Technical Bulletin N

Growing Tobacco as a Source of Nicotine[1]

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UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF PLANT INDUSTRY, IN COOPERATION WITH THE AGRICULTURAL EXPERIMENT STATIONS OF CALIFORNIA, LOUISIANA, MARYLAND, MISSOURI, NORTH CAROLINA, OREGON, PENNSYLVANIA, TENNESSEE, VIRGINIA, WEST VIRGINIA, WISCONSIN, AND THE NORTH CAROLINA DEPARTMENT OF AGRICULTURE

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INTRODUCTION

Nicotine has long been used as an insecticide. It is also a possible source of nicotinic acid. At present approximately a million pounds of the alkaloid are produced annually in the United States, the product being marketed chiefly in the form of nicotine sulfate. Up to the present the supply of nicotine has been derived almost entirely from byproducts of tobacco manufactures, particularly stems, leaf scrap, and clippings, and from low grade or damaged leaf poorly suited for the manufacture of tobacco products and therefore commanding very low prices. In view of the fact that in recent years there has been a marked increase in demand for nicotine as an insecticide and as a

[1] Submitted for publication September 1941.

[2] In these investigations the field plantings of tobacco, with the exception of those at the Arlington Experiment Farm, Va., and in Missouri and Oregon, were carried out by coworkers of the Division of Tobacco Investigations in conjunction with other cooperative tobacco-production projects in the tobacco-growing States and in certain cases by members of other Divisions of the Bureau of Plant Industry. Those most actively concerned were: In Wisconsin, James Johnson, of this Division and the State experiment station; in Pennsylvania, the late Otto Olson, of this Division; in West Virginia, T. C. McIlvaine, of this Division and the State experiment station; in Maryland, D. E. Brown, of this Division; in Virginia, W. W. Green, of this Division and the State experiment station; in North Carolina, E. G. Moss, of this Division and the State department of agriculture, and J. F. Bullock, of this Division; in Tennessee, F. S. Chance, of this Division and the State experiment station, and Lester Weakley, of the State experiment station; in Louisiana, George Arceneaux, of the Division of Sugar Plant Investigations; in California, G. A. Wiebe and C. A. Suneson, of the Division of Cereal Crops and Diseases, and G. J. Harrison and F. W. Herbert, of the Division of Cotton and Other Fiber Crops and Diseases. Special credit is due Messrs. Wiebe and Suneson for the rather extensive experiments that have been successfully carried out at Davis under irrigation through the courtesy of the California Agricultural Experiment Station. In Oregon the experimental plantings were under the supervision of G. R. Hyslop, H. B. Howell, and A. E. Engbretson, of the State experiment station; and in Missouri the field trials, located at Weston, through the helpful advice of C. A. Helm, of the State experiment station, were carried out by E. E. Brill, an experienced tobacco grower. A considerable portion of the chemical laboratory work was done by J. M. Hankins, formerly of this Division.

material from which to make nicotinic acid, it has seemed desirable to study experimentally the possibilities in growing tobacco primarily for extraction of nicotine. If this method proves economically feasible, it should enable tobacco growers to meet any demand in excess of the quantity of nicotine obtainable from present sources.

The tobacco crop of this country as now grown is estimated to contain an average of 2.5 to 3.0 percent nicotine (in the leaf), and the average yield of leaf is about 800 pounds per acre, equivalent to 20 to 24 pounds of nicotine per acre. Because of the woody character of the stalks, their content of nicotine is too low to justify their utilization for extraction purposes. The upper range in nicotine content of the leaf, which is attained only occasionally, is from 6 to 8 percent. Of the various types of leaf, the dark air-cured and fire-cured tobaccos average highest in nicotine, 4 to 4.5 percent, due primarily to cultural methods employed, whereas Maryland tobacco has perhaps the lowest nicotine content, around 2 percent. Some of the cigar types produce the highest average yield of leaf per acre, 1,200 to 1,400 pounds, but with an intermediate nicotine content. Accordingly, under present conditions of culture the output of nicotine per acre, if the entire leaf crop were used for extraction, would range from approximately 20 to 40 pounds. It would require 30 million pounds of leaf, or the product of somewhat less than 40,000 acres of average yield and nicotine content, to supply a million pounds of nicotine.

For the 10-year period 1929–38 the estimated average acre value of the tobacco crop was $135 or about 17 cents per pound. The corresponding output of nicotine per acre, even for those types of tobacco having the highest content, would be only 30 to 40 pounds and on the basis of a dollar per pound farm value for the nicotine, which is materially higher than prevailing prices applying to nicotine in tobacco byproducts, the gross return would be $30 to $40 per acre. Actually, the farm value of such tobacco when diverted to nicotine extraction has averaged 2 to 2.5 cents per pound, or not more than about $20 per acre. Obviously the per acre production of nicotine must be greatly increased or the cost of growing the crop must be greatly lowered to make it possible for the grower to receive a reasonable return on the crop to be used solely for insecticidal purposes. The necessary increase in nicotine production per acre can be accomplished only by increasing the tonnage of tobacco or the percentage content of the alkaloid, or both.

In addition to ordinary tobacco, *Nicotiana tabacum* L., the only species of *Nicotiana* showing any promise of meeting these requirements was *N. rustica* L. Preliminary tests with this species were begun more than 25 years ago, but it has been possible only in recent years to undertake sufficiently comprehensive experiments to yield definite results, especially as to the most favorable conditions of soil and climate for obtaining very high nicotine production. During this interval Collison and associates [3] have reported results of experiments with *N. rustica* in western New York State, indicating a yield of 100 to 150 pounds of nicotine per acre.

Present commercial tobacco culture is sharply localized, primarily because of the extremely exacting requirements as to conditions of soil and climate for producing high-quality leaf of the various types.

[3] COLLISON, R. C., HARLAN, J. D., and STREETER, L. R. HIGH-NICOTINE TOBACCO. N. Y. (Geneva) Agr. Expt. Sta. Bul. 562, 20 pp. 1929.

However, the tobacco plant can be readily grown under a very wide range of soil and climatic conditions if quality of product is ignored, so that culture for insecticidal purposes need not be restricted to present tobacco-producing areas. On the other hand, environment is an important factor affecting the quantity of nicotine formed in the plant.

Available information shows that three major factors or groups of factors influence the tonnage of dry matter produced per acre and the nicotine content of tobacco: (1) The species, variety, and strain used; (2) the environment in which the plant is grown, primarily the conditions of soil and climate; (3) the cultural, curing, and handling methods employed as, e. g., time of transplanting and harvesting, spacing of plants, topping, and suckering operations.

Previous work on the nicotine problem, largely from the standpoint of reducing the present content of nicotine in the various types of leaf tobacco used in the manufacture of cigars and cigarettes, has furnished a valuable background both in collection of seeds of species and varieties most suitable for the work and in extensive observational data on factors influencing the formation of nicotine in the plant.

PLAN AND PROCEDURES

The work as conducted has been concerned essentially with carrying through a series of field plantings of different species and varieties of tobacco in various localities to obtain data on yields and other comparative results, including laboratory studies of the experimental material to determine the actual production of nicotine. The field tests have been variously modified to include observations on effects of irrigation, early and late planting, early and late harvesting, high and low topping, frequent and infrequent suckering compared with no suckering, and wide and close spacing. Some observations were made on the inheritance of nicotine content in certain *Nicotiana rustica* hybrids and on the distribution of nicotine in the different organs of the plant. The results of inheritance studies are presented elsewhere.[4] Limited observations also were made on direct field planting to avoid transplanting operations and the possibilities of obtaining a second or sucker (ratoon) crop from a single planting.

The size of the plots varied considerably, usually from individual rows of one-hundredth acre to plots consisting of several rows and one-eighth or one-fourth acre in area. In most cases no fertilizer or manure was used. However, the tests conducted at Arlington Farm were an exception to this as 4–8–4 fertilizer at the rate of 800 pounds per acre was applied in the drill in addition to liberal broadcast applications of stable manure. In general, standard methods of planting, cultivating, and harvesting, with such modifications as were required for specific purposes, were followed. *N. rustica* usually was spaced 18 inches and ordinary tobacco 24 inches apart in the row, whereas the distance between rows was 3 or 3.3 feet for *N. rustica* and 3 or 3.5 feet for ordinary tobacco, except as shown in detail in the tabulation of results. Both the ordinary tobacco and *N. rustica* were topped and suckered, unless otherwise indicated in the tabulation of results.

[4] SMITH, HAROLD H., and BACON, CHARLES W. INCREASED SIZE AND NICOTINE PRODUCTION IN SELECTIONS FROM INTRASPECIFIC HYBRIDS OF NICOTIANA RUSTICA. Jour. Agr. Res. 63: 457–467, illus. 1941.

