INFLUENCE OF MANAGEMENT SYSTEMS, CULTIVARS, AND PLANTING DATES ON FLUE-CURED TOBACCO PRODUCTION: I. AGRONOMIC CHARACTERS.[1]

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Management systems for flue-cured tobacco (**Nicotiana tabacum** L.) involving variations in topping height, number of harvests, planting date, and cultivars with different ripening patterns were compared with a conventional system of topping and harvesting to evaluate their influence on yield and quality of flue-cured tobacco. With the conventional system (18/6), tobacco was topped at 18 leaves and harvested six times. The reduced systems consisted of an 18-leaf topping harvested three times (18/3), a 15-leaf topping with two harvests (15/2) and a 12-leaf topping with a once-over harvest (12/1). In each of the systems, the number of leaves per unit area was kept constant by modification of plant population. In addition, systems with increased leaf number and N fertilization were used for the 12-leaf (12/1(+)) and 15-leaf (15/2(+)) systems.

Evaluation of the systems involved yields by stalk positions, harvests, and the complete plant. Other measurements taken included dollars/quintal and analysis of the USDA grade distribution for group, quality, and color categories, and the tobacco companies' usability evaluation. Data were also collected on the relation between the date of planting and the date of harvest.

The 12-leaf topping with one harvest produced substantially lower yields and subtle quality alterations of the tobacco. These yield losses were primarily due to overripeness and loss of lower leaves. Quality alterations in the tobacco from once-over systems were characterized by changes in the USDA grade distribution. The intermediate systems 15/2(+) and 18/3 produced yields and quality equal to that of the conventional system. These advantages plus the potential labor savings and economic gains make the 15/2(+) and 18/3 feasible systems.

Date of planting-date of harvest relationships were evaluated by using two planting dates to lengthen the harvest season. However, prediction of the harvest interval from the planting interval is virtually impossible.

Flue-cured tobacco farmers are caught in a price-cost squeeze. Production costs are continually increasing with the labor cost rising as the supply decreases. As a result, farmers are seeking alternate, labor saving systems for harvesting tobacco (2, 4, 5). Generally, reducing the number of harvests of flue-cured tobacco to fewer than the conventional five or six saves labor costs, but yield and quality may be reduced (2, 3, 4, 5). The magnitudes of the yield and quality alterations are related to the degree of reduction in harvests.

With fewer harvests, handling and space problems become significant. A harvest schedule must be established and followed that permits optimum utilization of existing facilities and allows accommodation of all tobacco ready on a given day. The harvest season might be lengthened, thus offsetting the handling and space problems resulting from fewer harvests, by using tobacco cultivars with diverse ripening patterns and staggered planting dates. Normally, however, delays in transplanting do not result in similar delays in harvest but generally result in lower yield and quality (1, 5. 9, 10).

The primary objective of this study was to determine the feasibility of reducing the number of harvests through variations in plant spacings, topping heights, planting dates, and the use of cultivars with different ripening patterns while maintaining quality and quantities of tobacco acceptable to all segments of the tobacco industry.

MATERIALS AND METHODS

Experiments were conducted in 1971 and 1972 at the Lower Coastal Plain Tobacco Research Station near Kinston, N.C. and at the Central Crops Research Station near Clayton, N.C. The soil type at Kinston was Lynchburg fine sandy loam in 1971 and Norfolk fine sandy loam in 1972; Norfolk sandy loam was used both years at Clayton.

A split-split plot experimental design with three replications was employed. Two dates of planting, one week

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Table 1. Description of management systems.

Management system	Number of leaves/plant	Number of harvests	Stalk positions 1 2 3 4 5 6	Leaf number/ hectare	N fertilizer
12/1	12	1	[3 + 3 + 3 + 3][a]	281,700	Recommended
15/2	15	2	[3 + 3] [3 + 3 + 3]	281,700	Recommended
18/3	18	3	[3 + 3] [3 + 3] [3 + 3]	281,700	Recommended
18/6	18	6	[3] [3] [3] [3] [3] [3]	281,700	Recommended
12/1(+)	12	1	[3 + 3 + 3 + 3]	296,500	Recommended + 10%
15/2(+)	15	2	[3 + 3] [3 + 3 + 3]	296,500	Recommended + 10%

