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EFFECT OF SODIUM FLUORIDE STRESS ON THE PRODUCTIVITY OF *SOLANUM MELONGENA* L., (AUBERGINE, BRINJAL, EGGPLANT)

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ABSTRACT: Fluoride is present naturally in the environment and may reach levels that impair the bio-physiological processes in plants. The aim of the present study was to examine the effect of sodium fluoride (NaF) stress on the yield of *Solanum melongena* L., (aubergine, brinjal, eggplant), a member of the Solanaceae family with edible properties. In a pot experiment, lasting from August to October 2017, NaF was applied twice weekly as a soil drench and a foliar spray in concentrations of 100, 200, 300, 400, 500, and 600 ppm. The yield of *S. melongena* was severely affected by the NaF in a dose-related manner with the maximum yield reduction observed at 600 ppm NaF. The soil drench affected the plants more than the foliar spray application. The results showed that *S. melongena* is a salt sensitive crop.

Keywords: Biotic stress; Pakistan; Productivity; Sodium fluoride; *Solanum melongena* L.

INTRODUCTION

Both biotic stresses, caused by living organisms such as fungi, bacteria, viruses, nematodes, insects, arachnids, and weeds, and abiotic stresses, caused by environmental factors such as salinity, heat, cold, and drought, may affect the growth and productivity of plants.[1] Soil salinity may limit plant growth and metabolism.[2] It has been reported that, in the world, about 20% of the cultivated areas and 50% of the irrigated land are under salinity stress.[3] In Pakistan, salinity affects about 6.67 Mha of land.[4] Fluoride belongs to the halogen family and can form both organic and inorganic compounds.[5] Fluoride is one the most phytotoxic environmental pollutants and can persist, even at very low concentrations, for a long time in soil, air, and water. Fluoride has negative effects on all ecosystem levels.[6,7] Fluoride may be strongly retained in soil as fluorapatite [$Ca_5(PO_4)_3F$], cryolite (Na_3AlF_6), and some other phosphate rocks.[8] The average abundance of fluorine in the earth's crust is 0.32 g/kg.[9] Anthropogenic sources of fluoride include the aluminium, glass fibre, and steel industries.[10] Large amounts of fluorine are being added to a huge area of the world every year by the production and use of phosphate fertilizers as fluoride occurs in the phosphate rocks used as raw material for fertilizer production.[11] World-wide, salt stress limits the yield of crop and agriculture production and is an environmental and agricultural issue.[3,12] The ability of plants to tolerate fluoride toxicity varies between different plants and even within the cultivars of the same species.[13]

Solanum melongena, known as brinjal in Pakistan, is a common tropical and sub-tropical crop which is non-cold tolerant and one of the most cultivated crops of the Solanaceae family.[14] It has been known since Harappa civilization.[15] It is a crop that is both economically and nutritionally important in Asia and has an estimated global production about 46 Mt.[16] Fruit extracts of *S. melongena* have anti-oxidant,[17] hepato-protective,[18] anti-carcinoma,[19] anti-microbial, anti-viral anti-LDL,[20] and cardio-

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protective properties.[21] Brinjal has a fascinating ethno-botanical history with many common uses including as a medicine, a food, and an ornamental plant.[22] *Solanum melongena* is moderately sensitive to salt stress and the yield and growth of the plant is dependent upon the salinity of the soil.[23] Both the productivity and quality of *S. melongena* are adversely affected by abiotic salt stress.[24]

The aim of the present study was to examine the effect of sodium fluoride (NaF) stress on the biomass production and yield characteristics of *Solanum melongena* L., (aubergine, brinjal, eggplant), a member of the Solanaceae family with edible properties.

