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Boron requirements of flue-cured tobacco and soil residual effects from repeated applications to a granitic sand in north Queensland

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Abstract

The effect of boron on flue-cured tobacco yield and leaf quality was investigated by spraying 'Solubor' (20.5% boron) onto the soil at 0, 2, 4, 8 and 16 kg/ha (0, 0.41, 0.82, 1.64 and 3.28 kg B/ha). No significant differences in yield, leaf quality or the principal chemical attributes of the leaf were observed for the varieties Hicks Q46 and ZZ100, though, at the highest rate of application, root weights were significantly reduced. No accumulation of boron in the soil profiles to a depth of 1.2 m occurred following three years of application. Boron uptake ranged from 12 to 14 mg per plant (or 0.23 to 0.25 kg/ha for a plant density of 19 000/ha) without applied boron to 18 to 21 mg per plant (0.34 to 0.41 g/ha) at the highest rate of application. Boron accumulation occurred primarily in the leaf.

INTRODUCTION

Bartholomew and Nicholson (1976) identified cases of boron deficiency in the Dimbulah area which were corrected with a spray of 0.2% Solubor (20.5% B). A recent survey (T. B. Jacobsen pers. comm. 1983) of fifty tobacco farms in the Mareeba–Dimbulah area indicated that 96% of growers were applying boron (as Solubor) to crops to correct a physiological disorder known as leaf drop. The average rate of boron application was 0.86 kg/ha, with a small percentage (12%) of the growers applying above 1.43 kg/ha.

According to McCants and Woltz (1967), boron has been the most extensively studied of the micronutrients with respect to the nutrition and fertilisation of tobacco. Some of the reports in the literature, however, are not consistent.

For example, Bacon *et al.* (1950) noted that boron toxicity was caused by an application of 2.5 kg B/ha when tobacco grew in soil that already had a hot water soluble (HWS) concentration of 14 mg B/kg. On the other hand, Le Lacheur (1972) reported that tobacco did not exhibit toxicity symptoms when grown in soil with a concentration of 25 mg HWS B/kg. Reisenauer *et al.* (1973) claim that the range between adequate and toxic levels of boron is smaller than for any other nutrient element. Hutcheson and Woltz (1956) concluded that concentrations of 15 to 16 mg B/kg in bud leaves at flowering were near the deficient level for flue-cured tobacco, after observing toxicity on young plants when boron was applied at 1.0 kg/ha. Matthews and McVickar (1946) obtained a five per cent increase in yield and value of flue-cured tobacco with an application of 0.28 kg B/ha, but the claim of increased yield and quality has since been refuted by Hutcheson and Woltz (1956), Terry and Terrill (1969) and Jones and Leslie (1986). These three groups of researchers applied boron at rates up to 1.34, 0.56 and 1.68 kg/ha respectively, which are comparable to the rates applied by north Queensland tobacco growers.

Some tobacco growers in the Mareeba–Dimbulah area are currently diversifying into deeper rooted orchard crops. Concern was expressed by Departmental officers that prolonged use of boron on tobacco soils may lead to a toxic accumulation of the element in the lower soil profiles.

The objectives of this study were to investigate the effects of annual applications of boron (at rates up to 3.3 kg/ha) on tobacco yield, cured leaf quality and the incidence of leaf drop over a three year period. Soil boron to a depth of 1.2 m was also monitored during the experiment to study whether accumulation of applied boron in soil was occuring.

MATERIALS AND METHODS

Location

The field experiment was conducted at Southedge Tobacco Research Station (16°58′S; 145°21′E) on a red earth soil of granitic origin, locally known as Morganbury Loamy Sand (Gn 2.14, Northcote 1974). Some soil chemical attributes (0 to 150 mm) were: pH (1:5 H_2O) 5.8; organic carbon (Walkley and Black 1934) 0.6%; exchangeable cations (M NH_4Cl, pH 7.0) K 0.30, Ca 0.87 and Mg 0.23 cmol/kg; and HWS boron <0.1 mg/kg (Berger and Truog 1939).

A chacteristic of the soil was the high percentage of gravel (>2mm), with depth intervals of 0 to 150, 150 to 300, 300 to 600, 600 to 900 and 900 to 1200 mm containing 21%, 17%, 25%, 59% and 56% respectively; bulk densities in these profile increments were 1.61, 1.85, 1.88, 1.75 and 1.80 g/cc respectively.