Except when special tests were being made, the ordinary tobacco and *N. rustica* were harvested when judged to be ripe and were then subjected to the usual process of air-curing on the stalk. However, in the case of the *N. rustica*, as there was no question of quality involved, the material was allowed to dry out in more or less open sheds or in whatever type of building that was available. Actually, in most instances, a fairly good cure was obtained as the *N. rustica* leaves are thick and do not dry out as rapidly as ordinary tobacco leaves. The cured leaves take on a seal-brown color and have other properties in common with ordinary air-cured tobacco, although their greater thickness gives them the character of thin leather or chamois.

When the curing was completed and the proper weather conditions prevailed to permit the handling of the material without breakage, the plants were removed from the curing buildings and the yield of stalk and leaf determined separately. For nicotine determinations the material from 25 to 40 representative plants was sent to the laboratory. As soon as received the leaves and stalks were allowed to dry out separately under warm room conditions and when thoroughly air-dry the weights of each were taken. All the material was first ground in a hammer mill to pass through a ⅛-inch screen, and then, after thorough mixing, a subsample of about 1 quart was prepared for analysis by regrinding in a laboratory mill to pass a 30-mesh sieve.

The total alkaloid content was determined by a modification of the Keller method developed in the Division of Tobacco Investigations.[5] A few of the samples were also analyzed by the official method for nicotine,[6] and the values found were in substantial agreement.

In order that the acre yields and the nicotine content found in the different localities might be directly comparable, in most cases the values are given on a basis of 20-percent-moisture content. Three methods were used to calculate these figures. In some instances the moisture content of the crop was determined at the time it was weighed at the station where it had been grown, and in these cases it was only necessary to obtain the moisture content of the air-dried samples in order to make the computation. In other cases the moisture content of the material as weighed was not determined, and the assumption of a moisture content of 20 percent was made. Finally, in other samples it was necessary to compute the yields from the weights of the samples that were received and from the spacing data. However, in certain of the special tests, mostly made at Arlington Farm, Va., the acre yields and nicotine content are given on the air-dry basis (between 7 and 9 percent of moisture). Obviously the yields of nicotine per acre are independent of the moisture content of the material. In general, in computing the output of nicotine per acre the stalk as well as the leaf is included in the case of *N. rustica*, as it is considered that the *N. rustica* stalk is suitable for nicotine extraction. This does not apply, however, to ordinary tobacco, the stalk of which is hard and woody, so that, except as otherwise noted in the tables, only the leaf of the ordinary tobacco was used in computing the yield of nicotine per acre.

[5] GARNER, W. W., BACON, C. W., BOWLING, J. D., and BROWN, D. E. THE NITROGEN NUTRITION OF TOBACCO. U. S. Dept. Agr. Tech. Bul. 414, 77 pp., illus. 1934.

[6] ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. Ed. 4, 710 pp., illus. Washington, D. C. 1935.

CONDITIONS UNDER WHICH THE EXPERIMENTS WERE CARRIED OUT

The original introductions of species and strains were grown at the Arlington Experiment Farm, Arlington, Va. The preliminary trials that furnished a basis for the more extended tests were carried out chiefly at Lock Haven and Lancaster, Pa., and a preliminary report on these tests was issued by the Pennsylvania State Experiment Station.[7] In recent years, 1934–38, more detailed studies have been conducted at Arlington Farm, Arlington, Va., on the factors influencing the tonnage of dry matter per acre and the percentage content of nicotine.

Tests in the non-tobacco-producing areas on the Pacific coast were located at Shafter and Davis, Calif., and Corvallis and Astoria, Oreg. The tobacco was irrigated at the California locations but was not consistently irrigated in the Oregon tests. The midwestern locations were at Madison, Wis., and Weston, Mo. Trials were carried out at Lakin, W. Va., and Greeneville, Tenn. Tests of short duration were conducted at Upper Marlboro, Md.; Bowling Green, Va.; Willard and Wenona, N. C.; Houma, La., and Clarksville, Tenn.

The plantings at Shafter were on Delano sandy loam, which is rated as one of the best agricultural soils in California. At the Davis location the soil employed belongs to the Yolo series and varied from a sandy loam to a loam. This is a soil that shows some cracking following irrigation. The Oregon tests were located on Newberg sandy loam at Corvallis and on diked tideland, which is a sedimentary soil high in organic or peaty material, at Astoria. Miami silt loam, which had been heavily manured for 10 years, was the type on which the tests were located at Madison, Wis. Tests at Lakin, W. Va., were located on Huntington silt loam along the flood plain of the Ohio River, which had been subjected to overflow by the river occasionally during the winter. The Greeneville, Tenn., test was located on a silt loam soil that was in a low area where moisture was more abundant than is usual in this region, but in 2 years out of 3 the crop was so stunted by drought that results are given for only 1 year. The Pennsylvania tests were located on Hagerstown silt loam at Lancaster and Huntington sandy loam at Lock Haven. The Arlington Farm tests generally were located on soils that have been mapped as Keyport silt loam, although a few tests were located on an area known as the "flats," which had been pumped in from the Potomac River and was a sandy loam. The tests at Upper Marlboro were located on Collington very fine sandy loam.

The tests at Weston, Mo., were located on rolling Knox silt loam, but here the rainfall was so scant that results were poor though they serve to show the hazards to production in this area. Tests at Houma, La., were located on Yazoo very fine sandy loam, which is an extensive soil type of the region. It is considered the best sugarcane soil of the Mississippi alluvium. A single season's tests were conducted at Clarksville, Tenn., located on Clarksville silt loam. Tests in North Carolina were on muck at Wenona and Dunbar fine sandy loam at Willard. The soil at Bowling Green, Va., was a sandy loam that has not been mapped. This soil is possibly the most infertile of any

[7] HALEY, D. E., GARDNER, F. D., and WHITNEY, R. T. NICOTIANA RUSTICA AS A SOURCE OF NICOTINE FOR INSECT CONTROL. Science (n. s.) 60: 365–366. 1924.

on which the tests were located. It is evident that the soil types represented at these locations are quite varied and include some of the typical soils of the United States.

The weather conditions prevailing at the several locations varied from season to season and from location to location. The published records of the Weather Bureau can be consulted for detailed information concerning temperature and rainfall at the locations indicated in most cases or at the nearest station of that Bureau.

The several locations at which the tests were conducted are fairly representative of the possible climatic and soil combinations that occur in the United States. Although the tests have not been conducted for an extended period at the several locations, they will serve to indicate in an exploratory way approximately the results to be expected in the environments represented.

EFFECT OF SOIL AND WEATHER ON NICOTINE YIELD

The combined effect of soil and weather on nicotine production is well illustrated in tables 1 and 2, which set forth the comparative results obtained at various locations and in different years. In these plantings, the Madole variety of ordinary tobacco, which is a standard variety in the production of the dark fire-cured type of leaf tobacco, was used generally, except that local strains of burley were employed at Weston, Mo., and Lakin, W. Va., and the cigar-type variety, Havana Seed, at Madison, Wis. For the tests with *N. rustica*, the variety designated as No. 34752 was used in 1934 and the variety Brasilia in subsequent years. These varieties are further identified in the next section (p. 16).

TABLE 1.—*Summary of yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre in plantings of N. rustica and ordinary tobacco, both topped and suckered, at Astoria and Corvallis, Oreg.; Shafter, Calif.; Weston, Mo.; Greeneville, Tenn.; Houma, La.; Willard and Wenona, N. C., and Lancaster, Pa., during the period 1934–37*

YIELD PER ACRE (20-PERCENT-MOISTURE BASIS)

Species	Oregon			California, Shafter			Missouri, Weston		Tennessee, Greeneville, 1935	Louisiana, Houma		North Carolina		Pennsylvania, Lancaster		Average	
	Astoria, 1934	Corvallis		1934	1935	1936	1935	1936		1936	1937	Willard, 1935	Wenona, 1935	1934	1936		
		1934	1935														
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*[1]	*Pounds*[2]
N. rustica	2,736	2,553	2,708	1,670	------	------	1,515	1,248	1,768	2,272	810	1,744	1,890	3,089	4,551	2,196	1,981
Ordinary tobacco	1,638	1,672	2,890	2,925	3,200	2,914	1,946	1,325	1,720	------	------	1,390	1,560	------	------	2,107	1,896

NICOTINE CONTENT (20-PERCENT-MOISTURE BASIS)

	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*[1]	*Percent*[2]
N. rustica	4.38	3.66	3.33	5.84	------	------	3.73	3.13	4.56	2.73	1.80	1.67	3.30	3.33	4.46	3.53	3.73
Ordinary tobacco	2.16	1.13	.90	3.13	2.14	3.14	2.29	2.24	4.50	------	------	1.00	2.46	------	------	2.28	2.20

PRODUCTION OF NICOTINE PER ACRE

	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*[1]	*Pounds*[2]
N. rustica	119.9	93.4	90.2	97.5	------	------	56.6	39.1	80.6	62.0	14.6	29.1	62.5	102.7	203.0	80.9	74.3
Ordinary tobacco	35.3	18.9	25.9	91.6	68.5	91.5	44.6	29.7	77.4	------	------	13.7	38.4	------	------	48.7	41.7

[1] Average for entire period.
[2] Average where both ordinary tobacco and *N. rustica* occur in the same year.

