Influence of methods and stage of application of zinc, magnesium and boron on yield attributes, yield and micronutrients uptake of cotton in rainfed alfisols

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Abstract
A research experiment was conducted on cotton during kharif 2015 and 2016 at Regional Agricultural Research Station (RARS), Warangal (Telangana) “To study the Influence of methods and stage of application of zinc, magnesium and boron on yield attributes, yield and micronutrients uptake of cotton in rainfed alfisols”. Pooled results indicated that, foliar application of ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing along with soil application of recommended dose of fertilisers (RDF) recorded significantly higher sympodial branches, number of bolls per plant, seed cotton yield i.e 21.90, 43, 2811 kg ha⁻¹, respectively over other treatments. However, significantly higher Zn, Cu, Fe and Mn uptake i.e 191, 54.14, 2861 and 172 g ha⁻¹, respectively were found with foliar application of ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing along with soil application of recommended dose of fertilisers.

Keywords: Zinc, Magnesium and Boron foliar spray, seed cotton yield, micronutrients uptake

Introduction
The cotton was cultivated in 122.35 lakh ha with a production of 377 lakh bales and lint yield of 524 kg ha⁻¹ in India. In Telangana it was cultivated in 18.24 lakh ha with a production of 57 lakh bales and lint yield of 531 kg ha⁻¹. Cotton (Gossypium hirsutum L.) is considered the main fiber crop throughout industry in Telangana state as well as in India. In Telangana it was always and stills the main cash crop for most growers in alfisols under rainfed conditions and soils were low to marginal in micronutrients (Zn, Cu, Fe and Mn) availability. Hence, there is need to supplement the micronutrients with proper methods and stage of crop with recommended dose of major nutrients to produce more number of flowers and retain them on the plant to develop into bolls for final harvesting, assumed that yield can be increased considerably. Foliar application of micronutrients during flower and boll development stages have been shown to be effective in efficient utilization of nutrients by cotton and thereby reduce boll shedding and increase the yield (Radhika et al. 2013) [10]. Foliar application of B accelerates the translocation of nitrogen compounds, increases protein synthesis and stimulates fruiting. As small amounts of B are required, foliar application of B may be more efficient than soil application, especially when deficient conditions are suspected (Howard et al., 1998) [7]. Basavarajappa et al. (1997) [2] reported that, foliar application of ZnSO₄ leads to significant increase in cotton yield. Howard et al. (1998) [7] reported that application of 0.11 kg ha⁻¹ boron through foliage significantly increased the cotton yield by 10.30 %. Dordas (2006) [4] reported that foliar B application increased the number of bolls per plant and per square meter. Seed cotton yield and lint yield increased in case of 1000 g B ha⁻¹ (foliar application) which lead to 25% increase in seed cotton yield (Rashidi and Seilsepour, 2011) [11]. Zinc application significantly affected plant height, number of sympodial branches, number of bolls/plant and fiber uniformity ratio (Elayan, 2008 [6] and Abdallah and Mohamed, 2013) [1]. Foliar application of 1.0% MgSO₄ at flowering and boll development stage registered significantly superior seed cotton yield (2031 kg ha⁻¹) over no spray (1620 kg ha⁻¹) and rest of

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the foliar nutrients sprays. Shivamurthy naik et al. (2014) [12] reported that the uptake of iron, manganese and copper was significantly higher at all growth stages of cotton crop with the foliar application of boron @ 200 g ha⁻¹. Ibrahim reported that foliar application of GA and boron increased Na, K and B content of cotton leaf over control. Keeping in view of above facts, the current study was designed to investigate the effect of soil or foliar application of zinc, magnesium and boron on yield attributes, yield and micronutrients uptake in cotton.

