Tobacco

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LABOR REQUIREMENTS IN CONVENTIONAL PRODUCTION OF FLUE-CURED TOBACCO: THEIR RELATIONSHIP TO PLANTS, SUCKERS, HARVESTED LEAVES AND POUNDS PER ACRE

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ABSTRACT

The purpose of this study was to determine functional coefficients which relate per-acre labor costs of producing flue-cured tobacco to certain production variables. Closely-supervised controlled experiments on farms in 1963 through 1965 were employed to develop the data.

Multiple regression analysis was used to determine the relationships between plants, leaves, pounds and suckers and labor. Best estimates of labor requirements generally were obtained using plants, leaves or suckers as explanatory variables as opposed to using pounds. Relationships were found to be linear, and the slope coefficients were uniform among years, locations and stalk positions.

Procedures are outlined in the publication for using the coefficients to estimate actual labor costs for alternative combinations of cultural practices.

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PREFACE

Many people have contributed time and ideas to this study. The authors wish to thank G. L. Jones, W. G. Woltz, W. E. Splinter and W. H. Johnson for their help in organizing this study and determining cultural practices to be used. K. R. Keller deserves special thanks for his encouragement throughout the study, and J. S. Chappell provided many helpful ideas regarding the study and this publication. Financial aid was provided in part by a grant from the R. J. Reynolds Tobacco Company.

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INTRODUCTION

The flue-cured tobacco price support-supply control program has fostered numerous research studies. Since 1960, several of these studies have been conducted with the aim of determining optimum farm production strategies--given alternative policy programs. For example, Hartman and Tolley (1961) studied the effects of acreage controls on costs and techniques of production. Hunt _et al_. (1964) evaluated the effects of different levels of production practices on yield, market price and costs of production. Seagraves and Manning (1967) determined how tobacco allotment values are affected by the certainty attached to continuation of a price-support program.

In each of these studies, extensive use was made of input-output coefficients which were extracted from "typical" budgets, _i.e._, budgets assuming typical levels of production practices and yields. Such budgets were prepared by Greene (1936), Pierce and Williams (1952), Coutu and Mangum (1960) and the North Carolina Agricultural Extension Service (1965). Continual use of coefficients from these budgets tended to focus attention on their limitations. First, it generally was conceded

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that more extensive and precise field measurements were needed for several cost items, particularly labor costs. It was not so obvious, however, that certain types of input-output relationships were implicit in each coefficient relationship.

The study by Hunt et al. (1964) was instrumental in focusing attention on this latter limitation. Hunt's total cost equation was a synthetic one, based largely on the modal budget prepared by Coutu and Mangum (1960). Consequently, most of the cost coefficients were assumed (explicitly or implicitly) to be linear and have zero intercept values.

Bradford and Nelson (1969) were concerned with field measurements of labor costs corresponding to varying levels of plants, leaves and pounds. They quantified labor requirements and other operating costs for diverse levels of production practice combinations and analyzed the variation in labor costs attributable to locations, years and production practices. Their analyses showed that most unit labor costs did not vary with increased levels (intensity) of production practices. In contrast, most total (per acre) labor costs were found to vary directly as production practice intensity was increased. However, the nature of significant per-acre cost-production variable relationships was not analyzed. That is, continuous coefficients relating costs per acre to particular production variables were not estimated.

The primary objectives of this report are: (1) to report the procedures used in a study to determine functional coefficients which relate per-acre labor costs to certain production variables and (2) to report results of tests of certain hypotheses about the nature of functional relationships (between per-acre labor costs and production variables) existing in conventional flue-cured tobacco production. A secondary objective is to develop adaptations of existing experimental design and statistical analysis techniques for use in cost of production studies. More specifically, the use of covariance estimation models as a method of meeting the primary objectives is described in some detail. This is done because this method is considered different in several respects from the methods used in traditional cost of production studies.

Procedures

It is possible to use cost-per-pound or other unit cost measurements, like those quantified by Bradford and Nelson (1969), to estimate costs per acre for different yield levels or production practice intensities. However, a statement that priming costs are \$.0223 per pound implies that: (1) priming cost is a linear function of pounds; (2) the intercept coefficient is zero; (3) the same linear relationship applies to all locations and years, and (4) this same coefficient applies to all stalk positions. The analytical procedures employed in this study were designed to derive estimates of the functional relationships existing between individual labor operations and particular production variables.

Thus, in meeting the primary objectives, the above statements were reformulated as a series of null hypotheses which were tested for each labor operation commonly included in a flue-cured tobacco budget. One series of hypotheses was developed which described the true explanatory variable(s) for priming labor, e.g.; (1) priming labor = f(harvested leaves), (2) priming labor = f(pounds), or (3) priming labor = f(pounds and harvested leaves). For each of these "explanatory variable hypotheses" there was a corresponding "linearity hypothesis," e.g.; the relationship between priming labor and pounds is linear. Closely related to each "linearity hypothesis" there was an "intercept hypothesis," e.g.; the intercept value for the priming labor-pounds relationship is zero. Finally, the possibility of having different types of relationships depending upon the year, location and stalk position of the leaves was considered. Coefficients could depend upon the year and/or location. For example, with priming labor, the following "uniformity hypothesis" was tested: coefficients for the priming labor-pounds relationship do not vary significantly among years and locations. Similarly, the following "stalk position hypothesis" was tested: the coefficient for the priming labor-pounds relationship does not vary significantly among stalk positions of the harvested leaves.

Source of Data

To obtain labor time measurements corresponding to relatively diverse levels of production practices, it was necessary either to simulate actual field conditions or to survey a number of flue-cured tobacco farms. Farm survey data were regarded as insufficient, primarily because few farmers can afford to keep accurate records with a detailed breakdown on costs of labor operations. The data available from the few farmers who do keep such records represent a very narrow range of production practices. Because of such limitations, it was decided to use closely supervised controlled experiments at farmer-cooperator locations as the primary source of labor-time and yield data.

Experiments were conducted in 1963 through 1965 at four farm locations in North Carolina--three locations per year. In each experiment there were three basic treatments, each consisting of combinations of predetermined amounts of fertilizer, sucker control materials, plants and topping heights per acre. There were 112, 151 and 190 thousand (predetermined) leaves per acre for Treatments 1, 2 and 3, respectively. Predetermined fertilizer and sucker control amounts per acre were changed in intensity from treatment to treatment in approximately the same proportion as were leaves. Other practices, including the variety, were held constant for all treatments within each experiment. All tobacco was conventionally grown, harvested, cured and prepared for market.[1]

Each treatment of each experiment consisted of approximately 2 acres: this is the minimum acreage which normally accommodates the capacity of a conventional flue-cured tobacco curing barn. There were 2 plots of each treatment of approximately 1 acre each; plots were arranged in randomized complete block designs. Plots of this size were considered to be sufficiently large to obtain accurate labor-time measurements. More specifically, it was assumed that measurements made on 1-acre plots would be just as "accurate" as, say, measurements on 3-acre plots. Previous research work had indicated that using comparatively small experiment station plots, which ordinarily suffice for agronomic experiments, may not have resulted in "accurate" labor time measurements.

