# Effect of Arsenic in Three Wheat Varieties of Bangladesh

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**Abstract**

A pot experiment was conducted in net house of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2009 to February, 2010 to study the effect and accumulation of arsenic in three popular wheat varieties in Bangladesh. Three wheat varieties ($V_1$=*Protiva*, $V_2$=*Sourav* and $V_3$=*Gourav*) and five levels of arsenic ($As_0$=0, $As_{10}$=10, $As_{20}$=20, $As_{30}$=30, $As_{40}$=40 ppm $kg^{-1}$ soil) were used in the experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Result showed that addition of arsenic significantly ($p<0.05$) reduced the growth, yield parameters and seed yield of wheat varieties. However, *Gourav* showed the potentiality against the arsenic toxicity up to 30 ppm arsenate salt $kg^{-1}$ soil followed by *Sourav* and *Protiva*. The maximum plant height (100 cm), tillers $hill^{-1}$(6), grain $spike^{-1}$ (47), test weight (46 g), seed yield (4.51 t $ha^{-1}$) but the lowest maturity days (104) was harvested in $V_3As_0$. Separately the lowest plant height (87.33 cm), tillers $hill^{-1}$(4.33), grain $spike^{-1}$ (36.33), test weight (41.00 g) but maximum maturity days (114) and yield reduction (5.987% compared to control) was recorded in $V_1As_{40}$. Arsenic concentration in plant parts increased with increasing the arsenate concentration in soil. Plant tissues were susceptible in the order of root>straw>grain and the concentrations of arsenic were dependent on variety and treatment levels in polluted soils and statistically ($p<0.01$) maximum concentration of arsenic in root (3.08 μg $g^{-1}$), straw (0.9233 μg $g^{-1}$) and grain (0.16 μg $g^{-1}$) were measured in *Protiva* variety when it was cultivated with 40 ppm arsenic $kg^{-1}$ soil. On the contrary, *Gourav* contained significantly ($p<0.01$) less amount arsenic in root (2.34 μg $g^{-1}$), straw (0.376 μg $g^{-1}$) and grain (0.04 μg $g^{-1}$) at the same level of arsenic contaminated soil.



## 1. Introduction

Arsenic contamination of ground water now is a well recognized major health concern in Bangladesh, where contaminated water is used for drinking and irrigation purpose (Imamul Huq and Naidu, 2005). About 35-77 million people are exposed to arsenic contaminated well-water (Smith et al., 2007; Rabbani et al., 2000). Five years (1995-2000) joint survey of SOES and DCH in Bangladesh indicated that 73.34% tub-well water samples (total 22003 samples were collected from 64 districts) contain arsenic concentration above the WHO standard limit (0.01 mg $l^{-1}$) and 54 districts possess this limit and 74 blocks and approximately 2700 villages have already been identified ground-water arsenic concentration above 0.05 mg $l^{-1}$ (Chakraborti et al., 2002) and it has been estimated that between 200,000-270,000 people will die from arsenical cancer as a fate of arsenic water ingestion (WHO, 2001).

The people of Bangladesh are not only drinking this element contaminated water but also produce crops irrigated with this water. About 75% of the total cropped area and 30-40% of the net cropped area are dependent on ground-water irrigation (Dey et al., 1996). Irrigation water borne arsenic from contaminated ground-water is being accumulated in soils (Ullah, 1998; Sanaullah et al., 2009). Background concentrations of soil arsenic in Bangladesh are 4-8 mg $kg^{-1}$ soil. However, in areas where irrigation is done with arsenic contaminated groundwater, soil arsenic can reach up to 58 mg $kg^{-1}$ soil (Imamul Huq and Naidu, 2003). High arsenic concentration in soils and irrigation water is phytotoxic that adversely affect plant growth and fruit yields (Carbonell-Barrachina et al., 1995), discolored and stunted roots, withered and yellow leaves (Machlis, 1941), reductions in chlorophyll and protein contents, and in photosynthetic capacity of plant (Marin et al., 1993).

