THE LETHAL EFFECT OF GROUNDWATER FLUORIDE ON THE GERMINATION AND GROWTH OF MAIZE *(ZEA MAYS)* AND RICE (*ORYZA SATIVA*) SEEDS AND PLANTS

Elvis Kichana,[a,*] Solomon Minyila,[b] Gerard Quarcoo[c]

Tamale, Ghana

ABSTRACT: Fluoride from groundwater has been shown to not only pose health effects to humans, but also to be lethal to irrigated plants at high concentrations. This study sought to study the lethal effect of groundwater fluoride on the germination and growth of maize (*Zea mays*) and rice (*Oryza sativa*) seeds and plants. Groundwater fluoride levels of 10, 5, 2, and 1 mg/L were used to treat maize and rice seeds, with distilled water being used as a control. Descriptive statistics were used to estimate the mean germination rate (%) of the rice and maize seeds. The groundwater fluoride concentrations of 10 and 5 mg/L posed a significant lethal effect to the ability of the seeds to germinate, and the ability of the plants to survive after 30 days. In contrast, groundwater fluoride concentrations of 1 and 2 mg/L posed little or no lethal effect on the germination of the maize and rice seeds and on the growth of the plants after 30 days. It was concluded that the quality of the groundwater water used by farmers for irrigation purposes should be assessed before use in order to prevent fluoride toxicity.

Keywords: Groundwater fluoride; Irrigation by farmers; Maize; *Oryza sativa*; Rice; *Zea mays*.

INTRODUCTION

Fluoride (F) from groundwater has been shown to not only pose health effects to humans, but also to be lethal to irrigated plants at high concentrations.[1-3] Fluoride, the ion of the chemical element fluorine, is frequently found in groundwater, and has become one of the most important toxicological environmental hazards globally.[1-3] Fluorine is neither an essential trace element for humans nor necessary for the development of healthy teeth and bones and an excessive intake will cause chronic fluoride poisoning, such as dental fluorosis, skeletal fluorosis, and non-skeletal fluorosis.[4] While the lethal dose of sodium fluoride (NaF) for acute toxicity for most adult humans has been estimated to be 5 to 10 g, equivalent to 32 to 64 mg F/kg body weight,[1-3] the safe daily intake of fluoride for pregnant women to give protection from F-induced foetal neurotoxicity been estimated to be much lower at 0.04 mg F/day, equivalent to 0.0006 mg F/kg bw/day for a 70 kg woman.[5]

Groundwater resources sustain a significant and increasing share of irrigated agricultural production. Groundwater is used for over 40% of global irrigation on almost 40% of irrigated land.[6] Groundwater has become indispensable for agricultural production in many countries, it accounts for half of South Asia's irrigation, and it supports two-thirds of the grain crops produced in China.[6] The growing importance of groundwater for agriculture can largely be explained by the capacity of groundwater to act as a reliable water source for irrigation and to provide water on demand, while being largely unaffected by seasonal surface hydrological

[a]Regional Water Quality Laboratory, Ghana Integrated - Water, Sanitation and Hygiene, World Vision International, Tamale, Ghana; E-mail: ekichana@gmail.com, Telephone: +233241791652, [b]Regional Water Quality Laboratory, Ghana Integrated - Water, Sanitation and Hygiene, World Vision International, Tamale, Ghana; [c]Council for Scientific and Industrial Research - Water Research Institute, Tamale, Ghana. *For correspondence: Elvis Kichana, Regional Water Quality Laboratory, Ghana Integrated - Water, Sanitation and Hygiene, World Vision International, Tamale, Ghana; E-mail: ekichana@gmail.com

variations. In particular, groundwater irrigation enables high-value agricultural production to occur in the drought-prone regions of Southern Europe and California.[6]

Groundwater is known to naturally contain fluoride levels at different concentrations, produced by the weathering or leaching of rock sediments rich in fluoride such as fluorophosphate, apatite, and fluorites. In the past few years there has been much debate about fluoride in drinking water. Considerable evidence has accumulated on the effect of fluoride on teeth, including the effect of topical fluoride on dental caries,[4] but very few data are available on the effect of fluoride on plant growth.[7]

Most farmers in recent times have used groundwater to irrigate their crops and vegetables during the dry season to help feed the world's ever increasing populace. During a field trip, a mango farmer using irrigation reported that his mango seedlings died off when the plants were watered with borehole water. The borehole water was tested and found to contain a high fluoride level of 10.05 mg/L. Based on this report and evidence, the present investigation was initiated with the aim of studying the lethal effect of groundwater fluoride on the germination and growth/development of maize, *Zea mays*, and rice, *Oryza sativa*.

