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Impact of Arsenic on Legumes

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Abstract- Arsenic is harmful to most plants in high concentration as it interferes in metabolic activities and inhibits plant growth and reproduction process by arsenic induced phytotoxocity. It is a cancer inducing metalloid released into environment by both natural as well as anthropogenic activities. It also affects the leguminous crops like lentil and chickpea which is widely grown in these arsenic affected regions of West Bengal in India and in Bangladesh. However, a little is known about the arsenic accumulation on these crops when these crops are grown in the arsenic contaminated soils. Indo-Gangetic and Bramhaputra regions is one of the most arsenic contaminated points in the world and needs sustainable approach to control and avert their harmful effects on the crop plants, animals and human beings.

Key words: Anthropogenic, Arsenic, Cancer inducing, Leguminous crops, Phytotoxicity

I. INTRODUCTION

Arsenic (As) is found naturally and exists ubiquitously in both organic and inorganic form in the environment and it ranks 20^{th} in quantities in the earth crust, 14^{th} in the sea water and 12^{th} position in the human body (Mondal and Suzuki 2002). Arsenic contamination have been a matter of concern worldwide and is considered as risk factor in many countries including Bangladesh, Taiwan, India, Mexico, China, Chile, Argentina and USA. In India, the states of West Bengal, Jharkhand, Bihar, Uttar Pradesh, Assam, Manipur and Chhattisgarh are reported to be most affected by arsenic contamination of groundwater above the permissible level. Its contamination in ground water and soils is becoming a serious problem worldwide. Almost 50 million public are at health risk from arsenic contamination at Ganga-Meghna-Bramhaputra basin. In West Bengal, people have been reported to be suffering from groundwater arsenic toxicity for long period (Chakraborty *et al.* 2004; Pal *et al.* 2007). From 19 districts of West Bengal, 09 districts have ground water arsenic contamination (Nickson *et al.* 2000 ; Chakraborty *et al.* 2002). Between contaminated districts, Nadia district are the most affected in term of level of arsenic contamination and area coverage (Samal 2005 ; Bhattacharya *et al.* 2009). In rural people of West Bengal, many are not aware of the Food and Agricultural Organization (FAO) guidelines of arsenic in irrigation water (0.10 mg per litre of water, FAO 1985). Irrigation system in these areas is mostly operated from ground water and thus, there is a high probability of transfer of arsenic from contaminated ground water to soil of crops.

Arsenic contamination by irrigation from ground water has posed the serious health problem, threatening millions of people in West Bengal, Uttar Pradesh and Bihar in India and in Bangladesh. However, the arsenic contaminated water is not just used for irrigation, but, is also used for drinking and to wash and food preparations. Long term irrigation of agricultural soils with arsenic contaminated water can lead phyto-accumulation and food-chain contamination of the food crops with arsenic and other toxic metals. As a result, dietary exposure to arsenic and other toxic substances which could lead to adverse health effects caused by contaminated tube wells in West Bengal and in Bangladesh. Therefore, an effort has been made to study the effects of arsenic toxicity on the pulses production and health of the consumer.

II. IMPORTANCE OF ARSENIC

Arsenic is a cancer inducing metalloid released into environment by both natural as well as anthropogenic activities. The transfer of arsenic

from soil to plant systems reflects one of the vital pathways for human exposure to arsenic in their day to day life. Contamination of arsenic in food crops through irrigation water leads a serious issue on food safety. One of the recent cohort study revealed that daily intake of 500 grams of cooked rice containing arsenic
>200 µg/kg might result in genotoxic effects on human beings (Banerjee *et al.* 2013). Arsenic toxicity is considered beyond the disaster relating to the incidence of Bhopal, India in 1984 and Chernobyl, Ukraine, in 1986. The first arsenic poisoning (arsenicosis) patient was noticed in 1983 in West Bengal, India. It came into consideration very lately and the cause was established in 1993 in Chapai Nawabganj, Bangladesh (Islam and Islam 2019). So far, arsenic toxicity has affected 17 districts in Uttar Pradesh, 11 districts in Bihar and 09 districts in West Bengal while 59 districts out of 64 districts of Bangladesh is affected and there arsenic level have been reported above the nationally accepted limit (50 ppb).

