Jammu Kashmir J. Agri., 04 (01) 2024. 69-76 DOI: 10.56810/jkjagri.004.01.0141

Faculty of Agriculture, University of Poonch Rawalakot
Jammu Kashmir Journal of Agriculture
ISSN: 2958-3756 (Online), 2958-3748 (Print)
https://jkjagri.com/index.php/journal

FOLIAR SPRAY APPLICATION OF SALICYLIC ACID ($C_7H_6O_3$) ON TURNIP PLANTS GROWN WITH SALINE IRRIGATION

[a]Ghulam Qadir, [a]Abid Ali, [b]Maryum Sarfraz, [a]Khalil Ahmed, [a]Muhammad Shakar, [a]Muhammad Qaisar Nawaz, [a]Muhammad Faisal Nawaz, [a]Ghulam Shabbir, [a]Muhammad Rizwan, [a]Nadeem Iqbal, [d]Muhammad Arif, [e]Adnan Umair, [a]Alamgir Alvi, [b]Muhammad Abubakar Siddique, [c]Muhammad Nadeem, [b]Muhammad Zaighum Mushtaq, [a]Muhammad Ashfaq Anjum

[a] *Soil Salinity Research Institute Pindi Bhattian, Pakistan.*
[b] *Biochemistry section, PHRC, Ayub Agricultural Research Institute, Faisalabad, Pakistan.*
[c] *Soil and Water Testing Laboratory Hafizabad, Paksitan.*
[d] *Soil and Water Testing Laboratory Multan, Pakistan.*
[e] *Soil and Water Testing Laboratory Sialkot, Paksitan.*

ABSTRACT

Water quality is a concern to everyone. How to manage water in a specific situation can both be a practical and financial challenge. The impact of irrigation water on soil and plants depends on the water, soil, crop, and environmental conditions. Due to continuous increase in world population and competition among industrial and agricultural sectors for fresh water, it is opined that after every 35 years, water requirement will be doubled. In this scenario, use of underground saline water for crop production with acceptable economic yield is a viable strategy. Salicylic acid (SA) is key hormone that has been shown to protect various plant species against abiotic stress. Therefore, a pot study was conducted during 2019 to investigate the effect of exogenous application of salicylic acid (dissolved in Ethanol and sprayed using tap water) and 4 synthetic saline waters on yield of turnip. The treatments were: Saline water irrigation levels A: Tap water 0.80, 3, 5 and 7 dS m^{-1} and B: SA Spray (0, 150, 300 and 450 mg/L). Foliar sprays were applied 08 times during crop growing season. The experiment was conducted in factorial design having three repeats. Crop was harvested and yield data was recorded. Results revealed that maximum turnip yield (485.92 g/pot) was recorded with tap water and increasing levels of saline water irrigation decreased the turnip yield and minimum turnip yield (253.50 g/pot) was observed at 7 dS m^{-1}. Among SA levels, SA at 300 mg/L produced maximum turnip yield (402 g/pot). Interaction showed that maximum yield (381.33 g/pot) was produced with SA sprayed at 300 mg/L with saline irrigation of 3 dS m^{-1}. Therefore, it was concluded that SA at 300 mg/L was an effective strategy to alleviate the negative effects of saline water irrigation stress of up to3 dS m^{-1} for turnip production.

Keywords: Irrigation, Salinity; Salicylic acid, Turnip, Yield.

Corresponding Author: Ghulam Qadir
Email: tobateksingh7786@gmail.com
© 2024 Faculty of Agriculture, UPR. All rights reserved.

Article history
Received: March 17th, 2024
Revised: April 21th, 2024
Accepted: April 28th, 2024

INTRODUCTION

The turnip (*Brassica rapa*), a member of the cruciferous family is a root vegetable commonly grown in temperate climates worldwide for its white, bulbous taproot. Small, tender varieties are grown for human consumption, while larger varieties are grown as feed for livestock (Cheraghabadi et al., 2015). Nutritionally the 100 g turnip contains 34 calories, 0.12 % Fat, 7.84 % carbohydrates, 2.2 fibers, 1.10 percent protein, no cholesterol, while the root is high in vitamin C. Turnip root is rich source of Vitamin C

