Journal of Applied Agriculture and Biotechnology 2016 1(2): 48–57
ISSN (print): 2415-6728
ISSN (online): 2415-6736

Research article

Additional application of plant nutrients with farm yard manure for improving the adaptation of cotton crop to salinity stress

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HIGHLIGHTS

- Salinity stress increased leaf Na^+ concentration, decreased K^+ and K^+: Na^+ ratio
- Salinity stress caused a marked decrease in growth, yield and fiber quality of cotton
- Application of N, P, K and Zn, could provide a protective mechanism against salinity stress
- Combined application of N, P, K and Zn with FYM was more beneficial against salinity stress

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How to cite
Khan H.R., M. Ashraf, S.M. Shahzad, A. Aziz, M.A. Piracha and A.R. Siddiqui. 2016. Adequate regulation of plant nutrients for improving cotton adaptability to salinity stress. J. Appl. Agric. Biotechnol., 1(2): 48-57.

ABSTRACT

Cotton (*Gossypium hirsutum* L.) is the world's leading natural fiber, and generally considered moderately tolerant to salinity with a threshold level of 7.7 dS m^{-1}. Adequate regulation of plant nutrients can provide an important strategy to improve the adaptation of plants to saline environment. The present research was planned to investigate the role of plant nutrients in ameliorating the deleterious effects of salinity on growth, yield and fiber quality of cotton grown under salinity stress. Ten treatments comprising of nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn) with and without farm yard manure at 10 dS m^{-1} electrical conductivity (EC) were arranged in completely randomized design with three replications. Results revealed that imposition of 10 dS m^{-1} EC increased leaf Na^+concentration by 300% but decreased leaf K^+ by 46% and leaf K^+: Na^+ ratio 87% with a subsequent marked reduction in growth, yield and fiber quality characteristics of cotton. The application of additional N, P, K, and Zn either alone or in combination effectively reduced Na^+, increased K^+ concentration and K^+: Na^+ ratio, leading to improved plant growth and yield. Among all treatments, higher ameliorative effects were observed for 100 mg N+75 mg P_2O_5+75 mg K_2O+12 mg Zn kg^{-1} soil+ 5% FYM (w/w). This study suggested that nutrients-mediated reduction in Na^+ accumulation, increase in K^+ concentration and K^+: Na^+ ratios were the main factors contributing to the improved adaptation of cotton crop to saline environment.

Key words: Fiber quality, Nitrogen, Phosphorus, Potassium, Salinity

1. Introduction Soil salinization is a common problem in arid and semiarid regions where evapo-transpiration exceeds the leaching, leading to the deposition of soluble salts in the rhizosphere (Ashraf *et al*., 2012). About 10% of the total land area in the world is affected by salinity to varying degrees and posing severe threat to food safety and security. Sodium ion (Na^+) is a major contaminant of salt affected soils and assumed to imbalance cellular ions that resulted in ion toxicity, osmotic stress and oxidative damage, and consequently led to reduced plant growth and survival (Hashemi *et al*., 2010). Pakistan has a geographical area of 80.5 Mha, out of which 20.36 Mha are under cultivation. Approximately, 10 Mha of total agricultural land area in Pakistan is affected by salinity or sodicity (FAO, 2008). According to Sattar *et al*. (2010), soil salinity in Pakistan is the product of climatic conditions, original soil chemistry, land use, irrigation practices, and the shallow depth of the water table.

Cotton (*Gossypium hirsutum* L.) is a major cash crop grown in the plains of Pakistan. It occupies a unique position in the agriculture-based-economy and plays an important role in the economic viability of Pakistan. Pakistan is the fourth largest cotton producing country after China, USA and India (FAO, 2012). It provides raw material for the textile industry and is also a major source of high quality vegetable oil and feed for livestock. This crop is also the second source of plant proteins after soybean, and the fifth oil-producing plant after soybean, palm oil, canola and sunflower. It is placed in the moderately salt-tolerant group of plant species with a salinity threshold level 7.7 dS m^{-1}, its growth being severely reduced at high salinity levels depending upon plant growth stage, salt concentration and composition as well as duration of salinity stress. Dong (2012) reported that excessive salts in the soil led to a series of physiological and biochemical disorders in cotton plants mainly as a result of osmotic effects, nutritional imbalance and toxicity of salt ions (Na^+ and Cl^-). Khorsandi and Anagholi (2009) also reported that soil salinity delayed and reduced germination and emergence, decreased cotton shoot growth, and finally led to reduced seed cotton yield and fiber quality at moderate to high salinity levels.

