Available online at www.jpsscientificpublications.com
Volume – 1; Issue - 5; Year – 2015; Page: 387– 397

Indo – Asian Journal of Multidisciplinary Research (IAJMR)
ISSN: 2454-1370

# EFFECTS OF DIFFERENT SOURCES AND LEVELS OF MANGANESE ON GROWTH AND YIELD OF COTTON (*Gossypium hirsutum* L.) IN SALINE SODIC SOIL

**S. Sathiyamurthi* and K. Dhanasekaran**

*Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Annamalai Nagar – 608 001, Tamil Nadu,* India.

**Abstract**

The present study was aimed to explore the effects of different levels and sources of manganese on growth and yield of cotton in saline sodic soil. A pot experiment was conducted with four levels Mn (0, 1.25, 2.5 and 5.0 mg $kg^{-1}$) was applied through three different sources namely manganese sulphate, Mn- EDTA and Mn-humate. The experiment was conducted in factorial completely randomized design with three replications. The cotton variety LRA5166 was grown as test crop. The growth parameters like plant height, leaf area index (LAI), number of monopodial branches $plant^{-1}$, number of sympodial branches $plant^{-1}$ and number of squares plant $^{-1,}$ yield parameters like number of bolls per plant, boll weight and yield of cotton were recorded at appropriate stages of crop growth. The seed cotton yield, lint yield and seed yield were recorded in each pot separately. The results of the study indicated that application of Mn significantly increased the growth and yield parameters of the cotton. Among the three sources, manganese humate recorded the highest mean plant height, Leaf area index, Number of monopodial $plant^{-1}$, Number of sympodial $plant^{-1}$ and Number of squares $plant^{-1}$ as compared to other two sources.The treatment supplied with 2.5 mg Mn $kg^{-1}$ as Mn- humate recorded the highest yield parameter. This was on par with the treatment applied with 1.25 mg Mn $kg^{-1}$ as Mn-humate. This results of the experiment concluded that the application of 2.5 mg $kg^{-1}$Mn as humate was the optimum dose of Mn to maximize the productivity of cotton in a saline sodic soil.

**Key words**: Cotton, Micronutrient, Mn- humate, plant height, seed cotton yield, Saline sodic soil

## 1. Introduction

Cotton (*Gossypium hirsutum* L.) is an important fibre crop. It provides raw material for ever-expanding textile industry and protein-rich oilcake residue, which is the traditional source of protein in livestock feed (Dordas, 2006). Nutrient elements in soil must be sufficiently available to realize high yield and good quality produce. Both plant growth and yield are negatively affected by deficiency of nutrient elements in cotton. Amount of plant nutrient elements taken by cotton from soil varies and depend on many factors. The species of *Gossypium hirsutum* L. extracts more nutrients from the soil. It is estimated that a quarter of the world's soils currently suffer from micronutrient stress, known to cause greater production loss than any other factor (Hassan *et al*., 2007). Manganese (Mn) is an important plant micronutrient that is required by plants in second greatest quantity as compared to iron. Like any other element, it can have a limiting factor on plant growth if it is deficient or toxic in plant tissue. Manganese is used in plants as a major contributor to various biological systems including

**Corresponding author*: **S. Sathiyamurthi**
*E-mail*: sathya.soil@gmail.com
*Received*: 31.10.2015; *Revised*: 07.11.2015; *Accepted*: 30.11.2015.

photosynthesis, respiration, and nitrogen assimilation. Manganese is also involved in pollen germination, pollen tube growth, root cell elongation and resistance to root pathogens. In India, nearly 7.5 mha soils are affected by salts. The salt affected soils are characterized by poor physical properties, high pH, EC, low in organic matter content, micronutrients availability. Manganese deficiencies mainly occur on high-pH soils and sandy soils with low organic matter content as well as over-limed soils. The increasing occurrence of manganese deficiency and failure of crops at many sites due to Mn starvation necessitate studies to evolve technologies for the efficient management of Mn deficiency in crops. The present study was undertaken to establish the response of cotton to Mn application in saline sodic soil.

