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Effect of micronutrient humate and organic manure on growth, yield, and quality parameters of cotton (*Gossypium hirsutum*) under saline sodic condition

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Abstract
Therefore, study was conducted during 2018 at Karanampoondi village, Tamilnadu, India to evaluate the effect of different micronutrients humate and organic manure on the growth, yield and quality of cotton in saline sodic soil. In this study, three micronutrients humate namely, zinc humate, manganese humate and magnesium boro humate and three different organic manures viz., FYM, Vermi Compost, and Green Leaf Manure were used. The experiment was laid out in randomised block design __ replicated thrice. The results revealed that, application of $Zn_{5.0}Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha (T_5) recorded the highest growth (plant height, leaf area index and dry matter production), yield attributing character and yield of cotton. This was followed by T_4 ($Zn_{5.0}Mn_{1.25}$ $B_{1.0}$ along with FYM @12.5 t/ha). The quality parameter of cotton namely ginning percentage, fibre length, fibre fineness, and fibre bundle strength and fibre maturity co-efficient were positively influenced by the combined addition of Zn humate, Mn humate and Mg boro humate. However, significant increase was observed with fibre length and fibre bundle strength only. Application of $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$+ FYM @12.5 t/ha (T_5) recorded the higher fibre length and fibre bundle strength of 29.84 and 28.93, respectively which was found to be superior to T_4 (Fibre length and fibre bundle strength of 29.56 and 28.24, respectively). Thus, application of $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha would be sufficient to sustain the productivity and quality of cotton under salt stress condition.

Keywords: cotton, micronutrient humate, organic manure, quality, yield

Introduction
Micronutrients are becoming very essential for increasing crop productivity (Gogoi *et al*., 2016) [6], as agricultural intensification during the past decades without micronutrient in the fertilizers schedule (Rattan *et al*., 2012) [14] results of their emerging deficiency in different soil. In addition, the soil types like calcareous soil, sandy soils and strongly weathered soil, salt affected soils, Vertisols and poorly drained soils (Shukla *et al*., 2016) [16]. In many locations in India, sustainable yield of crops could not be achieved with judicious application of high analysis fertilizers due to Zn, B and Mn, deficiency. About 47, 33 and 5 % of soil in India are deficient in Zn, B and Mn, respectively.

Zinc plays an important role as a metal component of the enzyme or as a functional, structural or regulatory co-factor of a large number of enzymes. Boron is the one of the element required for the plant growth which is directly and indirectly involved with many plant metabolic functions (Debnath and Ghosh, 2011) [4]. It plays an important role in cell synthesis, root elongation, glucose metabolism, nucleic acid synthesis, lignification, tissue differentiation, synthesis of protein, formation of amino acids and chlorophyll (Ali *et al*., 2013) [1]. Boron deficiency is a particular problem on alkaline and heavily limed soils and on highly leached sandy soils. According to Marschner (2012) [10], Mn deficiency symptoms include: interveinal or blotched chlorosis in mature and young leaf blades and interveinal necrosis in young leaf blades. Soil application of inorganic Mn fertilizers results in their rapid oxidation forming insoluble hydroxides or oxides which are less readily available to plants.

The plant needs only a small amount of micronutrients for normal growth and development. However, its application rate is high due to the very low fertilizer use efficiency. In saline and sodic soil, the fertilizer use efficiency is exacerbated than normal soil. Nutrient management is one of the essential aspects of salt affected soil due to its low fertility status and sodium toxicity because it decreases the supply of nutrients and affects soil properties. In this context, the present investigation was undertaken to study the influence of micronutrient humate and organic manure on growth and yield and quality of cotton in saline sodic soil.

Materials and Methods
A field experiment was conducted in the Karanampoondi village, Tamil Nadu, India during June-October, 2018 to study the effect of micronutrients humates in the presence of organic manure on the growth, yield and quality

of cotton in saline sodic soil. The karanampoondi Village is geographically situated at 12º15 27' N latitude and 79º11' E longitude at an attitude of 160 m above sea-level.