MATERIALS AND METHODS

Twenty five (25) liters of groundwater, found by testing, to contain 10.05 mg/L of fluoride were sampled from a well (borehole) in a community in the Gusheigu District of the Northern part of Ghana. Certified and surface-sterilized seeds of maize (*Zea mays*), and of rice (*Oryza sativa*), developed by the Savanna Agriculture Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR), Ghana, were obtained and sown in enriched loamy soil contained in transparent disposal cups wrapped with aluminum foil. The sown seeds of both rice and maize were treated with different concentrations of groundwater containing standardized fluoride levels of 10, 5, 2, and 1 mg/L, and distilled water (control) with 0 mg F/L. The experiment was carried out with all the factors necessary for germination (temperature, oxygen, moisture, light, viable seeds, and seed depth) considered, for thirty (30) days. Descriptive statistics (bar graphs) were used to analyze the data.

Germination rate: To detect the lethal effect of groundwater fluoride on the germination of maize and rice seeds, a total of 320 transparent disposable cups wrapped with aluminum foil were each filled with 275g of enriched loamy soil. Ten (10) sets, with each set constituting sixteen (16) cups in duplicate were set in a box tray. Maize seeds, two (2) each, were planted in the first five (5) sets of 16 duplicate cups for thirty (30) days. Rice seeds, three (3) each, were also planted in the second batch of five (5) sets of 16 duplicate cups for thirty (30) days. The first four (4) sets of duplicate cups containing the maize seeds were treated with groundwater containing 10, 5, 2, and 1 mg F/L, respectively, and the same procedures and concentrations were repeated for the first four (4) sets of duplicate cups containing the rice seeds. The fifth (5th) set of duplicate cups containing the maize seeds was treated with distilled water containing 0 ppm of fluoride, and the same procedure was repeated for the fifth (5th) set of duplicate cups containing the rice seeds.

Growth/development: In order to detect the lethal effect of the various concentrations of groundwater fluoride on the growth and development of germinated maize and rice plants, various concentrations of fluoride, (10, 5, and 2) were used to treat for thirty (30) days a duplicate of five (5) cups each of the germinated maize plants and a control set (4th set) of germinated plants. This procedure was repeated in duplicate for three sets of germinated rice seedlings and for the control cups (4th set) of germinated rice seedlings.

RESULTS AND DISCUSSIONS

The groundwater fluoride levels of 5 ppm, and 10 ppm adversely affected both the germination and growth of the maize and rice seeds. Fluoride concentration levels of 2 ppm only affected the germination rate of the maize (*Zea mays*) seeds (Figure).

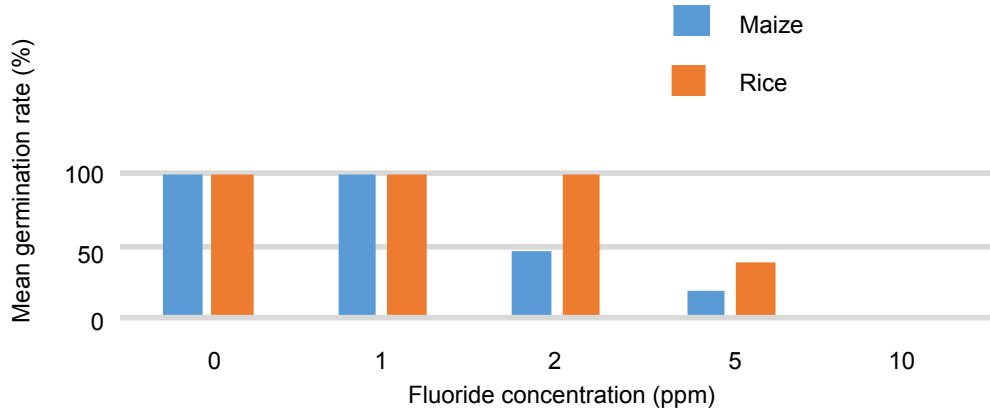

Figure. Mean germination rates (%) of maize and rice plants with various concentrations of fluoride: 0 (control), 1, 2, 5, and 10 ppm.

Groundwater containing fluoride levels of 10 and 5 mg/L adversely affected the germination of both maize and rice seeds. These results were contrary to those of a similar research experiment, conducted by Huma et al.,[8] which found that two genotypes of wheat recorded an increase in germination at fluoride levels of 50 and 100 mg/L. In the present study, at 10 mg/L, both the maize and rice varieties showed no germination. At 5 mg F/L, the maize and rice seeds recorded mean germination rates of 18.8% and 37.5%, respectively. At 2 mg F/L, the maize seeds recorded a mean germination rate of 46.9% while the rice seeds had a germination rate of 100%. With the 1 ppm F concentration, the mean germination percentages for both the maize and the rice seeds was 100%. The difference in our experimental results from that found by others, such as Huma et al.,[8] may be the result of different fluoride compounds being used. Whereas we used standardized natural fluoride from groundwater, most other experiments have used commercially prepared sodium fluoride. The differences in the experimental results could also be as a result of the presence of interference from accompanying components in the commercially produced fluoride, such as the sodium component of the sodium fluoride salt.