## 2. Materials Methods

A pot experiment was conducted at pot culture yard, faculty of Agriculture, Annamalai University during 2012 to study the effect of various levels and source of manganese on growth and yield of cotton (*Gossypium hirsutum* L.) in a saline sodic soil. The experimental soil was sandy loam in texture (Typicha plustalf) having pH 8.7 and EC1.23 dSm$^{-1}$. The fertility status of the soil was found low in available nitrogen ($KMnO_4$ oxidisable N) (228 kg ha$^{-1}$) and phosphorus (Olsen-P) (9.12 kg ha $^{-1}$) and medium in potassium ($NH_4OAc$ extractable) (290 kg ha $^{-1}$). The DTPA extractable Mn status of the soil was 1.90 mg kg$^{-1}$ of soil. The experiment was laid out in factorial completely randomized block design with three replications.

The treatments consisted of four levels of Mn (0, 1.25, 2.5 and 5.0 mg kg$^{-1}$) supplied through three different sources namely manganese sulphate ($S_1$), Mn-EDTA ($S_2$) and Mn- humate ($S_3$). All treatmental pots were applied with soil test based NPK dose of 8:4:4 g kg$^{-1}$. The Mn-humate used in this study was prepared by adding excess of saturated Mn sulphate solution into Na-humate at pH 5.5. The complex precipitated was first washed with Dil. HCl and later with distilled water to remove the hydroxide, if any. The Mn-humate complexes were then dried at 55 ºC. Mn content of the Mn-humate was estimate by using atomic adsorption spectrometer. The data on plant architecture i.e., plant height at maturity were recorded. Leaf area index (LAI) of Cotton leaves (i.e., blade without petioles of the fourth leaf from the top on the main stem) were sampled at 120 days after planting from each pot. Number of monopodial branches plant$^{-1}$, Number of sympodial branches plant$^{-1}$ and Number of squares plant$^{-1}$ were recorded at 120 days after sowing. Components of seed cotton yield (i.e., number of bolls plant$^{-1}$ and boll weight) were recorded at appropriate stage. At maturity, the crop was harvested manually, and data on seed cotton yield, lint yield and seed yield were calculated and expressed in g pot$^{-1}$.

## 3. Results

### Plant height

Application of graded levels of manganese from 0 to 2.5 mg kg$^{-1}$ through different sources significantly increased the plant height of cotton in saline sodic soil **(**Table1), beyond that decreased. Among the different levels of manganese, application of 2.5 mg Mn kg$^{-1}$ of soil significantly registered the maximum mean plant height of 28.47 cm at 30 DAS, 40.48 cm at 60 DAS, 73.13 cm at 90 DAS and 97.06 cm at maturity. This was found to be on par with application of 1.25 mg Mn kg$^{-1}$ of soil and recorded mean plant height of 27.79 cm at 30 DAS, 39.22 cm at 60 DAS, and 71.07 cm at 90 DAS and 95.22 cm at maturity. The control registered the lowest mean plant height at all stages of growth (23.31 cm at 30 DAS, 34.85 cm at 60 DAS, 63.90 cm at 90 DAS and 79.81 cm at maturity, respectively). Abdallah and Mohamed (2013) showed that cotton cultivars significantly varied in plant height due to Mn, Fe and Zn application. Among the three sources of manganese evaluated, lowest value was recorded with manganese sulphate at all growth stages (25.08 cm at 30 DAS, 36.48 cm at 60 DAS, 66.63 cm at 90 DAS and 86.92 cm at maturity. This was followed by application of manganese EDTA (26.44 cm at 30 DAS, 37.87 cm at 60 DAS, 68.70 cm at 90 DAS and 90.83 cm at maturity, respectively). Application of manganese humate was significant superior to other two sources in increasing plant height at all stages of crop growth and recorded the plant height of 27.85 cm at 30 DAS, 39.22 cm at 60 DAS, 71.07 cm at 90 DAS and 95.22 cm at maturity.