Karanampoondi soil is sandy loam in texture with pH 8.4, EC (4.5 dS/m), low in organic carbon (4.8 g/kg), available nitrogen ($KMnO_4$ oxidisable N- 228 kg/ha), available phosphorus (Olsen's P -10.9 kg/ha), medium in available potassium (NH_4OAc extractable-290 kg/ha) and medium in available sulphur (3.26 kg/ha). The exchangeable Ca, Mg of 4.25 and 3.04 cmol (P+)/kg. The DTPA extractable Zn, Fe, Mn, Cu and Hot water soluble B were 0.62, 12, 1.90, 0.68 and 0.32 mg/kg, respectively.

The field experiment was conducted with the following nine treatments viz., T_1-Control, T_2 - $Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5,}$ T_3 - $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5,}$ T_4 - T_2 + FYM @ 12.5 t/ha, T_5 – T_3+ FYM @ 12.5 t/ha, T_6 – T_2+Green leaf manure @ 6.25 t/ha, T_7 - T_3+ Green leaf manure @ 6.25 t/ha, T_7 - T_3+ Green leaf manure @ 6.25 t/ha, T_8 – T_2+ Vermi compost @ 4 t/ha, T_8 – T_2+ Vermi compost @ 4 t/ha.

The experiment was carried out in randomised block design (RBD) replicated thrice. N, P_2O_5 and K_2O (%) content of FYM, green leaf manure (Glyricidia) and vermicompost used in this study were 1.1, 0.42, 2.0 %, 2.76, 0.28, 4.60 % and 1.65, 0.92 and 1.21%, respectively. The experimental field was ploughed well and levelled; ridges and furrows were formed with help of tractor drawn implement. The plot size was 40 m^2 (5 rows of 8m length). Five furrows were left as out or border crop around the treatment plots. The required quantity of FYM, VC, GLM and humates of Zn, Mn and B were applied to the respective plots basally. All plots were applied with a uniform NPK dose of 80:40:40 kg/ha as urea, single super phosphate, and muriate of potash respectively. Cotton var. LRA5166 was chosen as test crop. Good and healthy seeds were sown in each plot at spacing of 60 × 50 cm. One week after sowing, thinning and gap filling was done. First irrigation was given immediately after sowing the seeds. Later, irrigation was given at 3-5 days interval depending up on the soil moisture level. Usual intercultural operation such as weeding and plant protection measure was carried out at appropriate time.

Growth and yield parameter *viz*., plant length, leaf area index, dry matter production, number of monopodial branches, number of sympodial braches, number of squares, and number of bolls/plant, boll weight, and seed cotton yield were recorded in the earmarked plants. The quality parameters like Ginning percentage, Lint index, Seed index, Fiber length(mm), Fiber bundle strength(g/tex), Fibre fineness(g/tex) and Fibre maturity coefficient.

Statistical Analysis

The data on various observations recorded during the course of the investigation were analysed statistically by adopting the procedure described by Gomez and Gomez (1983) [7]. The data were subjected to Fisher's method of analysis of variance and the level of significance used in F tests was P= 0.05. The critical differences were calculated at 5 per cent probability level wherever F value was significant.