[a] *Brackets enclose positions and number of leaves harvested at one time.*

earlier and one week later than normal for the location, were used as the whole plots. Seedlings for the early transplanting were obtained by seeding beds in early January and covering them with plastic; beds for the late transplanting were seeded one month later and covered with cloth. Three flue-cured tobacco cultivars, Speight G-41, Speight G-28,: Coker 319, and an experimental line, NC 6129 (believed adapted to reduced harvest (4)) were used as the subplot treatments. The sub-subplot treatments were six management systems **(Table 1)**; which consisted of 12-, 15-, and 18-leaf topping heights with 1, 2, 3, or 6 harvests, depending on the particular management system employed. Non-commercial lower leaves were removed and the plants topped as they displayed the desired leaf number. The systems had constant fertilization and leaf number per hectare (281,700) with the exception of the 12/1(+) and 15/2(+) systems, which had 10% additional leaves nitrogen per hectare. Yield has been reported to be a function of leaf number/acre, with 120,000 leaves/acre (296,500 leaves/hectare) considered optimum (13). The conventional management system was represented by the 18/6 treatment.

The management systems were randomly imposed on 1-row plots spaced 114.3 cm apart. Plant spacing within the row was varied, depending on topping height, to obtain the desired leaf number/ha. For general cultural practices not dictated by the treatment specifications, normal research station practices for flue-cured tobacco production were followed. Hand-suckering and Off-Shoot-T[7] were used to control suckers in 1971 and 1972, respectively. In 1972, fertilizer applications were adjusted to compensate for leaching losses at both locations according to recommendations for flue-cured tobacco (7, 11).

As noted in **Table 1**, the tobacco was kept in separate 3-leaf stalk segments when harvested, with stalk position numbering beginning at the bottom and proceeding up the stalk. As the tobacco neared maturity, individual plots were inspected daily to determine when to harvest to avoid excessive loss due to over-ripeness at the bottom of the particular harvest, while striving for a minimum of unripe and immature tobacco at the top of the harvest. Tobacco from the various management systems was cured in separate units whenever possible.

Tobacco of each 3-leaf stalk position was graded by a USDA Tobacco Marketing Specialist from the Tobacco Division, Agricultural Marketing Service. Dollars per quintal (based on the average warehouse prices paid for each grade for the current and previous year) was used as an index of quality.

To determine yield differences among treatments, data by stalk position and harvest (that tobacco removed from the plant on a given day) were used. Data were recorded as the percent weight of tobacco in each group and quality category (as described by the USDA Consumer and Market Service-Tobacco Division (12)) as well as the percent in the combined immature and unripe (degrees of maturity) categories.

In both 1971 and 1972, buyers from six tobacco companies evaluated the tobaccos of one replication from Kinston by scoring each lot of tobacco (by stalk position) as usable or not usable.

The split-split plot analysis of variance was used and appropriate tests of significance were made as indicated by the linear model assuming year and location effects to be random and date, cultivar, and system effects to be fixed. Tests of significance on the percentage data should be regarded as approximations only since such data may not satisfy the normality and/or homogeneity of error variance assumptions. The usability data were analyzed using Chi-square tests of homogeneity over various categories. Statistical significance at the 5% and the 1% levels has been indicated by one and two asterisks, respectively.

RESULTS

In no case were interactions among the primary factors (dates, cultivars, and systems) significant although in some cases these factors produced significant inter-

Table 2. Average yields (by stalk positions and system total) and average values for management systems.

Management System	Stalk Position Yield 1	2	3	4	5	6	Yield System	Value System
	kg/ha							$/quintal
12/1	(145	381	713	901)[a]			2140	179.19
15/2	(317	462)	(413	649	675)		2516	180.25
18/3	(281	400)	(498	528)	(473	463)	2643	179.41
18/6	(308)	(374)	(473)	(508)	(498)	(500)	2661	179.56
12/1(+)	(162	396	730	896)			2184	179.12
15/2(+)	(326	473)	(442	669	708)		2618	179.89
LSD .05							100	NS

[a] *Parentheses enclose yields for stalk positions harvested at the same time.*

Table 3. The weighted percentage of tobacco in each group category of the USDA grade for the tobacco of the various management systems.

