THE INFLUENCE OF NITROGEN RATE AND FOLIAR FERTILIZATION ON YIELD AND NITROSAMINE LEVELS IN BURLEY TOBACCO

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Abstract

Many burley tobacco (*Nicotiana tabacum* L.) producers believe that additions of nitrogen (N) rates greater than those recommended by university extension services will result in increased yield and income. In addition to high rates of N, many producers feel that additional foliar fertilizer will further increase yield and quality of burley tobacco and result in greater revenue. Concerns with excessive N additions include improper curing, elevated levels of tobacco specific nitrosamines (TSNA's), undesirable burning characteristics of the cured leaf, and unnecessary fertilizer costs. A non-irrigated field study was conducted at Lexington, KY and Springfield, TN in 2000 and 2001 to determine the effects of three N rates (224, 280, and 336 kg N ha^{-1}) and 3 foliar fertilizer products (Greenstim, Nutri-Leaf, and Penn-Ag) on yield, quality, revenue, and TSNA levels. Results from this study indicate that there was no significant yield or quality advantage in applying more than 224 kg N ha^{-1} in non-irrigated tobacco. Subsequently no increase in gross revenue resulted with higher rates of N additions. Yields were not significantly higher than the unsprayed check for any of the foliar fertilizer products at either location. However, at Springfield in 2001 all foliar products resulted in a higher grade than the unsprayed check, but no significant increase in revenue was observed. Gross revenue was significantly higher at Lexington in 2001 for the Nutri-leaf product as compared to the unsprayed check. This was not in agreement with the 2000 data, where no product performed better than the unsprayed check. Data from this experiment do not indicate that the use of a foliar product will result in consistently higher yields, quality, or gross revenue.

Introduction

Excessive use of N fertilizer is one of the most costly and detrimental additions to burley tobacco production. Not only is a producer spending unnecessary money on N that the crop is unable to utilize, but there are also concerns with improper curing (such as house burn and fat stems). elevated levels of TSNA's, and undesirable burning characteristics of the cured leaf. Recommended rates of N vary across the burley belt. Currently Tennessee recommends 168 – 224 kg N ha^{-1} preplant with an optional 28 – 56 kg N ha^{-1} side-dressed in wet seasons, whereas Kentucky recommends 168 – 336 kg N ha^{-1} depending on past cropping history without a side-dress option. Historically, N-rates exceeding 180 kg ha^{-1} have not proved profitable (Whitty, et al.. 1964). However many burley tobacco producers routinely apply 340-450 kg N ha^{-1} then supplement the crop with additional foliar applied fertilizer. Tobacco has the ability to absorb small amounts of nutrients through their leaves, however care must be taken in order to avoid high salt concentrations and thus burning the leaf (Pearce and Palmer, 1997). Typically the amounts of nutrients taken up from foliar applications are very small relative to total uptake. A foliar fertilizer application can be applied in conjunction with an insecticide treatment or a sucker control chemical, thus eliminating an extra trip through the field. The promoted benefits of foliar fertilizer include greening-up the crop. Growers believe a green, lush crop indicates a growing crop and increased yields. Many producers feel that the foliar fertilizer results in a higher grade and price for cured leaf. Finally, many producers feel that an application of foliar fertilizer at topping will promote leaf spread and lead to larger and heavier top leaves, which would increase weight and income. however this has not been shown (Wells and Strohmeier, 1981). All claims are reported to increase total income per hectare of tobacco. The objectives of this experiment were to determine the effects of soil applied N and foliar applied fertilizer on yield, quality, gross revenue per hectare, and chemical constituents in burley tobacco.