 DOI: 10.56810/jkjagri.004.01.0141

where as its leaves are rich source of Vitamin A, Vitamin C, Vitamin K, foliate and Calcium. It can be grown on variety of soil but turnip give best result when grown on loamy soils rich in organic matter. Avoid heavy or compact soils also very light soils as it produce rough, malformed roots. August-September is best time for sowing desi varieties October-November is ideal for European varieties. Sowing temperature of turnip ranges from 18-30 °C while harvesting temperature ranges from 10-15 °C. Major vegetables grown in the country are potato, onion, chilies, tomato, turnip, carrot, cauliflower, peas and gourd which cover 78% of the total area and vegetables accounting 81% of total production. Potato has the major share in area and production which is 30.2% and 40 & respectively, followed by onion with receptive share of 21.2% and 21.4%. Total area and production of vegetables including potato in 22018-19 is 0.46 million hectors and 8.37 million ton. In 2018-19, vegetable export was 1.02% million ton while in 2019-20, it is 8.80 million ton that was an increase of 16.1percent as compared to last year (Fruit, Vegetables and Condiments Statistics of Pakistan, 2018-19).

The purpose of the present research was to obtain data on turnip plants grown under 0.80, 3.0, 5.0 and 7.0 dS m^{-1} salinity levels/ saline irrigations and to determine the salinity effect on fresh yield and mineral contents of turnip. Salinity is a major problem affecting crop production all over the world: 20% of cultivated land in the world, and 33% of irrigated land, are salt-affected and degraded (Mony, 2015). This process can be accentuated by climate change, excessive use of groundwater (mainly if close to the sea), increasing use of low-quality water in irrigation, and massive introduction of irrigation associated with intensive farming.

Excessive soil salinity reduces the productivity of many agricultural crops, including most vegetables, which are particularly sensitive throughout the ontogeny of the plant. The salinity threshold of the majority of vegetable crops is low (ranging from 1 to 2.5 dS m^{-1} (Rui Manuel Almeida Machado and Ricardo Paulo Serralheir). Global constraints on freshwater supplies and the need to dispose of agricultural, municipal and industrial waste waters have intensified interest in water reuse options. In many instances, the value of the water is decreased solely because of its higher salt concentration. Although quantitative information on crop salt tolerance exists for over 130 crop species, there are many vegetables which lack definitive data. Accurate scheduling of irrigation is essential for maximizing crop production while conserving water and ensuring irrigation systems are environmentally and economically sustainable. Correct scheduling requires a good knowledge of crop tolerance to salinity, crop water demand and soil water characteristics and must account for the type of irrigation method used (Coşkun et al., 2021). Salicylic acid (SA) plays an important role in the defense response to pathogen attack and stresses in plant species (Shakirova et al., 2003). Several studies also supported a major role of SA in modulating the plant response to several abiotic stresses including salt and water stress (Senaratna et al., 2000; Yalpani et al., 1994).

Treating mustard seedlings with SA improved their thermo tolerance and heat acclimation (Dat et al., 1998). In maize plants, pre-treatment with SA induced the production of antioxidant enzymes, which in turn increased chilling and salt tolerance (Mony, 2015). There are many strategies used to overcome the negative impact of salinity, including treating plants with different substances such as hormones and growth regulators and the nature of their work and studying their effect on the different parts of plants, which is considered an important scientific application in the field of agriculture.

Plant hormones play an important role in directing the growth of plants in co-ordinating the patterns accompanying the metabolism process to supply energy and provide them for different physiological processes and building molecules to develop the external appearance.

Plants and salicylic acid (SA) are one of the phytohormones of a phenolic nature which works to regulate many physiological processes, including, regulation of Ion absorption, hormonal balance, stomatal regulation, and photosynthesis (Popova et al., 1997). In addition, salicylic acid plays an important role in regulating plants response to environmental stress conditions such as salt stress, drought stress, heat tension and tension resulting from heavy metals (Mir and Somasundaram, 2021). Water quality is a concern to everyone. How to manage water in a specific situation can be both a practical and financial challenge. Some irrigation waters can damage plants directly, while others damage soil structure. The impact of irrigation water on soil and plants depends on the water, soil, crop, and environmental conditions (Horneck et al., 2007). Managing Irrigation Water Quality for crop production in the Pacific Northwest.