TABLE 2.—*Summary of yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre in plantings of N. rustica and ordinary tobacco, topped and suckered, compared with N. rustica not topped and suckered, at Shafter and Davis, Calif.; Madison, Wis.; Lakin, W. Va.; Bowling Green, Va., and Upper Marlboro, Md., during the period 1934–36*

YIELD PER ACRE (20-PERCENT-MOISTURE BASIS)

Species	Treatment	California				Wisconsin, Madison, 1934	West Virginia, Lakin, 1934	Virginia, Bowling Green, 1934	Maryland, Upper Marlboro, 1935	Average	
		Shafter, 1934	Davis								
			1934	1935	1936						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds* [1]	*Pounds* [2]
N. rustica	Topped and suckered	1,670	2,144	3,488	3,010	3,098	1,111	1,312	2,216	2,256	2,420
Do	Not topped and suckered	2,592	4,254	5,888	3,834	3,478	1,733	1,612	2,605	3,249	3,630
Ordinary tobacco	Topped and suckered	2,925	2,945	2,500	2,859	1,396	2,698				2,554

NICOTINE CONTENT (20-PERCENT-MOISTURE BASIS)

		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent* [1]	*Percent* [2]
N. rustica	Topped and suckered	5.84	6.97	5.68	5.55	3.37	3.25	5.12	2.31	4.76	5.11
Do	Not topped and suckered	2.47	3.09	1.47	1.20	2.03	.84	1.32	.71	1.64	1.85
Ordinary tobacco	Topped and suckered	3.13	2.45	3.68	3.72	3.13	4.02				3.36

PRODUCTION OF NICOTINE PER ACRE

		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds* [1]	*Pounds* [2]
N. rustica	Topped and suckered	97.5	149.5	198.2	167.0	104.5	36.1	67.2	51.1	108.9	125.5
Do	Not topped and suckered	64.0	131.5	86.6	46.0	70.6	14.6	21.3	18.5	56.6	68.9
Ordinary tobacco	Topped and suckered	91.6	72.2	92.0	106.4	43.7	108.5				85.7

[1] Average for entire period.
[2] Average where both *N. rustica* and tobacco occur in the same year.

The poorest results were obtained at the southern locations, namely, Houma, La.; Willard and Wenona, N. C.; and Bowling Green, Va. The results obtained at Lakin, W. Va.; Greeneville, Tenn.; and Weston, Mo., are relatively poor, also. Results obtained at Clarksville, Tenn., for a single season are not shown in the tables, but here the *N. rustica* gave 60 pounds of nicotine whereas ordinary tobacco (*N. tabacum* L.) produced 70 pounds of nicotine per acre, a result more or less in line with previous observations. The tests are being continued, but present indications are that on the typical upland dark tobacco soils, that are of a rather droughty nature, comparatively low yields of nicotine may be expected.[8] The reason for the low yield of nicotine at these locations is not entirely clear, but high temperatures and uneven distribution of rainfall undoubtedly were important contributing causes. The relatively low fertility of the soil may be largely the explanation in some cases. At Weston, Mo., the soil employed is known to be relatively fertile, and lack of rainfall for long periods during the growing season in both years of the test is probably the chief reason for the low yields of nicotine obtained.

It is evident that the higher yields of nicotine have been obtained at the far western locations where it was generally customary to irrigate or during seasons when there was a good distribution of rainfall, as at Arlington Farm, Va., and Lancaster, Pa. It is true that the soils at these locations were considerably more fertile than at the southern locations.

Only 1-year's test is reported for Astoria, Oreg., so that definite conclusions are not justified, but this location, characterized by relatively low temperature, heavy fogs, and high humidity, gave promise of greater tonnage from *N. rustica* than was obtained at any other location (fig. 1). Under the conditions of the test the yield of nicotine

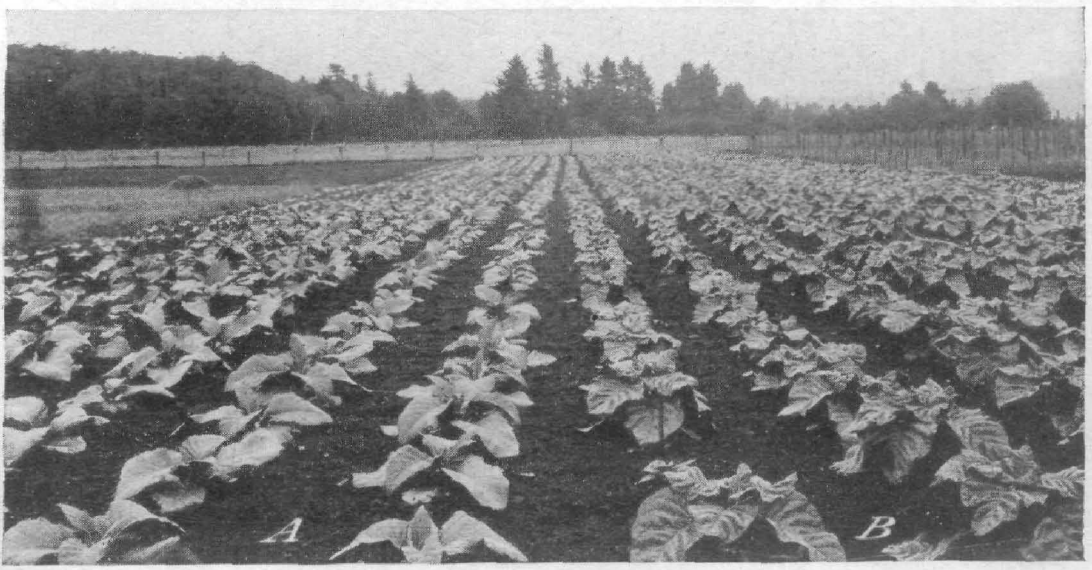

FIGURE 1.—Plantings of tobacco at Astoria, Oreg.: *A*, *Nicotiana tabacum*, Madole variety; *B*, *N. rustica*, strain 34753. Transplanted to field June 23; photographed August 3, 1934.

[8] An additional year's tests tend to substantiate these observations and also show that *N. rustica* does not yield any more nicotine than ordinary tobacco, namely, 50–70 pounds per acre, when grown on typical tobacco soils of the dark-fired area. However, when both are grown on moist areas approaching well-drained river bottom lands common in the area, *N. rustica* has yielded somewhat more than 100 pounds of nicotine but ordinary tobacco produced only about 50 pounds of nicotine per acre.

obtained, though above the average for all stations, was not very high when compared with results at the best locations. Unfortunately a windstorm damaged the crop just prior to harvest, so that there was a considerable loss of leaf material. The content of nicotine was relatively low, but this probably would have been increased if the date of harvest could have been deferred a sufficient number of days after the topping date. However, there is one serious draw-back to production in the Astoria region; namely, the difficulty of drying the crop after harvest, because of the excessive humidity. Additional tests were carried out in 1935 at Astoria, but, due to the loss of the crop by a freeze, samples were not obtained for analysis. It was observed at the Astoria location that ordinary tobacco had a peculiar type of growth characterized by the development of narrow, pointed leaves in the Madole variety, possibly because of the relatively low temperatures that prevail during the growing season. The *N. rustica* appeared to thrive under these climatic conditions, and further tests in this area would appear to be justified.

The results at the Shafter, Calif., location were not satisfactory with respect to growth of *N. rustica*, but this was not entirely due to weather conditions, as irrigation was applied. Insect and nematode damage apparently were the chief causes of poor growth of *N. rustica* at Shafter. The ordinary tobacco produced considerably more tonnage than *N. rustica* and gave a fairly good yield of nicotine in spite of insect and nematode attacks.

