PHYTOTOXICITY OF FLUORIDE IN THE GERMINATION OF PADDY (*ORYZA SATIVA*) AND ITS EFFECT ON THE PHYSIOLOGY AND BIOCHEMISTRY OF GERMINATED SEEDLINGS

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SUMMARY: This study reports the influence of 0, 10, 20, and 30 mg/L sodium fluoride (NaF) on paddy (rice, *Oryza sativa*) seeds and seedlings. After 15 days of treatment with 0 and 10 mg NaF/L, 100% germination occurred, but at 20 and 30 mg NaF/L, germination was reduced to 96 and 92%, respectively. Physiological parameters, viz., root length, shoot length, and dry weight decreased monotonically with increasing NaF concentration. At 30 mg NaF/L the average root length, shoot length, and dry weight were reduced to 50%, 27%, and 29%, respectively. The chlorophyll content of the leaves also decreased monotonically, but the reducing sugar and ascorbic acid content initially decreased and then increased with increasing concentration of NaF. Uptake of fluoride in the whole plant body increased with increasing levels of NaF; at 10 mg NaF/L the accumulation was less than 75 mg/kg dry mass, but at 20 mg/L NaF it increased to ca. 2000 mg/kg and double this level at 30 mg/L NaF.

Keywords: Fluoride phytotoxicity; Fluoride uptake in paddy; *Oryza sativa*; Paddy biochemistry; Paddy physiology; Paddy seed germination.

INTRODUCTION

The importance of seed germination in plant growth is widely recognized, and the effects of fluoride (F) toxicity on it have been studied by various researchers.[1,2] Many plants are especially sensitive to F. Certain physiological processes are known to be markedly affected by F, including, decreased plant growth, chlorosis, leaf tip burn, and leaf necrosis.[3-5] F is absorbed by plant roots[6,7] and then transported via xylematic flow to the transpiratory organs, mainly leaves, where it can be accumulated with adverse effects. Due to its high nutritional value and the widening market of its product, paddy (rice) is one of the major crops in India as well as in the state of West Bengal.

In 60 blocks of the Bankura, Barddhaman, Birbhum, Purulia, Midnapur, Malda, and West Dinajpur districts in West Bengal, groundwater is known to have elevated levels of F.[8] In these districts a substantial amount of paddy is being cultivated with F-contaminated groundwater used for irrigation. As a result, F accumulation in different parts of paddy is likely,[9] ultimately leading to F contamination in the food chain. In view of this situation, we have undertaken a laboratory study to assess the effect of F on paddy germination and seedlings with respect to their physiology, biochemistry, and F uptake.

MATERIALS AND METHODS

Three hundred healthy paddy seeds (*Oryza sativa* L.; var. Satabdi) were selected for the study. Twenty-five sterilized seeds were placed in individual petri dishes labeled as control and NaF concentrations ranging from 10 to 30 mg/L. Five mL of NaF solution having 0 (control), 10, 20, and 30 mg NaF/L was added to the respective labeled petri dishes. The average temperature and humidity during the

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experiment were 30.9ºC and 79.2%, the latter measured by a digital hygrometer (Model.HTC-1). After 15 days of treatment, various morphological parameters such as percent germination, root length, shoot length, fresh weight, dry weight and biochemical parameters such as levels of chlorophyll,[10] ascorbic acid,[11] and reducing sugar[12] were measured, and water-extractable F[13] from whole test seedlings were also estimated.

RESULTS AND DISCUSSION

EFFECT ON MORPHOLOGICAL PARAMETERS:

Percent Germination: Seed germination showed a direct decreasing trend with increasing concentration of NaF. At 0 and 10 mg NaF/L 100% germination of seeds had occurred, whereas at 20 and 30 mg NaF/L the percent germination decreased to 96% and 92%, respectively.

Root length and shoot length: As shown in Figure 1, the average root and shoot length decreased monotonically with increasing NaF concentration. At 30 mg NaF/L the average root length and shoot length were reduced to 50% and 27%, respectively.