In Pakistan, 86 million acre foot (MAF) of river water is diverted into irrigation canals (GOP, 2002). The challenge of future is to meet the food, fuel and fiber requirement of an increasing world population on a sustainable basis. Moreover, drought conditions, increasing demands of freshwater for agriculture and industrial sector has forced the farming community to pump more and more groundwater which is of marginal quality. Due to increased

 DOI: 10.56810/jkjagri.004.01.0141

cropping intensity, more agricultural demand and drought condition, seemingly enormous amount of irrigation water could not keep pace with the crop water requirement. To overcome this problem, inadequate supplies of water can be augmented with tube well water, however, 70-80 % tube wells pumped the water of poor quality (Murtaza et al., 2009). Obaid et al. (2021) reported that soil texture and electric conductivity (EC_e) are also the important factors controlling the growth of plants. Therefore, it is imperative that agricultural user must rely on this poor-quality water to supply food and fiber for a growing population (Elagib, 2014). This marginal quality water can be successfully used to increase agricultural productivity by preventing soil degradation if suitable management approaches are coupled with proper amendments.

MATERIALS AND METHODS

A pot study was conducted to investigate the effect of exogenous application of salicylic acid using saline water on yield of Turnip (Brassica rapa subsp. rapa) at campus, Soil Salinity Research Institute, Pindi Bhattian. The treatments studied were A- Salinity Levels (SL):- T_1- Control, T_2- EC_{iw} 3.0 dS m^{-1}, T_3- EC_{iw} 5.0 dS m^{-1}, T_4- EC_{iw} 7.0 dS m^{-1}, B:- Salicylic acid (SA) Levels: 1-No SA spray, 2- 150 ppm SA, 3- 300 ppm SA and 4- 450 ppm SA. The pots soil analysis showed pH_s = 8.02, EC_e = 1.48 (dS m^{-1}), SAR = 4.41 (mmol L^{-1})^{½}, Available P = 5.60 mg kg^{-1}, Extractable K = 96.0 mg kg^{-1}, O. M = 0.46% and Texture = Sandy Loam. Brackish tube-well irrigation water (EC_{iw} 0.80 dS m^{-1}, SAR 3.27 (mmol L^{-1})$^{1/2}$ and RSC 3.35 me L^{-1}) was used for irrigation.

Recommended dose of fertilizer @ 125-75-00 NPK kg ha^{-1} was applied. One third nitrogen was applied as basal dose while remaining two third N was top dressed in two splits 30 and 55 days after sowing. Cultural practices were carried out as and when required. Weeds were control through manual hoeing. Crop was harvested at maturity. Water salinity was developed by using Na_2SO_4, NaCl, $CaCl_2$ and $MgSO_4$ (4:3:2:1). Salicylic Acid was sprayed on the next day after saline water application. Salicylic Acid was dissolved in ethanol. Turnip variety round was sown. Cultural practices were carried out as and when required. Turnip sowing and harvesting date was 05-11-2019 and 16-03-2020 respectively. The effects of irrigation water salinity on turnip plants yield and mineral matter accumulation in turnips were investigated with a pot experiment.

For this purpose, three saline irrigation waters with electrical conductivities of 3.0, 5.0, 7.0 dS m^1 and tap water as a control treatment were utilized. The irrigation was applied @ 1.0 liter per pot. Data turnip yield was recorded and presented in table below. Quality parameters of sorghum fodder nitrogen free extracts (NFE), crude fiber, crude protein and crude fat were determined following the procedure of Horwitz and Latimer (2000), while phosphorus and calcium were estimated using the methods as per Tandon (2005). Composit soil samples were collected before the start of experiment and after the harvest of crop. Collected soil samples were air dried, passed through 2 mm sieve and analyzed by following the methods of U.S. Salinity Laboratory Staff (1954). All the data were subjected to analysis of variance using STATISTIX 8.1 package software following the method of Steel et al. (1997). Least significant difference (LSD) test at 5% probability level was employed to sort out significant differences among treatments means.

RESULTS

Maximum yield was obtained using tap water of EC_e 0.8 dS m^{-1} (485.92 g/pot). Yield increased using tap water by the application of Salicylic Acid spray at SA 150 mg/L. Increasing levels of saline water irrigation decreased the turnip. Minimum turnip yield (253.50 g/pot) was observed at 7 dS m^{-1} (Table 1, Figure 1).