Design and cultural data

Five rates of Solubor, 0, 2, 4, 8 and 16 kg/ha (0, 0.41, 0.82, 1.64 and 3.28 kg B/ha) were replicated four times in a randomised block design. The Solubor was applied as an aqueous solution just prior to planting. The varieties grown were Hicks Q46 in 1983 and ZZ100 in 1984 and 1985. Each plot comprised 72 plants (0.0038 ha), at a plant density of 19 000 /ha. The basal fertiliser was a commercial NPK mixture (9.7:5:28.8) which provided 70 kg N/ha. A sidedressing of sodium nitrate was applied four weeks after transplanting to increase the nitrogen application to 100 kg N/ha. Maleic hydrazide was used for sucker control at the rate of 16 L/ha. The Departmental reccommendations for other cultural practises such as irrigation and pesticide application were followed. Following transplanting, irrigation is withheld for 30 days then the crop is irrigated every 6 to 8 days with 20 mm water (K. H. Ferguson pers. comm. 1983). Leaf drop was regularly assessed during the experiments. A severe wind and hail storm in 1984 completely destroyed the mature crop in the second year with the result that this paper reports the findings of two years cultural data and three years soil data.

Plant analysis

Three plants were selected from each plot at budding on the basis of conformity with overall plot development. Over successive harvests, leaves were removed from these plants in a manner which simulated the harvest pattern for the remainder of the plot. The inflorescence (top), suckers and leaves of each plant were kept separate during the harvest period. At the completion of each experiment, the plants were carefully removed from the field, thoroughly washed to remove all soil and then divided into stem and root. All plant material (leaf, root, stem and top plus suckers) was dried at 65°C, weighed and ground to pass through a 0.8 mm sieve.

Total and saleable cured leaf weights were recorded in each experiment. Leaf quality was assessed by an officer of the Tobacco Leaf Marketing Board and a grade assigned.

The reserve price for each treatment was determined as the weighted average price of assigned grades in the 1984 and 1986 Grade and Price Schedule for Hicks Q46 (1983) and ZZ100 (1985) respectively.

Soil analyses

Soil was sampled at 0 to 150, 150 to 300, 300 to 600, 600 to 900 and 900 to 1200 mm on three occasions by compositing soils from three cores taken from within the rows of each treatment. Sampling times were January 1984, May 1985 and May 1986. Soil samples were air dried, sieved through a 2 mm screen and hot-water extractable boron (Berger and Truog 1939) determined using an auto-analyser (Basson *et al.* 1974).

Analytical methods

The four plant parts and cured leaf samples were analysed for boron by the method of Basson *et al.* (1974). The cured leaf samples were analysed for total alkaloids (Griffith 1957), reducing sugars (Harvey *et al.* 1969) and nitrogen (Varley 1966).

RESULTS

Cured leaf yield, quality and the dollar return per hectare were not significantly affected by the application of boron (data not shown). Mean total cured leaf yields of 4648 and 3361 kg/ha and mean dollar return per hectare of 18 487 and 14 993 were produced by Hicks Q46 (1983) and ZZ100 (1985) respectively. These yield differences and the resultant differences in mean monetary return between the two years are attributable to variety and season.

Toxicity symptoms were observed on young plants in the 3.28 kg/ha treatment for Hicks Q46 but plants recovered after irrigation commenced. No toxicity symptoms were observed on plants for the variety ZZ100.

Application of boron at up to 3.28 kg/ha had no significant effect on reducing sugar, total alkaloid and nitrogen content of the cured leaf. The total alkaloid level, however, was generally lower in the 3.28 kg/ha treatment for both varities (data not shown). Boron concentrations in cured leaf were increased by application of boron (Table 1). The boron level in the control plots was similar for each variety (Table 1).

For both varieties, between 10% and 15% of the applied boron was taken up when 0.41 kg/ha boron was applied (Table 1). For an application of 3.28 kg/ha boron only three to five per cent of the application was taken up by the plant. The plant component that was most effected by treatment was the root system. With Hicks Q46 the root weight was reduced at boron rates of 3.28 kg/ha (P=0.05), whereas, for ZZ100 the root weight increased then fell as more Solubor was applied; no significant changes were observed for leaf, stem and the tops (plus suckers) component. Boron concentration in the leaf increased as the application of boron increased (Table 1), whereas the changes in the other plant components were either not significant or small when compared with the control. This resulted in a higher proportion of the boron in the plant being present in the leaf component (Table 2).

Concentrations of boron found in the soil after successive applications of boron (Table 3) show, that even at the highest rate of application (3.28 kg B/ha/yr), accumulation in the top 900 mm of soil was small, and well below the concentrations considered to be toxic.

Leaf drop for all three experiments was very slight, amounting to only a few leaves for the whole of each experiment.

