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EVALUATION OF RESTORATIVE EFFECT OF SALICYLIC ACID ON *ABELMOSCHUS ESCULENTUS* L. YIELD AND BIOMASS ATTRIBUTES FOR ATTENUATING FLUORIDE TOXICITY

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ABSTRACT: Fluoride is non-essential element for the plant's growth. It becomes the part of food chain by natural and anthropogenic activities. World Health Organization has declared it "a health hazardous element". The objective of current investigation was to assess the remedial influences of Salicylic acid (100ppm, 200ppm) on *Abelmoschus esculentus* L. (Okra) under the stress of different concentrations of sodium fluoride (50ppm, 100ppm, 150ppm) to get maximum yield and biomass attributes. Okra variety "Sabz Pari" was studied during the spring season of growth (February to April) 2021. Sodium fluoride reduced biomass growth parameters (dry weight of shoots and roots and total dry weight, fresh weight of root and shoot and total fresh weight) in okra plants. Foliar application of different concentrations of salicylic acid, 100ppm and 200ppm, were applied twice a week under salt stress. Exogenous application of salicylic acid enhanced yield parameters (number of flowers, number of pods, number of seeds/pods, number of seeds/plants, pod length, pod fresh weight, pod dry weight, fresh weight of seeds/plant, dry weight of seeds/plant, 1000 seed weight, yield index) at both vegetative and reproductive stage. However, higher concentration of salicylic acid (200ppm) impedes the growth of applied plant. Additionally, salicylic acid is a growth regulator and antioxidant for improving yield and biomass by relieving the locked ions due to sodium fluoride in the soil. Hence salt tolerance was enhanced by the exogenous application of Salicylic acid in *Abelmoschus esculentus* L.

Key words: *Abelmoschus esculentus* L., sodium fluoride, salicylic acid, yield

INTRODUCTION

Productivity of agricultural land and food safety are at the verge of devastation due to increasing problem of salt stress due to which twenty percent of total cultivable land is endangered [1]. The range of susceptibility to F- intensity varies among plant species. Some species are vulnerable to minute concentrations (less than 20 µg/g), while others can survive massive amounts of more than 4000 µg/g [2]. The amount of fluoride in ground water is about 67mg/L, which is the cause of health concerns in more than 20 nations, according to the World Health Organization [3]. The main cause of polluted soil and water reserves is the breakdown of fluoride-based rocks [4]. Fluoride levels beyond a certain threshold would block mitochondrial reaction pathways in plants [5]. Fluoride emission is mostly caused by human activities, coal

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industries, and unlimited and excessive use of phosphatic fertilizers [6]. Acidic soil promotes the entrance of fluorides in the plants through irrigation water [7] [8]. Zeolite-based sediments in Indian groundwater had a large level of fluoride, resulting in toxicity in plants when water used for crops irrigation [9].

Roots and the stomatal openings are the two routes for the entry of fluoride in plant cells [10]. Fluoride is absorbed by plants through their roots, then transported through the xylem system to the aerial portions, where it is deposited in edible fruits [11]. Some plants have evolved a natural defensive mechanism against salt stressors based on antioxidants [12]. The word "salicylic acid" comes from the Latin word "salix." Salix is the scientific name for the willow tree. In plants, the production of salicylic acid is connected to the production of auxins and some other hormones [13]. Salicylic acid is defined as ortho-hydroxy-benzoic acid naturally created by the plants [14] placed under the category of phenolics. Plant growth is enhanced by the applications of the Salicylic acids but not more than 1mM which could have the negatives effects [15].

The application of salicylic acid blocks the apertures of the stomata that close the gateways for invading microorganisms [16]. Exogenous applications of salicylic acid on plants have an influence on the entry and transfer of ions [17]. Salicylic acid has a scheme of monitored receptors for stimulating the defense system of plants upon encountering any stress [18]. When okra plants are given a foliar spray of salicylic acid at a dosage of 240 mg/l, they produce the highest yield and have the best growth characteristics [19]. The phenylalanine lyase pathway and the iso-chorismate pathway are both involved in the production of salicylic acid. Phenyl alanine is converted to cinnamic acid by phenylalanine lyase. Benzoic acid is formed when cinnamic acid is transformed. Benzoic acid is used to make salicylic acid [20]. Salicylic acid treatments aid in the homeostatic balance of ions such as Na^+ and K^+. [21]. In okra, 240mg/L salicylic acid enhanced the number of pods, pod weight, pod length, and number of leaves [22].

Abelmoschus esculentus L. (Okra) belongs to family "Malvaceae" and is a commonly consumed vegetable in Pakistan. Several other common names of okra are "Bhindi" and "Ladyfinger". One of the industrial usages of Okra is its bast fiber composite of Ca, K, 67% cellulose, wax, hemicellulose 15%, 3.8% fats, 7.2% lignin. In every 100g of Okra the nutritional contents are 2g proteins, vitamins A, C, E, K in a percentage of 7%, 28%, 2%, 30% respectively. It is also a source of micronutrients (Zn, Fe) and macronutrients (Ca, Mg, K) essential for humans. Okra oil is used in the manufacturing of biodiesel [23]. Mucilage is abundant in okra roots, which is used to cure wounds, syphilis, and cuts [24]. The root system of the okra plant is the deepest, reaching up to 45cm below the surface [25]. Folic acid, which is found in okra, aids foetal development [26]. Okra crop faces abiotic stress as well by attack of certain insects.