The tests at Davis, Calif., have most consistently given a high yield per acre of nicotine (150 to 200 pounds) from *N. rustica*. It would appear, therefore, that the combination of weather and soil at this station is better than that of any other location at which the tests were conducted. The fact that the crop was grown under irrigation at this station and that no complicating diseases and insect pests occurred may be in a large measure responsible for the consistent production of a high nicotine yield each year.[9]

The effect of soil type on nicotine yield at the Arlington Farm, Va., location is shown in tables 9, 10, 11, and 12. Here, the light sandy loam soil type, when heavily manured, produced much the same yield of nicotine per acre in 1935 from both *N. rustica* and ordinary tobacco as the heavier silt loam soil manured in the same manner. Poor results were obtained from both *N. rustica* and tobacco on the light soil during the season of 1936. This result appeared to be associated with high temperatures of a few days' duration when the soil moisture was inadequate. These results serve to emphasize the fact that soil and climatic interrelationships are very closely associated with plant growth and behavior as they affect the production of nicotine.

RELATIVE EFFICIENCIES OF SPECIES, VARIETIES, AND STRAINS FOR PRODUCTION OF NICOTINE

There are many species of *Nicotiana*, but only two have the growth characteristics and content of nicotine that would justify consideration for present purposes, namely, *N. tabacum*, which is the ordinary tobacco of commerce, and *N. rustica*, also utilized for production of

[9] Further trials at Davis over a period of 2 years have yielded, in both years, about 300 pounds of nicotine per acre where improved practices, such as heavy irrigation (about 30 inches of water), late harvesting, and the other improvements in procedure described in this bulletin, were applied.

smoking and chewing tobaccos in certain foreign countries. *N. rustica* was the species used by the aborigines of eastern North America, whereas the original stocks of *N. tabacum* came from South America, Mexico, or the West Indies.

FIGURE 2.—Individual Maryland Broadleaf tobacco plant that has been topped and suckered; typical growth for commercial production in most tobacco areas.

The species *Nicotiana tabacum*, ordinary tobacco, of which there are numerous varieties, usually grows to a height of from 4 to 6 feet in the field when not topped. As ordinarily topped, the height ranges from 2 to 4 feet. The flowers are usually pink in color in most commercial types, although white and carmine-red forms of the species are known. The shape of the flower is tubular with flower tube greatly exceeding

the calyx in length. The lobes of the corolla, five in number, at the upper end are distinctly pointed and separated. Commonly the leaves are sessile, that is, without a petiole or stalk, and auricled or partly clasping the stem. They vary greatly in size and shape, depending upon the variety and the growth conditions. The leaves of some of the larger growing varieties may reach a length of 2 to 3 feet, with a width of about one-half the length, although some of the Turkish kinds, as grown commercially, are very small, sometimes less than 3 inches in length. It is customary in commercial tobacco production to top or disbud the plants and to break off the suckers in the leaf axils as they develop. An individual plant of Maryland Broadleaf so handled is shown in figure 2. This practice tends to

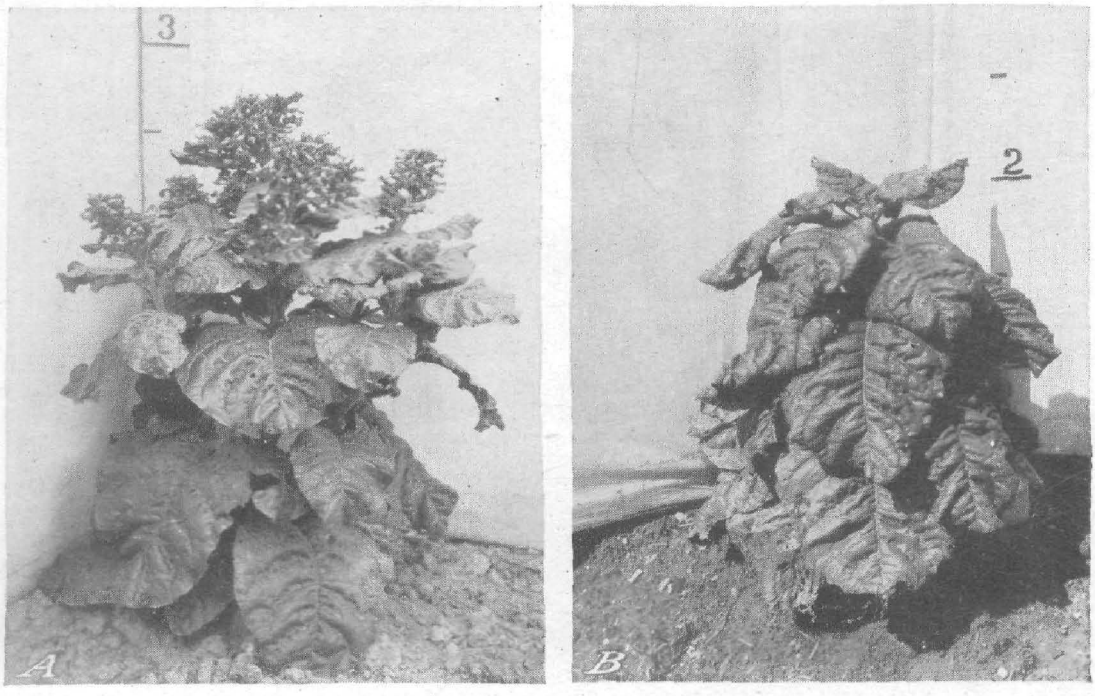

FIGURE 3.—*N. rustica* (34753 strain): *A*, Plant not topped nor suckered, showing pronounced sucker or axillary bud development characteristic of all known strains of this species; *B*, plant topped and suckered to induce maximum nicotine accumulation.

produce leaves of a larger size and with higher nicotine content than is produced by an untopped and unsuckered plant. (See table 2.)

The species *N. rustica*, as seen in field plantings at Arlington Farm, Va., has attained a height of 1½ to 3 feet (fig. 3, *A* and *B*). The leaves tend to be thick, broadly ovate or egg-shaped, with a distinct naked petiole or leafstalk. The plant is covered with a pubescence or hairy growth that is very sticky due to exuded gums. The flowers are smaller than in ordinary tobacco, with corolla pale yellow to greenish in color. The corolla tube is short and the lobes are distinctly rounded. All known strains of *N. rustica* show a decided development of suckers or axillary branches (fig. 3, *A*), but in culture these must be removed regularly, as shown in figure 3, *B*, if the plant is to develop a high nicotine content.

The relative size of *N. rustica* strains as compared with ordinary tobacco varieties is shown in tables 3, 4, and 5. It is evident from the data shown in these tables that there is a large variation in height of plant, length of internode, average area of individual leaves, and total leaf area per plant. The close spacings of both ordinary tobacco varieties and *N. rustica* of the Brasilia strain produced plants with longer internodes. This effect of close planting, however, was greater with the larger growing types than with Xanthi, a Turkish variety, and the Brasilia strain of *N. rustica*. The greatest total leaf area per acre did not necessarily appear to be correlated with the variety showing the largest average-size leaf. It is evident that the closer spacing definitely reduced the size of the individual leaf in all varieties of ordinary tobacco except the small-leaved Xanthi. The *N. rustica* was definitely smaller than ordinary tobacco, although Xanthi had a leaf area only slightly greater than the Brasilia strain of *N. rustica* when planted on the same soil and spaced the same distance. The widest spacing of *N. rustica*, 39 by 18 inches, did not show any advantage in size of plant over the 30 by 18 inches spacing. The close spacings with both ordinary tobacco and *N. rustica* produced a greater leaf area per acre.

TABLE 3.—*Average height and leaf counts of all plants of N. rustica strains and of Connecticut Broadleaf, grown at Arlington Farm, Va., 1934* [1]

Species and variety or strain selection	July 12 [2]			August 27 [3]				
	Height	Green leaves	Average length of internodes	Height	Leaves			Average length of internodes
					Dry	Green	Total	
N. rustica:	*Inches*	*Number*	*Inches*	*Inches*	*Number*	*Number*	*Number*	*Inches*
34752	17.43	13.50	1.29	18.00	1.93	12.83	14.76	1.22
34753	16.15	19.07	.85	18.17	2.40	17.33	19.73	.92
34754	21.60	16.20	1.33	20.20	2.10	15.00	17.10	1.18
Brasilia (A)	17.43	22.80	.76	19.93	2.03	20.07	22.10	.90
Brasilia (B)	17.40	22.43	.78	19.75	1.87	20.20	22.07	.89
68 (A)	21.20	18.87	1.12	26.23	2.47	16.73	19.20	1.37
N. tabacum:								
Connecticut Broadleaf	21.80	15.85	1.38	26.18	.85	12.50	13.35	1.96

[1] Transplanted to field May 23 and spaced 39 by 18 inches.
[2] Measurements and counts made about topping time.
[3] Measurements and counts made just prior to harvest, at which time a few of the leaves had dried.

