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Critical Levels of Iron, Zinc and Boron for Cotton in Varamin Rigion

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ABSTRACT

Cotton (*Gossypium hirsutum* L. cv. Varamin) an important industrial crop of Iran, is grown in 300,000 ha, with an average seed -cotton yield of 1750 Kg.ha^{-1}. The main obstacle in the way of increasing average cotton yield is imbalanced fertilizer use. Along with urea and triple super phosphate, cotton growers also need K, Mg, Zn, Fe, Mn, Cu, and B, so these elements' critical levels should be determined in cotton fields. Field experiments were conducted in 12 different fields in 1997 to determine critical levels of Fe, Zn, and B in soil, and to study the effects of these micronutrients on the yield and quality of cotton in Varamin region. The experiment design was a randomized complete block one (RCB) with four treatments and three replications. Treatments were; NPK, NPK+Fe, NPK+Zn, and NPK+B. Iron was applied as FeEDDHA (20 kg.ha^{-1}), Zn as zinc sulfate (40 Kg.ha^{-1}), and B as boric acid (20 Kg. ha^{-1}) prior to planting. Average seed cotton yield, lint yield, seed index, and boll weight increased significantly by adding Fe, Zn, and B. In a cotton field with higher soil B concentrations, cotton yield decreased with B fertilizer. Critical levels of Fe, Zn, and B were determined based on Cate-Nelson graphical and analysis of variance methods. In graphical method critical levels of Fe, Zn, and B were 4.8, 1.1, and 1.0 mg.Kg^{-1} soil, respectively, while on the basis of analysis of variance method, these levels were 5.5, 1.1, and 1.3 mg.kg^{-1} soil, respectively. In one field, boll shedding decreased by Zn and Fe treatments but was not affected by B addition. Iron to Zn ratio in cotton leaves increased at Fe treatment and decreased in Zn treatments. Boron treatment increased B content of leaves. Furthermore, zinc sulfate decreased B toxicity in the cotton leaves. In short, applying micronutrients increased quality and yield of cotton in Varamin region.

Key words: Boll shedding, Boron, Boron toxicity, Iron, Zinc.

INTRODUCTION

Iron, Zn, and B are essential elements for plant growth. Available Fe, Zn, and B are usually low in sandy and calcareous soils. Calcareous soils with high bicarbonates in soil solution or irrigation water, excessive P in soil, and management practices are related to Fe and Zn deficiency in plants (Coulombe *et al*., 1984; Mengel *et al.,* 1984: and Marschner 1995). Boron is a nonmetal nutrient, availability of which decreases in calcareous soils.

Soil testing is needed to assess soil fertility level (Melested and Peck 1973). Cate and Nelson (1965) developed a Graphical Method (GM) for partitioning two dimensional relative yields versus soil test level scattered into two groups. Cate and Nelson (1971) also reported another statistical procedure, i. e., Analysis of Variance Method (ANOVA) for separating yield data into two or more classes based upon maximization of the class sum squares (Nelson and Anderson 1984). The procedure used was: (i) ΔYs were calculated for each location by subtraction of yield at 0-level of fertilizer from yield at non-0-level of fertilizer, (ii) Soil test values (X) were obtained for each location, (iii) Data were ordered in an array based upon ranking of the X value, (iv) starting with the partitioning that placed two points to the left and ending with that which placed

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two to the right of the partition, the class sum of square was calculated according to techniques used in an ANOVA for a one-way classification, namely:

$CSS=(\Sigma\Delta Y_1)^2/n_1+(\Sigma\Delta Y_2)^2/n_2-(\Sigma\Delta Y)^2/n$

in which:

CSS= class sum of squares; $\Sigma\Delta Y_1$=Total ΔY for class1; $\Sigma\Delta Y_2$= Total ΔY for class2; n_1 and n_2 = Number of observations in class 1 and 2; n= Total number of observations, (v) Thraugh process a series of CSS values were obtained. The critical level of X was taken as that level of X division for which CSS was maximum.

