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Improving Cotton Productivity under Salinity Stress through Soil and Foliar Application of Potassium Humate and Ascorbic Acid

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ABSTRACT

Salinity stress is a major abiotic constraint that limits cotton productivity. Although cotton has moderate tolerance to salinity, the crop is more sensitive to saline conditions at critical growth stages. High levels of salinity can impede the growth of the cotton plant, thereby reducing yield and quality. In this context, the present research was performed to assess the effects of soil potassium humate and foliar ascorbic acid, applied singly and in combination, on mitigating the effects of salinity stress on the growth and productivity of cotton. A field investigation was conducted in at Agricultural Association, South Port Said, Port Said Governorate, Egypt, specifically in the 2024 and 2025 seasons, using a factorial arrangement within a completely randomized design (CRD). The findings revealed that all the treatments were effective in enhancing plant height, number of fruiting branches, setting%, number of bolls, average boll weight, seed cotton yield, seed index, lint%, and earliness%. In addition, the treatments were effective in enhancing fiber quality, like length uniformity index, fiber strength, fiber fineness, and upper half mean length. The simultaneous application of both treatments significantly enhanced production and fiber quality compared with either treatment alone, increasing seed cotton yield by 73.75% and fiber length by 14.57%. These findings show that the treatment strategies have the potential to improve cotton yields in saline environments. This, in turn, will contribute to a more sustainable agriculture.

Keywords: fiber fineness, fiber strength, fruiting branches, seed index, shedding, total of setting.

INTRODUCTION

Cotton (*Gossypium barbadense* L.) is considered moderately tolerant to salinity, with a threshold level of 7.7 dS m^{-1}, though there are significant effects on the growth of the vegetative parts, retention of bolls, and yield of seed cotton when the crop is exposed to saline conditions (Zhang et al., 2023). The effects of excessive salts on the growth of the crop can appear at different stages of the life cycle of the crop, from the stage of active growth to the mature stage, and the loss in biological as well as economic yield can be related to a number of physio-biochemical changes that appear at the cell and molecular level (Nawaz et al., 2010). Generally, these limiting factors are thought to be controlled by three main mechanisms, which include the effects of increased osmotic pressure in the root zone, which restricts water uptake, the toxic effects of sodium chloride accumulation, and the effects of nutrient imbalance, which restricts the uptake of necessary nutrients for proper plant functioning (Zhang et al., 2023).

Vegetative growth is substantially reduced in salinity, with reduced leaf area, reduced

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plant height, and biomass productivity (Akhtar et al., 2003; Petcu et al., 2007). The reproductive phase of cotton growth is sensitive to salt accumulation, with flowering and boll formation showing strong reactions to salt. Pollen fertility and boll retention, and fiber elongation are affected in salt-stressed plants (Meloni et al., 2003). Consequently, reduced yields are mainly due to reduced and lighter bolls, with lint quality reduced in length, strength, and fineness under salt-stressed conditions (Abdelraheem et al., 2019).

Relieving salinity stress in cotton requires an integrated approach involving agronomic practices, physiological management, and biostimulant application. Among biostimulants, potassium humate (PH) and ascorbic acid (AsA) have shown notable potential in alleviating salinity effects in crops like *Pittosporum tobira* and soybean (Lasheen et al., 2024; Kiruthiga et al., 2025). PH enhances soil structure by promoting aggregation, increasing porosity, and facilitating water movement, which reduces surface salt accumulation and supports root development (Rady, 2016; El-Beltagi et al., 2023). It also mitigates Na^+ toxicity through partial immobilization and improves the availability of essential nutrients such as K^+, Ca^{2+}, and Mg^{2+}, enabling cotton roots to access deeper, less saline soil for better water and nutrient uptake (Ahmed et al., 2013; Abdelraheem et al., 2019). Additionally, humic substances stimulate beneficial microorganisms, accelerating nutrient cycling and organic matter decomposition, which further alleviates stress (Pereira et al., 2019; Wang et al., 2025). Together, these effects enhance boll development, boll weight, and fiber quality by improving nutrient use efficiency and reducing oxidative stress (Alobaidy, 2013).

Ascorbic acid (AsA) plays a vital role as a major non-enzymatic antioxidant within the plant defense system. Neutralizing the reactive species formed during salt stress and thus prevents chloroplasts and mitochondria from oxidative damage (Meloni et al., 2003; El-Beltagi, et al., 2026). Studies of Aydogan et al. (2023) highlighted that AsA contributes to the detoxification of reactive oxygen species (ROS) and enhances stress tolerance. When applied via foliar spraying, it is essential in membrane stability and minimizes lipid peroxidation caused by the accumulation of Na^+ and Cl^- ions, which in turn results in better plant hydration and nutrient transport (Han et al., 2025). Such membrane protection at the cellular level results in agronomical aspects in that the crop tends to have better bolls in terms of retention, weight, and lint properties such as length, strength, and fineness in response to reduced oxidative stress and better nutrient utilization (Sharif et al., 2019).

Research carried out on saline-alkali cotton soils revealed that the application of potassium humate (PH), especially in combination with biochar, improves the soil condition and promotes the growth of cotton (Wang et al., 2025). Despite there is limited research on the application of AsA on cotton plants, research on other crops such as wheat (El-Hawary et al., 2023), and soybean (Kiruthiga et al., 2025) revealed the effective application of AsA in enhancing the tolerance level of plants to salinity stress. Thus, the main aim of the present research was to assess the combined effect of the application of potassium humate on the soil and ascorbic acid on the leaves of cotton plants for the alleviation of salinity stress with the aim of enhancing the yield quantity and quality.