Results and Discussion

Growth parameters of cotton

Application of Zn, Mn and B humates either alone or in combination with and organic manure significantly increased the plant height of cotton crop at 30 DAS, 60 DAS, 90 DAS and 120 DAS as compared to control (Table 1). Among the treatments, T_5 ($Zn_{5.0}Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha) recorded the highest plant height of 31.1 cm at 30DAS, 58.13 cm at 60 DAS, 89.2 cm at 90 DAS and 117.8 cm at maturity. This was followed by T_4 ($Zn_{5.0}Mn_{1.25}$ $B_{1.0}$ along with FYM @12.5 t/ha) which recorded 30.06 cm at 30DAS, 56.2 cm at 60 DAS, 87.6 cm at 90 DAS and 115.9 cm at maturity, respectively. FYM performed better than other organic manures in increasing plant height. Based on the plant height the treatments are arranged in descending order as follows $T_5>T_6>T_7>T_9>T_8>T_3>T_2$. The control registered the lowest plant height at all growth stages. LAI is the main physiological determinant of crop yield. The leaf area index was significantly influenced by combined application of Zn, Mn and B humates. Application of $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha (T_5) recorded the highest leaf area index of 4.19 at 90 DAS and 4.03 at 120 DAS. The treatment T_4 (FYM @12.5 t/ha + $Zn_{2.5}Mn_{1.25}B_{1.5}$) was ranked second best and registered the leaf area index of 4.08 at 90 DAS and 3.94 at 120 DAS. This was followed by T_7, T_6, T_9, T_8, T_3, $T_{2,}$ and $T_{1.}$ The treatment T_1 registered the lowest LAI of 3.21 at 90 DAS and 2.80 at 120 DAS. These results indicate that application of micronutrients as humates along with organic manure favourably improved the leaf area index of cotton at 90 DAS and 120 DAS. Among the organic manure, FYM (4.19) excelled the green leaf manure (3.99) and vermicompost (3.78) in increasing the LAI. The addition of micronutrient humates along with organic manures synergistically influenced the LAI of cotton.

The dry matter production of cotton was significantly increased due to application of micronutrient as humates either alone or in combination with organic manures. Among the treatments, the highest dry matter production was recorded in treatment supplied with $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha (T_5) and recorded the dry matter production of 198 kg/ha at 30DAS, 1263 kg/ha at 60 DAS, 3542 kg/ha at 90 DAS and 5163 kg/ha at 120 DAS, respectively. This was followed by treatment $Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha (T_4) which registered the dry matter production of 192 kg/ha at 30DAS, 1239 kg/ha at 60 DAS, 3400 kg/ha at 90 DAS and 4969 kg/ha at 120 DAS, respectively. This was followed by T_6, T_7, T_8, T_9, T_2 and T_3. The control (T_1) produced the lowest dry matter production of 144 kg/ha at 30DAS, 922 kg/ha at 60 DAS, 2391 kg/ha at 90 DAS and 3622 kg/ha at 120 DAS, respectively. It was apparent from the present study, the combined application of Zn-humate, Mn-humate and magnesium boro humate along with organic manure in cotton increased the dry matter production. Though all three organic manures showed a favorable influence on DMP, FYM excelled green leaf manure and vermicompost in improving the DMP of cotton at all stages of crop growth. Based on the DMP, the treatments are arranged in descending order as follows $T_5>T_4>T_7>T_6>T_9>T_8>T_3>T_2>T_1$.

Improved soil physical condition and balanced fertilization due to addition of organic manures could have improved the overall soil health and nutrient availability in soil. The favourable soil environment and higher nutrient uptake could be reason for improved plant height, DMP and LAI of cotton. Similar finding was reported by Arivalagan *et al.* (2014) [2]. In addition, supply of the sufficient amount of nutrients to plants stimulate enzymatic activities (Oosterhuits *et al.,* 2010) [11], leading to an improvement in biochemical processes like photosynthesis, respiration, and protein synthesis, as reported by Gomez *et al*.,(2008) [3]. Further, application of Zn and B along with organic manure could have accelerated mobility of photosynthates from source to sink (Hai and Mir, 1998) [8].

Humate ion released during the dissociation of Zn, Mn and B humates influenced the plant growth on sustainable basis, were also associated their effect on rhizosphere soil, root enzymes and nutrient absorption (Vaughan and MacDonald, 1976; Malcolm and Vaughan, 1979) [9]. Further, increase in leaf area index might be due to an adequate supply of nutrients by organic manures along with inorganic fertilizers with humic acid based micro nutrient chelates. The increase in dry matter production might be by augmenting photo synthesis process and higher production of photosynthates (Patel and Singh, 2010) [12].

Table 1: Effect of micronutrient humates and organic manures on plant height of cotton in a saline sodic soil.