Materials and methods
A research experiment was conducted during kharif-2015 and 2016 at RARS Warangal, located at 18°01.077 N latitude 79°36.197 E longitude and an altitude of 259 m above mean sea level to study the influence of methods and stage of application of zinc, magnesium and boron on yield attributes, yield and micronutrients uptake of cotton in rainfed alfisols of Warangal district in Telangana state. A composite soil sample was collected from 0-20 cm depth during the study years, processed and analysed for pH, electrical conductivity, organic carbon, soil available nitrogen, phosphorus, potassium and micronutrients (Zn, Cu, Fe, Mn and Boron) following standard procedures. The experiment was laid out in randomized complete block design with 10 treatments replicated in three times. The cotton seeds were sown on 3rd July in both seasons in rows 90 cm apart and plants 60 cm apart within a row where one plant left after thinning at 10 days after sowing. Soil application of nitrogen in three equal splits in the form of urea, phosphorus as basal in the form of single super phosphate, potassium in two equal splits as muriate of potash, zinc as zinc sulphate (ZnSO₄·7H₂O) while magnesium as (MgSO₄·7H₂O) and boron as boric acid (H₃BO₃) as basal. Foliar application of zinc, magnesium and boron was adopted as per the treatments and control treatment received water spray only. The other cultural practices were carried out according to the usual practices in the cotton fields. After completion of cotton pickings in the month of November for both years the seed cotton samples were collected, oven dried at 70 °C processed and analysed for total content of N, P, K, Zn, Cu, Fe and Mn following standard procedures.

Results and discussion

Initial soil fertility status
Fertilizer management is basically a technique employed for getting optimum response of the crop in relation to growth, subsequent yield and micronutrients uptake per unit area. In the present investigation, three micronutrient fertilizers were examined such as Zinc, Magnesium and Boron as foliar spray on cotton crop. The experimental soil was sandy clay loam in texture, alkaline in reaction (pH: 7.65) and non saline in nature (EC: 0.44 dS m⁻¹). Lower in organic carbon content (0.48%) and available nitrogen (169 kg ha⁻¹), medium in available phosphorus (58 kg ha⁻¹) and potassium (265 kg ha⁻¹), Zn, B, Cu, Fe and Mn were 0.66, 0.58, 1.38, 7.48 and 11.56 mg kg⁻¹, respectively

Sympodial branches
Significantly higher number of sympodial branches 26.93, 16.87 and 21.90 were recorded in 2015, 2016 and in pooled mean, respectively by the application of RDF+ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) over other treatments (Tabe-1). Sympodial branches bear bolls which directly involving in producing seed cotton on the plants. Increasing of micronutrient content in leaves might have increased the production of metabolites and thus the plant had the chance to bear more fruiting branches. These results were in agreement with findings of Kulvir Singh et al. (2015) [18] and Eleyan et al. (2014) [5].

Table 1: Influence of soil and foliar application of Zinc, Magnesium and Boron on sympodial branches of cotton in rainfed alfisols

| Treatments | Treatment details | Sympodial branches 2015 | Sympodial branches 2016 | Pooled |
|------------|-------------------|-------------------------|------------------------|--------|
| T₅         | RDF (120-60-60 kg NPK ha⁻¹) only | 13.33 | 9.33 | 11.33 |
| T₆         | RDF + ZnSO₄ soil application @ 50 kg/ha | 16.07 | 9.40 | 12.74 |
| T₇         | RDF + ZnSO₄ foliar application @ 0.2% at 30 and 45 days after sowing | 16.67 | 9.60 | 13.14 |
| T₈         | RDF + MgSO₄ soil application @ 50 kg/ha | 16.07 | 9.67 | 12.87 |
| T₉         | RDF + MgSO₄ foliar application @ 1% at 60 and 75 days after sowing | 17.00 | 9.73 | 13.37 |
| T₁₀        | RDF + Borax soil application @ 10 kg/ha | 17.13 | 10.67 | 13.90 |
| T₁¹        | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 17.47 | 10.80 | 14.44 |
| T₁²        | RDF + ZnSO₄+MgSO₄+Borax @ 50, 50 and 10 kg ha⁻¹ soil application, respectively | 17.73 | 10.81 | 14.27 |
| T₁³        | RDF + ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application | 26.93 | 16.87 | 21.90 |
| T₁₄        | Control | 9.60 | 7.47 | 8.54 |