MATERIAL AND METHODS

Two field experiments were carried out at South Port Said, Port Said Governorate, Egypt. The experiments involved Agronomy Research Division, Cotton Research institute, Agricultural Research Center, Giza, Egypt and the Agricultural Botany Lab, Faculty of Agriculture, Kafrelsheikh University. The main aim of this study was to examine and improve the response of cotton plants to salt stress using humic and ascorbic acids. The seeds of the cotton cultivar 'Giza 94' were obtained from the CPRD. In both seasons, the preceding crop was alfalfa (*Trifolium alexandrinum* L.). Before conducting the experiment, soil surface samples were collected from the experimental site and analyzed for their chemical properties according to the methods described by Dane and Topp (2020) and Sparks et al. (2020). The results of the soil chemical properties are presented in Table 1.

Table 1. Mean values of selected chemical soil properties at the experimental site prior to planting during the two growing seasons

Season	Properties												
	PH	Ec (ds/m)	SP	SAR	$CaCO_3$ (%)	Cations (mEq/L)				Anions (mEq/L)			
						K^+	Na^+	Mg^{++}	Ca^{++}	SO_4^-	Cl	HCO_3^-	CO_3^-
2024	8.59	8.63	83.72	10.51	21.89	0.19	49.90	12.50	34.87	54.06	31.15	12.25	-
2025	8.45	8.22	85.00	10.20	22.60	0.20	49.30	12.10	35.00	54.10	31.00	11.50	-

The soil was tilled two weeks before sowing and leveled using laser technology, and the experiment was arranged in a split-plot design with four treatments and five replicates per season. Main plots consisted of eight ridges, each 6 m long and spaced 70 cm apart, covering 33.6 m^2, while subplots measured 25.2 m^2. Sowing was performed on May 15, 2024, and May 25, 2025, under high-salinity conditions (Table 1), with seedlings thinned to two plants per hill before the first irrigation and harvesting in September. The treatments included a control, soil-applied potassium humate (PH, 10%) at 23.8 L ha^{-1}, foliar-applied ascorbic acid (AsA, 2 mM), and a combined PH + AsA application. PH was applied through drip irrigation during the first three irrigation events, while AsA was sprayed twice, at the beginning of flowering and two weeks later.

Fertilization practices were performed as recommended by of the Cotton Research Institute. Nitrogen was applied at a dose of 60 kg N/feddan using urea (46.5% N), where the dose was divided into two equal parts: the first dose was administered after thinning (before the first irrigation) and the second was applied before the second irrigation. Phosphorus was applied during soil preparation at a dose of 15.5 kg P_2O_5/feddan using calcium superphosphate (15.5% P_2O_5). Potassium fertilizer was applied after thinning at a dose of 24 kg K_2O/feddan using potassium sulfate (48% K_2O). Pest control measures were executed following the Egyptian Ministry of Agriculture’s recommended procedures for cotton cultivation.

Plant height and number of fruiting branches

Plant height was measured at harvest time for both seasons by measuring the spacing between the soil surface and the end of the main stem of the plant using a measuring stick. Fruiting branches were counted by the total number of branches present on the main stem.

Yield and Yield Components

For each treatment, fully opened bolls were hand-picked in three successive pickings to estimate the yield of cotton. The collected seed cotton was processed through a cotton gin to obtain both seed and fiber yields. During the second picking, a sample of 100 fully mature bolls was picked to evaluate the average boll weight and lint%. The average boll weight was estimated by dividing the weight of the seed cotton from 100 bolls by the total number of bolls. The lint percentage was estimated by dividing the weight of the lint obtained from the same sample by the corresponding weight of the seed cotton. Seed cotton yield (ton ha^{-1}) was estimated by weighing the seed cotton picked from two pickings per subplot (25.2 m^2).

Earliness index

Earliness index was calculated following Singh (2004) by dividing the seed cotton yield of the first picking by the total seed cotton yield and multiplying the result by 100.

Fiber quality

Lint samples were collected after ginning the seed cotton from each treatment and replicate to assess the fiber properties at the laboratories of the Cotton Research Institute, Agricultural Research Center (ARC), under standard conditions following ASTM (1998a, b, c). Upper half mean length of fibers (in mm), uniformity index (%), were recorded using a fibrograph. Micronaire readings for fiber fineness, and Pressley index for fiber strength, were recorded using a micronaire instrument and a Pressley tester, respectively.

Statistical analysis

Analysis of variance (ANOVA) was employed on the data, and the treatment effects were considered statistically significant at $p \leq 0.05$. The statistical analyses were carried out using the COSTAT statistical package (CoHort Software, 1986). Duncan's multiple range test was employed to compare the differences between the treatment means (Duncan, 1955).

RESULTS AND DISCUSSION

Plant height and number of fruiting branches

As shown in Figure 1a and 1b, both potassium humate (PH) and ascorbic acid (AsA) significantly increased plant height and the number of fruiting branches in both seasons, with PH producing the highest values. In the first season, plant height increased by 25.31% and 19.85%, and fruiting branches by 26.21% and 17.07% under PH and AsA, respectively. In the second season, plant height increased by 13.24% and 8.91%, while fruiting branches rose by 31.03% and 17.39%, respectively. Notably, the combined application was more effective than individual treatments, raising plant height by 30.37% and 18.19% and fruiting branches by 32.42% and 39.00% in the first and second seasons, respectively.

Total of setting and shedding %

Figure 1c and 1d shows that both potassium humate (PH) and ascorbic acid (AsA) significantly increased the total setting percentage compared to the control, with PH being more effective than AsA. In the first season, total setting increased by 22.38% and 19.27%, and in the second season by 13.38% and 5.56% for PH and AsA, respectively. The combined application of PH and AsA produced the greatest effect, increasing total setting by 24.96% and 25.30% in the first and second seasons, respectively. Additionally, all treatments significantly reduced boll shedding, with decreases of 38.32%, 26.17%, and 46.89% in the first season, and 43.97%, 34.98%, and 50.61% in the second season for PH, AsA, and their combination, respectively.