The objective of this current investigation was to estimate the remedial influences of Salicylic acid on *Abelmoschus esculentus* L. under the stress of different concentrations of Sodium fluoride to obtain maximum yield and biomass attributes.

MATERIALS AND METHODS

The current experiment was performed during the growth season of Okra (*Abelmoschus esculentus* L.), variety "Sabz Pari" in botanical garden (74º21-00-E, 31º35-00-N), University of the Punjab Lahore. Seeds were purchased from Roshan seeds center, Lahore. Healthy seeds were selected while the effected ones were removed carefully for raising the plants. The 48 Clay pots were arranged in 12 rows were arranged in Randomized Complete Block Design. Every 12 inch pot was prepared with 7kg of soil with the ratio 1:3 of sandy and loamy soil. Pots were left to be soaked in water for the best possible sowing of the seeds after 24 hours' time period. Different concentrations NaF 50ppm, 100ppm, and 150ppm were applied as soil drench and 100ppm and 200ppm of Salicylic acid were applied as foliar spray applied twice a week using 150mL of NaF in soil drench and 6mL of Salicylic acid as foliar spray per pot. After 37 days of sowing first treatment was given. Vegetative (45 Days after sowing [DAS]) and reproductive (70DAS) harvests were taken respectively to check the relieving impacts of Salicylic acid on biomass and yield of okra under Sodium fluoride stress. Biomass attributes was observed and calculated at both vegetative and reproductive harvests. Yield parameters was observed 70 DAS.

Statistical analysis: Mean, standard deviation, and standard error of all the data obtained from pot experiment was calculated using the software Costat version (3.03) by Steel and Torrie [27] in laboratory.

RESULTS

Yield of Okra was observed at 45DAS and 70DAS along with biomass assessment. Values of fresh weights of shoot, root and total fresh weights were reduced with increasing concentration of Sodium fluoride at both the harvests.

At 45DAS values for Shoot, root and total fresh weights were maximum in SA-100. Shoot weight showed percentage reduction of 48.43%, 54.52% and 61.86% at 50ppm, 100ppm and 150ppm, respectively. While Root weight showed reduction of 82%, 914% and 99.63% at 50ppm, 100ppm and 150ppm, respectively. Total fresh weight also showed the same trend with % reduction of 51.42%, 57.12% and 64.65% at 50ppm, 100ppm and 150ppm respectively (Figures 1A and 1B, Table 1).

Salicylic acid at 100ppm have an influential role on shoot, root, and total fresh weights i.e., -15.58, -75.36 and -19.95 respectively compared to SA-200 which showed a reduction of -7.96 %, -42.2% and -10.48% for shoot, root, and total fresh weights, respectively.

Same trend of reduction was observed at 70DAS with enhanced shoot, root, and total weight. % Reduction in NaF-50+SA-100 (1.39% for shoot, 23.18% for root and 3.06% for total fresh weight) was minimum than NaF-50+SA-200 (13.08% for shoot, 30.43% for root and 121% for total fresh weight) and NaF-50 (48.43% for shoot, 88.4% for root and 51.42% for total fresh weight). While 150ppm NaF caused significant reduction in shoot and root fresh weight. Same trend was observed for the shoot fresh weights, root fresh weights, and total fresh weights at 70 DAS with maximum values for these weights compared to that of 45DAS. Shoot, root and total dry weights showed the same trend for the treatments as shown by fresh weights. Dry weights of Shoots, root and total weight was maximum in SA-100 (-36.26% for shoot, -45.05% for root and -37.48% for total dry weight). % Age reduction for shoot