Materials and Methods

The experiment was conducted at Spindletop Farm in Lexington, KY and at the Highland Rim Experiment Station (HRES) in Springfield, TN. The experimental design was a randomized complete block with one split and three replications. The main plot was N-rate and consisted of 224, 280, and 336 kg N ha^{-1}. The subplots consisted of three foliar applied fertilizer products that are currently on the market plus a non-sprayed check. The foliar products are Greenstim (2-18-14), Nutri-Leaf (20-20-20), and Penn-Ag (26-0-0, 3-18-18, and 8-0-0-10 Ca). All foliar products also contain trace amounts of chelated micronutrients. The two tobacco fields had been in fescue sod for several years prior to being plowed for tobacco in 2000. The fields were fertilized according to the soil test for P and K and 224 kg N ha^{-1} was incorporated prior to transplanting. The remaining N, as ammonium nitrate, was side-dressed 4 weeks after transplanting to bring the remaining plots to their target N-rates. All other aspects of the crop production followed recommended practices. Foliar treatments were applied to four row plots 30.5 m long using a high clearance sprayer in 373 liters water ha^{-1}. The rates and cost of material per application for the foliar fertilizer is as follows: Greenstim 0.95 L ha^{-1} ($ 6.75 ha^{-1}); Nutri-Leaf 5.6 kg ha^{-1} ($4.50 ha^{-1}); and Penn-Ag 19 L ha^{-1} of 26-0-0 and 19 L ha^{-1} of 8-0-0-10 Ca alternated with 19 L ha^{-1} of 26-0-0 and 19 L ha^{-1} 3-18-18 ($ 23.50-26.90 ha^{-1}). All treatments were applied two weeks post transplant and every two weeks thereafter for a total of 6 applications. The experiment was not irrigated. The middle two rows of each plot were harvested for data collection and air-cured in a conventional burley barn. Tobacco was stripped into three farm grades then weighed and subsequent USDA grades were assigned to each plot. After grading. the qualitative USDA grade was converted to a numerical grade index ranging from 0 to 100. Each grade had a monetary value according to current government support prices for that year. Yield was determined on cured leaf at approximately 18-20 % moisture content. Gross income was calculated by multiplying the grade index for a particular treatment by the resulting yield for that treatment. At the Lexington location, samples from the highest and lowest N and foliar additions were taken and analyzed for nitrogenous compounds, including nicotine, nornicotine, total alkaloids, nitrate N, and individual TSNA's. The most common TSNA's are nitrosonornicotine (NNN). nitrosoanatabine (NAT), nitrosoanabasine (NAB), and 4-methyllnitrosoamino-1-(3-pyridyl)-1-butanone (NNK) (Wahlberg, et al., 1999). Data was analyzed using the GLM procedure in SAS and any significant differences among means were determined by LSD mean separation (SAS Institute, 2001). Statistical analyses were conducted on each location/year.

Results and Discussion

Yield data indicated that there were no significant effects of N-rate or foliar fertilizer application at either location or either crop year (Table 1). The 2001 crop year resulted in higher yields than 2000 at both locations and Lexington had higher yields than Springfield for both years. Yields for the soil incorporated N treatments ranged from 2958 with the 224 kg N ha^{-1} rate to 3017 kg ha^{-1} with the 336 kg N ha^{-1} rate when averaged across both locations and both crop years. From this it was concluded that no yield benefit was received by rates higher than 224 kg N ha^{-1} for either location. This is in agreement with Atkinson and associates (1971), where no benefit was seen with N-rates greater than 280 kg N ha^{-1}. No foliar product proved more beneficial than the unsprayed check from the perspective of a yield response.

Table 1. The effect of N-rate and Foliar Application on Yield for each location/year.

HRES 2000						Lex 2000			
	-------N-rate (kg N ha^{-1})-------					-------N-rate (kg N ha^{-1})-------			
Foliar	**224**	**280**	**336**	Mean		**224**	**280**	**336**	Mean
Check	2,337*	2.463	2,412	2,405		3,251	3.149	3.373	3,258
Greenstim	2,343	2.296	2,449	2,363		3,147	3,186	3,236	3,189
Nutri-leaf	2,337	2,419	2,509	2,421		3,050	3,220	3,354	3,208
Penn-Ag	2,351	2.526	2,574	2.483		3,211	3,196	3,233	3,214
Mean	2,342	2.426	2,485			3,165	3,188	3,299	
$LSD_{(0.05)}$ = NS						$LSD_{(0.05)}$ = NS			
HRES 2001						Lex 2001			
Check	2.908	2.666	2,526	2,699		3,428	3,343	3,480	3,417
Greenstim	3.059	2.846	2,853	2,919		3,406	3,653	3.622	3,560
Nutri-leaf	2,850	2.816	2,638	2,768		3,494	3,836	3.705	3.678
Penn-Ag	2,766	2.780	2,785	2,777		3,389	3,789	3,527	3,568
Mean	2.896	2,777	2,700			3,429	3.656	3.583	
$LSD_{(0.05)}$ = NS						$LSD_{(0.05)}$ = NS			

