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The Effects of
MALEIC HYDRAZIDE
On the Suitability of Tobacco For Cigarette Manufacture

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INTRODUCTION

On May 4, 1960, the Tobacco Subcommittee of the Committee on Agriculture of the House of Representatives released a statement dealing with the use of maleic hydrazide on tobacco.

The Tobacco Subcommittee directed the Department of Agriculture to "undertake a concentrated and comprehensive research program for the purpose of ascertaining definitely and conclusively the effects which the utilization of the chemical MH-30 (maleic hydrazide) in sucker growth control may have upon the tobacco leaf produced for cigarette manufacture."

Maleic hydrazide was first discovered to be a plant growth control regulator in purely academic research, and it was first found to control suckers on tobacco plants in the course of research of a university graduate student in 1949. Several state experiment stations and the United States Department of Agriculture have carried out many experiments on the agronomic effects of this chemical. Since the ultimate effects of the chemical could not be determined without the manufacture of cigarettes, it had not been possible for the Department to make such studies. The previous cooperative studies with industry have been helpful but not adequate to answer the Congressional request.

In the present study, a thorough and independent appraisal was made on a coded and therefore unbiased basis. The leaf was grown under carefully controlled conditions and was examined by leaf experts, subjected to laboratory evaluation by physical and chemical methods, and manufactured into cigarettes which were smoked by expert smoking panels.

The results are considered to be as conclusive as could be obtained in one season. This represents the most extensive experiment to date on the effect of a single agronomic practice on tobacco acceptability. It should be noted, however, that in addition to suckering methods, other farm practices such as kind and amount of fertilization, irrigation, and curing affect tobacco quality.

SUMMARY OF FINDINGS

The information on the effects of maleic hydrazide available prior to this study indicated that treatment with this chemical normally controlled suckers, increased yields, increased returns per acre, and caused differences in the physical and chemical composition of the leaf. No research data were publicly available on the physical properties or smoking properties of cigarettes made from treated leaf.

Experiments covering the entire cigarette tobacco-growing area were conducted on the 1960 crop. Tobacco was grown in Florida, Georgia, North and South Carolina, Virginia, Tennessee, Kentucky, West Virginia, and Maryland and was hand suckered or treated with maleic hydrazide at each of three stages of plant maturity.

The results were as follows:

1) In judging coded, cured-leaf samples when displayed on the warehouse floor, leaf experts indicated a significant preference for hand-suckered, flue-cured tobacco compared to chemically suckered samples. However, the results indicate it is not always possible for the leaf expert to differentiate individual treated and untreated lots on the warehouse floor. No significant preferences were demonstrated in the air-cured samples, represented by burley and Maryland tobaccos.

2) Certain of the physical and chemical analyses gave differences, reliable by statistical test, between the hand-suckered samples and those chemically suckered at all stages of maturity. Among the most consistent differences in flue-cured tobacco were decreases in specific volume

(filling power), total ash, alkalinity of the water soluble ash, and alpha amino nitrogen and increases in reducing sugars and moisture content on equilibration at 60 percent relative humidity. In air-cured tobacco, decreases in total ash and alkalinity of the water soluble ash were observed, along with increases in alpha amino nitrogen and in moisture content on equilibration at 60 percent relative humidity. Other trends were observed, such as that toward a decrease in alkaloids, which were not consistent enough to be statistically significant in the samples here described.

3) After the tobacco had been blended, aged and shredded, that from the chemically suckered plots caused more difficulty in cigarette manufacture than the hand-suckered tobacco.

4) The relative filling power of treated tobacco based on three separate kinds of determinations was as follows:

Basis of Determination of Filling Power	Hand Suckered	Time of Maleic Hydrazide Treatment: 1 week earlier	At full flower	1 week later
	%	%	%	%
Specific volume of leaf	100	93.8	95.4	94.9
"Draw" of cigarettes	100	89.0	94.4	96.3
Firmness of cigarettes	100	94.9	96.5	101.9
Average	100	92.6	95.4	97.7

5) Coded cigarettes made from hand-suckered tobacco were evaluated in three different ways by the members of expert smoking panels in comparison with coded cigarettes made from tobacco treated at each of three stages of growth with the following results:

a) The triangular test, which measures primarily differences in the taste of the smoke, gave a 9 to 1 probability that the

observed difference between hand-suckered and the earlier maleic hydrazide-treated samples was not due to chance, but there was no significant evidence of difference between hand-suckered samples and those chemically treated at full flower or later.

b) The binominal preference test, in which residual impressions from smoking a given cigarette are more readily discernible, gave an approximately 80 to 1 probability that the observed preference for the hand suckered over the earlier treated sample was not due to chance. No significant differences were found between the hand suckered and either of the later treated samples.

c) When panelists were asked to state their objections to the cigarette which they had not preferred of each of the pairs involved in the binomial test, critical adjectives were applied more frequently to samples chemically treated at the earlier and later stages of growth compared to the hand-suckered samples. No appreciable difference was noted between the hand-suckered sample and that treated at the full flowered stage.

6) Though the cost and labor of treating tobacco with maleic hydrazide are less than hand suckering, the principal financial incentive to the individual grower to use this chemical is the considerably greater yield per acre, especially if the chemical is used fairly early. Thus under existing acreage

control laws, the individual grower has an economic incentive to use this product at the time when it is most likely to affect the suitability of his tobacco for making cigarettes.

7) Because of smokers' preferences for cigarettes made from hand-suckered tobacco over those made from tobacco treated before full flower, and other unfavorable characteristics, the evidence collected in this study indicates that the application of maleic hydrazide at an early stage of growth results in the production of tobacco less suitable for cigarette manufacture. Statistically significant discrimination by smokers was not found at later times of treatment, but significant physical and chemical differences occur which are similar but generally not as pronounced as those found in the earlier treated tobacco. Since seasonal effects differ, the effect of later treatment in another season cannot be predicted on the basis of this research.

RESEARCH FINDINGS

Soon after the discovery in 1949 that maleic hydrazide would prevent sucker development in tobacco the United States Department of Agriculture and the State Experiment Stations started investigations with this chemical. Since neither the U. S. Department of Agriculture nor the State Experiment Stations have adequate facilities for judging acceptability of tobacco for manufacture and consumption, most of these studies have been based on yield, with price and acre return calculated from the average price of the U. S. official standard grades produced. These studies almost invariably show an increased acre return for the tobacco treated with maleic hydrazide. At first the difference most frequently mentioned in reports submitted by cigarette companies which had examined tobacco grown in State and Federal tests was in filling power. Later, other physical and chemical abnormalities were noted, especially after the 1958 season. Prior to the present study, no reports have been made public of smoking panel tests conducted with large numbers of smokers. Smoke evaluation tests appeared to be necessary before a definite answer could be given to the Tobacco Subcommittee. Through the full cooperation of all concerned, the tobacco produced in 1960 was put through accelerated aging and cigarettes manufactured and tested much sooner than would normally be possible. These tests are reported herein.

In planning and evaluating this research, consideration had to be given to what could be determined in quantitative terms. Addition to the number of opinions as to what was "better" or "worse" does not help in solving a situation already so confused that the Subcommittee requested the Department of Agriculture to undertake a research program on it. The questions which were believed to be

answerable with reasonable accuracy in a reasonable time as to the effects of sucker control by maleic hydrazide as compared to hand suckering are as follows:

1. Are tobaccos produced in these different ways detectable from each other by leaf experts on the auction warehouse floor?
2. Are these tobaccos different in physical and chemical composition as determined by the tests normally applied by the tobacco companies to evaluate tobacco leaf?
3. Are cigarettes made from treated and untreated tobacco detectably different in smoking characteristics or taste?

In order to answer these three questions as completely as possible on one season's results, it was necessary to grow tobacco at widely separated locations, in order to have as wide a range of weather and soil conditions and of normal cultural practices as possible. Advantage was taken of plans made by tobacco research workers at a Regional Sucker Control Conference held at North Carolina State College, in May 1960, which grew out of another conference on this problem held at the University of Tennessee in April of the same year.

Field Growth of Tobacco: Cigarette type tobacco was grown in Florida, Georgia, North and South Carolina, Virginia, West Virginia, Kentucky, Tennessee, and Maryland, comparing manual vs. chemical sucker control in adjacent plots of each location. In each state, tobacco was grown by procedures recommended for that area with respect to practices other than sucker control. Certain plots were hand suckered in the normal way and others were treated with maleic hydrazide

(MH-30) at the rate of approximately 1 pt. per 1000 plants. This rate is suggested by the manufacturer of the chemical. The active ingredient of this product is stated on the label to be 58% by weight of diethanolamine salt of 6 hydroxy-3-(2H) pyridazinone, equivalent to 30% of maleic hydrazide. In general, this means around 6 pts. per acre in the flue-cured tobacco and 8 pts. per acre in the burley. Evidence already indicated that the effects of the chemical depended to a considerable extent on the maturity of the tobacco at time of application. Three times of application were used. As a base point, the stage of flowering at which all plots were topped was at full flower, which was defined as the stage at which the first corollas were being shed on the majority of plants in the plots. This was illustrated by a picture sent to the research workers at each location in charge of growing the crop. The earliest time of treatment used in this study was as nearly as possible one week before full flower. This will be referred to in the text as the "earlier" treatment. This is not as early as some treatments have been applied by growers, but treatments earlier than that stage, at which a number of flowers would already be open, were already recognized by the research workers as undesirable from the standpoints of field and cured leaf appearance. The chemical was applied to the second group of treated plots just after topping at full flower. This will be referred to as the "full flower" treatment. The chemical was applied to the third group one week after full flower. This will be referred to as the "later" treatment. The three flower stages are shown in Fig. 1 in the Appendix. These three times of treatment were designed to cover the range of stages of growth at which the majority of treatments have been applied on farms.

