Queensland Journal of Agricultural and Animal Sciences, Vol. 39 (1), 27-34 (1982)
Published by Queensland Department of Primary Industries.

Influence of nitrate and ammonium nitrogen sources on leaf yield, quality and some leaf chemical constituents of flue-cured tobacco in north Queensland

P. E. Tonello, B.Agr.Sc., E. W. B. van den Muyzenberg and J. von Nordheim

Summary

A 2-year field study was undertaken to determine the influence of nitrate and ammonium nitrogen sources on leaf yield, quality and some leaf chemical constituents of flue-cured tobacco in north Queensland.

Sodium nitrate, ammonium nitrate, urea and aqua-ammonia were compared as N side-dressing sources at three application times in Experiment 1. Experiment 2 compared the same N fertilizers as the sole source of N at two planting times and at three N levels.

Although a trend towards increased P uptake with ammoniated N forms was evident in all experiments, leaf yield, quality and leaf chemical constituents were not significantly influenced by form of N. Split nitrogen dressings did not improve leaf yield or quality but raised the total alkaloid content in the upper leaves. Early plantings had leaf with higher N, P, K, Ca, Cl and total alkaloid but lower Mg and reducing sugar content.

The agricultural implications of these findings are discussed.

1. INTRODUCTION

In the production of flue-cured tobacco, nitrogen is considered to be the most critical nutrient because of its marked influence on maturity, yield and quality. The most acceptable well matured tobacco is produced when most of the available nitrogen is applied during early stages of plant growth.

The climate of the Mareeba-Dimbulah irrigation area can be described as dry tropical. Average annual rainfall ranges from 875 mm at Mareeba to 700 mm at Dimbulah with more than 80% of rainfall received between December and March. Tobacco is grown under irrigation using overhead spray systems.

On the nitrogen, phosphorus and sulphur deficient soils of the Mareeba-Dimbulah area (Ward 1967) fertilization of tobacco involves applications of low analysis compound fertilizer mixtures (3N; 6.1P; 15K; 12Ca; 9S) at rates equivalent to 1000 kg ha^{-1}. These mixtures have nitrogen in the nitrate form. With fertilizer prices increasing, manufacturing trends have been towards higher analysis fertilizer mixtures which are wholly or partly ammoniated.

The relative merits of nitrate and ammonium nitrogen in flue-cured tobacco production have been the subject of considerable research. McCants and Woltz (1967) reviewed tobacco nutrition, and concluded that the relative response of tobacco to application of the ammonium and nitrate nitrogen forms was influenced by nitrification conditions in the soil. Elliot (1970) reported that increasing the proportion of ammonium to nitrate nitrogen improved yield and quality.

Locally, Caulley and Ward (1972) found a more consistent yield and quality response to nitrogen in the nitrate form and that time of application had no significant effect. Ward, van Waveren, Thomson and Warrell (1973) found that neither form nor time of nitrogen application had any effect on cured leaf yield and quality. Both these studies were conducted on September (spring) plantings. The present trend towards winter (June-July) plantings may adversely affect the response of flue-cured tobacco to ammoniated fertilizers.

The chemical composition of cured leaf influences the quality and thus usability. Garner (1951) considered that total alkaloids and sugars were two of the most important constituents affecting usability. High sugar content is an important factor in imparting acidity to the smoke. Other constituents such as potassium also play important roles. McCants and Woltz (1963) cited ample evidence for positive correlation between potassium content and rate of burn or fire holding capacity of flue-cured tobacco. They suggested that the reduction in cation absorption with use of ammonium nitrogen may be sufficient to cause deficiency symptoms, particularly of potassium and magnesium. Total nitrogen and alkaloids tended to increase with ammonium nitrogen. Elliot (1970) found that increasing the proportion of ammonium decreased total N, total alkaloids and increased reducing sugars.

The objective of the present study was to determine the effect of nitrate and ammonium N sources at different planting times on yield, quality and on some chemical constituents of flue-cured tobacco grown in north Queensland.