Management System	Group N	P	X	C	H	B
12/1	6.7	4.0	14.8	16.8	3.2	54.4
15/2	1.3	10.1	17.2	13.5	4.4	53.6
18/3	2.2	8.9	16.5	14.7	2.4	55.3
18/6	2.0	9.3	15.4	13.5	1.6	58.2
12/1(+)	7.9	3.5	14.9	17.1	3.5	53.0
15/2(+)	1.4	10.7	17.8	10.6	6.5	53.0
LSD .05	NS	2.2	NS	NS	NS	NS

Table 4. The weighted percentage of tobacco in the various quality categories of the USDA grade by management systems and that in the unripe plus immature category.

Management System	Quality Category 1	2	3	4	5	6	Unripe plus immature
12/1	0.0	0.0	28.6	33.2	34.5	3.7	11.4
15/2	0.4	1.6	25.4	46.7	24.4	1.5	10.8
18/3	0.9	1.6	26.4	46.8	22.4	1.8	15.0
18/6	1.2	2.8	24.2	46.1	23.6	2.0	14.4
12/1(+)	0.0	0.9	22.8	36.4	35.9	4.0	10.6
15/2(+)	0.0	2.3	20.9	47.8	27.7	1.3	10.3

[7] *Mention of a trade name does not constitute a guarantee or warranty of the product by N.C. State University or the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.*

Table 5. Usability evaluation by company and management system.[a]

Management system	Company A	B[b]	C	D[b]	E[b]	F	G[b]	H
	No. lots usable/Total no. lots evaluated							
12/1	2/53	16/27	47/53	7/26	9/26	33/53	5/27	39/53
15/2	2/80	27/40	71/80	19/40	23/40	52/80	19/40	57/80
18/3	5/96	21/48	85/96	31/48	26/48	57/96	17/48	57/96
18/6	6/95	22/48	80/95	32/47	23/47	51/95	19/48	58/95
12/1(+)	4/52	16/27	43/52	6/25	9/25	32/52	9/27	38/52
15/2(+)	7/80	26/40	68/80	16/40	20/40	53/80	17/40	54/80

[a] *Data totaled for one replication at Kinston for 2 years, two dates of planting, and four varieties over stalk positions.*
[b] *Evaluation by companies B and G in 1971 and companies D and E in 1972.*

Table 6. Chi-square test for homogeneity of proportions usable by a given company over management systems.

System(s) comparison	d.f.	Company A	B	C	D	E	F	G	H
Total	5	3.77	8.61	2.11	24.17**	5.52	3.75	6.67	6.50
12/1 vs. 12/1(+)	(1)	.75	.00	.77	.06	.01	.01	1.54	.00
15/2 vs. 15/2(+)	(1)	2.94	.06	.49	.46	.45	.03	.20	.27
18/3 vs. 18/6	(1)	.11	.04	.76	.13	.26	.63	.18	.06
15 vs. 18	(1)	.00	8.10**	.02	8.98**	.08	3.01	1.02	3.19
12 vs. (15 + 18)	(1)	.00	.37	.06	14.71**	4.72*	.05	3.96*[a]	2.90

[a] *Not significant when corrected for continuity, $X^2=3.35$.*

actions with years and/or locations. Date of planting effects were not significant; consequently, all results are presented or discussed in terms of management system and cultivar effects and/or means.

Management Systems

At constant fertilizer and leaf number/hectare, conventionally topped tobacco (18 leaves) produced significantly higher yields, whether harvested three or six times **(Table 2)**, then did tobacco with reduced topping height and fewer harvests. The 15/2(+) system (15-leaf topping with two harvests with increased leaves/hectare (10% more) and increased N fertilization (10% more)) produced yields equivalent to those of the 18-leaf systems. These results compare favorably to the report that harvesting conventionally topped tobacco by third- or half-stalk postions only slightly reduced yields compared to that of conventionally harvested tobacco (8). Yields for both 12-leaf systems were equivalent, but they were lower than those of the other systems.

Yields at various stalk position designations can be used to explain yield differences among management systems **(Table 2)**. The yield of stalk position 3 in 15-leaf systems was depressed because it represented the lower, overripe leaves of the second harvest. It is apparent also that since a leaf position for the 12-leaf toppings had 50% more leaves/hectare than a leaf position for the 18-leaf topping, large reductions in average leaf weight occurred in the first stalk position and smaller losses in the second stalk position for the 12-leaf systems.