Total labor requirements were partitioned into 15 labor operations which are commonly required for conventional production of flue-cured tobacco. These operations are described in Table 1. They are listed chronologically as they normally occur during a production season.

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[1]More detailed information on the composition on each treatment and other experimental procedures are given by Bradford (1968, pp. 12-27).

Table 1. Description, classification and method of measurement for labor operations

Labor operation[a]	Description of sub-operations and techniques	Basis of measurement[b]
Plant bed	Preparation and care of plant beds	Experiment, prorated[c]
Land preparation	Breaking land, disking and harrowing, distributing fertilizer and laying-off rows	Experiment
Transplanting	Transplanting _per se_ using 1-row equipment	Plots
Transplanting support	Pulling plants, hauling plants, hauling water and replanting	Experiment, prorated[d]
Growing	Applying insecticides, cultivating and applying side-dress fertilizer and all other field cultural operations	Experiment
Topping and suckering	Topping, suckering and applying MH-30	Plots
Priming	Hand priming, 4 to 6 primers	Plots
Hauling to barn	Hauling leaves to barn on trailers or sleds	Plots
Handing and stringing	Hand stringing of leaves on sticks	Plots
Hanging in barns	Hanging strung sticks in curing barns	Plots
Removing to packhouses	Removing cured tobacco from barns to packhouses	Plots
Curing	Watching and regulating curing	Estimated[e]
Grading and tying	Preparation for marketing by removing cured leaves from sticks, grading, tying, "sticking up" and "packing down"	Plots
Other market preparation	Reordering and repacking	Plots
Other	Hauling to market, marketing, preparation of land and seeding of fall cover crop	Estimated[e]

Table 1 (continued)

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[a]Operations, generally, are listed in the order of the time of performance during the production season.

[b]The number of observations for each operation depended upon the method of measurement. Specifically, operations measured on a per-experiment basis had 9 observations--an observation on each of the 9 experiments; operations measured on a per-plot basis had 54 observations--an observation on each of the 6 plots in each experiment. Observations were made by individual primings for harvest and post-harvest operations.

[c]Observations were made on a per-experiment basis and prorated to individual plots on the basis of plant populations.

[d]Replanting measurements were made on a per-plot basis while the other sub-operations in this category were measured on a per-experiment basis and the time prorated to treatments on the basis of plant populations.

[e]Based on the budget prepared by North Carolina Agricultural Extension Service [1965, p. 23].

Starting with transplanting, most labor operations were measured on a per-plot basis. For example, priming labor measurements were made on each plot in each experiment. Thus, with 2 plots x 3 treatments x 3 locations x 3 years, there were 54 observations for the priming labor operation. Pretransplanting labor operations, comprising approximately 10 percent of total labor requirements, were measured on a per-experiment basis. There were 9 observations for each of these operations--3 locations x 3 years.

In addition to labor time measurements, production variables were measured for each plot of each experiment. Relatively wide treatment differences in fertilizer levels, plant populations and topping heights were maintained in each experiment. There were deviations (which were expected) in the levels of each practice within each treatment from experiment to experiment. In general, though, spreads in treatment intensity were wide enough to produce fairly wide differences in yields for each plot of each experiment. The labor time measurements, then, corresponded to relatively wide differences in production variables.

A scatter diagram of priming labor measurements plotted against harvested leaves per acre (Figure 1) illustrates the measured results which were common for most of the 15 individual labor operations. In Figure 1, three different characters shown in the legends are used to identify the three treatments. Locations are identified by letters, and years are identified by numbers, as specified in a footnote to the figure. The 27 observations are treatment averages, rather than the 54 per-plot observations, plotted this way for purposes of diagrammatic clarity.

Analytical Methods

Estimation procedures involved extensive use of various multiple regression models. In these models, plants, leaves and pounds per acre (production variables) served as continuous explanatory (independent) variables. Location, years and other sources of "qualitative" variation were represented by zero-one dummy variables and by cross products of observations for the zero-one dummies and the continuous explanatory variables. Such models often are referred to as covariance of mixed estimation models. A detailed discussion of the methods used to specify the models is given in the Appendix.

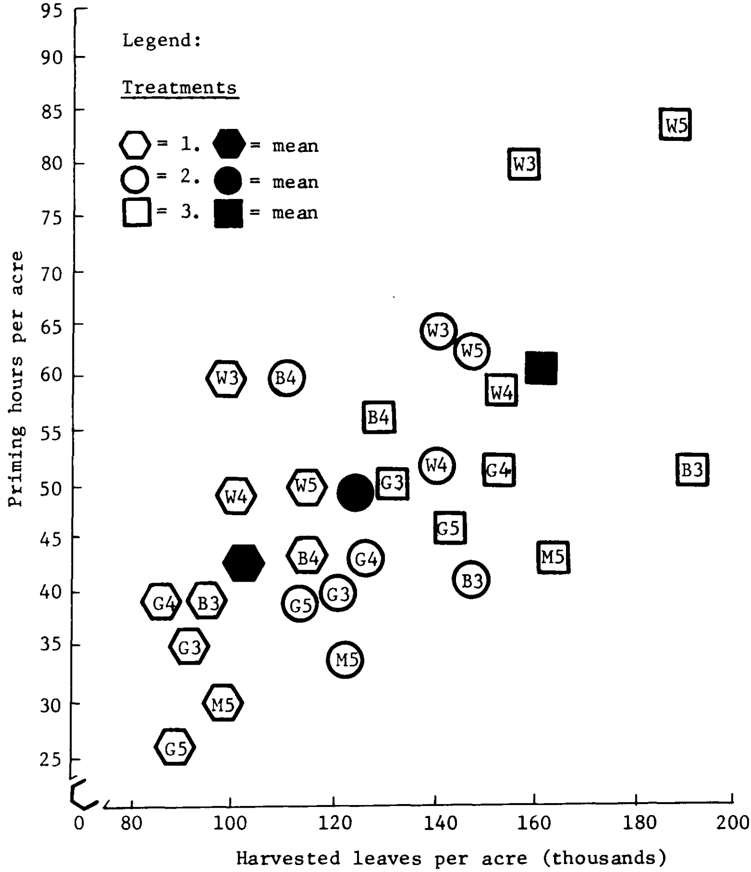

Figure 1. Treatment-average observations with priming labor related to harvested leaves per acre[a]

[a]Locations are denoted by the following letters: W, Wayne County; B, Bertie County; G, Granville County; and M, Moore County. Years are denoted by the following digits: 3, 1963; 4, 1964; and 5, 1965.

ANALYSIS OF PRIMING LABOR

Results of regression analyses followed a generally-consistent pattern from one labor operation to another. The problems encountered and results derived from the priming labor operation are used to illustrate the analyses of other labor operations.