Number of bolls per plant
Significantly higher number of bolls per plant (46) were recorded by the application of RDF + ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) over RDF (T₁) and Control (T₁₀) in kharif-2015. Significantly higher number of bolls per plant (39) were recorded by application of RDF+ZnSO₄ @ 0.2% at 30 days, ZnSO₄+ Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) over control (T₁₀) and RDF only(T₁) in 2016 and significantly higher number of bolls per plant (43) were recorded by application of RDF+ZnSO₄ @ 0.2% at 30 days, ZnSO₄+ Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) over control (T₁₀) and RDF only(T₁) in 2016 and significantly higher number of bolls per plant (43) were recorded by application of RDF+ZnSO₄ @ 0.2% at 30 days, ZnSO₄+ Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) over

RDF: Recommended Dose of Fertilizers
control (T₄), RDF only (T₁) and RDF + ZnSO₄ soil application @ 50 kg ha⁻¹ (T₂) in pooled mean (Table-2). Micronutrients may be due to production of more number of lateral branches, production of more number of bolls by arresting dropping of squares, flowers and bolls. This might be due to the reason that when nutrients are applied through foliar spray, the nutrients are supplied directly to where they are required and foliar application may increase the utilization of applied nutrient by enhancing the translocation of nutrients into the boll which increases the number and size of the boll.

Mahmooda Burio et al. (2016)⁹ reported that increased levels of boron, zinc and urea significantly enhanced opened bolls per plant and maximum response (38.4) was recorded with the foliar application of 0.1% boron + 0.1% zinc + 3.0% urea as compared with other treatments showed less response in terms of opened bolls per plant. Eleyan et al. (2014)⁵ reported that the highest boll number 16.44 and 15.84 were obtained in case of 1000 mg l⁻¹ B and 200 mg l⁻¹ Zn treatments, respectively as an average of two seasons.

| Treatments | Treatmental details | Bolls per plant |
|------------|---------------------|----------------|
|            |                     | 2015 | 2016 | Pooled |
| T₁         | RDF (120-60-60 kg NPK ha⁻¹) only | 32   | 28   | 30   |
| T₂         | RDF + ZnSO₄ soil application @ 50 kg ha⁻¹ | 37   | 30   | 34   |
| T₃         | RDF + ZnSO₄ foliar application @ 0.2% at 30 and 45 days after sowing | 40   | 33   | 37   |
| T₄         | RDF + MgSO₄ soil application @ 50 kg ha⁻¹ | 38   | 31   | 35   |
| T₅         | RDF + MgSO₄ foliar application @ 1% at 60 and 75 days after sowing | 40   | 33   | 37   |
| T₆         | RDF + Borax soil application @ 10 kg ha⁻¹ | 42   | 34   | 38   |
| T₇         | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 42   | 34   | 38   |
| T₈         | RDF + ZnSO₄ + MgSO₄ + Borax @ 50, 50 and 10 kg / ha soil application, respectively | 42   | 38   | 40   |
| T₉         | RDF + ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application. | 46   | 39   | 43   |
| T₁₀        | Control (T₀) | 25   | 16   | 21   |
|            | SE m⁴ | 2    | 3    | 3    |
|            | CD (P=0.05) | 7    | 9    | 8    |
|            | CV (%) | 11   | 16   | 14   |

