THE EFFECT OF SOLUBLE CALCIUM FERTILIZER AND OTHER AGRONOMIC FACTORS ON CURED LEAF YIELD, VALUE, AND NUTRIENT UPTAKE BY BURLEY TOBACCO

TOBACCO SCIENCE

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Finely ground limestone and soluble Ca materials often are applied by burley growers to maintain soil pH and to counter any detrimental effects of fertilizer-induced soil acidity, but the effects of these practices are not well known. A field experiment was conducted at Lexington, KY, over two years to determine the effect of soluble Ca fertilizer ($CaSO_4$) and other agronomic practices on cured leaf yield, value/ha, and nutrient concentration of burley tobacco (*Nicotiana tabacum* L. cv. KY 14). The experiment was conducted on a fertile soil (Maury silt loam, Typic Paleudalf) with pH of 6.6. Average cured leaf and stalk yield, total plant weight, leaf value/ha, and K concentration of cured leaf were increased with rate of Ca fertilization up to the 380 kg Ca/ha rate. However, significant irrigation x K x Ca and irrigation x N source interactions existed for most plant parameters, indicating that the effect of Ca rate was not the same for all irrigation:K fertilizer treatments and plant parameters were higher in plots treated with $NaNO_3$ than urea in the absence of irrigation. Overall, highest measured parameters occurred for plots treated with Ca (380 kg/ha), K and $NaNO_3$ fertilizer, and supplemental irrigation. Concentrations of K in cured leaf were increased by application of Ca, K, $NaNO_3$, and supplemental irrigation. Treatments had little if any effect on leaf N and P concentrations or leaf quality. These results can best be explained as a Viet's effect of Ca on K nutrition leading to increased plant K concentration, leaf and stalk yields, and leaf value/ha. However, this does not rule out the possibility of increased release of fixed K from soil clays in certain treatments, due to Ca additions.

Additional key words: irrigation, K fertilizer, N fertilizer, mineral constituents of tobacco.

INTRODUCTION

The soil pH recommended by the Kentucky Cooperative Extension Service for production of burley tobacco (*Nicotiana tabacum* L.) is 6.6 (1). Based on past research (8,11,12,19,20,24), tobacco growers most often apply agricultural limestone to acid soils to increase soil pH. However, more finely ground limestone and soluble Ca materials such as $CaSO_4$ are used by some to counter other detrimental effects of fertilizer-induced soil acidity as well as for maintenance of proper pH. The effects of adding the more soluble materials at high soil pH are not well known.

In an earlier report (21), dry weight of tobacco and concentrations of K, Ca, and Mg 40 days after transplanting were shown to increase with rate of Ca (gypsum) up to 380 kg Ca/ha. Generally, the response of tobacco to rate of Ca was greatest in the presence of supplemental irrigation, K fertilization, and use of a NO_3 source ($NaNO_3$) of N. The effects of the various agronomic treatments largely appeared to be a function of their effects on K nutrition.

The purpose of the current investigation was to determine the effects of soluble Ca and K fertilizer, supplemental irrigation, and source of N fertilizer on cured leaf yield, value, and nutrient uptake of burley tobacco. Rates of Ca were of primary interest but other treatment factors were studied, since they have been shown to interact with or enhance Ca accumulation by plants (5,7,25).

MATERIALS AND METHODS

Maury silt loam soil (Typic Paleudalf, fine, mixed, mesic) was used during 1989 and 1990 at Lexington, KY, to conduct the field experiment. The experimental areas had been in alfalfa (*Medicago sativa*) prior to plowing in 1989 and 1990, respectively. Initial surface soil chemical characteristics at different sites each year were: Mehlich III P, > 270 kg/ha at both sites; exchangeable K, 380 kg/ha at both sites; exchangeable Ca, 4816 and 4900 kg/ha; exchangeable Mg, 240 and 245 kg/ha; and soil pH 6.5 and 6.7, respectively.

A split plot experimental design was used.

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Table 1. Effect of irrigation, N source, and rate of K and Ca fertilizers on cured leaf yield and value of burley tobacco.

Treatment[a]	Leaf yield	Stalk yield	Total plant wt	Leaf price	Leaf value
	kg/ha			$/kg	$/ha
0 Calcium	3090	2740	5830	3.40	10512
190 Calcium	3145	2801	5946	3.42	10774
380 Calcium	3247	2999	6246	3.44	11174
760 Calcium	3127	2741	5868	3.40	10609
LSD 0.01	137	159	225	NS	496
- Potassium	3077	2713	5790	3.42	10505
+ Potassium	3228	2927	6155	3.42	11029
LSD 0.01	97	113	159	NS	351
- Irrigation	3084	2383	5467	3.44	10616
+ Irrigation	3220	3256	6476	3.40	10919
LSD 0.05	NS	227	428	0.03	270
$NaNO_3$	3222	2894	6116	3.42	10991
Urea	3082	2746	5828	3.42	10544
LSD 0.01	97	113	159	NS	351

[a]Rates of Ca as $CaSO_4$ were 0, 190, 380, and 760 kg Ca/ha; rates of K (K_2SO_4) were 0 and 280 kg K/ha; and $NaNO_3$ and urea were applied each at the rate of 336 kg N/ha.

