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Interactive Effects of Different Application Rates of Nitrogen and Boron on Yield, Yield Components and Quality of Cotton in the Arid Lands of Iran

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Abstract: Field experiments were carried out to study the interactive effects of different application rates of nitrogen and boron fertilizers on yield, yield components and quality of cotton (*Gossypium hirsutum* L.) in the arid lands of Iran. Nitrogen (N) was applied at rates of 0, 100, 200 and 300 kg ha^{-1} and boron (B) was applied as foliar at rates 0, 500 and 1000 g ha^{-1}. Statistical results of study showed that N application significantly ($P \leq 0.05$) enhanced boll number, boll weight, seed cotton weight of boll, seed cotton yield and lint yield. Moreover, N concentration of leaf blade was affected by N application rate and increased significantly. Results of study also indicated that the maximum seed cotton yield was recorded in case of 200 kg ha^{-1} N application rate and this application rate resulted in 19.6% increased seed cotton yield. Statistical results also indicated that foliar application of B significantly enhanced boll number, boll weight, seed cotton yield and lint yield. In addition, B concentration of leaf blade was affected by B application rate and increased significantly. Results also demonstrated that the maximum seed cotton yield was obtained in case of 1000 g ha^{-1} foliar application of B and this foliar application rate resulted in 25% increased seed cotton yield. Statistical results showed that effect of different application rates of N was not significant for all fiber properties (fiber length, fiber strength and fiber fineness). Conversely, results of study indicated that different application rates of B significantly affected some fiber properties. On the whole, application of 200 kg ha^{-1} N and 1000 g ha^{-1} B (two time foliar B application) resulted in the highest yield and yield components and enhanced fiber properties of cotton in the arid lands of Iran. The interaction of N × B was not significant for all studied traits.

Key words: Cotton · Yield · Yield components · Quality · Nitrogen · Boron · Arid lands · Iran

INTRODUCTION

In Iran, main portion of soils suffer from lack of organic matter and show nitrogen (N) deficiency. For this reason, N is one of the most important elements for crop production and agricultural productions highly depend on this element [1]. Similar to other crops, cotton needs N for regular growth and development. Many researchers have studied the effect of N on cotton [2-5]. N is required for all stages of plant growth and development because it is the essential element of both structural and nonstructural components of the plant. With lacking N, deficiency signs such as chlorosis, stunting and fewer and/or smaller bolls are prevalent in cotton [6]. Wullschleger and Oosterhuis [7] found that N uptake robustly influences development of cotton canopy. Moreover, Oosterhuis *et al*. [8] found that fast expansion of leaves during the vegetative stage of growth needs great quantities of N and subsequent stages of growth are also dependent on leaf development and photosynthetic integrity. Among the plant nutrients, N plays a very important role in crop productivity. It is an important determinant of growth and yield of irrigated cotton [9, 10]. Typically, applications of 100 to 215 kg ha^{-1} N fertilizers are required to optimize lint yield [3, 11-13].

Boron (B) is one of the most important elements that cotton requires throughout all stages of growth, particularly during flowering, fruiting and boll development. It has been generally known as the most essential micronutrient for cotton production. Moreover, cotton is very sensitive to B deficiency because of its high B requirement [14]. Anderson and Boswell [15] found that B application increased yields of cotton even when

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there was no obvious B lack in the plants. B fertilizers were also beneficial to cotton production in sandy and silt loam soils in several parts of USA and Africa [16-18]. In addition, fairly small amounts of B are needed to support growth and development process of cotton fibers [19]. B also increases the nitrogen and carbohydrate metabolism and sugar translocation in cotton [20]. Both foliar application and/or soil application of B can compensate low B concentrations [21]. However, foliar application may be much more efficient than soil application, particularly when lacking conditions in cotton are supposed. Foliar application also facilitates the translocation of nitrogen compounds, enhances synthesis of protein and motivates flowering and fruiting [22]. There are many reports on the effect of soil or foliar applications of B on growth and yield of cotton [21-26].

In Iran, too little researches have been done to study the response of cotton to N and B and there are no recommended application rates N and B fertilizers. As N and B can agronomically and physiologically affect cotton, the main purpose of this research was to study the effect of different application rates of N and B on yield, yield components and quality of cotton and to determine appropriate application rates of N and B for cotton production in the arid lands of Iran.

