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Interactive Effect of Nitrogen and Boron on Cotton Yield and Fiber Quality

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Abstract: This study aimed to determine the effect of application rates of N and B on cotton yield and fiber quality. Suregrow 125 (*Gossypium hirsutum* L.) was grown on a clay soil having an average 0.38 mg kg^{-1} B concentration. Analysis of leaf tissue taken at early bloom and before the nutrient application indicated that N and B concentrations were sufficient. Nitrogen was applied to the soil at rates of 0, 80 and 160 kg ha^{-1}, and B was applied to the foliage 3 times for totals of 0, 0.56 and 1.12 kg B ha^{-1}. Foliar-applied B significantly increased leaf blade B concentration in both years. Foliar-B sprays significantly increased boll number, boll weight, seed cotton and lint yield. The application of 1.12 kg ha^{-1} B and 160 kg ha^{-1} N resulted in the highest number of bolls. B increased boll weight from 5.93 to 6.92 g $boll^{-1}$ and boll bearing from 15.9 to 18.5 bolls $plant^{-1}$ in 2003. Consequently, B application resulted in 15.5% increased crop yield over the control. Neither N nor B treatments had any significant effect on fiber properties. This study demonstrated that cotton needed supplemental B when the soil B concentration was low.

Key Words: Cotton, foliar-B treatment, N rates, yield

Azot ve Bor'un Pamuk Verimi ve Lif Kalitesine Karşılıklı Etkisi

Özet: Bu çalışmada azot ve bor uygulama dozlarının, pamuk verimi ve lif kalitesi üzerine etkilerini saptamak amaçlanmıştır. Suregrow 125 (*Gossypium hirsutum* L.) pamuk çeşidi, ortalama toprak B konsantrasyonu 0.38 mg kg^{-1} olan killi toprakta yetiştirilmiştir. Çiçeklenme başlangıcında ve besin elementi uygulamalarından önce alınan yaprak örneklerinde yapılan doku analizleri, N ve B konsantrasyonlarının yeterli düzeyde olduğunu göstermiştir. Denemede, toprağa üç azot (0, 80 ve 160 kg ha^{-1}) dozu ile üç kez yaprağa, toplam 0, 0.56 ve 1.12 kg ha^{-1} bor uygulaması yapılmıştır. Yaprağa bor uygulaması ile yaprak B konsantrasyonu her iki yılda da önemli düzeyde artış göstermiştir.Yaprağa B uygulamaları koza sayısı, koza ağırlığı, kütlü pamuk verimi ve lif verimini önemli düzeyde arttırmıştır. En yüksek koza sayısı ile lif verimi 1.12 kg ha^{-1} B ile 160 kg ha^{-1} N uygulamasından elde edilmiştir. Bor uygulaması ile 2003 yılında, koza ağırlığında 5.93 gramdan 6.92 grama, koza sayısında ise 15.9'dan 18.5'a varan bir artış oluşmuştur. Buna bağlı olarak, B uygulaması kontrola oranla verimde % 15.5'lik bir artış sağlamıştır. N ve B uygulamalarının lif kalite özelliklerinde önemli bir etkisi gözlenmemiştir.Çalışma toprak B düzeyi düşük olduğunda, pamuk bitkisinin ek bor uygulamasına gereksinim duyduğunu ortaya koymuştur.

Anahtar Sözcükler: Pamuk, yaprağa B uygulaması, N dozları, verim

Introduction

Boron has been universally recognized as the most important micronutrient for cotton production. It aids in the transfer of sugars and nutrients from leaves to fruits, plays an essential role in plant cell formation and increases pollination and seed development. It performs a key function in the growth and fruiting process (Albers et al., 1993). While B is essential for all stages of cotton plant growth, an available supply is most important during flowering and boll development. Relatively small amounts of B are required to support the process of growth and development of cotton fibers in the boll (Stewart, 1986). Improved fiber quality (fineness, uniformity and strength) has been reported with B application. Total seasonal B requirement averages about 66-200 g B ha^{-1} for irrigated cotton. B removed by the lint and seed accounts for 9.3 g of B for every 100 kg of lint. B increases the nitrogen and carbohydrate