MATERIALS AND METHODS

Seeds of certified brinjal (*Solanum melongena* L.) were obtained from Mehar Seed Store, Ellah Abad. The seeds were examined and unhealthy seeds were removed. All seeds that were distorted, crinkled, or showing any other abnormality were discarded to protect the remaining healthy seeds from infection. Any seeds showing evidence of disease or fungal attack were removed and disposed off. The healthy seeds were placed brown paper bags for further use. The experiment was conducted in the Botanical Garden of Quaid-e-Azam Campus, University of the Punjab, Lahore, Pakistan. The location of experimental site was in the south of Lahore city. The pot experiment was conducted in a wire house so as to protect the plants from animals and birds. The duration of the experiment was from August 2017 to October 2017. Soil, with optimal proportions of ingredients, was prepared by mixing sand and loam in a 1:3 ratio along with the organic manure, like leaf manure. One hundred pots, 14 inches in diameter, were thoroughly cleaned and then arranged in a randomized complete block design (RCBD) manner. Seven treatments, each having six replicates, were applied to the labeled pots. After 12 hours of soaking, three seeds were sown in the prepared soil in each pot. The seeds germinated after five days. After germination was complete, the seedlings were thinned to one plant per pot. Any weeds present were removed manually. The plants were kept under observation so that any external attack could be dealt with immediately. The effects of sodium fluoride (NaF) on the plants was examined by applying it as a soil drench and a foliar spray twice a week. The concentrations of NaF applied to the plants were 100 ppm, 200 ppm, 300 ppm, 400 ppm, 500 ppm, and 600 ppm. Each solution was prepared using a standard formula. A weighed amount of NaF was dissolved in distilled water, placed in a bottle, and the bottle was filled up to the mark with distilled water. The control plants were given tap water as a soil drench and foliar spray. The crop management throughout the growing season was done in accordance with the local agricultural practices for managing plants grown in the experimental area. After a period of vegetative growth, flowering emerged, and this was recorded on a weekly basis until the formation of the fruit. The maturity harvest of the crop was taken at 90 days after sowing (DAS) by destructive harvesting with the whole plant being plucked from the soil. The harvested plants were taken to the laboratory and washed with tap water. The following yield parameters were recorded: (i) number of brinjal per plant, (ii) size of brinjal (cm^2), (iii) fresh weight of brinjal (g), and (iv) dry weight of brinjal (g). The statistical analysis involved calculating the mean and standard error. Duncan's Multiple Range (DMR) test was used to examine for statistical significance[25] by using the software package COSTAT (ver. 3.03).

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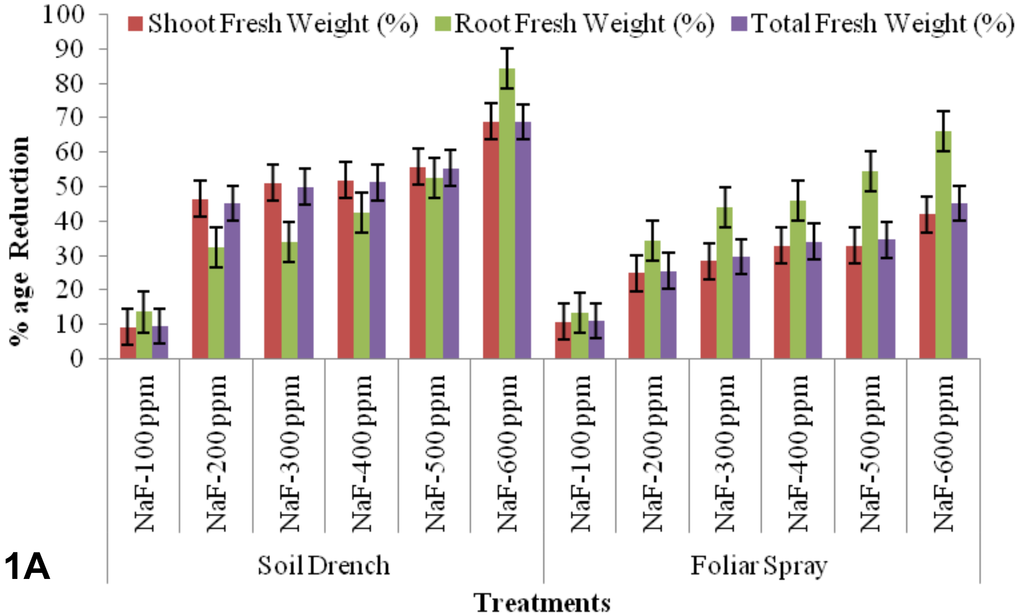
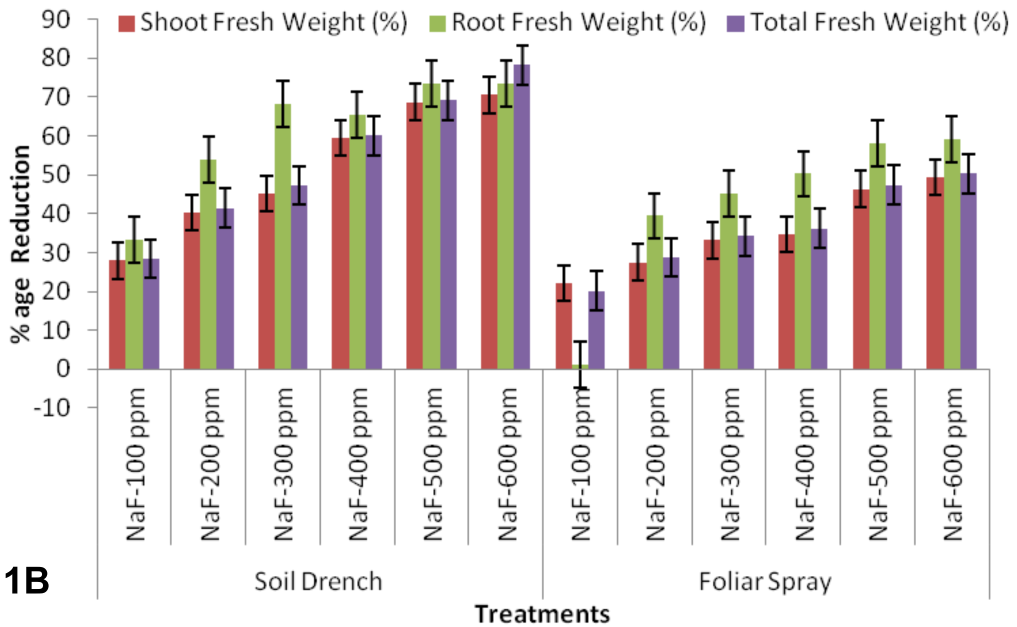
RESULTS