The critical levels of Fe, Zn, and B have been determined by many scholars. Lindsay and Norvell (1978) mentioned that the critical levels of DTPA-extractable Fe and Zn in soils were 4.5 and 1.0 $mg.kg^{-1}$, respectively. Page *et al.* (1982) classified Fe and Zn as: 0-5 $mg.kg^{-1}$(very low), 6-10 mg. Kg^{-1}(low), 11-16 $mg.kg^{-1}$ (medium) for Fe and 0.0-0.5$mg.kg^{-1}$ (very low), 0.6-1.0 $mg.kg^{-1}$(low), 1.1-3.0 $mg.kg^{-1}$(medium) and >3.0 $mg.kg^{-1}$ (high) for Zn. Critical range of B extractable with hot water related to soil texture, pH, and plant species were 0.0-0.4 $mg.kg^{-1}$ (very low), 0.5-0.8 $mg.kg^{-1}$ (low) 0.9-1.2 $mg.kg^{-1}$ (medium) and 1.3-2.0 $mg.kg^{-1}$(high).

Many biotic factors directly influence boll shedding. Nutritional problems are important factors in boll shedding. Nutritional theory proposes that sufficient amounts of nutrients lead to boll retention in cotton (Heitholt and Schmidt 1994; Swietlik and Faust, 1994). Low soil Zn availability and high level of soluble B are encountered in some soils of arid and semiarid zones. Zinc availability is inversely related to soil pH and deficiency of Zn was frequently noted for plant growth on calcareous soils (Graham *et al*., 1987). In Iran, B toxicity is a major problem in saline soils as well as irrigation waters in Kerman, Qom, Ardekan, Jiroft, Jahrom, and Yazd regions (Malakouti and Tehrani, 1998).

Due to soil depletion, intensive cropping in consecutive years, low organic matter level, and imbalanced fertilizer use in the past, determination of micronutrient critical level is needed in the study region. The objectives of this research were to determinate the (i) Fe, Zn and B critical levels, (ii) effects of these micronutrients on the yield and quality of cotton, and (iii) effects of $ZnSO_4$ on decreasing B toxicity.

Table 1. Range of physico-chemical properties of soils in 12 studied fields.

Range	Min.	Max.	Ave.
Clay (%)	27.1	39.6	33.3
Silt (%)	28.4	47.7	38.1
Calcium carbonate (%)	9.2	20.4	14.8
Organic carbon (%)	0.30	0.81	0.55
PH	7.5	7.9	7.7
EC ($dS.m^{-1}$)	0.98	4.90	2.94
CEC ($cmol.kg^{-1}$soil)	11.6	18.5	15.1
DTPA extractable Fe ($mg.kg^{-1}$)	3.40	7.50	5.45
DTPA extractable Zn ($mg.kg^{-1}$)	0.70	1.60	1.15
Hot water extractable B ($mg.kg^{-1}$)	0.58	4.32	2.45

MATERIALS AND METHODS

This experiment was carried out on 12 cotton fields in different locations of Varamin region. The experimental design was randomized complete block (RCB) with three replications. The size of the plots was $4.8\times11m^2$ with six rows per plot. Irrigation water and soil (0.30 cm depth) samples were taken from each location prior to planting. The treatments consisted of NPK, NPK+Fe, NPK+Zn, and NPK+B. Iron was applied as Sequestrene 138-Fe (20$kg.ha^{-1}$), Zn as $ZnSO_4$ (40 $kg.ha^{-1}$), and B as H_3BO_3 (20 $kg.ha^{-1}$). Phosphorus and K were added as concentrated superphosphate and potassium sulfate fertilizers before planting. Seeds of cotton (*Gossypium hirsutum* L. *cv*. Varamin) were sown. Nitrogen was applied as urea

Table 2. Chemical properties of irrigation water.