Adequate supplementation of plant nutrients to saline environment can provide a promising approach for improving plant adaptability to salinity stress. Some past studies had shown that salinity-induced growth inhibition could be reversed by proper use of fertilizers depending on plant species, salinity level, and environmental conditions (Tuna *et al*., 2007; Ashraf *et al*., 2009; Ashraf *et al*., 2010). Among different mineral nutrients, nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn) may play a significant role in improving plant adaptation to salinity stress (Chen *et al*., 2007; Cuin *et al*., 2008; Tahir *et al*., 2012). These nutrients have been reported to interact with Na^+, reduced its uptake and translocation to aerial plant parts (Zhu *et al*., 2004; Ahmad, *et al*., 2009). Nitrogen is an essential plant element and its uptake is generally restricted under salinity stress due to antagonism between NO_3^- and Cl^-, a major ion in saline soil (Mengel and Kirkby, 2001). Nitrogen addition to saline environment may help to improve plant tolerance to salinity due to its involvement in the mitigation of ion toxicity, osmotic adjustment and stimulation of antioxidant efficiency (Abdelgadir *et al*., 2005). Supplementary P may have a significant role in the alleviation of the adverse effects of high salinity because excessive absorption of Cl^- reduced the uptake of $H_2PO_4^-$ and interfered with energy synthesis (Naheed *et al*., 2007). Likewise, addition of K to salt stressed plants improved the level of endogenous K, leading to increased salt tolerance in many plant species (Akram *et al*., 2009). According to Cha-Um *et al*. (2010) maintaining an adequate supply of K in saline soil is an important factor in controlling the severity of specific ion toxicity, particularly in crops which are susceptible to Na^+ and Cl^- injury. It has also been reported that zinc (Zn) application to salt stressed medium significantly improved photosynthesis, water use efficiency, mesophyll efficiency and quantum yield. Robbins (1986) reported that use of waste matter and farm yard manure (FYM) improved water infiltration, water holding capacity and aggregate stability of soil. Walker *et al*. (2004) also reported that promotion in plant growth by manure in two *Brassica species* under salinity stress was related to decline in shoot Na^+ or increase in shoot K^+ concentration.

Despite considerable work has been reported to examine the role of mineral nutrition in salt tolerance of wide variety of crops, there is very little information regarding the contribution of N, P, K and Zn to alleviate salt toxicity in cotton. Accordingly, the present study was conducted to evaluate the effectiveness of N, P, K, and Zn in combination with FYM to improve the adaptation capability of cotton crop to salinity stress.

2. Materials and methods

2.1. Plant growth

A pot experiment was conducted to investigate ameliorative effects of N, P, K and Zn along with FYM on the adaptation capability of cotton (*Gossypium hirsutum* L.) to salinity stress. Cotton seeds of cultivar BT-Super 101 were sown in first week of June in earthen pots, filled with 12 kg well prepared soil in each pot. Initially, three seeds were grown in each pot which were thinned to one plant pot^{-1} after germination. Recommended dose of N (800 mg) as urea, P (500 mg P_2O_5) as single super phosphate and K (500 mg K_2O) as potassium sulfate were applied. Whole P and K were applied at the time of sowing while N was applied in two splits (at the time of sowing and 30 days after germination). Plants were irrigated with one liter of ground water thrice a week. All other cultural practices were followed uniformly for all treatments. Pre-sowing soil analysis of experimental soil was given in Table 1. The analysis of FYM and ground water used in this experiment was given in Table 2 and Table 3, respectively.

