Optimum Tobacco Yield And Marketing Strategies Under Poundage Quotas As Compared With Acreage Allotments

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OPTIMUM TOBACCO YIELD AND MARKETING STRATEGIES UNDER POUNDAGE QUOTAS AS COMPARED TO ACREAGE ALLOTMENTS

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Managers concern themselves with three general problems in supervising and coordinating a firm's resources, viz., (1) what to produce, (2) how to produce and (3) how much to produce. These three categories provide a convenient means of classifying the problems faced by many farm business managers. They provide an especially convenient system of classification for some of the major problems which may face burley tobacco farmers in event that some type of poundage-quota control program is adopted.

Several specific solutions to these three problems may be evident to most burley farmers after they have had some years of experience with a new tobacco program; just as burley farmers during the 1940's learned how to "play the game" under acreage quotas, they could during the 1970's learn how to do so under poundage quotas. Still, it would appear that economic research should provide some a priori answers. Such research usually consists of theoretical (more general) phases and empirical (more specific) phases. This report deals primarily with some of the more general reasons for expecting different burley tobacco farmer behavior with a poundage quota program. More specifically, the objectives are:

1. To examine some of the reasoning involved in determining yields under poundage quotas as opposed to the current acreage-control program, and
2. To specify a logical framework for use by tobacco farmers in determining optimum use of their poundage allotments over time.

Reasoning required to meet these objectives fall primarily under the "how-much-to-produce" problem and to some extent under the "how-to-produce" problem. Previous research conducted at Kentucky and North Carolina [4, 5] has rather clearly established that whatever the alternative uses of resources may be, it is quite profitable to produce tobacco to the extent of the acreage and/or poundage allotment.[1] Hence, as an answer to "what-to-produce," farm-planning research using budgeting or linear programming or any other technique has shown that with most price, cost and production situations it pays to first use all available productive resources for tobacco; then, use what remains for other enterprises. Various reasons may be advanced why this is the case, such as income benefits from the price-support, supply-control program. The point here, though, is that the most pressing research needs obviously involve "how-much-to-produce" and "how-to-produce" problems.

Several aspects of these problems have been covered in previous research work conducted by experiment stations in tobacco states and by USDA agencies [1, 2, 3, 6, 7]. However, a specific combination of problems implied by the objectives listed above will be covered in this report. This combination will be covered in two stages: (1) optimum yields and (2) optimum marketing.

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[1] That is, assuming it is profitable to produce some tobacco.

OPTIMUM YIELDS

With acreage controls, tobacco farmers tend to maximize production profits by maximizing net returns per acre (total dollar returns per acre less the cost of variable inputs). That is, each year it pays to use all of an acreage allotment in reaping the maximum dollar return above costs of variable inputs such as seed, pesticides, herbicides, fertilizer, hired labor, etc. That is true because allotted acres usually are the most scarce of all the owned or fixed resources. By maximizing net returns per acre the manager is able to maximize profits or net returns to the bundle of fixed (owned) resources.

Similarly, under poundage controls, farmers tend to maximize net returns per pound of tobacco sold. Note, however, an important distinction: Acreage control programs establish acres as a resource which must be used during the year in which allotted; whereas, the poundage control program that has been proposed for burley (and is now in existence for flue-cured tobacco types) allows the use of poundage in future years if not used in the present year. Also, to some extent, it allows the use of future allotment in the present year. Implications of this distinction will be discussed subsequently, since it lies at the crux of meeting the second objective. The immediate objective is to clarify whether maximizing net returns per acre versus maximizing net returns per pound leads to the same production behavior.

Theoretical Framework

Economic theory can be used to demonstrate that different production strategies will be expected under the two programs. Consider Figure 1 to see why this is the case.

In this figure hypothetical relationships are drawn between (1) price and yield and (2) average variable cost (cost/pound) and yield. There are theoretical reasons for expecting price and average cost curves having general shapes like those in the figure. Market price per pound is expected to increase up to a certain yield because the use of more plants, leaves, fertilizer and other variable inputs should result in a higher proportion of grades having better acceptance from buying companies. Likewise, after a certain yield is attained, market price is expected to decrease because of the use of too "heavy" a combination of variable inputs. Average variable cost is expected to decrease up to some yield and then start increasing because of the law of variable proportions. Notwithstanding such logic, many questions about the shape of the price and average variable cost curves deal with their specific shapes under particular market and production conditions—not about their general shapes. Such empirical questions will be covered in subsequent sections.