B: Recommended Dose of Fertilizers

Seed cotton yield
Application of RDF+ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₃) recorded significantly higher seed cotton yield i.e.2845, 2777, 2811 kg ha⁻¹ in 2015, 2016 and in pooled mean, respectively over RDF(T₁), RDF+MgSO₄ soil application @ 50 kg ha⁻¹ (T₄), RDF+MgSO₄ foliar application @ 1% at 60 and 75 days after sowing (T₃) and control (T₁₀) in 2015, in 2016 it is significantly higher over RDF (T₁), RDF+ZnSO₄ soil application @ 50 kg ha⁻¹ (T₄), RDF+MgSO₄ soil application @ 50 kg ha⁻¹ (T₄) and control (T₁₀) in and in pooled mean it is significantly higher over RDF(T₁), RDF+ZnSO₄ soil application @ 50 kg ha⁻¹ (T₄), RDF+MgSO₄ soil application @ 50 kg ha⁻¹ (T₄) and control (T₁₀). In 2016 it is significantly higher over RDF(T₁), RDF+ZnSO₄ soil application @ 50 kg ha⁻¹ (T₄), RDF+MgSO₄ soil application @ 50 kg ha⁻¹ (T₄) and control (T₁₀). In 2016 it is significantly higher over RDF(T₁), RDF+ZnSO₄ soil application @ 50 kg ha⁻¹ (T₄), RDF+MgSO₄ soil application @ 50 kg ha⁻¹ (T₄) and control (T₁₀) and it is on par with rest of the treatments (Table-3). Increase in seed cotton yield is due to increase in number of bolls per plant, boll weight and seed index. These results were supported by Mahmooda Burio et al. (2016)⁹, Basavarajappa et al. (1997) [2], Howard et al. (1998) [7] and Rashidi and Seilsepour (2011) [11]. Kulvirsingh et al. (2015) [8] reported that the highest seed cotton yield (3421 kg ha⁻¹) was recorded with application of MgSO₄ @ 1.0% + ZnSO₄ @ 0.5%. Better net returns Rs.1.1 lakh ha⁻¹ and improved B:C (4.06) ratio for MgSO₄ @ 1.0% + ZnSO₄ @ 0.5% clearly supported its application benefits to realize higher yield. Yield increase was the consequence of enhanced boll setting (Eleyan et al. 2014) [5].

| Treatments | Treatmental details | Seed cotton yield (kg ha⁻¹) |
|------------|---------------------|-----------------------------|
|            |                     | 2015 | 2016 | Pooled |
| T₁         | RDF (120-60-60 kg NPK ha⁻¹) only | 2295 | 2192 | 2244 |
| T₂         | RDF + ZnSO₄ soil application @ 50 kg ha⁻¹ | 2341 | 2312 | 2327 |
| T₃         | RDF + ZnSO₄ foliar application @ 0.2% at 30 and 45 days after sowing | 2452 | 2524 | 2488 |
| T₄         | RDF + MgSO₄ soil application @ 50 kg ha⁻¹ | 2361 | 2325 | 2298 |
| T₅         | RDF + MgSO₄ foliar application @ 1% at 60 and 75 days after sowing | 2663 | 2556 | 2611 |
| T₆         | RDF + Borax soil application @ 10 kg ha⁻¹ | 2690 | 2563 | 2616 |
| T₇         | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 2691 | 2587 | 2639 |
| T₈         | RDF + ZnSO₄ + MgSO₄ + Borax @ 50, 50 and 10 kg ha⁻¹ soil application, respectively | 2711 | 2758 | 2735 |
| T₉         | RDF + ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application. | 2845 | 2777 | 2811 |
| T₁₀        | Control | 1545 | 1535 | 1540 |
|            | SE m⁴ | 120  | 142  | 131  |
|            | CD(P=0.05) | 358  | 427  | 393  |
|            | CV (%) | 8.40 | 10.10| 9.10  |
Total Zn uptake (g ha\(^{-1}\))
Significantly higher total zinc uptake 124, 257 and 191 g ha\(^{-1}\) were recorded in 2015, 2016 and in pooled mean, respectively due to RDF+ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\) + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application (T\(_5\)) over other treatments though it is at par with RDF+ ZnSO\(_4\)+ MgSO\(_4\)+ Borax @ 50 + 50 + 10 kg ha\(^{-1}\) soil application, respectively (T\(_6\)) in both the years and in pooled mean. Foliar application improved the nutrient status of leaves compared to soil applied fertilizers alone. This improvement in nutrient status resulted in an increase in the number of flowers, number of bolls, and ultimately of seed-cotton yield and uptake of nutrient is a product of dry matter accumulation and nutrient concentration due to this reason RDF +ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\)+Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application (T\(_5\)) was accumulated more dry matter, seed cotton yield and thus have removed more Zn compared to remains.