2.2. Experimental treatments

Ten treatments comprising of T_1: Control (recommended N, P, K and Zn); T_2: 10 dS m^{-1} EC (electrical conductivity) + recommended N, P, K and Zn; T_3: 10 dS m^{-1} EC + 100 mg additional N kg^{-1} soil; T_4: 10 dS m^{-1} EC + additional 75 mg P_2O_5 kg^{-1} soil; T_5: 10 dS m^{-1} EC + additional 75 mg K_2O kg^{-1}; T_6: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O kg^{-1} soil; T_7: 10 dS m^{-1} EC + 12 mg Zn kg^{-1} soil; T_8: 10 dS m^{-1} EC + 12 mg Zn+ 5% FYM (w/w); T_9: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn kg^{-1} soil; T_{10}: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn + 5% FYM (w/w) were arranged in completely randomized design with three replications. Urea, single super phosphate, potassium sulfate and zinc sulfate were used as the source of N, P, K and Zn, respectively. All the treatments were applied at the time of sowing while FYM was incorporated before sowing. Salinity was developed in two intervals one week after germination using NaCl.

Table 1: Physicochemical properties of soil used in the experiment

Parameters	Unit	Value
Textural class	--	Sandy clay loam
Sand	%	49
Silt	%	23
Clay	%	28
pH		7.9
EC_e	dS m^{-1}	1.8
Saturation percentage	%	42
Organic matter	%	0.8
CO_3^{2-}	$mmol_c$ L^{-1}	Nil
HCO_3^-	$mmol_c$ L^{-1}	3.1
Ca^{+2}+Mg^{+2}	$mmol_c$ L^{-1}	3.2
Available K	mg kg^{-1}	220
P	mg kg^{-1}	8.4
SO_4^{2-}	$mmol_c$ L^{-1}	5.8
Na^+	$mmol_c$ L^{-1}	14
$CaCO_3$	%	4

2.3. Ionic determination

Forty days after treatment completion, leaf samples were collected, washed with distilled water, air dried and then oven dried to a constant weight at 70°C in a forced air oven. The dried leaf tissues were ground to 40-mesh with a Wiley mill fitted with stainless steel blades and chamber. A 0.5 g portion of ground leaf samples were digested with di-acid mixture of nitric acid and Perchloric acid (2:1). K^+ and Na^+ were determined with flame photometer, P with spectrophotometer while Zn with atomic absorption spectroscopy.

2.4. Plant growth and yield characteristics

At maturity, plant growth characteristics including plant height, number of leaves plant^{-1} and number of bolls per plant^{-1} were recorded.

Table 2: Characteristics of farm yard manure used in the experiment

Characteristics	Unit	Value
Water content	%	78.9
Organic matter	%	12.9
Nitrogen	%	0.27
Phosphorus	%	0.21
Potassium	%	0.18
Organic carbon	%	6.98
C: N ratio		25.9
C: P ratio		33.2
C: K ratio		38.8

2.5. Fiber quality

Fiber quality characteristics including ginning out turn was recorded as ratio between weight of the lint and weight of the seed cotton, fiber length by Fibrograph, fiber fineness by Micronaire Tester and fiber strength by Pressley Fiber Bundle Tester.

Table 3: Analysis of irrigation water used in the experiment

Characteristics	Unit	Value
Electrical conductivity	dS m^{-1}	0.94
Total soluble salts	mmol$_c$ L^{-1}	9.4
Carbonates	mmol$_c$ L^{-1}	0.4
Bicarbonates	mmol$_c$ L^{-1}	5.8
Chloride	mmol$_c$ L^{-1}	1.7
Sulphate	mmol$_c$ L^{-1}	1.5
Calcium+Magnesium	mmol$_c$ L^{-1}	5.2
Sodium	mmol$_c$ L^{-1}	4.2
Sodium adsorption ratio	(mmol$_c$ L^{-1})$^{1/2}$	2.60
Residual sodium carbonates	mmol$_c$ L^{-1}	1.0

2.4. Statistical analysis

The experiment was designed and analyzed based on completely randomized design with three replications. The recorded data were subjected to analysis of variance (ANOVA) by using Mstat-C statistical software. The differences between the treatment means were compared using the least significant difference test at 5% level of significance (LSD, P ≤ 0. 05).

