Nitrogen Fertilizer Source Selection and the Impact to Flue-Cured Tobacco Nutrient Assimilation & Yield

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Introduction

Historical nitrogen (N) recommendations for flue-cured tobacco suggest that 50% of the applied nutrient should be in the form of NO_3^- (Hawks, 1970). This recommendation was developed in order to promote cured leaf quality by reducing excessive assimilation of NH_4^+ and Cl^-. Likewise, this recommendation was likely developed at a time in North Carolina farming history where soil pH was relatively acidic due to low adoption rates of agricultural lime. Because of the low soil pH, it is plausible that nitrification rates were too slow to support the use of fertilizer sources dominated by NH_4^+. Peedin (1999) later suggested that N sources contain ≥30% NO_3-N and that in modern times, 100% urea-N programs were acceptable, specifically in seasons characterized with above average precipitation. However, urea-N was never formally recommended for flue-cured tobacco production due to the delayed N release observed during periods of moisture deficiencies. Comparisons of 100% NO_3^- (calcium nitrate), 50% NO_3^- + 50% NH_4^+ (ammonium nitrate), and 25% NO_3^- + 75% NH_4^+ (urea-ammonium nitrate (UAN)) by Parker (2009) reported no impact of N source to yield, quality, value, or leaf chemistry. Despite evidence that N form may not impact post-harvest measurements, a wider range of N species has not been evaluated in North Carolina for more than three decades. Furthermore, the impact of N species to the uptake and assimilation of other macro, secondary, and micronutrients has not been quantified – particularly in N programs comprised of liquid UAN.

Objectives

1.) Determine the effect of synthetic N source to flue-cured tobacco yield, quality, value, and cured leaf chemistry.

2.) Identify nutrient assimilation interactions with N species at various growth stages.

Materials and Methods

Growing Environments

Field experiments were initiated at the Lower Coastal Plain Research Station (LCPRS) located in Kinston, NC in 2016 and continued there in 2017; additional experiments were conducted in 2017 at the Oxford Tobacco Research Station (OTRS) located in Oxford, NC, and the Upper Coastal Plain Research Station (UCPRS) located near Rocky Mount, NC. Soils were classified as a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) at the LCPRS and UCPRS and an Appling sandy loam (fine, kaolinitic, thermic Typic Kanhapludults) at the OTRS.

Treatment Descriptions

Four N sources were evaluated in the current study: $CaNO_3$ (100% NO_3^-, 0% NH_4^+), NH_4NO_3 (50% NO_3^-, 50% NH_4^+), UAN (50% urea, 25% NO_3^-, 25% NH_4^+), and NH_4SO_4 (0% NO_3^-, 100% NH_4^+). Nitrogen rates varied by growing environment, with Kinston receiving 85 kg N ha^{-1}, Rocky Mount receiving 92 kg N ha^{-1}, and Oxford receiving 80 kg N ha^{-1} per recommendations from Vann and Inman (2016). Each experimental plot received 168 kg K_2O and 60 kg SO_4^{2-} ha^{-1} from K_2SO_4. Calcium application totals were increased by an additional 97 to 112 kg ha^{-1} when $CaNO_3$ was applied. Sulfate application was likewise increased by 91-105 kg ha^{-1} when NH_4SO_4 was the sole source of N.

Treatments were replicated four times in each environment and imposed in a randomized complete block design. Individual plots contained four treated rows, each 1.12 m × 15.24 m at Kinston and 1.22 m × 15.24 m at the Oxford and Rocky Mount. The center two plot rows were used for data collection and harvest. The cultivar NC196 (Gold Leaf Seed, Hartsville, SC) was planted to a density of 14,820 plants ha^{-1} in all growing environments.

Soil fumigation for disease and nematode suppression was utilized at Kinston (Telone C-17, 78.3% 1,3-dichloropropene + 16.5% chloropicrin, 98.2 L ha^{-1}) and Oxford (Pic Plus, 85.5% chloropicrin, 37.4 L ha^{-1}), but not at Rocky Mount. Prior to treatment application, soil cores from each field environment were collected from 0 to 15-cm and analyzed for pH, organic matter, P, K, Ca, and Mg content (Mehlich, 1984) and Cl^- content (California State Transportation Agency, 2014) by Waters Agricultural Laboratory in Warsaw, NC. Soil pH and organic matter were 5.9 and 0.60%, respectively, when averaged across all environments. Likewise, average residual P, K, Ca, Mg, and Cl concentrations were 143, 220, 560, 114, 51 kg ha^{-1}, respectively.