TABLE 4.—*Average measurements of 10 plants of N. rustica and of ordinary tobacco grown in Missouri, California, and Oregon, 1935*

N. RUSTICA (BRASILIA, TOPPED)

Location	Spacing of plants	Date of planting	Date measured	Height	Leaves			Average length of internode
					Dry	Green	Total	
	Inches			*Inches*	*Number*	*Number*	*Number*	*Inches*
Weston, Mo	42 by 18	June 6	Aug. 19	18.3	1.5	20.6	22.1	0.825
Davis, Calif	30 by 18	May 21	Aug. 24	12.5	.1	12.9	13.0	.961
Corvallis, Oreg	36 by 18	June 17	Aug. 26	15.3	.0	15.3	15.3	1.000
Astoria, Oreg	36 by 33	May 1	Aug. 27	28.2	.0	17.9	17.9	1.572

N. RUSTICA (BRASILIA, UNTOPPED)

Davis, Calif	30 by 18	May 21	Aug. 24	27.4	No leaf counts made

TABLE 4.—*Average measurements of 10 plants of N. rustica and of ordinary tobacco grown in Missouri, California, and Oregon, 1935*—Continued

Location	Spacing of plants	Date of planting	Date measured	Height	Leaves			Average length of internode
					Dry	Green	Total	
	Inches			*Inches*	*Number*	*Number*	*Number*	*Inches*
N. TABACUM (MADOLE, TOPPED)								
Shafter, Calif.	36 by 24	May 9	Aug. 22	33.0	2.2	15.5	17.7	1.875
Davis, Calif.	36 by 36	May 27	Aug. 24	22.8	2.9	11.4	14.3	1.594
Corvallis, Oreg.	36 by 24	June 17	Aug. 26	28.6	.0	14.8	14.8	1.932
Astoria, Oreg.	36 by 33	May 1	Aug. 27	36.6	.0	15.7	15.7	2.331
N. TABACUM (MARYLAND MAMMOTH, TOPPED)								
Shafter, Calif.	36 by 24	May 9	Aug. 22	36.4	5.4	26.0	31.4	1.159
Davis, Calif.	36 by 36	May 27	Aug. 24	29.8	5.8	25.6	31.4	.949
Corvallis, Oreg.	36 by 24	June 17	Aug. 26	18.9	.0	17.7	17.7	1.068
Astoria, Oreg.	36 by 33	May 1	Aug. 27	14.6	.0	21.6	21.6	.676
N. TABACUM (MARYLAND MAMMOTH, UNTOPPED)								
Shafter, Calif.	Border rows	May 9	Aug. 22	62.0	5.6	49.6	55.2	1.123
Davis, Calif.	do	May 27	Aug. 24	45.0	6.2	38.8	45.0	1.000
N. TABACUM (WHITE BURLEY (HALLEY), TOPPED)								
Weston, Mo.	42 by 18	June 6	Aug. 19	28.8	3.2	16.8	20.0	1.440

TABLE 5.—*Effect of spacing of plants on average height, number of leaves to which plants were topped, leaf area per plant, area per leaf, internode length, and total area per acre of various varieties of N. tabacum and Brasilia strain of N. rustica, grown on Keyport silt loam soil, field G, Arlington Farm, Va., 1935* [1]

Species and variety or strain	Spacing of plants	Height of plants	Leaves per plant	Length of internode	Average area per leaf	Average area per plant	Computed total leaf area per acre
	Inches	*Inches*	*Number*	*Inches*	*Square feet*	*Square feet*	*Thousand square feet*
N. tabacum:							
Maryland Medium Broadleaf (Robinson's)	39 by 18	30.0	12.4	2.42	1.74	21.62	193.2
	39 by 36	29.6	19.2	1.54	1.82	34.89	155.9
Maryland Broadleaf	39 by 18	33.2	10.8	3.07	1.78	19.17	171.3
	39 by 36	30.0	17.8	1.69	2.11	37.58	167.9
Maryland Mammoth	39 by 18	40.6	16.6	2.45	1.39	23.11	206.5
	39 by 36	34.4	20.0	1.72	1.92	38.45	171.8
Pennsylvania Broadleaf	39 by 18	32.6	13.0	2.51	1.81	23.52	210.1
	39 by 36	27.4	14.8	1.85	2.06	30.49	136.2
Connecticut Broadleaf	39 by 18	37.2	10.6	3.51	1.60	16.93	151.3
	39 by 36	34.0	10.1	3.37	2.29	23.32	104.2
White Burley (Judy's Pride)	39 by 18	33.0	12.8	2.58	1.53	19.63	175.4
Improved Yellow Mammoth (fire-cured type)	39 by 36	35.8	16.0	2.24	1.87	29.55	132.0
	39 by 18	37.4	11.0	3.40	2.02	22.12	197.6
	39 by 36	32.8	11.6	2.83	2.61	30.30	135.4
Cash (flue-cured type)	39 by 18	42.8	14.0	3.06	1.29	18.03	161.1
	39 by 36	36.2	12.4	2.92	2.08	25.81	115.3
Greenwood (fire-cured type)	39 by 18	40.4	13.4	3.01	1.62	21.77	194.5
	39 by 36	32.4	13.8	2.35	2.04	28.19	125.9
One Sucker (dark air-cured type)	39 by 18	35.4	12.4	2.85	1.59	19.67	175.8
	39 by 36	32.0	13.4	2.39	1.84	24.72	110.4
Madole (fire-cured type)	39 by 18	37.6	12.0	3.13	1.87	22.43	200.5
	39 by 36	26.6	12.8	2.08	2.17	27.79	124.1
Russian Red Flower	39 by 18	39.4	9.6	4.10	1.42	13.62	121.7
	39 by 36	38.0	10.4	3.65	1.70	17.67	78.9
Xanthi (Turkish)	39 by 18	43.2	18.2	2.37	.45	8.14	72.8
	39 by 36	39.0	18.0	2.17	.48	8.63	38.5
N. rustica:							
Brasilia	30 by 12	19.1	14.8	1.29	.39	5.71	99.5
	30 by 18	19.2	15.8	1.22	.44	6.89	80.0
	39 by 18	19.0	16.4	1.16	.42	6.85	61.2

[1] Measurements made Sept. 26 and 27, 1935, just prior to late harvest. The data represent averages based on 5 plants.

The life history of *N. rustica* appears to be somewhat different from that of ordinary tobacco. The plant tends to mature early regardless of the conditions under which it grows. If unfavorable growth conditions, such as deficiency of soil moisture, prevail or if the plant is allowed to stand in the seedbed for too long a period, it becomes dwarfed and will not make the normal increase in size when favorable growth conditions again prevail. This effect also is reflected in sucker or axillary bud development and will extend even to the growing of a sucker or ratoon crop. If the plant has been disbudded at all of the leaf axils, there is not the vigorous growth in the second set of axillary branches that occurs in the first growth, and a sucker or ratoon crop does not attain a uniformly large size.

In an effort to avoid the shock of transplanting, the method of direct seeding of *N. rustica* in the field was tried but without consistent success, as it was not possible to obtain a uniform stand. The possibilities are not exhausted, as these trials were made under conditions of natural rainfall at Arlington Farm, where dry periods frequently occur to retard or prevent germination. It is possible that this procedure could be used in regions of high soil moisture or where irrigation is practiced.

Although from the earlier observations *N. rustica* was known to contain as a rule a higher percentage of nicotine, because of its relatively small size, as compared with most varieties of *N. tabacum*, there remained a question whether it would consistently give higher yields of nicotine per acre. Systematic tests were therefore conducted to determine which would produce the greatest amount of nicotine when grown under the same conditions at different locations. In table 6 it is evident that *N. rustica* has usually produced a much higher yield of nicotine per acre than ordinary tobacco. For reasons that were not definitely determined, the growth of *N. rustica* at Lakin, W. Va., was unsatisfactory, except in 1938, resulting in a low yield of nicotine. At the other locations the nicotine produced by *N. rustica*, in pounds per acre, was almost double that obtained from ordinary tobacco. However, where temperature, soil conditions, and pests appear to interfere with the growth of *N. rustica* (see table 1), the tobacco does not always double the quantity of nicotine. This was usually the result of a higher nicotine content, although in some instances an increased tonnage of dry matter is the chief factor. It is surprising that *N. rustica*, which is a much smaller plant as shown by measurements in tables 3, 4, and 5, was able to produce in many instances a larger amount of dry matter than ordinary tobacco. Some of the difference is due to the inclusion of the stalk in the *N. rustica* yields, whereas weights shown for ordinary tobacco represent only the leaf, but the greater amount was due to the increased thickness and weight per unit area of the *N. rustica* leaf.

