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CH Ramulu
Department of Soil Science and Agricultural Chemistry, Regional Agricultural Research Station, Warangal, Telangana, India

E Narsaiah
Department of Soil Science and Agricultural Chemistry, Regional Agricultural Research Station, Warangal, Telangana, India

P Raghu Rami Reddy
Department of Soil Science and Agricultural Chemistry, Regional Agricultural Research Station, Warangal, Telangana, India

Corresponding Author:
CH Ramulu
Department of Soil Science and Agricultural Chemistry, Regional Agricultural Research Station, Warangal, Telangana, India

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

CH Ramulu, E Narsaiah and P Raghu Rami Reddy

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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 $ZnSO_4$ @ 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 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 $ZnSO_4$ @ 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 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 $ZnSO_4$ leads to significant superior 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% $MgSO_4$ 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

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 18^0 01.077 N latitude 79^0 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 ($ZnSO_4.7H_2O$) while magnesium as ($MgSO_4.7H_20$) and boron as boric acid (H_3BO_3) 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 ^{0}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+$ZnSO_4$ @ 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_9) 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 Kulvirsingh *et al.* (2015) [8] 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	Treatmental details	Sympodial branches		
		2015	2016	Pooled
T_1	RDF (120-60-60 kg NPK ha^{-1}) only	13.33	9.33	11.33
T_2	RDF + $ZnSO_4$ soil application @ 50 kg/ha	16.07	9.40	12.74
T_3	RDF + $ZnSO_4$foliar application @ 0.2% at 30 and 45 days after sowing	16.67	9.60	13.14
T_4	RDF + $MgSO_4$ soil application @ 50 kg/ha	16.07	9.67	12.87
T_5	RDF+$MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing	17.00	9.73	13.37
T_6	RDF + Borax soil application @ 10 kg/ha	17.13	10.67	13.90
T_7	RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing	17.47	10.80	14.44
T_8	RDF + $ZnSO_4$+$MgSO_4$+Borax @ 50, 50 and 10 kg ha^{-1} soil application, respectively	17.73	10.81	14.27
T_9	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.	26.93	16.87	21.90
T_{10}	Control	9.60	7.47	8.54
SE m±		0.95	0.68	0.82
CD (P = 0.05)		2.85	1.65	2.25
CV (%)		9.83	12.10	11.00

RDF: Recommended Dose of Fertilizers

Number of bolls per plant

Significantly higher number of bolls per plant (46) were recorded by the 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_9) over RDF(T_1), RDF+$ZnSO_4$ soil application @ 50 kg ha^{-1} (T_2), RDF+$MgSO_4$ soil application @ 50 kg ha^{-1} (T_4) and Control (T_{10}) in kharif-2015. Significantly higher number of bolls per plant (39) were recorded 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_9) over control (T_{10}) and RDF only(T_1) in 2016 and significantly higher number of bolls per plant (43) were recorded 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_9) over

control(T_{10}), RDF only (T_1) and RDF +$ZnSO_4$ soil application @ 50 kg ha^{-1} (T_2) 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 Buriro *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 mgl^{-1} B and 200 mgl^{-1} Zn treatments, respectively as an average of two seasons

Table 2: Influence of soil and foliar application of Zinc, Magnesium and Boron on number of bolls per plant of cotton in rainfed alfisols

Treatments	Treatmental details	Bolls per plant		
		2015	2016	Pooled
T_1	RDF (120-60-60 kg NPK ha^{-1}) only	32	28	30
T_2	RDF + $ZnSO_4$ soil application @ 50 kg ha^{-1}	37	30	34
T_3	RDF + $ZnSO_4$ foliar application @ 0.2% at 30 and 45 days after sowing	40	33	37
T_4	RDF + $MgSO_4$ soil application @ 50 kg ha^{-1}	38	31	35
T_5	RDF + $MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing	40	33	37
T_6	RDF + Borax soil application @ 10 kg ha^{-1}	42	34	38
T_7	RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing	42	34	38
T_8	RDF + $ZnSO_4$ + $MgSO_4$ + Borax @ 50, 50 and 10 kg /ha soil application, respectively	42	38	40
T_9	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.	46	39	43
T_{10}	Control	25	16	21
SE m±		2	3	3
CD (P = 0.05)		7	9	8
CV (%)		11	16	14

RDF: Recommended Dose of Fertilizers

Seed cotton yield

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_9) recorded significantly higher seed cotton yield i.e.2845, 2777, 2811 kg ha^{-1} in 2015, 2016 and in pooled mean, respectively over RDF(T_1), RDF+$MgSO_4$ soil application @ 50 kg ha^{-1} (T_4), RDF+$MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing (T_5) and control (T_{10}) in 2015, in 2016 it is significantly higher over RDF (T_1), RDF+$ZnSO_4$ soil application @ 50 kg ha^{-1} (T_2), RDF+$MgSO_4$ soil application @ 50 kg ha^{-1} (T_4) and control (T_{10}) and in pooled mean it is significantly higher over RDF(T_1), RDF+$ZnSO_4$ soil application @ 50 kg ha^{-1}(T_2), RDF+$MgSO_4$ soil application @ 50 kg ha^{-1} (T_4), RDF+$MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing (T_5) and control (T_{10}) 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 Buriro *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 $MgSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5%. Better net returns Rs.1lakh $ha^{-1}$and improved B:C (4.06) ratio for $MgSO_4$ @ 1.0% + $ZnSO_4$ @ 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].