* Yield of cured leaf in kg ha^{-1}

For three of the four location/years there were no significant differences in quality as measured by grade index (Table 2.). At the HRES location in 2001, all foliar products had a significantly higher grade index than the unsprayed check. No other significant effects were observed for quality. The reason for the lower grade indices for the 2001 crop year was due to an extremely dry curing season after tobacco was housed, more so with the Lexington location than with the HRES location. If tobacco cures too fast (e.g. hot and dry conditions), it has a tendency to be variegated or even green in color. Green and/or variegated tobacco is very undesirable to leaf processors and resulted in lower grades. With this in mind, the leaf at the HRES location could have benefited from the late fertilizer salt addition, which in turn may have retained more moisture during the curing process and kept the leaf from curing as fast as the unsprayed check. This could have also been true for the Lexington location to a lesser extent, although no significant differences were observed.

Table 2. The effect of N-rate and Foliar Application on Quality for each location/year.

HRES 2000						Lex 2000			
	-------N-rate (kg N ha^{-1})-------					-------N-rate (kg N ha^{-1})-------			
Foliar	**224**	**280**	**336**	Mean		**224**	**280**	**336**	Mean
Check	75*	74	70	73		71	69	75	72
greenstim	72	70	71	71		71	72	68	70
Nutri-leaf	75	69	71	72		70	74	72	72
Penn-Ag	75	69	69	71		72	70	74	72
Mean	74	71	70			71	71	72	
$LSD_{(0.05)}$ = NS						$LSD_{(0.05)}$ = NS			
HRES 2001						Lex 2001			
Check	56	63	68	62a		44	52	46	47
greenstim	66	68	66	67b		44	52	52	49
Nutri-leaf	67	68	67	67b		60	53	51	55
Penn-Ag	68	67	70	68b		46	46	53	48
Mean	64	67	68			49	51	50	
$LSD_{(0.05)}$ = Foliar treatment= 3.2 N-rate = NS						$LSD_{(0.05)}$ = NS			

* Grade Index out of 100, with higher number being better.

An increase in N-rate did not result in a subsequent increase in gross return. For the Lexington location in 2001 there was a significant effect of foliar fertilization for the Nutri-Leaf product as compared to the unsprayed check (Table 3). Although the quality for the location/year was not significant, when multiplied by the yield for this particular location/year a significant increase in revenue resulted.

Since the TSNA's and their precursor's are ultimately a result of N compounds, it might be expected that these nitrogenous compounds are directly related to applied N (Chamberlain and Chortyk, 1992), however this is not necessarily the case (MacKown, et al., 1984; Fischer et al., 1989). Burton and associates (1994) determined a high and significant correlation between nitrite and individual TSNA's for burley tobacco, nut not applied N. From the Lexington data collected for nitrogenous compounds, no significant treatment differences were observed for N-rate or foliar fertilizer (Tables 4 and 5). However, in 2000, with the exception of nicotine, all other nitrogenous compounds were numerically higher in the plots receiving 336 kg N ha^{-1} as compared to the 224 kg N ha^{-1} rate, but not significantly higher. No other trend has been observed for nitrogenous compounds concerning N-rate or foliar fertilizer additions (Tables 4 and 5).

Table 3. The effect of N-rate and Foliar Application on Revenue for each location/year.

