PRODUCTIVITY ASSESSMENT OF OKRA UNDER SODIUM FLUORIDE STRESS

Shakil Ahmed,[a,*] K Khalid,[a] F Jabeen,[a] M Nauman Ahmad,[b] Afia Zia,[b] Maha Muhajid,[c] Dania Zia,[c] A Haider[d]

Lahore, Pakistan

ABSTRACT: The objective of the present study was to assess the effects of sodium fluoride (NaF) on the growth and yield components of okra (*Abelmoschus esculentus*) in order to identify plant growth parameters that could be used for the early evaluation of different cultivars for fluoride stress. Two okra cultivars, Arka Anamika and Nirali, were studied in 80 pots and watered twice weekly, starting 31 days after sowing, with either tap water (control) or various concentrations of NaF (50, 100, 150, 200, 250, and 300 ppm). The plants were harvested 70 days after sowing. The yield parameters (no. of pods, pod length, fresh and dry pod weight, no. of seeds, fresh and dry weight of seeds) were found to decrease as the concentrations of sodium fluoride increased. The Nirali cultivar was more sensitive to fluoride stress than the Arka Anamika cultivar. In the Nirali cultivar, the no. of flowers decreased with an increase in the NaF concentration from 150 to 300 ppm. In the Arka Anamika cultivar, plants treated with 200 and 300 ppm NaF showed a reduction in the no. of flowers. There was a gradual reduction in the no. of pods as the NaF concentration increased in both cultivars. The percentage reductions in the pod length for the Nirali cultivar with 50, 100, 150, 200, 250, and 300 ppm NaF were 10.30, 17.09, 24.63, 30.24, 31.48, and 42.59%, respectively, as compared to the control. The effect of NaF on pod length in the Arka Anamika cultivar showed a similar trend to that found with the Nirali cultivar. The fresh and dry weights of the pods showed a maximum percentage reduction with 300 ppm NaF, (Nirali: 53.69% and 56.2%; Arka Anamika: 57.23% and 52.17%, respectively). For both cultivars, the no. of seeds per plant decreased with increasing NaF concentrations. In both cultivars, all these parameters were inversely related to the NaF concentrations with the reductions in the plant yield parameters being less in the 50 and 100 ppm NaF-treated plants than in the 250 and 300 ppm NaF-treated plants.

Keywords: Arka Anamika; Nirali; Okra; Sodium fluoride; Yield.

INTRODUCTION

Okra (*Abelmoschus esculentus*) is a very important vegetable crop in the family Malvaceae and is very well liked in the Indo-Pak subcontinent. It is extensively distributed from Africa to Asia, in southern Europe, and in America. It is a crop which can be grown in tropical to subtropical areas and also grows well in hot weather.[1] As it is adversely affected by low temperature, frost, drought, and water logging, its cultivation in different countries may result in different characteristics related to the country in which it is grown. It is mainly used as a vegetable crop and grown for its immature pods which are used as a fried or boiled vegetable or added to soups, salads, and stews.[2] The mature seeds of okra are an excellent source of protein and oil.[3] The protein from okra is recognized as having excellent nutritional qualities.[3] Okra is widely grown in Pakistan in plain areas, especially in the provinces of Punjab and Sindh. The area under okra cultivation in Pakistan is to be estimated to be 2.21×10^5 hectares yielding about 2.86×10^6 tons of green pods.

[a]Department of Botany, University of the Punjab, Lahore 54590, Pakistan; [b]Agricultural Chemistry Department, University of Agriculture, Peshawar, Pakistan; [c]University of Peshawar, Pakistan; [d]Institute of Agricultural Sciences, University of the Punjab, Lahore 54590, Pakistan; *For correspondence: Dr Shakil Ahmed, Plant Ecology & Applied Environmental Biology Research Lab, Department of Botany, University of the Punjab, Lahore 54590, Pakistan; E-mail: shakil.botany@pu.edu.pk