Major results of the regression analysis of priming labor are presented in Table 2. Coefficients listed in the table were estimated using the regression model which is specified in Appendix Table 1. The process of selecting this model was, in effect, a series of tests of the hypotheses delineated in the procedures section (above). Hence, the results in Table 2 are discussed using the hypotheses as an outline.

Explanatory Variable(s) Selection

The linear slope coefficient shown in Table 2, .26256 priming hours per 1,000 harvested leaves, was highly significant. The R^2 value corresponding to this regression equation was .86. With pounds per acre used as the continuous explanatory variable, rather than harvested leaves, a coefficient of 2.096 hours per 100 pounds was derived. But, the R^2 value corresponding to this regression equation was lower (.82). Hence, it was concluded that leaves served as a "better" estimator than pounds of changes in priming labor.

Inclusion of both pounds and leaves, as continuous explanatory variables, altered estimates of coefficients (cited above) beyond reasonable interpretation. This was due to the very high correlation which existed between the series of observations for these two variables.[2] Moreover, when compared to regression equations where only one of the two variables was included, use of pounds or leaves as a second continuous explanatory variable resulted in nonsignificant reductions in the error sum of squares.

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[2]Such correlation, of course, was expected since the experiments of this study were designed to obtain higher yields through use of more leaves and near-proportional increases in fertilizer amounts per acre.

Table 2. Regression coefficients, corresponding "t" values and simple correlation coefficients obtained by regressing priming labor on harvested leaves per acre, year, location and year-location dummy variables

Explanatory variable[a]	Regression coefficient[b] Hours per acre	Hours per 1000 harvested leaves	Calculated "t" value	Simple correlation coefficient with leaves[c]
Harvested leaves	---	.26256**	8.87	---
Dummy variables				
K_4 (1964)	-11.79**	---	-3.53	-.13
K_5 (1965)	-6.46	---	-1.92	.06
L_2 (Bertie Co.)	-26.64**	---	-7.93	.07
L_3 (Granville Co.)	-21.84**	---	-6.48	-.25
L_4 (Moore Co.)	-22.48**	---	-6.61	-.02
L_2K_4	27.46**	---	5.76	-.14
L_3K_4	12.83**	---	2.71	-.05
L_3K_5	1.83	---	.39	-.16
General intercept value[d]	16.00	---	---	---

[a]Dummy variables, identified by symbols, are described in Appendix Table 1.

[b]Double asterisks accompany dummy variable coefficients which were statistically significantly different from the "base dummy variables" at the 1-percent level. No asterisks indicate lack of significance at the 5-percent level. The "base dummy variables" as discussed in the narrative were (1) 1963 (K_3), (2) Wayne County (L_1) and (3) Wayne County, 1963 (L_1K_3). The double asterisk accompanying the coefficient for harvested leaves indicates it is significantly different from zero at the 1-percent level.

[c]Simple correlation coefficient between harvested leaves and the respective dummy variables.

[d]Computed by multiplying the general mean value for harvested leaves per acre (129,000) by the slope regression coefficient (.26256) and subtracting the resultant product from the general mean value for priming hours per acre (49.9). This value was judged to be significantly greater than zero; see subsequent discussion of the intercept(s) for specifics of making this test.

Linearity

The linearity hypothesis was tested by adding a quadratic variable to the regression equations from which the linear coefficients were derived. For example, leaves-squared was added as a variable to the regression equation from which the results in Table 2 were derived. Addition of the quadratic variable failed to reduce the error sum of squares significantly, and the R^2 value increased only to .87 (from .86).

The Intercept(s)

The general intercept value was 16.0 hours per acre for the priming labor-leaves linear regression (Table 2), compared to only 3.2 hours per acre for the priming-pounds regression. Both regressions also were fitted through the origin, and F tests were used to determine if intercept values were significantly different from zero. Only the leaves-intercept value was judged to be significant.[3] Similar results were detected for other labor operations.

Uniformity of Coefficients

Slope Values

Adding various sets of slope-changing dummy variables (described in the Appendix) to the zero-one and continuous explanatory variables, listed in Table 2, did not significantly reduce the error sum of squares for priming labor. In other words, F tests verified that the same slope value, .26256 hours of priming labor per 1,000 harvested leaves, applied to all years and locations. Similar results were found for other labor operations. These results were consistent with the lack of significant

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[3] Simple linear regressions (no dummy variables) were fitted through the origin and compared with the same linear regressions having intercept values. The additional reduction in sum of squares due to including the intercept term served as the numerator of the F ratio, with the error mean square of the through-the-origin regression serving as the denominator. In most cases, simple linear regression intercept values were less than corresponding general intercept values as shown in Table 2. General intercept values were judged to be significantly greater than zero when simple linear regression intercept values were found to be significantly greater than zero.

treatment x year or treatment x location interaction in the ANOVA results reported by Bradford and Nelson (1969).

Intercept Values

Intercept values varied widely among years and locations. As discussed above, this was expected and is demonstrated by the dummy-variable coefficients shown in Table 2. As indicated by the t values, all except two of the dummy coefficients were significantly different from zero. The differences shown, of course, apply to reparameterization bases specified in Appendix Table 1. The results showed that: (1) the highest priming labor requirement was in the Wayne County experiment of 1963 and (2) significantly lower amounts of labor were required at the other three locations and in 1964. These conclusions may be seen by examining Figure 1. The general intercept value, thus, may be viewed as an average of the intercept value for each of the nine experiments.

Stalk Position Effects

On the basis of ANOVA tests, it was concluded that priming cost per 1,000 harvested leaves did not vary significantly among stalk positions. Moreover, it was concluded that the lack of significance was fairly uniform among treatments. This uniform nonsignificance of treatment x stalk position interaction indicated that slope coefficients for different stalk positions were fairly uniform. Thus, the slope coefficient shown in Table 2 (.26256 per 1,000 harvested leaves) was hypothesized to apply to all stalk positions. This hypothesis was verified using "t" tests of the differences between functional slope coefficients for each of the four stalk positions.[4] Coefficients varied from a high of .292 for the lower position to a low of .227 for the mid-upper (third) position. These differences were in the direction which normally would be expected, but they were not large enough to be statistically significant.

[4] Coefficients were estimated for each stalk position using least squares regression analysis of covariance Model 4 (Appendix Table 1). Slope-uniformity and quadratic hypotheses also were tested for each position and rejected for each of the four positions. The lower stalk position consisted of the first priming (three or four leaves). Each of the remaining three positions included approximately one-third of the remaining leaves on the stalks.

ANALYSIS OF OTHER LABOR OPERATIONS

Regression analyses of other labor operations were similar in many respects to the analysis described for priming labor. In this section, results and implications of these analyses are summarized for the 15 labor operations defined and described in Table 1.