The interaction effect between levels and sources of manganese on plant height was significant. Application of Mn @ 2.5 mg as manganese humate recorded the maximum plant height at all stages and recorded the plant height of 30.26 cm at 30 DAS, 43.20 cm at 60 DAS, 77.20 cm at 90 DAS and 103.0 cm at maturity. This was on par with addition of 1.25 Mn as manganese humate and recorded 29.86 cm at 30 DAS, 42.20 cm at 60 DAS, 76.05 cm at 90 DAS and 100.95 cm at harvest. The increase in plant height might be due to reason that manganese acts as an activator for many enzymes which promote plant growth and flower production (Ohki, 1973). Also, the effect of Mn on plant height is probably due to the effect of Mn on stem elongation. Our result agrees with those obtained by Dordas (2009) who reported that manganese application increased plant height by an average of 9 and 10 % compared with the control at Larissa and Serres, respectively.

**Leaf area index**

Application of increasing levels of Mn from 0 to 5 mg $kg^{-1}$ favourably increased the leaf area index (LAI) of cotton in saline sodic soil up to 2.5 mg $kg^{-1}$ (Table - 2). A declining trend was noticed at 5.0 mg B $kg^{-1}$ level. Irrespective of manganese sources, the application of 2.5 mg Mn $kg^{-1}$ significantly registered the maximum mean leaf area index of 3.19 at 90 DAS and 3.48 at 120 DAS, respectively. This was found to be on par with application of 1.25 mg Mn $kg^{-1}$ of soil and recorded the second highest mean leaf area index of 3.13 at 90 DAS and 3.43 at 120 DAS. The lowest mean leaf area index of 2.75 at 90 DAS and 2.86 at 120 DAS was recorded in cotton. Among the various sources of manganese tried, least mean leaf area index was recorded with Mn sulphate ($S_1$) and recorded the LAI of 2.88 at 90 DAS and 3.11 at 120 DAS. This was followed by Mn EDTA ($S_2$) which recorded the LAI of 3.02 at 90 DAS and 3.26 at 120 DAS. Addition of Mn as Mn humate ($S_3$) was significantly superior to other two sources in increasing the mean leaf area index of 3.16 at 90 DAS and 3.40 at 120 DAS.

Interaction effect due to levels and sources of Mn on LAI was significant. Application of 2.5 mg Mn $kg^{-1}$ as Mn humate recorded the maximum leaf area index of 3.39 at 90 DAS and 3.68 at 120 DAS. However, this was on par with application of 1.25 mg Mn $kg^{-1}$ as manganese humate (3.32 at 90 DAS and 3.64 at 120 DAS, respectively). The lowest LAI of 2.75 at 90 DAS and 2.86 at 120 DAS was noticed in control. Increase in LAI may be due to participation of Mn in the biosynthetic pathway of isoprenoids (Lidon*et al*., 2004) and assimilation of nitrate (Ducic and Polle, 2005). Mn is involved in metabolic processes such as respiration, photosynthesis, synthesis of amino acids and hormone activation (indole acetic acid, IAA) throughout the IAA-oxidases (Burnell, 1988).

