THE EFFECT OF GOVERNMENT POLICY ON FLUE-CURED TOBACCO YIELDS

By WILLIAM E. FOSTER and BRUCE A. BABCOCK[1]

Statistical analysis using rainfall and time trends accounts for county average flue-cured tobacco yields in North Carolina from 1940 to 1987. A change in the annual yield growth path occurred in 1965. The data are consistent with the hypothesis that the switch from acreage allotments to poundage quotas for flue-cured tobacco beginning in 1965 caused a decline in both yield levels and rates of annual yield increase. Both declines are fully consistent with changed relevant incentives facing growers and reseachers.

Key words: *Nicotiana tabacum,* L., technical change, tobacco policy, average annual yield increase

INTRODUCTION

Between 1940 and 1987 North Carolina average per-hectare yields of flue-cured tobacco *(Nicotiana tabacum* L.) grew at an average rate of 1.9% per year (**Figure 1**). Percentage changes in yields were markedly higher through 1964 (averaging a gain of 3.8% per year) relative to the rates of increase after 1964 (0.8%). By contrast, the yields of other North Carolina commodities, for example, that of corn (**Figure 1**), did not exhibit this distinct decline. One possible explanation for the decline in tobacco yield increase lies in the economic response to a change in government policy, specifically the change from acreage allotments to poundage controls in 1965. An alternative explanation for the decline is a natural slowdown in the development and adoption of new yield-increasing technical advances, which occurred independently of the program change. In addition, yield increases may have been further slowed by the introduction in 1964 of the Minimum Standards Program for new varieties of flue-cured tobacco (1). Identifying the underlying process causing changes in the rate at which annual yields grow is important for the accurate prediction both of future growth and of production levels given changes in Federal tobacco policy.

This paper uses statistical methods to test which explanation is consistent with historical county-level yield data. The data support the hypothesis that the switch from acreage allotments to poundage quotas for flue-cured tobacco beginning in 1965 caused a decline in both yield levels and the rate of increase of annual yields over time. Both declines are fully consistent with changed economic incentives facing growers and researchers.

[1]*Assistant professors in the Department of Economics and Business, North Carolina State University, P.O. Box 8110, Raleigh, N.C. 27695-8110.*

Contribution received May 2, 1989; Tob. Sci. 34: 4-8, 1990.

MATERIALS & METHODS

Economic Reasoning

The Federal tobacco program has undergone many changes since 1940, as concisely described in Grise and Griffin (4). This paper concentrates on one specific change. Prior to 1965, the Federal tobacco program controlled market supplies by restricting the amount of land planted to tobacco both nationally and within individual counties. Growers could alter the scale of their tobacco enterprises by buying, leasing, and selling acreage allotments. Prior to 1962, the acreage allotments were attached to particular farms, making the transfer of allotments equivalent to the transfer of property. In 1965, the program adopted the present system of direct supply control (through poundage quotas) that restricts the amount of marketings both nationally and by producers within a county. Since the program change, growers have been able to alter the scale of their enterprises by buying leasing, or selling pounds of quota, in addition to acreage. After 1985, quotas have been attached to particular farms.

Restricting the total amount of land available for production would increase the per-unit cost of land relative to the per-unit cost of other inputs. A higher price for tobacco land would give growers the incentive to increase production by using land more intensively by applying greater amounts of non-land inputs per hectare, thus increasing yields. Growers could increase yields through either the adoption of new technologies or the greater application of existing inputs, such as fertilizer, labor, pesticides, and machinery. Moving from restrictions on total land use to restrictions on the total amount of tobacco that can be sold would reduce the price of land relative to non-land inputs. The altered incentives facing growers would induce greater use of land and less of non-land resources. Furthermore, tobacco researchers and plant breeders would respond to the decreased demand for yield-increasing technical advances and would give relatively greater attention to leaf quality and disease resistance (1).