**Table 5:** Effect of soil and foliar application of Zinc, Magnesium and Boron on total Zn uptake by cotton in rainfed alfisols

| Treatments | Treatmental details | Zn-uptake (g ha\(^{-1}\)) |
|------------|---------------------|--------------------------|
| T\(_1\)    | RDF (120-60-60 kg NPK ha\(^{-1}\)) | 88 | 171 | 130 |
| T\(_2\)    | RDF + ZnSO\(_4\) soil application @ 50 kg ha\(^{-1}\) | 107 | 241 | 177 |
| T\(_3\)    | RDF + ZnSO\(_4\)foliar application @ 0.2% at 30 and 45 days after sowing | 108 | 247 | 179 |
| T\(_4\)    | RDF + MgSO\(_4\) soil application @ 50 kg ha\(^{-1}\) | 81 | 214 | 148 |
| T\(_5\)    | RDF + MgSO\(_4\) soil application @ 0.2% at 30 days and 45 days after sowing | 87 | 225 | 156 |
| T\(_6\)    | RDF + Borax soil application @ 10 kg ha\(^{-1}\) | 101 | 227 | 164 |
| T\(_7\)    | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 105 | 236 | 171 |
| T\(_8\)    | RDF + ZnSO\(_4\) @ 50 kg ha\(^{-1}\) + MgSO\(_4\) @ 50 kg ha\(^{-1}\) + Borax 10 kg ha\(^{-1}\) soil application. | 117 | 254 | 181 |
| T\(_9\)    | RDF + ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\) @ 0.2% + Borax @ 0.2% at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application. | 124 | 257 | 191 |
| T\(_{10}\)  | Control | 45 | 132 | 89 |

**Total Cu uptake (g ha\(^{-1}\))**
Significantly higher total copper uptake 51.45, 56.82 and 54.14 g ha\(^{-1}\) were recorded in 2015, 2016 and in pooled mean, respectively with application of RDF+ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\) + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application (T\(_5\)) over other treatments though at par with application of RDF+ ZnSO\(_4\)+ MgSO\(_4\)+ Borax @ 50 + 50 + 10 kg ha\(^{-1}\) soil application, respectively (T\(_6\)) in both the years and in pooled mean. Foliar application improved the nutrient status of leaves compared to soil applied fertilizers alone. This improvement in nutrient status resulted in an increase in the number of flowers, number of bolls, and ultimately of seed-cotton yield and uptake of nutrient is a product of dry matter accumulation and nutrient concentration due to which application of RDF+ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\)+Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application (T\(_5\)) was accumulated more dry matter, seed cotton yield and thus have removed more Cu compared to remains.

**Table 6:** Effect of soil and foliar application of Zinc, Magnesium and Boron on total Cu uptake by cotton in rainfed alfisols

| Treatments | Treatmental details | Cu-uptake (g ha\(^{-1}\)) |
|------------|---------------------|--------------------------|
| T\(_1\)    | RDF (120-60-60 kg NPK ha\(^{-1}\)) | 34.07 | 37.48 | 36.33 |
| T\(_2\)    | RDF + ZnSO\(_4\) soil application @ 50 kg ha\(^{-1}\) | 35.19 | 43.63 | 39.41 |
| T\(_3\)    | RDF + ZnSO\(_4\) foliar application @ 0.2% at 30 and 45 days after sowing | 38.30 | 46.21 | 42.26 |
| T\(_4\)    | RDF + MgSO\(_4\) soil application @ 50 kg ha\(^{-1}\) | 39.05 | 48.26 | 43.66 |
| T\(_5\)    | RDF + MgSO\(_4\) foliar application @ 0.2% at 60 and 75 days after sowing | 41.40 | 48.74 | 45.07 |
| T\(_6\)    | RDF + Borax soil application @ 10 kg ha\(^{-1}\) | 42.44 | 49.29 | 45.87 |
| T\(_7\)    | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 43.43 | 52.88 | 48.16 |
| T\(_8\)    | RDF + ZnSO\(_4\) + MgSO\(_4\) + Borax @ 50, 50 and 10 kg ha\(^{-1}\) soil application, respectively | 44.61 | 54.05 | 49.33 |
| T\(_9\)    | RDF + ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\) @ 0.2% + Borax @ 0.2% at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application. | 51.45 | 56.82 | 54.14 |
| T\(_{10}\)  | Control | 24.15 | 26.77 | 25.46 |