BIOMASS ESTIMATION:

Shoot, root, and total fresh weight: At 50 and 90 DAS the shoot and root fresh weights were marked reduced in a dose-dependent manner by the NaF treatments. The control plants were healthy and had the highest shoot and root fresh weights (Figures 1A and 1B).



1A



1B

Figures 1A and 1B. The percentage reduction, compared to the control, in the shoot, root and total fresh weight of *Solanum melongena* L. harvested at 50 DAS (1A) and 90 DAS (1B) after treatment with different concentrations of sodium fluoride applied as a soil drench and a foliar spray.

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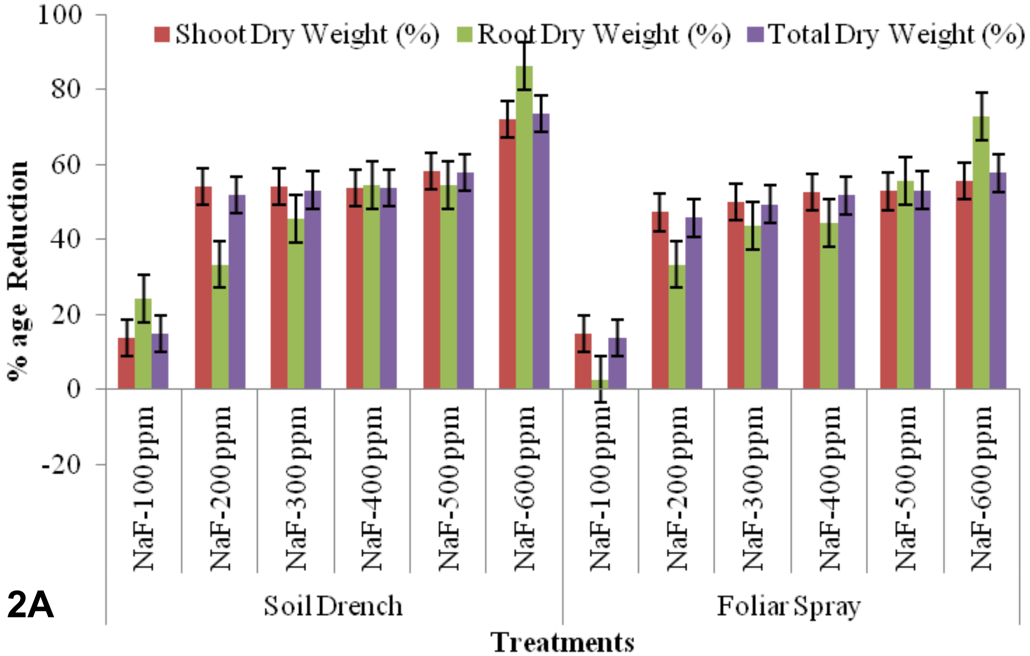
The plants treated with NaF in concentrations of 200 ppm, 300 ppm, 400 ppm, 500 ppm, and 600 ppm were less developed with reduced shoot and root fresh weights as compared to the control plants. At 50 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in shoot fresh weights of 68.92% and 41.9%, respectively. At 90 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in shoot fresh weights of 70.49% and 49.39%, respectively. The treatment by soil drench had a greater adverse effect on the shoot fresh weight of the plants than the treatment by foliar spray.