The most reduced systems (12/1 and 12/1(+)) had a lower percentage of the tobacco in the P group, but a higher percentage in the N group, than did the other systems **(Table 3)**. This is indicative of the adverse effects of a once-over harvest, even on tobacco with only 12 leaves/plant since P group tobacco is of better quality than N group tobacco. Gwynn (5) also reported that once-over harvest resulted in more nondescript grades of lower priced tobacco. In addition, the lower percentage of tobacco in the higher fourth quality category and the higher percentage in the lower fifth quality category for the 12-leaf systems are other indicators of the unfavorable effects of a once-over harvest on the quality of flue-cured tobacco **(Table 4)**. However, these differences were not reflected in the average prices paid on the warehouse floor **(Table 2)**.

The highest percentage of unripe plus immature tobacco was produced by the more conventional-type systems **(Table 4)**, which is contrary to the general assmuption that reducing the number of harvests increases the proportion of unripe and immature tobacco. In actual practice, however, the amount of unripe and immature and/or overripe tobacco will depend on the timing of the harvest.

The usability evaluation by the companies is presented in **Table 5**. Preferences were not discernible between comparable topping systems, i.e. between 12/1 and 12/1(+), 15/2 and 15/2(+), or 18/3 and 18/6 **(Table 6)**. However, company B declared 66% of the 15 leaf-topping lots to be usable, but only 45% of the 18 leaf-topping lots were deemed usable. Conversely, comparable preferences for those systems by company D were 44% and 66%, respectively. Thus, over all comparisons, there was no net preference between the 15- and 18-leaf systems. The decreased usability of the 12-leaf systems arises from the fact that companies D and E deemed the tobacco from the 12-leaf systems to be less usable than from the (15 + 18) systems.

Usability for different stalk positions is compared in **Table 7**. The chi-square test **(Table 8)** tests the hypothesis that the proportion of lots usable by stalk position is the same over management systems. Heterogeneity occurs in three places; the 12-leaf topping systems differ significantly from the other systems for stalk positions 2, 3, and 4, where the proportions usable for the 12-leaf systems and the average of all the other systems were, respectively, 63% and 76% for position 2, 56% and 70% for position 3, and 32% and 52% for position 4.

Cultivars

Cultivar variability was mostly genetic and not a con-

Table 7. Usability evaluation by stalk position and management systems.[a]

Management system	Stalk position 1	2	3	4	5	6
	No. lots usable/Total no. lots evaluated					
12/1	13/30	61/96	55/96	29/96		
15/2	51/96	70/96	70/96	48/96	31/96	
18/3	55/96	76/96	69/96	51/96	31/96	17/96
18/6	56/96	75/96	64/96	51/96	31/96	14/90
12/1(+)	12/24	59/96	53/96	33/96		
15/2(+)	46/96	72/96	65/96	51/96	27/96	

[a] *Data totaled for one replication at Kinston for 2 years, two dates of planting, four varieties, and six companies.*

Table 8. Chi-square test for homogeneity of proportions usable by stalk positions over management systems.

System(s) comparison	d.f.	Stalk position					
		1	2	3	4	5	6
Total	5	4.01	13.29**	11.64*[a]	21.36**	(3).58	(1).16
12/1 vs. 12/1(+)	(1)	.24	.09	.08	.38	----	----
15/2 vs. 15/2(+)	(1)	.52	.11	.62	.19	.40	----
18/3 vs. 18/6	(1)	.02	.03	.61	.00	.00	.16
15 vs. 18	(1)	2.06	1.17	.05	.09	.19	----
12 vs. (15 + 18)	(1)	1.18	12.01**	10.36**	20.74**	----	----

[a] *Not significant when corrected for continuity, X^2=10.12.*

sequence of the management system imposed as no significant interactions between management systems and cultivars occurred. Speight G-41 produced a higher yield than did the other three cultivars. However, cultivars did not differ in value/quintal.

Speight G-41 produced a higher amount of B group tobacco than did Speight G-28 and NC 6129. Speight G-41 also produced the highest quality tobacco as it had a significantly lower percentage of tobacco in the low quality fifth category of the USDA grade.

Even though cultivars were selected with the probability of being diverse in their maturity dates, there were no consistent differences in harvest dates among the cultivars.