**Total Fe uptake (g ha\(^{-1}\))**
Significantly higher total iron uptake 4367, 1355 and 2861 g ha\(^{-1}\) were recorded in 2015, 2016 and in pooled mean, respectively by application of RDF+ZnSO\(_4\) @ 0.2% at 30 days, ZnSO\(_4\) + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO\(_4\) @ 1% at 60 days and MgSO\(_4\) @ 1% at 75 days after sowing as foliar application (T\(_5\)) was accumulated more dry matter, seed cotton yield and thus have removed more Fe compared to remains.
sowing as foliar application (T₉) over other treatments though it is at par with application of RDF+ZnSO₄+MgSO₄+Borax @ 50 + 50 + 10 kg ha⁻¹ as soil application, respectively (T₅) in both the years and in pooled mean. Foliar application improved the nutrient status of leaves compared to soil applied fertilizers alone. This improvement in nutrient status resulted in an increase in the number of flowers, number of bolls, and ultimately of seed-cotton yield and uptake of nutrient is a product of dry matter accumulation and nutrient concentration. Hence, application of RDF +ZnSO₄ @ 0.2% at 30 days, ZnSO₄+Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) was accumulated more dry matter, seed cotton yield and thus have removed more Fe compared to remains.

### Table 7: Effect of soil and foliar application of Zinc, Magnesium and Boron on total Fe-uptake by cotton in rainfed alfisols

| Treatments | Treatmental details | Fe- uptake (g ha⁻¹) |
|------------|---------------------|---------------------|
| T₁         | RDF (120-60-60 kg NPK ha⁻¹) | 1508 | 553 | 1031 |
| T₂         | RDF + ZnSO₄ soil application @ 50 kg ha⁻¹ | 1567 | 623 | 1095 |
| T₃         | RDF + ZnSO₄ foliar application @ 0.2% at 30 and 45 days after sowing | 1571 | 632 | 1102 |
| T₄         | RDF + MgSO₄ soil application @ 50 kg ha⁻¹ | 1779 | 734 | 1257 |
| T₅         | RDF + MgSO₄ foliar application @ 1% at 60 and 75 days after sowing | 2234 | 761 | 1502 |
| T₆         | RDF + Borax soil application @ 10 kg ha⁻¹ | 2286 | 778 | 1532 |
| T₇         | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 3632 | 913 | 2272 |
| T₈         | RDF + ZnSO₄+MgSO₄ + Borax @ 50, 50 and 10 kg ha⁻¹ soil application, respectively | 4284 | 1293 | 2789 |
| T₉         | RDF + ZnSO₄ @ 0.2% at 30 days, ZnSO₄ @ 0.2% + Borax @ 0.2% at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application. | 4367 | 1355 | 2861 |
| T₁₀        | Control | 812 | 494 | 653 |