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metabolism and sugar translocation in cotton (Gascho, 1994). B deficiency in cotton may cause small deformed bolls, shorter fruiting branches, deformed leaves, poor fruit retention and reduced lint yields. It can also affect fiber quality, presumably because of the role of B in cell wall growth. Deficiency can be a problem in soils containing insufficient B, or when B availability to the plant is reduced as B changes form with higher soil pH. B may be applied either to the soil at or before planting or as a foliar application at or just prior to bloom. Soil-applied B increased cotton yields even when B deficiency was not evident in the plants (Anderson and Boswell, 1968). Foliar-applied B supplements and soil-supplied B can correct low B concentrations in cotton (Heitholt, 1994). Foliar application of B accelerates the translocation of nitrogen compounds, increases protein synthesis and stimulates fruiting. Because 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). Multiple foliar sprays of B will ensure an adequate supply of B during flowering and boll development. Preplant soil application plus foliar sprays of B during the season are recommended for soils testing low in available B. The critical level of hot-water-soluble B for cotton in most soils ranges from 0.2 to 1.0 ppm, depending on the soil pH, organic matter content and texture. Soils below the critical level generally will respond to applied B. The critical level of B in upper mature cotton leaves is about 15 ppm.

B occurs in the soil as an uncharged molecule (boric acid) and leaches readily. B that is held by the soil is associated primarily with organic matter and is released as the organic matter decomposes. Dry weather can trigger a temporary deficiency as organic matter decomposition slows. Furthermore, dry weather slows root growth and limits B uptake.

There are many reports on the growth and yield responses of cotton to soil or foliar applications of B. Reports of yield response to soil or foliar applications have been inconsistent, with some researchers reporting no yield response to B utilizing non-buffered spray solutions, and others reporting yield responses using B spray solutions buffered to pH 4.0. Work in Arkansas, USA, has shown no yield response to soil or foliar applications of B irrespective of soil N status (Oosterhuis, 2001). Soil applied B increased first harvest lint yields by 9%, 4 foliar applications, each at 0.11 kg B ha^{-1}, resulted in lint yields comparable to soil application of B at 0.56 kg B ha^{-1},and doubling the B foliar rate did not increase yields, but the B petiole concentration was significantly increased (Howard et al., 1998). Lint yield, boll production, flower production, boll retention percentage, and fiber properties were unaffected by soil or foliar applied treatments. However, foliar B fertilization resulted in leaf blade B concentrations of 154 mg kg-1 without detrimental effects (Heitholt, 1994). Soil or foliar applied B may not have been beneficial for obtaining high cotton yields. Similarly, there were no positive responses to applied soil-B or foliar-B in the high N soil level in any of the 5 experiments, except for where the low N treatments responded to applied B on a silt loam soil in Arkansas (Oosterhuis et al., 2000). Oosterhuis and Brown (2002) reported no effects on yield, fiber quality, boll number per meter, average boll weight, lint percentages,or petiole or leaf B concentrations of soil and foliar applied B treatments observed over 3 years. No significant effect of B on lint yield, individual boll weight, or petiole nitrate-N level and no significant N and B interactions were found in a regional study conducted to evaluate the interaction of N and B rates on cotton yields (Oosterhuis and Steger, 1998).

Interest in foliar fertilizers in cotton has arisen in recent years in Turkey. In Çukurova (Adana, southern Turkey), one of the cotton growing regions of Turkey, B nutrition of cotton has not been studied, and there is no recommendation for B fertilization based on results obtained from any research. Even though field tests were initiated to evaluate B in both soil and spray treatments on vegetables, there is no research showing the effects of B fertilizer applications on cotton. As soils in the experimentation site within the cotton areas in Adana were low in B, it is possible that B deficiencies in cotton occur there. Since B has the potential to affect many agronomic and physiological responses, it is important that these responses be characterized. Therefore, this study was initiated to investigate cotton response to applied B. The objective of this study was to determine 1) the effect of the application rate of N and B on cotton yield and fiber quality; 2) if N-fertilized cotton produced additional yield increases with added B; and 3) to evaluate possible N and B interactions.