The effect of the NaF treatment on the plant root fresh weight was similar to that seen with the shoot fresh weight. For both the soil drench and foliar spray NaF treatment methods, the maximum root fresh weight was found in the control plants while the minimum root fresh weight was observed at NaF-600 ppm. At 50 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in root fresh weights of 84.37% and 66.1%, respectively. At 90 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in root fresh weights of 73.4% and 58.98%, respectively. The treatment by soil drench had a greater adverse effect on the root fresh weight of the plants than the treatment by foliar spray.

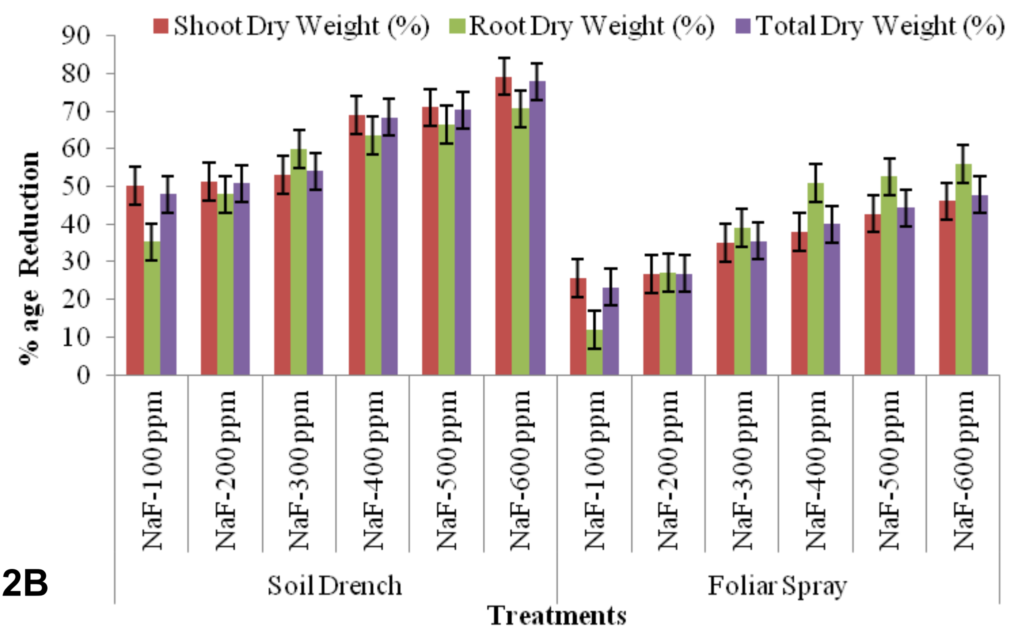
Shoot, root, and total dry weight: At 50 and 90 DAS the shoot and root dry weights were marked reduced in a dose-dependent manner by the NaF treatments. The control plants were healthy and had the highest shoot and root dry weights (Figures 2A and 2B).

The plants treated with NaF in concentrations of 200 ppm, 300 ppm, 400 ppm, 500 ppm, and 600 ppm were less developed with reduced shoot and root dry weights as compared to the control plants. At 50 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in shoot dry weights of 72.13% and 55.49%, respectively. At 90 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in shoot dry weights of 70.49% and 49.39%, respectively. The treatment by soil drench had a greater adverse effect on the shoot fresh weight of the plants than the treatment by foliar spray.