**Number of monopodial branches, sympodial branches and squares plant$^{-1}$**

Addition of graded levels of Mn through different sources favourably influenced the number of monopodial branches, sympodial branches and squares plant $^{-1}$ of cotton in saline sodic soil over control (Table - 3). Increase in the level of Mn from 0 to 5.0 mg $kg^{-1}$ significantly increased the number of monopodial branches $plant^{-1}$, sympodial branches $plant^{-1}$ and squares $plant^{-1}$ up to 2.5 mg $kg^{-1}$, thereafter decreased. The application of 2.5 mg Mn $kg^{-1}$ significantly registered the maximum mean number of monopodial branches $plant^{-1}$, sympodial branches $plan^{t-1}$ and squares $plant^{-1}$ of 2.15, 12.22 and 30.13, respectively. This was found to be on-par with application of 1.25 mg Mn $kg^{-1}$ of soil which recorded number of monopodial branches $plant^{-1}$, sympodial branches $plant^{-1}$and squares plant $^{-1}$ of 2.11, 11.88 and 29.66, respectively. All the three sources of manganese tried, least mean number of monopodial branches $plant^{-1}$, sympodial branches $plant^{-1}$ and squares $plant^{-1}$ of 1.91, 10.99 and 27.60, respectively was observed with $MnSO_4$

($S_1$). This was followed by Mn-EDTA ($S_2$). The highest mean number of monopodial branches plant$^{-1}$ (2.13), sympodial plant$^{-1}$ (12.07) and squares plant$^{-1}$ (29.97) was recorded in the treatment supplied with manganese humate ($S_3$).

The interaction effect between levels and sources of Mn on number of monopodial branches, sympodial branches and squares plant$^{-1}$ was significant. Addition of 2.5 mg Mn kg$^{-1}$ through manganese humate recorded maximum number of monopodial branches plant$^{-1}$, sympodial plant$^{-1}$ and squares plant$^{-1}$ of 2.30, 12.98 and 31.75, respectively. This was on par with application of 1.25 mg Mn kg$^{-1}$ as manganese humate which registered number of monopodial branches, sympodial branches and squares plant $^{-1}$ of 2.26, 12.78 and 31.55, respectively. The lowest number of monopodial branches, sympodial branches and square plant$^{-1}$ of 1.83, 10.49 and 26.80 was observed in control. The increase in the Mn contents of leaves might have boosted the increased Mn contents in leaves and boosts the production of metabolites synthesized and thus the plant had the chance to bear more fruiting branches. Moreover, Mn is involved in photosynthesis, respiration and as an activator of a number of enzymes in the tricarboxylic acid cycle (Wahdan ,1990 and Elayan, 2008).

**Number of bolls plant$^{-1}$ and boll weight**

Application of manganese through various sources significantly ($P \leq 0.05$) increased the bolls plant$^{-1}$ and boll weight of cotton over control in saline sodic soil (Table - 4). Addition of graded levels of Mn from 0 to 5.0 mg kg$^{-1}$ favourably increased the boll number as well was boll weight up to 2.5 mg kg$^{-1}$, beyond that decreased. Application of 2.5 mg Mn kg$^{-1}$ ($L_3$) significantly registered the maximum mean number of bolls plant$^{-1}$and boll weight of 14.05 and 2.97 g. This was found to be on par with application of 1.25 mg Mn kg$^{-1}$ ($L_2$) of soil which recorded number of bolls plant$^{-1}$ and boll weight of 13.73 and 2.92 g respectively. The lowest mean boll plant$^{-1}$ and boll weight of 11.82 and 11.82 g respectively was recorded in $L_1$. Among the three sources of Mn – humate ($S_3$) recorded, the highest mean number of bolls plant$^{-1}$and boll weight of 13.86 and 2.93 g. This was followed by Mn EDTA which recorded the bolls plant $^{-1}$ and boll weight of 13.20 and 2.78 g. Among the three sources, the least mean number of bolls plant$^{-1}$ (12.49) and boll weight (2.64 g) were noticed with $MnSO_4$.