2. MATERIALS AND METHODS

Two field experiments were conducted at Southedge Tobacco Research Station on a red earth of granitic origin, locally named Morganbury Loamy Sand (Gn 2.14). The experiments were conducted at sites on which two tobacco crops had been previously grown.

In Experiment 1, four N fertilizers were compared as sources of N for side-dressing tobacco at three growth stages following a September (late) planting. Experiment 2 compared the same N fertilizers as the sole sources of N to apply at transplanting for a May (early) and August (medium) planting.

Experiment 1

All plots received a total of 50 kg ha^{-1} N. Of this 30 kg ha^{-1} was applied at transplanting as a fertilizer mixture (3N; 6.1P; 15K; 12Ca; 9S) and 20 kg ha^{-1} was applied as a side-dressing of either sodium nitrate (16% N), urea (46% N), ammonium nitrate (34% N) or aqua-ammonia (20% N) at (a) transplanting, (b) hilling-up, (c) hilling-up and early budding. Nitrogen in the mixture was in the nitrate form.

The experimental area was fumigated with EDB (ethylene dibromide) at 225 L ha^{-1} 21 days before transplanting. Tobacco (cv. CSIRO 40T) was transplanted on 5 September 1974. The experimental design was a 4 × 3 factorial with four randomized blocks. Plots consisted of 5 rows of 17 plants (total) of which 3 rows of 12 plants were harvested (datum). Plant and row spacing were 0.53 m and 1.2 m respectively.

Experiment 2

Nitrate, urea, ammonium nitrate and aqua-ammonia were compared at three nitrogen levels (35, 50 and 60 kg ha^{-1} N) for a May and August planting.

The fertilizer mixture (3N; 6.1P; 15K; 12Ca) was used as nitrate source and was applied at the rate of 845 kg ha^{-1}. The required nitrogen level in the control was made up with the addition of sodium nitrate. The remaining treatments received P and K as single superphosphate (9.6% P) and potassium sulphate (42% K) at rates equivalent to those of the control.

Twenty one days after the experimental site had been fumigated, tobacco seedlings were transplanted and the fertilizer treatments applied. Tobacco cultivars were Sirone (29 May 1975 planting) and CSIRO 40T (8 August 1975 planting). The experimental design was a 4 × 3 factorial with four randomized blocks in the May planting and a 4 × 3 factorial with three randomized blocks in the August planting. Plots were planted as 5 rows of 16 plants (total) with 3 rows of 10 plants (datum) in May and 4 rows of 13 plants (total) with 2 rows of 10 plants (datum) in August. Plant and row spacings were similar to those in Experiment 1.

Conventional cultural practices were followed throughout the growth of the crop in both experiments.

Plant measurements

Leaf from each plot was sorted into bundles of similar leaf type. Data recorded included total and saleable leaf weights and leaf quality. Tobacco Leaf Marketing Board appraisers graded each bundle according to the 1974 minimum price schedule. Leaf quality assessment for each plot, expressed in cents per half kilogram, was obtained from the weighted average price of all bundles from a plot.

At harvest each of the four plant positions (lugs, cutters, leaf, tips) of six randomly selected plants was sprayed with a different coloured paint to identify samples for chemical analysis. Cured whole leaf samples from the four plant positions were oven-dried at 70°C, ground and digested (micro-kjeldahl). Nitrogen and phosphorus were determined colorimetrically using an autoanalyser, and potassium was determined by flame photometry. Calcium and magnesium were determined on the atomic absorption spectrophotometer. Reducing sugars were determined by an inverse colorimetric procedure using potassium ferricyanide. Chlorine levels were determined by the electrometric titration method of Best (Piper 1950). Total alkaloids were determined by UV spectrophotometric method using a steam distillation procedure (Griffith 1957).

Soil measurements

Composite soil samples (0 to 15, 15 to 30 cm) were collected from the cultivated land before transplanting in Experiment 2. Chemical analyses of the two sites are shown in Table 1.