Table 1. Dry matter yield and boron content in components of tobacco plants grown with various rates of applied boron

Treatment kg B/ha	Cured leaf mg/kg boron				Plant component, dry weight (g)				B in plant component (mg/kg)				B in Whole Plant (mg)	Uptake of B g/ha	% of applied B†
	X*	C	L	T	Leaf	Root	Stem	Top	Leaf	Root	Stem	Top			
Hicks Q46															
0.00	28	21	23	44	258.4	146.8	162.3	20.3	32	10	15	49	13.9	253	
0.41	36	30	35	53	260.4	131.0	162.7	22.5	40	10	16	46	15.3	293	9.8
0.82	37	34	42	64	264.0	143.2	160.3	20.2	42	10	16	45	15.7	301	5.9
1.64	50	40	44	62	258.9	125.1	159.8	19.7	53	10	17	48	18.6	356	6.2
3.28	81	56	58	73	233.1	91.0	167.7	20.9	70	10	17	44	21.2	408	4.7
LSD $P = 0.05$	14	6	7	8	n.s.	35.3	n.s.	n.s.	9	n.s.	n.s.	n.s.	3.1	59	
ZZ100															
0.00	30	26	45	54	169.6	108.2	109.4	116.2	34	9	13	33	12.0	231	
0.41	37	29	50	61	200.9	138.8	121.5	114.3	41	9	13	35	15.2	291	14.7
0.82	43	39	63	66	190.2	125.2	111.4	112.2	44	9	14	33	15.0	289	7.1
1.64	49	46	64	72	189.4	135.4	115.0	89.3	47	9	15	37	15.3	294	3.8
3.28	73	57	82	80	173.2	113.1	106.4	95.5	62	10	16	41	17.6	338	3.3
LSD $P = 0.05$	12	10	10	15	n.s.	21.1	n.s.	n.s.	11	n.s.	1	4	n.s.	n.s.	

* X = Lugs, C = Cutters, L = Leaf and T = Tips.

† Calculation of % of applied boron recovered = $\frac{\text{Uptake of } B_T(g) - \text{Uptake of } B_O(g)0}{B \text{ applied (g)}} \times 100\%$

where B_T = Boron uptake at a particular treatment.
B_O = Boron uptake by control treatment.

n.s. = not significant.

Table 2. Boron in plant component as a percentage of total plant boron

Treatment kg B/ha	Hicks Q46 (1983)				ZZ100 (1985)			
	Leaf	Root	Stem	Top	Leaf	Root	Stem	Top
0.00	62.7	11.2	18.4	7.7	48.1	8.2	12.1	31.6
0.41	67.5	8.8	17.0	6.7	55.6	8.7	10.8	24.9
0.82	68.9	9.2	16.2	5.7	57.0	7.4	10.7	24.9
1.64	74.1	6.7	14.4	4.8	58.7	7.7	11.0	22.6
3.28	77.2	4.6	13.6	4.6	62.3	6.0	9.3	22.4

Table 3. Effect of applied boron on concentration of hot water extractable B (mg/kg) in the soil profiles

Treatment kgB/ha	January 1984 B concentration (mg/kg) at various depths (mm)					May 1985 B concentration (mg/kg) at various depths (mm)					May 1986 B concentration (mg/kg) at various depths (mm)				
	00/150	150/300	300/600	600/900	900/1200	00/150	150/300	300/600	600/900	900/1200	00/150	150/300	300/600	600/900	900/1200
0.00	0.17	0.13	0.14	0.14	0.17	0.14	0.13	0.11	0.07	0.06	0.13	0.13	0.10	0.12	0.10
0.41	0.26	0.18	0.12	0.14	0.10	0.14	0.13	0.08	0.07	0.08	0.12	0.14	0.16	0.14	0.07
0.82	0.34	0.28	0.17	0.12	0.11	0.23	0.20	0.17	0.08	0.06	0.13	0.14	0.15	0.12	0.11
1.64	0.45	0.29	0.17	0.14	0.10	0.27	0.23	0.16	0.10	0.06	0.18	0.19	0.17	0.11	0.07
3.28	0.66	0.35	0.19	0.13	0.09	0.25	0.27	0.20	0.17	0.08	0.24	0.26	0.28	0.23	0.09
LSD $P = 0.05$	0.22	0.10	n.s.	n.s.	n.s.	n.s.	0.06	0.08	n.s.	n.s.	n.s.	0.08	n.s.	n.s.	n.s.

n.s. = not significant.

DISCUSSION

The current results demonstrate that flue-cured tobacco will tolerate high levels of applied boron when grown in coarse sandy soils of low boron status and that a significant accumulation of boron does not occur in the soil (Table 3). The lack of a marked increase in soil boron concentration after three successive applications was possibly due to the heavy summer rainfall which leached the boron beyond the 1.2 m depth.