Planting Date

The harvest interval between the tobaccos transplanted 2 weeks apart ranged from –4 to 20 days (**Table 9**). Harvest interval varied considerably for the individual harvests within each management system; consequently, it is virtually impossible to predict the harvest date based on the planting date. Much of the 2-week planting delay had been offset by the time of topping; for the 12/1 and 12/1(+) systems, the interval ranged from 6 to 8 days; for the other systems, from 5 to 11 days. Some compensation is expected under normal grow-in conditions. Faster maturation for later planted tobacco is a consequence of more rapid growth and, thus, thinner tobacco which may senesce faster. Later planted tobacco is also more susceptible to leaf diseases such as *A. alternata* (4, 6) and weather damage and, accordingly, must be harvested sooner to avoid yield and quality losses. Weather conditions at the time of planting also affects early growth and, thus, harvest date.

Differences among cultivars for a date-of-planting interval at harvest were inconsistent.

DISCUSSION

The use of management systems involving reduced topping height and fewer harvests can increase harvest efficiency of flue-cured tobacco. Once-over harvest permits more efficient use of mechanical primers in terms of the number of leaves harvested per unit area covered, and also requires less harvest time. However, reducing the number of harvests results in larger volumes of tobacco per harvest and thus a shorter harvest season, which must be dealt with by faster curing rates, scheduled use of barns, scheduled harvests, or by some other method.

Farmers utilizing management systems such as the 12/1 or 12/1(+) systems can expect yield losses and subtle quality alterations of flue-cured tobacco when compared to conventional management systems. Yield losses in the once-over systems result from overripeness of the bottom leaves as harvest is delayed while waiting for the top leaves to mature since flue-cured tobacco ripens progressively upward from the bottom to the top of the plant. The once-over harvest is best accomplished when the midstalk portion of the plant is ripe, but this will probably result in some overripe lower leaves or immature top leaves, both of which result in lower yields and quality of tobacco. In fact, some of the lower leaves may be too deteriorated to harvest.

The once-over harvest results in more nondescript (N group tobacco) at the expense of P group tobacco, substantiating the yield losses and quality alternations of these lower leaves. In addition, the tobacco companies did not find the tobacco from stalk positions 2, 3, and 4 of the 12-leaf systems as usable as that of the other systems. Yield lost in the once-over system (12 leaves) apparently cannot be compensated for by increasing leaf densities and N fertilization.

The 15-leaf systems harvested twice resulted in yields and quality more like those of conventionally managed

Table 9. Interval (days) between comparable toppings and comparable harvests of tobacco transplanted 2 weeks apart.

System	Variety	Interval maintained at topping time (range in days)	Interval maintained for individual harvests (range in days)[a]					
			1	2	3	4	5	6
12/1	Sp. G-41	6 to 8	2 to 8					
	Sp. G-28	6 to 8	6 to 10					
	NC 6129	6 to 8	0 to 10					
	C 319	6 to 8	3 to 8					
15/2	Sp. G-41	5 to 11	0 to 7	1 to 6				
	Sp. G-28	5 to 11	0 to 7	0 to 3				
	NC 6129	5 to 11	0 to 7	1 to 6				
	C 319	5 to 11	0 to 7	0 to 4				
18/3	Sp. G-41	6 to 11	1 to 14	3 to 13	–1 to 6			
	Sp. G-28	6 to 11	0 to 14	5 to 9	0 to 6			
	NC 6129	6 to 11	–4 to 14	–2 to 8	–3 to 6			
	C 319	6 to 11	0 to 14	3 to 8	1 to 7			
18/6	Sp. G-41	6 to 11	0 to 7	4 to 7	7 to 20	–1 to 10	–2 to 6	–1 to 6
	Sp. G-28	6 to 11	0 to 7	0 to 7	0 to 20	–1 to 8	–2 to 6	–1 to 6
	NC 6129	6 to 11	0 to 7	0 to 7	0 to 20	–1 to 8	–2 to 6	–2 to 6
	C 319	6 to 11	0 to 7	0 to 7	0 to 20	0 to 8	1 to 6	–1 to 6
12/1(+)	Sp. G-41	6 to 8	3 to 8					
	Sp. G-28	6 to 8	6 to 8					
	NC 6129	6 to 8	2 to 10					
	C 319	6 to 8	0 to 8					
15/2(+)	Sp. G-41	5 to 11	–3 to 7	1 to 4				
	Sp. G-28	5 to 11	0 to 7	1 to 8				
	NC 6129	5 to 11	2 to 7	2 to 14				
	C 319	5 to 11	–1 to 7	–1 to 10				