Among SA levels, SA at 300 mg/L produced maximum turnip yield (381.30 g/pot). Turnip variety white was sown .Cultural practices were carried out as and when required. Turnip sowing and harvesting date was 02-11-2020 and 03-03-2021 respectively. Data turnip yield was recorded and presented in table below. Post-harvest soil analysis data is also given in table 1 and figure 1.

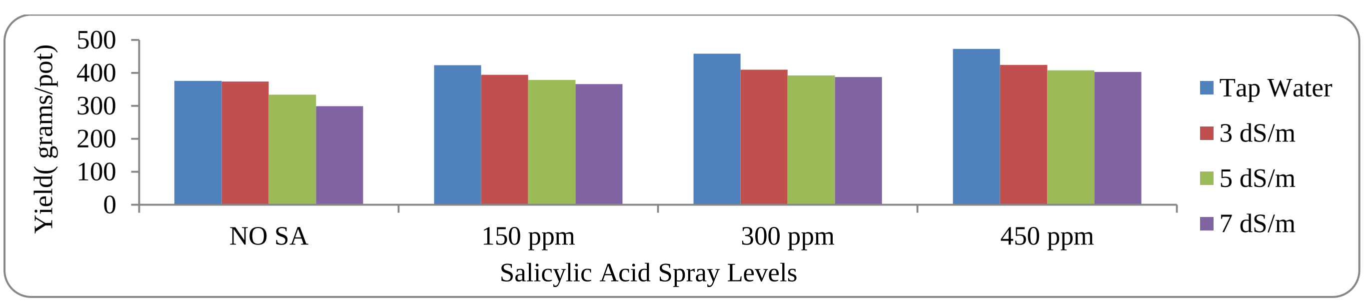

Figure 1: Effect of salicylic acid and different salinity levels on turnip yield, (Grams/pot) 2020-21.

Table 1: Effect of salicylic acid and different salinity levels on turnip yield (2020-21).

Salinity Levels	NO SA	150 ppm	300 ppm	450 ppm	Mean
Tap Water	375.67 DE	423.00 BC	458.67 AB	473.33 A	432.67 A
3 dS/m	373.67 DE	394.00 CDE	410.00 CD	424.67 BC	400.58 B
5 dS/m	333.67 FG	379.00 DE	392.67 CDE	407.67 CD	378.25 C
7 dS/m	299.67 G	366.67 EF	387.33 CDE	403.00 CDE	364.17 C
Mean	345.67 C	390.67 B	412.17 A	427.17 A	
Parameter					
SL			19.134		
SA			19.134		
Interaction			38.268		

Turnip yield reduced by increasing salinity levels. Minimum yield was obtained where EC_e 7.0 dS m^{-1} irrigation was applied, (364.67 b/pot). Maximum yield was obtained using tap water of ECe 0.8 dS m-1 (432.67 g/pot). Among SA Spray levels, statistically SA at 300 mg/L produced maximum turnip yield (412.17 g/pot).

Post-harvest Analysis

Post-harvest analysis (Table 2) showed that pH_s, EC_e and SAR somewhat increased with increase in salinity levels. Increasing salicylic acid levels showed improvement in chemical-parameters.

Table 2: Post-harvest soil analyses using salicylic acid levels.

		pH_s		
Treatments	NO SA	SA 150 ppm	SA 300 ppm	SA 450 ppm
Tap Water	8.00	8.00	7.99	7.98
3 dS/m	8.10	8.06	8.08	8.09
5 dS/m	8.15	8.18	8.19	8.20
7 dS/m	8.18	8.20	8.23	8.24
		EC_e (dS/m)		
Treatments	NO SA	SA 150 ppm	SA 300 ppm	SA 450 ppm
Tap Water	1.46	1.45	1.43	1.43
3 dS/m	1.90	2.10	2.00	2.20
5 dS/m	2.24	2.73	2.91	3.00
7 dS/m	2.96	3.00	3.61	3.92
		SAR $(mmol\ L^{-1})^{1/2}$		
Treatments	NO SA	SA 150 ppm	SA 300 ppm	SA 450 ppm
Tap Water	4.40	4.15	4.15	4.17
3 dS/m	6.10	5.63	5.51	5.68
5 dS/m	6.43	5.91	6.10	6.47
7 dS/m	7.00	6.20	6.40	6.96