Wheat is second important cereal crop after rice in Bangladesh. About 778,000 $ha^{-1}$ area is under wheat cultivation with production of 1,550,000 mt (FAO, 2003). Half the wheat is grown on irrigated land during dry season with groud-water. Arsenic contaminated irrigation water and soil can be harmful to wheat seedling at early developmental stages and physiological activities of wheat seedlings are also changed under arsenic stress (Li et al., 2007). Seed germination, biomass, root length and shoot height decreased, and arsenic accumulation increased on early seedlings of wheat as concentrations increased (Liu and Zhang, 2007). Arsenic promotes initiation of cancer cells in a broad array of tissues (Kayajanian, 2000). Threats that arsenic imposes to human and animal health is aggravated by its long-term existence in the environment (Hall, 2002). Arsenic may accumulate in agricultural soils and plants, and it is a cumulative poison that affects all body systems (Berman, 1980; Gonzalez et al., 2001). However, most works on arsenic toxicity in wheat have been short-term studies. It is hypothesized that arsenic reduces plant biomass and yield components in chronically-exposed wheat plants, and high arsenic concentrations affect arsenic distribution within the plant, especially in grains. The objectives of this study were to determine the arsenic effects on yield contributing characters and yield of wheat and the amount of arsenic in different plant parts. These results will be beneficial for future research to predict and reduce the risk of arsenic entrance into the wheat grain of Bangladesh.

Table 1: Physical and chemical properties of the experimental soil

| Soil characteristics | Value | Soil characteristics | Value | Soil characteristics | Value |
|---|---|---|---|---|---|
| Sand | 26% | Organic carbon | 0.45% | Arsenic | 0.00 µg $g^{-1}$ |
| Silt | 45% | Total nitrogen | 0.78% | Boron | 0.48 µg $g^{-1}$ |
| Clay | 29% | Phosphorus | 22.08 µg $g^{-1}$ | Copper | 3.54 µg $g^{-1}$ |
| pH | 6.9 | Sulpher | 25.98 µg $g^{-1}$ | Zinc | 3.32 µg $g^{-1}$ |

## 2. Materials and Methods

*2.1. Research site*

The study was carried out at the net house of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2009 to February, 2010. The experimental site is located under sub-tropical region situated between $23^0$ 74́ N latitude and $90^0$ 35́ E longitude. The mean air temperature during the study period was $20^0$C. The experimental soils were located under the AEZ (Agro-ecological Zone) of Bangladesh number 28.

*2.2. Preparation of arsenic solution*

The stock solution was prepared by sodium arsenate ($Na_2HA_sO_4.7H_2O$) where 6.5 g sodium arsenate was dissolved in 1000000 ml of de-ionized distilled water. Zero ppm arsenic solution was prepared by only using de-ionized distilled water and 10, 20, 30 and 40 ppm arsenic solution was prepared through adding 100, 200, 300 and 400 ppm stock solutions in 900, 800, 700 and 600 ml of de-ionized distilled water, respectively.

*2.3. Treatments and plant materials*

Three wheat (*Triticum aestivum* L.) varieties, viz. $V_1$=*Protiva*, $V_2$=*Sourav* and $V_3$=*Gourav*, and five levels of arsenic, viz. $As_0$=0, $As_{10}$=10, $As_{20}$=20, $As_{30}$=30 and $As_{40}$=40 ppm arsenic $kg^{-1}$ soil were used with fifteen treatment combinations, viz. $V_1As_0$, $V_1As_{10}$, $V_1As_{20}$, $V_1As_{30}$, $V_1As_{40}$, $V_2As_0$, $V_2As_{10}$, $V_3As_{20}$, $V_4As_{30}$, $V_2As_{40}$, $V_3As_0$, $V_3As_{10}$, $V_3As_{20}$, $V_3As_{30}$ and $V_3As_{40}$. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Therefore, there were 45 pots under the experiment each having the size of 43x40 $cm^2$.

*2.4. Soil preparation*

Twelve kg oven-dried soil was taken into each pot which was arsenic free and coarse-silty loam, collected from local farm of Sher-e-Bangla Agricultural University at 0-15 cm depth. It was crushed, mixed thoroughly and sieved through a 2 mm mesh. A composed sample from this soil was collected for physico-chemical analysis. Some soil properties are presented in Table 1. Arsenic solution was mixed thoroughly with the soil of each 15 pots @ 0 (control), 10, 20, 30 and 40 ppm $kg^{-1}$ soil. The soil was then air-dried, passed through a 2 mm sieve again, and aged for 1 week. As a basal dose different fertilizers like Urea: Triple super phosphate: Muriate of potash were applied at 80:160:70 kg $ha^{-1}$, respectively as per BARI ( Bangladesh Agricultural Research Institute, Joydevpur, Gazipur, Bangladesh) recommendation rate in the first 30 cm of the contaminated soil. Fertilizers were incorporated into the soil by hand, and applied before sowing of seeds. At crown root initiation stage 80 kg $ha^{-1}$ urea was applied in each pot.