General Results

It was concluded that plants, leaves or suckers (used individually) provided "best" estimates of changes in requirements for most labor operations. A major exception was grading and tying labor for which pounds provided better estimates. The use of two continuous explanatory variables did not significantly reduce the error sum of squares for any operation. The linearity hypothesis was accepted for all labor operations; i.e., significant nonlinear relationships were not detected. Most intercept values were significant when labor operations were regressed on plants or leaves but nonsignificant when the same operations were regressed on pounds. Linear (slope) coefficients generally were found to be uniform among years, locations or stalk positions. This is a particularly useful finding since it allows use of the same coefficients in estimating costs in different locations and/or years. In contrast, intercept coefficients for most labor operations varied widely among years, locations and stalk positions. This is due to widely-differing weather and soil conditions.

Linear Regression Results

Linear regression coefficients, confidence intervals for these coefficients, R^2 values and general intercept values are presented in Tables 3 and 4. Regression results in Table 3 reflect final conclusions for tests of hypotheses where individual labor operations were regressed upon plants or suckers or harvested leaves per acre. Regression results in Table 4 reflect final conclusions for tests of hypotheses where individual labor operations were regressed upon pounds per acre. In

Table 3. Linear regression coefficients, 95-percent confidence limits, coefficients of determination and general intercept values for individual labor operations regressed upon certain input production variables

Labor operation[a]	Linear regression coefficient[b]	95-percent confidence limits[c]	Coefficient of determination[d]	General intercept value[b]
			(percent)	(hours per acre)
	Hours per 100 plants			
Plant bed	.224**	±.038	.95	0
Land preparation[e]	0	--	--	5.9
Transplanting	.104**	±.025	.66	6.6**
Transplanting support	.308**	±.066	.96	5.5**
Growing[d]	0	--	--	17.6
Topping[f]	.048	--	--	0
	Hours per 1000 suckers			
Suckering[f]	.278	--	--	3.0
	Hours per 1000 harvested leaves			
Priming	.263**	±.061	.86	16.0**
Hauling to barn	.074**	±.024	.87	7.1**
Handing and stringing	.653**	±.150	.88	39.2**
Hanging in barns	.100**	±.032	.79	7.1**
Removing to packhouses	.078**	±.026	.82	4.4*
Curing[g]	0	--	--	22.7
Grading and tying	1.104**	±.274	.86	37.1**
Other market preparation	.015	±.002	.98	5.1**
Other[g]	0	--	--	9.2

Table 3 (continued)

[a]Operations are listed in the approximate order of their time of occurrence within the production season.

[b]Partial regression coefficients were derived by fitting covariance Model 4 (Appendix Table 1). The derivation and interpretation of general intercept values are explained in the narrative. Double asterisks and single asterisks accompany coefficients which are statistically significant at the 1-percent and 5-percent levels, respectively.

[c]Computed by multiplying the standard error of each regression coefficient by the 5-percent, tabled "t" values. Confidence intervals may be calculated by alternately subtracting and adding the limits (shown here) to the corresponding regression coefficients.

[d]R^2 value obtained from using all explanatory variables in Model 4 (Appendix Table 1).

[e]Measured on a per-experiment basis and assumed not to vary with any production variable. Thus, general intercept values are the general means.

[f]Slope coefficients for topping and suckering were derived by Hunt (1962). The general intercept value of 3.0 hours was the average time per acre required to apply MH-30 in the nine experiments of this study.

[g]Estimated and assumed not to be a function of any production variable.

Table 4. Linear regression coefficients, 95-percent confidence limits, coefficients of determination and general intercept values for individual labor operations regressed upon pounds per acre[a]

Labor operation	Linear regression coefficient	95-percent confidence limit	Coefficient of determination	General intercept value
	(hours per 100 pounds)		(percent)	(hours per acre)
Plant bed	.831**	±.262	.87	-.6
Land preparation	0	--	--	5.9
Transplanting	.272**	±.236	.57	5.8**
Transplanting support	1.098**	±.354	.94	5.4**
Growing	0	--	--	17.6
Topping and suckering	0	--	--	22.3[b]
Priming	2.096**	±.596	.82	3.2
Hauling to barn	.613**	±.222	.86	2.9
Handing and stringing	5.432**	±1.532	.86	2.3
Hanging in barns	.785**	±.304	.75	2.5
Removing to packhouses	.561**	±.164	.77	2.0
Curing	0	--	--	22.7
Grading and tying	10.475**	±2.096	.89	-54.2**
Other market preparation	0	--	--	7.1
Other	0	--	--	9.2

[a]Footnotes applying to Table 3 also apply to this table.

[b]An estimate, assuming sucker control chemicals are used.

general, the "final models" included eight, zero-one dummy variables representing years and locations. These dummy variables are specified in Appendix Table 1, and regression coefficients for these variables were listed by Bradford (1968, pp. 192-212).

Statistically significant slope and intercept coefficients are marked by asterisks which are interpreted in footnotes to Tables 3 and 4. With the exception of grading and tying, all labor operations were more closely related to plants or suckers or leaves than to pounds. Most preharvest operations were more closely related to plants; most harvest and postharvest operations were more closely related to harvested leaves. Closer regression relations are reflected by higher R^2 values and by confidence limits which are lower proportions of corresponding regression coefficients.[5] Zero slope coefficients for land preparation, growing, curing and "other" operations reflect assumptions or conclusions that these operations were solely a function of acreage. Thus, intercept values for these operations are the same as general mean values presented by Bradford and Nelson (1969, p. 15).

Coefficients for topping and suckering (Tables 3 and 4) are based upon estimates made by Hunt (1962, pp. 21, 24, and 44-45). Hunt's estimates are used, rather than those from this study, because of the very wide variation in topping and suckering labor requirement measurements and the lack of sucker-count data.[6] The intercept value (22.3 hours), shown in Table 4, is based on use of a sucker control chemical (MH) limiting the number of suckers per plant to 7. If no MH were used, the Hunt estimation procedure would increase this value to 53.3 hours.[7]

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[5]In other words, higher R^2 values and relatively lower confidence limits indicate which continuous production variable explained the largest proportion of treatment variation, i.e., variation over and above that explained by the dummy variables.

[6]Bradford and Nelson (1969, p. 17) discussed reasons for the wide variation in topping and suckering labor requirements.

[7]Assuming 7,967 plants per acre (the average in this study) and 21 suckers per plant the following calculations were made:

Suckering hours	= 46.5 = .278 (see Table 3) x 7,967 x 21
Topping hours	= 3.8
Applying MH hours	= 3.0
Total	53.3

Size of Intercept Values

For most labor operations, lower intercept values were obtained when pounds was used as the continuous explanatory variable than when plants or leaves were used. This may be seen by comparing values for the same operations in Tables 3 and 4. The results are most striking for the grading and tying operation. When this operation was regressed on harvested leaves, the general intercept value was 37.1, whereas it dropped to -54.2 when this same variable was regressed on pounds. Such a result is consistent with the fact that grading and tying labor per pound tended to vary directly with treatment intensity (thus with yield), but, in contrast, grading and tying labor per 1,000 harvested leaves declined slightly with treatment intensity.