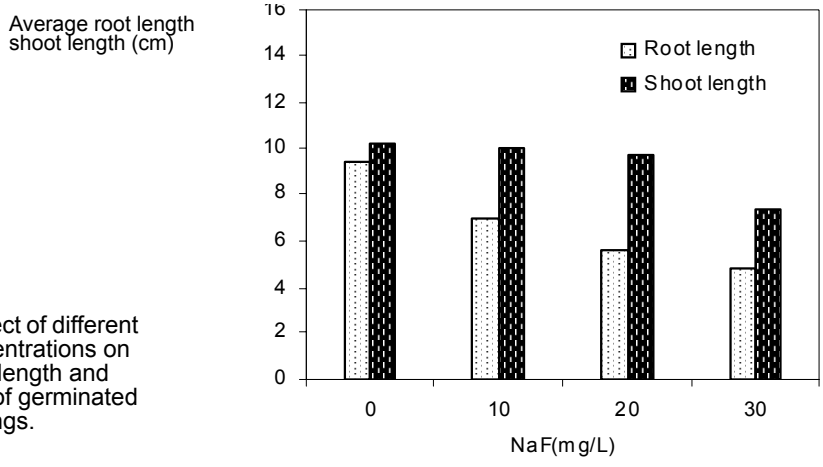

Figure 1. Effect of different fluoride concentrations on average root length and shoot length of germinated paddy seedlings.

Fresh weight and dry weight: The fresh and dry weight (drying at 80°C for 24 hr) of the seedlings decreased monotonically with increasing NaF concentration. At 30 mg NaF/L fresh weight and dry weight of the seedlings reduced by 20% and 29%, respectively (Figure 2).

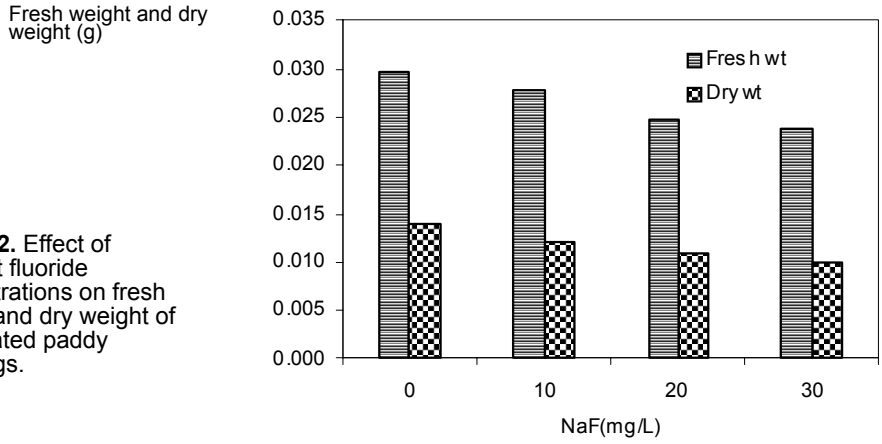

Figure 2. Effect of different fluoride concentrations on fresh weight and dry weight of germinated paddy seedlings.

EFFECT ON BIOCHEMICAL CONSTITUENTS:

Chlorophyll: As seen in Figure 3, chlorophyll-a, chlorophyll-b, and total chlorophyll content of the leaves decreased monotonically. At 30 mg NaF/L, both chlorophyll-a and chlorophyll-b decreased nearly 80%, whereas reduction in total chlorophyll content was 78%. This may be due to the break down of chlorophyll during stress or due to inhibition of chlorophyll biosynthesis, which is a primary symptom of fluoride-induced chlorosis.[5]

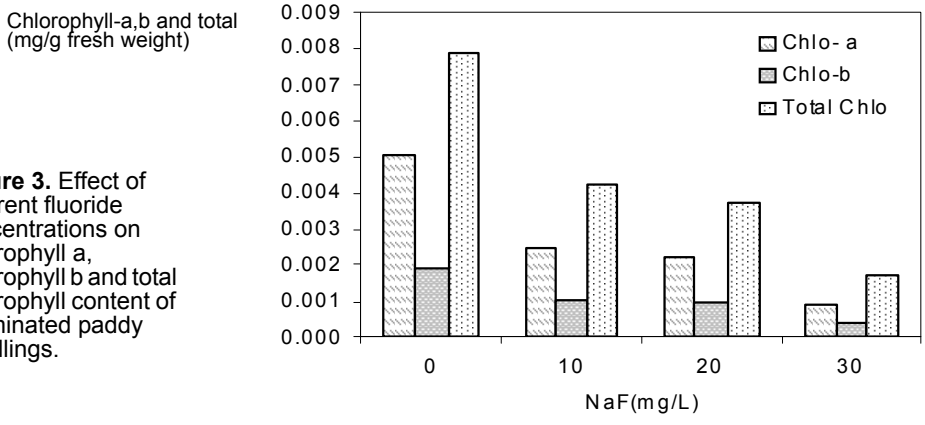

Figure 3. Effect of different fluoride concentrations on chlorophyll a, chlorophyll b and total chlorophyll content of germinated paddy seedlings.