An alternative explanation for the decline in the growth rates of annual yields is that the potential gains from the continued adoption of previous major innovations were exhausted, and that no new major advances came on line. Traditionally, one represents increases in annual per-hectare yield, in response to the introduction of a technical advance, as following an S-shaped adoption curve (2, 3, 6). Diffusion of the advance across producers (and thus the increase in yields) first begins slowly, then proceeds rapidly, and finally slows as the advance reaches all potential adopters. At any point in time, minor technical innovations may shift the diffusion curve upward, but without continued major advances, one expects to observe declining growth rates in aggregate yields as diffusion slows. The exhaustion of previous innovations in tobacco production and a slowdown in the rate of discovery of new innovations would lead to a decline in the rate

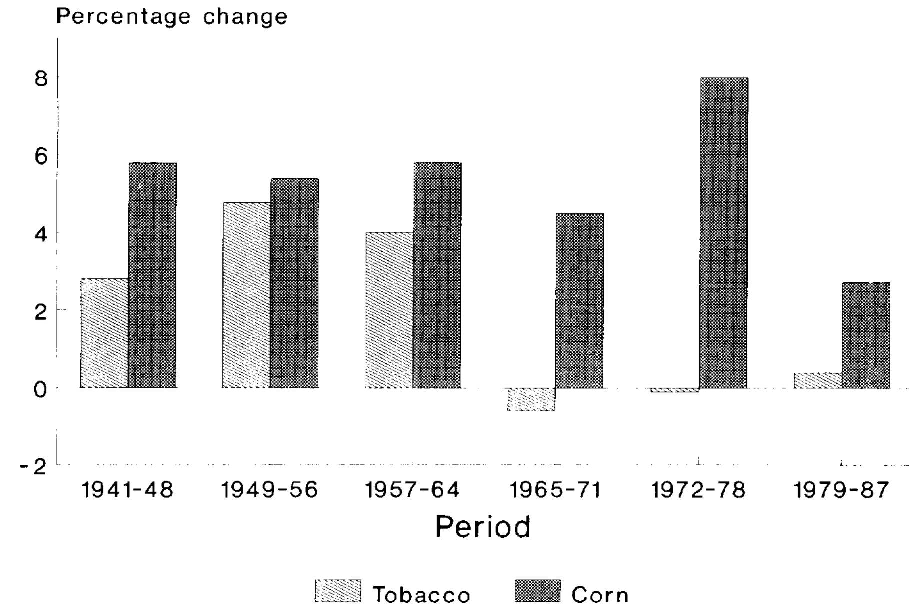

Figure 1. Average annual yield changes for corn and tobacco in North Carolina, 1940-1987.

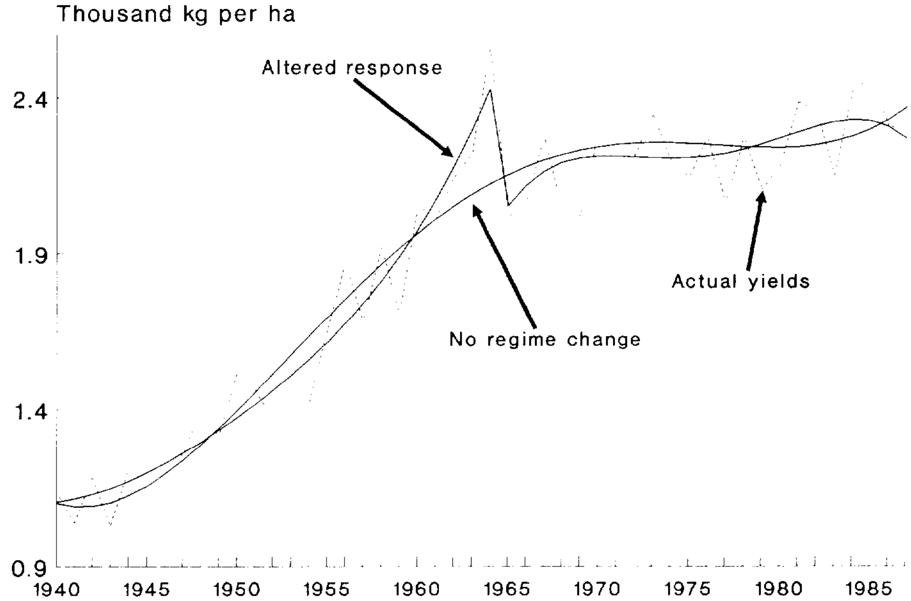

Figure 2. Actual and expected per-hectare flue-cured tobacco yields, 10-county average, for restricted and unrestricted fourth degree polynomial trend models.

of increase in yields.

