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Foliar Application of Salicylic Acid Improved Growth, Yield, Quality and Photosynthesis of Pea (*Pisum sativum* L.) by Improving Antioxidant Defense Mechanism under Saline Conditions

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Abstract: Pea is an important legume crop because of its higher bioactive compounds, and its seeds are famous as functional foods. However, the yield of pea is still limited because of multiple biotic and abiotic stresses which prevailed during the growth period. Saline conditions significantly hamper pea growth, yield, and quality among abiotic stresses. Salicylic acid is effective for the activation of oxidative, non-oxidative, osmolytes, and metabolites. Hence, the present study was conducted at exogenous application of salicylic acid (control, 1 μM, 2 μM, and 3 μM) to mitigate the adverse effects of salt stress (control, 25 mM, 50 mM, and 100 mM NaCl) in pea plants grown in the year 2019–2020. The aim of the present study was to evaluate pea performance under saline conditions by salicylic acid sprays. Pea growth and yield were significantly decreased at 100 mM NaCl compared with the control and other salinity levels. Moreover, the growth and yield of pea were improved under exogenous application of salicylic acid treatment at 3 μM than others. Quality traits, i.e., carotenoids, ascorbic acid, and phenolic content, were decreased at 100 mM NaCl, and these quality traits were significantly improved under salicylic acid treatment of 3 μM. Chlorophyll a, chlorophyll b, total chlorophyll, photosynthesis, and stomatal conductance were reduced at 100 mM NaCl. In contrast, photosynthetic pigments, photosynthesis, and stomatal conductance were enhanced at 3 μM salicylic acid. The increases in SOD, CAT, POD, and APX were observed at 100 mM NaCl and 3 μM salicylic acid. The current study proved that exogenous application of salicylic acid concentrations had the potential to mitigate the salinity's adverse effects by maintaining the physiological and metabolic activities of pea plants.

Keywords: enzymatic assays; metabolic process; NaCl levels; pigment molecules; salicylic acid; photosynthesis

1. Introduction

Temperature, drought, salinity, and a combination of these abiotic stresses drastically restrict crop production [1]. Among these stresses, salinity is one of the most damaging stresses for plants globally. Oxidative injury in leaf and root cells is due to induced salinity, resulting in irreversible damage or death of the whole plant or low yield [2]. There are a plethora of studies where it was shown that plant metabolism is affected under saline conditions [3]. Disturbance in the ion distribution and water availability restriction within plant cells under saline conditions results in stunted growth, low yield, and poor quality [4]. Salinity reduces the productivity of many horticultural crops, which includes tomato [5], cucumber [6] and soybean [7]. The response to salinity in legume crops is mainly based on different factors, including environmental conditions, soil properties, quality of irrigation water, and growth stages [8]. To overcome salt stress, a wide range of management strategies can be used, including the use of exogenous hormones, various macro and micronutrients, proteomics, many proteins, molecular methods, and genotypic variation [9]. These approaches are effective for the activation of the plant defense system by regulation of stomatal conductance, photosynthetic machinery, and protection from osmotic stress and oxidative injury [10].

Under high salinity conditions, the osmotic equilibrium is disturbed, and ion accumulation reaches a lethal threshold within the cellular compartments of plants, resulting in plant death [11]. Pea plants are chloride sensitive, and growth is restricted due to the accumulation of chloride ions in leaves as well as roots. Moreover, Na+ also had a unidirectional transport mechanism from the roots toward the leaves [12]. Transpiration, photosynthesis, and carbohydrate accumulation decreased because of the reduction rate of CO_2 diffusion to stomata under induced salinity conditions [13]. Higher accumulation of salts in chloroplasts reduces chlorophyll content, disturbs photosynthetic machinery, and hinders photosystem II activity which is the major metabolism in the plant [14]. To mitigate the detrimental effect of salinity, plants develop potential mechanisms to compartmentalize toxic ions by synthesizing different osmolytes such as glycine betaine, trehalose, proline, and ascorbates effective for the regulation of osmotic pressure [15]. ROS are produced when plants encounter reduced CO_2 because these signaling molecules are involved in the defense mechanism of plants [16]. However, higher ROS generation and accumulation in the cell are toxic for plants and adversely affect the photosynthetic efficiency and cellular metabolism of plants [17].

The ROS mediated enzymatic (superoxide dismutase, peroxidase, catalases, glutathione reductase, and ascorbates) and non-enzymatic (total soluble protein, proline, carotenoids, and flavonoids) compounds are synthesized within the plants to improve defense mechanisms under adverse stress conditions. These compounds scavenge the toxic ROS and prevent its hyperaccumulation [18]. The production of these compounds increased to enhance tolerance against higher salinity conditions. Numerous works are conducted on plant responses under salinity, however, information regarding the exogenous application of plant hormones is still limited in pea because salicylic acid has the potential to mitigate salinity effects in plants by improving the defense mechanisms of plants.

Salicylic acid is a natural plant hormone and signal molecule that increases plant tolerance by contracting the toxic effects of salinity on growth and yield. Exogenous application of phytohormones such as salicylic acid is considered the most effective molecule for regulating plant growth, glycolysis and yield, ions uptake and utilization, stomatal conduce, photosynthesis, transpiration, enzymatic, and non-enzymatic assays synthesized under environmental stresses [19]. The efficacy of the exogenous application of salicylic acid is mainly based on plant species and applied concentration. Salicylic acid concentration of 1 mM is more effective to increase plant growth compared with higher concentrations (greater than 1 mM) which decreases plant growth in numerous plant species [20]. Salicylic acid application increased tolerance against salinity stress with the decrease in Na^+, Cl^-, and H_2O_2 and increase in Ca^+ and K^+ within plants [21]. Salicylic acid has the potential to reduce ethylene biosynthesis, boron toxicity, and lipid peroxidation and protects the plant from membrane damage under salinity stress [22].