It is also reported that nearly 35 to 77 million peoples of Bangladesh are at risk by the contamination of arsenic in water as well as food crops contamination (IAEA, 2002). Worldwide, more than 100 million people have been reported to be chronically exposed to arsenic by drinking water. The situations are alarming in Bangladesh, India and Pakistan. Generally, arsenic is found naturally in all kind of soils throughout the world and it is also exposed into environment due to human and natural activities. Mineral ore, ground water, pesticides and geothermal processes are the major source of arsenic and it was also found in food crops which were grown in the arsenic contaminated soil or irrigated with arsenic contaminated ground water. In Deltaic region, especially Gangetic alluvium soil of Bangladesh and some parts of West Bengal, where ground water contaminated by arsenic toxicity and has been changed into one of the world's most important natural disaster. From decades ago, arsenic contaminated ground water have been used for drinking and irrigation, resulting into the contamination of food chain and it is suggested that arsenic in rice, lentil and other food sources would contribute to approximately 30% of the total arsenic intake (Alam *et al.* 2019).

III. ARSENIC IN PLANTS AND LEGUMES

Among the legume crop, Lentil and Chickpea are one of the majorly grown and consumed pulses in these Indo-Gangetic basin *i.e.* West Bengal, Assam in India and in Bangladesh. Lentil is one of the most ancient cultivated pulse crops and is grown in Bangladesh, China, India, Canada, Iran, Nepal, Syria, Turkey and USA in the world (FAO, 2010). Worldwide, total Lentil cultivated area is around 4.6 million ha. and production of 4.2 million tones with an average productivity of 1.095 tones/ha. Lentil is rich in protein, fiber and other vitamins and minerals, such as iron, zinc, folate and magnesium. Further, the phyto-chemicals, tannins and saponins are also found in lentil having antioxidant and anti-carcinogenic properties, showing that lentil might have significant anti-cancer effects (Mudryj *et al.* 2014). If we observe lentil growing regions, many lentil cultivating countries are highly arsenic contaminated and among them, west Bengal and Bangladesh combined the rank the second largest arsenic contaminated region in the world. The arsenic element is not-essential and generally toxic to most food crops including lentil crop. In the study, it is reported that root parts of lentil crop are the first tissue to be exposed to arsenic, where the metalloid hinders root extension and proper growth. Here the metal translocated from root to the shoot and grain and it can rigorously inhibit the normal physiological growth by slowing or stopping of growth and biomass accumulation and also compromise in plant reproductive capacity. Osmotic and oxidative stress increased in food crops due to the accumulation of arsenicin plant biomass and lipid peroxidation, H_2O_2 accumulation, root oxidizability, electrolyte leakage and other activities of antioxidant enzymes changed significantly in response to arsenic stress. Arsenic stressed plant shows reduced plant growth and pigment content. Especially, total chlorophyll, ascorbic acid and catalase content dramatically reduced in food crops in response to arsenic exposure (Alam *et al.* 2019). Chickpea growth on the arsenic contaminated soils is also not normal and it has been reported that chickpea plants when exposed in arsenic contaminated soils (5.0 mg/kg of dry soil) and studied for arsenic uptake, distribution and effects on growth, yield and quality of the seed. The roots accumulated the highest arsenic (7 mg/kg dry weight), followed by shoot (4.8 mg/kg dry weight) and seed (0.7 mg/kg). Arsenic reduced the growth of roots and shoots (based on dry weight) by 65% and 60%, respectively over the control and the shoot/root ratio declined from 4.3 in the control to 3.5 in arsenic contaminated plants. The number of pod/plant and grain yield also reduced by 53 and 66%, respectively over the control. A clear damage on membrane, reduction in chlorophyll and relative leaf water content were observed in arsenic treated plans (Jahid A Malik *et al.* 2011). Shamim and Pandey, (2019) also reported that morphological characters of almost all thrty two black gram genotypes were significantly decreased with increased concentration of arsenic in supplied nutrients, shoot length; root length was less affected, whereas shoot weight, root weight and total biomass were significantly decreased under arsenic stress condition.

