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TOXIC EFFECTS OF VARIOUS ARSENIC CONCENTRATIONS ON GERMINATION AND SEEDLINGS GROWTH OF WHEAT (*Triticum aestivum* L.)

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ABSTRACT

The present study was conducted to assess the effect of different arsenic concentrations on various germination and growth parameters of wheat. For this, wheat seeds of variety HUW-234 were exposed with five arsenic (AsV) concentrations viz., 50 μ M, 100 μ M, 150 μ M, 200 μ M and 250 μ M, while treatment without AsV considered as control (AsV 0). Various growth parameters such as germination percentage, germination index, shoot length, root length, seedling vigour index, dry matter has been recorded at 3 days of germination. Results of study revealed that the germination percentage, germination index, Shoot length, root length, dry matter and SVI significantly reduced at the increasing the arsenic (AsV) concentrations. Results of study suggested that arsenic have harmful effects on seed germination and establishment in wheat crops which restricts plant growth and development.

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1 Introduction

Wheat (*Triticum aestivum* L.) is one of the significant crops, grown as second most important staple food crop of the world. Wheat accounting nearly 30% of global cereal production and covers an area of 218.5 million hectares with an average productivity of 3.26 tonnes ha⁻¹ (FAOSTAT, 2019). In Indian, wheat production stood at record 99.70 million tonnes in 2017-18 cropping year while it crossed 100 million tonnes in the year 2018-19 (Ministry of agriculture, and farmer welfare, 2018-19). Among major wheat growing countries, China (134.34 million tonnes) ranked first in the wheat production, followed by India (98.51 million tonnes), Russia (85.86 million tonnes), and the United States (47.37 million tonnes) (FAOSTAT, 2019). In India, Uttar Pradesh ranked first in wheat production and productivity. The state produces up to 300.01 lakh tonnes of wheat followed by Punjab (164.72 lakh tonnes), Haryana (116.30 lakh tonnes), Madhya Pradesh (76.27 lakh tonnes), and Rajasthan (72.14 lakh tonnes) (Ministry of agriculture and farmer welfare 2018-19). World Bank estimates the demand for wheat in developing countries will increase 60% by 2050. (FAOSTAT, 2019). Wheat growers around the world need to increase their productivity for betterment of upcoming food demand and overwhelming increasing global populations.

More than 200 types of minerals was reported in the Earth's crust, it's maximum percentage (60%) are found in the form of arsenate, 20% are in the form of sulphides and rest 20% are mainly found at the form of arsenides, sodium silicates, metal oxides (Onishi, 1969). Arsenic mainly exist in several oxidation states such as As(-III), As(0), As(III), or As(V) (Panda et al., 2010). Plants can uptake arsenic mainly in inorganic form with the help of several transporter proteins (Neidhardt et al., 2015). The principle driving force for arsenic uptake in plant roots is a concentration gradient between source and sink. According to Lei et al. (2012) that As (V) uses various Pi channels for its entry into the plant root cell. Arsenic contaminations disturb physio-chemical properties of soils and leads to severe loss of crop yields (Rahman et al., 2007). Arsenic exists in the environment in two forms mainly inorganic and organic, with arsenate [As(V)] and arsenite [As(III)] being the most prevalent inorganic and most toxic forms of arsenic (Duxbury et al., 2003). Arsenate being a phosphate analogy interferes with phosphate metabolism (phosphorylation and ATP synthesis) in plants while As(III) binds to sulfhydryl groups of proteins affecting their structures and/or catalytic functions (Zhao et al., 2010). Several studies report that arsenic toxicities in plants increased production of reactive oxygen species (ROS) that leads to membrane damage, leakage, non-specific oxidation of proteins and membrane lipids and also causes DNA injury (Srivastava et al., 2011). The mechanism of As(III) allows As(III) to act as a cross-linking agent by binding up to three monothiol molecules, and disbalance functions of GSH and alternatively destroyed several antioxidant systems like SOD, APX, Glutathione, GPX etc in plant metabolic system (Kitchin & Wallace, 2006). Inappropriate arsenic concentrations can be harmful to wheat seedling at early developmental stages. Seed germination and seedling growth were not much affected at low concentration but at higher concentrations it inhibit both seed germination and seedling growth (5-

20 mg/kg soil). Physiological and biochemical activities of wheat seedlings were also changed under arsenic stress. Seed germination, biomass, root length and shoot height decreased, and as accumulation increased on early seedlings of several wheat varieties as concentrations increased (Liu et al., 2005). Wheat growers around the world need to increase their productivity, while the prices of wheat and other cereal grains decrease. In addition, with the expectation that prices for fertilizers and chemicals will continue to rise in the future, wheat producers must substantially improve their production efficiency to stay competitive. Arsenic in wheat grains was mainly found as inorganic form. Inorganic arsenic, a class I carcinogen, is more toxicant than other metalloids. So, it will result in health risk for wheat consumers. So understanding the mechanisms of arsenic metabolism in wheat is essential to fulfil the demand of future growing populations. Current study was conducted to access the effect of arsenic concentration on seed germination and seedling growth.