The effect of the NaF treatment on the plant root dry weight was similar to that seen with the shoot dry weight. For both the soil drench and foliar spray NaF treatment methods, the maximum root dry weight was found in the control plants while the minimum root fresh weight was observed at NaF-600 ppm. At 50 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in root dry weights of 86.11% and 72.72%, respectively. At 90 DAS, the plants treated with NaF-600 ppm by soil drench and foliar spray showed the maximum reduction in root dry weights of 70.61% and 55.93%, respectively. The treatment by soil drench had a greater adverse effect on the root fresh weight of the plants than the treatment by foliar spray.



2A



2B

Figures 2A and 2B. The percentage reduction, compared to the control, in the shoot, root and total dry weight of *Solanum melongena* L. harvested at 50 DAS (2A) and 90 DAS (2B) after treatment with different concentrations of sodium fluoride applied as a soil drench and a foliar spray.

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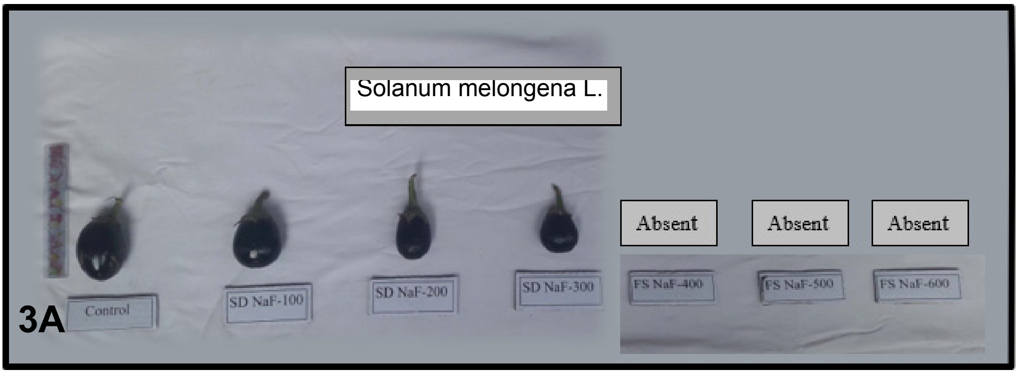
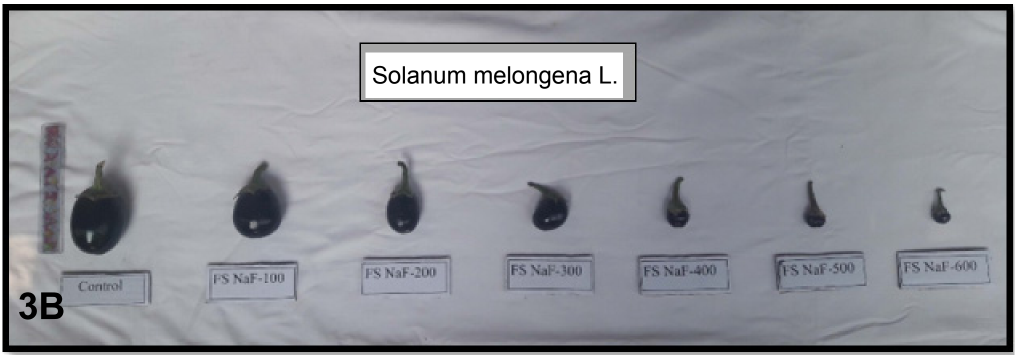
PRODUCTIVITY ASSESSMENT

Number of brinjals: At 90 DAS, the number of brinjals per pot was examined for the productivity assessment. The number of brinjals produced per plant remained constant at one brinjal per plant for the control plants, the plants treated with NaF as a soil drench at 100, 200, and 300 ppm, and the plants treated with NaF as a foliar spray at 100, 200, 300, 400, 500, and 600 ppm. However, no brinjals were produced in the plants treated with NaF as a soil drench at 400, 500, and 600 ppm NaF (Table and Figures 3A and 3B).