In high concentration, arsenic interferes in critical metabolic process, which even might lead to death of crop plants. Arsenic intake can cause serious diseases, including cancers. Despite all, this metalloid arsenic is present as universal in the environment because of human and geological activities. Generally arsenic in the soil is taken up by plants and it get accumulated in the edible parts and is further spread by human and other organisms which are higher in the food chain. At present, millions of people, mostly in South and South-east Asia, are in the risk for exposure to food contaminated with arsenic. In excessive consumption of arsenic through food chain results into arsenic accumulation in tissues and it inhibits cellular enzyme activates. Skin contact, inhalation and ingestion are the primary routes of human exposure to arsenic. Chronic arsenic intake is known to cause skin cancer and there are enough evidence that it increases risk for cancer of the bladder, lung, kidney, liver, colon and prostate. In the study, it have also shown that arsenic is associated with a number of non-neoplastic diseases, including cardiac disease, diabetes mellitus, pulmonary disease, cerebrovascular disease and diseases of the arteries, arterioles and capillaries. Persons with chronic Hepatitis B infection, malnutrition or protein deficiency can be more troublesome to the effects of arsenic. Thus, reduction of arsenic concentration in soils and food crops is significantly important for securing sustainable crop production and food safety (WHO, 1999).

IV. ARSENIC AND ITS EFFECTS ON DIFFERENT PLANT GROWTH STAGES

In soil, water and air, arsenic available in many chemical forms with variable degree of toxicity, bioavailability and mobility in the environment. The factors which affect these parameters include the arsenic concentration in the soil, the type of plant species, arsenic species and other soil properties which controls arsenic accumulation, accessibility and fate in soils, microorganisms and plants. Inorganic arsenic is more lethal and movable than their organic form. It is reported that plants intake of arsenic can hardly be down- regulated, as it often mediated by essential element transporters. Arsenic contamination has an adverse effects on the morphological (chlorosis), physiological (growth process inhibition) and biochemical (oxidative stress) response of plants. Studies on lentil crop under arsenic contamination are illustrated with different plant growth stages *i.e.* Dry weight of lentil plant, arsenic accumulation in lentil root, arsenic accumulation in lentil shoot and arsenic accumulation in grain and in all stages, the treatment and lentil varieties both showed significant differences on the effect of dry weight, root/shoot/grain arsenic accumulation of lentil plants (Alam *et al.* 2019).

In general, the potential of some vegetables to accumulate heavy metals with concentrations of Lead (Pb) is greater than Cadmium (Cd). The concentration of arsenic (As) and cadmium were higher in vegetables than the rice and pulses crops. The concentration of Pb was generally higher in rice than in pulses and vegetables. But, some vegetables like bottle gourd, elephant foot yam had higher concentration of Pb. The total arsenic concentration on food crops ranged between 0.000 to 1.464 mg/kg of dry weight. The highest mean concentration of arsenic was found in potato (0.456 mg/kg) followed by rice grain (0.429 mg/kg), whereas the total mean arsenic content in pulses and oilseeds varied between 0.076 to 0.168 mg/kg, in tuber crops ranged from 0.243 to 0.456 mg/kg, in spices ranged from 0.031 to 0.175 mg/kg, in fruits ranged from 0.021 to 0.145 mg/kg and in vegetables ranged from 0.032 to 0.411 mg/kg, respectively. Thus, arsenic accumulation in cereals, pulses, oilseed, vegetables, spices, cole crop and fruits crop might not be safe in future without any sustainable mitigation strategies to control the potential arsenic toxicity on the human health in the contaminated areas (Rahaman *et al.* 2013).