Fluorine is present naturally in water, soil and the atmosphere. Fluorides are compounds containing the element fluorine and are produced by the glass, aluminum, pottery, brick, and ceramic industries. In nature, fluorine appears in natural minerals, especially fluorite, apatite, muscovite, and biotite. High levels of the fluoride ion (F) in soils may reduce crop yields.[4] Fluoride is a well recognized widespread, non-biodegradable, and hazardous nonmetal pollutant.[5] Soil pollution by F is one of the main worldwide problems.[6] F is not necessary for normal plant growth and at high concentrations F can damage plants as well as the environment.[7]

The availability of F to plants tends to decrease with time following the application of F.[8] Normally, F accumulation follows the order of soil>root>shoot>grain. NaF shows a major interaction with plants and badly affects their various physiological and biochemical parameters, without necessarily showing any noticeable symptoms of damage. Sodium fluoride affects plant growth and processes by disturbing many metabolic pathways such as photosynthesis and respiration. It also affects the activity of various processes such as protein synthesis, nucleotide synthesis, and carbohydrate metabolism. Gaseous fluoride enters the leaf through the stomata and generally the leaves are most sensitive when they are young and still expanding.[9] It was reported that high levels of F in acid soils reduce crop yield due to increasing the aluminium uptake and decreasing the phosphorus uptake.[4] The objective of the present study was to identify plant growth parameters for okra that could be used as selection criteria for the early evaluation of different cultivars for fluoride stress. To achieve this aim, the study was done to assess the effects of sodium fluoride on growth and yield components.

MATERIALS AND METHODS

Certified seeds of the okra cultivar Arka Anamika were obtained from the Punjab Seed Corporation, Lahore, Pakistan, and seeds of the cultivar Nirali were purchased from Pride Seeds, Lahore. The Botanical Garden, Quaid-e-Azam campus, University of the Punjab, Lahore, was selected as the location for the experiment. It is located in the southern part of Lahore (31º35-00-N, 74º21-00-E). A total 84 pots, of 30 cm in length and 25 cm in diameter, were thoroughly cleaned and used in the present experiment. Each pot was filled with 3 kg of an already prepared moist soil. The arrangement for the growth of the particular varieties of okra used in the experiment was adequate to achieve accurate results. The pots were labeled according to their respective treatment, replicate number, and the lady okra cultivar used. The pots were randomly placed in a wire house.

The range of temperature during the experiment was 27±3ºC to 44±4ºC. The range of the relative humidity was 16±3% to 38±4% and the rainfall ranged from 22.4±2 mm to 41.2±3 mm. The data was obtained from Pakistan Meteorological Department Lahore. Various dilutions of sodium fluoride were prepared by mixing appropriate amount of solutes in distilled water. Different concentrations of sodium fluoride were applied to check their effect on the okra cultivars Nirali and Arka Anamika with the passage of time during the growth season 2016. The concentrations of sodium fluoride used in the present study are shown in Table1.

Table 1. Different concentrations of sodium fluoride

Concentration (ppm)	Amount of solute (mg/L)	Amount of solute (g/L)
Control	0.00	0.00
NaF-50	50	0.05
NaF-100	100	0.10
NaF-150	150	0.15
NaF-200	200	0.20
NaF-250	250	0.25
NaF-300	300	0.30

The pots were watered with measured amounts of sodium fluoride at various concentrations, i.e. 50, 100, 150, 200, 250, and 300 ppm, to create the condition of F stress. The control pots were watered with tap water. The first treatment with sodium fluoride was applied 31 days after sowing. Treatments were applied twice a week throughout the season till final harvest.

Harvest was taken at 70 days after sowing (DAS). At the final harvest, the yield parameters of the number of pods per plant; the pod length (cm); the number of seeds per pod and per plant; and the fresh and dry weights of seeds per plant (g) were recorded. The data was analyzed to give the treatment mean, standard error and Duncan's Multiple Range Test[10] by using the Costat computer software package (version 1.01).

