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Genotoxic Effects of Arsenic in Food-Crops: A Need for Transgenerational Studies

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ABSTRACT

Groundwater arsenic contamination has impacted millions of lives in over 100 countries; India and Bangladesh are the foremost victims. Arsenic contamination of food materials, especially rice, the staple food, is the biggest concern in these regions. Arsenic-tolerant rice varieties can help protect millions of impoverished people in arsenic-affected areas. However, transgenerational studies on the impact of arsenic on rice varieties over generations are highly neglected. This article highlights the need for transgenerational studies in arsenic-contaminated areas. A few rice varieties have shown tolerance to arsenic that could be explored to investigate whether these varieties can be sufficiently tolerant if they continue to be grown in an arsenic environment for a few consecutive generations. Transgenerational or epigenetics studies, therefore, are vital in protecting millions of human lives.

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Arsenic is a group 'A' human carcinogen, also known as a hepatotoxic, hematotoxic, and genotoxic metalloid that impacts millions of human lives in more than 100 countries through natural groundwater contamination [1-4]. The impact is confined to the socioeconomically impoverished populations in most Asian countries [4,5]. Among the 56 Asian countries, 33 countries are reported to have elevated levels of arsenic in the groundwater, impacting nearly 120 million individuals (Figure 1) [1,3,4,6].

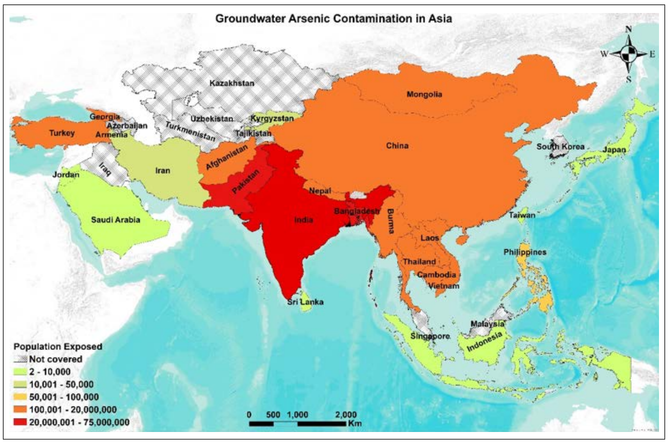

Figure 1: Arsenic contaminated countries and arsenic-exposed populations in Asia

India and Bangladesh are the two severely arsenic-affected Asian countries, where over 93 million inhabitants intake this nectar poison through water, food, soil, and air [1,4,7]. Consequently, thousands of the inhabitants died, and millions were at risk [7]. In addition to groundwater arsenic contamination, the entry of arsenic into the food chain in these regions poses the most significant challenge for scientists and policymakers to ensure millions of human lives' safety [1]. In these regions, arsenic has been detected in almost all the main food crops, including but not limited to rice, wheat, maize, and pulses [1]. Additionally, vegetables are also found to contain elevated levels of arsenic in various places in these areas [1].

Rice is one of the staple foods of more than 3 billion people globally, with the highest percentage (90%) of consumption in Asian countries, including India and Bangladesh, where rice plants have been found as one of the top arsenic accumulators [8, 9]. Several genotoxic effects on the consumers of arsenic-laced cooked rice have shown a red flag to the researchers and policymakers to pay serious attention to this global public health challenge [10,11]. Studies on the health effects of arsenic or other heavy metals have been limited to human beings [10]. On the contrary, research on the genotoxic effects of arsenic on plants has been conservative and inadequate. Still, there is considerable debate on the threshold values for different plant metals [12,13]. A handful of studies investigate genotoxic impacts on plant species grown in contaminated environments [14]. Chromosomal aberrations, growth inhibitions, and irregular or abnormal mitotic divisions of cells have been reported in a few plant species when cultured in contaminated environments [14]. Studies indicate that arsenic trioxide could produce several genotoxic effects in the root-tips of Allium cepa (onion), including the formation of micronuclei, chromosomal bridge, multipolar anatelophase, bacilliform nuclei, pyknotic nucleus, and non-functional nuclei, when treated with different concentrations of arsenic, ranging between 100 µg/L and 800 µg/L [15]. However, there is a lack of transgenerational studies to see the impact of arsenic throughout generations on the genetic properties of a plant species. Unfortunately, transgenerational studies on plants to understand the effect of the environment are still in the early stages [16]. In a recent study, cerium oxide nanoparticles have induced the production of smaller and weaker tomato seeds when treated with different concentrations of cerium oxide [17]. Only a few researchers indicated the need for studies on the epigenetic effects of several environmental contaminants, including arsenic [11,18]. Although several arsenic-induced epigenetic effects, like altered methylation levels of DNA and gene promoters, histone acetylation, methylation, phosphorylation, and miRNA expression, have been reported in human contexts, it is not enough to reveal the genetic path of arsenic-associated cancer [19]. In contrast, plant models have mainly been unexplored for epigenetic effects of arsenic.

Epigenetic studies could help us reveal the mechanism of transgenerational effects of arsenic on selected plant species, especially rice plants. Various rice varieties have been experimented with and have shown a significant level of tolerance to the toxic effects of arsenic, including but not limited to Swarnadhan, Pusa basmati, Badshabhog, and Tulsibhog [20,21]. In a recent study, several rice varieties typically grown in the northeastern Indian area were found to be tolerant of arsenic of 100µM [22]. Likewise, there is a need for continuing such experiments over a period to observe how different arsenic concentrations impact the growth and the genetic properties of the rice varieties across generations. In the consecutive generation, rice varieties may develop a natural resistance to arsenic that could develop arsenic-resistant rice varieties. The genetic mapping of these arsenic-resistant rice could also be adapted to developing other food-crops types such as wheat, maize, and pulse. The transgenerational study can be a miracle in the rural areas and the communities where arsenic-contained rice consumption is the maximum. Hence, solution-oriented arsenic studies are urgent to ensure millions of underprivileged people.

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