EFFECTS OF PHOSPHORUS RATES ON THE CHEMICAL COMPOSITION OF FLUE-CURED TOBACCO GROWN IN SOILS WITH VARYING PHOSPHORUS AVAILABILITY

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A test was conducted at ten farm locations in the flue-cured tobacco producing area of North Carolina for 3 consecutive years with the P_2O_5 treatments applied to the same plots. The six treatments were 0, 22.5, 45, 67.5, 90 or 180 kg P_2O_5 per hectare. The concentration of P, K, Ca and Mg was determined in the tissue of whole tobacco plants 5 and 7 weeks after transplanting. The concentration of reducing sugars (RS), total alkaloids (TA), N, P, K, Ca. Mg, RS/TA, and N/TA was determined in the cured leaf.

Responses to the six P_2O_5 rates were found mainly at the test location where the initial available soil P level was very low. The concentration of Ca in whole plants incresed as P_2O_5 increased up to 45 kg per ha. for each sampling. At a location very high in P availability, P in the whole plant 7 weeks after transplanting increased as P_2O_5 increased up to 180 kg per ha., whereas K at the 5th week after transplanting decreased with P_2O_5 rates higher than 45 kg per ha. Analyses of the cured leaf from all locations showed no effect of added P_2O_5.

Although location and year effects were significant (probably due to rainfall amount and distribution) for most of the characteristics studied, the P_2O_5 rates generally produced consistent results across the diverse years and locations since, in general, no significant Year x P, Location x P or Location x Year x P interactions were measured. It is concluded that as a result of previously high amounts of P_2O_5 application it is now possible to use smaller amounts and that 45 kg/ha of P_2O_5 are adequate to produce good marketable tobacco leaf.

INTRODUCTION

Historically, soils used for flue-cured tobacco production in North Carolina contained low levels of available P and therefore required large applications of fertilizer P to obtain maximum yields (19). It was estimated that applications of 168-224 kg/ha P_2O_5 per tobacco crop were common. These repeated large applications, coupled with low removal through cropping (1, 5, 6, 24) and essentially no losses from leaching have resulted in a considerable increase in soil test P levels in these soils (19). It has been suggested, therefore, that the rates of applied P_2O_5 can be reduced without hampering production and concomitantly reduce the cost of tobacco fertilization. However, the effects of such reduced applications on the chemical composition of the tobacco plant and ultimately on that of the cured leaves have not been well defined. The usefulness and suitability of tobacco in manufactured products is largely derived from the unique chemical properties of cured leaves (3, 19, 23, 25).

Most of the chemical constituents of tobacco, although genetically controlled, have been found to change with growth stage and a number of cultural practices, including P fertilization. Concentrations of P (and N and K) are usually high during early growth of the tobacco plant and decline as the plant approaches maturity (10, 14, 15, 18). Level of applied P directly influences concentrations of P (12, 28) and N and K (7) of the tobacco plant during early growth stages. However, at later growth stages differences in P concentration between high and low P application become smaller (12).

An increase in P application is generally associated with the following concentration changes in cured leaves: P increases (8, 17, 22), sugars increase (21, 26, 27), nitrogenous constituents decrease (5, 6,

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21, 26, 27) and N (2, 8) and K (2, 8, 17) decrease. However, high P rates have also been associated with reduced sugar (9) and increaed nicotine concentrations (2, 9). In other studies rate of applied P did not affect concentrations of sugars (5, 6) and nitrogenous constituents (12, 22). The conflicting results obtained in these studies may have been associated with the P levels of soils used, although the results obtained in one study (9) were not influenced by the initial level of soil P.

The objective of this study was to determine the effect of six P_2O_5 rates on the chemical composition of tobacco plants at two stages after transplanting and of cured leaves of flue-cured tobacco grown for three consecutive seasons on the same plots with different levels of soil test P.

