COMPARISON OF LIQUID AND GRANULAR NITROGEN FERTILIZER ON THE YIELD, QUALITY, AND VALUE OF FLUE-CURED TOBACCO[1]

TOBACCO SCIENCE

B. W. Maw, M. G. Stephenson, T. P. Gaines, and B. G. Mullinix[2]

Flue-cured tobacco (*Nicotiana tabacum* L. cv. McNair 944) was fertilized with liquid nitrogen (N) either in two applications or metered through a center-pivot irrigation system during the first nine weeks after transplanting. These treatments were compared with a control treatment of tobacco fertilized with conventional granular fertilizer applied in two bands near the plants. Total N for the control plots and treatments with split applications of N were applied at 34 kg N/ha. Whereas, the metered liquid fertilizer was applied at a total of 34, 48, or 68 kg N/ha. Tobacco grown using liquid N was comparable in both yield and quality to tobacco grown using granular fertilizer. Even though the results were inconsistent among years, overall, none of the treatment practices produced tobacco that was different from tobacco produced by any other treatment. All of the fertilization systems were comparable for the production of tobacco, implying that chemigation of N fertilizer is a viable management option for the production of flue-cured tobacco.

Additional key words: *Nicotiana tabacum* L., chemigation, metering fertilizer.

INTRODUCTION

Nitrogen (N) is usually applied to flue-cured tobacco (*Nicotiana tabacum* L.) in one or two applications of a granular fertilizer. The first application is made before, during, or within 10 days after transplanting, and the second application is made as a side-dressing 2-3 weeks after transplanting. The recommendation of N for the sandy soils of southern Georgia is 68 kg N/ha (13). Additional N may be required as a top-dressing if excess rain leaches it out of the root zone. The rate of additional N is based upon the depth-to-clay and the stage of growth (5).

The amount of N applied, the timing of application, and the uptake by tobacco have marked effects on growth, yield, and quality of cured leaves and smoke. Insufficient N produces small, thick, smooth, and pale leaves that often require harvesting before they have fully ripened (17). The cured leaves are pale, lacking in texture, low in alkaloids, high in sugars, and their smoke is flat and insipid. Excess N produces rough, large, thin leaves (17). Their ripening is delayed and curing them is difficult, often resulting in dark cured leaves, especially from the upper stalk positions. This tobacco is usually high in N and alkaloids, but low in sugars, and it produces smoke that is strong and pungent.

The timing of N uptake by plants is important. A deficiency of N early in the season reduces initial growth, and the adverse effects may persist throughout the growing season (10). Excessive N, or other nutrients, applied at or just after transplanting may burn young plants. Late-season absorption of excess N can delay leaf maturity, resulting in high nicotine and low sugar concentrations. Felipe & Long (5) tried leaching and flooding to alleviate the negative effects of excess N. Total concentration and accumulation of N by tobacco were reduced by leaching in their study (5), but leaf grades and chemical composition were not improved. It is one goal of N fertilization to ensure that soil reserves of N become exhausted by anthesis.

As early as 1939, experiments were conducted with flue-cured tobacco to determine the time and rate of nutrient absorption (9). Flue-cured tobacco made only 2.5% of its total growth during the first three weeks of a nine-week growth period. Eighty percent of the growth was made during the last 28 days of this period. The rate of growth increased from 2 kg/ha/day on the 21st day after transplanting to 21.4 kg/ha/day on the 35th day, and it reached a maximum of 48.4

[1] Supported by Hatch, State, and USDA funds allocated to The University of Georgia, College of Agriculture Experiment Stations. Additional funding was granted by the Georgia Agricultural Commodity Commission for tobacco and Philip Morris USA. The use of trade names in this publication does not imply endorsement by authors of products named, nor criticism of ones not mentioned.

[2] Associate Professor, Biological and Agricultural Engineering Department; Agronomist, USDA-ARS; Chemist, University of Georgia, Retired; and Agricultural Research Statistician, Statistical and Computer Services, University of Georgia, Tifton, Ga.

Contribution received Sept. 19, 1994. Tobacco Sci. 39: 77-82, 1995.

Table 1. Rates, time, and total application of N for granular and liquid formulations.