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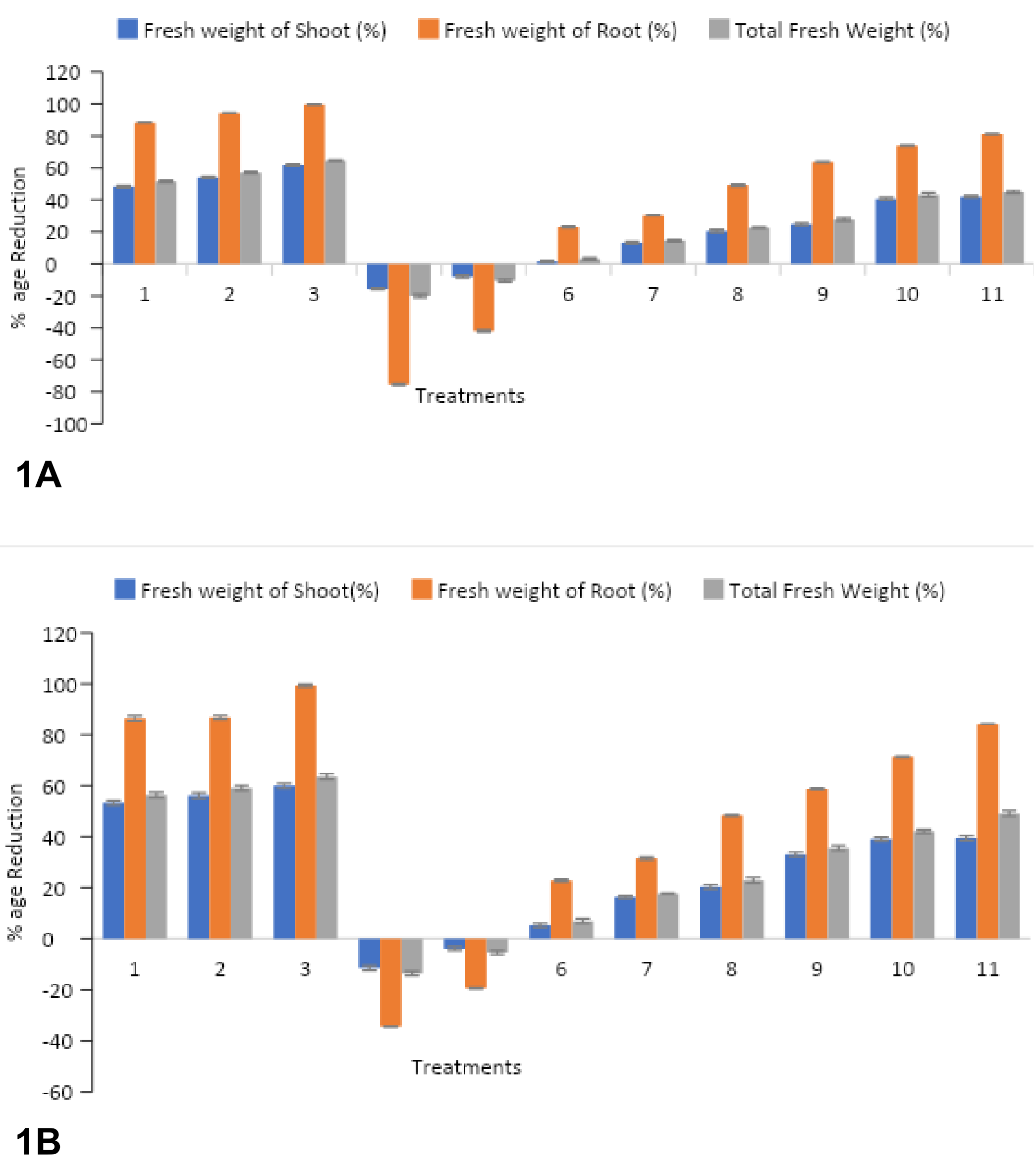
weight (76.69%, 88.73% and 91.82%), root weight (97.8%, 97.91% and 99.78%) and total dry weight (79.29%, 89.85% and 92.82%) for 50ppm, 100ppm and 150ppm, respectively (Figures 2A and 2B, Table 2). Same trend was observed at 70DAS with increased shoot, root and total dry weights with reduction in weights under stress of NaF and ameliorative effects of SA on all these weights.



Figures 1A and 1B. Showing pattern of percentage reduction in Fresh Weight of Shoot, Fresh Weight of Root and Total Fresh Weight in *A. esculentus* L. harvested at: 1A: 45 DAS. and 1B: 70 DAS under Sodium fluoride stress.

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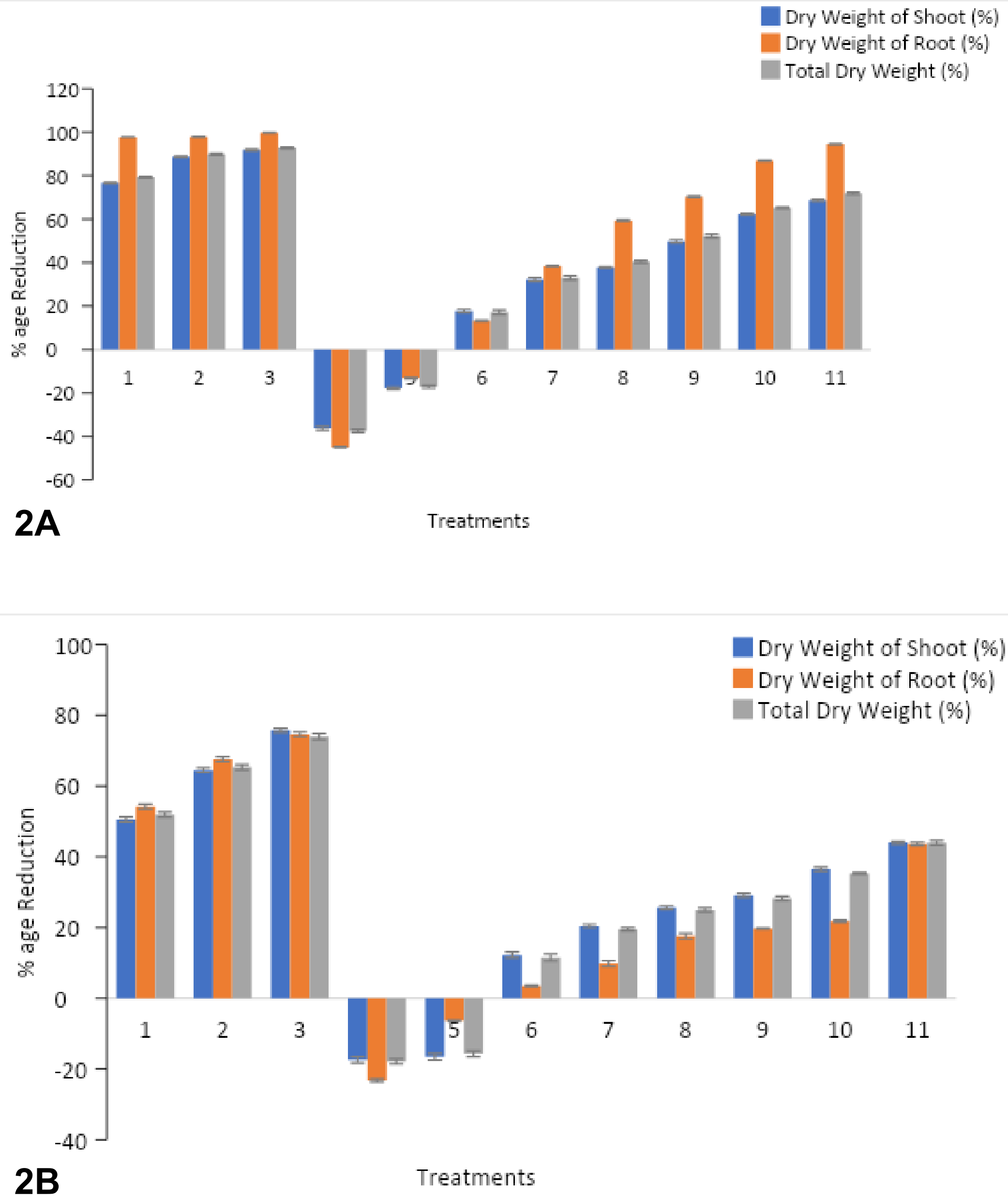