MATERIALS AND METHODS

Ten on-farm tests were initiated throughout the flue-cured tobacco producing area of North Carolina in 1973 to evaluate the effect of P rate on the chemical composition of tobacco grown on soils with three general levels of P (**Table 1**) as well as a wide range of soil types, climates, and production conditions. At each location, treatments consisted of six P_2O_5 rates (0, 22.5, 45, 67.5, 90 or 180 kg/ha) replicated twice in a randomized complete block (RCB) design. The P treatments were repeated in the same plots in 1974 and 1975. Triple superphosphate, the source of P, was balanced for calcium with gypsum and incorporated into fertilizer mixtures, which supplied 45 kg/ha N and 144 kg/ha K on all plots. The mixtures were applied preplant in a single band located 7.5 to 12.5 cm below where the roots of transplants were placed. Supplemental N and K were sidedressed at each location to meet all test recommendations. Adjustments were made as needed for N and K losses due to leaching. Production practices varied from location to location but were within the range normally accepted as desirable for the production of flue-cured tobacco. The varieties, which differed from location to location and from year to year within locations were: *Nicotiana tabacum* L. cv. Coker 319, Coker 411, NC 2326, Speight G-28, and Speight G-140.

The aboveground portion of five plants after 5 weeks and four plants after 7 weeks were taken each year from two locations that represented a low (Yadkin) and a high (Vance) level of available soil P, respectively. These samples were oven-dried, ground to pass through a 40-mesh screen, and analyzed for percent P (Molybdovanadate), Ca, Mg (atomic absorption spectrophotometry) and K (flame photometry).

Composite samples of cured leaves from the whole plant for each of the ten locations were analyzed for total alkaloids (TA) and reducing sugars (RS) as described by Harvey *et al* (11), N (Kjeldahl) and P, K, Ca and Mg as given above.

Data from each individual experiment were initially evaluated with an analysis of variance for a RCB design (13). Use of experimental errors in Bartlett's test for homogeneity of variances indicated a subdivision of the 10 tests into three groups, as shown below and in **Table 1.**

1. Very low available soil P: one location with 7 ppm soil P.
2. Medium-high available soil P: three locations with an average of 70 ppm soil P.
3. Very high available soil P: six locations with an average of 155 ppm soil P.

Soil P was extracted with double acid (HCL-H_2SO_4) and determined by the Agronomic Division of the North Carolina Department of Agriculture.

RESULTS AND DISCUSSION

The average 3-year mineral composition (P, K, Ca, Mg) at 5 and 7 weeks after transplanting of whole flue-cured tobacco plants grown in soils very low and very high in available P is shown in **Table 2.** Although some year effects were observed, no significant Year x P interactions were present; therefore, only the average effects over years are presented. Rate of P_2O_5 application, on the low P soil, did not influence significantly concentrations of P, K, and Mg in 5 and 7 week old plants. However, Ca concentration in the plant at both sampling dates increased with P_2O_5 rate up to 45 kg/ha. Generally, all mineral constituents tended to increase, although not significantly, with P_2O_5 rate.

Table 1. Initial soil analysis results for 10 on-farm locations by counties in North Carolina 1973.

Location County	pH	O.M. %	P ppm	K meq/100 cc	Ca meq/100 cc	Mg meq/100 cc
Yadkin	5.8	0.7	7 VL*	0.17	2.05	0.62
Harnett	6.0	0.7	97 MH	0.09	1.10	0.22
Richmond	5.6	0.8	47 MH	0.08	1.70	-
Rockingham	5.4	0.8	73 MH	0.17	1.90	0.20
Edgecombe	5.8	0.7	130 VH	0.28	2.00	0.30
Lenoir	5.5	2.4	139 VH	0.39	2.35	0.50
Martin	5.3	0.8	187 VH	0.10	1.85	0.18
Nash	6.0	0.7	155 VH	0.11	1.65	0.21
Vance	5.9	0.5	163 VH	0.16	2.30	0.17
Warren	5.6	0.5	153 VH	0.14	1.50	0.18

**Letters refer to the grouping of locations on the basis of their available soil P. VL = Very low; MH = Medium high; VH = Very High.*