If growers (and others) did respond to the change in the tobacco program, one would expect to see a discrete change in the path of yields beginning in 1965. This discrete change would comprise two components and two corresponding testable hypotheses. First, less incentive to generate and adopt yield-increasing innovations would lead to a kinked flattening in the upward path of expected yields over time. Second, growers would substitute land for non-land inputs, and this would lead to an observed drop in the level of tobacco yields in 1965 (accounting for random effects, such as weather). If growers did not respond to the change in the tobacco program, then expected rates of annual yield increase would follow a smooth time path.

Methodology

We first present a general model of yield change, then turn to a discussion of the data used to test the competing hypotheses. A time index, t, represents the influence of innovation and adoption on the increase in yields, and appropriate restrictions on estimated coefficients associated with time serve to represent various hypotheses regarding technical change. A sufficiently flexible function of time, G(t), allows for the possibility of a stable regime of technical change with varying rates of yield increase throughout the period of estimation. The statistical test for a non-stable regime of technical change, implying an economic response to the altered tobacco policy, against the null hypothesis of a stable regime, is a test of whether the estimated coefficients defining G(t) are equal before and after the implementation of poundage quotas.

Consider the following algebraic representation of county-level flue-cured tobacco yields,

$$Y_{tc} = \alpha_c + \beta \bullet W_{tc} + G(t) + u_{tc} \quad [1]$$

where Y_{tc} represents a given county's average yield in time t; α_c a county-specific shifter, invariant of time; W_{tc} county-specific weather variables; G(t) technical change as a function of time; and u_{tc} a county-specific, mean-zero error term accounting for unmodeled effects. This model becomes a time series of cross sections if more than one county is included. Initially, for flexibility take G(t) to be a fourth degree polynomial in time (t = 1 at 1940): $G(t) = a \bullet t + b \bullet t^2 + c \bullet t^3 + d \bullet t^4$. Under the null hypothesis of no structural shift in utilized tobacco technology in 1965, all of the estimated coefficients associted with

Tobacco Science, 1990, 34-2, p. 4-8, ISSN. 0082-4523.pdf

Table 1. Regression estimates of competing time-trend models explaining flue-cured tobacco yields (kg/ha) from 1940 to 1987.

	Restricted Model No Regime Change	Unrestricted Model Regime Change	Final Model Regime Change
Variable[a]			
T	-32.5 (19.3)[b]	-.961 (44.2)	.824 (7.61)
T^2	7.64* (1.58)	3.64 (6.72)	2.00* (.284)
T^3	-.250* (.048)	-.169 (.383)	0.
T^4	.002* (.0005)	.004 (.007)	0.
D	0.	-36242. (18685.)	805.3* (89.3)
D•T	0.	4141.0* (2095.5)	7.93 (7.87)
$D{\bullet}T^2$	0.	-174.1* (87.2)	-2.00* (.284)
$D{\bullet}T^3$	0.	3.26* (1.63)	0.
$D{\bullet}T^4$	0.	-.025 (.013)	0.
County-specific constants			
Wake	963.2* (133.3)	909.9* (133.7)	913.0* (117.4)
Guilford	897.1* (130.5)	866.8* (129.0)	876.5* (107.9)
Granville	806.2* (149.3)	697.0* (152.0)	729.5* (136.1)
Stokes	847.4* (132.3)	780.3* (139.5)	770.2* (119.9)
Johnston	1205.9* (133.2)	1165.5* (135.5)	1191.8* (118.3)
Pitt	845.6* (119.8)	761.6* (126.4)	773.1* (109.1)
Lenoir	919.6 (145.2)	923.9* (153.0)	905.8* (135.9)
Halifax	1179.2* (134.5)	1132.2* (137.2)	1138.0* (119.3)
Robeson	960.7* (120.9)	951.2* (116.3)	958.9 (97.0)
Cumberland	1033.3* (135.0)	1080.8* (146.4)	1039.3* (121.2)
Log-likelihood values	-2885.7	-2870.3	-2871.3

[a]Variable definitions: T - annual time index , 1940 = 1; D = dummmy variable, D = 0 if T ≤ 25, D = 1 if T > 25.

[b]Estimated standard errors are in parentheses.

*Significantly different from zero at the 5 percent confidence level.

G(t) would remain constant over the sample period.