Materials and Methods

Field studies were performed during the 2002 and 2003 growing seasons in the Çukurova University research fields in Adana, on a clay soil, identified as low in B (≤0.38 mg B kg^{-1}, average total N 28.6 kg ha^{-1}). The soil of the experimental plots, developed from alluvial deposits of river terraces, is typical for the Çukurova region, and is classified as a Vertisol (chromoxeret), and the relatively high clay content with the predominant clay minerals smectite and kaolinite are typical for the soils of the Çukurova region. Soil samples (0-20 cm) collected 25 days prior to planting indicated that pH was 7.7, organic matter was 1.32%, total cation exchange capacity was 23.9 meq 100 g^{1}, and total N (avg.) was 28.6 kg ha^{-1}. Average B levels in the top 20 cm soil profile were 0.40 mg kg^{-1} and 0.36 mg kg^{-1} in 2002 and 2003, respectively.

Weather conditions in Adana were generally considered good for cotton growth and yield, and did not differ greatly between the 2 years of the field experiment. Monthly rainfall totals in 2002 were 19.3 mm in May, 3.8 mm in June, 16.8 mm in July, 21.8 mm in August and 0.3 mm in September. In 2003, rainfall totals were 36.1 mm in May, 15.0 mm in June, 3.6 mm in July, and 52.3 mm in September. In the entire experimental period, there were no considerable deviations from long-term average temperatures. Good temperature conditions for planting existed in May and late April in 2002 and 2003.

The cultivar Suregrow 125 (*Gossypium hirsutum* L.) was planted on 10 May 2002 and 27 April 2003. Suregrow 125 is a very early maturing, upright, smooth leaf variety, and has good gin turnout and fiber characteristics, and has performed well on all soil types. Plots were 12 m in length and consisted of 6 rows of cotton planted with row spacing 0.8 m. Plots were overseeded and then thinned to 1 plant per 20 cm of row, or a population of 62,500 plants ha^{-1}, at approximately the first or second true leaf stage. Management was consistent with typical agronomic practices used for upland production in the region.

Three N fertilizer treatments of 0, 80 and 160 kg ha^{-1} and 3 levels of B (0, 0.56 and 1.12 kg ha^{-1}) were applied. Each N fertilizer treatment received preplant applications of the appropriate N rate. A split plot experimental design was used with N as whole plots and B rates as subplot treatments replicated 3 times. B subplot treatments were randomly assigned within N whole plot treatments. A split application of N was used because results from previous years indicated that significant yield increases were obtained by split applications (unpublished results). Each of the 80 and 160 kg N ha^{-1} rates were split into 3 applications (a third at preplanting, at pinhead square and 2 weeks later). Application rates were maintained on the same plots each year by broadcasting ammonium nitrate with a fertilizer spreader and incorporation with a rolling cultivator and harrow. B was applied foliarly as Bortrac (150 g l^{-1}, the pH of Bortrac is 8.2.) with a CO_2 backpack sprayer calibrated to deliver 150 g of the fertilizer material with 100 l ha^{-1} of water for each hectare to be treated. Foliar B applications began at the first flower stage and were repeated by 2 and 4 weeks after. The control treatment received water sprays. Leaf samples were obtained for N and B analysis 1 week before first flower and 1 week after each foliar B application. Samples were obtained by removing 20 leaves from each plot from the uppermost fully expanded main stem leaves.

After all bolls matured, all seed cotton at 10-m lengths of the center 4 rows was hand harvested at approximately 70% open boll for yield analyses. Yield was determined by hand harvesting the center 4 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 (g $boll^{-1}$), gin turnout (%), and fiber data were obtained from 30 hand-harvested boll samples collected from 0.5 m of the outer 2 rows. Gin turnout was obtained as the weight of lint expressed as a percentage of the weight of the seed cotton sample. 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). All data were analyzed with statistical analysis and means were separated with the LSD test at the 5% probability level.