The interaction effect between sources and levels of Mn on number of bolls plant$^{-1}$ and boll weight was significant. The treatment supplied with 2.5 mg Mn kg$^{-1}$ as manganese humate recorded the maximum number of bolls plant$^{-1}$ and boll weight of 14.92 and 3.16 g. This was on par with application of 1.25 mg Mn kg$^{-1}$ as manganese humate which registered number of bolls plant$^{-1}$and boll weight of 14.68 and 3.10 g. This was followed by application of 2.5 mg Mn kg$^{-1}$ as Mn-EDTA and 1.25 mg Mn kg$^{-1}$ as Mn-EDTA. The lowest number of bolls plant$^{-1}$(11.82) and boll weight (2.47 g) was recorded in control. The increase in bolls number may be due to the increase in number of sympodial branches plant$^{-1}$ in Mn applied plants and positive influence in metabolites synthesis. Similarly, observation in cotton was made by Abdallah and Mohamed (2013) and Dordas (2009).

**Seed cotton yield, lint and seed yield**

Application of Mn through different sources and levels significantly ($P \leq 0.05$) increased the seed cotton yield, lint and seed yield of cotton in saline sodic soil (Table - 5). Irrespective of the sources, application of increasing level of Mn from 0 to 5.0 mg kg$^{-1}$ increased the seed cotton yield up to 2.5 mg kg$^{-1}$, beyond that decreased. Application of 2.5 mg Mn kg$^{-1}$ significantly registered the maximum mean seed cotton yield, lint and seed yield of 72.92, 25.94 and 43.75 g pot$^{-1}$ ($L_3$), respectively. Application of 1.25 mg Mn kg$^{-1}$ of soil ($L_2$) recorded the mean seed cotton yield, lint and seed yield of 71.42, 25.27 and 42.84 g pot$^{-1}$, respectively. However, this was on par with application of 2.5 mg Mn kg$^{-1}$. The level, $L_1$ (control) registered the lowest mean seed cotton yield 65.16, lint yield 22.15 and seed yield 39.09 g pot$^{-1}$.

**Table - 1: Effect of soil application of different Mn sources and levels on plant height (cm) of cotton in saline soil**

| Levels / Sources | 30 DAS | | | | | 60 DAS | | | | | 90 DAS | | | | | HARVEST | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L_1$ | $L_2$ | $L_3$ | $L_4$ | **Mean** | $L_1$ | $L_2$ | $L_3$ | $L_4$ | **Mean** | $L_1$ | $L_2$ | $L_3$ | $L_4$ | **Mean** | $L_1$ | $L_2$ | $L_3$ | $L_4$ | **Mean** |
| **$S_1$** | 23.31 | 25.71 | 26.69 | 24.59 | **25.08** | 34.85 | 37.25 | 38.15 | 35.65 | **36.48** | 63.90 | 67.7 | 69.5 | 65.43 | **66.63** | 79.81 | 89.21 | 92.1 | 86.56 | **86.92** |
| **$S_2$** | 23.31 | 27.81 | 28.46 | 26.16 | **26.44** | 34.85 | 38.20 | 40.10 | 38.32 | **37.87** | 63.90 | 69.30 | 72.69 | 68.92 | **68.70** | 79.81 | 95.51 | 96.09 | 91.90 | **90.83** |
| **$S_3$** | 23.31 | 29.86 | 30.26 | 27.96 | **27.85** | 34.85 | 42.20 | 43.20 | 40.00 | **40.06** | 63.90 | 76.05 | 77.20 | 72.60 | **72.43** | 79.81 | 100.95 | 103.0 | 96.02 | **94.95** |
| **Mean** | **23.31** | **27.79** | **28.47** | **26.23** | | **34.85** | **39.22** | **40.48** | **37.99** | | **63.90** | **71.07** | **73.13** | **68.98** | | **79.81** | **95.22** | **97.06** | **91.49** | |

| | 30 DAS $SE_D$ | 30 DAS CD($P \leq 0.05$) | 60 DAS $SE_D$ | 60 DAS CD($P \leq 0.05$) | 90 DAS $SE_D$ | 90 DAS CD($P \leq 0.05$) | HARVEST $SE_D$ | HARVEST CD($P \leq 0.05$) |
|---|---|---|---|---|---|---|---|---|
| **S** | 0.43 | 0.89 | 0.41 | 0.85 | O.67 | 1.40 | 1.04 | 2.16 |
| **L** | 0.45 | 0.95 | 0.45 | 0.95 | 0.89 | 1.85 | 1.22 | 2.53 |
| **LX S** | 0.57 | 1.18 | 0.86 | 1.80 | 1.60 | 3.32 | 2.34 | 4.85 |