Figures 2A and 2B. Showing pattern of percentage reduction in Dry Weight of Shoot, Dry Weight of Root and Total Dry Weight in *Abelmoschus esculentus* L. at: 1A: 45 DAS and 1B: 70 DAS under sodium fluoride and Salicylic acid.

Table 1. Influence of Salicylic acid on Biomass assessment of A. esculentus L. harvested at 45DAS under Sodium fluoride stress.

Treatments	Biomass Parameters at 45DAS					
	Shoot Fresh Weight (g)	Root Fresh Weight (g)	Total Fresh Weight (g)	Shoot Dry Weight (g)	Root Dry Weight (g)	Total Dry Weight (g)
Control	17.20f ±0.90	1.38bcd ±0.31	18.59gh ±0.67	6.48gh ±0.29	0.91cde ±0.1	7.39fg ±0.37
NaF-50	8.87ef ±0.54	0.16abc ±0.13	9.03fg ±0.54	1.51fg ±0.38	0.02bcde ±0.1	1.53ef ±0.39
NaF-100	7.89de ±0.60	0.078abc ±0.1	7.97ef ±0.60	0.73ef ±0.39	0.019abcd ±0.1	0.75de ±0.41
NaF-150	6.56d ±0.33	0.005ab ±0.2	6.57de ±0.33	0.53def ±0.37	0.002abc ±0.1	0.53cde ±0.37
SA-100	19.88g ±0.60	2.42d ±0.46	22.30i ±1.005	8.83i ±0.84	1.32e ±0.21	10.16h ±0.73
SA-200	18.57fg ±0.84	1.96cd ±0.61	20.54hi ±0.80	7.63hi ±0.56	1.03de ±0.4	8.66gh ±0.61
NaF-50 +SA-100	16.96d ±0.60	1.06ab ±0.58	18.02d ±0.7	5.33cde ±0.77	0.79ab ±0.29	6.12bcd ±0.95
NaF-50 +SA-200	14.95bc ±0.64	0.96a ±0.04	15.91bc ±0.69	4.39abc ±0.84	0.56a ±0.25	4.95ab ±0.94
NaF-100 +SA-100	13.68c ±0.87	0.70ab ±0.52	14.39c ±0.44	4.03bcd ±0.31	0.37a ±0.31	4.40abc ±0.62
NaF-100 +SA-200	12.93ab ±0.77	0.50a ±0.25	13.44ab ±0.99	3.25ab ±0.74	0.27a ±0.20	3.53a ±0.80
NaF-150 +SA-100	10.21bc ±0.88	0.36ab ±0.32	10.57c ±1.19	2.44abc ±0.44	0.12a ±0.11	2.57ab ±0.39
NaF-150 +SA-200	9.98a ±0.59	0.26a ±0.20	10.25a ±0.79	2.03a ±0.59	0.05a ±0.2	2.08a ±0.57

Mean± S.E. (Mean is sum of three replicates); NaF: Sodium fluoride; SA: Salicylic acid; NaF-SA; Sodium fluoride-Salicylic acid. Duncan's multiple range test (DMRT) shows that values within each parameter that are not followed by the same letter are considerably different.

Table 2. Influence of Salicylic acid on Biomass assessment of A. esculentus L. harvested at 70DAS under Sodium fluoride stress.

Treatments	Biomass Parameters at 45DAS					
	Shoot Fresh Weight (g)	Root Fresh Weight (g)	Total Fresh Weight (g)	Shoot Dry Weight (g)	Root Dry Weight (g)	Total Dry Weight (g)
Control	27.06f ±0.96	2.79fg ±0.34	29.85fg ±0.99	15.41g ±0.71	1.42bcd ±0.12	16.83g ±0.72
NaF-50	12.63f ±0.85	0.38ef ±0.9	13.01f ±0.94	7.62fg ±0.66	0.65bcd ±0.7	8.09fg ±0.71
NaF-100	11.85e ±1.07	0.37de ±0.7	12.22e ±1.01	5.47ef ±0.66	0.46abcd ±0.7	5.84ef ±0.72
NaF-150	10.84e ±1.03	0.02cde ±0.6	10.86e ±1.03	3.73def ±0.55	0.36abcd ±0.62	4.38de ±0.93
SA-100	30.14g ±0.89	3.75h ±0.14	33.89h ±0.84	18.09h ±0.89	1.75d ±0.41	19.84h ±0.71
SA-200	28.13fg ±0.71	3.33gh ±0.22	31.47gh ±0.79	17.96h ±0.93	1.51cd ±0.13	19.47h ±0.82
NaF-50 +SA-100	25.62d ±0.80	2.15bcd ±0.42	27.77d ±0.90	13.52de ±0.84	1.37abcd ±0.20	14.89de ±1.0
NaF-50 +SA-200	22.63ab ±0.53	1.92ab ±0.52	24.55ab ±0.1	12.26b ±0.51	1.28ab ±0.8	13.54b ±0.43
NaF-100 +SA-100	21.54cd ±0.90	1.44abc ±0.28	22.99cd ±1.01	11.46cd ±0.45	1.17abcd ±0.8	12.63cd ±0.53
NaF-100 +SA-200	18.09a ±0.82	1.15ab ±0.24	19.24a ±1.03	10.93a ±0.58	1.14a ±0.12	12.08a ±0.60
NaF-150 +SA-100	16.48bc ±0.69	0.8ab ±0.21	17.28bc ±0.63	9.78bc ±0.57	1.11abcd ±0.29	10.89bc ±0.28
NaF-150 +SA-200	14.74a ±0.98	0.44a ±0.12	15.18a ±1.10	8.63a ±0.38	0.8abc ±0.45	9.43a ±0.65