3. Results

3.1. Plant growth characteristics

There was a significant effect of salinity and added plant nutrients on growth characteristics of cotton (Table 4). Maximum plant height was found in control which was decreased by 56.9% at 10 dS m^{-1} EC. However, plant height was markedly improved with the application of different plant nutrients and FYM. It was found that plant height was improved by 50.5% with the application N, 29.07 with P, 67.59% with K, 80.92% with N+P+K, 17.22% with Zn, 20.74% with Zn+FYM, 69.25% with N+P+K+Zn and 105% with N+P+K+Zn+FYM compared to salt stressed plants without additional fertilizers. Maximum number of bolls plant^{-1} was found in control which was decreased by 66.66% at 10 dS m^{-1} EC. Number of bolls plant^{-1} was increased by 60% with the application of N, 26% with P, 100% with K, 114% with N+P+K, 40% with Zn, 46% with Zn+FYM, 134% with N+P+K+Zn and 154% with N+P+K+Zn+FYM compared to salt stressed plants without additional fertilizers. Maximum number of leaves plant^{-1} were found in control which was decreased by 47.73% at 10 dS m^{-1} EC. Number of leaves plant^{-1} was increased by 45.48% with the application of N, 55.23% with P, 61.37% with K, 63.53% with N+P+K, 4.69% with Zn, 22.02% with Zn+FYM, 74.30% with N+P+K+Zn and 74.72% with N+P+K+Zn+FYM compared to salt stressed plants without additional fertilizers.

3.2. Leaf ionic composition

The perusal of data presented in Table 5 indicates that maximum leaf K^+ concentration was found in control which was decreased by 46% at 10 dS m^{-1} EC. Results revealed that leaf K^+ concentration was improved by 32% with the application of N, 34% with P, 98% with K, 111% with N+P+K, 15% with Zn, 41% with Zn+FYM, 115% with N+P+K+Zn and 118% with N+P+K+Zn+FYM compared to salt stressed plants without additional fertilizer application. In contrast, minimum Na^+ concentration was found in control treatment which was increased by 300% at 10 dS m^{-1} EC. However, leaf Na^+ concentration in cotton was decreased by 43% with the application of N, 29% with P, 46% with K, 53% with N+P+K, 20% with Zn, 18% with Zn+FYM, 56% with N+P+K+Zn and 51% with N+P+K+Zn+FYM compared to salt stressed plants without additional fertilizer application. Maximum leaf K^+: Na^+ ratio was found in control which was decreased by 87% at 10 dS m^{-1} EC. However, leaf K^+: Na^+ ratio was improved in cotton by 133% with the application of N, 90% with P, 272% with K, 353% with N+P+K, 45% with Zn, 72% with Zn+FYM, 390% with N+P+K+Zn and 350% with N+P+K+Zn+FYM compared to salt stressed plants without any additional fertilizers. Leaf P concentration was decreased by 41% at 10 dS m^{-1} EC. Phosphorus concentration in cotton leaves was improved by 21% with the application N, 131% with P, 42% with K, 158% with N+P+K, 147% with N+P+K+Zn and 163% with N+P+K+Zn+FYM compared to salt stressed plants without additional fertilizers. Leaf Zn concentration was decreased by 39% at 10 dS m^{-1} EC. Zinc concentration in cotton leaves was improved by 49% with the application N, 35% with K, 32% with N+P+K, 113% with Zn, 134% with Zn+FYM, 152% with N+P+K+Zn and 164% with N+P+K+Zn+FYM while it was reduced by 7% with P compared to salt stressed plants without additional fertilizers.

3.3. Fiber quality characteristics

There was a significant (P ≤ 0. 05) effect of salinity and plant nutrients (N, P, K, Zn and FYM) on fiber quality characteristics of cotton, however these characteristics were relatively less influenced by supplemental nutrients application under saline conditions as compared to growth and ionic characteristics (Table 6). All plant nutrients were found to be effective in ameliorating the adverse effects of salinity on fiber quality in terms of ginning out turn, staple length, staple strength, fiber fineness and maturity percentage. However, more pronounced ameliorating effects of plant nutrients against salinity stress were observed when these plant nutrients were added in combination, particularly along with FYM.