Recently, many efforts have been made to find an effective approach for developing salinity tolerance in plants that ultimately help plants thrive and survive under salinity-induced conditions. Exogenous use of plant phytohormones, especially salicylic acid use, is the most promising strategy for increasing plant tolerance under saline conditions. Hence, the current study focused on the exogenous application of salicylic acid to mitigate adverse salinity effects on pea growth, yield, and grain quality by reducing oxidative injury because pea is an important legume crop rich in bioactive compounds.

2. Materials and Methods

2.1. Planting Materials and Experimental Site

The seeds of the Pencil cultivar were purchased from Pooja Seeds Pvt. Ltd. Multan, Pakistan. The current study was conducted at the Department of Horticulture, Bahauddin Zakariya University, Multan, Pakistan. Soil analysis before the planting was listed in Table 1.

Table 1. Soil properties before and after planting under salinity conditions.

Soil Properties	Before Planting	After Planting			
		Control	25 mM	50 mM	100 mM
Soil texture	Loam	Loam	Loam	Loam	Loam
Saturation (%)	29	28	26	25	20
EC (mScm^{-1})	1.76	1.76	1.78	1.80	1.84
pH	8.0	8.0	8.1	8.1	8.3
Organic matter (%)	0.40	0.38	0.29	0.28	0.24
P (mg kg^{-1})	6.08	6.10	5.50	4.80	3.96
K (mg kg^{-1})	157	160	146	130	110
Sodium (mg kg^{-1})	138	141	224	251	262
Chloride (mg kg^{-1})	150	153	287	310	318

2.2. Seeds Sowing

The seeds of the Pencil cultivar were sown in clay pots (45 × 30 cm) on 1 November 2019 and on 3 November 2020 for the 1st and 2nd year crops. Three pickings were completed in the whole season, and the last picking was performed on 15 March 2020 (1st Year) and 21 March 2021 (2nd Year). These pots were filled with loamy soil (8 kg), and three seeds were sown at a depth (2–3 cm) in each pot. All three pickings were cumulative and the average was computed for further analysis.

2.3. Crop Maintenance

Plants were irrigated as needed after two days without any fertilizer application. Weeding and hoeing were practiced when plants were required regularly. After 22 days of germination, thinning was done to establish one plant of uniform size in each pot. Sucking insects were controlled by applying the insecticide "Confidor 200 SC".

2.4. Experimental Setup

The present pot study was planned under a completely randomized design (CRD) with four NaCl levels and four salicylic acid concentrations performed with three repeats. Salinity levels of NaCl (control, 25 mM, 50 mM, and 100 mM) were applied to pea plants during irrigation. The salinity stress was imposed after plant establishment and continued until harvesting. Moreover, salicylic acid concentrations (control, 1 µM, 2 µM, 3 µM, and 4 µM) of 10 mL were exogenously sprayed once a week. The application of salicylic acid was started after seven days of salinity treatment.

2.5. Growth and Yield Traits

Plant height and length of roots and pods were measured using the Vernier caliper (KKEGOL). Fresh and dry weights of plant biomass and pods and fresh weight of roots and 50 seeds weight were estimated through digital weighing balance (WT6002-D). The number of branches, leaves, and pods per plant and seeds per pod were counted. Leaf greenness was determined through a SPAD meter (Minolta Co. Ltd., Tokyo, Japan).

2.6. Carotenoid

Pea leaves of 0.5 g were collected from each treatment to estimate carotenoids. The method of Lichtenthaler [23] was adopted to determine carotenoids by grinding leaf samples in an acetone solution (80%). This homogenized solution was centrifuged at 15,000× *g* for 10 min. The supernatant was collected, and absorbance was noted at 480 nm through a spectrophotometer (UV-1900). The following equation was used for carotenoids estimation:

$$\text{Carotenoids (mg g}^{-1}\text{ FW)} = 0.3365 \times \text{A}^{480} - 0.007$$

2.7. Phenolic Content and Ascorbic Acid

Phenolic content was determined in pea grains using a procedure by Singleton and Rossi [24] by grinding 0.5 g in 80% methanol. After centrifuging (15,000× *g* for 10 min), the extracted solution was homogenized in Folin–Ciocalteu reagent (diluted 1:10 with water) and 5% sodium carbonate. After this, absorbance was noted at 725 nm through a spectrophotometer (UV-1900). For the determination of ascorbic acid in pea grains, the method of Ruck [25] was used with some changes by grinding leaf samples in liquid nitrogen to stop metabolic activities. Peapods were finely ground and their juice of 5 mL was titrated against 2, 6-dichlorophenolindophenol until the appearance of a light pink color.

2.8. Photosynthetic Pigments

For estimation of photosynthetic pigments, a described method of Lichtenthaler [23] was used from the leaf (0.5 g) and homogenized with acetone (80%). After centrifuging at 15,000× *g* for 10 min, absorbance was recorded at 646 nm and 663 nm for estimation of chlorophyll a and b, respectively. The following equations by Arnon [26] were followed to analyze photosynthetic pigments:

$$\text{Chlorophyll a (mg g}^{-1}\text{ FW)} = 100 \times [(\text{A}^{663} \times 0.0127 - \text{A}^{645} \times 0.00269)]/0.5$$

$$\text{Chlorophyll b (mg g}^{-1}\text{ FW)} = 100 \times [(0.0229 \times \text{A}^{645} - 0.00468 \times \text{A}^{663})]/0.5$$

$$\text{Chlorophyll a : b} = \frac{\text{chlorophyll a}}{\text{chlorophyll b}}$$

$$\text{Total chlorophyll (mg g}^{-1}\text{ FW)} = \text{chlorophyll a} + \text{chlorophyll b}$$