Mean± S.E. (Mean is sum of three replicates); NaF: Sodium fluoride; SA: Salicylic acid; NaF-SA; Sodium fluoride-Salicylic acid. Duncan's multiple range test (DMRT) shows that values within each parameter that are not followed by the same letter are considerably different.

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Figures 3 and 4 and Tables 3 and 4 depict the productivity assessment of *Abelmoschus esculentus* L.

% reduction in flower number at 50ppm, 100ppm and 150ppm was observed as 47.25%, 48.21% and 726%. NaF-50+SA-100 showed a %age reduction of 5.01%, NaF-100+SA-100 as 28.16% and NaF-150+SA-100 as 36.27%, respectively. While reduction was more 26.96% in case of NaF-50+SA-200, 29.59% in NaF-100+SA-200, and 44.15% in NaF-150+SA-200 treatments. Maximum number of flowers were observed at SA-100 (-29.59%). The number of flowers reduced as the quantity of

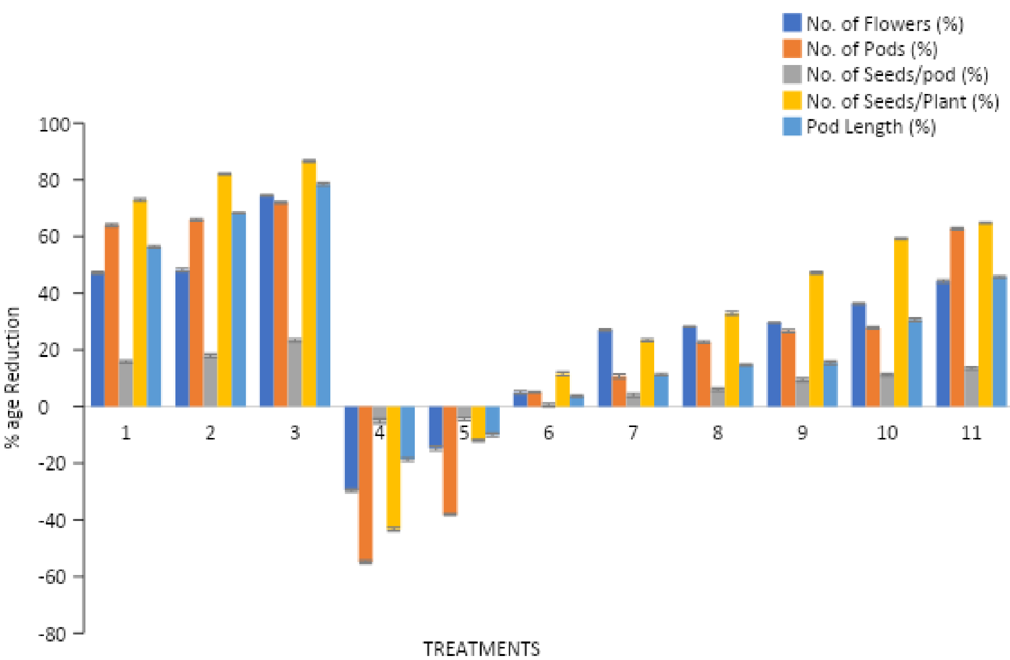

Figure 3. Percentage reduction in Number of Flowers, Number of pods, Number of seeds/pods, Number of seeds per plant and Pod length in Abelmoschus esculentus L. (Okra) harvested at 70 DAS under different concentrations of Sodium fluoride and Salicylic acid.

% Reduction in number of pods 64.03%, at 50ppm, 65.93% at 100ppm and 71.92% at 150ppm treatments. NaF-50+SA-100, NaF-100+SA-100, NaF-150+SA-100 showed a %age reduction of 5.04%, 22.72% and 27.76% respectively. While reduction was more in case of 10.72% at NaF-50+SA-200, 26.68% at NaF-100+SA-200, and 62.77% NaF-150+SA-200. Maximum number of pods were observed at SA-100 (-54.88%). The number of pods reduced as Sodium fluoride stress increased. % Reduction in number of seeds/pods at 50ppm was observed as 15.72%, 100ppm 17.91% as whereas at 150ppm as 23.32%. NaF-50+SA-100 showed a %age reduction of 0.54%, NaF-100+SA-100 showed 5.95%, NaF-150+SA-100 showed 11.14%. While reduction was more in case of NaF-50+SA-200, NaF-100+SA-200, NaF-150+SA-200 i.e., 4.04%, 9.44% and 13.54% respectively. Maximum number of seeds/pods were observed at SA-100 (-5.13%). Number of seeds/pods decreased with increase in concentration of Sodium fluoride stress.