Table 4: Plant nutrition effects on growth characteristics of cotton (*Gossypium hirsutum* L.) grown under salinity stress

Treatments	Plant height (cm)	Bolls $plant^{-1}$	Leaves $plant^{-1}$
Control	125.5a	15.0a	53.0a
10 dS m^{-1} EC	54.0f	5.0e	27.7f
10 dS m^{-1} EC+N	81.3cd	8.0c	40.3c
10 dS m^{-1} EC+P	69.7e	6.3d	43.0bc
10 dS m^{-1} EC+K	90.5c	10.0bc	44.7b
10 dS m^{-1} EC+N+P+K	97.7bc	10.7b	45.3b
10 dS m^{-1} EC+Zn	63.3e	7.0cd	29.0e
10 dS m^{-1} EC+Zn+FYM	65.2e	7.3cd	33.8d
10 dS m^{-1} EC+N+P+K+Zn	91.4c	11.7b	48.3ab
10 dS m^{-1} EC+N+P+K+ZN+FYM	110.7b	12.7b	48.4ab

Values in a column followed by the same letter are not significantly different at $P \leq 0.05$. T_1: Control (recommended nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn); T_2: 10 dS m^{-1} EC (electrical conductivity) + recommended N, P, K and Zn; T_3: 10 dS m^{-1} EC + additional 100 mg N kg^{-1} soil; T_4: 10 dS m^{-1} EC + additional 75 mg P_2O_5 kg^{-1} soil; T_5: 10 dS m^{-1} EC + additional 75 mg K_2O kg^{-1}; T_6: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O kg^{-1} soil; T_7: 10 dS m^{-1} EC + 12 mg Zn kg^{-1} soil; T_8: 10 dS m^{-1} EC + 12 mg Zn + 5% FYM (w/w); T_9: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn kg^{-1} soil; T_{10}: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn + 5% FYM (w/w)

4. Discussion

Reduction in plant height and number of leaves plant^{-1} under salinity stress were attributed to reduced cell turgidity, cell division and elongation, reduced photosynthesis and altered plant metabolism. Salinity also caused leaf injury and death, leading to lower number of leaves (Munns, 2005). Reduction in plant height under salt stress might be resulted from reduced leaf emergence, leaf expansion and final leaf area under saline conditions which consequently limited the process of photosynthesis, dry matter accumulation and ultimate growth (Higbie *et al*., 2010). The other causes of plant height reduction under saline conditions may include shrinkage of cell contents, reduced development and differentiation of tissues, unbalanced nutrition and damage of membranes (Kent and Lauchli, 1985). Kaya *et al*. (2001) reported that high NaCl induced P and K deficiencies in the leaves. Foliar spray of KH_2PO_4 alleviated the adverse effects of high salinity on plants and improved plant growth parameters. Marschner (1995) reported that N, P and K have been implicated in turgor regulation, thus deficiency of these plant nutrients in saline environment could contribute to the decrease in plant height, leaf emergence and leaf expansion in the NaCl-treated plants. Khan *et al*. (2013) also found that salinity-induced reduction in number of leaves plant^{-1} could be overcome by the application of foliar spray of N and K fertilizers. The significant reduction in number of bolls plant^{-1} was due to the reason that increased salt concentration produced a stressful effect on flowering and boll formation in cotton because of a decrease in number and growth of sympodia (fruit bearing branches). These findings were supported by Phogat *et al.* (2001) and Chaudhry *et al.* (2001). However, number of bolls plant^{-1} was significantly improved by the supplementation of N, P, K and Zn in combination with FYM. Pang and Laty (2000) reported a positive interaction between the combination of organic manures and NPK in improving plant tolerance to salinity. According to Khaliq *et al*. (2006), long term use of organic manures greatly improved the cotton growth and soil quality characteristics.