2.9. Enzymatic Assays

Pea leaves from each treatment were freshly harvested and ground in liquid nitrogen to inhibit enzymatic activities. A leaf sample (0.3 g) from each treatment was homogenized in 3 mL of sodium phosphate buffer (pH 7.8) and centrifuged at 15,000× *g* for 5 min and the supernatant was collected for estimation of SOD, CAT, POD, and APX. A frequently used method by Giannopolitis and Ries [27] was adopted to determine SOD activity in pea leaves. Absorbance was noted at 560 nm through a spectrophotometer. Chance and Maehly's [28] previously described method was used to estimate CAT and POD activities. The methodology by Nakano and Asada [29] was used to estimate APX activity in pea leaves. Absorbance for CAT, APX, and POD activities were measured at 240 nm, 290 nm, and 470 nm, respectively, through a spectrophotometer.

2.10. Leaf Gas Exchange Traits

These physiological traits were recorded through an Infrared Gas Analyzer (Bio Scientific Ltd., London, UK) from the uppermost fully expanded leaf [30].

2.11. Statistical Analysis

The computer-based software Statistix 8.1 (Tallahassee, FL, USA) was used to develop two way analysis of variance due to salinity and salicylic acid. However, the yearlong interaction was non-significant and average data were pooled and analyzed. All the applied treatment means were separated under a 0.05 probability of LSD test.

3. Results

3.1. Soil Properties under Normal and Saline Conditions

Soil saturation, organic matter, phosphorus, and potassium were gradually reduced under different salinity levels. However, soil EC, pH, sodium, and chloride contents were enhanced at a toxic level with increased salinity levels compared with the control due to distilled water applications in the soil. EC indicated the accumulation of salts in soil. The increase in EC indicated an increased in Na^+ and Cl^- (Table 1).

3.2. Effect of Salicylic Acid on the Yield of Pisum sativum Traits

The exogenous spray of 3 μM salicylic acid showed a higher number of pods per plant, fresh and dry pod weights, pod length, number of seeds per pod, and 50 seed weight in untreated plants. Moreover, the number of pods per plant and fresh pod weight was higher at 25 mM NaCl and 3 μM salicylic acid treatment (Table 2). However, a significant decrease was recorded in yield traits, i.e., number of pods per plant, fresh and dry weights of pod, pod length, number of seeds per pod, and 50 seed weight of those plants treated with 100 mM NaCl and control of salicylic acid because increased NaCl levels decreased pea yield (Table 2).

Table 2. Effect of irrigation water salinity levels and foliar treatments of salicylic acid on yield traits of pea.

Salinity Levels	Salicylic Acid Concentrations	Number of Pods per Plant	Fresh Pod Weight (g)	Dry Pod Weight (g)	Pod Length (mm)	Number of Seeds per Pod	50 Seed Weight (g)
Control	0 μM	11.71 cd	37.68 f	8.20 c	5.19 f	5.67 d	25.03 h
	1 μM	13.09 b	39.77 d	9.02 b	5.93 d	7.00 b	29.05 d
	2 μM	13.12 b	40.40 b	9.08 b	6.22 b	7.00 b	32.14 b
	3 μM	14.16 a	42.73 a	10.26 a	6.31 a	7.70 a	33.02 a
25 mM	0 μM	10.60 ef	35.53 h	6.96 d	5.13 g	5.00 e	25.02 h
	1 μM	12.06 c	38.51 e	9.01 b	5.29 e	7.00 b	27.70 e
	2 μM	13.10 b	37.32 g	8.03 c	5.93 d	6.00 c	30.12 c
	3 μM	14.11 a	42.12 ab	8.11 c	5.98 c	5.00 e	32.16 b
50 mM	0 μM	8.12 g	33.00 j	3.00 f	3.33 j	2.00 h	22.23 i
	1 μM	10.19 f	34.73 i	8.00 c	3.59 i	3.00 g	25.28 g
	2 μM	10.21 f	35.40 h	8.02 c	4.01 h	4.00 f	26.01 f
	3 μM	11.14 de	40.55 c	8.09 c	4.00 h	4.00 f	26.14 f
100 mM	0 μM	4.48 i	26.00 m	2.42 g	2.65 l	2.00 h	15.13 k
	1 μM	6.23 h	30.40 l	3.09 f	3.25 k	2.00 h	15.29 k
	2 μM	6.56 h	32.20 k	4.12 e	3.56 i	3.00 g	16.44 j
	3 μM	6.59 h	33.16 j	4.28 e	3.61 i	3.00 g	16.64 j
LSD value with significance level							
NaCl levels		0.52 **	0.23 **	0.28 **	0.03 **	0.21 *	0.16 **
Salicylic acid concentrations		0.49 **	0.22 **	0.27 **	0.04 **	0.19 **	0.14 **
NaCl levels × salicylic acid concentrations		0.78 **	0.35 **	0.42 **	0.05 **	0.33 *	0.25 **
CV		4.54	0.57	3.67	0.63	4.30	0.60

Mean values sharing different letter(s) in a column separately for salinity and salicylic acid treatments are statistically significant at $p = 0.05$ (LSD test). * Significant at $p < 0.05$; ** significant at $p < 0.01$ using ANOVA analysis.

