentration of 200 µM, at which fresh weight and dry weight were reduced by 52.51% and 39.62% respectively as shown in (Table 4). However, performance of DBW-187 and HUW-669 genotypes were better than other genotypes [11].

CONCLUSION

As a result of the foregoing experiment, it can be inferred that heavy metal arsenic had a significant impact on morphological and physiological properties the wheat genotypes. With increasing arsenic toxicity, percent germination, germination rate, radicle length, plumule length, seed vigour index, fresh weight and dry weight were decreased, whereas percent difference from control increased significantly. Among all genotypes viz. Sonalika, HUW-234, DBW-187 and HUW-669, DBW-187 and HUW-669 were found to be more tolerant to arsenic toxicity in comparison to other genotypes.

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