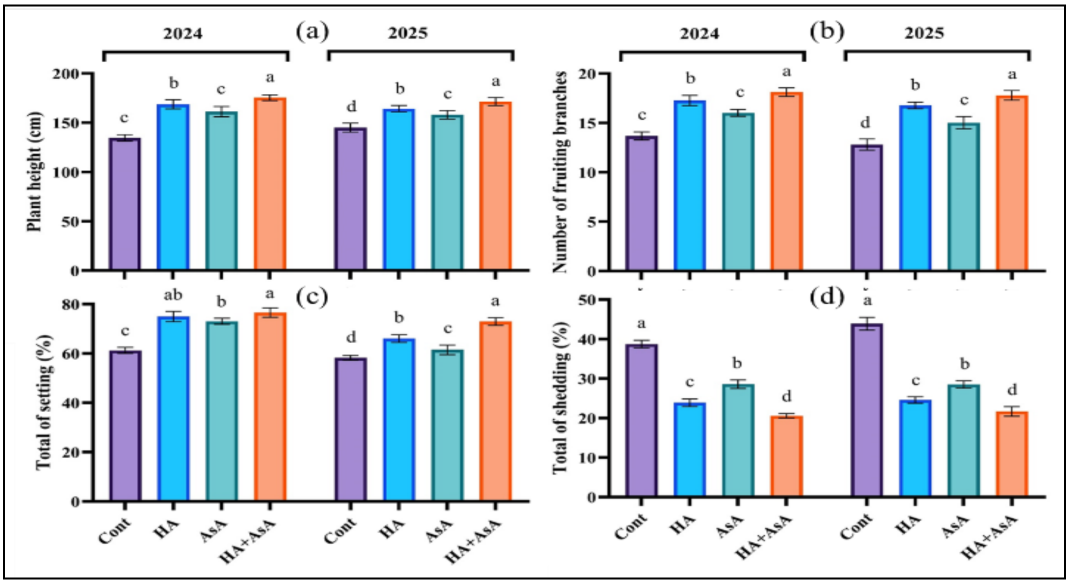

Figure 1. Effect of separate and combined applications of soil potassium humate and foliar ascorbic acid on plant height (a), the number of fruiting branches (b), total of setting% (c) and the total of shedding (d) in cotton plants grown under saline conditions at the end of the 2024 and 2025 seasons. Different letters above bars indicate significant differences between treatments at $p \leq 0.05$, based on Duncan's multiple range test.

Open boll number and boll weight

Figure 2a and 2b shows that both PH and AsA, individually and combined, increased the number of open bolls per plant and average boll weight compared to the control in both seasons. The number of open bolls per plant increased by 52.49%, 35.51%, and 62.72% in the first season, and by 51.40%, 32.64%, and 60.11% in the second season for PH, AsA, and their combination, respectively, though no significant difference was observed between PH alone and the combined treatment in the second season. Similarly, average boll weight increased by 52.77%, 29.64%, and 58.47% in the first season, and by 19.30%, 15.54%, and 29.82% in the second season, with no significant differences between PH alone and the combined treatment in the first season, nor between PH and AsA in the second season.

Seed cotton yield and seed index

Figure 2c and 2d shows that PH and AsA, applied individually or together, significantly increased seed cotton yield and seed index compared to the control in both seasons. Among the single treatments, PH was more effective, while the combined application of PH and AsA produced the highest improvements. Seed cotton yield increased by 66.30%, 32.79%, and 73.57% in the first season, and by 25.85%, 11.96%, and 28.18% in the second season for PH, AsA, and their combination, respectively. Likewise, the seed index increased by 10.89%, 7.67%, and 16.60% in the first season, and by 21.02%, 12.35%, and 34.58% in the second season under PH, AsA, and the combined treatment, respectively.

Lint and earliness percentages

From Figure 3a and 3b, it is observed that the use of PH and AsA, either alone or combined resulted in an increase in lint percentage and earliness in both seasons. Among the individual applications, PH performed better in both seasons, while the combined application of PH and AsA recorded the highest increase in lint percentage and earliness. The increase in lint percentage was 21.02%, 14.15%, and 28.11% in the 2024 season, while in the 2025 season, it was 15.58%, 6.10%, and 19.44% under PH, AsA, and their combined application, respectively. In addition, the increase in earliness percentage was 37.27%, 24.03%, and 43.38% in the 2024 season, while in the 2025 season, it was 27.13%, 20.39%, and 31.93% under PH, AsA.