3.3. Effect of Salicylic Acid on the Growth of Pisum sativum Traits

A significant decrease in pea growth was observed at 25 mM, 50 mM, and 100 mM NaCl. However, salicylic acid treatments improved the pea growth at 1 μM, 2 μM, and 3 μM. Plant height, the number of branches per plant, root length, and leaf greenness were decreased at 25 mM, 50 mM, and 100 mM NaCl compared with control plants. Salicylic acid treatments improved plant height, the number of branches per plant, root length, and leaf greenness under salinity conditions (Figure 1). The increased salinity concentration significantly reduced the number of leaves per plant, fresh and dry weights of plant biomass, and fresh root weight than untreated control plants. However, an increased concentration of salicylic acid improved the number of leaves per plant, fresh and dry weights of plant biomass, and fresh root weight (Figure 1).

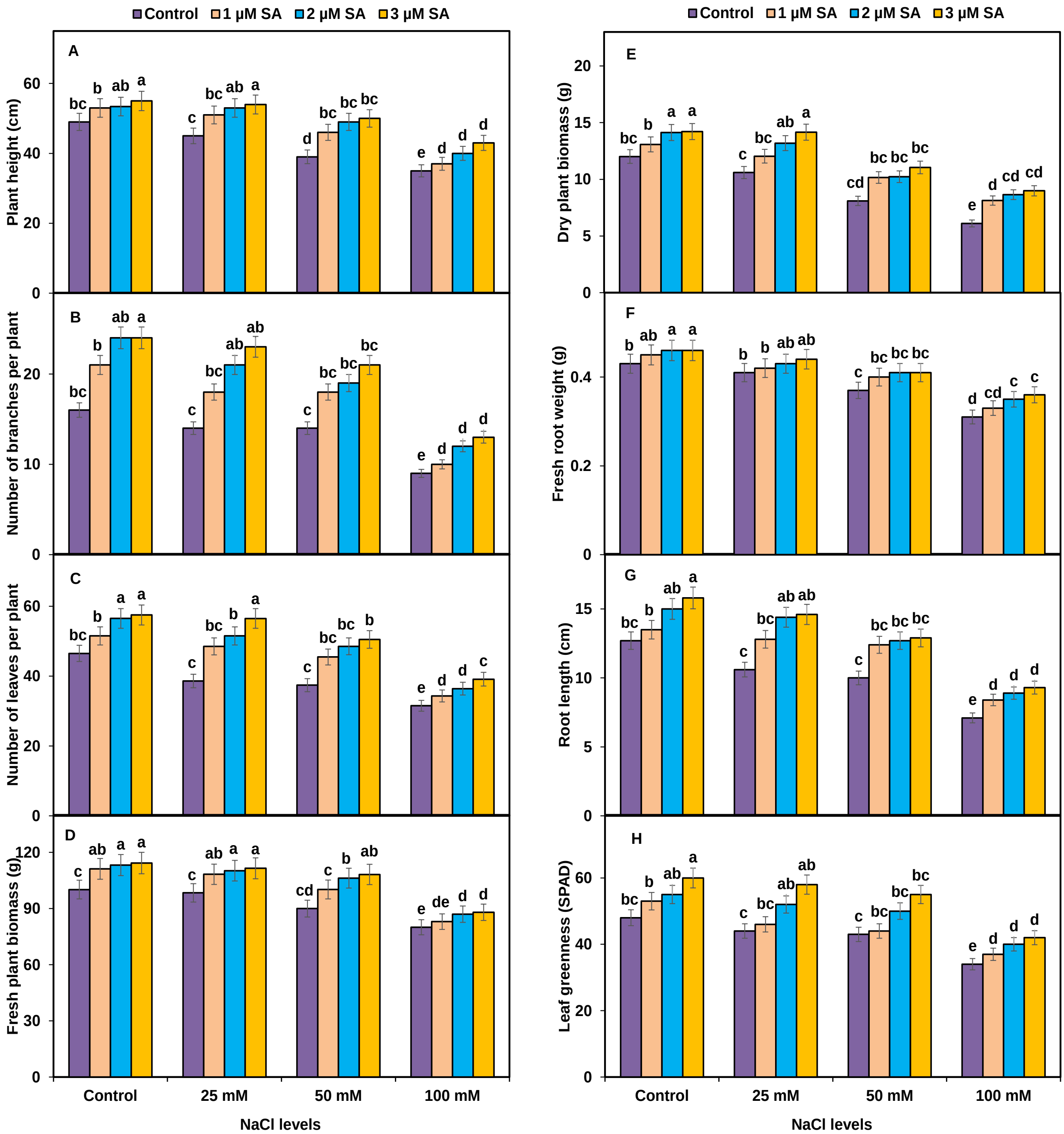

Figure 1. Effect of salinity levels and foliar treatments of salicylic acid concentrations on growth traits of pea. (**A**) plan height, (**B**) number of branches per pant, (**C**) number of leaves per plant, (**D**) fresh plant biomass, (**E**) dry plant biomass, (**F**) fresh root weight, (**G**) root length and (**H**) leaf greenness. Means ± SE, $n = 3$, significant differences are exhibited by lowercase letters (at $p < 0.05$), according to the LSD test.

3.4. Effect of Salicylic Acid on the Quality of Pisum sativum Traits

The quality of the grains was significantly improved with an exogenous salicylic acid spray under salinity-induced conditions. Carotenoid content was reported to be maximum at 3 µM of salicylic acid and control plants of salinity, followed by 3 µM salicylic acid, 25 mM, and 50 mM NaCl, and 2 µM salicylic acid and control. In contrast, the minimum carotenoids were recorded at 100 mM NaCl and salicylic acid control (Figure 2). Exogenous spray of 3 µM salicylic acid increased pea grains' phenolic and ascorbic acid content in both control and saline conditions. Still, both parameters were suggested to decrease significantly at 25 mM, 50 mM, and 100 mM NaCl (Figure 2).