RESULTS

The crop growth and yield of okra (*Abelmoschus esculentus* L.*)* were recorded for the two cultivars, Nirali and Arka Anamika, at 70 DAS during the growth season. In the cultivar Nirali, the number of flowers decreased with the increase in the sodium fluoride concentration. The plants treated with water (control) had the highest number of flowers while the plants treated with 300 ppm NaF had lowest number of flowers in the cultivars Nirali and Arka Anamika (Table 2). For the Nirali cultivar, plants from the treatments with 150, 200, 250, and 300 ppm sodium fluoride showed a significant reduction in number of flowers of 16.75%, 25%, 33.25%, and 33.25% respectively. Treatment with 50 and 100 ppm NaF had no significant effect on the number of flowers. Similarly, for the cultivar Arka Anamika, treatment with 50 and 100 ppm had no effect on the number of flowers.

Table 2. Yield and yield components of *Abelmoschus esculentus* cv. Nirali and cv. Arka Anamika at 70 days after sowing

Treatment (ppm of NaF)	Yield and yield components								
	No. of flowers	No. of pods	No. of seeds /pod	No. of seeds/ plant	Pod length (cm)	Pod fresh weight (g)	Pod dry weight (g)	Fresh weight of seeds/ plant (g)	Dry weight of seeds/ plant (g)
	Cultivar Nirali								
Control	5.67a ±0.33	4.33a ±0.33	30.00a ±0.58	96.33a ±0.88	16.20a ±0.15	2.98a ±0.01	2.53a ±0.05	15.07a ±0.07	7.77a ±0.09
NaF-50	4.67ab ±0.33	3.67ab ±0.33	25.67b ±0.33	81.33b ±0.88	14.53b ±0.29	2.80b ±0.06	2.38b ±0.04	12.25b ±0.13	5.85b ±0.03
NaF-100	4.67ab ±0.33	3.33bc ±0.33	21.33c ±0.33	76.33c ±0.88	13.43c ±0.23	2.53c ±0.03	2.17c ±0.04	10.47c ±0.27	3.95c ±0.03
NaF-150	4.33bc ±0.33	3.00bc ±0.00	19.67d ±0.33	51.00d ±0.58	12.17d ±0.18	2.38c ±0.07	1.97d ±0.03	6.52d ±0.7	2.77d ±0.09
NaF-200	3.67bc ±0.33	2.67cd ±0.33	18.00e ±0.58	50.33e ±0.33	11.30e ±0.17	1.78d ±0.06	1.43e ±0.03	5.5e ±0.06	2.07e ±0.02
NaF-250	3.33cd ±0.33	2.33cd ±0.33	14.67f ±0.33	37.33f ±0.67	11.10f ±0.10	1.57e ±0.07	1.25f ±0.03	3.67f ±0.09	1.16f ±0.02
NaF-300	2.33d ±0.33	1.67d ±0.33	11.67g ±0.33	31.0g ±0.58	9.30g ±0.15	1.38e ±0.07	1.08g ±0.04	3.05g ±0.03	0.95g ±0.03
	Cultivar Arka Anamika								
Control	4.00a ±0.00	3.67a ±0.33	30.67a ±0.67	119.00a ±0.58	14.67a ±0.33	3.04a ±0.03	2.53a ±0.01	19.13a ±0.70	10.71a ±0.05
NaF-50	4.00a ±0.00	3.33ab ±0.33	24.33b ±0.33	79.00b ±0.58	13.43b ±0.3	2.67b ±0.02	2.52b ±0.02	12.45b ±0.22	6.21b ±0.12
NaF-100	4.00a ±0.00	2.67bc ±0.33	24.0 b ±1.15	49.33c ±0.88	12.40c ±0.21	2.61c ±0.01	2.26c ±0.01	7.27c ±0.18	2.96c ±0.05
NaF-150	3.33ac ±0.33	2.33c ±0.33	15.33c ±0.33	34.33d ±0.88	11.40d ±0.21	2.30d ±0.01	2.15d ±0.01	5.05d ±0.03	1.75d ±0.08
NaF-200	3.00c ±0.00	2.0cd ±0.00	14.33c ±0.33	31.67e ±0.88	11.07e ±0.04	1.81e ±0.01	1.62e ±0.01	3.88e ±0.04	1.27e ±0.04
NaF-250	2.67c ±0.33	2.00cd ±0.00	13.67c ±0.33	30.00e ±0.58	10.13f ±0.09	1.59f ±0.01	1.31f ±0.01	3.45e ±0.03	1.00e ±0.08
NaF-300	2.67c ±0.33	1.33d ±0.33	11.33d ±0.33	29.00e ±0.58	8.33g ±0.33	1.30g ±0.01	1.21g ±0.01	3.09e ±0.01	0.87e ±0.02