Control | 100 ppm NaF | 200 ppm NaF | 300 ppm NaF | 400 ppm NaF | 500 ppm NaF | 600 ppm NaF

Concentration of NaF applied as a soil drench



Control | 100 ppm NaF | 200 ppm NaF | 300 ppm NaF | 400 ppm NaF | 500 ppm NaF | 600 ppm NaF

Concentration of NaF applied as a foliar spray

Figures 3A and 3B. The growth of the brinjal, compared to the control, harvested at 90 DAS, after treatment with different concentrations of sodium fluoride applied as a soil drench (3A) and a foliar spray (3B) during the 2017 growth season.

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Table. Productivity assessment of *Solanum melongena* L. (brinjal) harvested at 90 DAS after treatment with various concentrations of sodium fluoride applied as a soil drench and a foliar spray during the 2017 growth season (Values are mean±standard error [SE])

Method of application	Treatment	Parameters			
		Number of brinjal	Size of brinjal (cm^2)	Fresh weight of brinjal (g)	Dry weight of brinjal (g)
Soil drench	Control	0.33 ± 0.33	9.10 ± 0.12	84.53 ± 0.33	6.03 ± 0.09
	NaF-100 ppm	0.33 ± 0.33	8.60 ± 0.15	73.56 ± 0.14	5.43 ± 0.14
	NaF-200 ppm	0.33 ± 0.33	7.17 ± 0.2	44.23 ± 0.24	3.63 ± 0.18
	NaF-300 ppm	0.33 ± 0.33	6.80 ± 0.12	23.26 ± 0.29	1.43 ± 0.14
	NaF-400 ppm	0.00 ± 0	0.00 ± 0	0.00 ± 0	0.00 ± 0
	NaF-500 ppm	0.00 ± 0	0.00 ± 0	0.00 ± 0	0.00 ± 0
	NaF-600 ppm	0.00 ± 0	0.00 ± 0	0.00 ± 0	0.00 ± 0
Foliar spray	Control	0.33 ± 0.33	10.07 ± 0.07	101.80 ± 1.03	9.43 ± 0.2
	NaF-100 ppm	0.33 ± 0.33	8.97 ± 0.14	71.43 ± 0.18	5.70 ± 0.06
	NaF-200 ppm	0.33 ± 0.33	7.57 ± 0.36	62.03 ± 0.18	5.40 ± 0.06
	NaF-300 ppm	0.33 ± 0.33	6.87 ± 0.36	8.50 ± 0.23	1.40 ± 0.21
	NaF-400 ppm	0.33 ± 0.33	2.63 ± 0.14	7.13 ± 0.2	0.83 ± 0.14
	NaF-500 ppm	0.33 ± 0.33	2.17 ± 0.1	4.50 ± 0.15	0.73 ± 0.09
	NaF-600 ppm	0.33 ± 0.33	1.67 ± 0.12	2.5 ± 0.15	0.36 ± 0.07

Each treatment mean is the sum of three replicates. Within each parameter values not followed by same letter are significantly different at Duncan's multiple range test (DMRT).

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Size of the brinjals: The mean size of the brinjals at 90 DAS in the control plants after treatment with tap water, applied as a soil drench and foliar spray, was 9.10 and 10.07 cm^2, respectively (Table). The mean size of the brinjals at 90 DAS in the plants after treatment 100 ppm NaF, applied as a soil drench and foliar spray, was 8.60 and 8.97 cm^2, respectively. The size of the brinjals decreased with increasing NaF concentrations and was least, 1.67 cm^2, with 600 ppm applied by foliar spray. No brinjal were produced on the plants treated with the soil drench treatment method at NaF concentrations of 400, 500, and 600 ppm. The mean sizes of the brinjals after treatment with NaF as a foliar spray at concentrations of 200, 300, 400, and 500 ppm were 7.57, 6.87, 2.63, and 2.17 cm^2, respectively. The mean sizes of the brinjals after treatment with NaF as a soil drench at concentrations of 200 and 300 ppm were 7.17 and 6.80 cm^2, respectively. For the same NaF concentrations, the sizes of the brinjals were greater on the plants treated as a foliar spray than on those treated with a soil drench.