A producer desiring to maximize net returns per pound—as one would expect many producers operating under poundage quotas to prefer—could do so by attaining a yield equal to OM (Figure 1). At this yield, the difference between price and average cost per pound (BA) is the greatest. That is, maximum net returns (above variable costs) per pound are obtained.

A producer desiring to maximize net returns per acre—as many producers now operating under acreage controls seemingly desire—could do so only by attaining a yield greater than OM (Figure 1). To see why this is true, consider Figure 1. First, assume that maximum net returns per pound occur at only one yield, such as OM. Then choose any yield which is less than OM. Regardless of the lower yield that may be selected, net returns per acre will be less than at yield OM. This is true because:

Net returns per acre = (net returns per pound) x (yield)

and, by definition, both net returns per

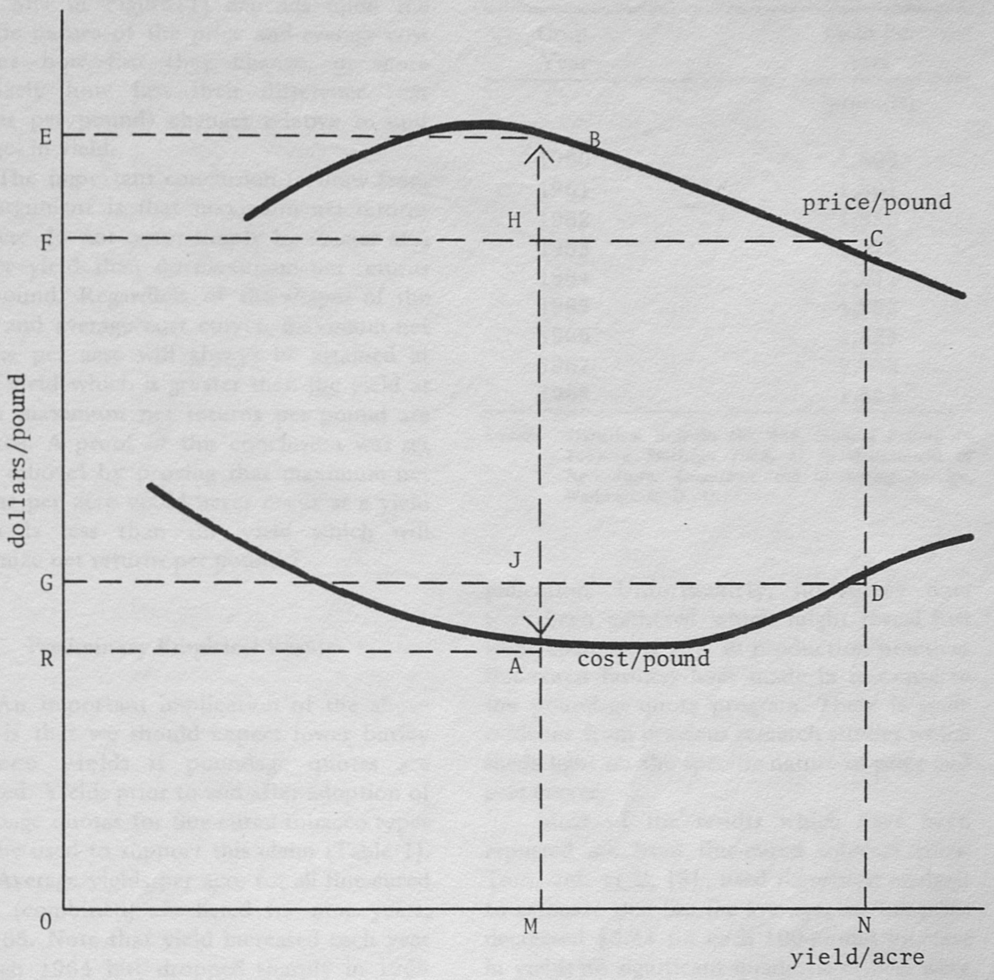

Figure 1.--Theoretical Price and Average Variable Cost Curves Related to Yield per Acre.

pound and yield are lower for yields less than OM. Thus, maximum net returns per acre can be attained only by producing some yield which is greater than OM. How much greater (e.g., MN in Figure 1) depends upon the specific nature of the price and average cost curves—how fast they change, or more precisely how fast their difference (net returns per pound) changes relative to unit changes in yield.