Each treatment mean is the sum of three replicates and ± represents the standard error (SE). Within each parameter, the values not followed by same letter are significantly different with Duncan's multiple range test.

There was a gradual reduction in the number of pods with increased NaF concentrations in both cultivars. In the Nirali cultivar at 70 DAS, the percentage reductions in the number of pods per plant with treatment with 50, 100, 150, 200, 250, and 300 ppm NaF were 15.24%, 23%, 30.71%, 38.33%, 46.18%, and 61.43%, respectively, as compared to the control. The control plants treated with water had the highest number of pods while the plants with treated with 300 ppm NaF had the lowest number of pods in both cultivars (Table 2). The pod length reduced as the NaF concentration increased. In the Nirali cultivar, the pod length was highest in the control and lowest in the 300 ppm NaF-treated group, i.e., 16.20 cm and 9.30 cm, respectively (Table 2). The percentage reductions in pod length for the Nirali cultivar with treatment by 50, 100, 150, 200, 250, and 300 ppm NaF were 10.30, 17.09, 24.63, 30.24, 31.48, 42.59%, respectively, as compared to the control. The percentage reduction in pod length in the cultivar Arka Anamika showed a similar trend to that of the Nirali cultivar (Table 2). The pod weight decreased as the sodium fluoride level increased (Table 2). In the Nirali cultivar, the fresh and dry weight of the pods showed a maximum percentage reduction in the NaF-300 ppm group, i.e., 53.69% and 56.2%, respectively. In the Arka Anamika cultivar, the fresh and dry weights of pods had maximum reduction in value in the NaF-300 ppm group, i.e., 57.23% and 52.17%, respectively. In Nirali cultivar, a decrease in the number of seeds per pod was recorded with increasing NaF concentrations (Table 2). In the Arka Anamika cultivar, the same decreasing trend was observed and the percentage decrease in the number of seeds per pod was recorded as 20.67%, 21.74%, 50.02%, 53.27%, 55.42%, and 63.05% with increasing NaF concentrations from 50 to 300 ppm (Table 2).

An increasing percentage reduction in the number of seeds per plant was observed with an increasing NaF concentration. In the Nirali cultivar, the percentage reduction in the number of seeds per plant was observed as 15.60%, 20.76%, 47%, 47.75%, 61.24%, and 67.81% at 50, 100, 150, 200, 250 and 300 ppm NaF respectively. In the Arka Anamika cultivar, the percentage reduction in the number of seeds per plant was observed as 33.6%, 58.5%, 71.15%, 73.38%, 74.70%, and 75.63% at 50, 100, 150, 200, 250 and 300 ppm NaF, respectively. For both cultivars, a decrease in the number of seeds per plant occurred as the NaF concentrations increased (Table 2).

In both cultivars, all these parameters were reduced with increasing NaF concentrations. With the 50 ppm and 100 ppm NaF treatments, the plants showed a smaller reduction in their yield parameters as compared to the 250 ppm and 300 ppm NaF-treated plants. The fresh and dry weights of the seeds were markedly reduced with the 250 and 300 ppm NaF treatments. The results showed that the effects of sodium fluoride concentrations are more obvious on the Nirali cultivar than on the Arka Anamika cultivar.