Quality Parameters Analysis

Ash%

The experiment investigated the impact of different salinity levels (NO, SA, 150 ppm, 300 ppm, 450 ppm) on tap water and three varying levels of salinity (3 dS/m, 5 dS/m, 7 dS/m). Results indicated that as salinity increased, there was a general trend of decreased mean values in tap water salinity levels, with the lowest mean observed at 450 ppm (Table 3). However, for the varying salinity levels, the trends were less consistent, with fluctuating mean values across different concentrations. Statistical analysis revealed significant main effects for both salinity level (SL) and salinity source (SA), as well as a significant interaction between the two. Overall, these findings underscore the complexity of salinity's influence on water properties and suggest that both the concentration and source of salinity are important factors to consider in water quality management.

Table 3: Effect of salicylic acid and different salinity levels on turnip ash%.

Salinity Levels	NO SA	150 ppm	300 ppm	450 ppm	Mean
Tap Water	12.867 A	11.867 ABC	11.633 ABC	11.233 BC	12.275 A
3 dS/m	12.100 AB	11.733 ABC	11.800 ABC	11.400 BC	11.675 AB
5 dS/m	12.300 AB	11.167 BC	12.167 AB	10.700 C	11.683 AB
7 dS/m	11.833ABC	11.933 ABC	11.133 BC	11.800 ABC	11.283 B
Mean	11.900 A	11.758 A	11.583 A	11.675 A	
Parameter					
SL			0.6398		
SA			0.6398		
Interaction			1.2796		

Crude Fat

The study investigated the effects of varying salinity levels (NO SA, 150 mg/L, 300 mg/L, 450 mg/L) on tap water and three different salinity sources (3 dS/m, 5 dS/m, 7 dS/m). Results indicated that as salinity levels increased, mean values of salinity in tap water generally fluctuated, with the highest mean observed at 450 mg/L (Table 4). However, the pattern was less consistent across different salinity sources, with fluctuations in mean values across different concentrations. Statistical analysis revealed significant main effects for both salinity level (SL) and salinity source (SA), as well as a significant interaction between the two.

Table 4: Effect of salicylic acid and different salinity levels on turnip crude fat.

Salinity Levels	NO SA	150 mg/L	300 mg/L	450 mg/L	Mean
Tap Water	1.5133 BCD	1.3167 E	1.5400 BCD	1.5567 BC	1.5617 A
7 dS/m	1.4233 CDE	1.5800 AB	1.5133 BCD	1.6433 AB	1.5883 A
3 dS/m	1.7133 A	1.5467 BCD	1.4033 DE	1.6067 AB	1.4467 B
5 dS/m	1.5967 AB	1.3433 E	1.4233 CDE	1.5467 BCD	1.4700 B
Mean	1.4817 B	1.5675 A	1.4775 B	1.5400 AB	
Parameter					
SL			0.0762		
SA			0.0762		
Interaction			0.1524		

Crude Protein

The study examined the influence of salicylic acid (SA) and various salinity levels (NO SA, 150 mg/L, 300 mg/L, 450 mg/L) on turnip crude protein content. Results revealed notable variations in crude protein levels across different treatments. While tap water exhibited the lowest mean crude protein content, with values gradually increasing with salinity concentration, the effect was more pronounced in the presence of salicylic acid. Notably, the highest mean crude protein content was observed at 450 mg/L salinity without SA (Table 5).

Crude Fiber

Results demonstrated varied crude fiber levels across the experimental conditions. Generally, tap water showed lower mean crude fiber content, while higher salinity concentrations tended to increase crude fiber content, especially notable in the absence of salicylic acid. Interestingly, the interaction between salinity levels and salicylic acid treatment significantly influenced turnip crude fiber content. Specifically, the highest mean crude fiber content was observed at 450 mg/L salinity without SA (Table 6). These findings underscore the complex interplay between salinity, salicylic acid, and turnip fiber composition, suggesting potential strategies for managing crop fiber content under different environmental conditions.