TABLE 6.—*Summary of yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre in plantings of N. rustica and ordinary tobacco at Davis, Calif., Madison, Wis., Lakin, W. Va., and Arlington Farm, Va., during the period 1934–38* [1]

Location	Year	Yield per acre (20-percent-moisture basis)		Nicotine content (20-percent-moisture basis)		Production of nicotine per acre	
		N. rustica	Ordinary tobacco	*N. rustica*	Ordinary tobacco	*N. rustica*	Ordinary tobacco
		Pounds	*Pounds*	*Percent*	*Percent*	*Pounds*	*Pounds*
Davis, Calif	1934	2,144	2,945	6.97	2.45	149.5	72.2
	1935	3,488	2,500	5.68	3.68	198.2	92.0
	1936	3,010	2,859	5.55	3.72	167.0	106.4
Average		2,881	2,768	6.07	3.28	171.6	90.2
Madison, Wis	1934	3,098	1,396	3.37	3.13	104.5	43.7
	1935	3,513	1,156	4.30	2.62	151.0	30.3
	1936	1,625	1,244	3.02	2.10	49.1	26.1
	1937	2,981	1,168	5.37	4.51	160.0	52.7
	1938	3,629	1,692	2.80	2.69	101.6	45.5
Average		2,969	1,331	3.77	3.01	113.2	39.7
Lakin, W. Va	1934	1,111	2,698	3.37	4.02	36.1	108.5
	1935	1,088	1,220	3.46	2.88	37.7	35.1
	1936	1,379	1,781	3.63	3.93	50.0	70.0
	1937	1,358	3,010	4.37	3.13	59.4	94.2
	1938	4,150	2,263	3.42	2.69	142.1	60.9
Average		1,817	2,194	3.65	3.33	65.1	73.7
Arlington Farm, Va	1934	2,317	2,787	7.03	3.19	162.9	89.2
	1935	3,472	2,671	5.68	4.59	197.1	122.6
	1936	5,365	2,664	4.75	4.47	254.7	119.2
Average		3,718	2,707	5.82	4.08	204.9	110.3

[1] Varieties of *N. rustica* and ordinary tobacco used are shown on page 6.

A comparison of yields and production of nicotine per acre between different varieties and strains of *N. rustica* is shown in table 7. Ordinary tobacco also was grown in these tests. There was quite a wide variation in nicotine production from season to season and in the different strains of *N. rustica*. This difference was due largely to variation in yields of dry matter rather than to any great change in nicotine content. The types included in this test were selected on the basis of growth habits. Nos. 34752, 34753, and 34754 were introduced into this country from Italy. The Brasilia and No. 34753 closely resemble each other in growth characteristics and appear to be almost identical strains. Strains Nos. 63, 64, and 66 were selections from crosses but were discarded because of poor growth habits or low nicotine yields. No. 68 is from a cross of the Brasilia on the Winnebago strain. It is a much taller growing strain, as shown by the measurements (table 3), with a long internode. This cross was made by the late Otto Olson, of the Division of Tobacco Investigations, who conducted the early work on nicotine production in Pennsylvania. The letters following the numbers represent selections within each strain. Although the results are not absolutely consistent, they apparently show that the Brasilia No. 34753 strain and No. 68 strain give the highest yields of nicotine per acre.

TABLE 7.—*Summary of yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre in plantings of N rustica varieties and strains and of ordinary tobacco at Arlington Farm, Va.*

Species and variety or strain, and selection	Yield per acre (20-percent-moisture basis)														
	1934			1935			1936			1937			1938		
	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
N. rustica:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Brasilia (A)	1,691	589	2,280	1,717	821	2,538									
Brasilia (B)	1,739	622	2,361	1,907	866	2,773				1,348	963	2,311			
34752	1,473	426	1,899	1,643	587	2,230	1,111	416	1,527	1,475	693	2,168			
34753 (A)	1,869	448	2,317	1,983	729	2,712	1,800	739	2,539	1,457	820	2,277			
34753 (B)				1,844	709	2,553	1,785	734	2,519	1,498	890	2,388	1,445	610	2,055
34754	1,716	592	2,308	860	431	1,291									
68 (A)	1,652	738	2,390	1,021	516	1,537	1,679	1,062	2,741	1,618	1,386	3,004	1,448	1,510	2,958
68 (B)				2,212	1,268	3,480	2,107	1,428	3,535	1,646	1,427	3,073	1,371	789	2,160
68 (C)				1,851	1,023	2,874	1,782	1,035	2,817	1,728	1,323	3,051	1,105	536	1,641
Winnebago				1,336	477	1,813	1,252	533	1,785	1,359	679	2,038	803	345	1,148
66				1,848	1,045	2,893	1,467	939	2,406	1,304	794	2,098	1,353	908	2,261
64				1,299	665	1,964	946	523	1,469	1,201	666	1,867			
63				1,170	713	1,883									
N. tabacum:															
Connecticut Broadleaf	2,098	699	2,797	2,103			2,296								

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TABLE 7.—*Summary of yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre in plantings of N. rustica varieties and strains and of ordinary tobacco at Arlington Farm, Va.*—Continued

Species and variety or strain, and selection	Nicotine content (20-percent-moisture basis)														
	1934			1935			1936			1937			1938		
	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
N. rustica:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Brasilia (A)	8.40	2.05	6.76	6.96	1.80	5.29									
Brasilia (B)	7.89	1.92	6.32	7.12	1.72	5.43				2.32	1.14	1.83			
34752	8.43	3.26	7.27	6.46	2.79	5.50	7.90	2.32	6.38	3.25	1.70	2.75			
34753 (A)	7.97	3.12	7.03	6.19	2.71	5.25	5.15	1.75	4.16	3.14	1.96	2.71			
34753 (B)				5.53	2.79	4.77	5.89	1.86	4.72	3.10	1.88	2.64			
34754	7.70	2.88	6.47	7.71	1.81	5.74							4.58	2.10	3.84
68 (A)	9.18	2.50	7.12	5.96	2.54	4.81	6.62	1.27	4.54	3.31	1.03	2.26	2.54	.79	1.65
68 (B)				7.42	2.25	5.53	6.79	1.29	4.57	4.00	1.42	2.80	6.54	1.42	4.67
68 (C)				7.29	2.23	5.48	7.54	1.69	5.39	4.20	1.50	3.03	5.61	1.42	4.24
Winnebago				7.62	2.37	6.23	6.99	2.06	5.52	3.17	1.73	2.69	4.73	1.26	3.68
66				7.51	1.78	5.44	7.46	1.26	5.04	5.61	1.59	4.09	4.71	.89	3.18
64				7.95	1.92	5.91	7.52	1.55	5.39	4.30	1.62	3.34			
63				8.15	1.66	5.69									
N. tabacum:															
Connecticut Broadleaf	3.95	.81	3.16	5.02			5.19								

Species and variety or strain, and selection	Production of nicotine per acre														
	1934			1935			1936			1937			1938		
	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
N. rustica:															
Brasilia (A)	142.1	12.1	154.2	119.4	14.8	134.2									
Brasilia (B)	137.2	12.0	149.2	135.8	14.9	150.7				31.3	11.0	42.3			
34752	124.2	13.9	138.1	106.2	16.4	122.6	87.8	9.7	97.5	47.9	11.8	59.7			
34753 (A)	149.0	14.0	163.0	122.8	19.7	142.5	92.7	12.9	105.6	45.7	16.1	61.8			
34753 (B)				102.0	19.8	121.8	105.2	13.7	118.9	46.4	16.7	63.1	66.2	12.8	79.0
34754	132.2	17.0	149.2	66.3	7.8	74.1									
68 (A)	151.6	18.4	170.0	60.9	13.1	74.0	111.1	13.4	124.5	53.6	14.3	67.9	36.8	11.9	48.7
68 (B)				164.1	28.6	192.7	143.1	18.4	161.5	65.8	20.3	86.1	89.7	11.2	100.9
68 (C)				134.9	22.8	157.7	134.3	17.5	151.8	72.6	19.8	92.4	62.0	7.6	69.6
Winnebago				101.7	11.3	113.0	87.6	11.0	98.6	43.1	11.7	54.8	38.0	4.3	42.3
66				138.9	18.6	157.5	109.4	11.9	121.3	73.2	12.6	85.8	63.7	8.1	71.8
64				103.3	12.7	116.0	71.1	8.1	79.2	51.6	10.8	62.4			
63				95.3	11.9	107.2									
N. tabacum:															
Connecticut Broadleaf	82.8	5.7	88.5	105.6			119.2								

In addition to its practical importance, the possibility of further increasing nicotine yields from *N. rustica* is a matter of some theoretical interest. The principal avenue of approach appears to be in greater yields per acre of dry material. This might be accomplished by producing strains of *N. rustica* with larger leaves, by increasing the thickness or density of the leaves, or by obtaining combinations of these with an increased number of leaves. It may well be that the physiological limit of percentage content of nicotine already has been approached in the 12.80 percent figure reported in table 18. With a content of 10 percent actual nicotine, organic salts probably constitute about one-third of the total dry weight of the leaf.

