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STATUS OF YIELD CHARACTERISTICS OF TURNIP (*BRASSICA RAPA* L.) UNDER FLUORIDE STRESS

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ABSTRACT: In this study, an examination was made of the size, fresh weight, and dry weight of turnip, *Brassica rapa* L., at 70 days after sowing (DAS) when different concentrations of sodium fluoride (NaF) (0 [control], 50 [NaF-50], 100, 150, 200, and 300 [NaF-300] ppm) were applied. The size of the turnip was maximal in the control plants, 20.82 cm^2. In the plants given NaF-50, as both a soil drench and as a foliar spray, the sizes were 16.32 cm^2 and 18.08 cm^2, respectively. The size of the turnip gradually decreased as the NaF stress was increased and was at a minimum with NaF-300 for both methods of application (soil drench: 2.47 cm^2, foliar spray 4.35 cm^2). At 70 DAS, the fresh weight was greatest, 66.60 g, in the control plants, followed by 43.06 g, in the plants given NaF-50 by foliar spray. The fresh weight successively declined as the concentration of NaF increased and at NaF-300 and it reached a minimum for both the soil drench, 1.36 g, and the foliar spray, 2.43 g. The dry weight was recorded by oven drying the fresh turnip at 70 DAS, and found to be at a maximum in the control plants, 6.60 g. When a fluoride stress was applied with NaF-50, as a soil drench and a foliar spray, the dry weight decreased to 4.30 g and 5.06 g, respectively. As the concentration of NaF increased, the dry weights decreased in a manner similar to that found with the fresh weights and the lowest values were found with NaF-300 (soil drench: 0.556 g, foliar spray: 1.20 g). In conclusion, NaF applied as both a soil drench and a foliar spray, at concentrations of 50–300 ppm, reduced the size, fresh weight, and dry weight of turnip compared to a control group with 0 ppm NaF. The application of the NaF by soil drench caused a greater degree of stress to the turnip than did the application by foliar spray.

Keywords: *Brassica rapa* L.; Fluoride stress; Pakistan; Turnip; Yield.

INTRODUCTION

A vast array of environmental hazards are extremely detrimental for plants such as low and high temperature, drought, alkalinity, salinity, UV stress, and pathogen infection.[1] Salt stress with salts, such as fluoride in soil or water, is one of the major stresses, especially in arid and semi-arid regions and can severely limit plant growth and productivity.[2,3] The vegetation is also severely affected by the accumulation of fluoride which can slowly reach alarming concentrations with the passage of time.[4] This increased amount of fluoride in plants can cause various disease including symptoms leaf burning, blackening and yellowing of leaves along with the necrotic spots, and general chlorosis, Fluoride interferes with the phosphorylation of phosphoproteins in cellular membranes [5] and enzymatic activity,[5,6] as well as with the formation of the pigments essential for the phenomena of photosynthesis and various other plant mechanisms.[7,8] Elevated amounts of fluoride in plants have harmful and toxic impacts. The sources of environmental fluoride include various industries, the eruption of volcanoes and the eroding of the materials expelled from them, and the phosphates used in fertilizer industry.[9,10] There are various areas where the soils are naturally enriched with the excessive amounts of fluoride. This natural fluoride can be translocated to the upper parts of the plants by passing through roots

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or it can sometimes directly enter the leaves from the atmosphere. The presence of fluoride in leaves at high concentrations is extremely harmful.[11,12] Fluoride is absorbed by the plant roots by direct absorption without employing any energy. The fluoride is not permanently bound to the root surfaces and can be removed from the roots by simply washing it off.[13] With the help of various anatomical studies, the concentration of fluoride has been found to be highest in the cell walls with lesser amounts present in the cell membranes and vacuolar membranes. Among the plant parts, shoot is the organ where fluoride is present at the lowest concentration due to the shielding effect of the endodermis which resists its entry. To reach the steller region, fluoride has to pass through an alternative pathway rather than endodermis which provides resistance.[14] The absorption of fluorides from the atmosphere can be greater than that from the ground pollutants. The concentration of fluoride has been found to be greater in the leaves than in the roots.[15, 16] Studies have revealed that the basic pathway for fluoride absorption is by direct entry through the leaves. Various researches have been carried out on the capability of various plants to cope with the effects of fluoride exposure. The absorption of fluoride by plants and the degree of accretion is dependent upon the type of plant and the medium in which it is allowed to grow. Relatively greater amounts of fluoride in the environment will ultimately lead to its accumulation at higher levels in plants.[4] Moreover the medium in which the plant is growing, especially the composition of soil, also effects the concentration of fluoride in the plant parts. Fluoride absorption in plants is reduced if the level of Ca is very elevated in the soil.[17]

The aim of the present study was to examine the effects of fluoride stress on turnip, *Brassica rapa* L., by measuring the size, fresh weight, and dry weight of turnip, at 70 days after sowing (DAS) when different concentrations of sodium fluoride (NaF) (0 [control], 50 [NaF-50], 100 [NaF-100], 150 [NaF-150], 200 [NaF-200], and 300 [NaF-300] ppm) were applied as a soil drench or a foliar spray.