Adequate regulation of plant nutrients played a crucial role in maintaining cell turgor through osmotic adjustment, reducing Na^+ uptake, increasing K^+ and maintaining a high cytosolic K^+: Na^+ ratio, and stimulating antioxidant defense system under salinity stress. Salinity-induced K^+ deficiency could usually be attributed to; firstly, high levels of Na^+ could inhibit K^+ activity in the soil solution, resulting in a reduction of K^+ availability, secondly, Na^+ not only interfered with K^+ translocation from root to shoot (Botella *et al*., 1997), but also competed with K^+ for uptake sites at the plasma membrane, resulting in lower K^+ uptake, thirdly, salinity stress led to plasma membrane dis-integrity and favored K^+ leaking, resulting in a rapid decline in cytosolic K^+ (Coskun *et al*., 2010). In addition, salinity-induced significant membrane depolarization and favored K^+ leaking through depolarization-activated outward-rectifying K^+ channels caused K deficiency under salinity stress. However, an adequate fertilization and application of additional N, P and K may enhance plant growth due to reduction in Na^+ and Cl^- toxicity and the maintenance of nutrient balances (Hu and Schmidhalter, 2005). It is well established fact that high leaf K^+ concentration may alleviate salt stress effects by minimizing oxidative stress and/or contributing to osmotic adjustment (Cakmak, 2005). Past studies demonstrated that application of fertilizers to the salt treated plants may reduce toxic ions uptake as well improve K and N status of salt treated plants. Nitrogen being an active participant of chlorophyll and protein is an essential element for plant growth. Potassium supplementation resulted in reduced Na^+ uptake, an increase in leaf K^+ content which was accompanied by increased growth rate and development. Hence, there was considerable improvement in growth even under saline conditions with the adequate regulation of mineral nutrients. Akram *et al.* (2009) observed a significant reduction in Na^+ uptake and accumulation with a consequent improvement in growth of sunflower due to the foliar spray of K_2SO_4 and KNO_3 at 1.25% under saline concentration of 150 mM NaCl. K^+: Na^+ ratio is an important parameter for the assessment of degree of salt tolerance in plants. Application of KNO_3 under salinity stress decreased Na^+ but increased K^+ in leaf and thus maintained high K^+: Na^+ ratio which contributed significantly to salt tolerance in plants (Gimno *et al*., 2009). Ashraf *et al*. (2015) also reported that K^+-induced salt-tolerance in sugarcane genotypes was believed to be associated with decreased Na^+ concentration and increased K^+ concentration, particularly in shoots with a resultant improvement in shoot K^+: Na^+ ratio of both salt tolerant and salt sensitive genotypes. The reduction in P availability in saline soils was to be a result of ionic strength effects that reduced the activity of phosphate.

Table 5: Nutrition effects on leaf ionic composition of cotton (*Gossypium hirsutum* L.) grown under salinity stress

Treatments	K^+ (%)	Na^+ (%)	K^+: Na^+	P (%)	Zn (ppm)
Control	2.52b	0.66e	3.81a	0.32c	49.1d
10 dS m^{-1} EC	1.36e	2.64a	0.51gh	0.19de	29.7f
10 dS m^{-1} EC+N	1.80cd	1.51c	1.19f	0.23d	44.4d
10 dS m^{-1} EC+P	1.83cd	1.88bc	0.97fg	0.44ab	27.1f
10 dS m^{-1} EC+K	2.70ab	1.42c	1.90de	0.27cd	40.0de
10 dS m^{-1} EC+N+P+K	2.87a	1.24cd	2.31d	0.49a	39.2e
10 dS m^{-1}EC+Zn	1.57de	2.10b	0.74g	0.19de	63.2bc
10 dS m^{-1}EC+Zn+FYM	1.92cd	2.16b	0.88fg	0.20de	69.6b
10 dS m^{-1}EC+N+P+K+Zn	2.93a	1.17d	2.50cd	0.47a	74.8a
10 dS m^{-1} EC+N+P+K+ZN+FYM	2.97a	1.29d	2.30d	0.50a	78.5a

Values in a column followed by the same letter are not significantly different at $P \leq 0.05$. T_1: Control (recommended nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn); T_2: 10 dS m^{-1} EC (electrical conductivity) + recommended N, P, K and Zn; T_3: 10 dS m^{-1} EC + additional 100 mg N kg^{-1} soil; T_4: 10 dS m^{-1} EC + additional 75 mg P_2O_5 kg^{-1} soil; T_5: 10 dS m^{-1} EC + additional 75 mg K_2O kg^{-1}; T_6: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O kg^{-1} soil; T_7: 10 dS m^{-1} EC + 12 mg Zn kg^{-1} soil; T_8: 10 dS m^{-1} EC + 12 mg Zn + 5% FYM (w/w); T_9: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn kg^{-1} soil; T_{10}: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn + 5% FYM (w/w)

Table 6: Plant nutrition effects on fiber quality characteristics of cotton (*Gossypiumhirsutum* L.) grown under salinity stress