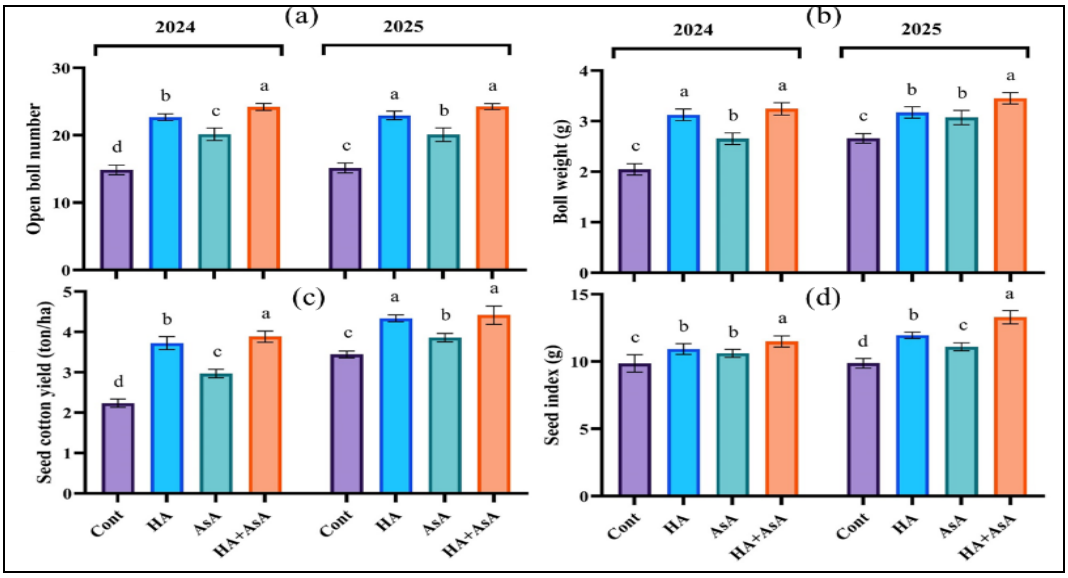

Figure 2. Effect of soil-applied potassium humate and foliar-applied ascorbic acid, individually and in combination, on the number of open bolls (a), the average boll weight (b), seed cotton yield (c) and seed index% (d) in cotton plants grown under saline conditions at the end of the 2024 and 2025 seasons. Significant differences among treatments at $p \leq 0.05$ are indicated by bars labeled with different letters, based on Duncan's multiple range test.

Length uniformity index and fiber fineness

Figure 3c and 3d shows that the use of PH and AsA, both singularly and in combination, increased length uniformity index (%) and fiber fineness in both seasons. Considering the separate treatments, PH was more effective than AsA, and the combined treatment was the best. In the 2024 season, length uniformity index increased by 5.37%, 4.31%, and 6.60% due to PH, AsA, and their combination, respectively, while in the 2025 season, this index increased by 4.38%, 2.50%, and 7.38% due to PH, AsA, and their combination, respectively. Similarly, fiber fineness increased by 23.16%, 14.80%, and 27.52% in the first season, and by 27.73%, 19.17%, and 36.47% in the second season due to PH, AsA, and their combination, respectively.

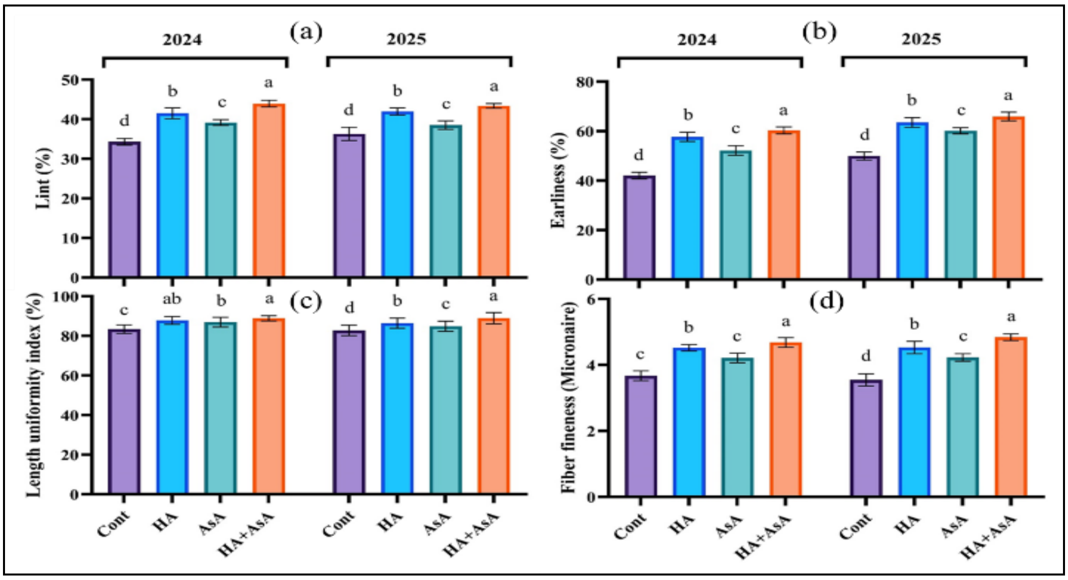

Figure 3. Effect of soil-applied potassium humate and foliar-applied ascorbic acid, individually and in combination, on lint percentage (a), earliness% (b), length uniformity index% (c) and fiber fineness (micronaire) (d) in cotton plants grown under saline conditions at the end of the 2024 and 2025 seasons. Significant differences among treatments at $p \leq 0.05$ are indicated by bars labeled with different letters, based on Duncan's multiple range test.

Fiber strength and upper half mean length

Figure 4 shows that the use of PH and AsA, whether used individually or in a mixture, increased fiber strength, as expressed by the Pressley index, and upper half mean length when compared to the control treatment. Potassium humate, used individually and in a mixture with AsA, was more effective in increasing the value of fiber strength and upper half mean length of cotton fibers when compared to AsA used individually. In the first season, the use of PH, AsA, and their mixture increased fiber strength by 9.22%, 4.79%, and 14.57%, while in the second season, the same treatment increased fiber strength by 8.64%, 5.73%, and 12.43%, respectively. Similarly, upper half mean length was increased by 13.36%, 7.83%, and 15.18% in the 2024 season, while in the second season, upper half mean length was increased by 8.71%, 5.13%, and 13.92%.