V. ARSENIC AND HUMAN HEALTH

Arsenic has shown to cause adverse health effects in human being as a consequence of exposure to arsenic by drinking water and consumption of contaminated food stuffs in excess quantities. Long period exposure to arsenic in drinking water are mostly related to the increased risks of cancer in the skin, bladder, lungs and kidney and also other changes such as hyperkeratosis and pigmentation changes. In fetus and early childhood stage, exposure to arsenic toxicity has been linked to negative impacts on cognitive development and increased deaths in young adults. Arsenic has also been reported to be able to induce epigenetic changes (in utero) and genetic mutations (a leading cause of cancer) in the body. Water soluble inorganic arsenic is acutely lethal and ingestion of large quantities might lead to gastrointestinal symptoms, disturbances of cardiovascular and nervous system functions and finally death. In some survivors; melanosis, hepatomegaly, bone marrow depression, haemolysis, polyneuropathy and encephalopathy might be seen. In some study, increased risks of lung and bladder cancer and arsenic associated skin lesions have been reported when intake of drinking water at concentration 50 µg of arsenic per litre.

VI. RECOMMENDED INTAKE OF ARSENIC AND ITS TOXICITY

Permissible limit of arsenic in food crop is 1.0 mg/kg. In drinking water; arsenic permissible limit is 0.01 mg/litre and for irrigation water 0.10 mg/litre. Tolerable limit of arsenic is 3.0 µg/kg body weight/day (2-7 µg/kg body weight/day based on the range of estimated total dietary exposure). By World Health Organization (WHO), the safe limit for arsenic in drinking water has been prescribed to be 10.0 µg/litre. In India, districts having more than 0.05 mg/litre in ground water is listed.

VII. PREVENTION AND CONTROL MEASURE

The first and foremost important action in arsenic affected areas is to prevent it from further exposure by the provision of a safe water supply for drinking, food preparation and irrigation of food crops. Some the options to be used for reduction of arsenic level in drinking water is listed here.

- Replacement of high-arsenic sources, like ground water,

  with low-arsenic or microbiologically safe sources such as rain water or treated surface water. Low-arsenic water can be used for drinking, cooking and irrigation purposes, while high-arsenic water can be used for other purposes like bathing and washing clothes.

- Differentiate between high-arsenic and low-arsenic sources. For intense, test water for arsenic levels and paint tube wells or hand pumps with different colours. It can be an effective and low-cost means to quickly reduce exposure to arsenic when accompanied by effective education.
- Irrigation with pond-stored groundwater in which partial decontamination can be done by sedimentation-cum-dilution with rainwater.
- Increased use of FYM and other organic manures or green manure crops and also the application of appropriate inorganic amendments (zinc/iron salts as and wherever applicable).
- Development/identification of varieties or crops which accumulate less arsenic in the consumable parts and where the ratio of inorganic to organic forms of arsenic is low.
- Developing cost-effective phyto-and bio-remediation options.
- Creation of general awareness by mass campaigning, holding of farmers' day, field demonstrations, taking due cognizance of the socioeconomic factors.
- Mix low-arsenic water with higher-arsenic water to achieve an acceptable arsenic concentration level.

- Install arsenic removal systems-either centralized or domestic and ensure the appropriate disposal of the removed arsenic. Technologies for arsenic removal include oxidation, coagulation precipitation, absorption, ion exchange and membrane techniques.

VIII. CONCLUSION

Groundwater has been a major source of irrigation in arsenic affected areas. For the many decades, excessive exploitation of the groundwater and indiscriminate use of agricultural chemicals have been carried out for the extensive cultivation of rice, wheat, pulses and vegetables to ensure food security. Therefore, the potential contamination source of arsenic is increasing every year in the groundwater. Though, arsenic toxicity does not pose an immediate danger, but the intake of arsenic by agricultural plants needs to be monitored periodically as there would be high possibilities of increase of arsenic toxicity in the crops in coming days. Screening of the crops under arsenic toxicity and their arsenic uptake level should be studied to check the potential genotypes which might be having low level of arsenic concentration, and then further their use in the breeding programme should be done for developing arsenic tolerant genotypes for cultivation in those areas.

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