MATERIALS AND METHODS

Research Site: This study was conducted at the Research Site of Varamin on a clay loam soil recognized as average in total N (0.07%) and low in B (0.4 mg kg^{-1}) for two successive growing seasons (2009 & 2010). The research site is situated at latitude: 35°19' N, longitude: 51°39' E and altitude: 1000 m in arid climate (150 mm rainfall annually) in the center of Iran.

Weather Parameters: The mean temperature and monthly rainfall of the research site from sowing (May) to harvest (November) during study years (2009 & 2010) are indicated in Fig. 1.

Soil Sampling and Analysis: The soil of the experimental site is classified as an Aridisol (fine, mixed, active, thermic, typic haplocambids). A composite soil sample (from 36 points) was collected from 0-30 cm depth 30 days prior to planting during the study years and was analyzed in the laboratory for pH, EC, OC, TNV, P, K, Fe, Zn, Cu, Mn, B and particle size distribution. Details of soil properties of the research site during the years of study (2009 & 2010) are given in Table 1.

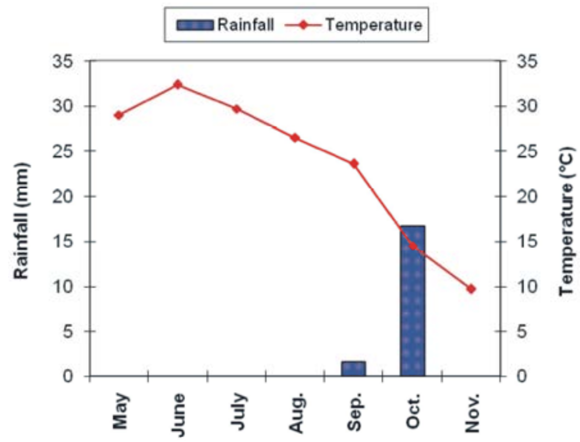

Fig. 1: Mean monthly rainfall and temperature from sowing to harvest (mean of 2009 & 2010)

Field Methods: A split plot experiment was laid out in a randomized complete block design (RCBD) with three replications to randomize different N and B application rates treatments in the main and subplots, respectively. The experiment comprised of four levels of N fertilizer, i.e. 0, 100, 200 and 300 kg ha^{-1} N as Urea and three levels of B, i.e. 0, 500 and 1000 g ha^{-1} B as boric acid foliar application (without, one time and two time foliar B application). Each one of the 100, 200 and 300 kg ha^{-1} N were divided into two applications, i.e. one third at pre-planting and two third at pinhead square. Boric acid foliar was applied with concentration of 0.5% (500 L ha^{-1}). Foliar B applications started at the first flower stage and were done again two weeks after. The control treatment only received water spray. All treatments were carried out on the identical plots during the study years (2009 & 2010). The dimension of each plot was 12.0 m × 6.0 m and a buffer zone of 3.0 m was provided among plots. In both years of study, the cultivar Varamin (*Gossypium hirsutum* L.) was planted manually on May 5, 2009 and May 7, 2010.

Table 1: Soil physical and chemical properties of the experimental site during study years 2009 & 2010 (0-30 cm depth)

Date	pH	EC (dS m^{-1})	OC (%)	TNV (%)	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	B (ppm)	Soil texture
2009	7.3	3.4	0.72	17	10.6	200	4.4	0.90	1.4	12.3	0.4	Clay loam
2010	7.6	3.0	0.81	17	9.50	224	5.2	0.42	0.5	11.5	0.5	Clay loam

Plots consisted of 6 rows of cotton planted with row spacing 0.8 m by keeping plant to plant distance 20 cm. For all treatments, irrigation scheduling was based on the basis of soil water content monitoring. Also, pest and weed control operations were performed based on common local practices and commendations. All other essential operations were kept identical for all the treatments.