The important conclusion to draw from this argument is that maximum net returns per acre do not occur simply by chance at a greater yield than do maximum net returns per pound. Regardless of the shapes of the price and average cost curves, maximum net returns per acre will always be attained at some yield which is greater than the yield at which maximum net returns per pound are attained. A proof of this conclusion was set forth (above) by proving that maximum net returns per acre could never occur at a yield which is less than the yield which will maximize net returns per pound.[2]

Preliminary Empirical Results

An important implication of the above logic is that we should expect lower burley tobacco yields if poundage quotas are adopted. Yields prior to and after adoption of poundage quotas for flue-cured tobacco types may be used to support this claim (Table 1).

Average yields per acre for all flue-cured types (combined) are listed for nine years, 1960-68. Note that yield increased each year through 1964 but dropped sharply in 1965 when poundage quotas were first in effect. Yield was even lower in 1966 (a "poor" crop year), increased in 1967 (a "good" crop year), and leveled off in 1968. Obviously, this is not conclusive evidence that flue-cured tobacco farmers intentionally produced lower yields under poundage quotas, but it is an indication. Unfortunately, no survey data have been gathered which might reveal just what changes, if any, in production practices flue-cured farmers have made in response to the poundage-quota program. There is some evidence from previous research studies which sheds light on the specific nature of price and cost curves.

TABLE 1

ANNUAL FLUE-CURED TOBACCO YIELDS, 1960-68

Crop Year	Yield Per Acre
	(pounds)
1960	1,808
1961	1,801
1962	1,930
1963	1,975
1964	2,211
1965	1,883
1966	1,825
1967	2,048
1968	1,854

Source: Statistical Bulletin No. 435, *Annual Report on Tobacco Statistics 1968,* U. S. Department of Agriculture, Consumer and Marketing Service, Washington, D. C.

Most of the results which have been reported are from flue-cured tobacco areas. Toussaint, et al. [8], used regression analysis to estimate that (on the average) market price decreased $5.41 for each 100-pound increase in yield; no significant quadratic effects were detected in fitting the model with data generated from on-the-farm controlled experiments.[3] Bradford and Nelson [2] employed analysis of variance using data generated from the same experiments to conclude that average variable cost did not vary either positively or negatively in the

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[2] A more sophisticated mathematical proof of this conclusion is presented in the Appendix.

[3] This change was considered valid within a yield range of approximately 1,600 to 2,800 pounds.

relevant range observed (approximately 1,600 to 2,800 pounds). These results are mentioned here primarily because the methods employed may be adapted for use in studying the same type of relationships for burley tobacco.

Some observers have argued that as burley yield gets higher so does price. Within some rather narrow yield range and in some years, this may be true. However, it is not easy to support this argument using survey or secondary data. It is typical to see secondary data used to seemingly demonstrate this point. In Table 2, for example, 10 Kentucky tobacco market locations were selected at random; yield and price averages were correlated for two years, 1966 and 1967.[4] The correlation coefficient was positive and significant for both years, viz., 0.94 for 1966 and 0.78 for 1967. But, to conclude that higher yields cause higher prices may be fallacious. It seems much more likely that farmers producing higher yields are better managers with better soil, and so naturally would be expected to produce better quality (higher priced) tobacco. In any event, it is not