Irrigation treatments (none and supplemental irrigation) were whole plots. Supplemental irrigation consisted of four applications each year (3 to 8 cm water/ha) and were made as necessary to approximate the normal rainfall of 6.1 cm/ha/wk during the growing season at this location. Sources of N ($NaNO_3$ or urea; 336 kg N/ha), K fertilizer (K2SO4; 0 and 280 kg K/ha), and rates of Ca as gypsum (0, 190, 380, 760, kg Ca/ha) were subplot treatments. Subplot treatments were arranged in factorial combination within whole plots. All fertilizer and lime materials were broadcast. All treatments were replicated three times. Molybdenum as $Na_2MoO_4 \cdot 2H_2O$ was added uniformly in the transplant water to all treatments at the rate of 0.2 kg Mo/ha. The tobacco (cv. KY 14) was cultured by methods conventional for burley tobacco production in Kentucky.

When mature, 60 plants from the two central rows of 4-row plots (each 15 m in length) were harvested and air-cured. After curing, the leaves were stripped and sorted into three grade groups and weighed for yield. Standard U.S. Government grades for each crop year (1989-90) were assigned to each leaf grade group of tobacco by an official government inspector. These grades were used to calculate price/kg and value/ha. Samples of cured leaf were taken from each plot and ground to pass a 1 mm screen in a Wiley mill for analytical determinations. Tissue samples were wet digested (nitric-perchloric acid) and then analyzed for K, Ca, and Mg by atomic absorption spectroscopy. Total N and P concentrations were determined by automated colorimetry following a micro-Kjeldahl digestion using the methods of Bradstreet (4) and Technicon Industrial Method 348R-7-31-5 adapted from Fiske and Subbarrow (6). Total plant uptake of nutrients was calculated by separately multiplying the percent nutrient concentration of cured leaf and cured stalks by their corresponding dry weights and then summing leaf and stalk contents of each nutrient.

Statistical analyses included analysis of variance following procedures of the SAS Institute (15). Data from each year was analyzed separately and then combined across years since year x treatment interactions were negligible. Fisher's protected least significant difference (LSD, $P \leq 0.01$, 0.05, or 0.10) was used in means comparisons.

RESULTS

Tobacco Yield and Leaf Value

Average cured leaf and stalk yields, total plant weight, and leaf value/ha increased with rate of Ca fertilization up to 380 kg Ca/ha (**Table 1**). Application of Ca at the 760 kg rate had no effect on yield, weight, and leaf value beyond

Table 2. Response of burley tobacco to irrigation x K x Ca fertilizer interaction effects.

Treatment[a]	Leaf yield	Stalk yield	Total plant wt	Leaf price	Leaf value
	kg/ha	kg/ha	kg/ha	$/kg	$/ha
-I-K 0 Ca	2892	2159	5051	3.42	9887
-I-K 190 Ca	3026	2311	5337	3.44	10406
-I-K 380 Ca	3022	2376	5397	3.48	10490
-I-K 760 Ca	3015	2035	5050	3.44	10367
-I+K 0 Ca	3175	2535	5710	3.46	10984
-I+K 190 Ca	3004	2464	5469	3.48	10438
-I+K 380 Ca	3315	2718	6033	3.46	11488
-I+K 760 Ca	3229	2472	5701	3.37	10866
+I-K 0 Ca	3070	3007	6077	3.35	10295
+I-K 190 Ca	3144	3214	6358	3.40	10665
+I-K 380 Ca	3328	3428	6756	3.44	10663
+I-K 760 Ca	3120	3176	6297	3.37	10537
+I+K 0 Ca	3223	3258	6481	3.40	10883
+I+K 190 Ca	3408	3214	6623	3.40	11663
+I+K 380 Ca	3325	3475	6801	3.42	11320
+I+K 760 Ca	3145	3278	6423	3.40	10665
LSD 0.01	156	181	256	0.11	566

[a]Rates of Ca as $CaSO_4$ were 0, 190, 380, and 760 kg Ca/ha and rates of K (K_2SO_4) were 0 and 280 kg K/ha.

the control, and leaf price was unaffected by Ca at any rate. Application of K fertilizer and use of $NaNO_3$ resulted in significant increases in yield of leaf and stalks, total plant weight, and leaf value/ha but had no effect on leaf price. Supplemental irrigation greatly increased total plant weight, primarily due to increasing stalk yield, and had smaller effects on other plant parameters (**Table 1**). Cured leaf yield was increased by irrigation at the 0.10 probability level. Supplemental irrigation resulted in a lower price/kg of cured leaf. The average increases due to treatment for most plant parameters were in the range of 5% to 7% but irrigation increased stalk and total plant weight 36% and 18%, respectively.