The statement on the label of the commercial product recommends treating flue-cured tobacco when "90% of the plants are in middle to full flower" or "90% of burley plants have flower head half opened."

These plots were located on areas controlled by Stations or Substations of the State Experiment Stations, and all phases of the growth and sucker control were supervised by men trained in tobacco research methods. In some instances these were Federal employees and in others were members of the State Experiment Station staffs. The tobacco was cured in the customary manner for the types involved, but with the tobacco from each plot carefully labeled. Since the early primings of flue-cured tobacco are removed from the plant before the time of sucker control treatment and the mature leaves at the base of stalk-cut tobacco have reduced physiological activity by this time, the leaf from the lower third of the plant was omitted from the experiment to make possible a more intensive study of the leaf more likely to be affected by the treatment than would otherwise have been possible with the available facilities. Since previous data indicated a greater effect of suckering practice on the more immature top leaves than on the leaves from the middle of the plants, the leaf from the top third and middle third were handled separately in leaf evaluation and physical and chemical analysis. In an effort to eliminate as far as possible any preconceptions in the evaluation of these samples, they were coded, with the portion of the code referring to sucker control treatment being unknown to the persons evaluating them.

EVALUATION BY LEAF EXPERTS

The tobacco was separated into grades much as would be done for sale on the auction market by farmers. Leaf from Florida, Georgia, and South Carolina was examined by leaf experts from the various cigarette tobacco companies at Mullins, S. C. The flue-cured tobacco from North Carolina was examined at Durham and from Virginia at Danville. Burley tobacco from Kentucky, Tennessee, North Carolina, Virginia, and West Virginia, and Maryland tobacco were examined at Richmond, Virginia. These leaf displays were conducted in auction warehouses or other facilities with similar light conditions.

Leaf experts representing at least 6 major cigarette companies separately evaluated under code all of the leaf samples from the four different treatments at each location, assigning a value of 4 for the one most usable by their company and so on down to 1 for the least usable. The average scores of all companies for flue-cured tobacco grown in North and South Carolina and Georgia are given in Table 1. The results show that the leaf experts preferred the hand suckered, with a group score of 2.87 which was significantly above that of any of the maleic-hydrazide treated samples. The earlier treatment was least desirable, while the full flower and later treated were intermediate. The leaf experts observed a greater difference related to treatment between the leaves of the top third of the plant than between those of the middle third.

More detailed results of this test are given in Table 11 of the appendix. They show that there was considerable variation from location to location.

However, the data were subjected to statistical analysis, and the averages given in Table 1 represent a difference in the acceptability of the flue-cured tobaccos under the conditions of these tests. It should be noted, however, from Table 11 that at some locations it was not possible for the leaf experts to differentiate between the hand-suckered samples and those treated with maleic hydrazide. Thus, it is clear that under some conditions treatment with maleic hydrazide cannot be recognized on the auction floor even in the aggregate, to say nothing of ability to recognize it on particular baskets.

The results of the evaluations by leaf experts on the air-cured tobacco, which included Kentucky, Tennessee, North Carolina, Virginia, and West Virginia burley and Maryland, are shown in Table 2. The averages are not sufficiently different to indicate that the leaf experts could distinguish between the hand-suckered and chemically suckered air-cured tobacco grown for this experiment. Again there were wide differences from location to location, as shown in Table 12 of the appendix, but there were no consistent discriminations between the different treatments in the burley or Maryland tobaccos under the conditions of this test.

In conclusion, the results of the leaf evaluation tests show that the leaf experts generally:

(1) Selected hand-suckered, flue-cured tobacco samples as more usable than the chemically suckered tobacco; however, there were locations where they could not detect differences.

(2) Did not select any one of the four sucker control treatments of burley or Maryland as significantly superior to the others.

Table 1. Relative usability [1] as judged by leaf experts of flue-cured tobacco from different sucker control treatments

Treatments	Rating [1]		
	Middle Leaves	Top Leaves	Mean [2]
Hand suckered	2.86	2.88	2.87
Maleic hydrazide			
Week before full flower	2.02	1.60	1.81
At full flower	2.39	1.61	2.00
Week after full flower	2.38	2.25	2.32

1/ Based on a scale of 1 to 4, 1 being least desirable and 4 most desirable. Therefore, the higher the number the more usable the sample.

2/ Required difference between means to indicate significant discrimination between individual treatments is 0.4. Thus on the average the hand suckered was preferred to any of the treated samples.

Table 2. Relative usability[1] as judged by leaf experts of air-cured (burley and Maryland) tobacco from different sucker control treatments

Treatments	Rating[1]		
	Middle Leaves	Top Leaves	Mean[2]
Hand suckered	2.29	2.46	2.38
Maleic hydrazide			
Week before full flower	2.10	2.12	2.11
At full flower	2.36	2.46	2.41
Week after full flower	2.42	2.17	2.30

1/ Based on a scale of 1 to 4; 1 being least desirable and 4 being most desirable. Therefore, the higher the number the more usable the sample.

2/ Required difference between means to indicate significant discrimination between individual treatments is 0.52.

CHEMICAL AND PHYSICAL COMPOSITION OF LEAF SAMPLES

After leaf evaluation had been completed, the material was prepared for chemical analyses. These samples consisted of the leaves from the middle third of the plants of each of the four treatments, and the top third of the plants of each of the same four treatments. The samples from each state were analyzed separately. There were 152 samples which were stemmed, each carefully mixed, and subsamples were taken from each of them for analyses. These samples were dried to about 5% moisture, milled in a Wiley mill to pass a 2 mm. screen and 300-gram samples were withdrawn for color and specific volume measurement. The remainder of each sample was then remilled to pass a 1 mm. screen, subsampled, bottled, and distributed to each of the participating laboratories. The following chemical and physical analyses were made on each of the samples:

Color
Specific volume
Moisture content at equilibrium with air of 60% relative humidity
Total ash
Alkalinity of the water soluble ash
Alkalinity of the total ash
Total nitrogen
Acid insoluble nitrogen
alpha amino nitrogen
Total alkaloids
Nornicotine
Anabasine
Anatabine
Total volatile bases
Reducing sugars (flue-cured only)
Water soluble acids
pH
Petroleum ether extract
Maleic hydrazide residue

One kind of analysis was made on all samples in one laboratory while others made other analyses, thus distributing the work between the laboratories

of the principal cigarette manufacturers, the Crops Research Division of the United States Department of Agriculture, and a commercial analytical laboratory under contract with the U. S. Department of Agriculture. All results were calculated to an oven-dry basis and all samples were analyzed under code.

The detailed results, involving nearly 3,000 different analyses, are too extensive for detailed discussion in this report. The mean values of the results obtained on some of the most pertinent tests from both middle- and top-leaf samples from the same locations covered in the leaf evaluation tables are given in Table 3 for flue-cured tobacco, and in Table 4 for air-cured tobacco. Average results of all determinations, by states, are presented in Appendix Tables 13 and 14. These results show that there were statistically significant differences in certain physical and chemical properties between the hand-suckered samples and those from all times of chemical sucker-control treatment in both flue-cured and air-cured tobacco. In general, the treated flue-cured tobacco was lower in specific volume, total ash, alkalinity of the water-soluble ash, alpha amino nitrogen and total volatile bases, and higher in reducing sugars and moisture content when in equilibrium with air at 60% relative humidity. The amount of deviation from the composition of hand-suckered tobacco tended to decrease in this type of tobacco as the time of chemical suckering treatment was delayed.

In the air-cured samples, even though leaf experts were not able to detect the effects of sucker treatment, differences are evident in the laboratory results. The most consistent differences resulting from chemical treatments

were a decrease in the total ash and alkalinity of the water-soluble ash, and an increase in alpha amino nitrogen and in the moisture content when in equilibrium with air at 60% relative humidity. In this type of tobacco, the mean values show no tendency toward decreases in effects of later chemical suckering.

In most previous studies, a decrease in total alkaloids, made up principally of nicotine, has been associated with the use of maleic hydrazide. This trend was observed in the mean values for both flue-cured and air-cured tobaccos but was generally not statistically significant in this test.

Table 3.--Physical and Chemical Determinations on Flue-Cured Tobacco Most Significantly Modified by Suckering Practices - Mean Values and Discriminations (1)

Determination	Hand Suckered	Time of Maleic Hydrazide Treatment		
		1 week earlier	At full flower	1 week later
Specific Volume	3.96	3.60	3.71	3.77
% Moisture on Equilibration at 60% Relative Humidity	16.22	16.81	16.74	16.37
% Total Ash	9.86	8.45	8.77	9.09
Alkalinity of the Water Soluble Ash - meq/10 g	2.53	1.91	2.23	1.98
% Total Nitrogen	2.13	2.04	2.09	2.14
% Amino Nitrogen	0.192	0.153	0.159	0.176
% Total Alkaloids	2.28	2.02	2.11	2.28
% Reducing Sugars	21.55	25.53	26.07	24.15

(1) The mean values which are underlined differ significantly by statistical test from the corresponding values for hand-suckered tobacco. Additional determinations are reported in the appendix.

Table 4.--Physical and Chemical Determinations on Air-Cured Tobacco Most Significantly Modified by Suckering Practices - Mean Values and Discriminations (1)

Determination	Hand Suckered	Time of Maleic Hydrazide Treatment		
		1 week earlier	At full flower	1 week later
Specific Volume	5.66	5.54	5.57	5.35
% Moisture on Equilibration at 60% Relative Humidity	13.04	13.24	13.44	13.47
% Total Ash	15.63	14.87	15.11	14.88
Alkalinity of the Water Soluble Ash - meq/10 g	9.78	7.97	8.46	7.86
% Total Nitrogen	3.52	3.74	3.65	3.64
% Amino Nitrogen	0.412	0.517	0.480	0.515
% Total Alkaloids	3.82	3.22	3.60	3.92

(1) The mean values which are underlined differ significantly by statistical test from the corresponding values for hand-suckered tobacco. Additional determinations are reported in the appendix.