Treatment	Plant height				Leaf area index		Dry matter production (kg/ha)
	30 DAS	60 DAS	90 DAS	Harvest	90 DAS	120 DAS	
T_1-Control	25.1	41.1	73	99.2	3.21	2.80	3622
T_2 - $Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5}$	26	43	74.6	102.7	3.36	3.13	3720
T_3 - $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$	27.3	45	76.2	105.5	3.55	3.28	3990
T_4 – T_2 + FYM @ 12.5 t/ha	30.6	56.2	87.6	115.9	4.08	3.94	4969
T_5 – T_3+FYM @ 12.5 t/ha	31.1	58.13	89.2	117.8	4.19	4.03	5163
T_6 – T_2+GLM @ 6.25 t/ha	29.6	51.9	83	111.8	3.89	3.77	4579
T_7 - T_3+ GLM @ 6.25 t/ha	30.1	54.3	84.7	113.8	3.99	3.86	4775
T_8 – T_2+ VC @ 4 t/ha	28.5	47.2	78	107.8	3.66	3.46	4186
T_9 - T_3 +VC @ 4 t/ha	29.1	49.5	80.9	109.9	3.78	3.65	4382
SEm±	0.19	0.77	0.72	0.87	0.037	0.042	79.83
CD (P=0.05)	0.42	1.63	1.52	1.84	0.08	0.07	168.45

*FYM: Farm yard manure, GLM: Green leaf manure, VC: Vermi compost, DAS: Days after sowing

Seed cotton yield, Lint yield and seed yield

Conjoint addition of Zn humate, Mn humate and Mg boro humate significantly increased the seed cotton yield, lint and seed yield of cotton (Table 2). Between the treatments T_3 and T_2 which was supplied with combined addition of Zn humate, Mn humate and Mg boro humate, T_3 performed better than T_2. However, this difference between T_2 and T_3 was minimized when it was applied along with organic manures. This was well evidenced when T_4 was compared with T_5 and T_6 with T_7 and T_8 with T_9. The highest seed cotton yield, lint and seed yield of 22.36, 8.33 and 13.41 q/ha, respectively was registered under T_5 ($Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$+ FYM @ 12.5 t/ha). This was followed by T_4 (application of $Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @ 12.5 t/ha) which registered the seed cotton yield, lint and seed yield of 21.25, 8.17 and 13.07 q/ha, respectively. Though, all the three organic manures in combination with micronutrient humates positively influenced the seed cotton yield, lint and seed yield. FYM along with micronutrient humates showed highest response as compared to other two organic manures with micronutrient combination.

The least seed cotton yield, lint and seed yield of 10.80, 3.77, 7.02 q/ha, respectively was obtained in the treatment T_1. In cotton, the yield depends on the accumulation of photosynthates and it's partitioning in different parts of the plant.

The yield is strongly influenced by the application of Zn, Mn and B humates indicating the role of these micronutrients in increasing the yield through their effect on various morpho-physiological traits. Increase in yield due to application of micronutrient in cotton was reported by Wankhade *et al*., (1994) [20]. Rajendran *et al*., (2010) also concluded that application of micronutrient either alone or in combination had a great effect in improving the efficiency of utilizing nutrients and improves the growth and seed cotton yield. Application of bulky organic manures, increase the seed cotton yield through sustained supply of nutrients to cotton (Arivalagan, *et al*. 2014) [2].

In the present study, the application of organic manures (FYM @ 12.5 t/ha or vermicompost @ 4t/ha) with micronutrient humates increased the LAI and dry matter accumulation in cotton which resulted in production of more photosynthates and higher yield. Increase in seed cotton yield may also be due to solubilization of native as well as applied zinc at higher levels by organic manures which produce complexing agent and nutrient after microbial decay of organic manure (Singh *et al*., 2003) [17]. The increased yield could be associated with benefits such as improvement of soil physical properties and better supply of macro and micronutrients from soil due to organic manure application (Yadav *et al.*, 2000) [21].

Table 2: Effect of micronutrient humates and organic manure on seed cotton yield, lint yield and seed yield (q/ha) of cotton in a saline sodic soil.