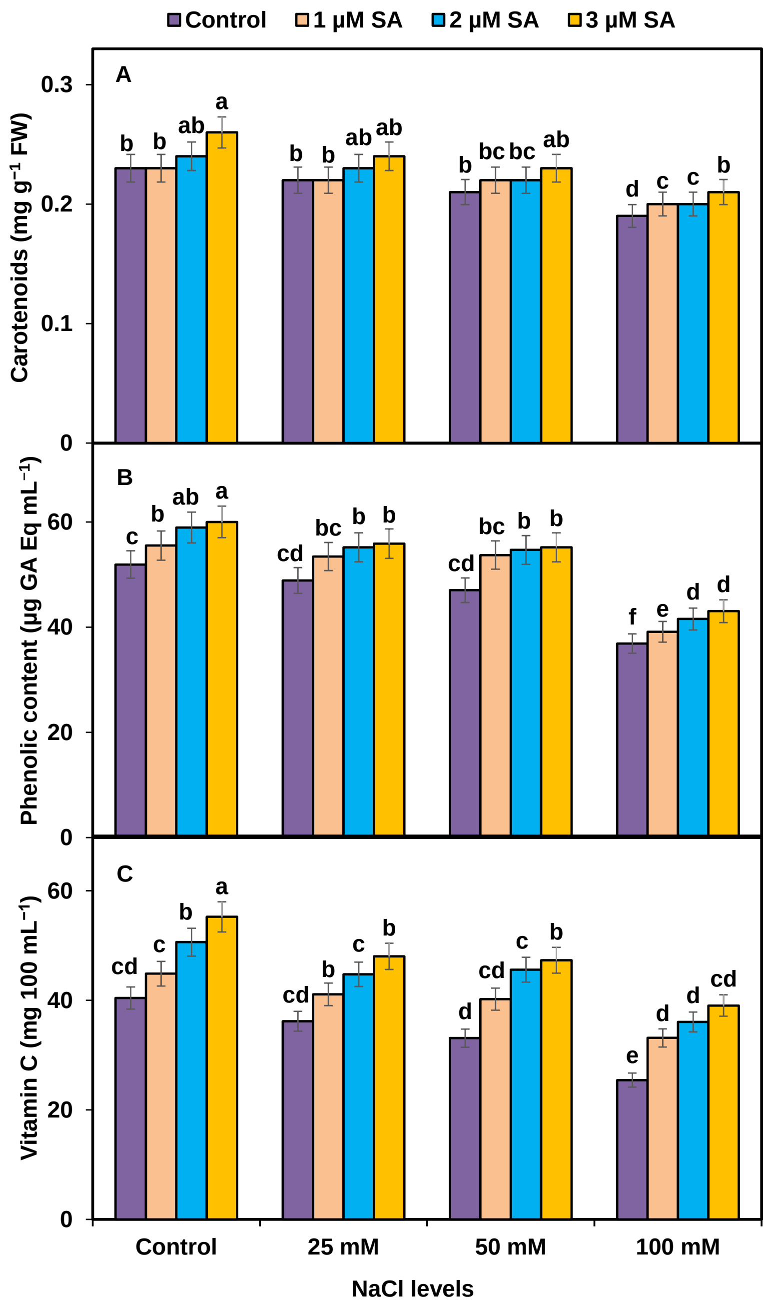

Figure 2. Effect of salinity levels and foliar treatments of salicylic acid concentrations on quality traits of pea. (**A**) carotenoids, (**B**) phenolic content and (**C**) vitamin C. Means ± SE, $n = 3$, significant differences are exhibited by lowercase letters (at $p < 0.05$), according to LSD test.

3.5. *Effect of Salicylic Acid on the Photosynthetic Pigments of Pisum sativum Traits*

Chlorophyll a and b, chlorophyll a:b, and total chlorophyll were increased under salicylic acid treatments. In contrast, chlorophyll a and b, chlorophyll a: b, and total chlorophyll were decreased at 25 mM, 50 mM, and 100 mM NaCl. Exogenous application of 3 µM salicylic acid significantly improved the concentration of chlorophyll a and b, chlorophyll a: b, and total chlorophyll under control, 25 mM and 50 mM NaCl (Figure 3).