Fresh weight of brinjals: The mean fresh weight of the brinjals at 90 DAS in the control plants after treatment with tap water, applied as a soil drench and foliar spray, was 84.53 and 101.80 g, respectively (Table). The mean fresh weight of the brinjals at 90 DAS in the plants after treatment 100 ppm NaF, applied as a soil drench and foliar spray, was 73.56 and 71.43 g, respectively. The fresh weight of the brinjals decreased with increasing NaF concentrations and was least, 2.5 g, with 600 ppm applied by foliar spray. No brinjal were produced on the plants treated with the soil drench treatment method at NaF concentrations of 400, 500, and 600 ppm. The mean fresh weights of the brinjals after treatment with NaF as a foliar spray at concentrations of 200, 300, 400, and 500 ppm were 62.03, 8.50, 7.13, and 4.50 g, respectively. The mean fresh weights of the brinjals after treatment with NaF as a soil drench at concentrations of 200 and 300 ppm were 44.23 and 23.26 cm^2, respectively. For the same NaF concentrations, the fresh weights of the brinjals were greater on the plants treated as a foliar spray than on those treated with a soil drench.

Dry weight of brinjals: The mean dry weight of the brinjals at 90 DAS in the control plants after treatment with tap water, applied as a soil drench and foliar spray, was 6.03 and 9.43 g, respectively (Table). The mean dry weight of the brinjals at 90 DAS in the plants after treatment 100 ppm NaF, applied as a soil drench and foliar spray, was 5.43 and 5.70 g, respectively. The dry weight of the brinjals decreased with increasing NaF concentrations and was least, 0.36 g, with 600 ppm applied by foliar spray. No brinjal were produced on the plants treated with the soil drench treatment method at NaF concentrations of 400, 500, and 600 ppm. The mean dry weights of the brinjals after treatment with NaF as a foliar spray at concentrations of 200, 300, 400, and 500 ppm were 5.40, 1.40, 0.83, and 0.73 g, respectively. The mean dry weights of the brinjals after treatment with NaF as a soil drench at concentrations of 200 and 300 ppm were 3.63 and 1.43 cm^2, respectively. For the same NaF concentrations, the dry weights of the brinjals were greater on the plants treated as a foliar spray than on those treated with a soil drench.

DISCUSSION

In the present study, we found that NaF applied as a soil drench, in concentrations of 100 and 200 ppm, and as a foliar spray, in concentrations of 100, 200, 300, 400, 500, and 600 ppm, reduced the shoot and root dry and fresh weights, and the number, size, and fresh and dry weights of the brinjals. No brinjals were produced with NaF applied as a soil drench at concentrations of 300, 400, 500, and 600 ppm.

Mishra et al.found that the application of NaF reduced the net primary productivity of tomato (*Lycopersicum esculentum*) and chilli (*Capsicum annum*) by 14.46–62.24% and 40.8–90.65%, respectively. Pod formation in chilli was inhibited with high concentrations of sodium fluoride.[26] Bustingorri et al. reported that high concentrations of NaF caused a 30% yield loss in soybean.[27]

Singh and Verma found that 100–500 ppm fluoride-contaminated irrigation water had negative results on seedlings of *Populous deltoides* (poplar) and the harvest index and other growth parameters were successively reduced with increasing fluoride concentrations.[28] Sabal et al. found that a significant reduction in percent seed germination, root and shoot length, and total biomass occurred in *Cyamopsis tetragonoloba* (cluster bean) seedlings with treatment by 5–30 μM NaF and that with 30 μM NaF a 100% mortality occurred in the seeds. [29] Reddy et al. treated *Salicornia brachiata* with 50–150 μM NaF and found a biomass reduction as the concentration of NaF increased. [30]

CONCLUSIONS

The yield of *Solanum melongena* was severely affected by the application of NaF, at concentrations of 100–600 ppm, in a dose-related manner. NaF applied as a soil drench, in concentrations of 100 and 200 ppm, and as a foliar spray, in concentrations of 100, 200, 300, 400, 500, and 600 ppm, reduced the shoot and root dry and fresh weights, and the number, size, and fresh and dry weights of the brinjals. No brinjals were produced with NaF applied as a soil drench at concentrations of 300, 400, 500, and 600 ppm. The soil drench affected the plants more than the foliar spray application. The results showed that *S. melongena* is a salt sensitive crop.

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