Table 1. Chemical soil analysis of the two sites used in 1975 (Experiment 2)

Chemical analysis	May		August	
	0 to 15 cm	15 to 30 cm	0 to 15 cm	15 to 30 cm
pH	5.7	5.8	5.5	5.6
Total N (%)	0.048	0.031	0.031	0.019
Organic carbon (%)	0.462	0.356	0.290	0.160
P (Olsen) (ppm)	9.8	5.8	6.3	2.6
Cl (ppm)	7.0	6.1	7.6	10.6

The pH was determined on a 1:2.5 soil/water suspension. Organic carbon was determined by the Walkley and Black titration procedure as detailed by Piper (1950), total nitrogen by a Kjeldahl type digestion procedure followed by steam distillation and titration, and extractable P by the method of Olsen, Cole, Watanabe and Dean (1954). Soil temperature was recorded during Experiment 2 (Table 2).

Table 2. Monthly means and average means of temperatures (°C) at Southedge Tobacco Research Station during Experiment 2 (1975)

Month	Minimum terrestrial		10 cm depth*		20 cm depth*	
May 1975	14.2		22.0		22.4	
average†		14.5		21.7		22.7
June	11.9		19.2		19.8	
average†		12.0		19.9		21.1
July	11.8		20.9		21.5	
average†		10.4		19.6		20.4
August	11.9		21.0		21.3	
average†		11.3		20.6		21.2
September	15.2		22.6		23.1	
average†		13.1		22.5		22.6
October	16.4		25.5		25.5	
average†		14.6		24.7		25.2
November	16.6		27.6		27.9	
average†		17.8		26.7		26.8
December	18.0		26.2		26.4	
average†		18.4		27.1		27.2

*Readings taken at 9.00 a.m.
†8 year average.

3. RESULTS

Experiment 1

Leaf yield, quality and gross return (Table 3) were not affected by form of N used as side-dressing. Time of application of the side-dressing had no significant effect on saleable yield, quality or gross return, but more total and saleable leaf was produced with the application at transplanting than with split applications.

Table 3. Effect of form of N and time of application on total and saleable leaf yield and quality of tobacco in Experiment 1

Treatment	Yields (kg ha^{-1})		Quality (\$ kg^{-1})	Returns (\$ ha^{-1})
	Total	Saleable		
Nitrogen side-dressing source				
Sodium nitrate	2956	2822	279.6	7875
Nitram	3020	2889	278.4	8035
Urea	3035	2931	276.6	8106
Aqua-ammonia	3131	3010	276.8	8310
l.s.d. $P < 0.05$	205.0*	200.0*	9.80*	582.0*
Time of application of nitrogen				
Transplanting	3132	3001	275.4	8254
Hilling-up	2953	2843	280.6	7946
Hilling-up and budding	3022	2894	278.4	8050
l.s.d. $P < 0.05$	178.0	174.0*	8.60*	505.0*

*Denotes no significant difference.

Cured leaf constituent ranges from lugs to tips were N (1.1 to 1.6), K (5.7 to 3.3), Ca (4.7 to 2.5), Mg (0.98 to 0.46), Cl (2.0 to 0.81) and reducing sugars (5.8 to 21.0) and were not affected by form of N. The partly ammoniated and nitrate forms, however, had lower P and total alkaloid levels (Table 4).

Table 4. Effect of form of N and time of application on the P (%) and total alkaloid (%) content of cured leaf in Experiment 1

Treatment	Lugs		Cutters		Leaf		Tips	
	P	T.A.	P	T.A.	P	T.A.	P	T.A.
Nitrogen side-dressing source								
Sodium nitrate	0.22	1.36	0.24	1.45	0.30	2.49	0.31	2.64
Nitram	0.20	1.33	0.23	1.35	0.28	2.29	0.31	3.18
Urea	0.24	1.44	0.26	1.59	0.31	2.62	0.33	3.39
Aqua-ammonia	0.22	1.44	0.25	1.52	0.30	2.68	0.32	3.26
l.s.d. $P < 0.05$	0.022	0.160*	0.019	0.200	0.025*	0.460*	0.026*	0.490
Time of application of nitrogen								
Transplanting	0.21	1.47	0.23	1.53	0.28	2.61	0.31	2.43
Hilling-up	0.22	1.31	0.24	1.41	0.31	2.68	0.31	2.68
Hilling-up and budding	0.23	1.38	0.26	1.50	0.30	2.27	0.32	3.25
l.s.d. $P < 0.05$	0.019	0.140	0.016	0.200*	0.022	0.390	0.023*	0.430

*Denotes no significant difference.