DISCUSSION

Fluoride is found in soil, water, air, and plants with varying concentrations but is non-essential for the normal growth of plants.[11] Fluoride contamination of soil, water, and vegetation has been a continuing problem in the world.[12] In plants, certain processes are known to be markedly affected by fluoride, e.g., decreased plant growth, chlorosis, leaf tip burn and necrosis, and a decrease in the content of chlorophyll, total soluble sugar, and protein.[13]

The results of the present study clearly indicated that the high concentrations of sodium fluoride significantly reduced plant growth of okra. The yield and yield components were also decreased with an increase of the sodium fluoride stress. Fluoride stress basically reduced the number of pods, the length of the pods, the number of seeds, and the weight of the seeds. Concentrations of 50 and 100 ppm of sodium fluoride were less harmful than concentrations of 250 and 300 ppm. For all the yield parameters, the maximum reduction took place with the 300 ppm NaF treatment and minimum was observed with the 50 ppm NaF treatment. The fresh and dry weights of the seeds were markedly reduced with 300 ppm NaF concentrations (79.76% and 87.77%), respectively, in the Nirali cultivar while the corresponding percentage decreases in the Arka Anamika cultivar were 83.84% and 91.45%, respectively. These results are similar to another study[13] that demonstrated the inhibitory effects of fluoride on plant growth.

CONCLUSION

The conclusion of the present studies is that the effects of sodium fluoride stress on the okra cultivars Nirali and Arka Anamika are very obvious. An increase in the fluoride concentration in the soil had a negative effect on growth, biochemical attributes, and yield. The Nirali cultivar was more responsive to the fluoride stress than Arka Anamika cultivar.

REFERENCES

1 Saifullah M, Rabbani MG. Evaluation and characterization of okra (*Abelmoschus esculentus* L. Moench.) genotypes. SAARC Journal of Agriculture 2009;7:92-9.

2 Akintoye HA, Adebayo AG, Aina OO. Growth and yield response of okra intercropped with live mulches. Asian J Agric Res 2011;5:146-53.

3 Oyelade OJ, Ade-Omowaye BIO, Adeomi VF. Influence of variety on protein, fat contents and some physical characteristics of okra seeds. J Food Eng 2003;57:111-4.

4 Elrashidi MA, Persaud N, Baligar VC. Effect of fluoride and phosphate on yield and mineral composition of barley grown on three soils. Communications in Soil Science and Plant Analysis 1998;29(3-4):269-83. doi:10.1080/00103629809369945

5 Agalakova NI, Gusev GP. Fluoride induces oxidative stress and ATP depletion in the rat erythrocytes *in vitro*. Environmental Toxicology and Pharmacology 2012;34:334-7.

6 Chaudhary K, Khan S. Effect of plant growth promoting rhizobacteria (PGPR) on plant growth and fluoride (F) uptake by F hyper accumulator plant *Prosopis juliflora*. International Journal of Recent Scientific Research 2014;5(11):1995-9.

7 Gao H, Zhang Z, Wan X. Influences of charcoal and bamboo charcoal amendment on soil-fluoride fractions and bioaccumulation of fluoride in tea plants. Environmental Geochemistry and Health 2012;34:551-62.

8 Mishra PC, Sahu SK. Effect of fluoride on locally available crops. Project report submitted to Vedanta Aluminium Company Ltd. Jharsuguda; 2013. pp. 124.

9 Khandare AL, Rao GS. Uptake of fluoride, aluminium and molybdenum by some vegetables by irrigation water.Journal of Human Ecology 2006;19:283-8.

10 Steel RGD, Torrie JH. Principles and procedures of statistics. New York: McGraw; 1960.

11 Weinstein LH, Davison AW. Fluorides in the Environment. Environmental Pollution 2004;126:5-9.

12 Szostek R., Ciećko Z. Content of fluoride in biomass depending on soil contamination by this element. Fluoride 2014;47:294-306.

13 Saini P, Khan S, Baunthiyal M, Sharma V. Effects of fluoride on germination, early growth and antioxidant enzyme activities of legume plant species *Prosopis juliflora*. J Environ Biol 2013;34(2):205-9.