We chose county-level data as the most appropriate available. State-level data limits the number of observations and the ability to acount for variations in growing conditions across regions, such as weather and soil types. Data generated on experimental plots are inappropriate for testing changes in growers' decisions because of the likely divergence of researchers' and growers' production objectives. County-level average yields and rainfall data were obtained for 10 counties representing the three different growing belts in North Carolina. The yield data were obtained from the North Carolina Department of Agriculture (7). The counties of Granville, Guilford, Stokes, and Wake represent the Old (and Middle) Belt; Halifax, Johnston, Lenoir, and Pitt represent the Eastern Belt; and Cumberland and Robeson represent the Border Belt.

The inclusion of relevant weather variables in the regression increases the efficiency with which one estimates the technology parameters of the yield equation. The present analysis uses county-specific monthly rainfall levels in May, June, and July. The yield equation allows a non-linear response to monthly rainfall. A quadratic function of monthly rainfall permits yields to respond negatively to increases in rainfall over some range. Data were obtained from North Carolina's Hydrologic Information Storage and Retrieval System for the weather stations in Oxford (2 SW), Greensboro (WSO AP), Dalton, Raleigh (NCSU), Enfield, Smithfield, Kinston (5 SE), Greenville, Fayetteville, and Lumberton (6 NW).

One yield equation of the form given by expression [1] exists for each of the 10 counties. We restrict the parameters associated with technical change to be the same for all counties. A separate intercept for each county, α_c, incorporates county-specific differences in average yields. To account for possible contemporaneous correlations between the error terms u_{tc}, parameter estimation requires the use of seemingly unrelated regression (SUR) (5, pp. 466-80). To test a hypothesis regarding a restriction on the parameters of G(t) requires two regressions: one imposing the null hypothesis of a set of restrictions, the other not imposing the restrictions. A χ^2 statistic, which equals twice the difference between the log-likelihood values from the SURs of the unrestricted and restricted models, provides a test of the null hypothesis (5, p. 216). The number of degrees of freedom of the χ^2 test equals the number of restrictions under the null hypothesis.

RESULTS

Allowing the coefficients of G(t) and the intercept term to change in 1965 provides a test of whether there is a discernable shift in the technology regime (5, pp. 800-06). We accomplish this by defining a dummy variable, D_t, which equals zero prior to 1965 and unity for years 1965 to 1987. The function G(t) is given by

$$G(t) = K{\bullet}D_t + (a + a'{\bullet}D_t){\bullet}t + (b + b'{\bullet}D_t){\bullet}t^2 + (c + c'{\bullet}D_t){\bullet}t^3 + (d + d'{\bullet}D_t){\bullet}t^4. \quad [2]$$

The parameter K represents a common shift in the intercept for each county equation. Under the null hypothesis of no change in technological regime—i.e., the observed slowdown in annual

Tobacco Science, 1990, 34-2, p. 4-8, ISSN. 0082-4523.pdf

Table 2. Regression estimates of the effects of monthly rainfall on flue-cured tobacco yields (kg/ha) from 1940 to 1987.

Rainfall Variable[a]	M	M^2	JN	JN^2	JY	JY^2
County:						
Wake	16.0	-.920	22.7	-1.18*	4.94	-.122
	(12.6)[b]	(.536)	(12.1)	(.519)	(6.98)	(.228)
Guilford	-15.3	.684	3.63	-.347	25.0*	-.759*
	(13.8)	(.667)	(13.9)	(.625)	(8.55)	(.252)
Granville	-11.8	.212	26.3*	-1.02*	12.1	-.283
	(18.0)	(.886)	(11.7)	(.502)	(7.31)	(.172)
Stokes	-16.8	.610	13.2	-.579	34.3*	-1.22*
	(15.7)	(.617)	(9.29)	(.348)	(12.9)	(.496)
Johnston	.871	-.127	-4.41	.013	14.7*	-.438*
	(11.6)	(.469)	(11.1)	(.400)	(6.75)	(.188)
Pitt	25.0*	-.994	23.2*	-1.09*	27.3*	-.687*
	(11.9)	(.513)	(8.98)	(.325)	(8.42)	(.246)
Lenoir	28.2*	-1.31*	6.22	-.221	26.2*	-.598*
	(14.4)	(.649)	(6.25)	(.162)	(8.89)	(.220)
Halifax	2.56	-.487	31.6*	-1.59*	-5.25	.104
	(13.3)	(.628)	(15.3)	(.689)	(10.6)	(.387)
Robeson	31.9*	-1.78*	23.7*	-.918*	4.83	-.088
	(9.59)	(.423)	(7.39)	(.240)	(7.42)	(.207)
Cumberland	.874	.081	13.0	-.833	4.23	-.217
	(12.4)	(.592)	(11.5)	(.451)	(8.56)	(.249)

[a]Variable definitions: M - May rainfall in cm; JN - June rainfall in cm; JL - July rainfall in cm.