*2.5. Wheat cultivation*

Seeds were surfaced-sterilized with hypochlorite for 2 minutes and washed with tap water. They were then submerged in distilled water, and cultured in an incubator for 24 h set at 37°C. After the radicle appeared, seeds were sown on 10 November, 2009 in experimental pots. Two seeds were sown in each pot maintaining 20 cm plant to plant distance. All the agronomic operations were kept normal and uniform for all the treatments.

*2.6. Data collection and statistical analysis*

Data were recorded on plant height, tiller $hill^{-1}$, grain $spike^{-1}$, total maturity days, test weight and seed yield that was converted to yield (t $ha^{-1}$) which was adjusted at 12% moisture. Harvested plants were separated into roots, stems (including straw and leaves) and spikes. Roots were washed completely using distilled water. Root, straw and grain of wheat were analyzed for arsenic by AAS (Atomic Adsorption Spectrometer) (Perkin Elmer-Analyst 200) using hydride generation technique. Data collected on various parameters under study were statistically analyzed using M-STAT. The means separation of growth and yield parameters were done by LSD test at $p$=0.05 where means of arsenic concentration in root, straw and grain were done at $p$=0.01 level of significance.

## 3. Results and Discussion

*3.1. Varietal effect on plant parameters*

Different phenotypic characters were observed during the experiment. From Figure 1, it is found that the tallest plant (96.75 cm) was recorded from variety *Gourav* followed by *Sourav* (95.26 cm) and *Protiva* (91.3 cm). Numerically, maximum number of tiller $hill^{-1}$ was observed in Gaurav (5.8) and it was also observed that there was no significant variation among variety due to effect of variety (Table 2). Number of grain $spike^{-1}$ was highest (44) in *Sourav* which was statistically similar with *Gourav* (43.87). On the contrary, the lowest number of grain $spike^{-1}$ (40.73) was obtained from *Protiva*. The maturity days of the testing varieties were not similar. These were 108, 106 and 105 days in *Protiva*, *Sourav* and *Gourav*, respectively. Among the three varieties, *Gourav* produced the maximum test weight (45.17 g) followed by *Protiva* (44.31 g) and *Sourav* (43.73 g), but the value 44.31 and 43.73 were statistically similar. The maximum seed yield (4.46 t $ha^{-1}$) was harvested from *Gourav* which was statistically significant with seed yield produced by other two varieties, i.e. 4.18 t $ha^{-1}$ in *Sourav* and 3.95 t $ha^{-1}$ in *Protiva*.

*3.2. Varietal effect on arsenic concentration in root, shoot and grain*

Arsenic concentration varied considerably between wheat varieties (Table 3). The maximum arsenic concentration (1.58 µg) in root, (3.887 µg) in shoot and (0.05 µg) in grain were recorded from variety *Protiva* followed by *Sourav* and *Gourav* which might be due to the later two varieties showed more resistance than the earlier for their genetical behavior. Similar result was also reported by Sen et al. (2008).

Table 2: Effect of variety on growth, yield attributes and yield of wheat

| Treatment | Plant height (cm) | Tiller $hill^{-1}$ | Grain $spike^{-1}$ | Maturity (days) | Test weight (g) | Seed yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $V_1$ | 91.30c | 5.467a | 40.73b | 108.2a | 44.31b | 3.95c |
| $V_2$ | 95.26b | 5.667a | 44.00a | 106.3b | 43.73b | 4.19b |
| $V_3$ | 96.75a | 5.80a | 43.87a | 104.7c | 45.17a | 4.46a |
| SEm± | 0.4199 | 0.2309 | 0.3498 | 0.1897 | 0.2834 | 0.03162 |
| CD ($p$=0.05) | 1.216 | 0.669 | 1.013 | 0.5496 | 0.8211 | 0.092 |