In May 1986, for the highest rate of application of boron, 4.8 kg B/ha was present in the 0 to 1200 mm soil profile and 0.5 kg B/ha had been removed from the field in the cured leaf. At the same sampling of the nil control treatment 2.4 kg B/ha remained in the soil profile and 0.3 kg B/ha had been removed in the cured leaf. By subtracting these plant and soil amounts, an estimate of the amount of boron remaining in the soil from the applied boron was found to be 2.6 kg B/ha or 27% of the total application. In a similar way, it was found that 56% of the boron appied in the 3.28 kg/ha treatment was present in the soil after the first tobacco crop. The reason for the disparity between these percentages was possibly that greater quantities of rainfall were recorded between transplanting and the time of soil sampling for the two ZZ100 crops. These amounts were 913 and 1000 mm respectively compared with 519 mm of rainfall recorded in the six months to January 1984. The fact that only 56% of applied boron could be accounted for in plant and soil after 519 mm of rainfall, indicates either that this soil is highly susceptibile to leaching because of its high gravel content, particularly below 600 mm, or our sampling intensity was not sufficient to detect applied boron.

The study found no agronomic benefit in terms of cured leaf yield, quality or monetary return from applying boron. The site for this experiment was chosen because of its low hot water soluble boron status. Because leaf drop in all plots, including the control, was very low some other unknown factor must be responsible for the disorder.

Boron removed from the field in cured leaf was 0.11 to 0.16 kg/ha, and 0.25 to 0.3 kg/ha was accounted for in the whole plant. The latter quantity would not be supplied by tobacco fertilisers which contain 10 to 20 mg B/kg (G. Price, Consolidated Fertilisers Limited, pers. comm. 1982) since only 12 to 15 g B/ha would be applied at current rates. The amount of Solubor required to provide the 0.25 to 0.3 kg B/ha requirement is 1.1 to 1.2 kg/ha. In view of previous recorded instances of deficiency and the highly leachable nature of boron in this soil, tobacco growers are advised to maintain the current recommendation of applying Solubor at a rate of 2 kg/ha.

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References

Bacon, C. W., Leighty, W. R. and Bullock, J. F. (1950), *Boron, copper, manganese and zinc requirement tests of tobacco*, USDA Technical Bulletin Number MIX.

Bartholomew, B. L. and Nicholson, A. J. (1976), Boron deficiency in tobacco, *Queensland Agricultural Journal* **102**, 273–76.

Basson, W. D., Pille, P. P. and De Preez, A. L. (1974), Automated in situ preparation of Azomethine H and the subsequent determination of boron in aqueous solution, *Analyst*, **99**, 168–70.

Berger, K. C. and Truog, E. (1939), Boron determination in soils and plants using the quinalizarin reaction, *Industrial Engineering Chemistry* **11**, 540–45.

Griffith, R. B. (1957), The rapid determination of total alkaloids by steam distillation, *Tobacco Science* **1**, 130–37.

Harvey, W. R., Stahr, H. M. and Smith, W. C. (1969), Automated determination of reducing sugars and nicotine alkaloids in the same extract of tobacco leaf, *Tobacco Science* **13**, 13–15.

Hutcheson, T. B. Jr. and Woltz, W. G. (1956), *Boron in the fertilisation of flue-cured tobacco*, North Carolina Agricultural Experiment Station Technical Bulletin Number CXX.

Jones, J. L. and Leslie, R. G. (1986), Effects of boron, copper and zinc on yield and quality of flue-cured tobacco, *Tobacco Science* **30**, 75–80.

Le Lacheur, K. E. (1972), A comparison of boron levels in flue-cured tobacco produced at various locations in the Allantic provinces, *The Lighter* **42** (3), 27–28.

Matthews, E. M. and McVickar, M. H. (1946), *The effects of boron and yield and quality of bright tobacco*, Virginia Agricultural Experiment Station Bulletin CCCXCV.

McCants, C. B. and Woltz, W. G. (1967), Growth and mineral nutrition of tobacco: Part 12, Boron, *Advances in Agronomy* **19**, 254–57.

Northcote, K. H. (1974), *A Factual Key for the Recognition of Australian Soils*, Fourth edn., Rellim Technical Publications, Glenside, S.A.

Reisenauer, H. M., Walsh, L. M. and Hoeft, R. G. (1973), Testing soils for sulphur, boron, molybdenum and chlorine, in L. M. Walsh and J. D. Beaton (eds), *Soil Testing and Plant Analysis*, 2nd edn., Soil Science Society of America, Madison, Wisconsin 173–200.

Terry, D. L. and Terrill, T. R. (1969), *Flue-cured tobacco research in sandhills area of North Carolina*, Department of Soil Science, North Carolina State University, Raleigh, North Carolina USA.

Varley, J. A. (1966), Automatic method for the determination of nitrogen, phosphorus and potassium in plant material, *Analyst* **91**, 119–26.

Walkley, A. and Black, T. A. (1934), An examination of Degtjareff method for for determining soil organic matter, and a proposed modification of the chromic acid titration method, *Soil Science* **37**, 29–38.

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