$S_1$ – Mn sulphate, $S_2$- Mn EDTA $S_3$- Mn humate, $L_1$- 0 mg Mn $kg^{-1}$ of soil , $L_{2-}$ 1.25 mg Mn $kg^{-1}$ of soil , $L_3$- mg Mn $kg^{-1}$ of soil and $L_4$- mg Mn $kg^{-1}$ of soil .

**Table - 2: Effect of soil application of different Mn sources and levels on Leaf area index (LAI) and dry matter production (g) of cotton in saline soil.**

| Levels / Sources | LAI at 90DAS | | | | | LAI at 120 DAS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **$L_1$** | **$L_2$** | **$L_3$** | **$L_4$** | **Mean** | **$L_1$** | **$L_2$** | **$L_3$** | **$L_4$** | **Mean** |
| **$S_1$** | 2.75 | 2.95 | 3.02 | 2.78 | **2.88** | 2.86 | 3.22 | 3.29 | 3.05 | **3.11** |
| **$S_2$** | 2.75 | 3.13 | 3.16 | 2.99 | **3.02** | 2.86 | 3.43 | 3.47 | 3.21 | **3.24** |
| **$S_3$** | 2.75 | 3.32 | 3.39 | 3.14 | **3.16** | 2.86 | 3.64 | 3.68 | 3.43 | **3.41** |
| **Mean** | **2.75** | **3.13** | **3.19** | **2.97** | | **2.86** | **3.43** | **3.48** | **3.23** | |

| | **$SE_D$** | **CD($P \leq 0.05$)** | **$SE_D$** | **CD($P \leq 0.05$)** |
|---|---|---|---|---|
| **S** | 0.03 | 0.07 | 0.04 | 0.09 |
| **L** | 0.04 | 0.09 | 0.04 | 0.10 |
| **LX S** | 0.06 | 0.14 | 0.07 | 0.15 |

$S_1$ – Mn sulphate, $S_2$- Mn EDTA $S_3$- Mn humate, $L_1$- 0 mg Mn kg$^{-1}$ of soil , $L_{2-}$ 1.25 mg Mn kg$^{-1}$ of soil , $L_3$- mg Mn kg$^{-1}$ of soil and $L_4$- mg Mn kg$^{-1}$ of soil .

**Table - 3: Effect of soil application of different Mn sources and levels on number of monopodial branches, sympodial branches and squares plant $^{-1}$ of cotton in saline soil.**

| Levels / Sources | Number of monopodial branchesplant$^{-1}$ | | | | | Number of sympodial branches plant$^{-1}$ | | | | | Number of squares plant $^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$L_1$** | **$L_2$** | **$L_3$** | **$L_4$** | **Mean** | **$L_1$** | **$L_2$** | **$L_3$** | **$L_4$** | **Mean** | **$L_1$** | **$L_2$** | **$L_3$** | **$L_4$** | **Mean** |
| **$S_1$** | 1.83 | 1.95 | 2.01 | 1.86 | **1.91** | 10.49 | 11.21 | 11.49 | 10.77 | **10.99** | 26.80 | 27.60 | 28.60 | 27.40 | **27.60** |
| **$S_2$** | 1.83 | 2.12 | 2.15 | 1.98 | **2.02** | 10.49 | 11.64 | 12.20 | 11.51 | **11.46** | 26.80 | 29.83 | 30.03 | 28.15 | **28.70** |
| **$S_3$** | 1.83 | 2.26 | 2.30 | 2.14 | **2.13** | 10.49 | 12.78 | 12.98 | 12.03 | **12.07** | 26.80 | 31.55 | 31.75 | 29.78 | **29.97** |
| **Mean** | **1.83** | **2.11** | **2.15** | **1.99** | | **10.49** | **11.88** | **12.22** | **11.44** | | **26.80** | **29.66** | **30.13** | **28.44** | |
| | **$SE_D$** | | | **CD($P \leq 0.05$)** | | **$SE_D$** | | | **CD($P \leq 0.05$)** | | **$SE_D$** | | | **CD($P \leq 0.05$)** | |
| **S** | 0.02 | | | 0.06 | | 0.15 | | | 0.30 | | 0.49 | | | 1.02 | |
| **L** | 0.03 | | | 0.07 | | 0.20 | | | 0.35 | | 0.52 | | | 1.08 | |
| **LX S** | 0.04 | | | 0.10 | | 0.30 | | | 0.50 | | 0.77 | | | 1.50 | |