HRES 2000						Lex 2000			
	-------N-rate (kg N ha^{-1})-------					-------N-rate (kg N ha^{-1})-------			
Foliar	**224**	**280**	**336**	Mean		**224**	**280**	**336**	Mean
Check	12,024*	10,996	10,423	11,147		13,494	12,874	13.946	13.440
greenstim	12,716	11,866	11,779	12,120		12,683	13.197	13,296	13,059
Nutri-leaf	11,784	11,759	10,966	11,502		12,483	13.321	13,820	13.207
Penn-Ag	11,431	11,581	11,636	11,549		13,230	13.272	13,385	13,296
Mean	11.987	11,552	11,201			12.973	13.165	13,613	
$LSD_{(0.05)}$ = NS						$LSD_{(0.05)}$ = NS			
HRES 2001						Lex 2001			
Check	9,150	10,116	10,114	9,792		11,248	11,883	11,591	11.574a
greenstim	9,914	9.659	10,418	9,998		11,213	12,854	12,898	12,320a
Nutri-leaf	9,896	10,284	10,608	10,262		13,309	13.810	13,113	13.410b
Penn-Ag	9.834	10,195	10,810	10,279		11,315	13,242	12.461	12,338a
Mean	9,699	10,064	10,487			11,772	12,948	12,515	
$LSD_{(0.05)}$ = NS						$LSD_{(0.05)}$ = Foliar treatment = 991 N-rate = NS			

* Revenue in $ per hectare

Table 4. The Effect of N-rate on chemical constituents of cured leaf.

Chemical Constituent	Lexington 2000		Lexington 2001	
	Soil Incorporated N (kg ha^{-1})			
	224	**336**	**224**	**336**
Nicotine (mg g^{-1})	40.2	40.1	19.0	20.0
Nornicotine (μg g^{-1})	535	684	182	225
Total Alkaloids (%)	4.07	4.09	2.22	2.38
NO_3-N (μg g^{-1})	4879	5369	*	*
NNN (μg g^{-1})	8.85	11.38	1.33	1.41
NAT & NAB (μg g^{-1})	7.10	7.37	0.99	0.90
NNK (μg g^{-1})	0.90	0.95	0.11	0.06
TSNA (μg g^{-1})	16.8	19.7	2.43	2.37
$LSD_{(0.05)}$ = NS				

* NO^{3-} was not measured for 2001 data

Table 5. The Effect of Foliar Fertilization on chemical constituents of cured leaf.

Chemical Constituent	Lexington 2000		Lexington 2001	
	Foliar Fertilizer Treatment			
	Check	**Penn-Ag**	**Check**	**Penn-Ag**
Nicotine (mg g^{-1})	38.1	42.3	19.9	20.0
Nornicotine (µg g^{-1})	800	419	203	170
Total Alkaloids (%)	3.89	4.27	2.33	2.30
NO_3-N (µg g^{-1})	4557	5691	*	*
NNN (µg g^{-1})	12.2	8.1	1.40	1.20
NAT & NAB (µg g^{-1})	6.94	7.54	0.90	0.96
NNK (µg g^{-1})	0.87	0.97	0.09	0.07
TSNA (µg g^{-1})	20.0	16.6	2.40	2.22
$LSD_{(0.05)}$ = NS				

* NO^{3-} was not measured for 2001 data

Conclusions

Results from this study indicate that there is no significant yield advantage in applying more than 224 kg N ha^{-1} in non-irrigated tobacco production. No increase in grade was observed with increasing levels of soil applied N and subsequently income per acre was not significantly greater with higher rates of soil applied N. Applications of the Nutri-Leaf treatment resulted in numerically higher yields and grade indices, which resulted in a significantly higher gross income as compared to the un-sprayed check in 2001 at Lexington. This was not in agreement with 2000 data, where Nutri-Leaf did not perform any better than other foliar treatments. In Springfield for 2001, a significant increase in grade index did occur with all three foliar products as compared to the check. However, a significant increase in income did not result from the increased grade index at the Springfield location. No consistent results have been observed at either location to prove that one foliar product is better than another or the unsprayed check. Data from this experiment do not indicate that the use of foliar products result in consistently higher yields, quality, or income.

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