Figure 2 is used to illustrate why per pound intercept values generally were lower than comparable per plant or per harvested leaf intercept values. Two hypothetical relations are shown with three characters used to represent the observations made for the three levels of treatment intensity. Labor hours per acre, measured on the vertical axis, are the same for each relationship. However, the number of pounds (yield) comparable to the harvested leaf count for each treatment becomes proportionately smaller as treatment intensity increases (implying a quadratic relationship of pounds with leaves). As a result, the linear regression line for pounds has a greater slope and, consequently, a lower intercept value than the comparable regression for leaves.

There are two possible explanations of the grading and tying results. First, for more intensive treatments, proportionately more leaves were required to give a pound of green weight, probably because stem sizes were smaller and leaf surface areas were less. Also, as treatment intensity increased, a proportionately larger number of leaves normally was discarded (most unintentionally) during harvesting and market preparation operations. Leaf counts used in regression analyses were made during harvesting, at the stringing shed. Pounds primed (which could not be measured) are equivalent to these counts; but, as a result of the leaves discarded, pounds sold (yield) normally were proportionately less as treatment intensity increased.

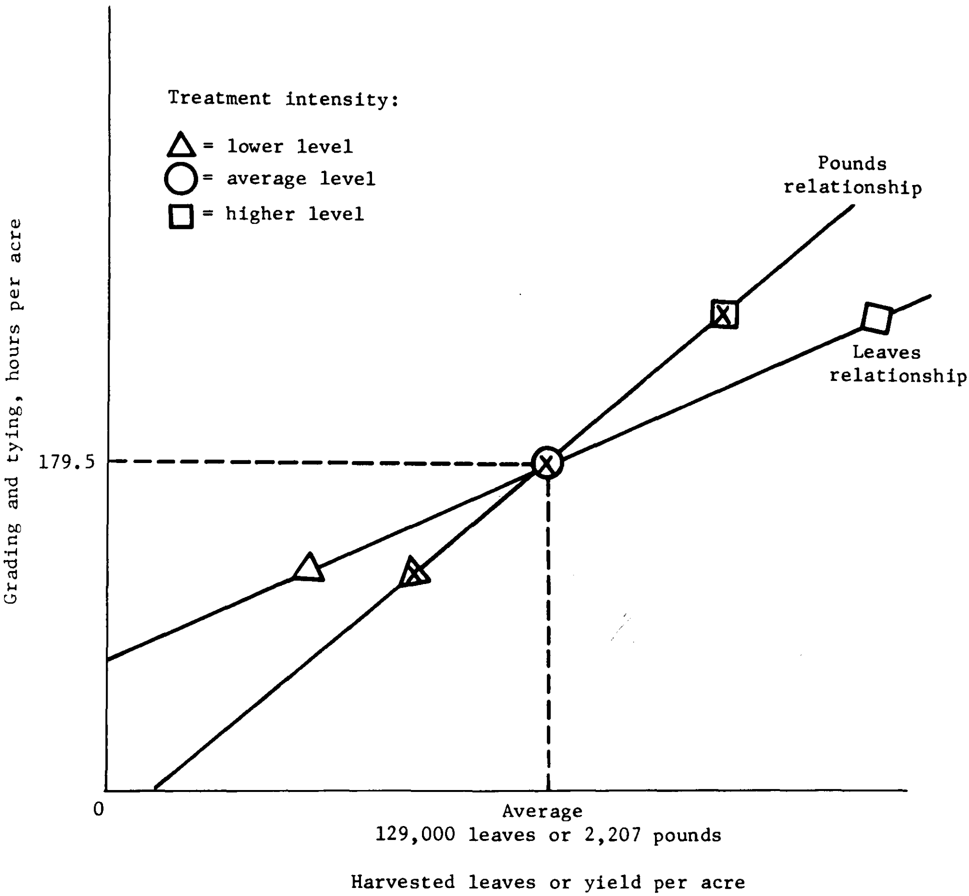

Figure 2. Effect on grading and tying regression relationships of smaller leaves and more leaves discarded as treatment intensity is increased

Absence of Nonlinear Relationships

The fact that no significant nonlinear relationships were detected should not be construed to mean that these relationships do not exist. Although it is a matter of speculation, it is entirely possible that relationships between some labor operations and production variables are nonlinear, and that these relationships could be quantified _if_ adequate data are available. On the other hand, within the range of usual farmer operations, covered by treatments within this study, the relationships may be linear.

To detect significant quadratic relationships or other degrees of nonlinearity which may exist it is necessary to (1) have a relatively wide range in observations for the explanatory variable(s) and (2) have a sufficient number of observations at different points along this range. However, as previously discussed, field sizes, money and time prohibited using more than the number of experiments and plots per experiment used in this study.

ESTIMATING LABOR COSTS USING LINEAR COEFFICIENTS

Tobacco researchers frequently find it useful to estimate labor cost(s) for diverse yield levels and/or levels of production intensity. The regression coefficients and intercept values presented in Tables 3 and 4 (above) may be used to make such estimates. There are several considerations which should be borne in mind when using these coefficients. In this section, some of these considerations are discussed following a presentation of the basic procedures which might be followed in estimating labor costs per acre and unit labor costs.

Basic Estimation Procedure

The following procedure may be used to obtain the estimated labor cost for any particular labor operation:

(a) Specify the labor hours per acre for a starting level of the production variable to which the labor operation is most closely related, e.g., 44.6 hours of priming labor for 130 thousand leaves.

(b) To obtain an estimate of the added (or reduced) labor hours per acre, multiply the regression (slope) coefficient times the added (or reduced) amount of the production variable, e.g., .263 hours per 1,000 leaves x 30 thousand leaves = 7.9 hours.

(c) To obtain an estimate of the total labor hours per acre for the alternative levels of the production variable, add (subtract) the product obtained in (b) to the starting hours per acre, e.g., 44.6 hours ± 7.9 hours = 52.5 hours for 160 thousand leaves or 36.7 hours for 100 thousand leaves.

(d) To obtain an estimate of the labor cost per acre for each alternative level of the production variable, simply multiply the results obtained in (c) by the appropriate wage rate, e.g., 52.5 hours x $1.30 = $68.25 per acre.

(e) To obtain an estimate of the labor cost per pound for each alternative level of the production variable, divide the respective results obtained in (d) by the known or estimated yield level, e.g., $68.25 per acre ÷ 2500 pounds = $.0273 per pound.

This procedure is designed to give valid estimates of labor costs _if_ starting levels of the labor operation and production variable are known or can be closely approximated. In some cases starting levels can be based upon records or results from the particular farm or experimental location for which the estimate is being made. For example, 1966-68 records might have shown an average of 40 hours of priming labor when 130 thousand leaves were used at the Moore County location. This value (40 hours) can be used as a basis for estimating priming labor cost assuming, say, 150 thousand leaves were observed. Alternatively, the intercept values presented in Tables 3 or 4 (above) can be used as starting levels; in effect, they are estimates of labor requirements for zero levels of the production variables. In the absence of more specific data, typical budget estimates of labor requirements, such as those presented by Bradford and Nelson (1969, p. 15), may be used as starting levels.