Splitting the N side-dressing increased P content in the lugs and cutter plant positions and total alkaloids in the tips (Table 4). The other cured leaf constituents were not affected by time of application of the N side-dressing.

Table 5. Effect of source of N and level of N at two planting times on total and saleable leaf yield and quality of tobacco in Experiment 2

Treatment	May planting				August planting			
	Yields (kg ha^{-1})		Quality	Returns	Yields (kg ha^{-1})		Quality	Returns
	Total	Saleable	(\$ kg^{-1})	(\$ ha^{-1})	Total	Saleable	(\$ kg^{-1})	(\$ ha^{-1})
Source of nitrogen								
Nitrate	1757	1668	307.8	5146	2770	2731	303.8	8305
Nitram	1782	1662	313.6	5227	2732	2612	287.4	7511
Urea	1709	1622	308.6	5022	2643	2585	291.4	7540
Aqua-ammonia	1495	1430	313.8	4493	2716	2652	293.4	7791
l.s.d. $P < 0.05$	104.2	125.0	14.30*	507.4*	175.7*	179.3*	11.58	698.2*
Level of nitrogen								
35 kg ha^{-1} N	1647	1584	316.4	5020	2578	2484	291.8	7255
50 kg ha^{-1} N	1688	1616	310.0	5019	2751	2690	294.8	7944
65 kg ha^{-1} N	1722	1586	306.6	4877	2817	2762	295.4	8161
l.s.d. $P < 0.05$	90.3*	108.3*	12.38*	439.5*	152.2	155.3	10.02*	604.7

*Denotes no significant difference.

Experiment 2

With the exception of aqua-ammonia at the May planting, leaf yield and gross return (Table 5) were not affected by source of N. Aqua-ammonia lowered yields and gross return but not leaf quality. Nitram and urea lowered cured leaf quality in the August planting.

Increasing the N level had no effect at the May planting, but at the August planting it increased yields and gross return without affecting leaf quality.

In the May planting, aqua-ammonia lowered the leaf N, Mg total alkaloids and raised P and reducing sugar content (Table 6), while the other sources of N gave similar results. Urea lowered Mg content in lugs, cutter and leaf plant positions (Table 7).

Increasing the N level raised the N and total alkaloid and lowered reducing sugar content of leaf at both planting times. Cured leaf from the May planting had a higher N, P, K, Ca, Cl and total alkaloid content and lower Mg and reducing sugar content than leaf from the August planting. Cured leaf constituent ranges from lugs to tips were, in the May planting, K (4.2 to 2.4), Ca (4.2 to 2.5), Cl (1.7 to 1.0) and, in the August planting, K (4.2 to 1.9), Ca (5.3 to 2.0), Cl (1.1 to 0.6), P (0.24 to 0.31).

4. DISCUSSION

The field experiments did not show any consistent significant difference in yield and quality between forms of N used in side-dressings or as sole N sources in May, August and September plantings. These findings are in agreement with those of Ward *et al.* (1973) whose studies were conducted in what was then the main growing season of September to January. Soil temperatures during this period range between 21 and 27°C in the fertilizer zone (0 to 10 cm). Table 2 shows that soil temperatures were higher than 19°C during the field period of the May planting. Parker and Larson (1962) found that, although temperatures below 20°C decreased nitrification, even at 16°C nitrification continued to such an extent that it had no effect on corn yields. On this basis, nitrification in the May planting would be expected to proceed readily.