TABLE 2

BURLEY TOBACCO YIELD AND MARKET PRICE AVERAGES FOR SELECTED LOCATIONS, 1966 AND 1967

Location[a]	1966 Yield Per Acre	 Price Per 100 Pounds	1967 Yield Per Acre	 Price Per 100 Pounds
	(lb)	(dollars)	(lb)	(dollars)
Covington (Kenton Co.)	2,250	$68.98	2,208	$62.08
Cynthiana (Harrison Co.)	2,610	71.94	2,607	67.66
Henderson (Henderson Co.)	1,970	66.35	1,846	57.59
Mayfield (Graves Co.)	1,860	68.05	1,887	62.90
Mt. Sterling (Montgomery Co.)	2,590	72.40	2,397	68.46
Ownesboro (Daviess Co.)	2,320	70.65	2,260	63.84
Paris (Bourbon Co.)	2,780	72.54	2,782	67.94
Richmond (Madison Co.)	2,800	72.29	2,561	66.25
Shelbyville (Shelby Co.)	2,630	72.31	2,827	66.37
Somerset (Pulaski Co.)	2,630	71.68	2,141	65.98

[a] Yield data correspond to counties listed in parentheses, whereas price data are averages for all tobacco sold at the auction centers towns located in each county.

Sources: *Light Air-Cured Tobacco Market Review, 1966 Crop and 1967 Crop,* United States Department of Agriculture, Consumer and Marketing Service, Washington, D. C.

Kentucky Tobacco Market Report, 1966 and 1967, Kentucky Department of Agriculture, Frankfort.

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[4] There are 33 auction market centers for burley tobacco located in the state of Kentucky. The 10-location sample used here was selected to exclude Lexington because of difficulties of obtaining corresponding yield data for this large market. County data corresponding to price data for the other markets were more easily determined.

possible to conclude much from secondary data of these types. To make a valid test, it is necessary to determine what will happen to price as yield is increased by using more plants, fertilizer and other variable inputs while management, soil, etc., are held constant or "randomized out."

Byers and Atkinson (unpublished research) conducted small-plot experiments from 1963 through 1966 at the University of Kentucky Agricultural Experiment Station in Lexington. Their primary objective was to determine the effects of different levels of fertilizer, plants and irrigation on yield, price and certain variable costs (particularly labor).[5] Regression analysis of their data generally failed to detect significant positive or negative relationships between price and yield and between labor cost per pound and yield.[6] A large amount of the variation in price or labor cost per pound could not be explained by the yield variable (or variables), regardless of the type of model used.[7] Possibly, the use of more than two replications and/or larger plots is needed to reduce error variation and allow for more precise estimation of parameters of these hypothesized relations. Further empirical studies may also be made using both survey data and data from controlled experiments.

OPTIMUM MARKETINGS

Should burley farmers adopt poundage quotas, it seems most likely that these quotas will be in addition to acreage allotments, i.e., combined acreage-poundage quotas similar to those now in existence for flue-cured tobacco. Hence, each farmer will be faced not only with a decision about the optimum yield per acre but also with a "follow-up" decision of the optimum poundage to market each year.

Under the current acreage allotment program, the quota (if used at all) must be used in the year it is allotted. In contrast, under a poundage program with carry-forward provisions the quota resource is durable—it can be used in future production periods. Thus, poundage quotas offer in advantage in the sense that farmers have an opportunity to recoup (insure) any losses of this year's tobacco with replacement pounds from crops of future years.[8] Poundage quotas, however, may be disadvantageous when a farmer over-produces his quota and is forced to destroy (discard) or store the excess.

Assume that each burley producer would have the privilege of marketing a maximum of 110 percent of his quota in any given year. Any over-production which forces destruction of poundage will be referred to as excess discarding; the only legal alternative to such

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[5] Each of their experiments was constructed in 2 complete blocks with 3 levels of fertilizer, 4 plant populations and 2 levels of irrigation serving as the 24 treatments in each block.

[6] Simple linear regression models which were fitted showed a significant positive relationship between price and yield in 1965, whereas relationships in other years were not judged significant. The relationship between labor cost per pound and yield was significantly positive in 1966, significantly negative in 1965 and nonsignificant in 1963 and 1964.

[7] R^2 values ranged below 0.15 even when quadratic equations were used. No significant quadratic relationships were detected.