Treatment	N Fertilizer Applied at Weeks after Transplanting								
	2	3	4	5	6	7	8	9	Total
	kg N/ha								
1. Granular	34		34						68
2. Liquid	34		34						68
3. Liquid	2.9	2.9	2.9	3.5	3.5	3.5	7.4	7.4	34
4. Liquid	4.2	4.2	4.2	4.5	4.5	4.5	10.9	10.9	48
5. Liquid	5.7	5.7	5.7	6.8	6.8	6.8	14.7	14.7	68

kg/ha/day when the plants were 63 days old.

Parker et al. (11) reported that a preplant granular fertilizer application of 1680 kg/ha of 4-8-12 (67.2 kg N/ha) was superior to the same amount applied during the first and second cultivations after transplanting as split side dressings. When fertilizer was applied as a split application, 95% of maximum yield and grade were obtained with 84 kg N/ha. Increasing N fertilizer rates increased concentrations of N and alkaloids while it decreased reducing sugars in cured leaf lamina.

Technology has been developed to provide for better control of both irrigation water and N fertilizer. Irrigation can be applied by sprinklers, guns, flooding, or drip tubes. Chemicals, including N, may be applied to the crop in liquid form through sprinkler irrigation systems. Metering the liquid fertilizer is a possible means of controlling the amount of N when it is required by the crop.

For shade-grown cigar wrapper tobacco, Rathier et al. (14) metered $Ca(NO_3)_2$ as the sole source of N over eight equal installments through an overhead irrigation system. Various rates of N were used. Leaf quality was not affected compared with tobacco fertilized by the conventional method, but yields and crop indices increased linearly with increased amounts of N.

There are several advantages to metering liquid N for tobacco: (a) quantities of N may be adjusted to reflect the growth curve for tobacco, (b) quantities of N may be modified to meet requirements indicated by leaf tissue analyses, (c) compensation of N may be made for losses due to leaching, (d) quantities of N may be modified to reflect local climatic variations, and (e) liquid N is easily applied through a sprinkler irrigation system.

The purpose of this study was to compare the effects of granular and liquid fertilizer on the production of flue-cured tobacco.

MATERIALS AND METHODS

The study was conducted for three years with flue-cured tobacco (cv. McNair 944) that was transplanted in April (3rd week in 1987, 1st week in 1988, and 2nd week in 1989). Tobacco was grown in five quadrants under two single-tower, center-pivot irrigation systems (four quadrants under one center-pivot system, and one quadrant under a second system) located at the Bowen Farm, on the Coastal Plain Experiment Station. Each center-pivot system covered 0.72 ha (0.18 ha/quadrant) of an Ocilla loamy coarse sand (a loamy, siliceous, thermic, aquic, Arenic Paleudults) (12). With the exception of N applications, tobacco and soil moisture were managed according to practices recommended by the Georgia Cooperative Extension Service (2).

There were five treatments, allocated in the way of one treatment per quadrant. Treatments were: (a) two applications of granular fertilizer (68 kg N/ha total), (b) two applications of liquid fertilizer (68 kg N/ha total), (c) eight applications of liquid fertilizer (34 kg N/ha total), (d) eight applications of liquid fertilizer (48 kg N/ha total), and (e) eight applications of liquid fertilizer (68 kg N/ha total). The rates and time of applications of N are shown in **Table 1**. The recommended rate of N for tobacco grown on sandy soils in Georgia is 68 kg N/ha (13). For crop rotation, treatments were rotated among quadrants each year. All treatments had two randomly chosen sampling areas within each quadrant.

Nitrogen sources were 100% KNO_3 for the granular fertilizer, and 32% urea and NH_4NO_3 for the liquid fertilizer. KNO_3 was applied in two bands 5 cm from the row and 5 cm deep. Liquid N was applied through the center-pivot irrigation system in 2.5 mm of water per application. This was the minimum amount of

Table 2. Nitrogen treatment effects on leaf yield, grade index, and financial return of flue-cured tobacco grown in 1987, 1988, and 1989.