*3.3. Effect of arsenic on plant parameter*

Addition of arsenic to the soil significantly reduced all phenotypic parameters of all wheat varieties. The highest plant height (97.33 cm) was recorded in $As_0$ followed by $As_{10}$ (95.61 cm), $As_{20}$ (94.62 cm), $As_{30}$ (93.07 cm)) and $As_{40}$ (91.56 cm) (Table 4). It is identified that plant height was decreasing with increasing arsenic concentration in soil in the tested varieties. Significantly, maximum number of tillers $plant^{-1}$ and numbers of grain $spike^{-1}$ were recorded in $As_0$ and the figures are 6 and 45.44, respectively followed by $As_{10,}$ $As_{20}$, $As_{30}$ and $As_{40}$. The maturity days of wheat varieties were interestingly increasing with increasing arsenic concentration and reached peak up to 109.79 days whereas it took only 104.33 days for maturity of wheat plant when there was no arsenic in soil (Table 4). Test weight was highest (45.56 g) in $As_0$ which was statistically similar with test weight also recorded from $As_{10}$ (45.55 g) and $As_{20}$ (44.89 g) (Table 4). The maximum seed yield (4.27 t $ha^{-1}$) was harvested in $As_0$ then 4.26 t $ha^{-1}$ in $As_{10}$ and 4.20 t $ha^{-1}$ in $As_{20}$ which were statistically similar with each other and the trend was decreased with increased level of arsenic concentrations in soil.

Table 3: Varietal effect of arsenic concentration in root, shoot and grain of wheat

| Treatment | As in root (µg $g^{-1}$) | As in straw (µg $g^{-1}$ ) | As in grain (µg $g^{-1}$) |
|---|---|---|---|
| $V_1$ | 1.58a | 0.3887a | 0.05a |
| $V_2$ | 1.25b | 0.2121b | 0.01a |
| $V_3$ | 1.12b | 0.1901b | 0.02a |
| SEm± | 0.06831 | 0.01826 | 0.052 |
| CD (p=0.05) | 0.2670 | 0.07135 | 0.208 |

*3.4. Effect of arsenic in root, shoot and grain arsenic concentration*

A general trend was found that increasing of arsenic in root, shoot and grain with increasing levels of arsenic in soil (Table 5). No arsenic was found in root, shoot and grain of all varieties grown in control soils. However, arsenic concentration in root and shoot grain varied significantly among the three varieties but arsenic accumulation (0.01 to 0.05 µg $g^{-1}$) in grain was not significant among the varieties.

*3.5. Interaction effect of variety and arsenic on different growth and yield parameters*

Table 4: Effect of different levels of arsenic on growth , yield attributes and yield of wheat

| Treatment | Plant height (cm) | Tiller $hill^{-1}$ | Grain $spike^{-1}$ | Maturity days | Test weight (g) | Seed yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $As_0$ | 97.33a | 6.00a | 45.44a | 104.33d | 45.56a | 4.27a |
| $As_{10}$ | 95.61b | 5.89a | 44.78a | 104.33d | 45.44a | 4.26a |
| $As_{20}$ | 94.62b | 5.78a | 43.44b | 105.67c | 44.89a | 4.20ab |
| $As_{30}$ | 93.07c | 5.67a | 41.11c | 107.78b | 43.77b | 4.16bc |
| $As_{40}$ | 91.56d | 4.89b | 39.56d | 109.79a | 42.37c | 4.10c |
| SEm± | 0.4199 | 0.2309 | 0.3498 | 0.1897 | 0.2834 | 0.03162 |
| CD ($p$=0.05) | 1.21g6 | 0.669 | 1.013 | 0.5496 | 0.8211 | 0.09161 |

Table 4 shows the interaction effect of variety and arsenic concentration on plant parameters and arsenic concentration in root, shoot and grain. Arsenic contaminated soil had marked influence on the plant height, tiller $hill^{-1}$, grain $spike^{-1}$, maturity days, seed yield and percent yield loss (Table 6). The highest plant height was noted in three control pots of each replication of the experiment, and among the three varieties *Gourav* showed the best performance (100 cm) than others. Similar trend was also reported by Abedin et al. (2002) in grass plant rice where they reported that the progressive accumulation of arsenic in plants with time exposure caused the plant height reduction. Among the twelve treatment combinations, treatment $V_1As_{40}$, $V_2As_{40}$ and $V_3As_{40}$ produced the significantly minimum number of tillers $hill^{-1}$ and those were 4.33, 5.00 and 5.33 respectively, whereas rest of the treatments produced statistically similar number of tillers $hill^{-1}$ and it indicated that