Treatments	Ginning out turn (%)	Staple length (mm)	Staple strength (tppsi)	Fiber fineness (µg/inches)	Maturity percentage
Control	38.04b	29.4a	96.87a	4.5bc	81.8ab
10 dS m^{-1} EC	31.66d	26.3c	76.47f	3.8f	77.5f
10 dS m^{-1} EC+N	40.34a	27.3bc	85.63cd	4.4c	81.1b
10 dS m^{-1} EC+P	38.67b	28.5b	87.00c	4.4c	80.3c
10 dS m^{-1} EC+K	38.09b	27.8bc	92.37b	4.6b	80.9bc
10 dS m^{-1} EC+N+P+K	36.29b	28.7b	93.13b	4.5bc	82.2a
10 dS m^{-1} EC+Zn	35.81c	26.5c	80.90e	4.2d	81.4b
10 dS m^{-1} EC+Zn+FYM	37.63b	26.8c	84.27d	4.4c	80.9bc
10 dS m^{-1} EC+N+P+K+Zn	39.4ab	28.7b	91.87b	4.8a	81.7ab
10 dS m^{-1} EC+N+P+K+ZN+FYM	41.11a	29.2a	95.70a	4.7ab	82.2a

Values in a column followed by the same letter are not significantly different at $P \leq 0.05$. T_1: Control (recommended nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn); T_2: 10 dS m^{-1} EC (electrical conductivity) + recommended N, P, K and Zn; T_3: 10 dS m^{-1} EC + additional 100 mg N kg^{-1} soil; T_4: 10 dS m^{-1} EC + additional 75 mg P_2O_5 kg^{-1} soil; T_5: 10 dS m^{-1} EC + additional 75 mg K_2O kg^{-1}; T_6: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O kg^{-1} soil; T_7: 10 dS m^{-1} EC + 12 mg Zn kg^{-1} soil; T_8: 10 dS m^{-1} EC + 12 mg Zn + 5% FYM (w/w); T_9: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn kg^{-1} soil; T_{10}: 10 dS m^{-1} EC + 100 mg N + 75 mg P_2O_5 + 75 mg K_2O + 12 mg Zn + 5% FYM (w/w)

Application of P under saline conditions improved energy flow and contributed to salt tolerance (Grattan and Grieve, 1992). Khoshgoftar *et al*. (2004) reported that Zn application increased dry matter yield at different levels of salinity.

Salinity also had an adverse effect on fiber characteristics of cotton as evidenced by marked reduction in ginning out turn, staple length, staple strength, fiber fineness and maturity percentage of cotton at 10 dS m^{-1} EC. These results are in agreement with the findings of Görmüs (2005); Ahmad *et al*. (2009); Sawan (2014). In saline environment, excess Na^+ or deficiency of K^+, particularly at reproductive stage could damage the structure of fruit-bearing organs, and decreased the seed cotton yield and fiber quality (Zhang *et al.,* 2014). External supplementation of plant nutrients alleviated the deleterious effects of salinity and improved fiber quality characteristics. The results indicated that N, P, K and Zn supplementation either alone or in combination with FYM proved effective in mitigating the adverse effect of salinity and improving the fiber quality characteristics under salinity stress. These results were in agreement to previous results reported by Faircloth *et al.* (2004) where it was found the application of N improved fiber quality in cotton. Some other studies, for example Aneela *et al.* (2003); Pervez *et al.* (2004); Pettigrew *et al.* (2005); Sharma and Sundar (2007); Sawan (2014) also reported an improvement in cotton growth, lint yield and fiber quality by regulating plant nutrition.

5. Conclusion

Salinity had deleterious effects on cotton growth, ionic composition, yield and fiber quality, however the growth and yield were more affected than fiber quality. Exogenous application of plant nutrients interacted with Na^+, reduced its uptake while increased K^+ and K^+: Na^+ ratio with the subsequent improvement in cotton growth, yield and fiber quality. Although, individual application N, P, K or Zn was effective to mitigate the damaging effects of increasing salinity but maximum improvement in plant growth and fiber quality characteristics of cotton was found when N, P, K and Zn were applied in combination, particularly along with FYM.

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