2 Materials and Methods

In the present study, 6 different concentrations of arsenic (AsV) viz., 0, 50, 100, 150, 200 and 250 µM was used to access the effect of As on wheat seed germination and seedling growth. Each treatment contained 5 healthy and uniform sized seed in each petriplates. In experiment, three petri plates per combination will be arranged in randomized block design and experiments were repeated three times in a BOD chamber. Data were recorded each after 3 days intervals of experimental setup. Thereafter, germination percentage, germination index, shoot length, root length, dry matter and seedling vigour index was observed and analyzed.

2.1 Germination percentage (%)

Numbers of germinated seeds were recorded after 48 hours of seed germination. Germination percentage was calculated as per the Association of official seed analysis (1983).

Germination percentage = (No of seed germinated/ total number of seed sown) × 100.

2.2 Germination Index (GI):

Germination index of wheat seed were calculated by the formula given by Ranal & Santana (2006).

$$GI = (4 \times N_1) + (3 \times N_2) + \dots +$$

Where N₁, N₂ ...N₄ is the number of germinated seeds on the first, second and subsequent days until 3rd day and the multipliers (e.g. 4, 3 ...etc.) are weights given to the days of the germination

2.3 Seedling vigor index (SVI):

Seedling vigor index was measured in 7 day old seedlings and it was calculated by the formula given by Goodi, & sharifzadeh, (2006).

SVI= germination % × Dry wt. of 7 days old seedling.

Figure 1 Effect of Arsenic on Germination percentage in wheat seeds

Figure 2 Effect of Arsenic on germination index and seedling vigour index in wheat seeds

2.4 Root and shoot length

The maximum root and shoot length was measured with the help of scale at 3rd days of germinations.

2.5 Total dry matter

Seedlings were excised and placed into an oven (NSW-142) at 105°C for 5 minutes, this was followed by 65°C till the getting constant weight. Dry weight is taken at electrical balance (ADGR-200) at 3 days.

3 Results and Discussion

Germination percentage is the most important traits which revealed germination capacity of plant. The value of GI indicates both the

germination percentage and germination speed. Likewise, shoot length represents the vertical growth of the plants, root length is the important seedling parameters indicates the better establishment of seedlings and dry matter measure the production photosynthates in relation to productivity. Whereas, SVI is the important parameter indicates the seedling establishment and growth. The observations recorded for GP, GI, shoot length, root length, dry matter and SVI under different concentrations of arsenate (AsV) has been represented in figure 1-4. Presented data showed that the germination percentage, GI, Shoot length, root length, dry matter and SVI significantly decreased as compared to **control** (no AsV) with the increasing concentration of arsenic (50, 100, 150, 200 μM, 250μM). The highest germination percentage (84.3%), germination index (487.3), SVI

Figure 3 Effect of Arsenic on Shoot and Root length of wheat seedling

Figure 4 Effect of Arsenic on total dry matter of wheat seedlings

(810.6), shoot length (5.27 cm), root length (4.02 cm) and dry matter (0.126g) were recorded in control, whereas, the least germination percentage (32.6%) germination index (251.7), SVI (372.3), shoot length (2.40 cm), root length (2.02 cm) and dry matter (0.041 g) were recorded in highest concentration of arsenic (250 μM).

Results of study revealed that comparatively higher concentrations of arsenic have higher toxicities, it might be because of arsenic entry in to plants cells which can destroys thiol (SH) groups of enzymes that inhibits biochemical pathways of cells and disturb physiological activities (Abbas et al., 2018). In *Brassica juncea*

and *Arabidopsis thaliana* crops arsenic mainly present as AsIII in tissues which form complexes with thiol compounds such as glutathione (GSH) and phytochelatin (PCs) (Castillo-Michel et al., 2011). In another study when plants were exposed to arsenic, reactive oxygen species (ROS) produced which induces lipid peroxidation and causes plant wilting (Farooq et al., 2016). Similar study was found that, plant species cultivated on AsV contaminated sites can readily adapt to suppression of P transporters (Meharg & Hartley-Whitaker, 2002). Arsenic can severely inhibit plant growth by arresting cell division expansion and significant dry matter accumulation, as well as disturbing plant

reproductive capacity and reducing crop production (Garg & Singla, 2011). Further, it was observed that seedlings of *Cicer arietinum* (Malik et al., 2011) and *Oryza sativa* (Vromman et al., 2013) showed stunted growth of roots, shoots and also suppress the number of leaves, leaf area, and fresh and dry mass of plants (Nath et al., 2014).

Conclusion

In the presented study, effect of Arsenic (AsV) on wheat germination and seedling growth evaluated. The increasing concentration of arsenic has severe negative effects in terms of demodulate seed germination, overall roots, shoots and leaves length, and on the dry biomass. It was observed that concentrations of arsenic (AsV, 250 µM) showed maximum decreasing effects in all parameters. These findings showed that harmful effect of arsenic toxicities in agricultural crops, and its effects on seed germination and overall yield in wheat crops. Further research is required under both lab and field conditions, to use several remediation techniques for practical applications of agriculture for better crop productions.

Conflict of Interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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