Ascorbic acid: Ascorbic acid as an antioxidant plays an important role in protection against physiological stress.[14] Ascorbic acid content initially decreased and then increased with increasing NaF concentration. At 30 mg NaF/L, ascorbic acid content increased 300 times over that of 10 mg NaF/L (Figure 4). This increasing trend in ascorbic acid may be responsible for binding of F with ascorbic

acid oxidase enzyme thereby inhibiting the breakdown of ascorbic acid in the plant system.

Soluble sugar: The sugar level in plants is directly related to stress factors.[15] Like ascorbic acid, the reducing sugar content also initially decreased and then increased with increasing concentration of NaF (Figure 4). At 30 mg NaF/L, the sugar content increased 118 times that at 10 mg NaF/L. An increased level of reducing sugar in tissues may be due to its non-conversion to non-reducing sugar.[4] This might be a mechanism adopted by particularly paddy (rice) to reduce the effect of F stress.

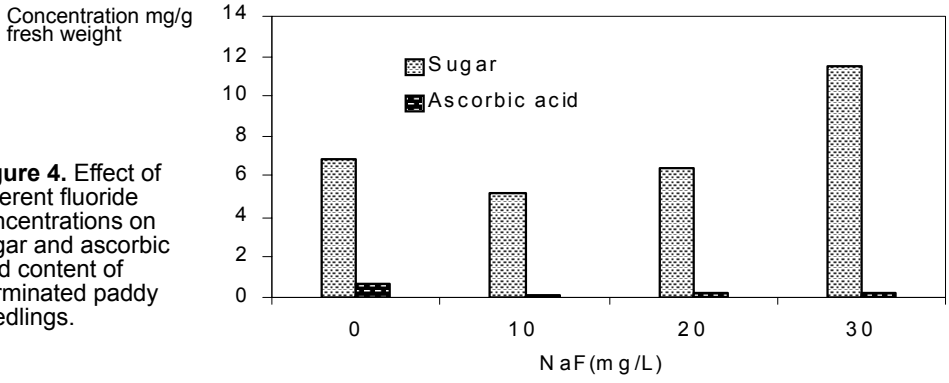

Figure 4. Effect of different fluoride concentrations on sugar and ascorbic acid content of germinated paddy seedlings.

Fluoride uptake by paddy seedlings:

Fluoride uptake in the experimental paddy seedlings increased with increasing NaF concentration. With respect to 10 mg NaF/L fluoride uptake was found to increase 26 times and 53 times in 20 and 30 mg NaF/L, respectively (Figure 5). Substantial amounts of F uptake in the seedlings may be an indicator of a later higher accumulation of F in the edible part, i.e., paddy seeds also.

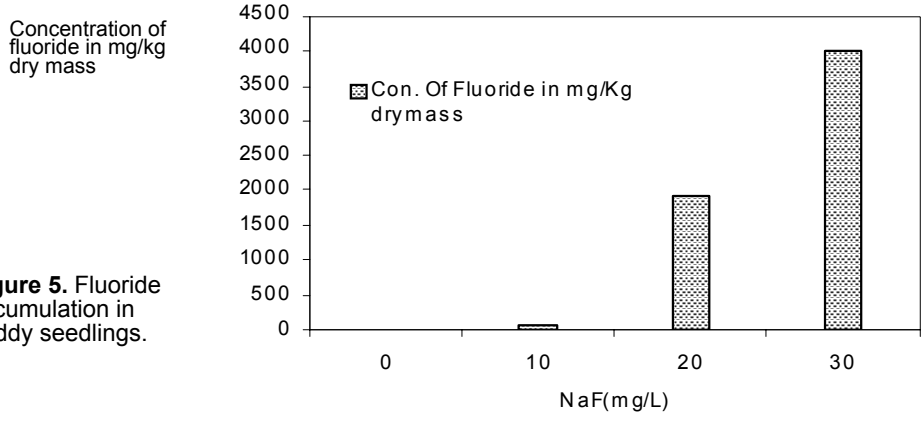

Figure 5. Fluoride accumulation in paddy seedlings.

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