Treatments	Seed cotton yield (q/ha)	Lint yield (q/ha)	Seed yield (q/ha)
T_1-Control	10.80	3.77	7.02
T_2 - $Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5}$	14.49	5.67	8.81
T_3 - $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$	15.25	5.91	9.23
T_4 – T_2 + FYM @ 12.5 t/ha	21.25	8.17	13.07
T_5 – T_3+FYM @ 12.5 t/ha	22.36	8.33	13.41
T_6 – T_2+GLM @ 6.25 t/ha	17.91	7.05	10.85
T_7 - T_3+ GLM @ 6.25 t/ha	18.72	7.37	11.34
T_8 – T_2+ VC @ 4 t/ha	17.25	6.35	9.94
T_9 - T_3 +VC @ 4 t/ha	17.60	6.95	10.64
SEm±	0.45	0.15	0.26
CD (*P*=0.05)	0.95	0.32	0.56

*FYM: Farm yard manure, GLM: Green leaf manure, VC: Vermi compost

Seed index and lint index

The combined application of Zn humate, Mn humate and Mg boro humate to cotton had a significant impact on seed index and lint index (Table 3). When the treatment T_2 and T_3 are compared, T_3 recorded significantly higher seed index and lint index as compared to T_2. Inclusion of organic manure with humates showed a more perceptible improvement in the seed as well as lint index of cotton. Among the treatments imposed, T_5 ($Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$+ FYM @12.5 t/ha) recorded the highest seed index and lint index of 9.70 and 4.60. The treatment T_4 ($Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha) registered the seed index and lint index of 9.65 and 4.52, respectively. The treatment T_4 and T_5, T_6 and T_7 and T_8 and T_9 were on par with each other in respect of seed index and lint index. The control (T_1) produced the lowest seed index and lint index as compared to all other treatments. The treatment T_1 control recorded the seed index and lint index of 7.19 and 3.32, respectively. The highest seed and lint index in organic manure with micronutrient humates applied treatment may be due supply of judicious amount of nutrient at all growing stage as well as activation of various enzymes that regulate different biochemical reactions, assimilation of photosynthetic product in to reproductive parts which led to increased flowering and seed cotton yield, lint index and seed index of cotton. Improvement in yield due to combined application of inorganic fertilizer (macro and micro nutrients) and organic manures might be attributed to sustained release of nutrients in the soil through mineralisation of organic manure which might have facilitated better growth (Shahid *et al.,* 2013) [15]

Table 3: Effect of micronutrient humates and organic manures on seed index and l int index of cotton in a saline sodic soil.

Treatments	Seed index	Lint index
T_1-Control	7.19	3.32
T_2 - $Zn_{2.5}$ $Mn_{1.25}$ $B_{1.5}$	7.56	3.65
T_3 - $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$	7.64	3.73
T_4 – T_2 + FYM @ 12.5 t/ha	9.65	4.52
T_5 – T_3+FYM @ 12.5 t/ha	9.70	4.60
T_6 – T_2+GLM @ 6.25 t/ha	8.77	4.10
T_7 - T_3+ GLM @ 6.25 t/ha	9.18	4.28
T_8 – T_2+ VC @ 4 t/ha	8.14	3.98
T_9 - T_3 +VC @ 4 t/ha	8.32	4.05
SEm±	0.17	0.11
CD (*P*=0.05)	NS	NS

*****FYM**:** Farm yard manure, GLM: Green leaf manure, VC: Vermi compost

Ginning percentage, fibre length, fibre fineness, fibre bundle strength and fibre maturity coefficient