Year	Treatment number	Source of N (No. Applications)	Total N	Yield	Grade Index	Crop Value	
			----------- kg/ha	-----------		----- $/ha-----	-----$/cwt-----
1987							
	1	Granular	68	3060 a[a]	29 a	9811 a	145 ab
	2	Liquid(2)	68	2885 a	33 a	9628 a	151 a
	5	Liquid(8)	68	3100 a	30 a	9705 a	142 b
		Std. error of mean		92.6	2.1	344.6	2.8
1988							
	1	Granular	68	2472 bc	30 b	8007 bc	148 b
	2	Liquid(2)	68	2771 ab	32 b	8917 ab	147 b
	3	Liquid(8)	34	2260 c	43 a	7495 c	151 b
	4	Liquid(8)	48	2737 ab	42 a	9095 ab	151 b
	5	Liquid(8)	68	2867 a	41 a	10055 a	160 a
		Std. error of mean		113.2	2.3	381.5	1.5
1989							
	1	Granular	68	2251 a	47 bc	7737 a	156 a
	2	Liquid(2)	68	2337 a	44 c	8060 a	157 a
	3	Liquid(8)	34	2019 a	53 ab	6876 a	155 a
	4	Liquid(8)	48	2162 a	57 a	7495 a	158 a
		Std. error of mean		83.1	2.3	279.0	1.0

[a] Values followed by the same letter are not significantly different ($P=0.05$) within the same year according to Duncan's new multiple range test (16).

water that the center-pivots could deliver during a single pass over the plots, and this amount of water was considered insignificant compared with natural rainfall and normal irrigation. Weekly applications of liquid N were based on anticipated changes in the need for N during the growing season (Dr. Leslie Tolley-Henry, N. C. State Univ., Raleigh, Person. Comm.). Phosphate and potassium fertilizer were applied as a granular formulation (0-10-20) to all treatments as recommended (2).

NO_3-N was determined for soil in a tobacco row at a depth of 10-15 cm and for tobacco leaf lamina. Soil samples were also taken from an unplanted and unfertilized portion of land bordering the plots to provide background information on levels of NO_3-N. Soil samples were taken by mixing soil from cores taken at 15 randomly chosen sites within each treatment plot. Leaf tissue samples were taken from lamina (20-mm disks providing 20 grams) of the top three leaves of randomly selected plants within a treatment. Soil samples were collected weekly beginning the fourth week after transplanting. Tissue samples were collected weekly beginning the tenth week after transplanting, following the application of all liquid N. Following harvest, the leaves were cured, weighed, graded, and analyzed for chemical constituents.

Chemical analyses were made for the cured leaves of 1988 and 1989 experiments. Total N and reducing sugars were determined by methods described by Gaines & Mitchell (7). Total alkaloids were determined by the Cundiff-Markunas method as described by Gaines (6). Cured-leaf samples were composited by weight from each priming. They were dried overnight at 24°C, midribs removed, and the dried lamina ground in a Wiley mill to pass a 40 mesh sieve. Grade index and crop value were based on equivalent governmental grades according to Bowman et al. (1). In 1989, treatment 5 inadvertently received the wrong amount of N, and thus results from that treatment are not reported.

The experimental design was completely randomized. Data were analyzed using PROC GLM (15). Duncan's multiple range test was done according to Steel & Torrie (16).

RESULTS AND DISCUSSION

There were no significant differences in yield among treatments in 1987, where the total N rate was constant at 68 kg N/ha, whether by a granular or liquid formulation (**Table 2**). In 1988, yields increased with the rate of liquid N, but there was no significant difference in yield between the treatment with two applications and the treatment with eight applications of

Tobacco Science, 1995, 39-13, p. 77-82, ISSN. 0082-4523.pdf

Table 3. **Nitrogen treatment effects on the chemical analyses of flue-cured tobacco grown in 1988 and 1989.**

Year	Treatment number	Source of N (No. Applic.)	Total N Applied	Total Nitrogen (TN)	Reducing Sugars (RS)	Total Alkaloids (TA)	TN/TA	RS/TA
			kg/ha	%				
1988								
	1	Granular(2)	68	2.72 a[a]	11.3 c	4.59 a	0.59	2.5
	2	Liquid(2)	68	2.15 b	13.7 ab	3.91 b	0.54	3.5
	3	Liquid(8)	34	1.85 b	15.9 a	2.99 c	0.62	5.3
	4	Liquid(8)	48	2.05 b	15.0 a	3.45 bc	0.59	4.3
	5	Liquid(8)	68	2.14 b	12.4 bc	3.26 c	0.66	3.8
		Std. error of mean		0.08	0.6	0.22		
1989								
	1	Granular(2)	68	2.22 b	18.0 b	3.42 ab	0.65	5.3
	2	Liquid(2)	68	2.64 a	15.5 c	3.61 a	0.73	4.3
	3	Liquid(8)	34	1.72 c	23.1 a	2.71 c	0.63	8.5
	4	Liquid(8)	48	1.88 bc	19.2 b	3.20 bc	0.59	6.0
		Std. error of mean		0.14	0.7	0.13		