The trend towards increased uptake of phosphorus with ammoniated N forms was evident in all experiments and is in agreement with findings of Ward *et al.* (1973).

Although no visual ammonium toxicity symptoms were observed, the use of aqua-ammonia as sole nitrogen source in the May planting depressed yields but not cured leaf quality. It seems probable that this effect arose from damage to the root system during aqua-ammonia application.

Locally, use of nitrogen side-dressing is a common practice. Current and past (Ward *et al.* 1973) field studies have shown that splitting the nitrogen dressing did not increase yield or improve cured leaf quality. Late applications of nitrogen resulted in higher total alkaloid levels in the upper leaves.

The similarity in responses obtained with both nitrate and ammonium fertilizers in the past and current field experiments during different growing periods show the possibility of using ammoniated or partly ammoniated fertilizers in flue-cured tobacco production. These fertilizers are cheaper per unit of N and handling costs would be lower. However, the need for specialized equipment and the potential danger to crop and operator make aqua-ammonia a less suitable form of N.

Table 6. Effect of source and level of N on the N, P, Mg, total alkaloid and reducing sugar percentage content of cured leaf in the May planting of Experiment 2

Treatment	Lugs					Cutters					Leaf					Tips				
	N	P	Mg	T.A.	R.S.	N	P	Mg	T.A.	R.S.	N	P	Mg	T.A.	R.S.	N	P	Mg	T.A.	R.S.
Source of N																				
Nitrate (control)........	2.2	0.24	0.68	2.51	11.5	2.0	0.31	0.44	3.26	19.9	2.1	0.35	0.35	4.10	22.1	2.4	0.39	0.34	4.15	21.0
Nitram	2.2	0.25	0.65	2.78	10.1	2.1	0.30	0.42	3.49	18.3	2.2	0.35	0.35	4.11	19.9	2.3	0.39	0.33	4.34	18.9
Urea	2.3	0.27	0.69	2.79	11.4	2.1	0.33	0.40	3.46	18.9	2.1	0.42	0.34	4.18	22.1	2.4	0.40	0.34	4.27	18.3
Aqua-ammonia	2.0	0.30	0.53	2.40	16.8	1.8	0.38	0.35	2.87	23.3	2.0	0.41	0.31	3.52	24.7	2.1	0.46	0.31	3.42	23.4
l.s.d. $P < 0.05$	0.215*	0.027	0.096	0.362*	2.87	0.19	0.043	0.055	0.418	3.68*	0.25*	0.058	0.039*	0.676*	3.37*	0.21	0.054	0.039*	0.474	3.18
Level of N																				
35 kg ha^{-1} N	2.0	0.26	0.59	2.31	14.0	1.9	0.33	0.39	3.02	21.4	1.9	0.38	0.33	3.61	24.3	2.1	0.42	0.32	3.84	22.5
50 kg ha^{-1} N	2.1	0.26	0.64	2.69	12.6	2.0	0.32	0.39	3.27	20.1	2.1	0.39	0.32	4.06	22.1	2.3	0.41	0.34	4.00	20.3
65 kg ha^{-1} N	2.4	0.27	0.68	2.86	10.8	2.1	0.35	0.42	3.51	18.7	2.2	0.37	0.35	4.27	20.2	2.4	0.40	0.33	4.31	19.3
l.s.d. $P < 0.05$	0.18	0.023*	0.083*	0.314	2.48	0.17	0.037*	0.048*	0.363	3.20*	0.22	0.049*	0.034*	0.586*	2.92	0.18	0.047*	0.034*	0.410*	2.75*

*Denotes no significant difference.