EVALUATION OF CIGARETTES

Preparation of Cigarette Blends: Under the supervision of a representative of the U. S. Department of Agriculture, the leaf samples remaining after obtaining the chemical samples were combined into groups according to each of the four sucker control treatments within each of the three types - flue-cured, burley, and Maryland. In preparation for blending, the stalk positions and the tobacco from each state were as uniformly represented as possible in making up the four treated lots of each of the three types. After blending, each of the 12 lots were redried on an apron-type drier and thief samples drawn for determination of maleic hydrazide. The blends were then put in hogsheads in the usual manner and placed into sweat on November 23. The four flue-cured blends were dried to about 11¼% moisture, English standard (3¼ hours at 110°C), and sweated at 90°F and 70% relative humidity ambient. The four burley blends and the four Maryland blends were redried to about 11½% moisture, domestic standard (3 hours at 100°C), and sweated at 95°F and 75% relative humidity ambient. The tobaccos were taken out of sweat on December 21 and replaced on December 30. Sweat was completed on January 13.

Thus, it may be noted that this tobacco was subjected to accelerated aging rather than natural aging over a period of years, as is typical of commercial cigarette production. However, the accelerated aging procedure here used is similar to those which are being used by a number of cigarette manufacturers in evaluating the effects of other changes in farm practices, such as new varieties, irrigation, etc.

A casing solution consisting of invert sugar and water was applied to blends of the air-cured types on January 16. The type blends derived from tobacco with a given treatment were then carefully blended in a proportion of 60% flue-cured, 35% burley, and 5% Maryland. Thus, one lot of tobacco from which cigarettes were to be made contained only tobacco from hand-suckered plants, another lot only tobacco from plants treated with maleic hydrazide at full flower, a third that was treated one week before full flower, and a fourth that was treated one week after full flower. The following day, a water solution of glycerine and invert sugar was applied to each treatment blend, so that the total amount of casing per 100 lbs. redried weight was 8.86 lbs. of invert sugar and 3.41 lbs. of glycerine. In the course of casing and blending, the tobaccos were passed repeatedly through a blending reel in order to insure uniform blending and even distribution of the casing materials. Following casing, the samples were bulked overnight, cut on a guillotine-type cutter, dried in a rotary dryer, and adjusted to about 12½% moisture, domestic standard. Final adjustment of moisture was made by exposing in conditioning rooms.

A high degree of success was obtained in the attempt to attain uniformity between lots in type, location and part of plant as shown in appendix Table 15.

Flue-cured tobacco from Florida and Virginia was not used in making cigarettes, as nearly all of the samples available were used in preparing analytical samples. Thus, each cigarette blend contained tobaccos from only one suckering treatment, but all contained the same proportion of tobacco from

different types, and nearly the same proportion of that from different states and different parts of the plant. All the blended cigarettes contained amounts of sugar and glycerine, fairly typical of American blend cigarettes but not exactly like any specific brand of cigarettes, as they did not contain any of the flavoring additives used by the various manufacturers. All blends contained a higher proportion of tobacco from the tops of the plants and less from the bottom than the usual commercial cigarettes.

Since this investigation involved the handling of a large number of tobacco samples by many different people at different locations, and a mixing of samples could confuse the results obtained, the blends of each type of tobacco from each treatment were sampled and analyzed for maleic hydrazide. The values obtained are shown in Table 5. The values of about 5 parts per million obtained on the hand-suckered leaf approach the limits of accuracy of the method. Since the hand-suckered plots were adjacent to treated plots to obtain soil uniformity, spray drift was possible. The unintentional presence of small amounts of treated tobacco was also possible. Since the analytical values for maleic hydrazide on the blends of treated leaf are from 10 to 37 times those on the hand-suckered blends, cigarettes made from these blends should show differences in smoking properties typical of treatment when such differences exist. The treated blends contain amounts of residue frequently encountered in farm-treated crops.

The maleic hydrazide values in Table 5 and in appendix Tables 13 and 14 show that there is generally a smaller concentration on the earlier treatment samples than on the later two treatments. The concentration has been more

Table 5.--Results of Determinations of Maleic Hydrazide in Blends of Flue-Cured, Burley, and Maryland Tobacco Used In Making Cigarettes

Blend	Hand Suckered 1/	Time of Maleic Hydrazide Treatment		
		1 week earlier	At full flower	1 week later
	ppm	ppm	ppm	ppm
Flue-cured	4	61	147	130
Burley	6	66	111	97
Maryland	4	80	99	152
Final Blend (weighted average)	5	64	132	120

1/ The value of 5 parts per million approaches the limit of accuracy of the method of determination. See text.

diluted by subsequent growth and there has been more opportunity for weathering from the earlier samples. Since, as shown later, the effects are more pronounced from early treatment, the results of maleic hydrazide determinations cannot be reliable estimates of the effect of the treatment on the leaf. Analyses of the green leaf in connection with another study conducted on material from many of these plots, show that the reduction in maleic hydrazide value is widely different in different cases. Weather records from the locations where the tobacco was grown show that rainfall soon after treatment may be responsible for low values on treated plots.

Other physical and chemical properties of the shredded tobacco from which the cigarettes were made are compared in Table 6. The nicotine content, total volatile bases, and total volatile acids are lower in the earlier treated sample than in the hand suckered. The color or "brightness" is also less, but the sugar content is greater. As the time of maleic hydrazide treatment is delayed, the general trend is toward a return from the different values in the earlier treated sample toward the hand-suckered value. Though the moisture of the shredded tobacco had been adjusted to between 12.5 and 13.0% in all lots before manufacture, exposure of this tobacco at 65% relative humidity caused considerably more moisture absorption in the earlier treated than in the hand-suckered sample and intermediate amounts of absorption at later dates of treatment. The changes here observed are similar to effects which have been attributed to maleic hydrazide in other work, though they are not nearly as extreme as in some experiments which have been reported.

Table 6.--Comparison of the Physical and Chemical Properties of the Blended Tobacco Used in Experimental Cigarettes

Determination	Hand Suckered	Time of Maleic Hydrazide Treatment		
		1 week earlier	At full flower	1 week later
% Total Volatile Base	.450	.427	.442	.489
% Nicotine	2.46	2.19	2.33	2.52
% TVB minus Nicotine	.192	.197	.197	.224
Ratio Nicotine/TVB	.57	.54	.55	.54
% Reducing Sugars	17.9	20.7	19.3	19.3
% Ash	12.77	12.93	11.89	12.05
% Total Volatile Acids	.136	.115	.119	.117
Color (Agtron, 5007-5034)	64	56	60	61
% Moisture as packed	12.55	12.69	12.59	12.94
Equilibrium Moisture % at 65% RH and 75° F.	14.22	15.15	15.11	14.78

Manufacture of the Blended Cigarette: For reasons which will appear later in connection with the smoking of these cigarettes under code, it was necessary to prepare the cigarettes produced from hand-suckered tobacco with 6 different code letters and those from each of the chemically suckered tobaccos with 3 different letters. The cigarettes were made on a regular commercial cigarette-making machine in the factory of a cooperating manufacturer but under observation of a U. S. Department of Agriculture representative. The code letters were printed by the machine on the cigarette in the location ordinarily occupied by the brand name. This necessitated stopping the machine for each change in code letter. Four thousand cigarettes were made of each code letter or a total of 60,000 experimental cigarettes. The operators of the machine did not know which lots of cigarettes corresponded to which treatment.

Much more difficulty was encountered in making cigarettes from the tobacco of the earlier maleic hydrazide treatment and the least with the hand-suckered sample. The principal difficulty consisted of a "choking up" in the rod reducer section and under the tongue. The pores of the long conveyor belt seemed to become clogged with a deposit resulting in a different "feel" to the belt and a lack of positive feed. The different lots of shredded tobacco from which the cigarettes were made were observed to differ in elasticity or "springiness," with the hand-suckered lot being most elastic, the earlier treated lot the least elastic, and the later two treatments intermediate.

Physical Properties of the Cigarettes: A comparison of certain physical properties of the cigarettes made from these tobacco blends is shown in Table 7, and the data from which they are calculated are given in Appendix Table 16. The length and circumference of cigarettes from all treatments are similar, but the cigarettes from the chemically suckered treatments are 3.0 to 4.8 percent heavier, even though manufactured at similar moisture contents. The "draw" of the cigarettes from the chemically treated tobacco is easier, especially in the case of the earlier chemically suckered sample. This was determined two different ways in different laboratories, one of which measured pressure drop at constant rate of air flow and the other air flow at constant suction. When the results of other studies on the effects of moisture, cigarette circumference and weight are used to adjust for the effect of these variables, it can be calculated that the filling power of the earlier treated tobacco is about 11 percent less than that of hand-suckered tobacco, or expressed in another way, about 11 percent more of the earlier treated tobacco than of the hand-suckered tobacco would have to be used to produce cigarettes with a uniform draw. The effects of later treatments are intermediate between the earlier treated samples and the hand-suckered samples.