Table 3: Effect of soil and foliar application of Zinc, Magnesium and Boron on seed cotton yield in rainfed alfisols

Treatments	Treatmental details	Seed cotton yield (kg ha^{-1})		
		2015	2016	Pooled
T_1	RDF (120-60-60 kg NPK ha^{-1})	2295	2192	2244
T_2	RDF + $ZnSO_4$ soil application @ 50 kg ha^{-1}	2341	2312	2327
T_3	RDF + $ZnSO_4$foliar application @ 0.2% at 30 and 45 days after sowing	2452	2524	2488
T_4	RDF + $MgSO_4$ soil application @ 50 kg ha^{-1}	2361	2235	2298
T_5	RDF + $MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing	2665	2556	2611
T_6	RDF + Borax soil application @ 10 kg ha^{-1}	2669	2563	2616
T_7	RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing	2691	2587	2639
T_8	RDF + $ZnSO_4$ + $MgSO_4$ + Borax @ 50, 50 and 10 kg ha^{-1} soil application, respectively	2711	2758	2735
T_9	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.	2845	2777	2811
T_{10}	Control	1545	1535	1540
SE m±		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 191g 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_9) 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_8) 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_9) 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})		
		2015	2016	Pooled
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 + $MgSO_4$ foliar application @ 1% at 60 and 75 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
SE m±		7.99	12.11	10.05
CD(P=0.05)		24	36.24	30.12
CV (%)		14.38	9.51	11.95

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_9) 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_8) 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_9) 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})		
		2015	2016	Pooled
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 @ 1% 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
SE m±		4.11	4.89	4.50
CD(P=0.05)		12.30	14.64	13.47
CV (%)		18.06	18.25	18.16

RDF: Recommended Dose of Fertilizer

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_9) over other treatments though it is at par with application of RDF+ $ZnSO_4$+ $MgSO_4$+ Borax @ 50 + 50 + 10 kg ha^{-1} as soil application, respectively (T_8) 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 +$ZnSO_4$ @ 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_9) 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})		
		2015	2016	Pooled
T_1	RDF (120-60-60 kg NPK ha^{-1})	1508	553	1031
T_2	RDF + $ZnSO_4$ soil application @ 50 kg ha^{-1}	1567	623	1095
T_3	RDF + $ZnSO_4$ foliar application @ 0.2% at 30 and 45 days after sowing	1571	632	1102
T_4	RDF + $MgSO_4$ soil application @ 50 kg ha^{-1}	1779	734	1257
T_5	RDF + $MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing	2243	761	1502
T_6	RDF + Borax soil application @ 10 kg ha^{-1}	2286	778	1532
T_7	RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing	3632	912	2272
T_8	RDF + $ZnSO_4$ + $MgSO_4$ + Borax @ 50, 50 and 10 kg ha^{-1} soil application, respectively	4284	1293	2789
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.	4367	1355	2861
T_{10}	Control	812	494	653
SE m±		165.06	88.36	126.71
CD(P=0.05)		494	265	380
CV (%)		11.89	18.79	15.34

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)+$ZnSO_4$ @ 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_9) over all other treatments in 2015 and in pooled mean and in 2016 it is significantly higher over application of RDF (T_1), RDF+$ZnSO_4$ soil application @ 50 kg ha^{-1}(T_2), RDF+$ZnSO_4$ foliar application @ 0.2% at 30 and 45 days after sowing (T_3), RDF+$MgSO_4$ soil application @ 50 kg ha^{-1} (T_4), and control (T_{10}) 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+$ZnSO_4$ @ 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_9) 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 +$ZnSO_4$ @ 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_9) 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})		
		2015	2016	Pooled
T_1	RDF (120-60-60 kg NPK ha^{-1})	141	59.55	100
T_2	RDF + $ZnSO_4$ soil application @ 50 kg ha^{-1}	178	62.04	120
T_3	RDF + $ZnSO_4$foliar application @ 0.2% at 30 and 45 days after sowing	189	78.16	134
T_4	RDF + $MgSO_4$ soil application @ 50 kg ha^{-1}	162	81.71	122
T_5	RDF + $MgSO_4$ foliar application @ 1% at 60 and 75 days after sowing	176	85.92	131
T_6	RDF + Borax soil application @ 10 kg ha^{-1}	165	85.79	125
T_7	RDF + Borax foliar application @ 0.2% at 45 and 60 days after sowing	170	93.82	132
T_8	RDF + $ZnSO_4$ + $MgSO_4$ + Borax @ 50, 50 and 10 kg ha^{-1} soil application, respectively	195	99.28	147
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.	241	103.08	172
T_{10}	Control	137	43.24	90
SE m±		7.07	6.03	6.55
CD(P=0.05)		21.18	18.04	19.61
CV (%)		6.98	13.17	10.08

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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