In most cases it will be desirable to estimate costs using only the coefficients for plants, leaves and acres (Table 3). If estimates are needed prior to the production season (before yields are known), then it becomes necessary to rely solely upon the coefficients.

In other cases it may be desirable or necessary to estimate costs using only the yield (pounds) coefficients (Table 4). With the exception of grading and tying market preparation labor, it was concluded that these coefficients would not give estimates which were as accurate as the coefficients presented in Table 3. However, the differences in accuracy should be relatively small since the R^2 values were only slightly less.

Regardless of which type of coefficients is used, it is necessary to know yields and wage levels (or have estimates of them) before cost per pound may be estimated. Estimates of cost per pound which are made using yield levels for a particular year at a particular farm location should be expected to be quite sensitive to the yield response peculiar to that season. The argument is sometimes advanced that the per acre cost of producing, say, 2500 pounds per acre in a "good" year is no more than producing, say, 1800 pounds per acre in a "poor" year. This is simply an acknowledgement of the fact that sometimes the yield response to a particular set of production practices is abnormally good. The relevant problem here, however, is one of calculating valid comparative cost of producing 1800 versus 2500 pounds for the same weather conditions. The coefficients derived in this study are designed to give such comparative estimates of per acre costs. Realistic, comparable estimates of per pound costs may be made only if the yield response is known or can be accurately estimated.

Aggregate Estimates

Basic estimation procedures, outlined above, are designed to make estimates of the costs of individual labor operations for higher or lower yields or levels of production intensity. In general, the same procedures may be used to estimate costs for several labor operations (aggregated).

To obtain an estimate for the specific aggregate labor cost category, the simplest procedure, conceptually, is to estimate the cost for each individual operation and sum these costs. An alternative procedure which will require fewer calculations involves multiplying aggregate regression coefficients times the changes in the respective production variables. For example, the following product will result in an estimate of the added harvesting labor, when the yield is increased from, say, 1800 to 2500 pounds per acre:

(1) 700 pounds x .09487 hours per pound = 66.4 hours

where: the slope coefficient (.09487) is the sum of the regression coefficients for priming, hauling to barn, handing and stringing, hanging in barns and removing to packhouse operations, each of which was presented in Table 4.

This same procedure could be followed for preharvest and postharvest operations and the products summed to make an estimate of the added hours per acre for all (combined) labor operations when using conventional labor techniques, viz.,

(2) 700 pounds x .22163 hours per pound = 155.14 hours

The input coefficients, which were presented in Table 3, also may be aggregated into an equation which may be used to estimate the added hours per acre for all (combined) labor operations, viz.,

(3) ΔH = (.684)(100 plants)+(.278)(1,000 suckers)+(2.287)(1,000 leaves)

where:

ΔH = added labor hours per acre,

.684 = sum of regression coefficients for plant bed through topping labor operations (Table 3),

.278 = the regression coefficients for suckering labor (Table 3), and

2.287 = the sum of regression coefficients for harvest and postharvest labor operations.

The aggregate coefficients of equations (1), (2) and (3) could have been obtained by regressing the respective aggregate labor categories upon the same set of continuous and dummy explanatory variables which was used to derive the coefficients presented in Tables 3 and 4. Thus, regression procedures used in this study result in coefficients which may be used to estimate changes in labor requirements for individual labor requirements and aggregate labor categories.

Use of the Coefficients

Collins et al. (1969, pp. 12-13) have used the coefficients of this study to estimate net returns in their on-farm experiments designed to demonstrate the effects of varying leaves per plant and per acre. They made measurements of yield and market price and subtracted costs estimated using the coefficients of this study to obtain net return estimates.

As techniques of production, harvesting and marketing preparation change, the linear regression coefficients and intercept values developed in this study will need to be updated. Various types of semi-automatic harvesting machines already have been adopted by many farmers. Completely mechanical systems now are being tested, and it appears that systems of this type could be widely adopted during the next decade. Thus, it is important to know, "How may the regression coefficients derived in this study be updated so that they may be used to estimate costs with these new systems?"

Obviously, it is possible to conduct a new series of controlled experiments to generate data from which a separate set of coefficients could be developed for each new system of production. But, the cost of developing such coefficients could be high, even prohibitive. Thus, as technology changes, different research methods may have to be employed to develop new coefficients. A simple method of adapting the coefficients presented in Tables 3 and 4 for use with a nonconventional system of harvesting is illustrated briefly in the following discussion.

Consider, for example, any new machine which is designed to lower harvesting and, to some extent, market preparation labor requirements, e.g., an automatic tying machine. This machine obviously has no effect upon coefficients for preharvest operations; also, it is easily coupled with hand priming, so conventional regression coefficients may still be applied to the preharvest, priming and hauling to barn operations.

Survey results have shown that barn labor requirements are reduced an average of approximately 40 percent with automatic tying machines.[8] Such percentage reductions generally appear to be fairly uniform from farm to farm and for different levels of yields and production practice intensities. Assuming this finding or some other uniform percentage reduction holds true, it suggests that if barn labor requirements are known for one level of yield or production practices, estimates for other levels can be made by a simple extension of the basic estimation procedures outlined above. This amended procedure is illustrated in Figure 3.

Point A in Figure 3 represents the measured barning labor requirements (including handing and stringing and hanging-in-barn operations) for the average production intensity level employed on a given, hypothetical farm. Conventional barning labor requirements for higher (lower) yield levels, points B and C, may be estimated by multiplying the combined regression coefficients for handing and stringing and hanging in barns (6.217 hours per 100 pounds) times the proposed yield changes and adding (subtracting) these changes to barning labor requirements for the average yield level.

Automatic stringing, barning labor requirements may be estimated using points lying on the line BAC as a basis. Requirements for the low yield level are estimated to be 40 percent less than conventional requirements. This is shown in Figure 3 by the decrease from point B to point B*. An identical estimation procedure, if followed for the median and high yield levels, would produce points A* and C* from

[8]Chappell and Toussaint (1965, p. 13).