Table 5: Effect of arsenic in root, shoot and grain arsenic concentration of wheat

| Treatment | Arsenic concentration ($\mu g\ g^{-1}$) | | |
|---|---|---|---|
| | Root | Shoot | Grain |
| $As_0$ | 0.00e | 0.000e | 0.00a |
| $As_{10}$ | 0.68d | 0.091d | 0.01a |
| $As_{20}$ | 1.36c | 0.232c | 0.03a |
| $As_{30}$ | 1.93b | 0.427b | 0.05a |
| $As_{40}$ | 2.60a | 0.567a | 0.20a |
| SEm± | 0.06831 | 0.01826 | 0.05164 |
| CD (*p*=0.05) | 0.2670 | 0.07135 | 0.2018 |

40 ppm As $kg^{-1}$ soil drastically reduced the number of tillers $hill^{-1}$. Significantly highest grain $spike^{-1}$(47) was found in $V_3As_0$ followed by $V_2As_0$ (46.00), $V_2As_1$ (45.33) and $V_3As_1$ (45.33). Other arsenic levels and varietal combinations gave the lowest number of grain $spike^{-1}$ compared with arsenic level 0 and 10 ppm. These findings agreed well with Zhang et al. (2009) who found that increased arsenic level in soil decreased grain $spike^{-1}$ in wheat. There were considerable variations in plant sensitivity to arsenic concentration among the wheat variety. Highest maturity days (114) were derived from $V_1As_{40}$ and second maximum maturity days (110) was obtained from $V_1As_{30}$. On the contrary, the lowest maturity days (104) were recorded in $As_0$, $As_{10}$ and $As_{20}$ along with variety *Gourav*. Interestingly, the highest test weight (46.00 g) was found in $V_3As_0$, $V_1As_0$ and $V_1As_1$ although it was genetical character but decreased to 42.43 g which might be that environmental character was dominated over genetical. The seed yield decreased remarkably as a result of higher arsenic levels and seed yield varied between 4.07 to 3.84 t $ha^{-1}$ in *Protiva*, 4.22 to 4.07 t $ha^{-1}$ in *Sourav* and 4.51 to 4.30 t $ha^{-1}$ in *Gourav*. Irrespective of treatment differences *Gourav* performed better and showed little bit tolerance against different concentration of soil arsenic and statistically maximum seed yield (4.51 t $ha^{-1}$ ) was harvested in $As_0$ followed by $As_{10}$ (4.49 t $ha^{-1}$) and $As_{20}$(4.46 t $ha^{-1}$). In addition, the percent yield decreased was lower (0.445 to 4.88 %) in *Gourav* at different levels of arsenic followed by *Sourav* (1.184 to 4.914 %) and *Protiva* (1.75 to 5.987%). These results were consistent with the results of Sen et al. (2008). On the contrary, in *Protiva* the seed yield was decreased drastically with increased levels of arsenic along with percent seed decreased over control, and statistically the minimum seed yield (3.84 t $ha^{-1}$) was obtained when this variety was treated with 40 ppm As $kg^{-1}$ soil and the maximum percent yield decreased (5.987) was found in this stage whereas in *Sourav* and *Gourav* it was 4.914 and 4.88%, respectively. This result was similar with Zhang et al. (2009). They reported that high levels of arsenic in soil reduced the growth and yield parameters which eventually negatively influenced the seed yield of wheat.

Table 6: Interaction effect of variety and arsenic on different growth and yield parameters of wheat