$S_1$ – Mn sulphate, $S_2$- Mn EDTA $S_3$- Mn humate, $L_1$- 0 mg Mn $kg^{-1}$ of soil , $L_{2-}$ 1.25 mg Mn $kg^{-1}$ of soil , $L_3$- mg Mn $kg^{-1}$ of soil and $L_4$- mg Mn $kg^{-1}$ of soil .

**Table - 4: Effect of soil application of different Mn sources and levels on number of bolls $plant^{-1}$ and boll weight (g) of cotton in saline soil.**

| Levels / Sources | Number of bolls $plant^{-1}$ | | | | | Boll weight(g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Mean | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Mean |
| $S_1$ | 11.82 | 12.60 | 13.20 | 12.35 | **12.49** | 2.47 | 2.73 | 2.80 | 2.55 | **2.64** |
| $S_2$ | 11.82 | 13.77 | 14.02 | 13.20 | **13.20** | 2.47 | 2.91 | 2.95 | 2.77 | **2.78** |
| $S_3$ | 11.82 | 14.81 | 14.92 | 13.89 | **13.86** | 2.47 | 3.12 | 3.16 | 2.95 | **2.93** |
| **Mean** | **11.82** | **13.73** | **14.05** | **13.15** | | **2.47** | **2.92** | **2.97** | **2.76** | |

| | Number of bolls $plant^{-1}$ $SE_D$ | Number of bolls $plant^{-1}$ CD($P \leq 0.05$) | Boll weight(g) $SE_D$ | Boll weight(g) CD($P \leq 0.05$) |
|---|---|---|---|---|
| **S** | 0.24 | 0.51 | 0.03 | 0.09 |
| **L** | 0.26 | 0.55 | 0.04 | 0.12 |
| **LX S** | 0.36 | 0.75 | 0.07 | 0.16 |

$S_1$ – Mn sulphate, $S_2$- Mn EDTA $S_3$- Mn humate, $L_1$- 0 mg Mn $kg^{-1}$ of soil , $L_2$- 1.25 mg Mn $kg^{-1}$ of soil , $L_3$- mg Mn $kg^{-1}$ of soil and $L_4$- mg Mn $kg^{-1}$ of soil .

**Table - 5: Effect of soil application of different Mn sources and levels on seed cotton yield, lint yield and seed yield of cotton in saline soil**

| Levels / Sources | Seed yield cotton (g pot$^{-1}$) | | | | | Lint yield (g pot$^{-1}$) | | | | | Seed yield (g pot$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Mean | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Mean | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Mean |
| $S_1$ | 65.16 | 67.70 | 69.85 | 66.34 | **67.26** | 22.15 | 23.55 | 24.44 | 22.88 | **23.26** | 39.09 | 40.62 | 41.91 | 39.80 | **40.36** |
| $S_2$ | 65.16 | 71.02 | 72.00 | 68.10 | **69.07** | 22.15 | 25.07 | 25.70 | 23.15 | **24.02** | 39.09 | 42.61 | 43.20 | 40.86 | **41.44** |
| $S_3$ | 65.16 | 75.50 | 76.90 | 71.05 | **72.15** | 22.15 | 27.18 | 27.68 | 25.22 | **25.56** | 39.09 | 45.30 | 46.14 | 42.63 | **43.29** |
| **Mean** | **65.16** | **71.41** | **72.92** | **68.50** | | **22.15** | **25.27** | **25.94** | **23.75** | | **39.09** | **42.84** | **43.75** | **41.10** | |