Results and Discussion

The effect of N and B rates on cotton parameters is given in Table 1. The main effects associated with N and foliar B applications were significant for boll number, boll

Table 1. Mean squares (MS) from analysis of variance of cotton yield and fiber properties combined across years. SL: span length; Unif: fiber uniformity; elg: elongation; fin: fineness

		Mean squares										
Source	df	Boll number	Boll weight	Seedcotton wt. of boll	Gin turnout	Seed cot.yield	Lint yield	2.5% SL	Unif.	Fiber str.	Fiber elg.	Fiber fin.
Replicate	2	0.210	1.894	0.083	1.852	7813.1	161051.7	0.589	6.147	0.591	0.006	0.056
Year	1	1.215	1.176	1.248	1.852	6186.7	129546.2	0.060	57.042**	21.534	51.979*	1.098*
Error (a)	2	0.069	0.722	0.427	0.519	1114.0	17445.27	0.007	0.047	4.785	0.568	0.040
N rate (A)	2	70.45**	1.891**	0.846*	15.79**	12162.5**	339837.1**	0.179	0.492	2.489	0.712	0.109
Year x A	2	1.404*	0.067	0.001	2.574	527.463	3612.98	0.834	1.911	0.208	0.648	0.295
Error (b)	8	0.303	0.160	0.136	1.074	935.370	16484.3	0.506	2.085	4.110	0.737	0.328
B rate (B)	2	18.251**	3.496**	0.236	2.074	15234.0**	289823.6**	0.174	5.575*	1.280	0.028	0.286
Year x B	2	1.701*	0.080	0.036	0.074	323.852	5525.68	0.732	0.941	0.996	0.413	0.134
A x B	4	2.375**	0.073	0.001	1.880	297.667	8750.85	0.308	0.804	2.046	0.229	0.062
Year x A x B	4	0.609	0.201	0.014	1.546	105.074	5750.35	0.619	1.394	2.231	1.213*	0.110
Error (c)	24	0.480	0.456	0.108	2.750	1314.278	25622.24	0.390	1.232	1.762	0.401	0.111

*,** Denote significance at the 0.05 and 0.01 levels of probability, respectively.

weight, seed cotton yield and lint yield. The interaction term (N x B treatments) was significant ($P \leq 0.01$) for number of bolls. Significant year x N treatment ($P \leq 0.05$) and year x B treatment ($P \leq 0.05$) interactions were found for number of bolls. The year x N x B treatment interaction was significant ($P \leq 0.05$) for elongation. Statistical differences were not detected for fiber length 2.5% SL or fiber strength.

Number of bolls

The main effects associated with N and B treatments were significant with respect to number of bolls in each year, and in both years combined. In 2002, number of bolls significantly increased with an increase in N rates. The highest boll number was obtained with the N-160 treatment. Cotton responded to B treatment at rate of 1.12 kg ha^{-1} while no significant differences were found between the rate of 0.56 kg ha^{-1} and the control. In 2003, number of open bolls significantly increased with an increase in N and B rates (Table 2). The N x B treatment interaction was significant for number of bolls in 2003. The highest number of bolls was obtained with the application of 1.12 kg ha^{-1} B and 160 kg ha^{-1} N (Table 3). Under high N conditions, the foliar B treatment showed the greatest number of bolls, with the control having the least. Similarly, Oosterhuis and Steger (1998) reported that the number of bolls tended to be greatest in the high N treatment with foliar B application.

Boll weight

No significant boll weight differences were observed among the treatments in 2002. However, the response in boll weight was significantly affected by the soil-applied N in 2003, and in both years combined. Cotton responded to N-160 treatment, while no significant difference was found between the N-80 treatment and the control. Foliar-applied B significantly affected the boll weight at 1.12 kg ha^{-1}; there were no significant differences between the rate of 0.56 kg ha^{-1} and the control in 2003, or in both years combined (Table 2).

Seed cotton weight of boll

No significant differences in seed cotton weight of boll among the treatments for either year were observed. Although not statistically significant, there was a tendency for N and B to increase the seed cotton weight of boll. Over 2 years, N-160 treatment resulted in a significant increase in seed cotton weight of boll while no significant difference was found between the N-80 treatment and the control.

Gin turnout

Significant differences with N treatment were evident for gin turnout in 2002, but not in 2003. The highest gin turnout was obtained with the N-160 treatment, which did not differ from the N-80 treatment. Over 2 years, the same tendency was observed with N treatment. A

Table 2 . Effects of rate of nitrogen and boron on cotton yield components.