The quality parameter of cotton namely ginning percentage, fibre length, fibre fineness, and fibre bundle strength and fibre maturity co-efficient were positively influenced by the combined addition of Zn humate, Mn humate and Mg boro humate (Table 4). However, significant increase was observed with fibre length and fibre bundle strength only. Both the treatments T_2 and T_3 which were supplied with micronutrient humates alone recorded significantly higher fibre length and fibre bundle strength as compared to control. However, the treatment T_3 recorded significantly higher fibre length of 27.85 and fibre bundle strength of 24.63 as compared to T_2 which registered the lower fibre length of 27.39 and fibre bundle strength of 23.95. Conjoint application of humates with organic manures showed a significant increase in fibre length and fibre bundle strength` as compared to the treatment supplied with humates alone. Application of humates along with green leaf manure (T_6 and T_7) recorded higher fibre length and fibre bundle strength as compared to the treatments supplied with pressmud +humates (T_8 and T_9). Among the three organic manures, application of FYM @12.5 t/ha + micronutrient humate excelled the other two in improving the fibre length and fibre bundle strength. Among the treatments, application of $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$+ FYM @12.5 t /ha(T_5) recorded the higher fibre length and fibre bundle strength of 29.84 and 28.93, respectively which was found to be superior to T_4 (fibre length and fibre bundle strength of 29.56 and 28.24, respectively). Based on fibre length and fibre bundle strength value, the treatments are arranged in ascending order as follows T_5>T_4>T_7>T_6>T_9>T_8 >T_3>T_2>T_1. The lowest fibre length and fibre bundle strength` of 26.75 and 23.20, respectively was noticed in control. The quality parameters are the main criteria that decide the market value of the cotton. Application of Zn, Mn and B humates with different organics significantly increase the fibre length and fibre bundle strength of the cotton. Though, the other parameters like Ginning percentage, Fibre fineness, and Fibre Maturity coefficient were not significantly improved by the application of different treatment a positive trend was noticed with these quality parameters also. The combined application of $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$ + FYM @12.5 t/ha (T_5) recorded the highest fibre length and fibre bundle strength of cotton in saline sodic soil. This was followed FYM @12.5 t/ha+ $Zn_{2.5}Mn_{1.25}B_{1.5}$ (T_4) this might be due to favourable effect of treatment on soil physical properties, nutrient availability, and nutrient uptake by plants which played greater role in increasing the fibre quality. Similar findings have been earlier reported Vaiyapuri *et al*. (2010) and Gobi and Vaiapuri, 2012).

Table 4: Effect of micronutrient humates and organic manures on Ginning percentage, fibre length, fibre fineness, fibre bundle strength (g tex^{-1}) and fibre maturity coefficient of cotton in a saline sodic soil.

Treatments	Ginning percentage	Fibre length (mm)	Fibre fineness (g/tex)	Fibre bundle strength (g/tex)	Fibre maturity coefficient
T_1	33.87	26.75	3.68	23.20	0.640
T_2	34.32	27.39	3.57	23.95	0.641
T_3	34.67	27.85	3.58	24.63	0.642
T_4	36.43	29.56	3.21	28.24	0.649
T_5	36.75	29.84	3.21	28.93	0.649
T_6	35.70	28.99	3.24	26.85	0.648
T_7	36.05	29.30	3.25	27.50	0.648
T_8	34.91	28.26	3.25	25.48	0.643
T_9	35.31	28.67	3.24	26.17	0.645
SEm±	0.18	0.12	0.02	0.33	0.018
CD (*P*=0.05)	NS	0.24	NS	0.67	NS

*FYM: Farm yard manure, GLM: Green leaf manure, VC: Vermi compost, NS: Not Significant

Conclusion

Application of micronutrient humate (Zn, Mn and B) with different organic manure was found better in growth and yield of cotton over the rest of the treatment without organic manure. The quality parameters like fibre length and fibre bundle strength had a significant influence on the application of micronutrient humate (Zn, Mn and B) with different organic manure. But the quality parameters like ginning percentage, fibre fineness and fibre maturity coefficient were not shown any significant effect due to the application of micronutrient humate (Zn, Mn and B) with organic manure. From the results of this study, it can be concluded that application $Zn_{5.0}$ $Mn_{1.25}$ $B_{1.5}$+ FYM @ 12.5 t/ha improved the growth, yield and quality of cotton in saline sodic soil.

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