The data in table 7 again show that the output of nicotine from ordinary tobacco is much lower than from the better strains of *N. rustica*. In one instance the nicotine content of the stalk of ordinary tobacco is shown and obviously it is quite low. The data of tables 9 to 12, relating primarily to effects of differences in spacing the plants in the field and time of harvest on nicotine production, will be found, when considered collectively, to further emphasize the high yields of nicotine that are obtained from *N. rustica* in comparison with ordinary tobacco. The two varieties of *N. rustica* dealt with in table 10 do not differ greatly in nicotine production. Under the conditions of the experiments summarized in tables 11 and 12 the different varieties of ordinary tobacco show in some cases wide differences in production of nicotine per acre, which for the most part are due to variations in tonnage of dry matter produced. It is interesting to note that the Turkish strain, Xanthi, had a very high nicotine content under the particular conditions of the test, although this type as grown commercially in the Near East is generally noted for its relatively low nicotine content. This difference probably is due chiefly to differences in spacing and topping the plants.

EFFECT OF CULTURAL METHODS ON NICOTINE YIELDS

The use of suitable cultural methods often constitutes the principal means the grower has for better adapting the tobacco plant to some particular use. This is particularly true where the production of nicotine is of chief concern. Some cultural methods or procedures that may be modified are: Topping and suckering of the plants, spacing in the field, varying the transplanting and harvest dates, use of irrigation, and applying manures and fertilizers.

The effect of topping and suckering on nicotine yield from *N. rustica* is well shown in table 2. It is evident that the production of nicotine per acre was materially increased by topping and suckering, and in many instances the output was doubled. A high yield of nicotine is shown at the Davis location for the year 1934 on the treatment indicated as not topped and suckered. However, due to a misunderstanding, the *N. rustica* on this plot was disbudded frequently; that is, the flower buds were removed and no seed pods were allowed to form. This really constituted a sort of high topping applied to both the main stem and the suckers. In all other cases (table 2) the plants on the plots that were not topped and suckered were allowed to develop without mutilation. Low topping (about 10 leaves) appears to have produced no gain in yield of nicotine for *N. rustica* as compared with the regular or high-topped (18 to 20 leaves) plants (table 8). In fact,

with normal spacing of the plants the yield of nicotine per acre from the low-topped plants was lower than from high-topped plants. However, in one case in which irrigation was practiced, early and consequently low topping gave an increased yield of nicotine (see table 17). Suckering at approximately weekly intervals produced no gain in nicotine production as compared with intervals of about 2 weeks. (See table 17.)

It seemed possible that with a small-growing plant such as *N. rustica* close spacing would give greater nicotine yields. This possibility was tested in some detail at Arlington Farm, Va., and the results are set forth in tables 8 to 10. There appears to be as a rule a disadvantage in close spacing, 30 by 12 inches (fig. 4), as compared

FIGURE 4.—*N. rustica*, spacing 30 by 12 inches, field G, Arlington Farm, Va.: *A* and *B*, Strain 68; *C* and *D*, Strain 34753. Photographed September 10, 1936, a few days prior to second harvest date, 45 days after topping. Scale indicates height in feet. (See table 10 for nicotine production.)

with wider spacings, 30 by 18 inches (fig. 5) and 39 by 18 inches (fig. 6). During the season of 1936, when an extremely hot and dry period prevailed for a few days, the close spacing on the sandy soil appeared in some instances to give a lower yield of nicotine from the later harvests than from the earlier harvests. This may be explained by the higher water requirements of close spacing, which served to cause burning of the lower leaves.

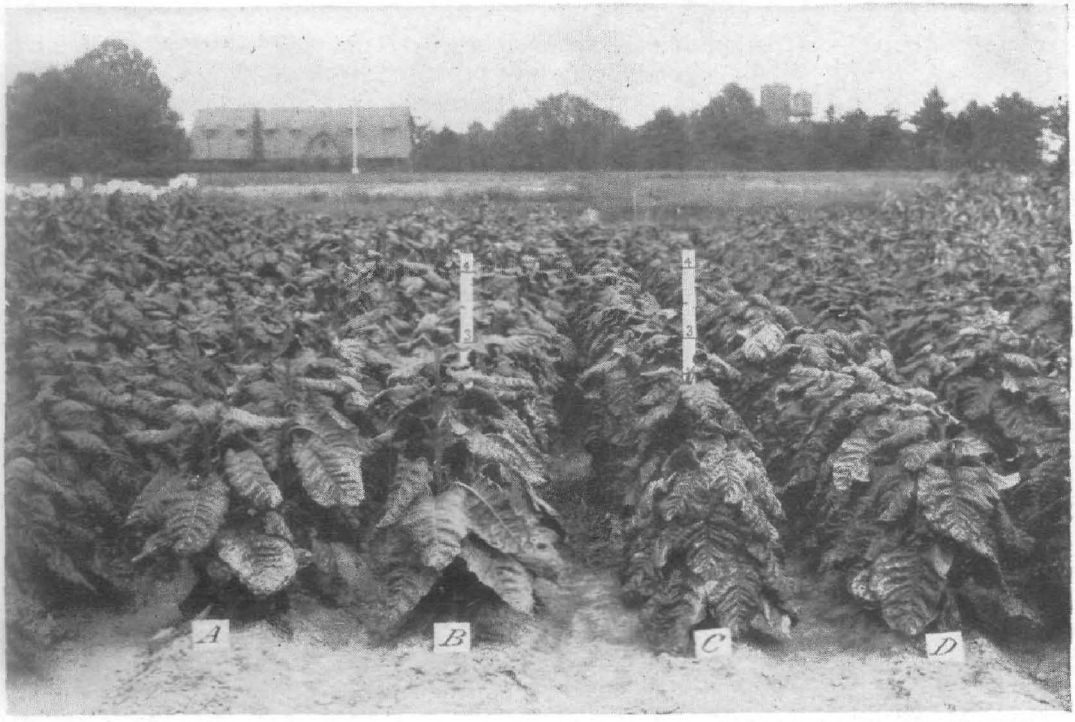

FIGURE 5.—*N. rustica*, spacing 30 by 18 inches, field G, Arlington Farm, Va.: *A* and *B*, Strain 68; *C* and *D*, Strain 34753. Photographed September 10, 1936, a few days prior to second harvest date, 45 days after topping. Scale indicates height in feet. (See table 10 for nicotine production.)

FIGURE 6.—*N. rustica*, spacing 39 by 18 inches, field G, Arlington Farm, Va.: *A* and *B*, Strain 68; *C* and *D*, Strain 34753. Photographed September 10, 1936, a few days prior to second harvest date, 45 days after topping. Scale indicates height in feet. (See table 10 for nicotine production.)

TABLE 8.—*Effect of spacing, height of topping, and time of harvest on yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from leaves and stalks of N. rustica 34753 grown on Keyport silt loam at Arlington Farm, Va., 1936*

Spacing of plants (inches) and topping	Harvest date	Yield per acre (air-dry basis)			Nicotine content (air-dry basis)			Production of nicotine per acre		
		Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
		Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*
30 by 12, regular topping	Aug. 31	2,186	1,208	3,394	3.32	1.43	2.65	72.6	17.3	89.9
	Sept. 14	2,709	1,844	4,553	4.20	1.85	3.25	113.8	34.1	147.9
	Sept. 29	2,984	1,703	4,687	3.92	2.18	3.29	117.0	37.1	154.1
30 by 12, low topping	Aug. 31	1,921	800	2,721	4.92	1.95	4.05	94.5	15.6	110.1
	Sept. 14	2,132	1,105	3,237	5.46	2.15	4.33	116.4	23.8	140.2
	Sept. 29	2,291	1,238	3,529	5.15	2.76	4.31	118.0	34.2	152.2
30 by 18, regular topping	Aug. 31	2,271	1,133	3,384	4.52	1.82	3.62	101.8	20.6	122.4
	Sept. 14	2,502	1,528	4,030	5.41	2.08	4.15	135.4	31.8	167.2
	Sept. 29	3,203	1,927	5,220	5.48	2.74	4.47	180.5	52.8	233.3
30 by 18, low topping	Aug. 31	1,843	651	2,494	5.92	2.28	4.97	109.1	14.8	123.9
	Sept. 14	2,109	960	3,069	5.99	2.18	4.80	126.3	20.9	147.2
	Sept. 29	2,162	1,032	3,194	4.77	2.61	4.07	103.1	26.9	130.0
39 by 18, regular topping	Aug. 31	2,099	982	3,081	5.91	1.95	4.65	124.1	19.1	143.2
	Sept. 14	2,590	1,457	4,047	6.69	2.31	5.11	173.3	33.7	207.0
	Sept. 29	3,079	1,659	4,738	6.33	2.12	4.86	194.9	35.2	230.1
39 by 18, low topping	Aug. 31	1,810	510	2,320	7.71	2.48	6.56	139.6	12.6	152.2
	Sept. 14	2,015	683	2,698	8.40	3.04	7.05	169.3	20.8	190.1
	Sept. 29	2,061	792	2,853	6.38	2.58	5.32	131.5	20.4	151.9