Observation and Data Collection: Leaf samples were obtained for N and B analysis one week before first flower and one week after each foliar B application. Samples were obtained by removing 20 leaves from the uppermost fully expanded main stem leaves from each plot. After all bolls matured, all seed cotton at 10 meter lengths of the four center rows was hand harvested at approximately 70% open boll for yield analyses. Yield was determined by hand harvesting the four center rows from each plot twice and weighing the seed cotton. Twenty plants in each plot were randomly selected in mid-September of each year for measurement of number of open bolls. Boll weight and fiber data were obtained from 20 hand-harvested boll samples collected from 0.5 m of the two outer rows. Lint yields were calculated by multiplying the lint percentage by seed cotton weights. Fiber properties for each sample were determined in High Volume Instruments (HVI).

Statistical Analysis: All collected data were subjected to the Analysis of Variance (ANOVA) following Gomez and Gomez [27] using SAS statistical computer software. Moreover, means of the different treatments were separated by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Boll Number: Statistical results of study indicated that different application rates of N and B (as foliar B) significantly ($P \leq 0.05$) affected boll number (Table 2 and Table 3). Results showed that boll number significantly increased with an increase in N application rate. The highest boll number (19.8) was obtained in case of 200 kg ha^{-1} N treatment but there was no significant difference between 200 and 300 kg ha^{-1} N treatments. The lowest boll number (12.9) was obtained in case of 0 kg ha^{-1} N treatment (Table 2). Results also demonstrated that boll number significantly increased with an increase in B application rate. The highest boll number (18.1) was obtained in case of 1000 g ha^{-1} B treatment (two time foliar B application) and the lowest boll number (14.1) was obtained in case of 0 g ha^{-1} B treatment, i.e. no foliar B application (Table 3). These results are in agreement with those of Oosterhuis and Steger [23] who concluded that N application and foliar B application considerably increased boll number. Interaction of N × B was not significant for this trait.

Boll Weight: Results of study also showed that different application rates of N and B significantly influenced boll weight (Table 2 and Table 3). Results indicated that boll weight significantly increased by increasing N application

Table 2: Effect of different N application rate on yield, yield components and quality of cotton (mean of 2009 & 2010)

N application rate (kg ha^{-1})	Boll number * (plant^{-1})	Boll weight *(g)	Seed cotton weight of boll * (g)	Seed cotton yield * (kg ha^{-1})	Lint yield * (kg ha^{-1})	N concentration of leaf blade * (mg kg^{-1})	B concentration of leaf blade ^{NS} (mg kg^{-1})
0	12.9 c	6.26 b	4.11 b	3642 c	1489 c	2.22 c	56.9 a
100	17.2 b	6.50 ab	4.41 ab	4151 b	1596 b	3.16 b	53.9 a
200	19.8 a	6.90 a	4.49 a	4363 a	1659 a	3.61 b	58.9 a
300	19.6 a	6.80 a	4.47 a	4358 a	1649 a	4.21 a	60.3 a

NS = Non-significant

* = Significant at 0.05 probability level

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

Table 3: Effect of different B foliar application rate on yield, yield components and quality of cotton (mean of 2009 & 2010)

B application rate (g ha^{-1})	Boll number * (plant^{-1})	Boll weight * (g)	Seed cotton weight of boll NS (g)	Seed cotton yield * (kg ha^{-1})	Lint yield * (kg ha^{-1})	N concentration of leaf blade ^{NS} (mg kg^{-1})	B concentration of leaf blade * (mg kg^{-1})
0	14.1 c	6.15 b	4.48 a	3541 b	1400 c	3.61 a	43.1 c
500	16.8 b	6.49 ab	4.61 a	3991 ab	1562 b	3.43 a	55.0 b
1000	18.1 a	7.02 a	4.52 a	4428 a	1752 a	3.54 a	67.6 a

NS = Non-significant

* = Significant at 0.05 probability level

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

rate. The highest boll weight (6.90 g) was recorded in case of 200 kg ha^{-1} N treatment but there was no significant difference among 100, 200 and 300 kg ha^{-1} N treatments. The lowest boll weight (6.26 g) was recorded in case of 0 kg ha^{-1} N treatment (Table 2). Moreover, statistical results showed that boll weight significantly increased by increasing B application rate. The highest boll weight (7.02 g) was recorded in case of two time foliar B application treatment but there was no significant difference between two and one time foliar B application treatments. The lowest boll weight (6.15 g) was recorded in case of no foliar B application treatment (Table 3). These results are also in line with the results reported by Oosterhuis and Steger [23] that N application and foliar B application noticeably increased boll weight. Again, interaction of N × B was not significant for this trait.