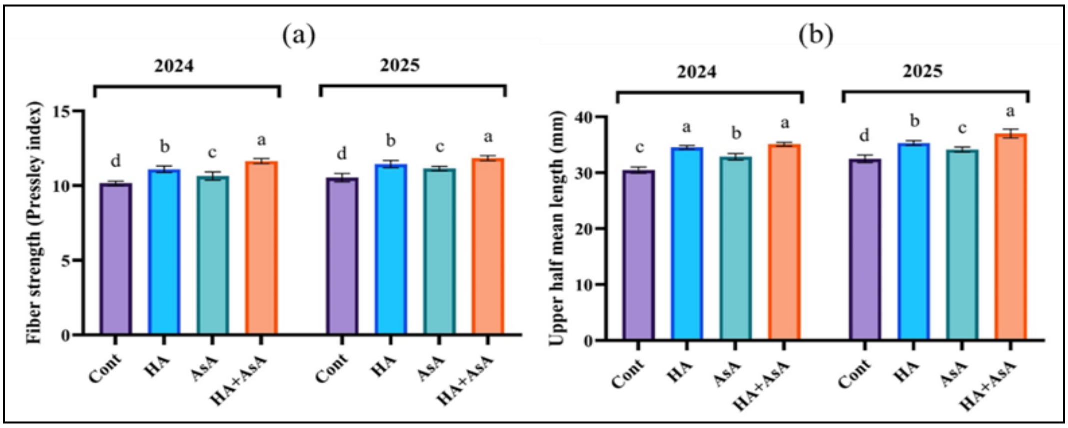

Figure 4. Effect of soil-applied potassium humate and foliar-applied ascorbic acid, individually and in combination, on fiber strength (a) and upper half mean length (b) in cotton plants grown under saline conditions at the end of the 2024 and 2025 seasons. Significant differences among treatments at $p \leq 0.05$ are indicated by bars labeled with different letters, based on Duncan's multiple range test.

Soil analysis (Table 1) indicates high salinity levels in the study area, which impose significant physiological constraints on cotton growth, ultimately reducing yield and fiber quality. Salinity markedly inhibits vegetative growth, as evidenced by decreased plant height and fewer fruiting branches. This reduction is mainly attributed to lowered soil water potential under saline conditions, which restricts plant growth and stem elongation (Munns and Tester, 2008). Additionally, the accumulation of toxic ions (Na^+ and Cl^-) disrupts enzymatic activity and membrane integrity, further limiting growth (Akhtar et al., 2010). Salinity also impairs the uptake of essential nutrients such as K^+, Ca^{2+}, and nitrogen, causing nutritional imbalances that negatively affect vegetative development and fruiting branch formation (Zhang et al., 2023).

Salinity also disrupts the balance of plant hormones such as auxins, gibberellins, and cytokinins; reduced gibberellin activity limits stem elongation, while altered cytokinin levels affect branching (Chaudhary et al., 2024). It further decreases chlorophyll content and stomatal conductance, lowering energy production and thereby reducing plant height and branch formation (Muhammad et al., 2025). Moreover, salinity induces excessive production of reactive oxygen species (ROS), which damage cellular structures and impair cell division and differentiation essential for plant development (Nxele et al., 2017).

Salinity adversely affects reproductive processes, reducing flower formation and boll development. Osmotic and ionic stresses also hinder carbohydrate translocation to bolls, leading to fewer bolls, lower boll weight, and increased shedding, ultimately causing significant yield losses (Zafar et al., 2022). Additionally, salinity impairs fiber elongation and alters cell wall composition due to ionic toxicity, resulting in poorer fiber quality and uneven boll development that negatively affects lint properties (Maryum et al., 2022).

The results showed that potassium humate (PH) and ascorbic acid (AsA), applied individually or in combination, alleviated salinity stress, with PH alone and especially its combined application with AsA outperforming AsA alone across all studied traits. PH mitigates salinity effects by enhancing nutrient uptake, stimulating hormone-like activity, promoting root growth, and improving photosynthetic efficiency, which leads to increased plant height, more fruiting branches, and higher boll setting (Alobaidy et al., 2019; Wang et al., 2025). It also reduces boll shedding through improved nutrient balance and hormonal regulation, thereby enhancing boll retention and yield stability. The observed increases in open bolls and boll weight are attributed to improved flowering, fruit set, nutrient assimilation, and photosynthesis (Alobaidy et al., 2019). Consequently, seed cotton yield increases due to reduced shedding and higher boll number, along with an improved seed index, while lint percentage and fiber quality are enhanced due to better fiber development and reduced stress, and maturity is accelerated through earlier boll opening.

The results indicate that ascorbic acid (AsA) positively enhances cotton growth and productivity under stress through integrated physiological mechanisms. It promotes plant height by stimulating cell division and elongation, reducing oxidative damage, and improving membrane stability (Meloni et al., 2003; Han et al., 2025), while also supporting branching via hormonal balance and enhanced photosynthesis (Hasanuzzaman et al., 2023). AsA improves boll setting by alleviating oxidative stress and stabilizing reproductive processes, and reduces boll shedding through stronger antioxidant defense and better nutrient assimilation. Increased boll opening is linked to enhanced carbohydrate translocation under reduced stress, while greater boll weight results from improved photosynthetic efficiency (El-Beltagi and Mohamed, 2010; Hossain et al., 2017; Smirnoff, 2018). Consequently, seed cotton yield increases due to reduced shedding and higher boll weight, alongside improved lint percentage through stabilized fiber development. AsA also enhances boll retention by protecting reproductive organs and minimizing boll abortion, while sustaining carbohydrate supply for rapid boll filling and early opening (Kamal et al., 2017; Sadaf et al., 2025). Additionally, its interaction with growth regulators such as auxins and gibberellins coordinates vegetative and reproductive development, shortening the period between flowering and maturity (Smirnoff, 2018). Under salinity stress, AsA further improves fiber quality by maintaining photosynthesis and assimilate supply while scavenging reactive oxygen species, thereby producing stronger and finer fibers (Mohamed et al., 2009; Kamal et al., 2017; Sharif et al., 2019; El-Beltagi et al., 2026).