Another way in which cigarettes are judged to see whether they are firmly enough packed to be satisfactory is by determining how much they will be flattended by a given force, particularly when the cigarettes have been exposed to a relative humidity characteristic of summer conditions in much of

Table 7. Comparison of Physical Properties of Experimental Cigarettes 1/

Property	Hand Suckered	Time of Maleic Hydrazide Treatment: 1 week earlier	At full flower	1 week later
	%	%	%	%
Weight of cigarettes	100	104.8	103.0	104.4
"Draw" of cigarettes				
Suction required for equal air flow	100	70.0	74.2	92.8
Air flow at equal suction	100	119.4	103.5	99.4
Calculated filling power	100	89.0	94.4	96.3
Firmness of cigarettes	100	87.3	92.0	103.8
Calculated filling power	100	94.9	96.5	101.9

1/ The detailed data from which these relative values are calculated are presented in Appendix Table 16.

the country. Comparisons based on this method are presented in the lower part of Table 7. The data on which they are based are given in Appendix Table 16. They show an increased compressibility (decreased firmness) of 12.7 percent in the earlier treated compared to the hand-suckered sample. The decreased firmness of the cigarettes made from tobacco treated at full flower was 8 percent, but an increased firmness of 4.1 percent was observed on the later treated sample. When experimentally determined relationships between firmness and amount of tobacco in the cigarette are applied to these data, the changes in the amount of treated tobacco which would be required to produce cigarettes of firmness equal to the hand-suckered sample would be +5.1, +4.5, and -1.9 percent, respectively, for the three chemical treatments.

The determination of specific volume is a third method of estimating filling power. Using the mean values of specific volume from Tables 3 and 4, the losses in filling power relative to the hand-suckered sample are found to be 6.5, 4.6, and 5.1 percent, respectively, for the three chemical treatments. All three of these methods are brought together in the table in item 4 of the Summary of Findings. The three methods, even though based on different principles, all give values of the same order of magnitude. The relative filling power, based on the averages of the three methods and using hand suckered as a standard, were -7.4, -4.6, and -2.3 percent for the earlier, full flower, and later treatments, respectively.

Data on the burning properties of the cigarettes and on the composition of the smoke drawn from them by a smoking machine are given in Appendix Table 17. The static burn is a test of the average time required for these "regular-size" cigarettes to burn, when not being puffed, from the original length of

70 mm. to a 30 mm. butt. This time is significantly greater on all the treated samples, and especially so on the earlier treated ones. When smoked on a machine, the length burned in a given time is reduced by the sucker control treatment, as would be expected from the above observation. Both kinds of observation indicate poorer burn for the chemically treated tobacco.

The amount of smoke or particulate matter obtained is not significantly different between any of the cigarettes. The amount of nicotine in the main stream smoke appears to be slightly less in the early treated samples, but this is probably only a reflection of the lower original nicotine content of these samples.

Cigarette Evaluation by Smoking Panels: The experimental cigarettes were evaluated by smokers under code. All available expert smoking panels were utilized, whether associated with tobacco manufacturers, tobacco exporting groups, the manufacturer of maleic hydrazide or with public agencies. Only panels composed of persons previously selected for ability to detect differences in cigarette smoke were used in the principal tests, since the available supply of cigarettes made of tobacco of known history and limited time made a complete consumer acceptance test impossible. The selection of methods to be used in conducting subjective tests such as are involved in testing food, drink or smoke is a very difficult field about which much remains to be discovered. On the basis of available information, two kinds of tests were selected: (1) The triangular test and (2) the binomial test.

In the triangular test, each panelist was given three cigarettes at a time, each labeled with a different code letter, but two of these cigarettes were composed of tobacco from the same sucker-control treatment, and one from a different treatment. At another time, each panelist was given three other cigarettes, differently labeled, but containing tobacco from the same two treatments. This time two cigarettes contained tobacco of the treatment represented by one cigarette in the first instance, and the third cigarette contained tobacco of the other treatment. In each instance the panelist was asked, "Which of these three cigarettes is different?" In instances where he cannot detect a difference among the cigarettes when presented three at a time, he has one chance in three of correctly guessing the "different" cigarette. Thus decisions as to whether cigarettes are detectably different by this method are based on the relative number of right and wrong selections of the "different" cigarette compared to the statistically probable proportion of 1 in 3 if no difference is detected. In the present case the hand-suckered sample, under various code designations, was compared separately with each of the three chemically treated samples. Obviously this test is designed to answer the question, "Is there a difference between these cigarettes which can be detected when lighted three at a time and puffed in rotation?" In this test, counting all participating organizations and panelists, this question was asked 326 times with respect to groups of three cigarettes containing hand-suckered vs. early maleic-hydrazide-treated tobacco. In 125 cases the "different" cigarette was correctly identified. The probability of this degree of selection being other than chance is about 9 out of 10 by statistical test.

In comparing the cigarettes containing tobacco treated at full flower, the "different" cigarette was chosen 105 times out of 317 or almost exactly one-third. In the later treatment, compared with hand suckered, the "different" cigarette was chosen 118 times out of 319. Neither of the latter two comparisons indicated a significant preference.

In the binomial test, the same expert smoking panels were used, but each person was given only two cigarettes at a time under code, one made from hand-suckered and one from chemically suckered tobacco. Subsequently, he compared the hand-suckered with each of the other two treatments. In this instance he was asked (1) to select the cigarette of the pair which he preferred, and (2) to describe the reasons for his objections to the other cigarette. In this case the panelist usually smoked the cigarettes one at a time, so had an opportunity to observe aftereffects, as well as taste. In comparing the preferences of the panelists for the cigarettes made of hand-suckered or of chemically suckered tobacco, the results of the paired tests were as follows:

Preferences	No. of Panelists Preferring Indicated Treatment		
	One week before full flower	At full flower	One week after full flower
Hand suckered favored by	65	47	55
Chemically suckered favored by	38	58	52
No preference shown by	13	11	7
Statistical significance	significant	not significant	not significant

The above results show that 65 panelists preferred the hand-suckered tobacco compared with 36 favoring the earlier treatment and 13 with no preference. Using the most conservative estimate, these data indicate probabilities of approximately 80 to 1 that a significant preference for the hand-suckered tobacco has been shown. The other two comparisons do not show significant preferences.

As noted above, the panelists involved in the binomial test were asked to report their objections to the cigarette they did not prefer. Thus, the form of the question and the natural attitude of persons on test panels combined to bring out all possible critical adjectives. The results obtained are shown in Table 8. In many cases, a panelist gave more than one criticism and all are recorded in the table; consequently, the total number of observations is larger than the number of panelists.

Table 8. Panelists' criticisms of smoking characteristics of cigarettes made from hand-suckered and maleic hydrazide-treated tobacco

Criticism	No. of panelists reporting each criticism					
	Hand	MH earlier	Hand	MH full flower	Hand	MH later
Strong	17	22	14	13	14	17
Irritating	2	22	12	16	4	16
Lacks taste	1	16	1	13	2	11
Bitter	--	15	--	12	2	12
Harsh or hot	3	13	13	7	8	9
Dirty taste	--	6	6	--	--	6
Musty	--	6	6	--	--	6
Off-taste	3	2	5	1	2	2
Lacks flavor	2	2	2	2	5	2
Sharp	2	3	1	2	3	3
Not as sweet	1	2	1	--	--	--
Astringent	--	1	1	--	2	--
Woody	2	1	7	--	--	--
Green	--	1	--	--	1	--
Hay-like	6	--	--	6	6	--
Earthy	1	--	--	--	--	--
Not as smooth	1	--	--	--	--	--
Drier	1	--	--	--	--	--
Biting	--	--	1	--	--	4
Metallic aftertaste	--	--	--	--	1	--
Oily flavor	--	--	--	1	--	--
Acid	--	--	--	1	--	--
Totals	42	112	70	74	50	88

These results indicate that the terms "irritating," "lacks taste," and "bitter" were more frequently applied to the cigarettes made from tobacco treated with maleic hydrazide than to those from hand-suckered tobacco. The results show that in comparison of hand suckered with either the earlier or later treatments, the panelists gave many more critical descriptions of the cigarettes containing treated tobacco than the hand-suckered samples. A few more critical adjectives were used in referring to the full flower treatment than the hand suckered, even though the "votes" were in the other direction. It should be noted that this test, like the others, was conducted under code so as to avoid as far as possible any preconceptions of the panelists as to any of the samples involved. These results provide evidence that cigarettes made from tobacco treated with maleic hydrazide for sucker control were more strongly discriminated against by the panelists.

The results here presented demonstrate some of the difficulties in arriving at a "definite and conclusive" answer as to the effect of this chemical on tobacco for cigarette use. Certainly the ultimate test of a cigarette is its acceptability to the smoker. So far as known, there has never been another problem on which such a large number of expert cigarette smoke panelists have cooperated in an effort to find an answer. In fact, a large majority of those in the United States who qualify as experts in this field participated in this test. The results show that tobacco which has been treated with maleic hydrazide a week before full flower stage is inferior to hand-suckered tobacco in smoking properties. Presently known methods of human smoke testing do not differentiate clearly between later-treated and hand-suckered tobacco,

even though it can be shown that this tobacco also differs significantly from hand suckered in physical and chemical properties in the same direction as the earlier treatment.

In view of the indications of a greater ability of the expert panels to differentiate between these cigarettes when smoked individually, so that aftereffects could be observed, and other evidence that the effect of this chemical treatment was to produce an aftertaste or feeling in the throat, it seemed possible that even nonexperts might provide some evidence of the results to be obtained on continued smoking of the experimental cigarettes. Whole packs of each of the four kinds of cigarettes, still under code, were given to 14 smokers who were not expert panelists. Three of the smokers did not note any differences between the four samples. The other 11 all preferred the hand-suckered samples. The earlier treated sample was considered by each of them to be definitely inferior, especially as reflected by nasal irritation and residual feeling in the throat. Some considered the later chemically-treated samples of doubtful acceptability. No statistical tests were applied to these results but they do represent results with "average" smokers. When combined with the foregoing, they indicate that widespread use of maleic hydrazide would have an unfavorable effect on tobacco suitability, especially since the available evidence indicates that the longer a person smokes the treated cigarettes the more clearly he discriminates against them.