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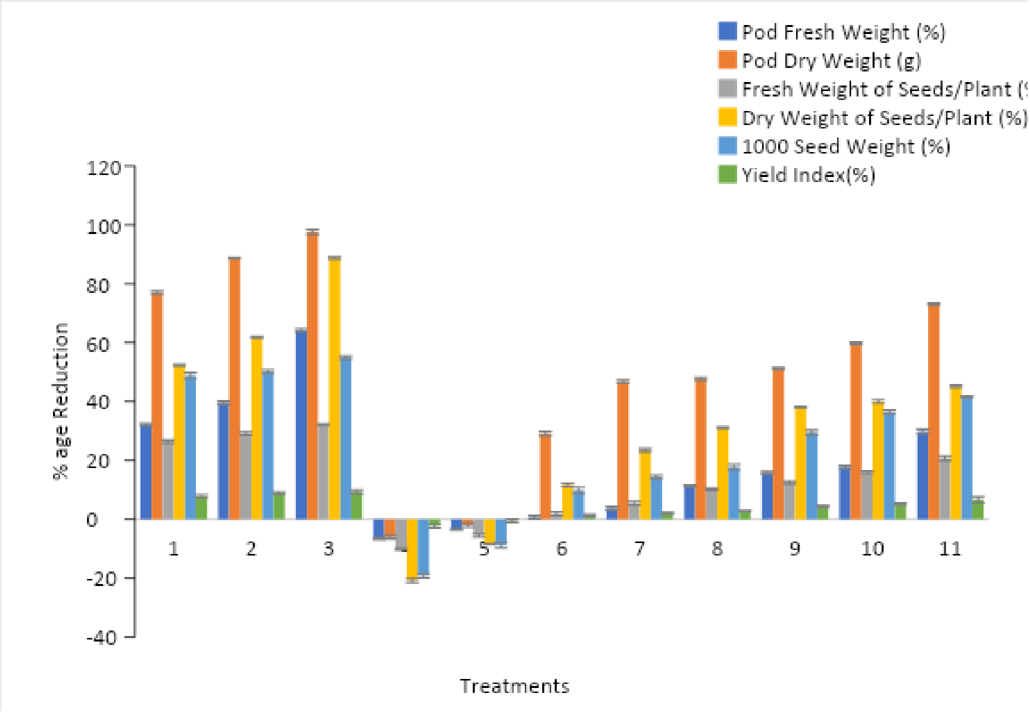

Figure 4. Showing pattern of percentage reduction in Pod Fresh Weight, Pod Dry Weight, Fresh Weight of Seeds/Plant, Dry Weight of Seeds/Plant, 1000 Seed Weight and Yield Index in Abelmoschus esculentus L. (Okra) harvested at 70 DAS under different concentrations of Sodium fluoride and Salicylic acid.

% Reduction in numbers of seeds/plant at 50ppm, 100ppm and 150ppm was observed as 72.9%, 82.11% and 86.61%. NaF-50+SA-100 showed a %age reduction of 11.51%, NaF-100+SA-100 showed 32.89% while 59.28% showed NaF-150+SA-100. While reduction was more in case of NaF-50+SA-200 (23.4%), NaF-100+SA-200 (47.22%) NaF-150+SA-200 (64.82%). Maximum number of seeds/plants were observed at SA-100 (-43.32%). Number of seeds/plants decreased with increase in concentration of Sodium fluoride stress. % Reduction in length of pod at 50ppm, 100ppm and 150ppm was observed as 56.37%, 68.31% and 78.44%. NaF-50+SA-100 showed a %age reduction of 3.64%, NaF-100+SA-100 showed 14.67% while NaF-150+SA-100 showed 30.56%. While reduction was more 11.23% in case of NaF-50+SA-200, 15.48% in case of NaF-100+SA-200, 45.74% in case of NaF-150+SA-200. Maximum length of pod was observed at SA-100 (-18.72%). Length of pod was decreased with increase in concentration of Sodium fluoride stress.

% Reduction in Fresh weight of pod at 50ppm, 100ppm and 150ppm was observed as 32.16%, 39.58% and 64.19%. NaF-50+SA-100, NaF-100+SA-100, NaF-150+SA-100 showed a %age reduction of 0.69%, 11.32% and 17.76% respectively. While reduction was more in case of NaF-50+SA-200, NaF-100+SA-200, NaF-150+SA-200 i.e., 3.77%, 15.8% and 29.79% respectively. Maximum fresh weight of pod was observed at SA-100 (-6.57%). Fresh weight of pod was decreased with increase in concentration of Sodium fluoride stress. % Reduction in dry weight of pod at 50ppm,

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100ppm and 150ppm was observed as 76.98%, 88.66% and 97.63%. NaF-50+SA-100, NaF-100+SA-100, NaF-150+SA-100 showed a %age reduction of 29.1%, 47.71% and 59.72% respectively. While reduction was more in case of NaF-50+SA-200, NaF-100+SA-200, NaF-150+SA-200 i.e., 46.7%, 51.26% and73.09% respectively. Maximum dry weight of pod was observed at SA-100 (-6.09%). Dry weight of pod was decreased with increase in concentration of Sodium fluoride stress.