[8] Under either program, producers must insure (formally or bear the risk) against losses on the returns to the ordinary factors of production—land, labor and purchased inputs. Producers, however, are automatically insured against losses to the poundage resource to the extent that the poundage quota is of value in future years.

discarding will be storage.[9] A second type of discarding could take place if tobacco which could be marketed within the poundage quota is voluntarily discarded. This type of discarding will be referred to as replacement discarding. Under certain conditions, either or both types of discarding may be profitable. Some of the variables bounding these conditions will be discussed in the next three sections.

Excess Discarding

In event of excess production, many burley tobacco farmers probably would try to store the excess. Still some may find that storage is impractical or else if it is tried the tobacco, for some reason, may deteriorate beyond use. In other words, production in excess of 110 percent of the poundage quota would be wasted. As the lowest-priced grades are destroyed, average price (received for the tobacco sold) will increase. But, in computing cost per pound of the tobacco sold, costs of producing the destroyed poundage cannot be ignored. Cost per pound of tobacco sold (not destroyed) increases directly with the percentage of the quota destroyed. Therefore, profit is lowered unless the average price increase is greater than the cost-per-pound increase.

Reasoning involved in reaching this (above) conclusion may be made more clear by use of the following hypothetical example: Consider Farmer Jones who has 5 acres on which he can use to produce and sell 10,000 pounds (equaling 110 percent of his quota). First, suppose Mr. Jones combines the 5 acres with moderate-yielding production practices and produces 10,000 pounds—all of which he sells for a 60-cent average price. Subtracting his cash operating costs of 25 cents per pound gives him a 35-cent net return. In comparison, suppose Mr. Jones had produced 12,000 pounds by using higher-yielding practices (the same weather conditions holding as for the lower production). Cost per pound increases by at least 20 percent—from 25 to 30 cents—because the total cost of producing 12,000 pounds must be spread over (divided by) only the 10,000 pounds sold. Hence, average price also must increase by 5 cents to maintain a 35-cent profit margin. In other words, even if the 12,000 pounds would have averaged 60 cents, to maintain a 35-cent profit margin the 10,000 pounds which was marketed must average 65 cents. In this example, it is possible to calculate that the average price of the destroyed grades would have been 35 cents.

Excess discarding is more likely to be profitable as (1) the range of grade prices is wider, (2) the percentage (of a quota) which must be destroyed is lower, and (3) operating cost is lower. A wide range of grade prices—such as much 30-cent tobacco, and then a jump to where most of the other grades sell in excess of 60 cents—will result in more of an average-price increase (because of destroying low-priced grades). A small quota excess causes less of a cost-per-pound increase and allows the destruction of less high-priced tobacco. A low operating cost results in less of an absolute cost-per-pound increase from discarding.

Using Figure 2, one can estimate the profitability of excess discarding. Cost per pound and the increase in average price are measured on the vertical axis in cents per pound. Percentage of a poundage quota destroyed is measured on the horizontal axis. The increase in cost per pound of the tobacco sold is specified by the line dividing the plain and cross-hatched areas of the graph. This particular line is based on a 25-cent operating cost, identical to the Farmer Jones example. If the variable (operating) cost of producing the entire crop of tobacco (that sold plus excess) was lower, the dividing line would rotate downward and to the right. The graph

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[9] The 10 percent over-tolerance provision has been followed in the flue-cured program. Also, in this program it has been illegal to market any tobacco beyond this excess by using poundage quota from another farmer's marketing card.