Tobacco for export: It was recognized when this test was planned that, from an economic standpoint, an important part of the problem was involved in the use of maleic hydrazide on tobacco for export. A major foreign manufacturer participated in the evaluation of flue-cured leaf, but could not evaluate American blend cigarettes. There was not enough tobacco from the experimental plots to permit the shipment of a sufficient quantity of the flue-cured leaf overseas for evaluation there. Consequently, samples of farmer-grown tobacco, both of the same U. S. official standard grade, B3F, one lot of which was shown by analysis to be free of maleic hydrazide and the other to contain 66 ppm., were shipped to Great Britain where they were analyzed and made into cigarettes and tested under the auspices of the Tobacco Advisory Committee of the United Kingdom. These samples were not entirely comparable since the two lots tested were not grown under the same conditions. The filling capacity and ash content of the treated sample were found to be lower, and the equilibrium moisture content higher than the sample which did not contain maleic hydrazide. The firmness of the cigarettes filled to a given density was decreased in the treated sample, and those smokers who indicated a preference preferred the cigarette made with the hand-suckered tobacco. These results are based on treated and hand-suckered "farm run" tobacco and, although not from experimentally controlled tests, are confirmatory of the results obtained on the samples of known history described above.

INFLUENCE OF MALEIC HYDRAZIDE ON YIELD AND LABOR REQUIREMENTS

The use of maleic hydrazide in controlling suckers in lieu of suckering by hand reduces the unit cost of producing tobacco in two ways. First, the cost of suckering is reduced, and second, the yield per acre is increased with the result that the cost per pound of tobacco produced is lower. In addition, it makes sucker control possible when the labor supply is too limited for effective hand suckering.

Costs of sucker control: Information has been obtained from agricultural experiment stations in five States - Georgia, South Carolina, North Carolina, Tennessee, and Kentucky - to determine the relative cost of hand suckering compared to using maleic hydrazide to control suckers in flue-cured and burley tobacco. The cost for hand suckering varies greatly with the season and many other conditions. The estimated costs range from a low of $15 to a high of $60 per acre. The more usual costs are from $20 to $40 per acre, with generally a slightly higher cost in the burley area because of the larger number of plants per acre. The higher costs are encountered when there are late rains and large or numerous suckers.

The cost of controlling suckers with maleic hydrazide is estimated from $15 to $22 an acre, including the application of the chemical. This is the approximate cost using 6 pints to 1 gallon per acre. Thus, by controlling tobacco suckers through the use of maleic hydrazide, a saving of from $5 to $20 per acre may be expected, with a saving of up to $40 per acre as a possibility under some conditions.

Relative Yields: One of the most consistent characteristics resulting from the use of maleic hydrazide for sucker control in tobacco is the increased yields of the treated plants. Data have been accumulated over a period of years from various states showing this result. In a 5-year test on burley tobacco in Tennessee, the hand-suckered control produced an average of 2,266 pounds per acre compared to 2,591 pounds per acre for that treated with maleic hydrazide for sucker control, a difference of 325 pounds per acre. In these tests the chemical was applied before the full flower stage. With approximately the same value per 100 pounds, which is based on U. S. official standard grades, the maleic hydrazide-treated tobacco returned $199 per acre more than the hand-suckered. The hand-suckered tobacco was valued at $61.21 per hundred and the maleic hydrazide-treated tobacco at $61.04 per hundred. In general, the standard grades do not differentiate between hand-suckered and maleic hydrazide-treated tobacco.

As an average of three years at Tifton, Georgia, the yield of flue-cured tobacco, topped and treated for sucker control with maleic hydrazide, was 1,991 pounds per acre compared with 1,762 pounds for the hand-suckered control, a difference of 229 pounds or an increase in value of over $100 per acre. The maleic hydrazide was applied when approximately 90 percent of the plants reached the flowering stage. These results are shown in Table 9. It is also noteworthy that if the tobacco were not topped or suckered, the yield was considerably lower. Similar trends have been found on flue-cured tobacco in North and South Carolina. Repeated tests have shown that earlier treatments produce greater yield increments than later treatments.

Table 9. Influence of topping practice and use of maleic hydrazide on three-year average yield and value of tobacco. Experimental data from Georgia

Treatment and Topping Practice [1/]	Pounds per acre	Acre value	Price per cwt.
		(dollars)	(dollars)
Topped:			
Maleic hydrazide	1,991	1,057	52.10
Hand suckered	1,762	943	53.25
Difference	229	114	
Not topped:			
Maleic hydrazide	1,781	944	52.21
Hand suckered	1,605	824	50.18
Difference	176	120	

1/ The maleic hydrazide was applied when approximately 90 percent of the plants reached the flowering stage.

In Kentucky a two-year test on burley tobacco produced the results shown in Table 10. Applying the chemical at the early flower stage resulted in a difference in yield of 187 pounds per acre favoring the chemical treatment compared to 48 pounds per acre when applied at the late flower stage.

These results are consistent in showing increased yields per acre brought about by sucker control with maleic hydrazide and especially with earlier treatment. The returns to the grower from increased yields are greater than the saving in cost by using the chemical for sucker control. Thus, the financial incentive to the grower appears to be more from the standpoint of increased yields, particularly from earlier applications than from the saving in production expense due to the use of the chemical. It should be recognized that hand suckering is drudgery and reports indicate that it is often difficult to obtain labor for this work. Consequently, among the advantages of chemical control is the elimination of this tedious operation.

One question which naturally rises in connection with tobacco suckering is: Do any other alternatives exist besides hand suckering and the use of maleic hydrazide? Some data were obtained in the course of the present tests on (a) use of oil, (b) not suckering, and (c) not topping or suckering. There is also much more data available on these practices and all of it indicates that:

(1) The loss in income to the cigarette tobacco grower resulting from failure to top or failure to sucker is usually considerably greater than the cost of these operations.

Table 10. Yield of burley tobacco chemically treated for sucker control compared to hand suckered. Experimental data from Kentucky, average of 2 years, 1958 and 1959

Time of Application	Hand Suckered	Maleic Hydrazide	Difference
	Lbs/A	Lbs/A	Lbs/A
Early flower	2,273	2,460	187
Late flower	2,196	2,244	48

(2) Any of the oils so far tried are unreliable, as they often fail to produce satisfactory sucker control and sometimes result in considerable loss by rotting of the stalks or leaves. Thus, oil treatment is not an economical alternative from the grower's standpoint, so the smaller change in chemical composition of the leaf as compared to maleic hydrazide treatment usually observed has little practical importance.

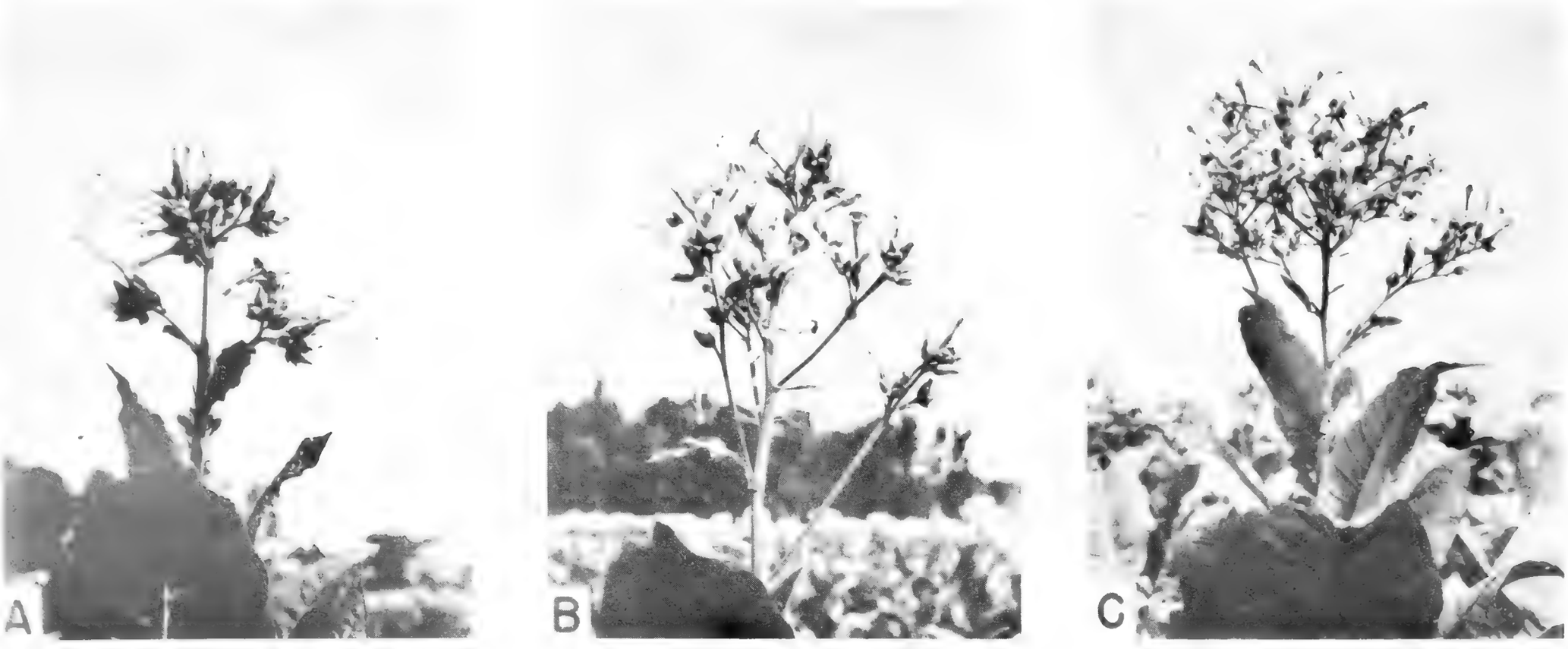
(3) Many other chemicals have been tried as means of tobacco sucker control, but so far, none have proven to be effective and dependable.