| | Seed yield cotton $SE_D$ | Seed yield cotton CD($P \leq 0.05$) | Lint yield $SE_D$ | Lint yield CD($P \leq 0.05$) | Seed yield $SE_D$ | Seed yield CD($P \leq 0.05$) |
|---|---|---|---|---|---|---|
| **S** | 0.73 | 1.52 | 0.35 | 0.74 | 0.48 | 1.00 |
| **L** | 1.34 | 2.78 | 0.58 | 1.20 | 0.72 | 1.50 |
| **LX S** | 1.69 | 3.49 | 0.68 | 1.40 | 0.99 | 2.05 |

$S_1$ – Mn sulphate, $S_2$- Mn EDTA $S_3$- Mn humate, $L_1$- 0 mg Mn kg$^{-1}$ of soil , $L_{2-}$ 1.25 mg Mn kg$^{-1}$ of soil , $L_3$- mg Mn kg$^{-1}$ of soil and $L_4$- mg Mn kg$^{-1}$ of soil .

All the three sources of manganese tried, favourably improved the seed cotton yield over control. Application of manganese humate was found to be superior to other two sources in increasing mean seed cotton yield, lint and seed yield. Addition of Mn humate recorded the mean seed cotton yield, lint yield and seed yield of 72.15, 25.56 and 43.29 g $pot^{-1}$, respectively. This was followed by Mn- EDTA (69.07, 24.02 and 41.44 g $pot^{-1}$g, respectively) and lowest mean seed cotton yield, lint and seed yield of 65.26, 23.26 and 40.36 g $pot^{-1}$, respectively was recorded with manganese sulphate. A positive interaction on seed cotton yield was noticed due to levels and sources of Mn. Application of 2.5 mg Mn $kg^{-1}$ as manganese humate recorded the maximum seed cotton yield, lint and seed yield of 76.90, 27.68 and 46.14 g $pot^{-1}$, respectively. This was on par with application of 1.25 mg Mn $kg^{-1}$ as manganese humate (75.50, 27.18 and 45.30 g $pot^{-1}$). This was followed by $S_2L_3$ (72.00, 25.70 and 43.20 g $pot^{-1}$), $S_2L_2$ (71.02, 25.07 and 42.16 g $pot^{-1}$) and $S_1L_2$ (67.70, 23.55 and 40.62 g $pot^{-1}$. The control registered the lowest seed cotton yield, lint and seed yield of 65.16, 22.15 and 39.09 g $pot^{-1}$. The results are in agreement with Yaseen *et al.* (2013). The highest yield of cotton may be due to application of Mn through Mn humate which could have improved plant nutrient uptake and photosynthetic efficiency (Mousavi *et al*., 2007; Crosier *et al*., 2004; Kelling and Speth, 2001; Hiller, 1995).

## 4. Conclusion

The present study established that the application of Mn humate would maximize the growth and yield by cotton in saline sodic soil. The treatment supplied with 2.5 mg Mn $kg^{-1}$ of Mn as Mn- humate recorded the highest yield parameter. However, 1.25 mg Mn $kg^{-1}$ of Mn as Mn- humate was on par treatment supplied Mn @ 2.5 mg $kg^{-1}$ as Mn-humate. The present study concluded that application of 2.5 mg Mn $kg^{-1}$ as Mn humate recorded marked improvement on the growth and yield of cotton in a saline sodic soil.

## 5. References


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