Range	Min	Max.	Ave.
EC($dS.m^{-1}$)	0.58	2.05	1.31
pH	8.1	8.5	8.3
CO_3^{2-}($meq.lit^{-1}$)	0.2	0.6	0.40
HCO_3^- ($meq.lit^{-1}$)	1.7	3.3	2.5
$(Ca+Mg)^{2+}$($meq.lit^{-1}$)	3.6	10.8	7.2

Table 3. Seed cotton yields (kg.ha^{-1}) as affected by fertility treatments.

Field No.	NPK (kg.ha^{-1})	NPK+Fe (kg.ha^{-1})	NPK+Zn (Kg.ha^{-1})	NPK+B (Kg.ha^{-1})	F-Value
1	3406	3752	3614	3389	1.07$^{n.s}$
2	2394^{c}	2840^{a}	2722^{ab}	2534^{bc}	3.92*
3^{a}	2394^{b}	2645^{a}	2562^{ab}	2454^{ab}	2.73$^{n.s}$
4	2999	3411	3286	3209	1.37$^{n.s}$
5	2997	3006	2866	3003	0.64$^{n.s}$
6	2697^{b}	3047^{a}	2996^{a}	2728^{b}	4.03*
7	2960	3237	3124	3097	1.04$^{n.s}$
8	3144	3308	3046	3200	1.39$^{n.s}$
9	3422	3665	3602	3550	0.15$^{n.s}$
10	2220^{b}	2634^{a}	2529^{a}	1975^{b}	4.77*
11	3181^{ab}	3779^{a}	3653^{ab}	3463^{ab}	4.34*
12	2287	2219	2602	2343	1.26$^{n.s}$
Ave.	2842	3129	3050	2912	

^{a}F-Value was not significant but variance between treatment in Duncan's multiple range test was significant (α=0.05) , n. s.= Non-significant , *Significant at α=0.05

(200 kg.ha^{-1} N) at two stages, i.e., 60% at thinning and 40% at flowering stage. Soil available Fe and Zn were determined by DTPA extractant method and B was measured by hot water method (Page *et al.* 1982). All other soil characteristics were measured according to the conventional methods. Leaf samples were collected from newly matured or from the four uppermost leaves in flowering stage. Leaf samples were washed with distillated water then oven dried at 65°C and digested by dry ashing with HCl. Boll shedding was measured only in one of the fields (NO. 6). Ten plants were randomly chosen and the number of abscised and retained bolls masured in each plot every week after flowering. Twenty bolls were sampled in each plot from nodes 8-12. Seed cotton was collected for one plot through picking bolls by hand. Seed cotton of boll sample was weighted and ginned by an electrical gin. Seed and lint indexes were determined, lint yield being calculated for every plot at each location. The results were analyzed using MSTATC and QPRO5 software packages.

RESULTS AND DISCUSSION

The soil and irrigation water characteristics are given in tables 1 and 2.

Iron, Zn, and B application increased seed cotton yield in most cotton fields (Table 3), the increase being significant in fields No. 2, 6, 10, and 11; but in field No. 3, F-value was not significant, while differences between treatments were significant as determined by Duncan's multiple range test.

Iron addition significantly increased seed cotton yield in fields No. 2, 3, 6, and 10 with initial Fe levels of 3.6, 3.4, 4.8, and 4.3 (mg.kg^{-1}soil), respectively. Zinc treatment significantly increased seed cotton yield in field No. 2, 6, and 10 with initial Zn levels of 1.10,0.70, and 0.78 mg.kg^{-1}soil, respec-

Table 4. Boll weight (g. boll^{-1}) at different treatments.