Table 7. Effect of source and level of N on the N, Mg, total alkaloids and reducing sugar percentage content of cured leaf in the August planting of Experiment 2

Treatment	Lugs				Cutters				Leaf				Tips			
	N	Mg	T.A.	R.S.	N	Mg	T.A.	R.S.	N	Mg	T.A.	R.S.	N	Mg	T.A.	R.S.
Source of N																
Nitrate	1.7	0.99	1.99	8.4	1.6	0.58	2.58	21.1	1.7	0.44	3.52	23.4	1.8	0.39	3.83	23.6
Nitram	1.8	1.02	2.15	8.4	1.6	0.46	2.60	23.0	1.7	0.41	3.48	24.7	1.8	0.39	3.85	22.7
Urea	1.8	0.79	2.27	10.3	1.6	0.39	2.48	25.2	1.8	0.34	3.27	24.9	1.8	0.36	3.68	24.2
Aqua-ammonia	1.9	0.94	2.24	7.3	1.7	0.49	2.92	19.1	1.8	0.38	3.70	22.4	1.9	0.37	4.11	23.0
l.s.d. $P < 0.05$	0.17	0.147	0.292*	3.27*	0.19*	0.106	0.490*	3.20	0.16*	0.064	0.539*	2.75*	0.15*	0.063*	0.533*	2.37*
Level of N																
35 kg ha^{-1} N	1.6	0.87	2.04	10.9	1.5	0.47	2.32	23.6	1.6	0.42	3.10	25.7	1.7	0.41	3.67	24.1
50 kg ha^{-1} N	1.8	0.93	2.14	8.7	1.6	0.47	2.67	22.5	1.8	0.37	3.50	23.4	1.8	0.36	3.73	24.0
65 kg ha^{-1} N	1.9	0.97	2.30	7.7	1.7	0.49	2.95	20.3	1.9	0.36	3.88	22.9	1.9	0.37	4.20	22.2
l.s.d. $P < 0.05$	0.13	0.114*	0.253*	2.54	0.15	0.082*	0.435	2.48	0.12	0.049*	0.467	2.13	0.11	0.049*	0.462*	1.83*

*Denotes no significant difference.

5. ACKNOWLEDGEMENTS

These studies were undertaken with funds provided by the Tobacco Industry Trust Account. We also acknowledge help given by Biometry Branch for statistical analysis of the data and Agricultural Chemistry Branch for analysis of cured leaf constituents.

References

Caulley, J. T., and Ward, D. K. (1972), 'A comparative study of standard and high analysis fertilizer mixtures for tobacco'. *Queensland Journal of Agricultural and Animal Sciences* **29**, 17–20.

Elliot, J. M. (1970), 'Effect of rates of ammonium and nitrate nitrogen on bright tobacco in Ontario'. *Tobacco Science* **14**, 131–37.

Garner, W. W. (1951), *The Production of Tobacco.* McGraw-Hill (N.Y.), pp. 430–45.

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

McCants, C. B., and Woltz, W. G. (1963), 'Relationship between forms of fertilizer nitrogen and quality components of flue-cured tobacco'. *Proceedings 3rd International Tobacco Science Congress.* Salisbury, pp. 325–28.

McCants, C. B., and Woltz, W. G. (1967), 'Growth and mineral nutrition of tobacco'. *Advances in Agronomy* **19**, 211–65.

Olsen, S. R., Cole, C. V., Watanabe, F. S., and Dean, L. A. (1954), *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate.* U.S. Department of Agriculture Circular No. 939.

Parker, D. T., and Larson, W. E. (1962), 'Nitrification as affected by temperature and moisture content of mulched soils'. *Soil Science Society America Proceedings* **16**, 238–42.

Piper, C. S. (1950), *Soil and Plant Analysis.* University of Adelaide, Adelaide.

Ward, D. K. (1967), 'Studies on the nutrient status of some tobacco soils in far North Queensland'. *Queensland Journal of Agricultural and Animal Sciences* **24**, 253–60.

Ward, D. K., van Waveren, P. H. J., Thomson, L. D. J., and Warrell, L. A. (1973), 'Studies on inorganic nitrogen fertilizers for tobacco'. *Queensland Journal of Agricultural and Animal Sciences* **30**, 1–8.

(Received for publication 6 October 1980)

The authors are officers of Agriculture Branch, Queensland Department of Primary Industries, stationed at Mareeba, Q. 4880.