The combined foliar application of potassium humate (PH) and ascorbic acid (AsA) under salinity stress exerts synergistic effects on cotton growth, yield, and fiber quality. This treatment enhances plant height and the number of fruiting branches through improved nutrient availability by PH and protection of metabolic processes by AsA against oxidative damage (Chen et al., 2004; Kamal et al., 2017). It also reduces boll shedding and enhances boll setting and retention, as PH improves nutrient balance while AsA protects reproductive organs from oxidative stress (Sadaf et al., 2025). Consequently, the number of open bolls, boll weight, and seed cotton yield increase. Under saline conditions, fiber quality is typically reduced due to oxidative stress and metabolic imbalances; however, the combined treatment improves fiber traits by stabilizing physiological functions. Fiber strength is enhanced through AsA-mediated protection against oxidative damage and PH-supported nutrient supply for secondary wall formation (Abdelraheem et al., 2019; Xiao et al., 2021). Fiber fineness and length improve due to sustained carbohydrate supply and enhanced cell elongation, while uniformity and maturity are promoted by reduced stress-induced delays and improved nutrient availability, leading to better overall fiber development (Kamal et al., 2017; Sadaf et al., 2025).

Figure 5 illustrates that under saline soil conditions, applying potassium humate to the soil and spraying ascorbic acid on foliage whether individually or together enhanced fiber quality traits such as strength, fineness, and length uniformity. These treatments also increased seed cotton yield while reducing boll shedding. Notably, the combined application proved more effective than either treatment alone, resulting in a 73.57% increase in seed cotton yield, a 62.72% rise in the number of open bolls, and a 14.57% improvement in fiber strength.

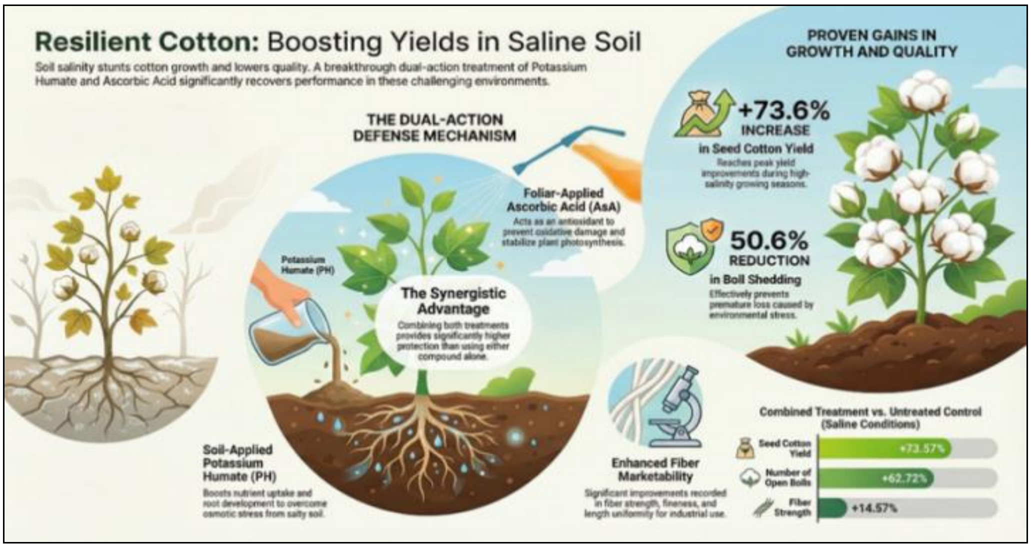

Figure 5. A graphical abstract illustrating the positive effects of applying potassium humate to the soil and ascorbic acid as a foliar spray either individually or in combination - on cotton growth, yield, and fiber quality traits under saline soil conditions

CONCLUSIONS

The present study is one among a few that have evaluated the co-action of potassium humate and ascorbic acid in mitigating salinity stress in cotton plants. The outcomes indicate that the exogenous application of potassium humate to the soil and ascorbic acid as a foliar treatment, whether applied individually or in combination, significantly improves the plant growth, yield, and fiber quality in cotton plants. Such practices have great potential to improve cotton productivity in saline environments, making farming more sustainable.

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REFERENCES

Abdelraheem, A., Fang, D.D., Zhang, J., 2019. *Salt tolerance in cotton*. Advances in Agronomy, 155: 1-71. https://doi.org/10.1016/S0735-2689(02)80036-3

Ahmed, A.H.H., El-Bassiony, A.M., Fawzy, Z.F., 2013. *Effect of putrescine and potassium humate on growth, yield and chemical composition of cotton under saline soil conditions*. World Journal of Agricultural Sciences, 9(3): 230-236. https://doi.org/10.5829/idosi.aejaes.2013.13.04.1965

Akhtar, S., Wahid, A., Rasul, E., 2003. *Emergence, growth and nutrient composition of sugarcane sprout under NaCl salinity.* Biologia Plantarum, 46(1): 113-116. DOI: 10.1023/A:1022326604192

Akhtar, J., Saqib, Z.A., Sarfraz, M., Saleem, I., Haq, M.A., 2010. *Evaluating salt tolerant cotton genotypes at different levels of NaCl stress in solution and soil culture*. Pakistan Journal of Botany, 42(4): 2857-2866.