% Reduction in fresh weight of seeds/plant at 50ppm, 100ppm and 150ppm was observed as 26.4%, 29.17% and 32.22%. NaF-50+SA-100 showed a %age reduction of 1.9%, 10.2%, NaF-100+SA-100, NaF-150+SA-100 showed 16.03%. While reduction was more in case of NaF-50+SA-200 (., 5.43%) NaF-100+SA-200 (12.48%), NaF-150+SA-200 (20.68%). Maximum fresh weight of seeds/plant was observed at SA-100 (-10.2%). Fresh weight of seeds/plant was decreased with increase in concentration of Sodium fluoride stress. % Reduction in dry weight of seeds/plant at 50ppm, 100ppm and 150ppm was observed as 52.24%, 61.83% and 88.77%. NaF-50+SA-100 showed a %age reduction of 11.63%, NaF-100+SA-100 as 31.02% whereas NaF-150+SA-100 (40%). Maximum dry weight of seeds/plant was observed at SA-100 (-20.81%). The seed/plant dry weight decreased as the sodium fluoride stress concentration rose.

% Reduction in 1000 seed weight at 50ppm, 100ppm and 150ppm was observed as 48.74%, 50.13% and 54.94%. NaF-50+SA-100 showed a %age reduction of 9.88%, NaF-100+SA-100 showed 17.73%, NaF-150+SA-100 showed 36.44%. While reduction was more 121% in case of NaF-50+SA-200, 29.43% in case of NaF-100+SA-200 and 41.62% in case of NaF-150+SA-200. Maximum 1000 seed weight was observed at SA-100 (-19.24%). 1000 seed weight was decreased with increase in concentration of Sodium fluoride stress. % Reduction in yield index at 50ppm, 100ppm and 150ppm was observed as 7.73%, 8.88% and 9.37%. While reduction was more in 2.09%, case of NaF-50+SA-200, 2% in NaF-100+SA-200, 6.58% in NaF-150+SA-200 treatments. Maximum yield index was observed at SA-100 (-2.3%). Yield index was decreased with increase in concentration of Sodium fluoride stress.

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Table 3. Productivity assessment of Abelmoschus esculentus L. var. Sabz Pari harvested at 70 DAS under Sodium fluoride and Salicylic acid.

Treatments	Productivity assessment of Abelmoschus esculentus at 70 DAS				
	No. of Flowers	No. of Pods	No. of Seeds/pod	No. of Seeds/Plant	Pod Length (cm)
Control	4.19def ±0.44	3.17b ±0.18	18.31efg ±0.73	42.22j ±0.54	9.88fg ±0.59
NaF-50	2.21cde ±0.42	1.14b ±0.48	15.43efg ±0.44	11.44i ±0.51	4.31efg ±0.38
NaF-100	2.17bcd ±0.6	1.08b ±0.40	15.03defg ±0.65	7.55h ±0.30	3.13ef ±0.19
NaF-150	1.07bcd ±0.20	0.89b ±0.35	14.04cdef ±0.54	5.65g ±0.34	2.13ef ±0.49
SA-100	5.43f ±0.49	4.91c ±0.5	19.25g ±0.80	60.51l ±0.56	11.73h ±0.62
SA-200	4.81ef ±0.76	4.38c ±0.3	19.12fg ±0.61	47.29k ±0.36	10.87gh ±0.57
NaF-50 +SA-100	3.98bcd ±0.57	3.01b ±0.13	18.21bcd ±0.56	37.36f ±0.70	9.52e ±0.26
NaF-50 +SA-200	3.06ab ±0.3	2.83a ±0.8	17.57abc ±0.64	32.34c ±0.51	8.77bc ±0.40
NaF-100 +SA-100	3.01bc ±0.11	2.45b ±0.39	17.22bcd ±0.50	28.33e ±0.68	8.43d ±0.35
NaF-100 +SA-200	2.95ab ±0.10	2.324a ±0.57	16.58ab ±0.56	22.28b ±0.40	8.35ab ±0.56
NaF-150 +SA-100	2.67ab ±0.27	2.29a ±0.36	16.27abcd ±0.41	17.19d ±0.24	6.86c ±0.54
NaF-150 +SA-200	2.34a ±0.59	1.18a ±0.35	15.83a ±0.47	14.85a ±0.20	5.36a ±0.37

Mean± S.E. (Mean is sum of three replicates); NaF: Sodium fluoride; SA: salicylic acid; NaF-SA; Sodium fluoride-Salicylic acid. Duncan's multiple range test (DMRT) shows that values within each parameter that are not followed by the same letter are ignificant.

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Table 4. Productivity assessment of Abelmoschus esculentus L. var. Sabz Pari harvested at 70 under Sodium fluoride and Salicylic acid..