[b]Estimated standard errors are in parentheses.

*Significantly different from zero at the 5 percent confidence level.

yield increases is consistent with a stable technology regime—all the coefficients associated with the dummy variable in expression [2] (K, a ', b ', c ', and d ') equal zero. This is the *restricted* model. The parameter estimates of G(t) and the county-specific intercepts and associated statistics from this regression are given in the first column of **Table 1.** The alternative hypothesis that allows for a technical regime change in 1965 yields the parameter estimates of G(t) in column two of **Table 1.** This is the *unrestricted* model. The parameter estimates relating monthly rainfall to yields are not reported for these two models.

Average predicted yields over the sample from the two regressions are found by replacing the rainfall variables by their means in each county and averaging the county-level predictions. The two series of predicted yields as well as actual yields for the ten-county averages are shown in **Figure 2.** The log-likelihood values for the regressions are given at the bottom of each column in **Table 1.** The calculated χ^2 test statistic for testing the null hypothesis of no regime change is 30.8 which is well beyond the 0.01 critical value of 15.09 with five degrees of freedom. Therefore, we reject the null hypothesis of no producer response to the change in the tobacco program.

One may more accurately characterize the nature of the structural change by testing various restrictions on the path of annual yield increases after 1964. There are three more specific hypotheses regarding the change in yield trends: 1) that growers continued using the same 1964 technology base and resource levels, with only the adoption rate of new technologies changing, that is, there was no immediate effect on per-hectare input use; 2) growers immediately altered their per-hectare use of inputs, but the development and incorporation of yield-increasing innovations did not change; and 3) that growers immediately altered their production practices, specifically substituting land for non-land inputs, and that the adoption of yield-increasing innovations was slowed.

If the first hypothesis is correct, then the post-1964 trend curve would pass through the expected 1964 yield level (where t = 25). This hypothesis can be tested by restricting the parameters associated with the dummy variables in equation [2] in the following manner:

$$K + a'\bullet 25 + b'\bullet 25^2 + c'\bullet 25^3 + d'\bullet 25^4 = 0 .$$

This hypothesis implies no restrictions regarding the rate of annual yield increase after 1964. The calculated χ^2 statistic for testing this structure is 14.1, which is well beyond the 0.01 critical value of 6.64 with one degree of freedom. The rejection of this hypothesis regarding technical change is evidence that yield levels fell due to the program change.

If the second hypothesis is correct, then the post-1964 trend curve would be identical to the preceding trend curve except for an intercept shift. This hypothesis can be tested by restricting the parameters associated with dummy variables in equation [2] in the following manner:

$$a' = b' = c' = d' = 0 .$$

This hypothesis implies no restrictions regarding the level of expected yields in 1965. The calculated χ^2 statistic for testing this structure is 10.2, which is beyond the 0.05 critical level of 9.49 with four degrees of freedom. The rejection of both of these first