Field No.	NPK^{a}	NPK+Fe	NPK+ Zn	NPK+B
1	5.97^{a}	6.37^{a}	6.22^{a}	5.98^{a}
2	5.95^{b}	6.60^{a}	6.41^{a}	6.19^{a}
3	5.80^{b}	6.31^{a}	6.07^{b}	5.96^{a}
4	6.30^{a}	6.73^{a}	6.49^{a}	6.50^{a}
5	6.19^{a}	6.31^{a}	6.18^{a}	6.18^{a}
6	6.34^{b}	6.68^{a}	6.77^{a}	6.34^{b}
7	6.60^{a}	6.83^{a}	6.68^{a}	6.71^{a}
8	6.72^{a}	6.98^{a}	6.70^{a}	6.73^{a}
9	6.30^{a}	6.71^{a}	6.45^{a}	6.31^{a}
10	5.48^{b}	6.14^{a}	6.10^{a}	5.03^{c}
11	5.95^{b}	6.48^{a}	6.35^{b}	6.12^{b}
12	5.89^{a}	6.03^{a}	6.67^{a}	5.88^{a}
Ave.	6.12	6.51	6.42	6.16

^{a}Mean separation in row by Duncan's multiple range test at (α=0.05) tively. Although in most cotton fields, B treatments increased seed cotton yield, but these changes were not significant (α=0.05). Boll weight increased in Fe, Zn and B treatments (Table 4). Although available Fe, Zn and B level, in literature, were at medium to high levels in some fields, there was a good response to application of micronutrients. This can be explained by (i) imbalanced use of fertilizer (especially P), (ii) high $CaCO_3$ in soil.

Critical levels of Fe, Zn and B were determined by ANOVA and GM methods of Cate-Nelson. Critical level of Fe based on GM at relative yield 88% was 4.8 (mg. kg^{-1}soil) (Fig. 1-a) and by ANOVA was 5.50 (mg.kg^{-1} soil)(Table 5). Critical points for Zn and B based on GM were 1.1 and 1.0 (mg.kg^{-1} soil) (Fig.1 b, c) and with ANOVA method were 1.1 and 1.3(mg.kg^{-1} soil), respectively (Table 5). The values calculated from ANOVA method fitted better than GM, becausse of high level of $CaCO_3$, high available P and bicarbonate in soil solution and irrigation water.

Boll shedding decreased in field No. 6 by Fe and Zn treatments but B treatment did not affect boll shedding (Data not shown). These results were not significant (α=0.05). In Fe treatment, chlorophyll content of leaves increased production of nutritional materials such as carbohydrates consequently leading to decreased boll shedding.

A decrease in boll shedding in Zn treatments was probably due to the role of Zn in carbohydrate synthesis and translocation in

Table 5. Determination of critical levels of Fe, Zn, and B by ANOVA method.

Fe treatment			Zn treatment			B treatment		
Field No.	X (mg.kg^{-1})	CSS	Field No.	X (mg.kg^{-1})	CSS	Field No.	X (mg.kg^{-1})	CSS
3	-	-	6	-	-	4	-	-
2	3.48	9052	10	0.74	21927	2	0.53	26250
10	3.96	27722	1	0.79	16171	9	0.63	31625
6	4.60	36660	12	0.82	33153	1	0.73	12060
5	5.05	410	9	0.95	24794	3	0.78	9783
1	5.37	2914	2	1.08	50311	11	0.79	48514
11	5.55	56075	7	1.13	40592	7	0.88	68838
8	5.89	29681	3	1.24	34580	8	1.01	70525
12	6.24	2225	8	1.33	3.36	5	1.17	60598
9	6.35	7912	11	1.39	40820	12	1.33	75544
4	6.94	-	4	1.47	-	6	1.40	-
7	7.50	-	5	1.55	-	10	2.87	-

X= Average of soil test between two groups , CSS= Class Sum Squares.

Table 6. Iron to Zn ratio at different treatments.

Field No.	1[a]	2	3	4	5	6	7	8	9	10	11	12	Ave.
NPK	4.19[a]	4.04[b]	4.12[b]	4.64[a]	4.38[a]	4.29[a]	4.41[a]	4.61[a]	4.81[a]	4.81[a]	4.51[a]	4.65[a]	4.45
NPK+Fe	4.38[a]	4.24[a]	4.28[a]	4.69[a]	4.52[a]	4.39[a]	4.61[a]	4.6[a]	4.85[a]	4.88[a]	4.73[a]	4.68[a]	4.57
NPK+Zn	4.01[b]	3.89[b]	4.13[b]	4.53[a]	4.4[a]	4.21[b]	4.31[a]	4.58[a]	4.69[a]	4.68[b]	4.48[a]	4.45[b]	4.36

[a]Mean separation in column by Duncan's multiple range test at (α=0.05)

Table 7. Effect of B fertilization on leaves B content.