RDF: Recommended Dose of Fertilizer

### Total Mn uptake (g ha⁻¹)

Significantly higher total Mn uptake 241, 103 and 172 g ha⁻¹ were recorded in 2015, 2016 and in pooled mean, respectively with application of RDF(as soil)+ZnSO₄ @ 0.2% at 30 days, ZnSO₄ + Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) over all other treatments in 2015 and in pooled mean and in 2016 it is significantly higher over application of RDF (T₁), RDF+ZnSO₄ soil application @ 50 kg ha⁻¹(T₂), RDF+ZnSO₄ foliar application @ 0.2% at 30 and 45 days after sowing (T₃), RDF+MgSO₄ soil application @ 50 kg ha⁻¹ (T₅), and Control (T₁₀) though at par with rest of the treatments. Foliar application improved the nutrient status of leaves compared to soil applied fertilizers alone. This improvement in nutrient status resulted in an increase in the number of flowers, number of bolls, and ultimately of seed-cotton yield and uptake of nutrient is a product of dry matter accumulation and nutrient concentration. Hence, application of RDF+ZnSO₄ @ 0.2% at 30 days, ZnSO₄+Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) was accumulated more dry matter, seed cotton yield and thus have removed more Mn compared to remains. These results were in conformity with shivamurthy naik et al. (2014) [12]. Application of RDF +ZnSO₄ @ 0.2% at 30 days, ZnSO₄+Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application (T₉) was accumulated more dry matter, seed cotton yield and thus have removed more Zn, Cu, Fe and Mn compared to remains.

### Table 8: Effect of soil and foliar application of Zinc, Magnesium and Boron on total Mn-uptake by cotton in rainfed alfisols

| Treatments | Treatmental details | Mn- uptake (g ha⁻¹) |
|------------|---------------------|---------------------|
| T₁         | RDF (120-60-60 kg NPK ha⁻¹) | 141 | 59.55 | 100 |
| T₂         | RDF + ZnSO₄ soil application @ 50 kg ha⁻¹ | 178 | 62.04 | 120 |
| T₃         | RDF + ZnSO₄ foliar application @ 0.2% at 30 and 45 days after sowing | 189 | 78.16 | 134 |
| T₄         | RDF + MgSO₄ soil application @ 50 kg ha⁻¹ | 162 | 81.71 | 122 |
| T₅         | RDF + MgSO₄ foliar application @ 1% at 60 and 75 days after sowing | 176 | 85.92 | 131 |
| T₆         | RDF + Borax soil application @ 10 kg ha⁻¹ | 165 | 85.79 | 125 |
| T₇         | RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing | 170 | 93.82 | 147 |
| T₈         | RDF + ZnSO₄ + MgSO₄ + Borax @ 50, 50 and 10 kg ha⁻¹ soil application, respectively | 195 | 99.28 | 147 |
| T₉         | RDF + ZnSO₄ @ 0.2% at 30 days, ZnSO₄ @ 0.2% + Borax @ 0.2% at 45 days, Borax @ 0.2% + MgSO₄ @ 1% at 60 days and MgSO₄ @ 1% at 75 days after sowing as foliar application. | 241 | 103.08 | 172 |
| T₁₀        | Control | 137 | 43.24 | 90 |

RDF: Recommended Dose of Fertilizer
Conclusion
It is inferred that cotton responds to foliar application of zinc, magnesium and boron in rain fed alfisols. It could be a viable option to break the yield barrier in cotton. Pooled data of two years study revealed that application of RDF +ZnSO$_4$ @ 0.2% at 30 days, ZnSO$_4$+Borax @ 0.2% each at 45 days, Borax @ 0.2% + MgSO$_4$ @ 1% at 60 days and MgSO$_4$ @ 1% at 75 days after sowing as foliar application can enhance seed cotton yield and nutrients uptake significantly by improving yield attributing parameters and should be exploited by farmers to enhance cotton productivity under rainfed condition grown in red loamy soils with low availability of nitrogen, medium availability of phosphorus and potassium with marginal available micronutrients (Zn, Cu, Fe and Mn). Foliar application improved the nutrient status of leaves compared to soil applied fertilizers alone. This improvement in nutrient status resulted in an increase in the number of flowers, number of bolls, and ultimately of seed-cotton yield. The increased yield resulted in 20%-30% more economic benefit over NPK fertilizers alone.

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