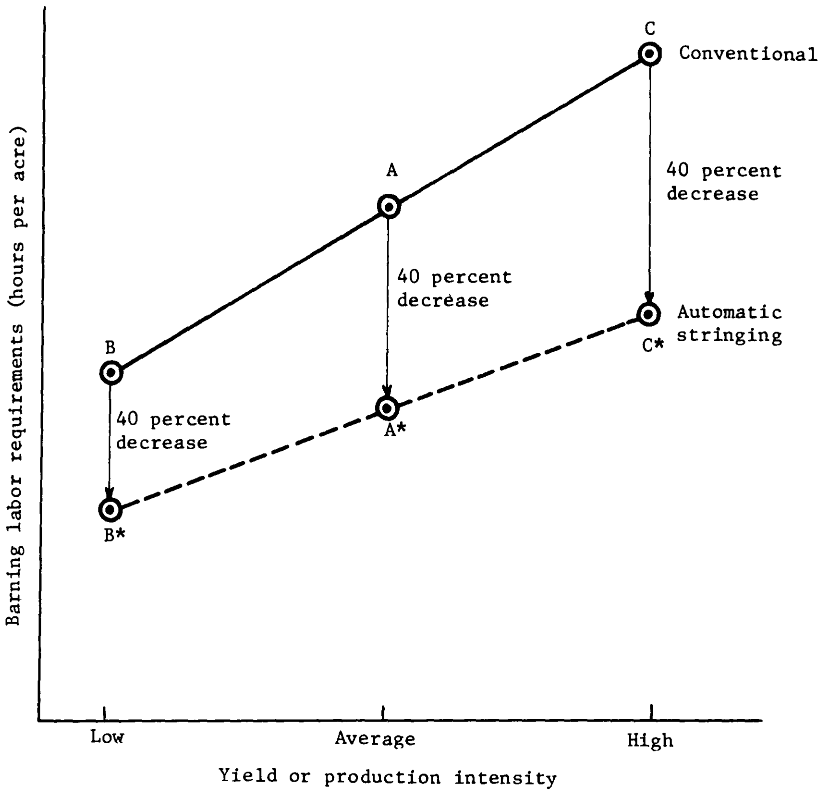

Figure 3. A hypothetical linear relationship between barning labor and yield, generated for the automatic stringing method of harvesting from the known relationship for the conventional method

points A and C. The resulting relationship (defined as B*A*C* in Figure 3), like the relationship for the conventional method, would be linear but would have 40 percent less slope and a 40 percent lower intercept value.

In general, relationships like B*A*C* in Figure 3 may be constructed for any labor-saving system of production, harvesting and market preparation provided an estimate of the uniform reduction in labor requirements is available. After the percentage(s) adjustment is made, estimation of the relationship(s) can follow the basic estimation procedures previously described.

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APPENDIX

A Simple Covariance Model

Covariance estimation models frequently are termed mixed models because they are composed of both continuous and discrete explanatory variables.[9] The priming labor-leaves diagram (Figure 1) provided an example of using both types of variables. Leaves served as a continuous explanatory variable. The three years served as one set of discrete variables. The resultant model including both types of variables may be written in terms of vectors for a set of priming labor observations as:

(1) $$P = I\alpha + K_3\alpha_3 + K_4\alpha_4 + K_5\alpha_5 + X\beta + U,$$

where: P and X are 54 x 1 column vectors of the 54 observations for priming hours and pounds per acre, respectively, with β being the 1 x 1 cost parameter corresponding to X; I is a 54 x 1 vector of 1's representing the intercept term, with α being the corresponding 1 x 1 intercept parameter; U is the 54 x 1 vector of residual values; and

K_3, K_4 and K_5 are column vectors of discrete or zero-one dummy variables representing 1963, 1964 and 1965, respectively--α_3, α_4 and α_5 being the corresponding parameters.

The discrete variables are called zero-one, dummy variables because one (1) is entered as the observation when the priming observation corresponds to the discrete variable and zero (0) is entered otherwise. For example, in this model (Model 1) if priming (P) observations were made in 1963, 1's were entered for K_3 and 0's entered for K_4 and K_5. Similarly, 1's were entered for K_4 corresponding to the priming observations made in 1964--0's otherwise; and 1's were entered for K_5 corresponding to the

[9] Economists often refer to these models as dummy-variable models, and there have been a variety of other names used. A more thorough description of covariance models and their theoretical properties is given by Johnston (1963, pp. 221-228) and Graybill (1961, pp. 383-403).

priming observations made in 1965--0's otherwise. Thus, for the 54 observations specified by Model 1, each of the three dummy variables (K_3, K_4 and K_5) have 18 observations entered as 1's and 36 observations entered as 0's. For any particular observation, however, only one of the three variables has a 1 entered--the other two have entries of 0.

Reparameterization Method

Since the intercept vector (I) has all 54 of its observations entered as 1's, a linear combination of the year, dummy vectors will exactly sum or equal to the intercept vector. Consequently, it would not be possible to estimate the paramters of Model 1, as it stands, using least squares regression analysis.[10] A situation of perfect multicollinearity exists and, as a result, no inverse of the sum-of-squares and cross-products matrix exists. This is true of any covariance model when stated in its original or nonreparameterized form.

Two general methods of respecifying or reparameterizing covariance models commonly are used. The method used in this study involved elimination of discrete variables by combining parameters.[11] One variable was eliminated from each set of zero-one, dummy variables. For example, with Model 1, use is made of the fact that $K_3 + K_4 + K_5 = I$ or, in alternative form, $K_3 = I - K_4 - K_5$. When this alternative form is substituted for K_3, variables multiplied times parameters and terms collected, the model is reformulated as

$$(2) \qquad P = I(\alpha + \alpha_3) + K_4(\alpha_4 - \alpha_3) + K_5(\alpha_5 - \alpha_3) + X\beta + U$$

This is the reparameterized version of the model. Least squares regression analysis may be applied to it to derive estimates of $\alpha + \alpha_3$, $\alpha_4 - \alpha_3$, $\alpha_5 - \alpha_3$ and β.

[10] Analysis of variance techniques often are used to derive sums-of-squares which are corrected for the covariate (pounds per acre in the example used here). Such procedures are described by Steel and Torrie (1960, pp. 305-311) and in other texts on statistical methods. In this study, such a procedure was not used since quantitative estimates of the functional parameters were desired, especially for the labor-production parameters (β in Model 1).

[11] The second method involves imposing linear restrictions on the coefficients of the parameters. It is the method commonly used in ANOVA models and is described in various texts on statistical theory. For example, see Anderson and Bancroft (1952, pp. 217-226).

Interpretation of Coefficients in the Reparameterized Model

As shown above, the method of reparameterization does not affect the estimate of the parameter for the continuous explanatory variables, *i.e.*, β in Model 2. The intercept term, however, is affected. Composition of the intercept term which is estimated depends upon which variable, in the original model, the reparameterization is based. In the case of Model 2, 1963 was used as the base year. As a result, the constant term to be estimated by regression analysis became $\alpha + \alpha_3$. Estimates of $\alpha + \alpha_4$ or $\alpha + \alpha_5$ may be obtained, however, from (2) simply by subtracting the coefficient of K_4, or K_5 from the coefficient of I. This is why zero-one, dummy variables are sometimes referred to as intercept-shifting, dummy variables. Each dummy coefficient is a potential shifter of the intercept. In the case of Model 2, there are three possible intercept values corresponding to each of the three years--1963, 1964 and 1965 data being pooled together into one overall relation for which a common slope, β, could be estimated. Differences between 1964 and 1963 and between 1965 and 1963 are estimated by the coefficients to K_4 and K_5 respectively, *viz.*, $(\alpha_4 - \alpha_3)$ and $(\alpha_5 - \alpha_3)$. The difference between 1964 and 1965 also could have been obtained by subtracting the coefficient for K_5 from the coefficient for K_4. In short, estimates for coefficients of dummy variables in any reparameterized model are invariant; desired contrasts may be obtained by "proper" interpretation of regression estimates or by "proper" linear combinations of those estimates.