Field No.	1[a]	2	3	4	5	6	7	8	9	10	11	12	Ave.
NPK	96.1[a]	72.35[b]	92.11[a]	76.9[b]	99.7[a]	102.8[a]	91.2[a]	99.35[a]	84.1[b]	293.6[a]	84.5[b]	112.3[a]	108.6
NPK+B	100[a]	81.23[a]	98.95[a]	89.4[a]	101.8[a]	110[a]	98.7[a]	111.2[a]	91.8[a]	293.9[a]	93.8[a]	117.4[a]	115.7

[a]Mean separation in column by Duncan's multiple range test at (α=0.05)

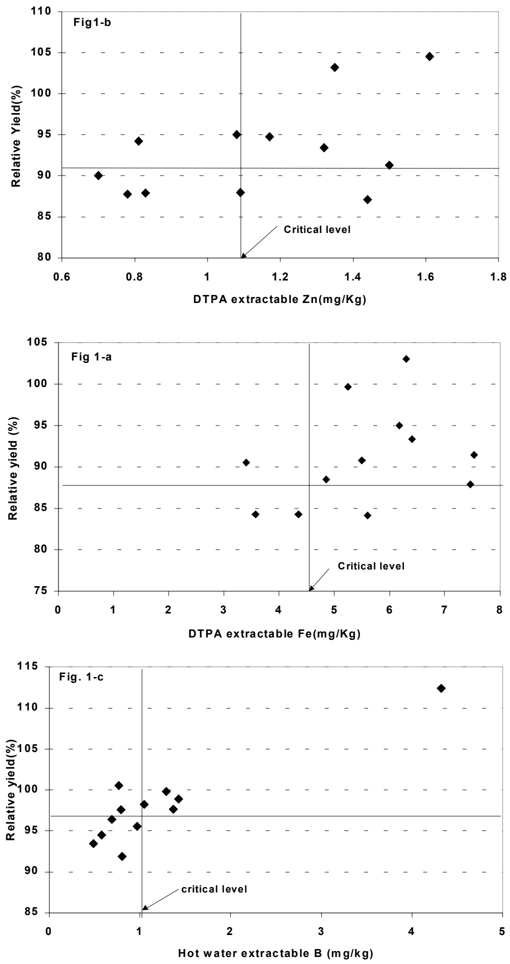

Figure 1. Determination of critical levels of Fe, Zn and B by Cate-Nelson graphical method.

plant. Although B is important in boll shedding phenomenon, but in this field available B was sufficient in soil. Iron to Zn ratio in leaves increased by Fe application and decreased by Zn treatment (Table 6). Also B application increased B concentration in leaves (Table 7).

Use of $ZnSO_4$ in field No. 10 with high B content (4.3mg.kg^{-1} B) and low available Zn (0.78 mg.kg^{-1} soil) led to decreased B toxicity in leaves (Fig. 2). Similar results were reported by Graham *et al.* (1988), Swietlik and Laduke (1991); and Swietlik (1995). Graham *et al.* (1987) reported that Zn deficiency enhanced accumulation of B in barley (*Hordeum vulgare* L.) up to a toxic level. They speculated that Zn performs a protec-

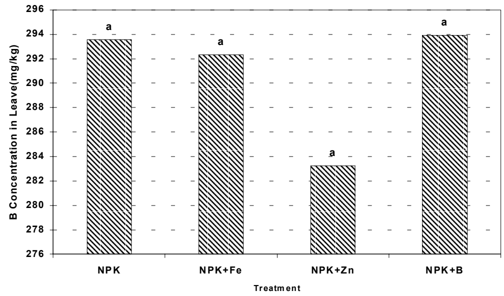

Figure 2.- Boron concentration in different treatments.

tive role at the external root surfaces or root cell membranes. In this field, B concentration in leaves was a excessive decreasing seed cotton yield, and boll weight in B treatment.