MATERIALS AND METHODS

Certified hybrid seeds of turnip (*Brassica rapa* L.), variety Purple Top White Globe, were procured from Punjab Seeds Corporation, Lahore, Pakistan. The seeds were then checked and only those seeds which were equal in size and healthy were selected for the experiment. All other seeds with any kind of disease attack by insects or fungus were removed from the experimental material. The Botanical Garden of the University of the Punjab, Quaid-e-Azam campus, Lahore, Pakistan, was chosen as the experimental site. It is situated in the southern area of Lahore (74º 21-00-E, 31º 35-00-N), on the outlying part of the city near open wide plots. The land used measured approximately 21×15 m. The plants grown in the experimental work were carefully treated and protected from other environmental hazards and pests by keeping them in a netted frame of steel wire. The pots were placed in the wire enclosure according to a randomized complete block design (RCBD) so that the impacts of the surrounding atmosphere were controlled for. Different dilutions of sodium fluoride, in ppm, were prepared to study its toxicity on turnip cultivars during the growth season. The methods of application of the sodium fluoride to the turnip plants employed in the present study were foliar spray and soil drench at a frequency of twice weekly during the experimental season. The first treatment of sodium fluoride as both soil drench and foliar spray, was applied 30 days after sowing (DAS).

Pots were irrigated with sodium fluoride to create the fluoride stress conditions by using 100 mL of a sodium fluoride solution with concentrations of 50 [NaF-50], 100 [NaF-100], 150 [NaF-150], 200 [NaF-200], and 300 [NaF-300] ppm (Table 1).

Table 1. Different concentrations of sodium fluoride

Concentration of NaF (ppm)	Amount of solute (mg NaF/L)
Control	0.000
NaF-50	50
NaF-100	100
NaF-150	150
NaF-200	200
NaF-250	250
NaF-300	300

The control plants were given distilled water with 0 ppm NaF. The NaF was given as a soil drench by applying 100 mL of NaF solution for a single pot with 1 kg soil. The NaF was given as an exogenous foliar spray by applying 10 mL of NaF solution to each plant. The yield parameters of the number of turnips per pot, the size of turnip, the fresh weight of turnip (g), and the dry weight of turnip (g) were recorded for the harvests at 70 days after sowing (DAS) during the 2016-2017 turnip growth season. Three plants, each in a separate pot, were grown for each experimental condition. The mean values and standard error were obtained by analysing the results for the plants in each group of three pots.

The results were analysed statistically by measuring the treatment mean and the standard error and using Duncan's Multiple Range Test to test for significant differences between groups.[18] The analysis was done in the laboratory by employing the Costat software package (version 3.03) in laboratory computers.

RESULTS

For the assessment of productivity, the number of turnips produced by the one plant in each pot was examined at 70 DAS. The data recorded showed that the number of turnips produced per plant remained constant as the concentration of NaF increased. In each pot only one turnip was produced. The number was same for both the foliar spray and the soil drench. The number of turnips in plants which were given 50 ppm NaF was 1 in the plants treated with both the soil drench and the foliar spray. Similarly, the plants given 300 ppm sodium fluoride also developed only 1 turnip per plant after the application of both the soil drench and the foliar spray.

Table 2 shows the size of turnips produced at 70 DAS when different concentrations of NaF were applied. Data recorded showed that the size of turnip was maximum in the control plants, 20.82 cm^2, followed by the plants given a 50 ppm concentration of NaF by foliar spray, 18.08^2 cm, and soil drench, 16.32 cm^2. The size of the turnip gradually decreased as the stress applied was increased by increasing the concentration of NaF and became minimal at the 300 ppm concentration of NaF with both methods of application. The size of turnip with the soil drench of NaF-300 was

2.47 cm^2 while in plants given a foliar spray of NaF-300 it was 4.35 cm^2. The size of the turnips in the plants treated with a soil drench of NaF, with concentrations of 100, 150, 200, and 250 ppm, was 10.20, 8.02, 6.16, and 3.39 cm^2, respectively.