Significant irrigation x K x Ca fertilizer rate interactions existed for cured leaf and stalk yields, total plant weight, and for price and value of cured leaf (**Table 2**). Generally, values for each plant parameter increased with rate of Ca up to 380 kg Ca/ha but the effect of increased Ca was not the same for each combination of K rate and irrigation level. The most consistent leaf, stalk, total plant yield, and price response to Ca fertilization occurred in the presence of irrigation and the absence of added K. The highest leaf value response to Ca occurred in the absence of both irrigation and K fertilization. Overall, the highest leaf and stalk yields, total weight, and leaf value occurred in plots treated with the combination of 380 kg Ca/ha, supplemental irrigation, and 280 kg K/ha.

Significant irrigation x N source interactions occurred for leaf yield, total plant weight, leaf value, and the concentration of K in cured leaf (**Table 3**). In unirrigated plots, values for each

Table 3. Response of burley tobacco to irrigation x N source interaction effects.

Plant characteristics	- Irrigation + $NaNO_3$	- Irrigation + urea	+ Irrigation + $NaNO_3$	+ Irrigation + urea	LSD 0.05
Leaf yield, kg/ha	3196	2972	3248	3192	148
Stalk yield, kg/ha	2485	2283	3303	3210	NS
Total plant wt, kg/ha	5681	5255	6551	6402	318
Leaf price, $/kg	3.44	3.44	3.37	3.40	NS
Leaf value, $/ha	11011	10218	10969	10868	788
Leaf K, g/kg	31.9	28.8	35.3	34.7	3.0

Table 4. Irrigation, N source, and rate of K and Ca fertilizer effects on mineral constituents in cured leaf of burley tobacco.

Treatment[a]	N	P	Mineral Elements K	Ca	Mg
	g/kg				
0 Calcium	37.4	2.7	31.8	38.2	7.4
190 Calcium	37.8	2.7	32.2	38.4	7.4
380 Calcium	36.8	2.6	34.1	38.5	7.3
760 Calcium	37.5	2.7	32.8	38.9	7.4
LSD 0.05	NS	NS	2.1	NS	NS
- Potassium	37.9	2.8	28.1	39.1	7.8
+ Potassium	36.8	2.6	37.4	37.9	6.9
LSD 0.01	NS	0.1	2.0	0.8	0.3
- Irrigation	38.1	2.7	30.4	37.8	7.7
+ Irrigation	36.7	2.8	35.1	40.3	7.1
LSD 0.05	NS	NS	4.7	NS	NS
$NaNO_3$	37.1	2.7	33.7	38.2	7.2
Urea	37.6	2.7	31.8	38.8	7.6
LSD 0.05	NS	NS	1.5	0.6	0.3

[a]Rates of Ca as $CaSO_4$ were 0, 190, 380, and 760 kg Ca/ha; rates of K (K_2SO_4) were 0 and 280 kg K/ha; and $NaNO_3$ and urea were applied each at the rate of 336 kg N/ha.

parameter were greater for $NaNO_3$ than urea treatments. However, differences due to N source were not significant for irrigated plots. Irrigation x N source interactions for concentrations of N, P, Ca, and Mg of cured leaf were not significant but a trend existed for values,with exception for N and P, to be slightly higher in urea than $NaNO_3$ plots (data not shown).

Mineral Constituents of Burley Tobacco

Average concentration of K in cured leaf was highest with applications of 380 kg Ca/ha, K and $NaNO_3$ fertilizers, and by supplemental irrigation (**Table 4**). The concentrations of Ca and Mg were decreased by both K and $NaNO_3$ fertilization while concentrations of these nutrients were unaffected by irrigation and rates of Ca. Leaf concentrations of N and P were unaffected by all treatments, except P was lowered by additions of K.

Irrigation x K x Ca fertilizer interactions occurred for total plant uptake of N, P, K, Ca, and Mg (**Table 5**). Similar to plant yield parameters shown in **Table 2**, uptake of most nutrients increased with rate of Ca fertilization up to the 380 kg Ca/ha rate but the amount of increase due to added Ca was not the same for each K rate-irrigation level combination. The greatest response in K uptake to Ca fertilization occurred in treatments that were irrigated but unfertilized with K.