For plants grown on the very high P soil, K concentration in 5-week old plants decreased and P concentration in 7-week old plants increased as P_2O_5 rate increased. Concentrations of Ca and Mg were not affected consistently by P_2O_5 rate. Tobacco plants grown in the soil with very high available P level were higher in P, K, and lower in Ca and Mg concentrations than plants grown in soil with very low initial P. Soil test results (**Table 1**) show that the two soils differed, besides their difference in P, only in Mg concentration. The low P soil was more than three times higher in Mg than the high P soil. It is, therefore, suggested that the observed responses and/or tendencies can be attributed to the P_2O_5 rate except for Mg. Concentrations of all mineral elements decreased from 5 to 7 weeks after transplanting (**Table 2**) as reported by others (10, 14, 15, 18). In a study on nutrient accumulation in flue-cured tobacco, P absorption occurred at a fairly constant rate throughout the growing season and the total amount of P absorbed was the least of the major elements (24).

Table 2. Effect of P_2O_5 rate on P, K, Ca and Mg concentrations of whole flue-cured tobacco plants at 5 and 7 weeks after transplanting on soils with very low and very high levels of soil P (3-year average).

P_2O_5 Kg/ha	P % V. Low	P % V. High	K % V. Low	K % V. High	Ca % V. Low	Ca % V. High	Mg % V. Low	Mg % V. High
				5 Weeks				
0.0	25	.40	5.08	5.90	1.53	1.53	.50	.58
22.5	25	.40	5.16	6.00	1.63	1.52	.56	.53
45.0	26	.42	4.96	5.65	1.78	1.44	.64	.52
67.5	.25	.41	5.12	5.28	1.87	1.38	.65	.45
90.0	26	.46	5.16	5.34	1.83	1.49	.68	.49
180.0	29	.44	5.36	5.20	1.74	1.55	.66	.49
LSD .05	NS	NS	NS	.35	.23	NS	NS	NS
C.V.%	15	13	12	14	11	23	20	18
Year	NS	**	**	**	NS	NS	NS	**
Year x P	NS	NS	NS	NS	NS	NS	NS	NS
				7 Weeks				
0.0	.17	.26	4.12	4.14	1.29	1.35	.54	.40
22.5	.19	.28	4.05	4.04	1.28	1.30	.52	.36
45.0	.20	.29	4.23	4.22	1.52	1.35	.60	.39
67.5	.21	.31	4.42	4.30	1.49	1.31	.57	.41
90.0	.20	.30	4.24	3.89	1.52	1.24	.67	.41
180.0	.21	.36	4.32	3.96	1.40	1.42	.62	.39
LSD .05	NS	.03	NS	NS	.23	NS	NS	NS
C.V.%	17	8	20	10	14	21	23	15
Year	**	**	*	NS	NS	NS	NS	**
Year x P	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of P_2O_5 rate on P, K, Ca and Mg concentrations of cured tobacco leaves grown on soils with three different levels of available P (3-year average).

P_2O_5	P, %			K, %			Ca, %			Mg, %		
Kg/ha	V. Low	M. High	V. High	V. Low	M. High	V. High	V. Low	M. High	V. High	V. Low	M. High	V. High
0.0	.17	.23	.24	2.16	2.46	2.23	1.76	1.45	1.67	.62	.33	.43
22.5	.16	.22	.24	2.19	2.31	2.30	1.96	1.54	1.65	.62	.34	.43
45.0	.18	.21	.25	2.08	2.44	2.12	2.15	1.56	1.70	.68	.34	.44
67.5	.18	.24	.25	2.08	2.20	2.18	1.96	1.59	1.69	.64	.32	.42
90.0	.17	.24	.25	2.02	2.31	2.16	2.00	1.62	1.69	.68	.35	.46
180.0	.18	.24	.26	2.02	2.35	2.15	1.88	1.70	1.68	.69	.36	.46
LSD .05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	18	19	19	11	25	15	14	21	20	16	20	27
Loc		NS	**		NS	**		NS	NS		NS	NS
Loc x P		NS	NS		NS	NS		NS	NS		NS	NS
Loc x Year		**	**		**	**		**	**		**	**
Year	**	**	**	NS	**	**	NS	*	NS	*	NS	**
Year x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loc x Yr. X P		NS	NS		NS	NS		NS	NS		**	NS