Alobaidy, M.G., 2013. *Effect of putrescine and humic acid on cotton plant growing under salinity stress conditions.* Doctoral dissertation, Faculty of Agriculture, Cairo University, Egypt. https://doi.org/10.13140/RG.2.2.14527.76969

Alobaidy, M.G., Ahmed, H.H.A., Darwish, E., 2019. *Chemical and morphological effects of humic acid on cotton plant growing under salinity stress conditions.* 5th International Student Symposium at Trakya University, Edirne, Turkey.

Aydogan, C., Girici, Z., Turhan, E.C.E., 2023. *Exogenous application of ascorbic acid to induce tolerance against salt stress in common bean plants*. Romanian Agricultural Research, 40: 117-130. https://doi.org/10.59665/rar4011

ASTM, 1998a. *American Society for Testing Materials. Standard test method for length and length uniformity of cotton fibers by fibrograph measurement (D1447-89)*. Annual Book of ASTM Standards, Vol. 07.01. ASTM, West Conshohocken, PA: 391-395.

ASTM, 1998b. *American Society for Testing Materials. Standard test method for micronaire reading of cotton fibers (D1448-97).* Annual Book of ASTM Standards, Vol. 07.01. ASTM, West Conshohocken, PA: 396-398.

ASTM, 1998c. *American Society for Testing Materials. Standard test method for breaking strength and elongation of cotton fibers (flat bundle method) (D1445-95).* Annual Book of ASTM Standards, Vol. 07.01. ASTM, West Conshohocken, PA: 383-390.

Chaudhary, M.T., Majeed, S., Rana, I.A., Ali, Z., Jia, Y., Du, X., Hinze, L., Azhar, M.T., 2024. *Impact of salinity stress on cotton and opportunities for improvement through conventional and biotechnological approaches.* BMC Plant Biology, 24(1): 20. https://doi.org/10.1186/s12870-023-04558-4

Chen, Y.O.N.A., Clapp, C.E., Magen, H., 2004. *Mechanisms of plant growth stimulation by humic substances: The role of organo-iron complexes.* Soil Science and Plant Nutrition, 50(7): 1089-1095. https://doi.org/10.1080/00380768.2004.10408579

Dane, J.H., and Topp, C.G., 2020. *Methods of soil analysis*. Part 4: Physical Methods, John Wiley & Sons.

Duncan, D.B., 1955. *Multiple Range and Multiple F-Tests*. Biometrics, 11: 1-42. http://dx.doi.org/10.2307/3001478

El-Beltagi, H.S., and Mohamed, A.A., 2010. *Changes in non-protein thiols, some antioxidant enzymes activity and ultrastructural alteration in radish plant (Raphanus sativus L.) Grown under lead toxicity*. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 38(3): 76-85. https://doi.org/10.15835/nbha3834631

El-Beltagi, H.S., Al-Otaibi, H.H., Parmar, A., Ramadan, K.M., Lobato, A.K.D.S., El-Mogy, M.M., 2023. *Application of potassium humate and salicylic acid to mitigate salinity stress of common bean.* Life, 13(2): 448. https://doi.org/10.3390/life13020448

El-Beltagi, H.S., El Nady, M.F., Mahmoud, A., Metwaly, M.M.S., 2026. *Amelioration of salinity stress in tomato by foliar sprays of ascorbic acid and proline.* Bioagro, 38(1): 407-420. https://doi.org/10.51372/bioagro381.2

El-Hawary, M.M., Hashem, O.S.M., Hasanuzzaman, M., 2023. *Seed Priming and Foliar Application with Ascorbic Acid and Salicylic Acid Mitigate Salt Stress in Wheat.* Agronomy, 13: 1-19. https://doi.org/10.3390/agronomy13020493

Han, P., Ma, H., Lu, L., Zhu, J., Nie, X., Xu, J., Li, Z., 2025. *Ascorbic acid priming boosts cotton seed chilling tolerance via membrane stability and antioxidant cycles*. Plants, 14(20): 1-16. https://doi.org/10.3390/plants14203122

Hasanuzzaman, M., Raihan, M.R.H., Alharby, H.F., Al-Zahrani, H.S., Alsamadany, H., Alghamdi, K.M., Ahmed, N., Nahar, K., 2023. *Foliar application of ascorbic acid and tocopherol in conferring salt tolerance in rapeseed by enhancing K^+/Na^+ homeostasis, osmoregulation, antioxidant defense, and glyoxalase system.* Agronomy, 13(2): 1-20. https://doi.org/10.3390/agronomy13020361

Hossain, M.A., Munné-Bosch, S., Burritt, D.J., Diaz-Vivancos, P., Fujita, M., Lorence, A., 2017. *Ascorbic acid in plant growth, development and stress tolerance*. Springer, Berlin.

Kamal, M.A., Saleem, M.F., Shahid, M., Awais, M., Khan, H.Z., Ahmed, K., 2017. *Ascorbic acid triggered physiochemical transformations at different phenological stages of heat-stressed Bt cotton*. Journal of Agronomy and Crop Science, 203(4): 323-331. https://doi.org/10.1111/jac.12211

Kiruthiga, N., Dhanapal, S., Devi, L.A., Joan, C.D., Shabeena Begum, A.B., Saravanan, K., 2025. *Exogenous ascorbic acid priming for mitigation of salinity stress in soybean [Glycine max (L.) Merrill] cv. Indira Soy*. Crop Research, 60: 0970-4884. https://doi.org/10.31830/2454-1761.2025.CR-998