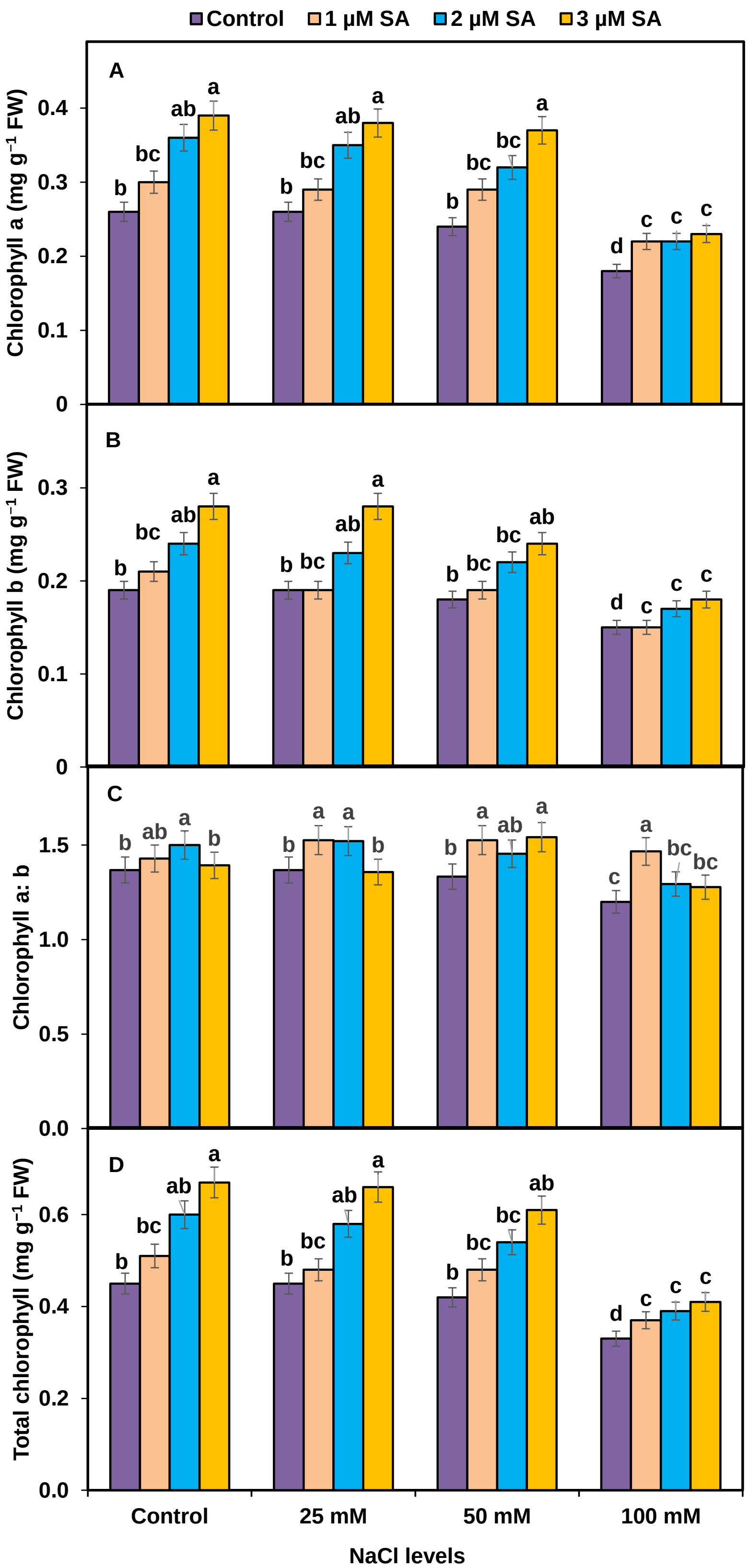

Figure 3. Effect of salinity levels and foliar treatments of salicylic acid concentrations on photosynthetic pigments of pea. (**A**) chlorophyll a, (**B**) chlorophyll b, (**C**) chlorophyll a:b, and (**D**) total chlorophyll. Means ± SE, n = 3, significant differences are exhibited by lowercase letters (at $p < 0.05$), according to LSD test.

3.6. Effect of Salicylic Acid on the Enzymatic Activities of *Pisum sativum* Traits

SOD, CAT, POD, and APX activities were increased under salinity-induced conditions. Exogenous application of salicylic acid also increased the production of enzymatic activities. SOD activity was increased at 100 mM NaCl and 3 µM salicylic acid, followed by 50 mM NaCl and 3 µM salicylic acid, while SOD activity was decreased in control plants (Figure 4A). CAT was higher at 50 mM and 100 mM NaCl and 3 µM salicylic acid, followed by 100 mM NaCl and all the studied salicylic acid treatments (Figure 4B). POD was the maximum at 50 mM and 100 mM NaCl and 3 µM salicylic acid, followed by 100 mM NaCl and 2 µM, and 25 mM NaCl and 3 µM of salicylic acid (Figure 4C). APX activity was significantly greater at 25 mM, 50 mM, and 100 mM NaCl, and 2 and 3 µM salicylic acid compared with the control (Figure 4D).

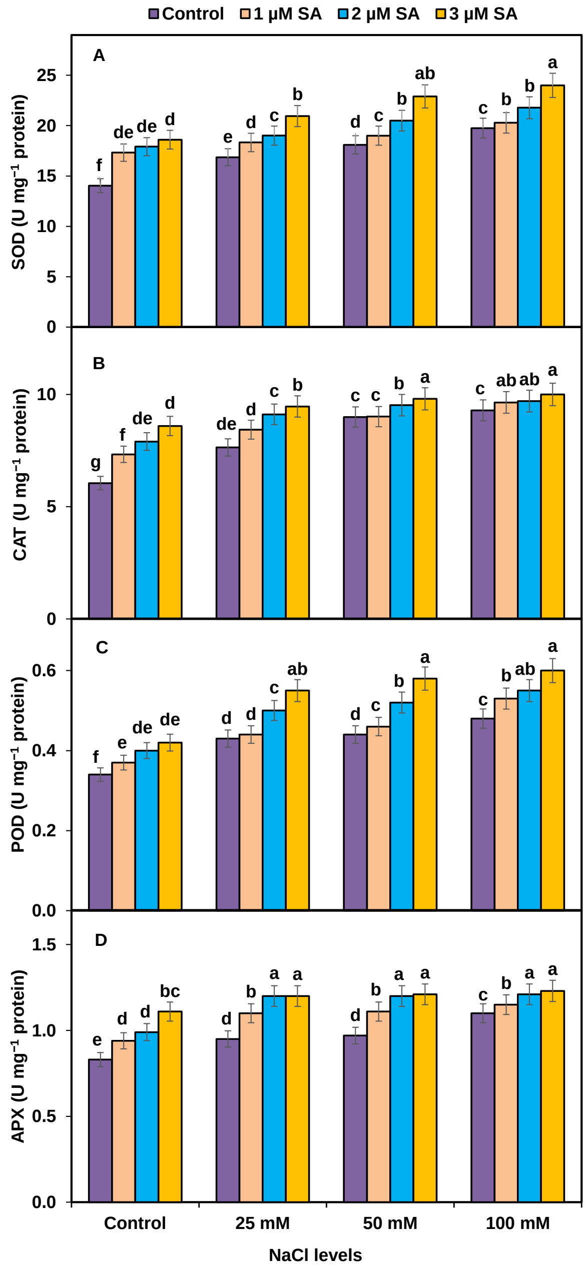

Figure 4. Effect of salinity levels and foliar treatments of salicylic acid concentrations on antioxidant assays of pea. (**A**) SOD, (**B**) CAT, (**C**) POD and (**D**) APX. Means ± SE, $n = 3$, significant differences are exhibited by lowercase letters (at $p < 0.05$), according to LSD test.