DISCUSSION

The findings indicate that tap water resulted in the highest turnip yield, with a gradual decrease in yield as the level of saline water irrigation increased. This highlights the detrimental impact of saline water on crop productivity, which aligns with existing literature emphasizing the negative effects of salinity on plant growth and development (Munns, 2002).

Table 5: Effect of salicylic acid and different salinity levels on turnip crude protein.

Salinity Levels	NO SA	150 mg/L	300 mg/L	450 mg/L	Mean
Tap Water	4.430 F	7.060 E	9.920 BC	11.203 A	10.649 A
3 dS/m	4.843 F	6.653 E	9.743 BC	10.620 AB	9.394 B
5 dS/m	5.253 F	6.653 E	9.220 CD	10.503 AB	6.668 C
7 dS/m	4.787 F	6.303 E	8.693 D	10.270 AB	4.828 D
Mean	7.5133 B	7.9075 AB	7.9650 AB	8.1533 A	
Parameter					
SL			0.4674		
SA			0.4674		
Interaction			0.9348		

Table 6: Effect of salicylic acid and different salinity levels on turnip crude fat.

Salinity Levels	NO SA	150 mg/L	300 mg/L	450 mg/L	Mean
Tap Water	1.5133 BCD	1.3167 E	1.5400 BCD	1.5567 BC	1.5617 A
7 dS/m	1.4233 CDE	1.5800 AB	1.5133 BCD	1.6433 AB	1.5883 A
3 dS/m	1.7133 A	1.5467 BCD	1.4033 DE	1.6067 AB	1.4467 B
5 dS/m	1.5967 AB	1.3433 E	1.4233 CDE	1.5467 BCD	1.4700 B
Mean	1.4817 B	1.5675 A	1.4775 B	1.5400 AB	
Parameter					
SL			0.0762		
SA			0.0762		
Interaction			0.1524		

Furthermore, the application of SA, a key hormone known for its role in mitigating abiotic stress in plants, proved to be beneficial in alleviating the negative effects of saline water irrigation. Specifically, SA at 300 mg/L resulted in the maximum turnip yield, indicating its potential as a strategy to enhance crop resilience under saline conditions. This finding is consistent with previous research demonstrating the positive effects of SA on mitigating salt stress in various plant species (Noreen et al., 2009).

The interaction analysis revealed that the combined application of SA at 300 mg/L with saline irrigation at 3 dS m-1 produced the highest yield, indicating a synergistic effect between SA and moderate levels of saline water. This suggests that SA application can effectively counteract the detrimental effects of moderate salinity levels on crop productivity, supporting its potential as a practical solution for managing saline water in agriculture (Hussain et al., 2008; Ijaz Ahmad et al., 2014).

From a practical standpoint, the findings of this study offer a promising approach for farmers facing challenges associated with saline water availability. By utilizing SA application alongside moderate levels of saline water irrigation, farmers can potentially maintain or even increase crop yields while mitigating the adverse impacts of salinity on soil and plants. However, it's important to consider the financial implications of implementing this strategy (Shemi et al., 2021). While SA application may offer benefits in terms of yield improvement, its cost-effectiveness needs to be evaluated against the potential gains in crop productivity. Additionally, factors such as SA application frequency, availability, and environmental considerations should be taken into account when assessing the feasibility of this strategy on a larger scale.

CONCLUSION

This study highlights the potential of utilizing underground saline water for crop production, offering a practical solution amidst rising water scarcity. By investigating the effects of exogenously applied salicylic acid (SA) and synthetic saline waters on turnip yield, the study demonstrates that SA at 300 mg/L effectively mitigates the adverse impacts of saline water irrigation stress up to 3 dS m-1, resulting in improved crop yields. These findings underscore the importance of innovative approaches, such as hormone application, in sustainable water management practices for agricultural production in saline environments.

CONFLICT OF INTEREST

The authors declare that there is no conflict in the publication of this article.

AUTHOR'S CONTRIBUTION

All the authors contributed equally in the research and manuscript.

REFERENCES

Cheraghabadi, M.M., Roshanfekr, H., Hasibi, P., Meskarbashi, M., 2015. The effect of salicylic acid on ion relations and some biochemical traits of two sugar beet cultivars under salinity stress. Journal of Biodiversity and Environmental Sciences 6, 40-49.