An estimate of what may be termed the general intercept value, taken alone in Model 2, may be obtained by using the following relationship:

$$\hat{\alpha} = \bar{P} - \hat{\beta}(\bar{X}) \tag{3}$$

where: $\bar{P}$ = the general mean for priming hours per acre,

$\bar{X}$ = the general mean for harvested leaves per acre, and

$\hat{\beta}$ = the estimated regression coefficient of labor on leaves per acre.

A distinction between the general intercept value and the covariance constant term (in equation (2) above, $\alpha + \alpha_3$) is quite important when testing the null hypothesis that the intercept term is zero. The covariance constant term always contains "unwanted effects," so the hypothesis to be tested necessarily must concern the general intercept term. However, a variance statistic could not be calculated directly for the general term as defined in equation (3), so an alternative procedure was used to test the intercept hypothesis.

Alternative Covariance Models

The covariance model specified by equation (2) includes only one set of dummy variables, those for years. Examination of Figure 1 and a review of ANOVA results reported by Bradford and Nelson (1969) indicated that a set of variables accounting for location variation also should be included. This was also the case for most other cost components.[12] Locations, followed by years, gave rise to the largest source of nontreatment variation. Seldom were any of the other sources, as specified by ANOVA models, deemed large enough to be included in the covariance models as specified initially. Initial models, thus, were specified on the basis of the variation in each labor operation as detected by ANOVA. Alternative and final models were specified as the hypotheses were tested.

Correspondence between ANOVA sources of variation and the variables used in reparameterized covariance models is further illustrated in Appendix Table 1. Sources of variation and corresponding variables are those of the covariance model, referred to as Model 4 in the discussion, which was used in estimating coefficients for most labor operations. The Wayne County location (denoted by L_1) and 1963 (denoted by K_3) were employed as a basis for reparameterization. Hence, the covariance constant term includes coefficients corresponding to these effects (γ_1 and α_3) and a coefficient corresponding to the interaction effect (γ_1 α_3). Intercept values for other experiments may be calculated by recombining appropriate dummy coefficients, similar to the procedure described above. Degrees of freedom for location-within-year variation

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[12]This reasoning should not be misconstrued to imply that the discussion accompanying Model 2 was not relevant. Instead, as noted above, the model was used to illustrate the process of model specification, reparameterization and resultant interpretation.

Appendix Table 1. Explanatory variables and corresponding coefficients, in a covariance estimation model, attributed to significant sources of variation as determined by the analysis of variance of per-plot, stalk-total observations

Analysis of variance source of variation	Degrees of freedom	Covariance model explanatory variable[a]		Coefficient corresponding to variable[b]
		Description	Symbol	
Correction factor	1	Covariance constant term	I	$\alpha + \alpha_3 + \gamma_1 + \gamma_1\alpha_3$
Year	2	1964	K_4	$\alpha_4 - \alpha_3$
		1965	K_5	$\alpha_5 - \alpha_3$
Location[c]	3	Bertie Co.	L_2	$\gamma_2 - \gamma_1$
		Granville Co.	L_3	$\gamma_3 - \gamma_1$
		Moore Co.	L_4	$\gamma_4 - \gamma_1$
Location-year[c]	3	Bertie Co., 1964	L_2K_4	$\gamma_2\alpha_4 - \gamma_1\alpha_3$
		Granville Co., 1964	L_3K_4	$\gamma_3\alpha_4 - \gamma_1\alpha_3$
		Granville Co., 1965	L_3K_5	$\gamma_3\alpha_5 - \gamma_1\alpha_3$
Treatment, linear	1	Leaves, pounds or plants per acre	X	β
Residual	44[d]	--	U	--

[a]Referred to as covariance Model 4 in the narrative.

[b]Regression coefficients were estimates of the contrasts, such as $\alpha_4 - \alpha_3$, shown for the discrete variables.

[c]Location within year variation specified by Bradford and Nelson (1969, p. 22) was partitioned into these two sources in the covariance models.

[d]A residual with 44 degrees of freedom assumed that the 54, per-plot, stalk-total observations were being fitted. The residual sum of squares included variation due to (1) replication within years and locations, (2) treatment-location and/or treatment x year interaction and (3) treatment x replication variation as specified by Bradford and Nelson (1969).

were partitioned into three location and three location-year variables.[13] This is explained in a footnote to Appendix Table 1; it was done in order to obtain separate measures of location and location x year variation. The estimate for β is not affected by the method of specifying particular dummy variables, given that this set is included in the reparameterized model.[14] The remaining or second degree of freedom for treatment variation, not specified in the table, corresponds to a quadratic continuous explanatory variable.

The question of which dummy variables to include in each model was integral to the "uniformity" hypothesis. The answer varied only slightly with the particular cost component or category being analyzed, and in final analysis the variables listed in Appendix Table 1 usually were sufficient. However, in initial analyses, various alternative models were specified and fitted.

At one stage of the study, dummy variables were included which corresponded to replication-within-year variation. These variables did not significantly change the estimates of β (in Appendix Table 1), nor did they explain a significant proportion of the total variation in any cost component. Consequently, they were not included in the "final" models.

In another stage of the study, sets of what were termed slope-shifting dummy variables were included in alternative models. These sets corresponded to treatment x year and treatment x location interaction variation. Observations for these dummy variables were specified as column vectors, similar to the zero-one dummy variables, except each vector (variable) consisted of zero's or continuous observations taken from the particular production (explanatory) variable rather than zero's _or_ one's. Hence, in effect, observations in these vectors were products

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[13] Observations were made at the Moore County location, represented by L_4 in Appendix Table 1, only in 1965. Thus, this variable was, in a sense, a location-year variable and could have been denoted as L_4K_5.

[14] The set of six dummy variables, corresponding to the location-within-year variation, would have included L_4, L_2K_4, L_3K_4 and L_3K_5 as specified in Appendix Table 1. Instead of L_2 and L_3, the remaining two variables would have been L_2K_3 and L_3K_3. Though, not shown here, use of L_2K_3 and L_3K_3 in lieu of L_2 and L_3 did not affect the estimate of β.

of the production variable (vector) and the location or year dummy vectors specified in Appendix Table 1. They were used as a means of testing the hypothesis that slope relationships, between given cost and production variables, were uniform.[15]

[15]Ben-David and Tomek (1965) describe characteristics and uses of slope-changing dummy variables in more detail.

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