Treatments	Boll number (plant-1)			Boll weight (g)			Seedcotton wt. boll (g)		
	2002	2003	Avg.	2002	2003	Avg.	2002	2003	Avg.
N rates (kg ha^{-1})									
0	14.9 ^{c}	14.8 ^{c}	14.9 ^{c}	6.42	6.10 ^{b}	6.26 ^{b}	4.45	4.16	4.31 ^{b}
80	16.7 ^{b}	17.7 ^{b}	17.2 ^{b}	6.70	6.29 ^{b}	6.50 ^{ab}	4.64	4.33	4.49 ^{ab}
160	18.8 ^{a}	18.8 ^{a}	18.8 ^{a}	6.98	6.82 ^{a}	6.90 ^{a}	4.89	4.58	4.74 ^{a}
LSD $_{(0.05)}$	0.39	0.64	0.63	ns	0.41	0.46	ns	ns	0.42
B rates (kg ha^{-1})									
0	16.2 ^{b}	15.9 ^{c}	16.1 ^{b}	6.37	5.93 ^{b}	6.15 ^{b}	4.50	4.28	4.39
0.56	16.7 ^{b}	16.8 ^{b}	16.8 ^{b}	6.60	6.37 ^{b}	6.49 ^{ab}	4.66	4.36	4.51
1.12	17.6 ^{a}	18.5 ^{a}	18.1 ^{a}	7.12	6.92 ^{a}	7.02 ^{a}	4.82	4.42	4.62
LSD $_{(0.05)}$	0.68	0.66	0.80	ns	0.52	0.78	ns	ns	ns
Mean	16.8	17.0	16.9	6.69	6.41	6.55	4.66	4.36	4.51

Means followed by different letters within columns are significantly different (p=0.05).

Table 3. Boll number as affected by N x B interaction in 2003.

	Boll number/plant			
Treatments, kg ha^{-1}	N0	N-80	N-160	Avg.
B-0	14.4 f	16.2 de	17.3 cd	15.9
B-0.56	14.8 f	17.3 c	18.4 bc	16.8
B-1.12	15.4 ef	19.6 ab	20.7 a	18.6
Avg.		14.9	17.7	18.8

Means followed by different letters within columns are significantly different (p=0.05).

significant response was detected with N-80 and N-160 treatments. B had no effect on gin turnout either year or in both years combined (Table 4).

Seed cotton yield

Applications of N and B were found to increase seed cotton yield compared to the untreated control in 2002, and in both years combined. In 2002, increased N fertility raised cotton seed yields significantly, but had no effect in 2003. Averaged across years, N-160 treatment gave the highest yield with an increase of 13.8% over the control. B applications increased seed cotton yield appreciably (P£0.01) in 2002 and in both years combined. When B was applied, the application of 160 kg N ha^{-1} increased yield. However, when B was not applied, the same application reduced yield. This result indicates that applied B may improve the utilization of applied N by cotton plants by increasing the translocation of N compounds into the boll. A restriction in the flow of carbohydrates out of the leaves could influence the number and size of the bolls. Yield increase was the consequence of enhanced boll setting and boll weight. With hot-water-soluble B in our experimental fields being 0.40 mg B kg^{-1}, the soils were low in B. It is generally accepted that a soil water-soluble B content of approximately 0.15 to 0.20 ppm approaches the

Table 4 . Effects of rate of nitrogen and boron on gin turnout and cotton yields.

Treatments	Gin turnout (%)			Seedcotton yield (kg ha^{-1})			Lint yield (kg ha^{-1})		
	2002	2003	Avg.	2002	2003	Avg.	2002	2003	Avg.
N rates (kg ha^{-1})									
0	37.77 [b]	38.00	37.88 [b]	3912 [c]	3573	3742 [b]	1478 [c]	1359	1419 [c]
80	39.44 [a]	39.33	39.38 [a]	4130 [b]	3972	4051 [ab]	1629 [b]	1563	1596 [b]
160	40.22 [a]	39.00	39.61 [a]	4332 [a]	4186	4259 [a]	1743 [a]	1635	1689 [a]
LSD $_{(0.05)}$	1.13	ns	1.20	18.26	ns	35.42	69.66	ns	14.87
B rates (kg ha^{-1})									
0	38.88	38.44	38.66	3880 [b]	3602 [b]	3741 [b]	1511 [c]	1388 [c]	1450 [c]
0.56	39.00	38.77	38.88	4050 [b]	3932 [ab]	3991 [ab]	1581 [b]	1523 [b]	1552 [b]
1.12	39.55	39.11	39.33	4444 [a]	4177 [a]	4321 [a]	1758 [a]	1646 [a]	1702 [a]
LSD $_{(0.05)}$	ns	ns	ns	34.88	35.43	41.98	1519	1582	18.54
Mean	39.18	38.77	38.96	4124	3910	4018	1617	1520	1568