Lasheen, F.F., Hewidy, M., Abdelhamid, A.N., Thabet, R.S., Abass, M.M., Fahmy, A.A., Saudy, H.S., Assan, K.M., 2024. *Exogenous application of humic acid mitigates salinity stress on pittosporum (Pittosporum tobira) plant by adjusting the osmolytes and nutrient homeostasis*. Journal of Crop Health, 76(1): 317-325. https://doi.org/10.1007/s10343-023-00939-9

Maryum, Z., Luqman, T., Nadeem, S., Khan, S.M.U.D., Wang, B., Ditta, A., Khan, M.K.R., 2022. *An overview of salinity stress, mechanism of salinity tolerance and strategies for its management in cotton*. Frontiers in Plant Science, 13: 1-22. https://doi.org/10.3389/fpls.2022.907937

Meloni, D.A., Oliva, M.A., Martinez, C.A., Cambraia, J., 2003. *Photosynthesis and activity of superoxide dismutase, peroxidase and glutathione reductase in cotton under salt stress.* Environmental and Experimental Botany, 49(1): 69-76. https://doi.org/10.1016/S0098-8472(02)00058-8

Mohamed, A.A., El-Beltagi, H.S., Rashed, M.M., 2009. *Cadmium stress induced change in some hydrolytic enzymes, free radical formation and ultrastructural disorders in radish plant*. Electronic Journal of Environmental, Agricultural and Food Chemistry, 8: 969.

Muhammad, N., Dong, Q., Luo, T., Zhang, X., Song, M., Wang, X., Ma, X., 2025. *New developments in understanding cotton's physiological and molecular responses to salt stress*. Plant Stress, 15: 1-16. https://doi.org/10.1016/j.stress.2025.100742

Munns, R., and Tester, M., 2008. *Mechanisms of salinity tolerance*. Annual Review of Plant Biology, 59: 651-681. https://doi.org/10.1146/annurev.arplant.59.032607.092911

Nawaz, K., Hussain, K., Majeed, A., Khan, F., Afghan, S., Ali, K., 2010. *Fatality of salt stress to plants: Morphological, physiological and biochemical aspects.* African Journal of Biotechnology, 9: 5475-5480.

Nxele, X., Klein, A., Ndimba, B.K., 2017. *Drought and salinity stress alters ROS accumulation, water retention, and osmolyte content in sorghum plants*. South African Journal of Botany, 108: 261-266. https://doi.org/10.1016/j.sajb.2016.11.003

Pereira, M.M.A., Morais, L.C., Marques, E.A., Martins, A.D., Cavalcanti, V.P., Rodrigues, F.A., Pasqual, M., Dória, J.O.Y.C.E., 2019. *Humic substances and efficient microorganisms: elicitation of medicinal plants-a review.* Journal of Agricultural Science, 11(7): 268-280. https://doi.org/10.5539/jas.v11n7p268

Petcu, E., Schitea, M., Badea, D., 2007. *The behavior of some Romanian alfalfa genotypes to salt and water stress.* Romanian Agricultural Research, 24: 51-54.

Rady, M.M., 2016. *Humic acid application improves field performance of cotton under saline conditions.* Journal of Plant Nutrition, 39(3): 356-367.

Sadaf, U.S., Shah, S., Jamal, A., Mihoub, A., Farhan, S.M., Ahmad, I., Radicetti, E., Zia, A., Mastinu, A., Erný, J., 2025. *Foliar application of ascorbic acid and α-tocopherol enhances salinity tolerance in Hordeum vulgare L. by regulating antioxidant enzymatic activity and improving physiological and biochemical responses.* Journal of Crop Health, 77(4): 1-21. https://doi.org/10.1007/s10343-025-01182-0

Sharif, I., Aleem, S., Farooq, J., Rizwan, M., Younas, A., Sarwar, G., Chohan, S.M., 2019. *Salinity stress in cotton: effects, mechanism of tolerance and its management strategies.* Physiology and Molecular Biology of Plants, 25(4): 807-820. https://doi.org/10.1007/s12298-019-00676-2

Singh, P., 2004. *Cotton Breeding*. Kalyani Publishers, New Delhi, India, 295p.

Smirnoff, N., 2018. *Ascorbic acid metabolism and functions: A comparison of plants and mammals.* Free Radical Biology and Medicine, 122: 116-129. https://doi.org/10.1016/j.freeradbiomed.2018.03.033

Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., 2020. *Methods of soil analysis, part 3: Chemical methods*. John Wiley & Sons.

Wang, X., Ding, J., Wang, J., Han, L., Tan, J., Liu, J., Ge, X., 2025. *Humic acid enhances the soil amelioration effect of biochar on saline-alkali soils in cotton fields*. Agronomy, 15(10): 1-17. https://doi.org/10.3390/agronomy15102412

Xiao, M., Li, Z., Zhu, L., Wang, J., Zhang, B., Zheng, F., Zhao, B., Zhang, H., Wang, Y., Hang, Z., 2021. *The multiple roles of ascorbate in the abiotic stress response of plants: Antioxidant, cofactor, and regulator*. Frontiers in Plant Science, 12: 1-13. https://doi.org/10.3389/fpls.2021.598173

Zafar, M.M., Shakeel, A., Haroon, M., Manan, A., Sahar, A., Shoukat, A., Mo, H., Farooq, M.A., Ren, M., 2022. *Effects of salinity stress on some growth, physiological, and biochemical parameters in cotton (Gossypium hirsutum L.) germplasm*. Journal of Natural Fibers, 19(14): 8854-8886. https://doi.org/10.1080/15440478.2021.1975596

Zhang, D., Zhang, Y., Sun, L., Dai, J., Dong, H., 2023. *Mitigating salinity stress and improving cotton productivity with agronomic practices.* Agronomy, 13(10): 1-15. https://doi.org/10.3390/agronomy13102486