Treatments	Productivity assessment of Abelmoschus esculentus at 70 DAS					
	Pod Fresh Weight (g)	Pod Dry Weight (g)	Fresh Weight of Seeds/Plant (g)	Dry Weight of Seeds Plant^{1}(g)	1000 Seed Weight (g)	Yield Index
Control	7.15ef ±0.58	5.91g ±0.63	10.49efg ±0.50	4.9fg ±0.5	588.09j ±0.78	96.58j ±0.64
NaF-50	4.85ef ±0.36	1.36f ±0.54	7.72efg ±0.50	2.34ef ±0.29	301.44i ±1.06	89.11i ±0.54
NaF-100	4.32ef ±0.56	0.67e ±0.11	7.43defg ±0.52	1.87de ±0.32	293.25h ±0.63	88.27h ±0.44
NaF-150	2.56def ±0.53	0.14f ±0.8	7.11def ±0.23	0.55cde ±0.35	264.96g ±0.57	87.53g ±0.60
SA-100	7.62f ±0.31	6.27g ±0.58	11.56g ±0.33	5.92g ±0.7	701.26l ±0.73	98.81l ±0.61
SA-200	7.40ef ±0.23	6.03g ±0.60	11.07fg ±0.58	5.31fg ±0.10	639.7k ±1.01	97.03k ±0.57
NaF-50 +SA-100	7.10cde ±0.57	4.19def ±0.71	10.29cde ±0.61	4.33bcd ±0.56	529.98f ±1.01	95.56f ±0.34
NaF-50 +SA-200	6.88bc ±0.57	3.15abc ±0.48	9.92abc ±0.58	3.75bc ±0.51	503.34c ±0.69	94.56c ±0.30
NaF-100 +SA-100	6.34cde ±0.33	3.09cde ±0.5	9.42bcde ±0.29	3.38bcd ±0.26	483.81e ±0.92	93.93e ±0.23
NaF-100 +SA-200	6.02b ±0.45	2.88ab ±0.30	9.18ab ±0.48	3.03b ±0.19	414.97b ±0.86	92.33b ±0.34
NaF-150 +SA-100	5.88bcd ±0.56	2.38bcd ±0.35	8.809abc ±0.49	2.94bcd ±0.58	373.79d ±0.77	91.58d ±0.38
NaF-150 +SA-200	5.02a ±0.7	1.59a ±0.34	8.32a ±0.81	2.69a ±0.43	343.32a ±0.35	90.22a ±1.04

Mean± S.E. (Mean is sum of three replicates); NaF: Sodium fluoride; SA: Salicylic acid; NaF-SA; Sodium fluoride-Salicylic acid. Duncan's multiple range test (DMRT) shows that values within each parameter that are not followed by the same letter are considerably different.

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DISCUSSION

Amount of fluoride in polluted soil is about 3500ppm. Some of the plants have developed a natural defense mechanism against the salt phytotoxicity. Plant growth can be enhanced by exogenous applications of Salicylic acid, but its amount should not exceed 1mM because it could have negative influences [28]. Results of present study advocated that plant development in terms of biomass and yield was reduced with increasing concentration of fluoride concentration. The minimum plant biomass was observed at 150ppm of sodium fluoride (NaF) stress. Fluoride used as a micronutrient for plant growth but in higher concentration it caused stress in plants. Furthermore, growth of plant under stress was improved by applications of Salicylic acid (100ppm). But at 200ppm it could have a negative influence on growth of plant.

Higher fresh and dry weights of shoots and roots were observed in Control and SA-100. These weights decreased with maximum reduction in weight at 150ppm. Zaharuddin et al.[29] noticed that when 100mg/L of Salicylic acid was applied on sunflower all the growth and biomass parameters were increased under salinity stress. It was documented that salt has a negative impact on the fresh and dry weights of the shoot and root [30]. Ali et al.[31] observed the reduced dry matter of plant due to stress of NaCl. The growth parameters were improved by foliar applications of Salicylic acid (1mM). As Shoot 82% and root fresh weight 62% was improved while shoot dry weight was improved by 37% and root dry weight was 67%. Also, length of pod and weight of seeds/pod, yield index and 1000 seed weight showed maximum reduction at 150ppm of Sodium fluoride. Reduction was minimum at 50ppm. Dry weight of plant including roots and leaves was reduced under 600mM concentration of NaCl in two varieties of *A. albus* and *A. hybridus* at the rate of 70% and 60% respectively [32].

Our findings were in accordance with Ahmed et al.[33] who reported that plant biomass and yield parameters in *Abelmoschus esculentus L. var.* Nirali cutivar were reduced with increasing concentration of Sodium fluoride. They noticed that 300ppm of NaF caused 79.76% reduction in fresh weight of seeds and dry weight was reduced by 87.77%. While reduction in both these parameters (83.84% and 91.45%) was more in case of Arka Anamika variety. Bustingorri et al. [34] reported that at 375mg/L of F^- the yield loss in soyabean was 30%. [35] Alan et al. reported that the foliar application of 240mg/L Salicylic acid could enhance all the morphological and yield parameters (pod length, pod weight) in Okra which was under drought conditions. Yield of both straws and grains in case of wheat under salt stress was boosted by foliar applications of Salicylic acid [36]. Previous researchers, Martin-Mex et al. noticed that the flowering in the *Gloxinia* plants was increased by 25-37% due to applications of (1-0.001 μM) Salicylic acid [37]. Yield and productivity of Okra was found to be enhanced by exogenous applications of Salicylic acid at concentration of 2mM [38].

CONCLUSIONS

The results of current experiment advocate that higher concentration of NaF impedes the yield and biomass metrics of Okra plants. The biomass and yield characteristics were severely reduced by NaF at 150ppm, with the largest % drop. Foliar application of Salicylic acid (100ppm) improved salt tolerance, yield, and biomass in *Abelmoschus esculentus* L. Higher concentration of salicylic acid

(200ppm) decreased the biomass and yield of Okra plants under Sodium fluoride. Salicylic acid concentrations of 100ppm were found to be beneficial in combating salt stress. However, additional comprehensive research work under field conditions seems mandatory to reconnoiter the mechanism of salicyclic acid for NaF stress mitigation and growth improvements of F-stress in okra plant.

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