Coşkun, F., Demir, S., Alptekin, Y., 2021. The effectiveness of arbuscular mycorrhizal fungi and salicylic acid against *Verticillium dahliae* infecting pepper (*Capsicum annuum* L.). Applied Ecology and Environmental Research 19, 543-554.

Dat, J.F., Foyer, C.H., Scott, I.M., 1998. Changes in salicylic acid and antioxidants during induced thermotolerance in mustard seedlings. Plant Physiology 118, 1455-1461.

Elagib, N.A., 2014. Development and application of a drought risk index for food crop yield in Eastern Sahel. Ecological Indicators 43, 114-125.

Horneck, D.A., Ellsworth, J.W., Hopkins, B.G., Sullivan, D.M., Stevens, R.G., 2007. Managing salt-affected soils for crop production. Oregon State University.

Horwitz, W., Latimer, G.W., 2000. Official methods of analysis of AOAC International. AOAC international Gaithersburg.

Hussain, M., Malik, M., Farooq, M., Ashraf, M., Cheema, M., 2008. Improving drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower. Journal of Agronomy and Crop Science 194, 193-199.

Ijaz Ahmad, I.A., Basra, S.M.A., Abdul Wahid, A.W., 2014. Exogenous application of ascorbic acid, salicylic acid and hydrogen peroxide improves the productivity of hybrid maize at low temperature stress. International Journal of Agriculture and Biology 16, 825-830.

Mir, R.A., Somasundaram, R., 2021. Salicylic acid and salt stress tolerance in plants: A review. Journal of Stress Physiology and Biochemistry 17, 32-50.

Mony, F.T.Z., 2015. Effect of salicylic acid and varieties on incidence of aphid and yield of mustard, Department of Entomology. Sher-E-Bangla Agricultural University, Dhaka.

Munns, R., 2002. Comparative physiology of salt and water stress. Plant, Cell and Environment 25, 239-250.

Murtaza, G., Ghafoor, A., Owens, G., Qadir, M., Kahlon, U., 2009. Environmental and economic benefits of saline-sodic soil reclamation using low-quality water and soil amendments in conjunction with a rice–wheat cropping system. Journal of Agronomy and Crop Science 195, 124-136.

Noreen, S., Ashraf, M., Hussain, M., Jamil, A., 2009. Exogenous application of salicylic acid enhances antioxidative capacity in salt stressed sunflower (*Helianthus annuus* L.) plants. Pakistan Jounal of Botany 41, 473-479.

Obaid, u.R., Mehdi, S.M., Abad, R., Saleem, S., Khalid, R., Alvi, S.T., Munir, A., 2021. Soil characteristics and fertility indexation in Gujar Khan area of Rawalpindi: Soil characteristics of Gujar Khan area. Pakistan Journal of Scientific & Industrial Research Series A: Physical Sciences 64, 46-51.

Popova, L., Pancheva, T., Uzunova, A., 1997. Salicylic acid: properties, biosynthesis and physiological role. Bulgarian Journal of Plant Physiology 23, 85-93.

Senaratna, T., Touchell, D., Bunn, E., Dixon, K., 2000. Acetyl salicylic acid (Aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plants. Plant Growth Regulation 30, 157-161.

Shakirova, F.M., Sakhabutdinova, A.R., Bezrukova, M.V., Fatkhutdinova, R.A., Fatkhutdinova, D.R., 2003. Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant Science 164, 317-322.

Shemi, R., Wang, R., Gheith, E.-S.M., Hussain, H.A., Cholidah, L., Zhang, K., Zhang, S., Wang, L., 2021. Role of exogenous-applied salicylic acid, zinc and glycine betaine to improve drought-tolerance in wheat during reproductive growth stages. BMC Plant Biology 21, 1-15.

Tandon, H.L.S., 2005. Methods of analysis of soils, plants, waters, fertilisers and organic manures. CAB International.

Yalpani, N., Enyedi, A.J., León, J., Raskin, I., 1994. Ultraviolet light and ozone stimulate accumulation of salicylic acid, pathogenesis-related proteins and virus resistance in tobacco. Planta 193, 372-376.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.