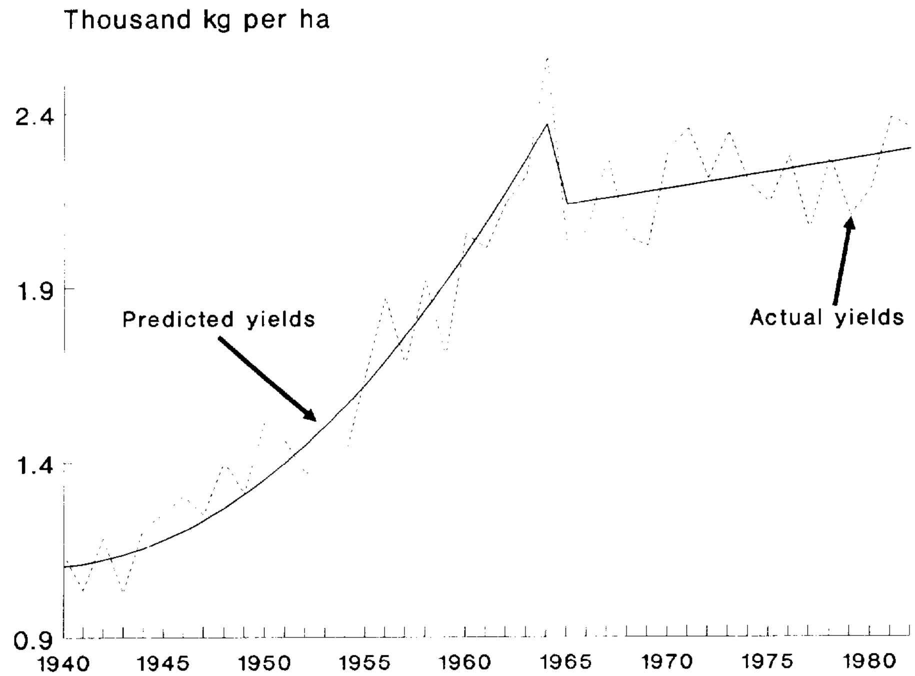

Figure 3. Actual and expected per-hectare flue-cured tobacco yields, 10-county average, for quadratic-linear trend model.

two hypotheses is evidence supporting the third, that both annual yield levels and rates of increase declined after the implementation of poundage controls in 1965.

Although a fourth-degree polynomial provides flexibility in describing historical yield trends, it may be an inappropriate model to predict the future time path of yield increases based on the data after 1964. A polynomial of a high degree may overfit the data in the sense that it offers no statistically significant improvement over a polynomial of lower degree in describing historical trends. Purely random effects in a small sample may cause the estimated trend line to be quite different than that which would be estimated from a larger sample. The danger of overfitting the data is, that if the trend is actually a function of time of a lower-degree, then out-of-sample predictions of yields based on a higher-degree polynomial may be highly inaccurate. For example, from inspection of **Figure 2**, it is unlikely that there is a long-term downward trend in yields beginning in 1984 as is implied by the unrestricted (regime-change) model. It is likely that the apparent downturn during this period is due to random effects.

A more parsimonious model is that expected yields grew quadratically until 1964 and linearly afterwards. The restrictions imposed by this hypothesis are ($c = c' = d = d' = 0$), and ($b + b' = 0$). The parameter estimates associated with the time trend variables and the county-specific constant terms from the regression imposing these five restrictions are presented in column three of **Table 1.** In this case, one *cannot* reject this hypothesis against the alternative hypothesis of the unrestricted fourth degree polynomial model. The calculated χ^2 statistic associated with this restricted model is 2.72, which is well below the 0.10 critical value of 9.24 with five degrees of freedom. The parameter estimates relating rainfall to county yield levels from this final model are presented in **Table 2. Figure 3** presents actual and expected yields for this final model of technical regime change. The change in the growth path of annual yields from quadratic to linear beginning in 1965 is consistent with decreased economic incentives to discover and adopt yield-increasing technologies.

DISCUSSION

The statistical evidence supports the hypothesis that the change to poundage quotas in 1965 altered the adoption of yield-increasing technical advances, and in particular that the rate of yield increase slowed due to the change. Prior to the program change expected yields grew at an increasing rate; after the change, yields grew linearly over time. Furthermore, the evidence also implies that in the first year of its introduction the poundage quota program decreased yield levels.

There are two related influences explaining the decline in rates of increase in annual yields after 1965: that growers had less incentive to adopt yield-increasing technologies after 1964, and that fewer yield-increasing innovations were available from plant breeding and other research activities. The second influence is also consistent with the adoption in 1964 of the Minimum Standards Program (MSP) for new varieties of flue-cured tobacco (1). The MSP, however, does not explain the immediate decline in 1965 in rates of annual yield increase, because of inherent time lags in the adoption of innovations. The MSP could have contributed to the decline in the rate of yield increases, but the results here demonstrating a sudden decline in yields in 1965 indicate that producers altered their production methods immediately in response to altered incentives. Future research will seek to determine the effect of the MSP and changes in Federal policy on the production of new variety characteristics.

This analysis has two broad implications. First, analyses that seek to anticipate future yield increases should also anticipate the policy environment in which those increases will take place. Second, there appears to be a large potential for an increase in yields if and when such increases become profitable.

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Tobacco Science, 1990, 34-2, p. 4-8, ISSN. 0082-4523.pdf