[a] *Averaged over replications.*

tobacco. An early harvest of the two bottom positions resulted in little or no leaf loss; delayed harvesting of the top three stalk positions of the 15-leaf systems permitted weight gains not available to those leaves present in the 12-leaf systems. In addition, the two harvests resulted in more uniform maturity within each harvest permitting a better cure and, consequently, higher quality tobacco. Tobacco quality equal to that of the conventional system can be obtained by the 15-leaf systems (with two harvests). When leaf population and N fertilization were increased by 10% for the 15-leaf system, thus providing additional resources, the yield equaled that of the conventional system.

The 18-leaf system harvested three times (18/3) also produced yield and quality equal to those of the 18/6 system.

The results of the study suggest that the USDA grade distribution is indicative of actual quality of the tobacco and possibly should replace the value/quintal as a quality index, inasmuch as buying patterns by tobacco companies in recent years result in small differences in value/quintal among tobaccos.

The use of cultivars with different maturity patterns and the staggering of planting dates may be only partially successful in extending the harvest season to alleviate overcrowded curing facilities resulting from larger volumes of tobacco in few harvests. Successive planting dates may offer some potential for extending the harvest season, but the variability and unpredictability of maintaining a date of planting interval through harvest make their chances of success small. Optimal environmental conditions from establishment until harvest will likely be necessary for the successful use of staggered planting dates to lengthen the harvest season.

An intermediate system between the most reduced and conventional systems, such as the 15/2(+) or the 18/3, appear to be quite usable compromises. These systems offer tobacco growers potential labor savings and thus economic gains while producing tobacco of desirable yield and quality.

LIST OF REFERENCES

1. Beake, C. 1956. Early planting of tobacco. **Izlojba Jugoslov.** Duvana, Skoplje. pp. 38–44.
2. Brown, G. W. and T. R. Terrill. 1972. Effects of method of harvest of flue-cured tobacco. I. Agronomic Factors. **Agron. J.** 64:619–622.
3. Chappell, J. S. 1971. Reducing tobacco harvest. **Res. Farm. N.C. Agr. Exp. Sta. Bull.** 29. p. 11.
4. Gwynn, G. R. 1969. Influence of harvesting methods on flue-cured tobacco. **Agron. J.** 61:429–433.
5. Gwynn, G. R. 1974. Modified systems of production and harvesting of flue-cured tobacco. **Tob. Sci.** 18:23–25.
6. Hawks, S. N. 1970. **Principles of flue-cured tobacco production.** S. N. Hawks, Jr. Raleigh, N.C.
7. Hawks, S. N. and C. B. McCants. 1968. Guides for fertilizing flue-cured tobacco. **N.C. Agr. Exp. Sta. Bull.** 212.
8. Johnson, W. H. 1966. Influence of harvesting procedures and curing variables on characteristics of Virginia type tobacco. **Fourth Int. Tob. Sci. Congr.** Athens, Greece. pp. 300–315.
9. Muraoka, Y. and T. Tokitsu. 1959. Effects of time of planting on yield and quality of tobacco leaves. **Okayama Tob. Exp. Sta. Bull.** 17. pp. 2–10.
10. Pointer J. P. and W. G. Woltz. 1956. Investigations of hail damaged tobacco. **N.C. Agr. Exp. Sta. Bull.** 123.
11. Terry, D. L. and C. B. McCants. 1970. Quantative prediction of leaching in field soils. **Soil Sci. Soc. Amer. Proc.** 34: 271–276.
12. U.S. Department of Agriculture. **Official standard grades for flue-cured tobacco.** Consumer and Market Service Tobacco Division, U.S.G.P.O. Wash., D.C.
13. Woltz, W. G. and D. D. Mason. 1966. Effects of plant spacing and height of topping on bright tobacco on some agronomic characteristics. **Fourth Int. Tob. Sci. Congr.** Athens, Greece. pp. 197–208.