Means followed by different letters within columns are significantly different (P = 0.05).

deficiency level (Anderson and Boswell, 1968). Positive crop responses to B are attributed to a greater B requirement by cotton compared with most other field crops (Shorrocks, 1992). The maximum increase in seed cotton yield with foliar-applied B ranged from 14.5% in 2002 to 16.5% in 2003, with an average of 15.5% over the control (Table 4).

Lint yield

Lint yield differences were highly significant between the N treatments in 2002, but not in 2003. Lint yield of the N-60 treatment was 6% and 17% higher than the N-80 treatment and the control, respectively (Table 4). Application of optimal N rates has been reported to benefit cotton yield by producing larger bolls at a greater number of fruiting sites (Boquet et al., 1994). Boll counts conducted in this study suggest that greater lint yields produced at elevated levels of N may have been due mostly to a greater number of harvestable bolls per plant. A tendency toward higher lint yield with increasing N rates was observed for 2002. Cotton yield response to N-160 treatment was 265 kg ha^{-1} over the control. Over 2 years, lint yields increased from 1419 kg ha^{-1} in the control treatment to 1552 kg ha^{-1} in the N-80 treatment and to 1689 kg ha^{-1} in the N-160 treatment. These yield increases were 133 and 270 kg ha^{-1} over the control. In 2003, differences in lint yield between N treatments were not significant; however, lint yield was numerically higher in the N-160 treatment. B applications increased lint yield significantly ($P \leq 0.01$) in each year and in both years combined. The maximum increase in lint yield with foliar-applied B ranged from 16% in 2002 to 18% in 2003 with an average of 17% over the control (Table 4).

Leaf blade B concentration

In 2002, foliar-applied B increased leaf tissue B concentration (to 67.6 mg kg^{-1}) above that of the control (43.1 mg kg^{-1}) (Table 5). The concentrations of P, K, Ca, Mg, Zn, and Ca in leaf blades were unaffected by any of the B treatments. However, a decline in 2003 in tissue B concentration was detected with increasing rates of applied N (N x B interaction $P \leq 0.01$). In 2003, foliar-applied B increased leaf blade B concentration from 39.9 mg kg^{-1} to 71.5 mg kg^{-1}. N % levels in the tissue increased with N application (treatment effect $P \leq 0.01$). Initial tissue levels, obtained 1 week before first flower, was 3.46%, which is within the acceptable range (3.5-4.5%) for cotton. For the July 25 sampling the N tissue level was 4.7% (above the acceptable range), but N in the leaf tissue declined rapidly with each subsequent sampling after flowering (3.90%).

Table 5. Averaged leaf blade boron levels (mg kg-1) for 2002 and 2003.

Foliar B kg ha^{-1}	2002			
	Soil N applied, kg ha^{-1}			
	0	80	160	Average
0	48.2	39.0	42.2	43.1 c
0.56	53.5	58.6	52.8	55.0 b
1.12	63.1	67.2	72.6	67.6 a
Average	54.9	54.9	55.9	
Foliar B kg ha^{-1}	2003			
	Soil N applied, kg ha^{-1}			
	0	80	160	Average
0	42.5	39.2	38.0	39.9 c
0.56	64.5	59.2	54.6	59.4 b
1.12	75.5	68.7	70.2	71.5 a
Average	60.8 a	55.7 b	54.2 c	

Means followed by different letters within columns are significantly different (p=0.05).