3.7. Effect of Salicylic Acid on the Physiology of Pisum sativum Traits

Photosynthesis and stomatal conductance were improved under the exogenous spray of salicylic acid. Moreover, the transpiration rate was reduced under foliar application of salicylic acid in pea plants. However, increased salinity levels decreased the photosynthesis rate and stomatal conductance, while the transpiration rate was enhanced (Figure 5).

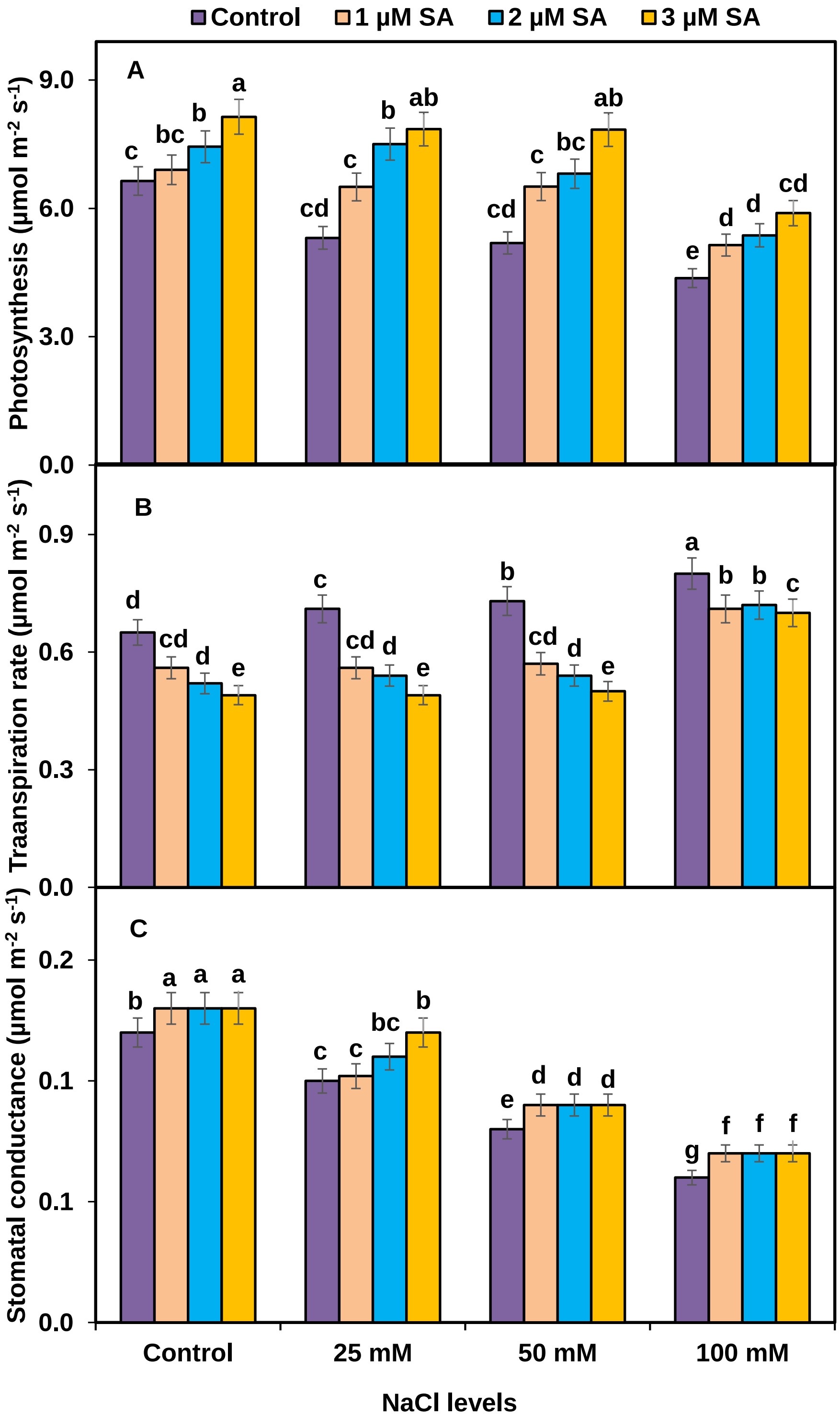

Figure 5. Effect of salinity levels and foliar treatments of salicylic acid concentrations on photosynthesis (**A**), transpiration rate (**B**), and stomatal conductance (**C**) of pea. Means ± SE, n = 3, significant differences are exhibited by lowercase letters (at $p < 0.05$), according to LSD test.