Nitrogen applications were split-applied side-dress 7-10 d and 4-5 wk after transplanting in a single furrow adjacent to each plot row, approximately 12-cm away from the row ridge to a depth of 12-cm. Applications of liquid UAN were delivered with a CO_2-pressurized backpack sprayer (Bellspray, Opelousas, LA) containing a single TG-3 full-cone nozzle (TeeJet Technologies, Glendale Heights, IL) at an operating pressure range of 100 to 125 kPa.

Data Collection

Leaf nutrient concentration was quantified at five intervals within each growing season: 3 wk after transplanting, at layby, 2 wk after layby, at flowering, and after curing. Plots were harvested four times and leaves were cured in forced-air bulk curing barns on each research station. After curing, yield, quality, value, price and chemistry (total alkaloids and reducing sugars) were quantified in a manner similar to Jernigan et al. (2018) and Vann et al. (2013).

Table 1. Applied macro and secondary nutrient totals from each nitrogen (N) fertilizer source [a].

N Source [b]	N	P_2O_5	K_2O [c]	Ca	Mg	S [c]
	kg ha^{-1}					
$CaNO_3$	80 – 92	0	0	98 – 112	0	0
NH_4NO_3	80 – 92	0	0	12 – 14	3	0
UAN	80 – 92	0	0	0	0	9 – 10
NH_4SO_4	80 – 92	0	0	0	0	72 – 105

[a] Lower Coastal Plain Research Station = 85 kg N ha^{-1}; Upper Coastal Plain Research Station = 92 kg N ha^{-1}; Oxford Tobacco Research Station = 80 kg N ha^{-1}.
[b] $CaNO_3$ = 15.5-0-0-19%Ca calcium nitrate (100% NO_3^-); NH_4NO_3 = 27-0-0-4%Ca-1%Mg calcium ammonium nitrate (50% NO_3^- + 50% NH_4^+); UAN = 28-0-0-3%S liquid urea-ammonium nitrate (25% NO_3^- + 75% NH_4^+); NH_4SO_4 = 21-0-0-24%S (100% NH_4^+).
[c] 168 kg K_2O and 54 kg SO_4^{2-} ha^{-1} applied to each treatment from 0-0-50-18%S.

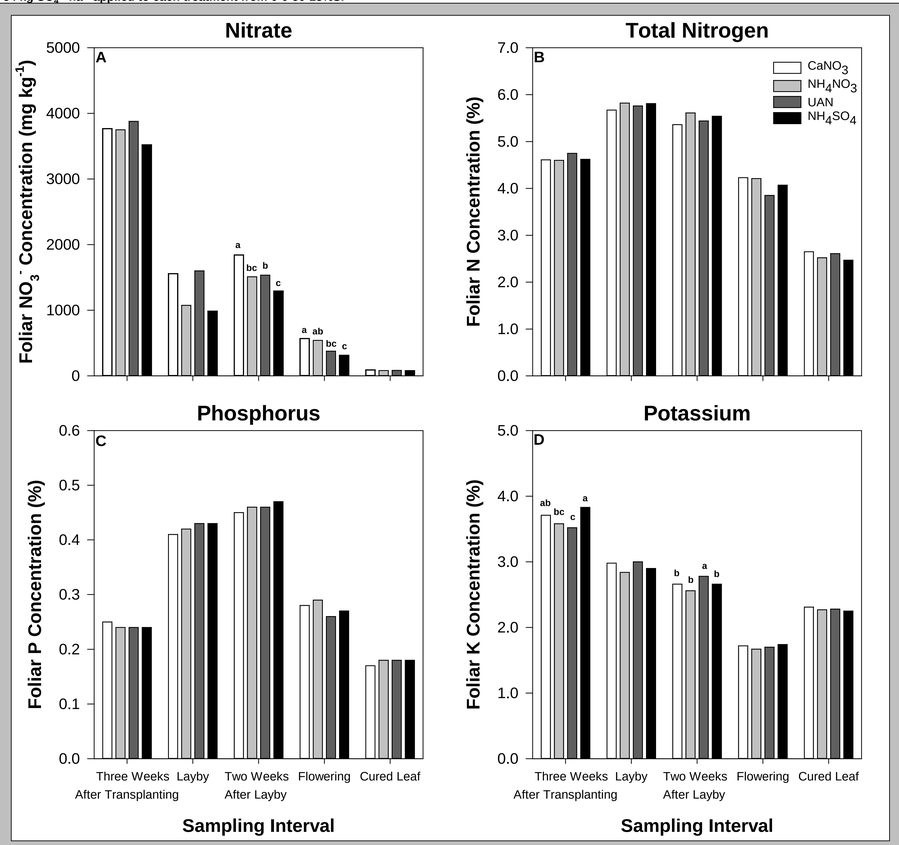

Figure 1. Foliar macronutrient concentration at various stages of tobacco growth. Treatment means followed by different letters within the same nutrient and sampling interval are significantly different at the α=0.10 level. Treatment means absent of letters are not significantly different.