These results could be attributed to favorable effects of Fe, Zn and B on seed cotton yield, lint yield, boll weight, and seed index. Balanced applications of macro- and micronutrients, in addition to increasing yield may decrease toxicity of other elements as well. For example, in the present experiment B toxicity decreased with application of $ZnSO_4$. Decreasing B toxicity in Zn treatment was probably due to a biological membrane integrity effect (Graham *et al.*, 1987, Swietlik and Laduke, 1991, and Switlik, 1995).

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تعیین حد بحرانی آهن، روی و بَر برای پنبه در منطقه ورامین

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چکیده

پنبه یکی از گیاهان صنعتی مهم در ایران است که در بیش از ۳۰۰ هزار هکتار کشت شده و متوسط عملکرد وش آن ۱۷۵۰ کیلوگرم در هکتار می‌باشد. یکی از مهمترین موانع عملکرد بالا در مزارع پنبه مصرف نامتعادل کود است. به عبارت دیگر زارعین علاوه بر استفاده از اوره و سوپرفسفات تریپل بایستی از کودهای حاوی پتاسیم، منیزیم، روی، آهن، منگنز، مس و بَر نیز استفاده نمایند. برای استفاده بهینه از این کودها لازم است حد بحرانی آنها در مزرعه تعیین گردد. بدین منظور آزمایش مزرعه‌ای در ۱۲ مزرعه مختلف در سال ۱۳۷۶ به منظور تعیین حد بحرانی آهن، روی و بَر در خاک و نیز بررسی اثرات این عناصر کم مصرف بر روی عملکرد و کیفیت پنبه در منطقه ورامین انجام گرفت. آزمایش در قالب بلوک کامل

تصادفی با تیمارهای NPK+Zn, NPK+Fe, NPK و NPK+B با سه تکرار انجام گرفت. آهن از منبع سکوسترین آهن ۱۳۸ به میزان ۱۰، روی از منبع سولفات روی به میزان ۴۰ و بَر از منبع اسیدبوریک به میزان ۲۰ کیلوگرم در هکتار قبل از کاشت به خاک اضافه گردید. در اوایل گلدهی نمونه‌های برگ از کاملترین برگ جوان تهیه و تجزیه گردید. حد بحرانی آهن، روی و بَر براساس روش تصویری و روش تجزیه واریانس کیت- نلسون تعیین گردید. نتایج نشان داد که دراثر مصرف بهینه کود متوسط عملکرد وش، عملکرد الیاف، وزن غوزه در تیمارهای آهن، روی و بَر افزایش یافت. در یکی از مزارع پنبه، غلظت بالای بَر در خاک سبب کاهش عملکرد وش در تیمار بَر گردید. در روش گرافیکی حد بحرانی آهن، روی و بَر به ترتیب ٤/٨، ۱/۱ و ۱/۰ میلی‌گرم در کیلوگرم خاک بود در حالی که در روش تجزیه واریانس به ترتیب ۵/۵، ۱/۱ و ۱/۳ میلی‌گرم در کیلوگرم خاک گردید. در یکی از مزارع، ریزش غوزه در تیمار روی و آهن کاهش یافت، اما در تیمار بَر تغییری نداشت. نسبت آهن به روی در برگهای پنبه در تیمار آهن افزایش و در تیمار روی کاهش نشان داد. همچنین تیمار بَر میزان بَر را در برگ افزایش و در تیمار روی، سمیت بَر، در برگهای پنبه کاهش یافت. در جمع‌بندی چنین استنباط گردید که مصرف عناصر کم مصرف در مزارع پنبه ورامین کمیت و کیفیت پنبه را افزایش داد.