The fluoride levels of 10 and 5mg/L resulted in lethal effects on both the maize and the rice plants. The application of 10 mg F/L to the plants resulted in all of them dying off, after initial symptoms of marginal and tip necrosis of the leaves. The maize

plants died after 14 days and the rice plants died after 9 days. None of the control plants watered with 0 mg F/L died or showed marginal or tip necrosis.

With 5 mg F/L, the maize plants died off after 24 days while the rice plants died off after 21 days. No control plants watered with 0 mg F/L died.

At 2 mg F/L, no maize plants had died after 30 days although yellowing of leaves was recorded. For the rice plants, no plant deaths or leaf yellowing was observed. For the control plants of rice and maize, watered with 0 mg F/L, no plant deaths or leaf yellowing was recorded.

The lethal effect of groundwater fluoride on maize and rice seeds is probably due to a dephosphorylation of the phytin compound which releases free phosphates, and is thus a source of energy for the germination of seeds. In the literature, several groups have studied the effect of fluoride on plants.[8-11] However, our results are consistent with the research carried out by Singh et al.[9] who found that at fluoride concentrations above 2mg/L, both the germination and growth of *Raphanua sativus* L.were affected.

CONCLUSION

From our experiment, we was found that fluoride levels of 10 and 5 mg/L adversely affected the germination and the subsequent growth and development of both maize and rice seeds and plants. The statement made by the mango farmer, that his mango seedlings died off when the plants were watered with borehole water, which was found to contain a high fluoride level of 10.05 mg/L, which was part of the background to the study, is likely to be found to be true if an experiment was carried out on mango seeds and seedlings. We therefore recommend that the fluoride levels in groundwater should be assessed before the water is used for plant irrigation in order to avoid fluoride-induced plant toxicity.

REFERENCES

1 Gosselin RE, Smith RP, Hodge HC. Clinical toxicology of commercial products. 5th ed. Baltimore, MD, USA; Williams and Wilkins; 1984. ISBN 0-683-03622-7. pp. III–185-93.

2 Baselt RC. Disposition of toxic drugs and chemicals in man. 8th ed. Forster City, CA, USA: Biomedical Publications; 2008. ISBN 978-0-9626523-7-0. pp. 636-40.

3 IPCS. Environmental health criteria 227 (Fluorides). Geneva: International Programme on Chemical Safety, World Health Organization; 2002. ISBN 92-4-157227-2. p.100.

4 Scientific Committee on Health and Environmental Risks (SCHER). Opinion of critical review of any new evidence on the hazard profile, health effects, and human exposure to fluoride and the fluoridating agents of drinking water. Brussels, Belgium: Directorate General for Health and Consumers, European Commission; 2011 May 16. pp. 2-4.

5 Spittle B. Prevention of fluoride ion-induced IQ loss in children [editorial]. Fluoride 2017;50(4):385-92.

6 OECD. Drying wells, rising stakes: Towards sustainable agricultural groundwater use. Paris, France: OECD Publishing; 2015. Paris. Available from: https://doi.org/10.1787/9789264238701-en.

7 White M. Effect of fluoride on growth and germination of bean plants. School Science and Mathematics 1966;66(2):180-90, Available from Wiley Online Library: https://doi.org/10.1111/j.1949-8594.1966.tb14958.x.

8 Alim H, Ahmad MA, Munir I, Kahn I, Mustafa G, Ullah I, et al. The effect of different concentrations of the fluoride ion on the growth and nutritional value of two elite genotype of *Triticum aestivum*. Fluoride 2017;50(1 Pt 2):143-50.

9 Fina BL, Lupo M, Dri N, Lombarte M, Rigalli A. Comparison of fluoride effects on germination and growth of *Zea mays*, *Glycine max*, and *Sorghum vulgare*. Journal of the Science of Food and Agriculture 2016:96(11):3679-87.

10 Singh S, Singh J, Singh N. Studies on the impact of fluoride toxicity on growth parameters of *Raphanua sativus* L. Indian Journal of the Science of Food and Agriculture 2013;4(1):61-3.

11 Saini P, Khan S, Baunthiyal M, Sharma V. Effects of fluoride in germination, early growth and antioxidant enzyme activities of legume plant species *Prosopis juliflora*. Journal of Environmental Biology 2013:34(2):205-9.