[a] Values followed by the same letter are not significantly different (P=0.05) within the same year according to Duncan's new multiple range test (16).

total liquid fertilizer at 68 kg N/ha. In 1988, the yield of the granular fertilizer treatment was relatively low compared with other treatments. In 1989, two applications of liquid fertilizer (68 kg N/ha total) gave the highest yield followed by the treatment with granular N fertilizer. Apparently, eight applications of liquid fertilizer at 34 kg N/ha total and 48 kg N/ha total were insufficient to attain maximum yields. However, with the exception of the treatment with eight applications of liquid fertilizer (34 kg N/ha total) in 1989, all yields were similar to or above the state average for the year concerned (3).

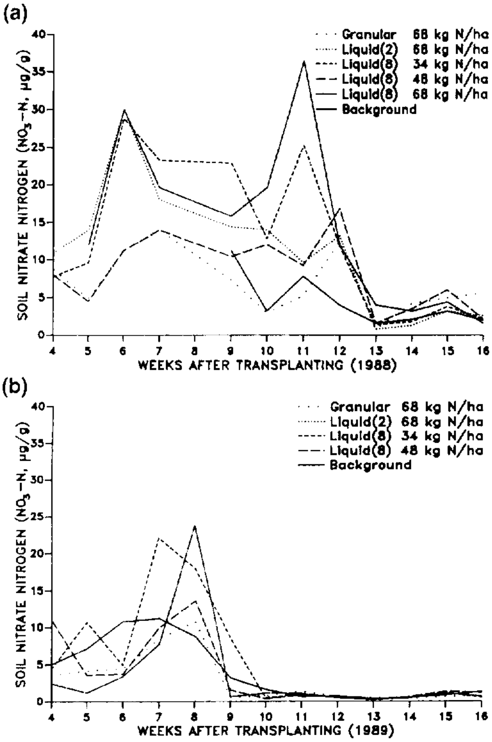
Grade indices were similar among treatments in 1987 (**Table 2**). In 1988, the grade indices for all liquid N treatments applied eight times were significantly higher than the grade indices for the liquid N applied twice or for the granular treatment. In 1989, the treatments receiving eight applications of liquid fertilizer at 34 or 48 kg N/ha had the highest grade indices. It appears that in 1989 eight applications of liquid fertilizer (68 kg N/ha total) was more N than was necessary for production of an optimum grade index.

The trends for crop value ($/ha) were similar to those for yield (**Table 2**), and crop value ($/cwt) followed a pattern similar to that for grade index. However, yields and grade indices appeared to be unrelated to each other. Eight applications of liquid fertilizer (68 kg N/ha total) gave the highest crop value measured both by $/ha and $/cwt in 1988.

The total leaf N was highest for the granular treatment in 1988 (**Table 3**), and it was relatively high for that treatment in 1989. In 1988, liquid fertilizer treatments gave N concentrations in leaves that varied in relation to the amount of total N applied, but they were not significantly different from each other. In 1989, the treatment having two applications of liquid fertilizer (68 kg N/ha total) had a significantly higher total N concentration than the other treatments. The lowest total N concentration in leaves occurred with the lowest N rate, eight applications of liquid fertilizer (34 kg N/ha total), for both years. However, most of the treatments were within the acceptable limits of 1.8-2.2% N in the leaves (8). The uptake of N by tobacco is influenced by cultural and climatic factors. Even though our study did not find a negative correlation between N accumulation and grade or yield, this problem has been reported (8).