An expanded research program should be developed to find methods of sucker control acceptable to both farmers and industry. As soon as promising methods are found, but before they are introduced into general practice, they should be tested by many of the methods used in this research to determine the acceptability of the tobacco produced.

The Agricultural Experiment Stations of Florida, Georgia, Kentucky, Maryland, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia, assisted in the planning and conduct of the experiments here reported, and in many instances, in experiments of prior years, the results of which were considered in reaching the conclusions here presented. The following groups participated in the evaluation of the tobacco in this study: Brown and Williamson Tobacco Corporation, Food and Drug Research Laboratories, Liggett and Myers Tobacco Company, Phillip Morris, Inc., R. J. Reynolds Tobacco Company, Texaco Experiment Inc., The American Tobacco Company, The Imperial Tobacco Company of

Great Britain and Ireland, the P. Lorillard Company, and a group of export interests represented by Dr. I. W. Tucker, Industrial Research Consultant.

Since the various forms of evaluation were all conducted under code, and in view of the form of the Congressional Request to the U. S. Department of Agriculture, the conclusions reached are those of the U. S. Department of Agriculture.



Appendix Figure 1

APPEARANCE OF FLOWER HEADS AT TIMES OF MALEIC HYDRAZIDE TREATMENT

A - Earlier treatment - one week before full flower

B - Full flower - at shedding of first corolla

C - Later treatment - one week after full flower

Appendix Table 11

Relative Usability [1], as Judged by Leaf Experts, of Flue-Cured Tobacco as Related to Location and Suckering Method

Location	Part of Plant	No. of Selections	Hand Suckered	Time of Maleic Hydrazide Treatments			Hand Suckered as 1st Choice [2]
				1 wk. earlier	At full flower	1 wk. later	
							%
Georgia	Middle	12	2.71	2.50	2.87	1.92	25
	Top	8	2.50	1.71	1.58	2.54	33
S.Carolina	Middle	8	2.87	1.50	1.75	2.71	17
	Top	5	2.25	1.22	1.58	1.62	33
N.Carolina	Middle	37	3.01	1.86	2.56	2.53	32
	Top	35	3.88	1.88	1.67	2.57	89
Means	Middle	57	2.86	2.02	2.39	2.38	28
	Top	50	2.88	1.60	1.61	2.25	70

[1] If the leaf from all samples of a given treatment was first choice of all leaf experts, that treatment would score 4.00. If always last choice, it would score 1.00.

[2] This column gives the percentage of the total number of choices in which the hand suckered sample was first choice.

Appendix Table 12

Relative Usability [1], as Judged by Leaf Experts, of Air Cured Tobacco as Related to Location and Suckering Method

Location	Part of Plant	No. of Selections	Hand Suckered	Time of Maleic Hydrazide Treatments			Hand Suckered as 1st Choice [2]
				1 wk. earlier	At full Flower	1 wk. later	
							%
Tennessee	Middle	23	2.39	2.72	2.48	2.42	6
	Top	30	2.76	2.56	2.36	2.31	23
Kentucky	Middle	5	2.04	2.21	2.38	1.71	8
	Top	13	2.11	3.06	2.25	1.97	6
N.Carolina	Middle	12	2.00	2.38	2.71	2.92	8
	Top	11	2.29	1.17	2.66	3.04	8
Virginia	Middle	6	2.33	2.08	1.92	2.00	33
	Top	5	2.46	2.29	1.83	1.75	17
W.Virginia	Middle	8	2.42	1.50	2.25	2.16	25
	Top	10	2.75	1.12	2.75	1.71	42
Maryland	Middle	12	2.58	1.71	2.42	3.29	33
	Top	9	2.38	2.54	2.88	2.21	8
Means	Middle	66	2.29	2.10	2.36	2.42	15
	Top	78	2.46	2.12	2.46	2.17	19

[1] If the leaf from all samples of a given treatment was first choice of all leaf experts, that treatment would score 4.00. If always last choice, it would score 1.00.

[2] This column gives the percentage of the total number of choices in which the hand suckered sample was first choice.

Appendix Table 13

Physical and Chemical Analyses of Flue-Cured Tobacco Samples by State, Plant Position, and Sucker Control Treatment

State	Plant Part	Sucker Control Treatment[1]	Code	Color	Specific Vol.	Moisture Equilibrium at 60% RH[2]	Total Ash	Alkalinity Water Sol. Ash	Alkalinity Total Ash	Total Nitrogen	Acid Insol. N	Alpha Amino N	Total Alkaloids	Nornicotine	Anabasine	Anatabine	T.V.B.	Red. Sug.	Water Sol. Acids	pH	Pet. Ether Extract	M.H.
						%	%	meq./10 g.	meq./10 g.	%	%	%	%	parts 10,000	parts 10,000	parts 10,000	%	%	meq./ 10 g.		%	ppm
Florida	Middle	Hand	1	37	4.96	15.92	12.49	1.72	36.85	2.02	0.92	.228	1.50	0.5	0.2	0.5	0.26	17.12	3.54	5.10	8.9	118
		Earlier	2	34	4.92	15.13	13.76	2.47	38.10	2.27	0.93	.253	2.15	1.0	0.5	1.0	0.34	13.28	4.18	5.20	6.7	172
		Full flower	3	37	5.24	14.52	13.53	1.42	36.67	2.25	0.95	.242	2.05	3.0	0.5	0.5	0.35	13.08	3.92	5.18	6.5	43
		Later	4	24	5.24	14.72	14.60	4.02	39.76	2.51	1.00	.340	2.50	5.0	2.0	1.0	0.41	7.89	4.26	5.23	7.6	90
	Top	Hand	4	9	4.40	15.67	9.01	3.02	38.02	2.73	1.11	.323	2.48	2.0	0.5	0.5	0.43	11.82	4.45	5.00	6.9	54
		Earlier	3	8	4.26	15.93	10.11	4.31	39.61	2.96	1.06	.358	3.29	2.5	1.8	1.5	0.51	11.43	5.16	5.06	6.7	142
		Full flower	2	5	4.72	15.26	9.83	3.40	38.72	2.89	1.09	.370	3.12	3.0	1.5	1.0	0.50	10.52	4.74	5.10	7.8	39
		Later	1	14	4.80	15.45	11.58	4.22	39.77	2.94	1.05	.376	3.37	6.0	1.5	1.0	0.53	8.54	5.08	5.19	8.0	66
Georgia	Middle	Hand	2	47	4.20	16.85	9.64	1.54	36.04	1.90	0.83	.142	2.10	1.0	0.2	0.5	0.29	26.86	3.41	4.81	5.3	20
		Earlier	3	37	3.84	16.71	9.34	1.39	35.98	1.92	0.85	.143	2.09	1.0	0.4	0.3	0.28	27.29	3.30	5.09	4.6	162
		Full flower	4	42	4.18	16.95	9.78	1.53	35.80	1.90	0.84	.139	2.02	0.5	0.2	0.3	0.29	29.12	3.47	4.92	5.3	365
		Later	1	47	4.16	16.79	9.52	1.29	35.61	1.96	0.81	.151	2.08	1.0	0.3	0.5	0.30	25.31	3.54	4.85	5.6	357
	Top	Hand	3	49	3.72	16.98	7.02	1.99	36.49	2.30	1.00	.187	2.77	2.0	0.3	0.8	0.40	27.52	3.75	5.00	5.3	14
		Earlier	2	40	3.60	17.48	6.65	1.71	36.22	2.33	1.03	.169	2.62	2.0	0.5	1.8	0.37	25.70	3.67	5.06	5.5	174
		Full flower	1	43	3.38	17.48	6.39	2.13	36.64	2.39	1.12	.169	2.60	2.0	0.5	0.5	0.37	28.08	3.77	5.00	6.4	484
		Later	4	44	3.62	15.73	7.28	1.51	36.11	2.47	1.04	.167	3.05	4.0	1.0	1.0	0.42	23.15	4.00	5.05	5.7	272
S. Carolina	Middle	Hand	4	26	3.84	17.08	11.16	3.54	38.38	2.02	0.96	.203	2.09	2.0	0.3	0.5	0.30	23.19	2.93	5.60	5.7	0
		Earlier	1	33	3.54	17.62	8.99	2.70	37.59	1.88	0.99	.143	1.68	1.0	0.1	0.5	0.25	26.01	2.78	5.50	5.1	83
		Full flower	2	26	3.62	17.19	9.94	3.13	38.02	1.96	0.92	.155	1.83	1.0	0.2	0.6	0.26	24.41	3.04	5.51	4.9	68
		Later	3	20	3.60	17.23	10.31	2.96	37.80	1.96	0.93	.177	1.91	1.5	0.2	0.5	0.28	22.81	2.75	5.68	5.6	562
		Oil	5	38	3.90	16.93	11.08	3.68	38.51	2.00	0.87	.196	1.80	1.5	0.2	0.3	0.27	23.30	2.81	5.70	5.8	0
		N.T.-N.S.	6	29	4.28	16.28	11.70	4.66	39.44	2.11	1.02	.247	1.24	1.5	0.2	0.2	0.25	18.34	2.58	5.83	5.8	17
		None	7	39	4.14	16.71	11.01	3.17	37.83	1.90	0.88	.185	1.68	1.0	0.2	0.5	0.26	21.46	2.77	5.66	6.4	0
	Top	Hand	1	23	3.82	16.59	9.82	2.53	37.68	2.56	1.05	.244	3.07	3.0	0.5	1.0	0.38	18.05	3.09	5.65	6.5	38
		Earlier	2	29	3.38	16.72	8.42	2.14	37.09	2.45	1.09	.181	2.46	2.0	0.2	1.0	0.35	19.16	3.54	5.53	5.5	39
		Full flower	3	30	3.58	16.58	8.92	2.46	37.60	2.45	1.10	.199	2.63	2.0	0.2	2.0	0.37	18.78	3.24	5.62	6.0	37
		Later	4	27	3.48	16.27	8.97	2.24	37.17	2.57	1.09	.224	2.90	2.5	0.3	3.0	0.40	18.35	3.40	5.68	5.9	369
		Oil	5	27	3.94	15.94	6.76	3.09	38.20	2.25	0.92	.255	2.15	2.0	0.2	2.0	0.35	16.52	3.54	5.70	6.5	6
		N.T.-N.S.	7	26	4.08	15.46	14.29	3.84	38.67	2.32	1.06	.277	1.51	1.5	0.2	2.5	0.28	14.82	3.89	5.72	6.5	8
		None	6	32	4.06	15.76	10.71	3.13	38.15	2.13	0.91	.251	1.93	2.5	1.5	0.2	0.32	16.78	2.95	5.83	6.9	18
N. Carolina	Middle	Hand		57	4.34	16.16	10.95	3.42	37.46	1.78	0.89	.158	1.71	2.1	0.3	1.7	0.26	22.77	2.85	5.42	6.5	19
		Earlier		65	3.96	16.61	9.90	2.57	37.16	1.71	0.84	.139	1.54	1.1	0.1	0.7	0.23	25.97	2.87	5.31	5.9	85
		Full flower		61	4.18	16.48	10.78	2.80	38.20	1.79	0.86	.146	1.67	1.4	0.2	0.9	0.25	24.59	2.83	5.40	6.2	227
		Later		61	4.21	16.32	10.43	2.70	37.38	1.76	0.86	.151	1.71	1.2	0.2	1.1	0.25	24.79	3.07	5.38	6.5	85
	Top	Hand		41	3.87	15.68	9.22	1.65	35.85	2.21	1.00	.206	2.28	2.2	0.8	2.6	0.36	19.51	3.72	5.25	7.0	7
		Earlier		56	3.41	16.51	7.62	1.62	36.25	1.93	0.94	.145	1.95	1.4	0.4	1.6	0.28	25.72	3.08	5.24	5.4	68
		Full flower		51	3.41	16.83	7.17	1.57	35.54	2.05	0.99	.141	2.17	1.5	0.4	2.2	0.30	28.60	3.19	5.27	5.2	147
		Later		49	3.56	16.42	7.94	1.29	35.59	2.15	1.01	.140	2.32	2.4	0.7	2.6	0.34	25.26	3.42	5.20	5.5	89
Virginia	Middle	Hand	2	0	4.36	15.54	14.14	1.33	36.81	2.52	0.98	.344	2.53	3.0	0.2	0.3	0.43	7.11	2.79	5.72	5.1	26
		Earlier	4	0	4.28	14.70	14.11	1.32	36.77	2.33	0.97	.314	2.38	2.0	0.2	0.2	0.43	7.90	2.79	5.81	5.8	199
		Full flower	3	0	4.84	14.77	13.80	1.25	36.62	2.31	1.02	.298	2.32	3.0	0.2	0.2	0.42	7.63	2.81	5.85	5.8	225
		Later	1	0	4.50	14.92	14.29	1.30	36.80	2.51	1.07	.323	2.51	5.0	0.2	0.3	0.47	7.64	2.77	5.82	5.6	199
		Oil	5	0	4.94	14.76	13.71	1.12	36.15	2.45	1.03	.319	2.56	4.0	0.2	0.4	0.46	7.11	2.80	5.59	6.2	9
	Top	Hand	1	15	3.84	16.19	9.25	1.41	36.86	2.72	1.30	.334	1.86	2.5	0.2	0.3	0.40	16.04	3.36	5.28	4.1	160
		Earlier	3	18	3.50	16.40	9.53	1.17	36.54	2.65	1.24	.295	1.87	2.5	0.1	0.3	0.39	16.97	3.26	5.30	3.9	154
		Full flower	4	20	3.66	16.46	9.43	1.15	36.33	2.75	1.22	.337	1.86	2.0	1.0	0.3	0.41	16.51	3.35	5.35	3.5	36
		Later	2	21	3.64	16.49	9.09	1.41	36.66	2.63	1.29	.285	1.57	2.0	0.2	0.3	0.38	17.75	3.18	5.30	4.0	53
		Oil	5	14	3.50	16.29	9.42	1.08	36.16	2.65	1.18	.314	2.10	3.0	2.0	0.4	0.42	16.06	3.19	5.42	3.9	7