Seed Cotton Weight of Boll: Statistical results of study indicated that different application rates of N significantly affected seed cotton weight of boll (Table 2). Results showed that seed cotton weight of boll significantly increased with an increase in N application rate. The highest seed cotton weight of boll (4.49 g) was obtained in case of 200 kg ha^{-1} N treatment but there was no significant difference among 100, 200 and 300 kg ha^{-1} N treatments. The lowest seed cotton weight of boll (4.11 g) was obtained in case of 0 kg ha^{-1} N treatment (Table 2). Moreover, results indicated that effect of different application rates of B was not significant for seed cotton weight of boll (Table 3). Although effect of different application rates of B was not significant for this trait, the highest seed cotton weight of boll (4.61 g) was obtained in case of one time foliar B application treatment and the lowest seed cotton weight of boll (4.48 g) was obtained in case of no foliar B application treatment (Table 3). Once more, interaction of N × B was not significant for this trait.

Seed Cotton Yield: Results of study showed that different application rates of N and B significantly influenced seed cotton yield (Table 2 and Table 3). Results indicated that seed cotton yield significantly increased by increasing N application rate. The highest seed cotton yield (4363 kg ha^{-1}) was recorded in case of 200 kg ha^{-1} N treatment and there was no significant difference between 200 and 300 kg ha^{-1} N treatments. Therefore, for reaching the highest seed cotton yield use of 200 kg ha^{-1} N can be recommended. The lowest seed cotton yield (3642 kg ha^{-1}) was recorded in case of 0 kg ha^{-1} N treatment (Table 2). The maximum increase in seed cotton yield with 200 kg ha^{-1} N treatment was about 19.6% as compare to 0 kg ha^{-1} N treatment. Additionally, results showed that seed cotton yield significantly increased by increasing B application rate. The highest seed cotton yield (4428 kg ha^{-1}) was recorded in case of two time foliar B application treatment but there was no significant difference between two and one time foliar B application treatments. The lowest seed cotton yield (3541kg ha^{-1}) was recorded in case of no foliar B application treatment (Table 3). These results are in agreement with findings by Gormus [19] which showed that B application may increase the utilization of applied N by enhancing the translocation of N compounds into the boll which increases the number and size of the bolls. These results are also in line with previous findings of Anderson and Boswell [15] who reported that yield increase was the result of increased boll number and size. Moreover, positive crop responses to B may be attributed to a superior B requirement by cotton plant [14]. The highest increase in seed cotton yield with two time foliar B application treatment was about 25% as compare to no foliar B application treatment. Another time, interaction of N × B was not significant for this trait.

Lint Yield: Statistical results of study indicated that different application rates of N and B significantly affected lint yield (Table 2 and Table 3). Results showed that lint yield significantly increased with an increase in N application rate. The highest lint yield (1659 kg ha^{-1}) was obtained in case of 200 kg ha^{-1} N treatment but there was no significant difference between 200 and 300 kg ha^{-1} N treatments. Therefore, for reaching the highest lint yield use of 200 kg ha^{-1} N can be recommended. The lowest lint yield (1489 kg ha^{-1}) was obtained in case of 0 kg ha^{-1} N treatment (Table 2). Results of this study suggested that better lint yields at elevated application rates of N may have been owing to the greater number of bolls per plant. These results are in line with the results reported by Boquet *et al*. [28] that application of optimal N rates may have beneficial effects on lint yield by increasing number and size of the bolls. Furthermore, results showed that lint yield significantly increased with an increase in B application rate (Table 3). The highest lint yield (1752 kg ha^{-1}) was obtained in case of two time foliar B application treatment and the lowest lint yield (1400 kg ha^{-1}) was recorded in case of no foliar B application treatment (Table 3). The maximum increase in lint yield with two time foliar B application treatment was about 25% as compare to no foliar B application treatment. The similar results were also reported by Anderson and Boswell [15] and

Heitholt [21] in field experiments where lint yield increased significantly with an increase in B application rate. Yet again, interaction of N × B was not significant for this trait.