The desirability of tobacco for cigarette manufacture is largely influenced by its chemical composition. The nitrogenous constituents are considered the most important in determining flavor and smoking quality of tobacco (3). Within broad limits, the balance of sugars and nitrogenous constituents in cured leaves is indicative of their usefulness in manufactured products (3, 23). Tobaccos with extremely low TA/N ratios are associated with inferior aroma and smoke flavor (3, 25). Pearce (23) established relative concentrations for N, P, K, Ca, and Mg as well as sugar and nicotine of cured leaf to meet quality requirements for flue-cured tobacco. The chemical composition of cured leaves was not affected significantly by the P_2O_5 rates in any of the three levels of initial soil P (**Tables 3 and 4**). Concentrations of N, P, Ca, and Mg were within the ranges reported by others (14, 15, 19, 20, 23, 24). However, P concentration in the cured leaves from the location with very low soil P was at the lower limits of the ranges given in the literature. At this location tobacco plants in most plots exhibited slight P deficiency symptoms during the second and third years. The values for K concentration generally were lower than the values cited in the literature, but K deficiency was not observed at any location. Generally, P and Mg in cured leaves increased and K decreased although not significantly as P_2O_5 rates increased. Concentration of P, K, and RS were higher and those of Ca, Mg, TA, and N were lower in cured leaves of tobacco grown on high available P soils compared to tobacco grown in soils very low in initial P as reported in the literature (8, 17, 21, 22, 26, 27 and 2, 5, 6, 8, 21, 26, 27 respectively).

Concentrations of most of the chemical constituents measured in whole tobacco plants or cured leaves generally depended on location or year of the test as indicated by the significant Loc and/or Year effect or Loc x Year interactions. These concentrations, however, were not affected by the P_2O_5 rates because usually no significant Loc x P, Year x P, or Loc x Year x P interactions were measured.

The results may have been affected to some extent by the varieties used since sometimes a different variety was grown from location to location or from one year to another at the same location. Some workers (3, 4, 14, 20) reported a varietal response in similar studies. However, the varieties used in these tests did not show significant differences for concentrations of sugars, nicotine and N in the Official Variety Tests (25) for the period 1973-1975.

A previous study (16) showed that 45 kg/ha of P_2O_5 were sufficient

Table 4. Effect of P_2O_5 rate on chemical composition of flue-cured tobacco leaves grown on soils with three different levels of available P (3-year average).

P_2O_5	Red. Sugars %			TA, %			N, %			Red. Sugar/TA RAtio			N/TA Ratio		
Kg/ha	V.Low	M.High	V.High	V.Low	M.High	V.High	V.Low	M.High	V.High	V.Low	M.High	V.High	V.Low	M.High	V.High
0.0	11.2	11.1	15.1	3.26	3.17	2.28	3.11	2.81	2.20	3.40	4.15	7.21	.90	.76	.96
22.5	10.7	11.8	14.9	3.39	3.10	2.27	3.00	2.81	2.25	3.08	4.96	6.98	.83	.77	.95
45.0	11.0	12.7	14.7	3.46	3.00	2.41	3.00	2.75	2.25	3.17	5.04	6.51	.78	.77	.98
67.5	11.8	12.6	14.8	3.51	3.18	2.35	3.17	2.75	2.27	3.30	5.29	6.87	.86	.74	.90
90.0	12.3	11.8	14.7	3.38	3.18	2.33	2.77	2.80	2.18	3.61	4.47	6.76	.77	.76	.92
180.0	11.8	12.7	14.7	3.41	3.14	2.40	2.87	2.74	2.26	3.43	5.01	6.67	.79	.74	.93
LSD .05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	13	17	20	10	11	22	10	10	9	30	34	22	10	9	15
Loc		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS
Loc X P		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS
Loc. x Yr.			**		**	**		**	**		**	**		**	**
Year	*			*			**			NS			*		
Year x P	NS			NS			NS			NS			NS		
Loc x Yr. x P		NS	NS		*	NS		NS	NS		NS	NS		NS	NS

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to produce good flue-cured tobacco plant growth and a high cured leaf yield and quality even for soils low in available P. The results of the study herein support these findings because the P_2O_5 rates used did not significantly change the chemical composition of cured tobacco and therefore the desirability of the cured leaf for manufactured products.

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