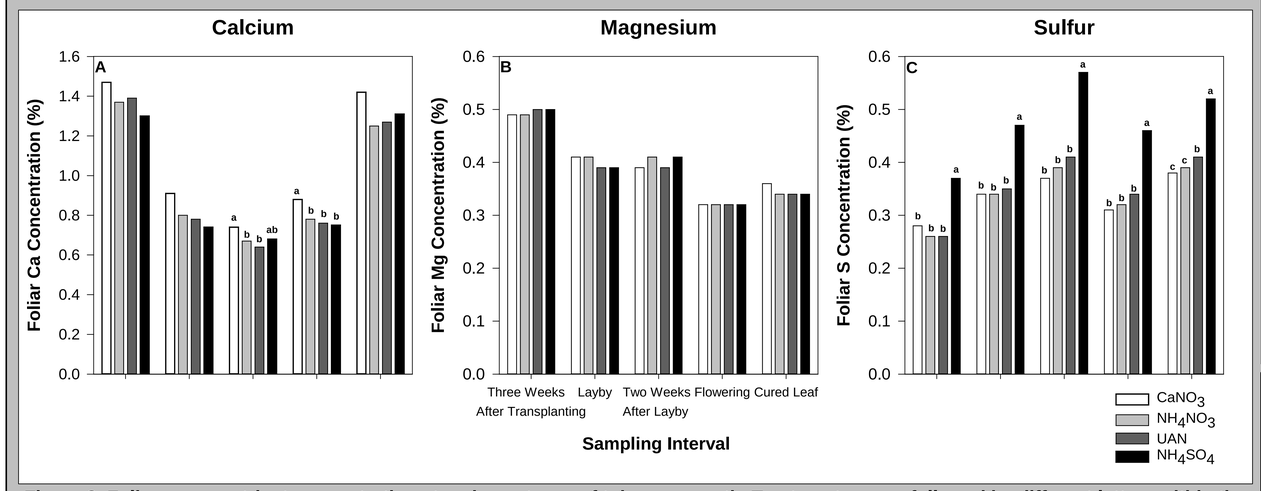

Figure 2. Foliar macronutrient concentration at various stages of tobacco growth. Treatment means followed by different letters within the same nutrient and sampling interval are significantly different at the α=0.10 level. Treatment means absent of letters are not significantly different.

Table 2. The influence of nitrogen (N) fertilizer source to cured leaf yield, quality, price kg^{-1}, value ha^{-1}, and total alkaloid and reducing sugar concentration[a,b].

N Source [c]	Yield	Quality [d]	Value	Price	Total Alkaloids	Reducing Sugars
	kg ha^{-1}		$US ha^{-1}	$ kg^{-1}	%	
$CaNO_3$	3,323 a	79 a	11,812 a	3.62 a	2.68 a	15.6 a
NH_4NO_3	3,227 a	76 a	10,722 a	3.40 a	2.79 a	15.8 a
UAN	3,178 a	74 a	10,418 a	3.28 a	2.69 a	16.5 a
NH_4SO_4	3,050 a	73 a	9,959 a	3.24 a	2.68 a	16.4 a

[a] Treatment means followed by the same letter within the same column are not significantly different at the α = 0.10 level.
[b] Lower Coastal Plain Research Station = 85 kg N ha^{-1}; Upper Coastal Plain Research Station = 92 kg N ha^{-1}; Oxford Tobacco Research Station = 80 kg N ha^{-1}.
[c] $CaNO_3$ = 15.5-0-0-19%Ca calcium nitrate (100% NO_3^-); NH_4NO_3 = 27-0-0-4%Ca-1%Mg calcium ammonium nitrate (50% NO_3^- + 50% NH_4^+); UAN = 28-0-0-3%S liquid urea-ammonium nitrate (25% NO_3^- + 75% NH_4^+); NH_4SO_4 = 21-0-0-24%S (100% NH_4^+).
[d] Quality assessed on a scale of 1-100, with 100 being of the highest quality.