| Treatment | Plant height (cm) | Tiller $hill^{-1}$ | Grain $spike^{-1}$ | Maturity (days) | Test weight (g) | Seed yield (t $ha^{-1}$) | % yield decreased |
|---|---|---|---|---|---|---|---|
| $V_1As_0$ | 94.50de | 6.00a | 43.33e | 106.00g | 46.00a | 4.07d | 0.00 |
| $V_1As_{10}$ | 93.17fg | 6.00a | 43.67de | 105.00g | 46.00a | 4.00 de | 1.75 |
| $V_1As_{20}$ | 92.00g | 5.67ab | 41.67f | 107.00e | 45.17ab | 3.95ef | 3.03 |
| $V_1As_{30}$ | 89.50h | 5.33ab | 38.67g | 110.00b | 43.40c | 3.87fg | 5.167 |
| $V_1As_{40}$ | 87.33i | 4.33c | 36.33h | 114.00a | 41.00e | 3.84g | 5.987 |
| $V_2As_0$ | 97.50b | 6.00a | 46.00ab | 104.00h | 44.67b | 4.27c | 0.00 |
| $V_2As_{10}$ | 96.33bc | 5.67ab | 45.33bc | 105.00h | 44.67b | 4.22c | 1.184 |
| $V_2As_{20}$ | 95.50cd | 5.67ab | 44.67cd | 106.00f | 43.67c | 4.20c | 1.666 |
| $V_2As_{30}$ | 94.13ef | 6.00a | 43.33e | 108.00d | 43.23cd | 4.19c | 1.909 |
| $V_2As_{40}$ | 92.83g | 5.00bc | 40.67f | 109.33c | 42.43d | 4.07d | 4.914 |
| $V_3As_0$ | 100.00a | 6.00a | 47.00a | 104.00h | 46.00a | 4.51a | 0.00 |
| $V_3As_{10}$ | 97.33b | 6.00a | 45.33bc | 104.00h | 45.83a | 4.49a | 0.445 |
| $V^3As_{20}$ | 96.37bc | 6.00a | 44.00de | 104.00h | 45.67a | 4.46ab | 1.12 |
| $V_3As_{30}$ | 95.57cd | 5.67ab | 41.33f | 105.33g | 44.67b | 4.33b | 4.157 |
| $V_3As_{40}$ | 94.50de | 5.33ab | 41.67f | 106.00f | 43.67c | 4.30b | 4.88 |
| SEm± | 0.4199 | 0.2309 | 0.3498 | 0.1897 | 0.2834 | 0.03162 | - |
| CD (*p*=0.05) | 1.216 | 0.669 | 1.013 | 0.5496 | 0.821 | 0.09161 | - |

*3.6. Interaction effect of variety and arsenic concentration in root, straw and grain*

In general the trend of arsenic accumulation of three varieties was root>straw>grain (Table 7). Arsenic concentration concentration in roots was highest (3.08 $\mu g\ g^{-1}$) in *Protiva* at 40 ppm As salt in $kg^{-1}$ soil. The second highest of arsenic concentration (2.36 $\mu g\ g^{-1}$) in root was measured in $V_2As_{40}$ followed by $V_1As_3$ (2.36 $\mu g\ g^{-1}$) and $V_3As4_0$ (2.34 $\mu g\ g^{-1}$). The lowest arsenic concentration in root was measured in *Gourav* at each treatment combinations. Very little amount of arsenic was detected in grain of three wheat varieties, the maximum amount of arsenic (0.16 µg $g^{-1}$) was found in $V_1As_{40}$ followed $V_2As_{40}$ by (0.13 µg $g^{-1}$ ) and interestingly statistically similar amount arsenic in grain was found in rest of the treatments.

## 4. Conclusion

Among the five levels of arsenic in soil, 40 ppm arsenic in $kg^{-1}$ soil greatly influenced the different growth and yield parameters of three wheat varieties. *Gourav* showed the best performance or seem to tolerant against the different arsenic concentrations in respect to all parameters followed by *Sourav* and *Protiva*. *Protiva* was the most susceptible to different levels of arsenic concentration in soil. Arsenic accumulation varied among the varieties and plant parts and follows the order of root>straw>grain. Maximum concentration of arsenic was measured in all plant parts of *Protiva*.

Table 7: Interaction effect of variety and arsenic in root, straw and grain arsenic concentration of wheat

| Treatment | Arsenic concentration (µg $g^{-1}$) | |
|---|---|---|
| | Root | Grain |
| $V_1As_0$ | 0.00i | 0.00i |
| $V_1As_{10}$ | 0.83g | 0.83g |
| $V_1As_{20}$ | 1.65d | 1.65d |
| $V_1As_{30}$ | 2.36b | 2.36b |
| $V_1As_{40}$ | 3.08a | 3.08a |
| $V_2As_0$ | 0.00i | 0.00i |
| $V_2As_{10}$ | 0.66gh | 0.66gh |
| $V_2As_{20}$ | 1.28ef | 1.28ef |
| $V_2As_{30}$ | 1.93c | 1.93c |
| $V_2As_{40}$ | 2.36b | 2.36b |
| $V_3As_0$ | 0.00i | 0.00i |
| $V_3As_{10}$ | 0.55h | 0.55h |
| $V_3As_{20}$ | 1.14f | 1.14f |
| $V_3As_{30}$ | 1.54de | 1.54de |
| $V_3As_{40}$ | 2.34b | 2.34b |
| SEm± | 0.06831 | 0.05164 |
| CD ($p$=0.05) | 0.2670 | 0.202 |

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