Table 2. Productivity assessment of turnip (*Brassica rapa* L.) measured at 70 days after sowing (DAS) after applying different sodium fluoride concentrations, by foliar spray and soil drench, during the 2016-2017growth season

Method of application	Treatment	Parameter			
		Number of turnips	Size of turnip (cm^2)	Fresh weight of turnip (g)	Dry weight of turnip (g)
Foliar Spray	Control	1a±0.00	20.82e±0.77	66.60de±2.34	06.60d±0.65
	NaF-50	1a±0.00	18.08d±1.04	43.06e±3.96	05.06d±0.12
	NaF-100	1a±0.00	13.88d±0.74	31.70d±2.66	04.10c±0.10
	NaF-150	1a±0.00	11.66c±0.33	18.50bc±2.28	03.20c±0.36
	NaF-200	1a±0.00	09.01b±0.42	12.46c±0.67	02.20b±0.23
	NaF-250	1a±0.00	07.37b±0.34	06.06b±1.07	01.63a±0.23
	NaF-300	1a±0.00	04.35a±0.58	02.43a±0.29	01.20a±0.15
Soil Drench	Control	1a±0.00	20.82e±0.77	66.60d±2.34	06.60c±0.65
	NaF-50	1a±0.00	16.32d±0.45	25.90d±2.28	04.30b±0.20
	NaF-100	1a±0.00	10.20d±0.56	18.56c±2.48	03.36b±0.43
	NaF-150	1a±0.00	08.02c±0.52	12.66c±0.66	02.30b±0.10
	NaF-200	1a±0.00	06.16c±0.39	09.30b±0.89	01.66a±0.20
	NaF-250	1a±0.00	03.39b±0.25	05.60a±0.78	01.16a±0.12
	NaF-300	1a±0.00	02.47a±0.25	01.36a±0.27	0.566a±0.20

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

Turnips produced in the pots in which NaF was applied as foliar spray had sizes comparatively greater than that of the plants treated with the soil drench of same concentration. The size of turnips in the plants treated with a foliar spray of NaF, with concentrations of 50, 100, 150, 200, and 250 ppm, was 18.08, 13.88, 11.66, 9.01, 7.37, and 4.35 cm^2 respectively.

The data recorded showed that the fresh weight was greatest in the control plants, 66.60 g, followed by the plants given the lowest concentration NaF, 50 ppm, as a foliar spray, 43.06 g. The fresh weight successively declined as the concentration of NaF increased until at 300 ppm it became minimal with both applications, soil drench, 1.36 g, and foliar spray, 2.43 g. The values of fresh weights for the plants treated with NaF as a soil drench at 50, 100, 150, 200, 250, and 300 ppm were 25.90, 18.56, 12.66, 9.30, 5.60, and 1.36 g, respectively and the corresponding values for the NaF treatment as a foliar spray were 43.06, 31.0, 18.50, 12.46, 6.06, and 2.43 g, respectively (Table 2)

The dry weights of the turnips showed a similar decreasing pattern with increasing levels of NaF stress. The values of the dry weights were recorded after oven drying of the fresh turnips at 70 DAS. The value of dry weight was found to be at a maximum in the control plants, 6.60 g. When the NaF stress at a concentration of 50 ppm was applied, the weight decreased to 4.30 g in the soil drench group and 5.06 g in the foliar spray group. As the concentration of NaF increased, the dry weight decreased in a manner similar to that found with the fresh weight and the lowest values were found to be in the plants treated with NaF-300 as a soil drench and a foliar spray of 300 ppm, 0.56 and 1.20 g, respectively (Table 2).

DISCUSSION

Fluoride is present naturally in the earth's crust in varying amounts and it often acts as an environmental pollutant. As a phytotoxicant, its presence in water, air, and soil is quite common. Through a number of human activities, including brick making in kilns in Pakistan, this pollutant is often released into the environment.[7] Throughout the world, fluoride contamination of soil and water is an important problem affecting the health of vegetation, animals, and humans. Fluoride from a number of different sources, at various concentrations, can severely impact on plant health.[19] Increased concentrations of sodium fluoride in soil result in phytotoxic effects on morphological, biochemical, and yield parameters.

As well as higher concentrations of soil sodium fluoride altering plant metabolism and causing a reduction in yield, fluoride can also cause pollen sterility.[20,21] An extensive literature is available which shows that plant growth is dependent on plant photosynthetic capacity. Reduced plant productivity because of salinity stress has been linked with the reduction in the capacity for photosynthesis.[22, 23] These findings are consistent with the results of the present study which indicates that the yield of the turnip is affected by sodium fluoride.

CONCLUSION

The number of turnips produced, their size, fresh weight, and dry weight were reduced by the treatment with sodium fluoride. These parameters decreased as the concentration of sodium fluoride increased and the higher concentrations of NaF resulted in a significantly reduced yield.

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