[1] Hand - Topped at full flower and hand suckered whenever suckers were 4-6" long
Earlier - Topped with maleic hydrazide about a week before full flower, topped at full flower
Full flower - Topped at full flower and sprayed with maleic hydrazide immediately after topping
Later - Topped at full flower and sprayed with maleic hydrazide one week later, suckered then if necessary
Oil - Topped at full flower. Oil placed on cut stalk.
N.T.-N.S. - Not topped or suckered
None - Topped at full flower. Not suckered.

[2] Moisture upon equilibrium at 60% RH and 75° F.

Appendix Table 14. Physical and Chemical Analyses of Air-Cured Tobacco Samples by States, Plant Position, and Sucker Control Treatment

State	Plant Part	Sucker Control Treatment 1/	Code	Color	Specific Vol.	Moisture Equilibrium at 60% RH	Total Ash	Alkalinity of Water Sol. Ash	Alkalinity of Total Ash	Total Nitrogen	Insol. Acid N	Alpha Amino N	Total Alkaloids	Nicotine	Anabasine	Anatabine	T.V.B.	Water Sol. Acids	pH	Pet. Ether Extract	M.H.
						%	%	meq./10 g	meq./10 g	%	%	%	%	Parts 10,000	Parts 10,000	Parts 10,000	%	meq./g		%	ppm
Tenn.	Middle	Hand		44	5.84	13.41	14.35	7.96	44.36	4.20	1.79	0.364	4.70	21	0.5	4.5	0.86	2.76	6.23	7.0	0
		Earlier		46	5.87	13.36	14.65	7.02	43.65	3.98	1.67	.393	4.66	21	.4	4.1	.81	2.80	6.15	7.0	20
		Full flower		44	5.68	13.72	14.93	7.01	43.25	4.09	1.67	.438	4.63	23	.5	4.3	.84	3.01	6.10	7.1	34
		Later		43	5.26	13.85	14.63	6.42	42.73	4.32	1.74	.477	4.73	20	.5	4.4	.92	3.04	6.14	6.7	53
	Top	Hand		28	4.87	13.37	13.37	9.17	45.21	4.42	1.60	.500	5.42	25	1.1	4.8	1.01	3.72	5.80	7.7	12
		Earlier		31	5.02	13.30	13.51	8.55	44.59	4.13	1.56	.489	4.95	22	.7	3.9	.92	3.64	5.75	8.0	30
		Full flower		21	4.92	13.78	13.05	8.05	43.92	4.40	1.52	.580	5.43	29	1.4	4.5	1.04	3.72	5.74	7.5	32
		Later		25	4.57	13.78	13.43	8.74	45.00	4.51	1.59	.585	5.32	25	1.1	4.0	1.29	3.87	5.75	7.7	30
N. C.	Middle	Hand	4	17	5.52	14.18	15.30	9.56	46.33	3.79	1.53	.436	4.80	30	.3	2.5	.89	2.54	6.30	6.8	5
		Earlier	3	17	5.32	14.96	14.41	5.60	42.31	4.07	1.74	.596	3.86	32	.3	3.0	.91	2.39	6.18	7.1	66
		Full flower	1	20	5.56	14.49	13.97	7.16	42.91	3.83	1.66	.505	3.94	35	.3	5.0	.86	2.49	6.12	7.1	180
		Later	2	20	5.62	14.72	14.33	6.11	42.88	3.79	1.46	.506	4.59	30	.3	6.0	.89	2.68	6.15	7.9	203
	Top	Hand	3	14	5.28	13.91	15.10	12.46	48.82	3.90	1.68	.513	4.19	30	.2	2.0	.87	2.65	6.00	7.0	0
		Earlier	4	21	5.30	14.55	12.62	5.99	42.05	4.35	2.20	.559	2.27	20	.1	.5	.71	2.51	5.82	6.5	131
		Full flower	2	14	5.20	14.69	13.15	7.53	43.67	4.12	1.96	.591	2.94	25	.1	1.0	.78	2.68	5.88	6.4	180
		Later	1	25	4.96	14.14	12.75	7.20	43.52	3.93	1.70	.569	3.75	28	.1	1.5	.85	2.76	5.88	5.8	128
Ky.	Middle	Hand	3	60	6.26	11.99	16.60	12.83	48.77	3.10	1.46	.301	2.80	10	.2	2.5	.51	1.97	6.25	6.9	6
		Earlier	4	55	6.28	12.15	15.78	13.39	49.18	3.30	2.01	.387	2.64	10	.2	2.0	.59	1.97	6.30	7.0	189
		Full flower	2	60	6.42	12.38	16.55	12.60	48.55	3.25	1.54	.326	2.51	9	.2	1.5	.53	1.64	6.32	7.5	459
		Later	1	58	6.08	12.16	15.70	10.05	46.25	3.43	1.58	.372	2.84	9	.2	2.5	.59	2.07	6.30	7.8	283
	Top	Hand	4	46	5.24	12.13	13.48	10.36	45.62	3.89	1.44	.693	3.50	10	.2	1.5	.87	3.33	5.70	7.3	14
		Earlier	3	38	5.20	12.67	13.40	7.72	43.16	4.32	1.56	.896	2.98	6	.2	1.0	.94	3.42	5.62	7.6	231
		Full flower	1	45	4.84	12.44	14.21	8.73	44.19	4.08	1.43	.777	3.27	9	.1	1.5	.90	3.43	5.68	7.3	297
		Later	2	44	4.90	12.60	13.78	8.93	44.58	4.40	1.59	.888	3.39	10	.3	3.0	.98	3.55	5.72	7.6	259
W. Va.	Middle	Hand	1	35	5.68	12.26	17.08	12.34	48.06	3.04	1.20	.238	4.30	28	.3	1.5	.70	2.64	6.10	7.5	0
		Earlier	3	24	4.98	13.38	16.76	11.77	47.51	3.60	1.26	.441	4.29	25	.3	1.0	.90	3.00	6.00	6.8	53
		Full flower	2	29	5.80	13.11	16.35	12.44	48.29	3.43	1.28	.336	4.84	28	.3	1.5	.86	2.81	6.12	6.5	27
		Later	4	30	5.74	12.87	16.77	11.64	47.25	3.39	1.22	.365	5.16	22	.4	1.0	.90	3.09	6.02	7.3	59
	Top	Hand	4	26	5.42	12.73	16.25	10.89	46.82	3.46	1.13	.439	4.96	25	.3	2.0	.90	3.59	5.68	7.8	0
		Earlier	2	20	5.08	12.51	14.36	9.59	45.29	4.19	1.45	.713	3.98	32	.3	2.0	1.04	3.67	5.60	7.7	75
		Full flower	1	20	4.72	13.13	15.14	10.77	46.68	3.96	1.08	.602	5.58	23	.5	2.0	1.05	4.15	5.62	7.9	26
		Later	3	17	4.64	13.65	15.59	10.14	46.03	3.06	1.11	.682	5.74	30	.5	3.0	1.19	4.34	5.68	6.8	49
Va.	Middle	Hand	4	26	5.00	14.51	15.84	7.78	44.62	3.71	1.23	.455	4.71	20	.3	2.5	.92	3.10	5.90	5.7	72
		Earlier	1	32	4.50	14.96	16.02	11.59	48.40	3.97	1.15	.466	5.43	18	.4	7.0	1.04	3.08	6.05	6.0	83
		Full flower	3	24	4.56	15.34	15.70	8.82	45.71	4.00	1.22	.528	5.48	22	.3	4.0	1.10	3.26	6.08	5.6	72
		Later	2	31	4.62	14.79	15.66	7.91	44.93	4.08	1.25	.540	5.07	15	.3	7.0	1.10	3.23	6.00	5.5	68
	Top	Hand	2	13	4.46	14.94	14.05	7.64	43.97	4.71	1.61	.858	5.13	20	.2	2.0	1.27	4.05	5.60	6.0	65
		Earlier	1	13	4.24	15.04	14.07	9.27	45.52	4.74	1.49	.817	5.44	18	.2	2.5	1.28	4.15	5.60	6.6	56