As expected, the trend for reducing sugar concentrations was inverse to that of the total N for both years (**Table 3**). The highest reducing sugar concentration occurred with the lowest N fertilizer rate of eight applications of liquid fertilizer (34 kg N/ha total), and the lowest reducing sugar concentration was with a high N fertilizer rate (two applications of granular fertilizer [68 kg N/ha total] in 1988 and two applications of liquid fertilizer [68 kg N/ha total] in 1989). Reducing sugars ranged from 11.3 to 15.9% in 1988 and from 13.8 to 23.1% in 1989. With the exception of treatments with two applications of granular fertilizer (68 kg N/ha total) in 1988 and eight applications of

Figure 1. Influence of N treatments on the concentration of nitrate nitrogen (NO_3-N) in the soil, 1988 (a) and 1989 (b).



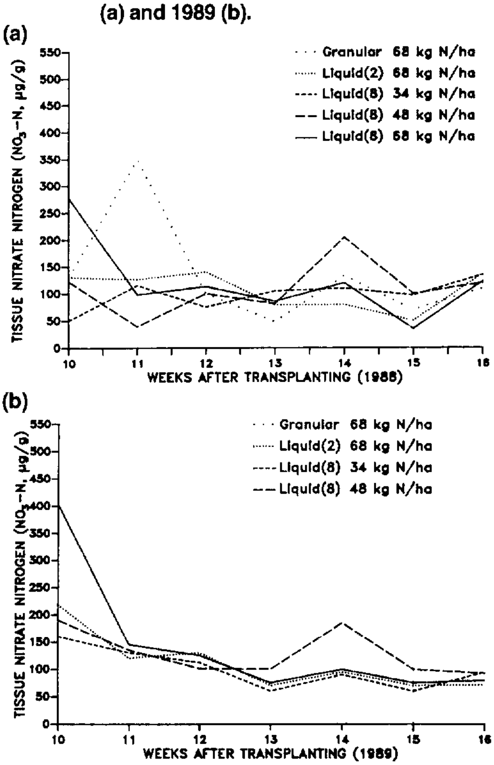
liquid fertilizer (48 kg N/ha total) in 1989, all levels of reducing sugars fell within acceptable limits of 15-22% (8).

The trends for total alkaloid concentrations were similar to total N concentrations during both years (**Table 3**). The granular fertilizer treatment had the highest concentration of total alkaloids in 1988, while the lowest rate of liquid N gave the lowest concentration of alkaloids during both years. In 1989, the treatment having two applications of liquid fertilizer (68 kg N/ha total) gave the highest alkaloid concentration. With the exception of treatments having eight applications of liquid fertilizer at 34 kg N/ha total and 68 kg N/ha total, alkaloid concentrations may be considered higher than the acceptable limits 2.14-3.37% (8).

The ratios of total N to total alkaloids (TN/TA) were similar in 1988 and 1989 among all treatments **(Table 3)**, and they were close to the appropriate value of 0.7 (8). The ratios of reducing sugars to total alkaloids (RS/TA) had a wider range than an appropriate value of 6.4 (8) both years. A positive correlation has been reported between grade index and the RS/TA ratio for flue-cured tobacco grown in Georgia (8).

All treatments reached minimum levels of 1-5 µg/g NO_3-N in the soil within 13 weeks after transplanting in 1988 (**Fig. 1a**) and within 10 weeks in 1989 (**Fig. 1b**). Liquid fertilizer treatments had higher soil NO_3-N levels than the granular treatment in 1988. In 1988, most of the liquid N treatments had an initial peak of approximately 30 µg/g, at six weeks after transplanting. The liquid N treatments had another peak 11-12 weeks after transplanting at 37, 16, and 25 µg/g for the 68, 48, and 34 kg N/ha rates, respectively. In 1989, treatments with liquid N had the highest soil NO_3-N levels peaking 7-8 weeks after transplanting (**Fig. 1b**). Background N levels were comparatively low and had a minimal effect upon soil NO_3-N levels in the treatments. A second peak of soil nitrate nitrogen occurred in 1988 during 11-12 weeks after transplanting, but no second peak occurred in 1989. This was attributed to the natural rainfall pattern of 1988, which had several intense events during a season of generally low rainfall. Conversely, 1989 had

Figure 2. Influence of N treatments on the concentration of nitrate nitrogen (NO_3-N) in the lamina of the top three leaves, 1988 (a) and 1989 (b).



more consistent rainfall during the growing season. Periods of high rainfall caused nitrogen to leach from the root zone, whereas periods of drought caused nitrogen to accumulate in the root zone until it was used by the tobacco plants.