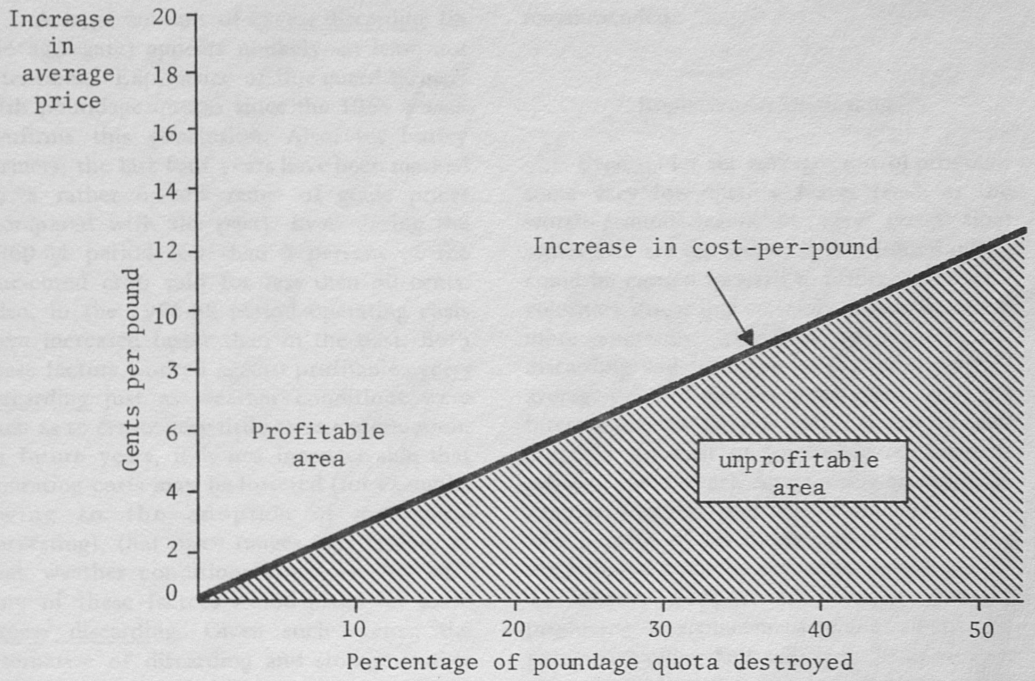

Figure 2.--Average Market Price Increases Necessary to Make Different Percentages of Poundage Destruction Profitable.

should be used by assuming a certain percentage destruction (say, 20 percent as in the example) and then reading vertically to see how much of a price increase is needed to offset the per-pound cost increase. The price increase needed (it is the increase over the average price received when producing 110 percent of the quota) becomes larger as the percentage of the quota destroyed becomes larger.

A large amount of excess discarding (in the aggregate) appears unlikely—at lease not intentional. Experience of flue-cured farmers with poundage quotas since the 1964 season confirms this conclusion. Also, for burley farmers, the last four years have been marked by a rather narrow range of grade prices (compared with the past). Even during the 1960-64 period less than 5 percent of the flue-cured crop sold for less than 30 cents. Also, in the 1965-68 period operating costs have increased faster than in the past. Both these factors worked against profitable excess discarding just as weather conditions were such as to create very little excess production. In future years, it is not inconceivable that operating costs may be lowered (for example, owing to the adoption of mechanical harvesting), that price ranges may widen, or that weather conditions could be "better." Any of these factors would make for more excess discarding. Given such events, the alternative of discarding and storage (rather than discarding and destruction) may become more feasible.

Storage

Storing discarded grades will be profitable if profit on the stored grades exceeds profit on grades the stored tobacco replaces (that is, tobacco which could be produced next season). Profit on the stored grades equals their average price minus the cost of storage. A comparable profit estimate for the next season's grades equals the expected average price minus the normal costs of production. This bare expected-value logic, however, skims over the hazards connected with stored tobacco such as the uncertainty of its price due to insect damage, molding, discoloration, etc. Certainly, some burley farmers already know of instances where storage has worked rather well, but much more technical research knowledge and experience needs to be gained before over-production and storage could be recommended.

Replacement Discarding

Even under the acreage-control program, some very low quality leaves (such as the worst ground leaves or very green tips) sometimes are discarded. If the unused quota could be carried forward to future years, such voluntary discarding certainly should be much more common. The cost of replacement discarding will be equal to (1) the potential, average price of the discarded grades plus (2) interest returns on this year's potential sales plus (3) the cost of producing replacement tobacco (next year). Again, using an example, suppose Farmer Jones has produced short of 110 percent of his quota and is considering discarding a grade he estimates would sell for 40 cents. Suppose his average cost of producing a replacement grade up to the point of hauling and selling is 22 cents (per pound). Adding the two together (40 + 22) we see that the replacement grade must sell for more than 62 cents before discarding is profitable. How much more depends upon the extent that Farmer Jones needs his money during the current season, that is, the interest rate. In short, replacement discarding is profitable only if next year's (replacement) price exceeds this year's price by more than the cost of producing replacement tobacco (to the same seasonal point in time or production stage).