4. Discussion

The decrease in soil saturation, organic matter, phosphorus, and potassium was due to an excess of salinity. Soil EC, pH, sodium, and chloride were greatly enhanced at a toxic level due to increased salinity compared with the control. A higher concentration of Na^+ and Cl^- ions in irrigation water resulted in stunted growth and reduced vegetative period. The increased concentration of NaCl is the cause of growth inhibition, meagre development, decreased protein synthesis, low respiration rate, imbalance photosynthesis, and poor CO_2 fixation in salt-sensitive plants [31]. The accumulation of Na^+ was suggested to be increased in older leaves; therefore, the dropping of leaves was increased, thereby leading to senescence [32,33]. Earlier reports suggested that ethylene biosynthesis and the abscisic acid level were increased, while cytokinin and indole-3 acetic acid decreased, resulting in leaf senescence due to salinity-induced conditions [34]. In the present findings, overall pea growth (Figure 1) and yield (Table 2) were reduced under salinity, and the maximum decrease was observed at 100 mM NaCl. Therefore, a lower yield resulted from poor growth, disruption in photosynthesis, low mineral uptake, mesophyll conductance destruction, stomatal closure suppression, and a higher accumulation of Na^+ and Cl^- in leaf [35]. The severe decrease in growth and yield indicated that the pea crop is sensitive to salinity. Current results are in accordance with the earlier work of Maksimović et al. [36], who suggested that pea cultivars are susceptible to salt stress. The exogenous spray of salicylic acid is effective for the increase in growth and yield by reducing the toxic effects of salinity in numerous crops, i.e., cucumber [37], tomato [38], peppers [39], and lettuce [35]. Salicylic acid regulates the uptake of Na^+ and K^+ by mesophyll conductance and improves stomatal conductance under salinity stress, all of which contribute to increased growth and yield [40]. As illustrated in the present study, salicylic acid is suggested to enhance pea growth and yield.

Pea is a rich source of bioactive compounds, which is necessary for a healthy life in humans. Salinity-induced conditions greatly disturbed the quality of pea. In the present findings, the decrease in rate was observed under 100 mM NaCl. It has been proved that an increased concentration of NaCl decreases pea grain quality, such as carotenoids, phenolic compounds, and ascorbic acid. However, salicylic acid treatments indicated that quality was improved by the exogenous application of different concentrations of salicylic acid in pea plants. The maximum quality was increased at 3 μM of salicylic acid by mitigation of adverse effects of salinity. The small concentration of salicylic acid improves fruit quality compared with higher concentrations. Therefore, the current results are in accordance with previous work because the quality of tomato was enhanced with little applications of salicylic acid [41]. Higher concentrations of salicylic acid sprayed on mung beans improved grain quality, water status, photosynthesis mechanism, and yield [42,43].

The generation of ROS is minimal under normal conditions; however, their excessive production becomes toxic under environmental stresses within the plants. Toxic ROS is the primary cause of the reduction in photosynthetic pigments, i.e., chlorophyll a, b, a:b, and total chlorophyll contents [44]. ROS production increases the injury of cellular metabolism, membrane integrity, nucleic acids, and some other metabolic processes that occur in mitochondria and chloroplasts under salinity-induced conditions. These disruptions of the membrane system of various organelles result in cell death and ultimately death of the plant [45]. Salicylic acid is involved in the reduction in ROS production by increasing the scavenging ability within plant cells [46–48]. ROS reduction might result in improved photosynthetic pigments and ultimately the growth yield of plants is enhanced [49,50]. According to the current findings, salicylic acid increased chlorophyll content in pea plants grown in salinity conditions. Salicylic acid strengthens the plant's defense mechanism against toxic reactive oxygen species (ROS), making it a critical hormone for enhancing pea tolerance under high salinity stress.

Under saline conditions, the synthesis of enzymatic assays increased, and this trend is higher in tolerant cultivars. In the present study, enzymatic assays, i.e., SOD, CAT, POD, and APX were increased with increased concentration of NaCl (100 mM). Current findings align with previous work because the increased antioxidant assays in plants were also observed under salinity [51]. The increased level of SOD, CAT, POD, and APX could scavenge toxic ROS. ROS reduction prevents the plants from oxidative injury and osmotic stress by maintaining the photosynthesis mechanism. Moreover, the reduction in ROS is necessary to decrease lipid peroxidation and H_2O_2 within plant cells. Membrane rupturing is enhanced by the increased production of H_2O_2 and MDA content [52]. Exogenous application of salicylic acid increases the production of SOD, CAT, POD, and APX under saline conditions to improve the survival of plants by decreasing ROS production. Current results are concordant with Nazar et al. [46], who suggested that the salicylic acid treatments could be an effective strategy for reduction and detoxification of ROS, MDA, and H_2O_2.

Physiological traits, i.e., photosynthesis rate and stomatal conductance were decreased, while transpiration rate increased in pea plants treated with 100 mM. Similarly, Ashraf and Harris [53] also observed alteration in photosynthesis, carbon reduction pathways, and electron transport chain under salinity-induced conditions. Moreover, disturbance in photosynthetic machinery may cause osmotic stress by the reduction in the accumulation of solutes and water potential [54–56]. Salicylic acid has been shown to improve the physiological mechanism of the plant by increasing the immune system within the plant's cell. Current findings are in line with the results of Stevens et al. [57] which revealed that salicylic acid helps sustain photosynthesis, transpiration rate, stomatal conductance, and membrane integrity under saline conditions.

5. Conclusions

Salinity-induced conditions significantly decreased the pea growth and yield because of oxidative injury. The disturbance of photosynthesis was observed in pea plants, leading to osmotic stress under salinity. However, the production of antioxidants was enhanced to strengthen the plant defense mechanism. Exogenous application of salicylic acid improved pea growth and yield, and increased plants' defense mechanisms because it can mitigate the adverse effects of salinity by lessening of membrane permeability and regulation of membrane functioning and stability. In the light of current findings, salicylic acid is helpful for the maintenance of physiological activities and numerous metabolic processes in pea plants exposed to salt stress. Salicylic acid is essential to provide tolerance to the plant against salt stress by improving the defense mechanisms of plants. More research is necessary to understand the molecular mechanism to understand the biochemical pathway and gene regulating the tolerance mechanism, which might be beneficial for breeder and genetic engineers to design crops that might be suitable mitigating the effects of climate change as salicylic acid is more effective for sustainable production of agricultural crops.

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