N Concentration of Leaf Blade: Results of leaf blade chemical analyses showed that different application rates of N significantly affected N concentration of leaf blade (Table 2). The highest N concentration of leaf blade (4.21 mg kg^{-1}) was recorded in case of 300 kg ha^{-} N treatment and the lowest N concentration of leaf blade (2.22 mg kg^{-1}) was recorded in case of 0 kg ha^{-1} N treatment (Table 2). Oosterhuis *et al*. [8] studied the distribution of N in plant components. They found that N concentration of leaf blade significantly increased by increasing N application rate. Results also indicated that effect of different application rates of B was not significant for N concentration of leaf blade (Table 2). Again, interaction of N × B was not significant for this trait.

B Concentration of Leaf Blade: Results of leaf blade chemical analyses indicated that effect of different application rates of N was not significant for B concentration of leaf blade (Table 2). However, different application rates of B significantly influenced this trait (Table 3). The highest B concentration of leaf blade (67.6 mg kg^{-1}) was obtained in case of two time foliar B application treatment and the lowest B concentration of leaf blade (43.1 mg kg^{-1}) was obtained in case of no foliar B application treatment (Table 3). Similar results have been reported by Zhao and Oosterhuis [29]. They reported that B concentration of leaf blade considerably increased with an increase in soil-applied B. Once more, interaction of N × B was not significant for this trait.

Fiber Properties: Statistical results of study showed that effect of different application rates of N was not significant for fiber properties, i.e. fiber length, fiber strength and fiber fineness (Table 4). In earlier studies, no effects or inconsistent effects of the increased N application rates on fiber length were reported [19, 30]. Likewise, no relationship between the increased N application rates and fiber strength were reported [19, 30, 31]. As well, researchers found no effects of the N application rate at all on micronaire readings [19, 30, 32]. Results of study also indicated that different application rates of B significantly affected some fiber properties (Table 5). Fiber length was affected by increasing B application and increased significantly. The highest fiber length (31.7 mm) was obtained in case of two time foliar B application treatment and the lowest fiber length (29.2 mm) was obtained in case of no foliar B application treatment, but there was no significant difference between one and two time foliar B application treatments (Table 5). Although fiber strength was not influenced by increasing B application, the highest fiber strength (28.6 g tex^{-1}) was obtained in case of two time foliar B application treatment and the lowest fiber strength (28.1 g tex^{-1}) was obtained in case of no foliar B application treatment (Table 5). Moreover, results showed that fiber fineness was affected by increasing B application and increased significantly. The highest fiber fineness (5.8) was obtained in case of two time foliar B application treatment and the lowest fiber fineness (4.9) was obtained in case of no foliar B application treatment, but there was no significant difference between one and two time foliar B application treatments (Table 5). The beneficial effects of B application in enhancing fiber properties were reported by Roberts *et al*. [18] and Oosterhuis and Steger [23]. Another time, interaction of N × B was not significant for fiber properties.

Table 4: Effect of different N application rate on cotton fiber properties (mean of 2009 & 2010)

N application rate (kg ha^{-1})	Fiber length ^{NS} (mm)	Fiber strength ^{NS} (g tex^{-1})	Fiber fineness ^{NS}
0	29.6 a	28.1 a	5.2 a
100	29.5 a	28.6 a	5.4 a
200	29.2 a	28.7 a	5.3 a
300	30.1 a	29.1 a	5.4 a

NS = Non-significant

* = Significant at 0.05 probability level

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

Table 5: Effect of different B foliar application rate on cotton fiber properties (mean of 2009 & 2010)

B application rate (g ha^{-1})	Fiber length * (mm)	Fiber strength ^{NS} (g tex^{-1})	Fiber fineness *
0	29.2 b	28.1 a	4.9 b
500	31.4 a	28.2 a	5.7 a
1000	31.7 a	28.6 a	5.8 a

NS = Non-significant

* = Significant at 0.05 probability level

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

CONCLUSIONS

For reaching the highest yield and yield components and enhanced fiber properties of cotton in the arid lands of Iran use of 200 kg ha^{-1} N and 1000 g ha^{-1} B (two time foliar B application) was found as the most appropriate and beneficial application rates of N and B, respectively. Also, the interaction of N × B was not significant for all studied traits.

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