Replacement discarding is more likely to be profitable as (1) the cost of producing replacement tobacco is lower, (2) this year's potential price is lower and (3) the potential replacement price is higher. The first two of these generalizations are the same as those listed (above) for excess discarding. Thus, both types of discarding have some of the same implications. Any method of production which lowers operating costs (such as use of harvesters and other mechanized processes) will tend to make replacement discarding more profitable. It is estimated that burley-tobacco operating costs prior to harvest average less than 10 cents per pound.[10] Thus, if stalks having leaves worth less than an average of, say, 40 cents can be identified and discarded in the field, they can profitably be replaced by leaves selling for more than 50 cents next year. Thin-leafed grades which have a potentially low price will tend to be replaced by heavier grades (lugs and leaf) which have a potentially high replacement price. Additional research is needed on this question but it would seem reasonable that the cost per pound of producing the lighter grades would be substantially more than for the heavier grades.

Aggregate Amounts of Discarding

The previous discussion has been limited primarily to how individual farmers' costs of production (by grades) and grade-price variation (for successive production seasons) will affect the amount of tobacco profitably discarded. A number of interacting variables should determine the aggregate amount discarded, including (1) type of season with its obvious effect on grade and price distributions, (2) variability of grade and price distributions among farmers, (3) the distinct possibility of some type of workable on-the-farm storage of tobacco produced in excess of quotas, (4) sale of excess tobacco on other marketing cards (legal or illegal), (5) future grade-price supports established by the government grading service, and (6) the elasticity of demand for various grades most subject to discarding.

Most observers of burley tobacco production and marketing will attest to the impact of the first two variables. Still, quantifying effects of these variables could be very difficult if not mostly guesswork. The third variable is one which is just emerging as a possible relevant factor. As noted previously, storing tobacco will be profitable if the average price of the stored grades (when sold the next season) is greater than the average price of the grades replaced (i.e., next season's production) by the amount of storage costs plus interest charges on production costs incurred in the current season rather than the next one. In substance, though, there are many unanswered technical and marketing questions about this variable. The fourth variable is highly dependent upon the first and second variables. Doubtless there will be some transfer of poundage among marketing cards. The system of compensation for such services is open to question, but there is little question that officials might not be able to enforce effectively any provision of the poundage-control law which regulates this activity. The last two variables are closely connected to each other; demand elasticity by grades remains a major area for much needed empirical inquiry.

Market prices for various grades may change substantially over time—i.e., we lack knowledge about the elasticity of demand by grades. If many burley farmers do find it profitable to discard certain grades (which are now the lower-prices grades) the prices of these grades may increase drastically for a period of time. After an initial wave of discarding these grades, resultant higher prices may then make it unprofitable. However, if a large proportion of such discarding takes place at the time of harvesting, the "equilibrium price" on these grades may not

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[10] Estimate made by Dr. Joe Smiley, Tobacco Specialist, Department of Agronomy, University of Kentucky.

be reached until another sales season; or, one might speculate that this activity could result in continuously fluctuating price with no stable equilibrium being reached.

The possibility of mass discarding of certain grades with a resultant erratic price pattern leads one to ask if tobacco companies may after certain seasons be forced to make certain buying adjustments.[11] Is it possible that they may be forced to change cigarette or cigar blends? In any case there is the possibility that companies may substitute some foreign grades or certain grades of other types of tobacco (e.g., flue-cured, Oriental) for the grades which have been heavily discarded. It may be only a slight possibility that such substitution will occur in much magnitude. Rather, it appears more probable that most of the discarding will be done at the time of grading for the market; if so, then higher prices within a season will be met by greater offerings of these grades. Some grade-price adjustments by the government grading service may be needed, but in total the price system should work adequately as a signaling system to insure "adequate" supplies of various grades.

CONCLUSION

This report has dealt primarily with conceptual aspects of differences in optimum burley tobacco production and marketing strategies, under poundage quotas as compared with acreage allotments. It has been shown that under poundage quotas maximum profits will be attained at lower yields. In addition, there are sound reasons to expect much less concern with salvaging as many leaves if (as expected) poundage quotas were made durable or timeless, i.e., allowing use of present allotment in future years and vice versa. To some extent, the magnitude of these expected directions has been quantified. However, results reported here must be regarded as preliminary.