Fiber properties

In both years, neither soil-applied N nor foliar-applied B affected 2.5% span length (Table 6). Earlier studies found no or inconsistent effects of the N application rate on fiber length (Grimes et al.,1969; Boman and Westerman, 1994). Heitholt (1994) reported that the 2.5% and 50% span lengths were greater in the control and foliar B treatments. Fiber uniformity was not affected by N fertility levels, but B rate ($P \leq 0.05$) and year ($P \leq 0.01$) effects were significant (Table 1). Average fiber uniformity decreased with the application of 1.12 kg B ha^{-1}. Fibers were more uniform ($P \leq 0.01$) in 2003, on average differing by 2.5% between these 2 years. Fiber elongation was not affected by N or B fertility levels (Table 6), but the year ($P \leq 0.05$) effect was significant (Table 1). Fibers had greater elongation values in 2003 than in 2002. N and B fertility levels did not influence fiber strength (Table 6). Similarly, other researchers found no relationship between fiber strength and N treatment (Boman and Westerman, 1994; Fritschi et al., 2003). A significant year effect on micronaire was found. Mean micronaire readings were lower in the second year of the experiment than those in the first. Increased N application rates were reported to have no

Table 6. Effects of rate of nitrogen and boron on fiber properties. SL: span length

Treatments	2.5% SL (mm)			Fiber elongation (%)			Uniformity (%)		
	2002	2003	Avg.	2002	2003	Avg.	2002	2003	Avg.
N rates (kg ha^{-1})									
0	27.3	27.7	27.5	7.6	9.2	8.4	84.0	85.7	84.9
80	27.5	27.6	27.5	6.9	9.3	8.1	83.2	86.0	84.6
160	27.5	27.2	27.3	7.0	9.0	8.0	83.8	85.4	84.6
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	ns	ns	ns	ns
B rates (kg ha^{-1})									
0	27.2	27.5	27.3	7.4	9.0	8.2	83.9 a	86.0	85.0 a
0.56	27.7	27.3	27.5	7.1	9.3	8.2	84.2 a	85.8	85.0 a
1.12	27.3	27.7	27.5	7.2	9.1	8.1	82.8 b	85.3	84.0 b
$LSD_{(0.05)}$	ns	ns	ns	ns	9.2	ns	0.83	ns	0.75
Mean	27.4	27.5	27.5	7.2	9.2	8.2	83.6	85.7	84.7

Means followed by different letters within columns are significantly different (p=0.05).

Table 6 (Continued). Effects of rate of nitrogen and boron on fiber properties.

Treatments	Fiber strength (g tex^{-1})			Fiber fineness		
	2002	2003	Avg.	2002	2003	Avg.
N rates (kg ha^{-1})						
0	27.4	28.5	28.0	5.4	5.1	5.2
80	27.5	28.7	28.1	5.6	5.1	5.4
160	27.9	29.4	28.7	5.3	5.2	5.3
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns
B rates (kg ha^{-1})						
0	27.6	28.5	28.0	5.3	5.2	5.3
0.56	27.6	28.7	28.2	5.6	5.3	5.5
1.12	27.7	29.4	28.6	5.4	5.0	5.2
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns
Mean	27.6	28.9	28.3	5.4	5.2	5.3

Means followed by different letters within columns are significantly different (P = 0.05).

effect at all on micronaire or to increase or decrease micronaire readings (Boman and Westerman, 1994; Boman et al., 1997). Based on 11 years of data, Boman et al. (1997) reported that micronaire readings were reduced by applied N in low-micronaire environments and increased by applied N in high-micronaire environments.

Conclusion

Cotton responded well to N and B. However, the extent of the response varied from year to year. N fertilization produced high leaf N levels, but rank growth at the expense of flower production was not observed. Cotton was more responsive to applied B when N was not at a low rate. The existence of a yield response to supplemental B in this study indicated that initial soil B levels as determined by hot-water-soluble extraction methods appeared to be inadequate for cotton in this soil type. In 2002, lint yield was increased by 151 and 265 kg ha^{-1} over the control for the 80 and 160 kg ha^{-1} rates of N. In both 2002 and 2003, cotton yield response to B applied at the rate of 1.12 kg ha^{-1} was favorable. At the 1.12 kg ha^{-1} rate of B, lint yields tended to increase significantly when higher N rates were applied. The highest yields were obtained with the combination of 160 kg N ha^{-1} and 1.12 kg B ha^{-1}. The findings support the recommendation of a B rate of 1.12 kg ha^{-1} for high yield cotton.

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