DISCUSSION

The above data reflecting treatment effects over the entire growing season of tobacco mirror, to a large extent, results reported for plant growth at 40 days after transplanting (21). Cured leaf and stalk yields, total plant weight, leaf value/ha, K concentration, and total plant uptake of N, P, K, Ca, and Mg all increased as Ca fertilizer rate increased up to the 380 kg Ca/ha rate. Average increases due to Ca ranged from 5% to 15% but varied with particular combinations of the other treatments. Generally, plant response to Ca was positive and greatest in the presence of added K fertilizer, the NO_3 source of N, and supplemental irrigation.

The effects of Ca and other treatments on plant parameters in this study are largely a reflection of their effect on K nutrition. Calcium is known to play a role in enhanced membrane integrity and stability and governs the flux of ions across membranes, both in and out of cells (10). Earlier, Viets (23) reported increased uptake of monovalent cations and Mg due to Ca application. The results for Ca in our study can most likely be explained by Ca preventing K efflux from root cells, since in burley culture soil pH is lowered 0.5 to 1 pH unit by fertilizer induced soil acidity (14,18,19). Such a mechanism suggests that greater Ca availability is partially negating any adverse

Table 5. Irrigation x K x Ca fertilizer interaction effects on total nutrient uptake by burley tobacco.

Treatment[a]	Total N	Total P	Total K	Total Ca	Total Mg
			kg/ha		
-I -K 0 Ca	159	12	114	122	26
-I -K 190 Ca	172	13	125	130	29
-I -K 380 Ca	177	13	130	131	29
-I -K 760 Ca	168	11	117	127	28
-I +K 0 Ca	176	13	167	132	26
-I +K 190 Ca	179	13	172	125	25
-I +K 380 Ca	187	14	185	142	29
-I +K 760 Ca	185	14	173	134	27
+I -K 0 Ca	185	15	151	142	29
+I -K 190 Ca	194	16	159	145	29
+I -K 380 Ca	192	17	192	152	29
+I -K 760 Ca	190	16	169	148	29
+I +K 0 Ca	190	16	205	142	27
+I +K 190 Ca	188	16	213	147	27
+I +K 380 Ca	204	16	223	146	27
+I +K 760 Ca	182	16	211	144	26
LSD 0.01	12	1	16	7	2

[a]Rates of Ca as $CaSO_4$ were 0, 190, 380, and 760 kg Ca/ha and rates of K (K_2SO_4) were 0 and 280 kg K/ha.

effects that higher concentrations of H, Mn, and Al in the tobacco rhizosphere environment might have on the uptake of K by plants.

Use of an ammonium source of N (urea) resulted in lower leaf and stalk yields, total plant weight, value/ha, and concentration and total plant uptake of K than did use of $NaNO_3$ (**Tables 1, 3, and 4**). In contrast, concentrations and uptake of N and P were generally unaffected by source of N, and concentrations of Ca and Mg were greater in urea treatments (**Table 4**). The increased Ca and Mg concentrations in urea plots are a reflection of dry matter dilution in $NaNO_3$ treatments, but also suggest that the higher tissue K concentrations in the $NaNO_3$ treatments resulted in decreased tissue Ca and Mg, particularly Mg. Lower plant yields, plant weight, and tissue K concentrations in urea treatments may also have been related to Ca additions. Added Ca has been shown to lessen the efflux of N from root cells, leading to decreased K content in plants (2,16,17,22). Differences in plant growth due to N sources can also be expected for other reasons. Marschner (10) noted that N source effects on plant growth could be caused by phytohormone balance, cation-anion balance, root-induced pH changes in the rhizosphere, energy metabolism, and cation uptake.

Supplemental irrigation resulted in large increases in stalk yields as compared to unirrigated plots (**Tables 1, 2, and 3**). Reasons for this effect are unknown but may be due to the time water was applied. Three of the four irrigations made each year occurred between 40 and 65 days after transplanting. This corresponds to the most rapid phase of plant growth for burley tobacco (3).

The data above can best be explained as a Viets effect of Ca on K nutrition. However, this does not rule out the possibility of increased release of K from soil clays such as mica, interstratified vermiculite, or hydroxyinterlayered vermiculite in certain treatments. Powell and Hutcheson (13) studied the effects of liming and K additions to other soils in Eastern Kentucky and suggested that Ca ions may prop open edges of clay mineral packets, thus preventing entrapment of K ions and releasing previously "trapped" (fixed) K. Lumbanraja (9) found that greater levels of soluble Ca caused greater rates of NH_4-K exchange on interlayer exchange sites at the edge of vermiculite soil clay in another Kentucky soil.

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