More detailed analyses of survey and experimental data not currently available are needed. There is a need to know the effects of yield changes upon price and costs, regardless of the type of tobacco program which is in operation. Tobacco producers need to know more about the effects of changes in production practices (variable inputs) upon price and costs; they also need to know how these effects are related to the size of operation (tobacco acreage), and how technically feasible mechanical harvesting systems may be related to each of these variables. These and other relevant problems will be considered in subsequent studies.

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[11] This possibility seems even more probable in view of the apparent lower stocks of many grades now carried by tobacco companies, i.e., in comparison with those of the 1950's.

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APPENDIX

The discussion accompanying Figure 1 was designed to prove verbally that the maximum profit per pound is always attained at a lower yield than the maximum profit per acre. Some readers may prefer a more rigorous approach. The proof set forth here will hold only if one assumes a unique yield for which maximum profit per pound exists.

Definitions and Symbols

P = Market price per pound; $P = f(Y)$,
C = Average variable cost or variable cost/pound; $C = g(Y)$,
Y = Yield (pounds per acre),
π^* = Net returns ("profit") per pound $= P\text{-}C$,
π° = Net returns ("profit") per acre $= (P\text{-}C)Y$,
$P' = \frac{d(P)}{dY}$,
$C' = \frac{d(C)}{dY}$,
Y^* = Yield which will maximize π^*,
Y° = Yield which will maximize π°:

Necessary Conditions

Maximum profit per pound is attained with a yield where

$$\frac{d(\pi^*)}{dY} = 0$$

or where,

$$P'\text{-}C' = 0$$

Maximum profit per acre is attained with a yield where

$$\frac{d(\pi^\circ)}{dY} = 0$$

or where,

$$\frac{d[(P\text{-}C)Y]}{dY} = 0.$$

This equality can be written as follows:

$$(P\text{-}C)\frac{dY}{dY} + Y\frac{d(P\text{-}C)}{dY} = 0,$$

which reduces to

$$(P\text{-}C) + Y(P' - C') = 0,$$

which further reduces to

$$Y = (P\text{-}C)\,\frac{-1}{P' - C'}\,.$$

If $P\text{-}C > 0$, then in order for $(P\text{-}C)\frac{-1}{P'\text{-}C'}$ to be positive it is necessary that $C' > P'$. Otherwise, $\frac{-1}{P'\text{-}C'}$ will be negative (undefined if $C' = P'$) and the resultant product will be negative. Hence, it is necessary for $C' > P'$ in order for Y° to be positive.

The Proof

Consider (as implied above) only positive yield levels. For either Y^* or Y° to exist, it is mandatory that $P\text{-}C > 0$. Otherwise profit, either π^* or π°, is negative.

For any yield level where $C' > P'$ (the necessary condition for having a maximum π°) it is not possible to have a maximum π^*. This is the case because unit cost and price are converging—by definition π^* is decreasing. Hence, the only combination of P and C functions which are "practically relevant" are those which behave as follows:

(1) For low yield ranges (zero up to some positive yield), $P' > C'$. If this holds then π^* is increasing; also as Y increases π° is also increasing. But, π° can only reach a maximum when $C' > P'$.

(2) As yield is further increased, C' will increase relative to P' to a point where $P' = C'$. At this yield, as proved above, the maximum

π^* will occur.[1]

(3) For all higher yield ranges, $C' > P'$. Selecting any yield in this range, it is impossible to achieve a maximum π^* because this can only occur when $P' = C'$. It is not possible to achieve a maximum π° at a yield level lower than the one at which π^* exists, since for all yields less than the yield where $P' = C'$ the condition that $C' < P'$ has been imposed in order to make the combination of the two functions obey practical relevance.

Therefore, Y° will only occur (under these conditions) at some level which is greater than the level where Y^* occurs.

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[1] Indeed, it is only possible for the equality $P' = C'$, to occur when, for a certain yield range just below the yield where $P' = C'$, the P and C functions are diverging, i.e., in order for $P' = C'$ then $P' > C'$ for yields just below this point.