NO_3-N from leaf tissue did not follow the same seasonal trends as NO_3-N in the soil. Levels of NO_3-N in leaf tissue from the granular treatment were higher than those in leaf tissue from the treatments having liquid fertilizer (**Fig. 2a & 2b**). Leaf tissue NO_3-N from the granular treatment peaked at 350 µg/g in week 11 during 1988, and a higher value was observed at an earlier date during 1989. Leaf tissue NO_3-N for all treatments generally leveled at concentrations of 40-75 µg/g about 12 weeks after transplanting.

We hypothesized that there would be no differences in the yield and quality of tobacco grown using either liquid or granular fertilizer. This hypothesis was substantiated by our data, which showed no consistent trends in yields, grade indices, crop value, or chemical characteristics when either liquid or granular N fertilizer was applied at the same total levels of N. Thus, we concluded that tobacco may be successfully grown with either liquid or granular fertilizer formulations. In addition, we think that metering liquid N fertilizer during the first nine weeks after transplanting is a viable option compared with applying the same amount of liquid fertilizer in two applications.

ACKNOWLEDGEMENTS

Appreciation is extended to Davis Martin, Steve Lahue, and Billy Wilson for their technical assistance in the field and to Ellen Hall for chemical analysis of soil and leaf tissue samples.

LITERATURE CITED

1. Bowman, D.T., A.G. Tart, E.A. Wernsman, and T.C. Corbin. Revised North Carolina grade index for flue-cured tobacco. **Tob. Sci.** 32:39-40. 1988.

2. Anonymous. Tobacco Production. Ga. Coop. Exten. Serv., Univ. Ga. Circular 638. 1987.

3. Anonymous. Georgia farm report. Ga. Agric. Statistics Serv. 90(2):5. 1990.

4. Anonymous. 1990 Tobacco Grower's Guide. Ga. Coop. Exten. Serv., Univ. Ga. Misc. Pub. 377. 1989.

5. Felipe, E.F., and R.C. Long. Management of flue cured tobacco grown with excess nitrogen. **Tob. Sci.** 32: 53-56. 1988.

6. Gaines, T.P. Chemical methods of tobacco plant analysis. Ga. Agric. Exp. Stn. Res. Rept. 97. 1971.

7. Gaines, T.P. and G.A. Mitchell. Chemical methods for soil and plant analysis. Univ. Ga. Coastal Plain Exp. Stn., Agronomy Handbook 1. 1979.

8. Gaines, T.P., A.S. Csinos, and M.G. Stephenson. Grade index and yield correlations with chemical quality characteristics of flue-cured tobacco. **Tob. Sci.** 27:101-105. 1983.

9. Grizzard, A.L., H.R. Davies, and L.R. Kangas. The time and rate of nutrient absorption by flue-cured tobacco. **Agron. J.** 34:327-339. 1942.

10. McCants, C.B., and W.G. Woltz. Growth and mineral nutrition of tobacco. **Adv. Agron.** 19: 211-265. 1967.

11. Parker, M.B., C.F. Douglas, S.H. Baker, M.G. Stephenson, T.P. Gaines, and J.D. Miles. Nitrogen, phosphorus and potassium experiments on flue-cured tobacco. Ga. Agric. Exp. Stn. Res. Bull. 415. 1993.

12. Perkins, H.F., V.R. Owen, and M.E. Walker. Soils of the Coastal Plain Experiment Station Bowen Farm. Ga. Agric. Exp. Stn. Res. Bull. 317. 1984.

13. Plank, C.O. Soil Test Handbook for Georgia. Univ. Ga. Coop. Exten. Serv. 1989.

14. Rathier, T.M., C.R. Frink, and G.S. Taylor. Metered applications of calcium nitrate in overhead irrigation: Effects on yield and quality of shade-grown cigar wrapper tobacco. **Tob. Sci.** 28:3-6. 1984.

15. SAS Institute, Inc. *SAS/STAT Users Guide* (Ver. 6, 4 edition, vol. 2). SAS Institute, Inc., Cary, N.C. 1989.

16. Steel R.G.D. and J.H. Torrie. *Principles and Procedures of Statistics.* McGraw-Hill, N.Y. 1960.

17. Weybrew, J.A., W.A. Wan Ismail, and R.C. Long. The cultural management of flue-cured tobacco quality. **Tob. Sci.** 27:56-61. 1983.