Data Analyses

Analysis of variance was conducted using PROC MIXED in SAS version 9.4 (SAS Institute, Cary, NC) to test the effects of N source to leaf nutrient concentration, yield, quality, price kg^{-1}, and value ha^{-1}, and final chemistry. Within each analysis, N source was considered to be a fixed factor, while environment and replication were considered as random factors. Treatment means were reported using least means squares and were separated using Fisher's Protected LSD at $P \leq 0.10$. Figures were created using Sigma Plot version 14.0 (Systat Software, Inc., San Jose, CA).

Results and Discussion

Nutrient Assimilation

Macronutrients: Nitrate concentration was similar among treatments in early and late-season sampling intervals and was greatest in $CaNO_3$ treatments between layby and flowering (Fig. 1.A), Total N and P were not affected by N fertilizer source (Fig. 1.B&C). It is plausible that total N remained consistent despite differences in NO_3^- concentration because of NH_4^+ absorption that would have satisfied N demand. Likewise, supplemental P was not applied due to sufficient legacy P from previous crops. It is likely that N form had little impact on P assimilation in these high P soils, such as those found in the majority of North Carolina tobacco growing areas (Vann, 2013). Foliar K concentration was impacted by N source three weeks after transplanting and two weeks after layby, sampling events which were temporally closest to basal and layby N application. Within each interval, results are conflicting as UAN treatments had both the lowest and highest K concentrations (Fig. 1.D). Regardless of K concentration, these results are of little agronomic value as K concentration was well above the established sufficiency minimum of 1% (Campbell, 2013).

Secondary Nutrients: Foliar Ca concentrations were impacted by N source between layby and flowering. Within these intervals, Ca concentration was greatest in treatments comprised of $CaNO_3$, which would have provided an additional 95-112 kg Ca ha^{-1}. Interestingly, residual Ca was >500 kg ha^{-1} which is 10 times greater than what is required for maximized yield and quality; therefore, the slight increase in Ca uptake has little practical value. Furthermore, foliar Ca concentration was deficient two weeks after layby (<0.75%) and were borderline deficient at flowering, regardless of treatment. Cured leaf concentration was remarkably higher, thus indicating that deficient Ca concentrations are often transient and will recover post-topping. Sulfur concentration was always greatest in NH_4SO_4 treatments, which supplied 91-105 kg SO_4^{2-} ha^{-1}. In general, S assimilation from other N sources were similar to one another, except in cured leaf where UAN application increased S concentration by 0.2-0.3% relative to $CaNO_3$ and NH_4NO_3.

Micronutrients: Chloride assimilation was not influenced by N fertilizer source and foliar concentration did not exceed 0.85% across treatments and sampling intervals (data not shown). This observation suggests that across a wide range of growing environments and management systems, Cl^- assimilation is not excessive when it is not applied in fertilizer. Foliar boron (B) concentrations were identified as deficient in all treatments 3 wk after transplanting and at layby (data not shown). Applications of UAN reduced B concentration by ≈2 to 4 mg kg^{-1} relative to other N sources 2 wk after layby and at flowering, with only the latter below the established sufficiency minimum of 18 mg kg^{-1} (data not shown). Visual B deficiency symptoms were not observed. This observation is in agreement with Jernigan et al. (2018) who analytically quantified B deficiency in tissue samples in the absence of visual deficiency symptoms. Jernigan et al. (2018) ultimately concluded that the B sufficiency minimum for flue-cured tobacco might be too high and proposed that it might be lowered to 10 – 15 mg kg^{-1}.

Cured Leaf Yield, Quality, Price, Value, and Chemistry

Post-harvest measurements were not impacted by N fertilizer source (Table 2). Similar results were recently reported by Budimir et al. (2019). Likewise, our results are consistent with those reported in North Carolina by Parker (2009). Interestingly, foliar Ca and B concentrations were sometimes deficient in UAN treatments; however, this did not impact cured leaf properties.

Conclusions

Nitrogen fertilizer source appears to have little practical effect on the assimilation of plant essential macro, secondary, and micronutrients. While nutrients, such as Ca and B, were deficient at different stages of growth, visual symptoms of deficiency were not observed nor were yield, quality, price, value, or chemistry impacted. Based upon these results it appears that commercial farmers have great flexibility in regards to N source selection.

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