		Full flower	4	18	4.54	14.39	13.13	7.15	43.37	4.62	1.62	.847	4.32	21	.2	2.5	1.11	3.99	5.51	5.4	62
		Later	3	16	4.56	15.18	13.88	8.12	44.36	4.79	1.57	.832	5.38	20	.3	2.5	1.27	4.14	5.62	5.9	58
Md.	Middle	Hand	2	13	6.76	11.90	18.72	6.63	42.01	2.34	1.31	.184	1.74	2	.2	.1	.37	1.74	6.03	6.8	0
		Earlier	4	11	6.36	12.23	18.11	6.06	52.28	2.32	1.31	.203	1.21	2	.2	.1	.33	1.70	6.00	6.4	66
		Full flower	1	16	6.58	11.80	18.78	5.66	41.05	2.28	1.24	.215	1.56	2	.2	.1	.37	1.98	5.85	6.1	116
		Later	3	16	6.48	12.17	17.04	5.20	40.61	2.39	1.25	.229	1.83	2	.2	.1	.41	2.15	5.84	5.8	106
	Top	Hand	4	13	5.70	12.44	16.03	5.59	41.07	3.09	1.38	.436	1.83	2	.1	.1	.61	2.45	5.83	5.3	11
		Earlier	2	9	5.98	12.76	15.14	4.04	39.94	3.11	1.45	.489	1.53	1	.1	.1	.64	2.61	5.74	5.6	112
		Full flower	3	11	5.98	12.92	14.98	4.61	40.22	3.06	1.48	.430	1.31	1	.1	.1	.60	2.19	5.89	6.1	111
		Later	1	6	5.12	12.68	14.83	4.14	39.56	3.22	1.46	.480	1.83	2	.1	.1	.70	2.65	5.69	5.0	203

1/ Hand = Topped at full flower and hand suckered whenever suckers were 4-6" long.
Earlier = Sprayed with maleic hydrazide about a week before full flower, topped at full flower.
Full flower = Topped at full flower and sprayed with maleic hydrazide immediately after topping.
Later = Topped at full flower and sprayed with maleic hydrazide one week later, suckered then if necessary.

Appendix Table 15

Proportion of Tobacco from Different Sources in Final Cigarette Blends

Part of Blend	Hand Suckered	Time of Maleic Hydrazide Treatment: 1 week earlier	At full flower	1 week later
	%	%	%	%
By Type				
Flue-cured	60.0	60.0	60.0	60.0
Burley	35.0	35.0	35.0	35.0
Maryland	5.0	5.0	5.0	5.0
By States				
Georgia	9.7	8.3	9.2	9.0
South Carolina	13.0	10.6	10.3	11.7
North Carolina-flue	37.3	41.1	40.5	39.3
North Carolina-burley	7.0	7.0	7.0	7.0
Tennessee	9.6	10.3	9.7	9.6
Kentucky	7.8	7.2	7.8	7.9
Virginia-burley	7.0	7.0	7.0	7.0
West Virginia	3.6	3.5	3.5	3.5
Maryland	5.0	5.0	5.0	5.0
By part of plant				
Middle third	55.9	52.9	50.0	54.6
Top third	44.1	47.1	50.0	45.4

APPENDIX TABLE 16.--Comparison of Physical Properties of Experimental Cigarettes

Determination	Hand Suckered	Time of Maleic Hydrazide Treatment: 1 week earlier	At full flower	1 week later
Length (mm)	70.0	70.0	70.0	70.0
Circumference (mm)	25.79	25.72	25.83	25.56
Weight per cigarette (gm)	1.010	1.058	1.040	1.054
Calc. Wt. per cigarette at 12% moisture (gm)	1.004	1.050	1.030	1.043
"Draw" of cigarette:				
Measured by suction necessary to pull air through cigarette at given rate (cm H_2O). (Low values = easy draw)	9.7	6.8	7.2	9.0
Measured by air flow through cigarettes at given suction (cc/sec) (High values = easy draw)	16.5	19.7	17.9	16.4
Calc. air flow at standard conditions 1/	15.0	20.7	17.9	16.9
Calc. filling power compared to hand suckered to give uniform flow 2/	Standard	-11.0%	-5.6%	-3.7%
Density of cigarette at 65% RH and 75°F. (g/cc)	.260	.274	.267	.272
Compressibility:				
As calc. deflection (mils) at uniform density 3/	31.5	35.5	34.0	30.3
Calc. loss in firmness compared to hand suckered	Standard	-12.7%	-8.0%	+3.8%
Calc. filling power compared to hand suckered	Standard	-5.1%	-3.5%	+1.9%

1/ Corrected to uniform moisture (12%), uniform circumference (26.75 mm) and uniform cigarette weight (1.040 gm/cgt) on basis of other work.

2/ Calculated on basis of other work which indicates that 20 mg difference in tobacco per cigarette will cause a difference in air flow of 1 cc/sec.

3/ Data obtained on cigarettes equilibrated to 65% RH and 75°F. and corrected to uniform density of 0.268 gm/cc.

APPENDIX TABLE 17.--Comparison of Burning Properties and Smoke Composition of Experimental Cigarettes

Determination	Hand Suckered	Time of Maleic Hydrazide Treatment: 1 week earlier	At full flower	1 week later
Static burn time (min) [LSD(.05) = .36]	11.51	13.30	12.83	12.54
Machine smoking burn rate (mm/min)	3.52	3.40	3.43	3.31
Number of puffs/40 mm.				
Test 1	8.1	8.3	8.4	8.4
Test 2	8.9	8.0	8.0	8.3
Materials in trap:				
Smoke (mg/cig):				
Test 1	48.2	47.5	47.1	47.0
Test 2	45.6	48.8	46.6	44.8
Water (mg/cig):				
Test 1	9.0	10.5	8.8	8.3
Test 2	8.8	13.2	10.9	8.0
Dry Smoke (mg/cig):				
Test 1	39.2	37.0	38.3	38.7
Test 2	36.8	35.6	35.7	36.8
Nicotine (mg/cig):				
Test 1	2.45	2.27	2.34	2.48
Test 2	2.31	2.30	2.34	2.40
Nicotine transfer (%)				
Relative[1]	17.7	18.8	18.6	17.3
Absolute[2]	50.2	45.6	46.5	42.9

1/ Nicotine in the smoke expressed as a percentage of the nicotine in the tobacco burned - corrected for cigarette weight and weight of butt.

2/ Nicotine in the smoke expressed as a percentage of the nicotine in the tobacco burned during puffing only - same corrections as above plus correction for tobacco burned during the interval between puffs.

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