TABLE 9.—*Effect of spacing and time of harvest on yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from N. rustica (Brasilia) grown on two soil types at Arlington Farm, Va., 1935*

KEYPORT SILT LOAM SOIL, FIELD D

Spacing of plants (inches)	Harvest date	Yield per acre (air-dry basis)			Nicotine content (air-dry basis)			Production of nicotine per acre		
		Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
		Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*
30 by 12	Aug. 14	1,235	620	1,855	5.85	1.42	4.37	72.2	8.8	81.0
	Aug. 30	1,378	663	2,041	6.51	1.42	4.86	89.7	9.4	99.1
	Sept. 16	1,488	834	2,323	6.49	1.98	4.87	96.6	16.5	113.1
30 by 18	Aug. 14	1,107	543	1,649	6.59	1.55	4.94	73.0	8.4	81.4
	Aug. 30	1,400	623	2,023	7.41	1.75	5.66	103.7	10.9	114.6
	Sept. 16	1,542	789	2,331	7.40	2.24	5.65	114.1	17.7	131.8
39 by 18	Aug. 14	1,249	604	1,853	7.77	1.65	5.77	97.0	10.0	107.0
	Aug. 30	1,378	608	1,986	8.97	2.04	6.85	123.6	12.4	136.0
	Sept. 16	1,611	794	2,405	8.15	2.27	6.21	131.3	18.0	149.3
KEYPORT SILT LOAM SOIL, FIELD G										
30 by 12	Aug. 30	1,415	622	2,037	7.31	1.85	5.64	103.4	11.5	114.9
	Sept. 16	1,998	880	2,878	7.39	2.08	5.77	147.7	18.3	166.0
	Sept. 30	2,503	1,000	3,503	6.31	2.24	5.15	157.9	22.4	180.3
30 by 18	Aug. 30	1,319	531	1,850	7.69	1.88	6.02	101.4	10.0	111.4
	Sept. 16	1,774	770	2,544	7.46	2.08	5.83	132.3	16.0	148.3
	Sept. 30	2,480	992	3,472	7.08	2.17	5.68	175.6	21.5	197.1
39 by 18	Aug. 30	1,082	399	1,481	8.98	2.11	7.13	97.2	8.4	105.6
	Sept. 16	1,508	582	2,090	7.87	2.14	6.28	118.7	12.5	131.2
	Sept. 30	1,512	593	2,105	6.29	2.24	5.15	95.1	13.3	108.4
SANDY SOIL, "FLATS"										
39 by 18	Aug. 14	1,396	701	2,097	7.09	1.52	5.23	99.0	10.7	109.7
	Aug. 30	1,777	871	2,648	8.38	1.75	6.20	148.9	15.2	164.1
	Sept. 16	1,927	1,058	2,985	7.76	1.85	5.66	149.5	19.6	169.1

TABLE 10.—*Effect of spacing and time of harvest on yields of tobacco, percentage content in the tobacco, and production of nicotine per acre from two varieties of N. rustica, 34753 and 68, grown on two types of soil at Arlington Farm, Va., 1936*

Spacing of plants (inches)	Harvest date	Yield per acre (air-dry basis)			Nicotine content (air-dry basis)			Production of nicotine per acre		
		Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
		Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*
N. RUSTICA 34753 ON SANDY SOIL, "FLATS"										
30 by 12	Aug. 31	2,034	967	3,001	5.43	2.20	4.39	110.4	21.3	131.7
	Sept. 14	1,738	792	2,530	5.07	2.64	4.31	88.1	20.9	109.0
	Sept. 29	998	602	1,600	4.36	2.64	3.71	43.5	15.9	59.4
30 by 18	Aug. 31	1,712	714	2,426	6.37	2.30	5.17	109.1	16.4	125.5
	Sept. 14	1,576	656	2,232	6.22	2.54	5.14	98.0	16.7	114.7
	Sept. 29	1,142	554	1,696	6.05	2.64	4.94	69.1	14.6	83.7
39 by 18	Aug. 31	1,544	719	2,263	6.49	2.28	5.15	100.2	16.4	116.6
	Sept. 14	2,067	954	3,021	6.30	2.84	5.21	130.2	27.1	157.3
	Sept. 29	1,645	803	2,448	5.79	2.67	4.77	95.3	21.4	116.7
N. RUSTICA 68 ON SANDY SOIL, "FLATS"										
30 by 12	Aug. 31	1,877	1,504	3,381	5.25	1.43	3.55	98.5	21.5	120.0
	Sept. 14	1,655	1,229	2,884	5.07	1.71	3.64	83.9	21.0	104.9
	Sept. 29	996	1,018	2,014	3.32	1.60	2.45	33.1	16.3	49.4
30 by 18	Aug. 31	1,604	1,153	2,757	6.24	1.41	4.22	100.1	16.3	116.4
	Sept. 14	1,971	1,316	3,287	5.94	1.76	4.27	117.1	23.2	140.3
	Sept. 29	2,099	936	3,035	5.70	1.74	4.48	119.6	16.3	135.9
39 by 18	Aug. 31	1,355	911	2,266	7.08	1.36	4.78	95.9	12.4	108.3
	Sept. 14	1,647	1,157	2,804	6.87	1.63	4.71	113.1	18.9	132.0
	Sept. 29	1,544	1,139	2,683	6.80	1.73	4.65	105.0	19.7	124.7
N. RUSTICA 34753 ON KEYPORT SILT LOAM, FIELD G										
30 by 12	Aug. 31	2,035	1,011	3,046	5.17	1.81	4.05	105.2	18.3	123.5
	Sept. 14	2,357	1,377	3,734	5.81	2.14	4.46	136.9	29.5	166.4
	Sept. 29	2,725	1,874	4,599	5.83	2.56	4.50	158.9	48.0	206.9
30 by 18	Aug. 31	2,081	974	3,055	5.06	1.78	4.01	105.3	17.3	122.6
	Sept. 14	2,805	1,690	4,495	5.42	1.88	4.09	152.0	31.8	183.8
	Sept. 29	2,751	1,738	4,489	5.42	2.37	4.24	149.1	41.2	190.3
39 by 18	Aug. 31	2,122	924	3,046	6.22	1.78	4.87	132.0	16.4	148.4
	Sept. 14	2,540	1,340	3,880	7.14	2.10	5.40	181.4	28.1	209.5
	Sept. 29	2,954	1,696	4,650	7.28	2.34	5.48	215.1	39.7	254.8
N. RUSTICA 68 ON KEYPORT SILT LOAM, FIELD G										
30 by 12	Aug. 31	1,833	1,383	3,216	4.97	1.18	3.34	91.1	16.3	107.4
	Sept. 14	2,034	2,005	4,039	5.99	1.46	3.74	121.8	29.3	151.1
	Sept. 29	2,446	2,396	4,842	4.79	1.73	3.28	117.2	41.5	158.7
30 by 18	Aug. 31	2,022	1,483	3,505	6.04	1.31	4.04	122.1	19.4	141.5
	Sept. 14	2,350	2,099	4,449	7.00	1.44	4.38	164.5	30.2	194.7
	Sept. 29	2,756	2,472	5,228	6.57	1.71	4.27	181.1	42.3	223.4
39 by 18	Aug. 31	1,994	1,271	3,265	6.82	1.33	4.68	136.0	16.9	152.9
	Sept. 14	2,257	1,836	4,093	7.69	1.38	4.86	173.6	25.3	198.9
	Sept. 29	1,799	2,125	3,924	8.15	1.66	4.64	146.6	35.3	181.9

The effect of spacing on nicotine yield with ordinary tobacco varieties is shown in table 11. There appears to be some advantage for the 39 by 18 inches over the 39 by 36 inches in the 1935 tests (table 11), but the same difference did not always occur in the 1936 tests (table 11, fig. 7). The advantage of the close spacing is more apparent with the smaller growing strains of tobacco, Xanthi and Russian Red Flower, than with the broadleaved strains. The difference is apparently due to the production of a larger tonnage of leaf rather than to any considerable change in the final percentage content of nicotine in

the leaf. The nicotine content of earlier harvested material was higher in the wide spacing than in the close spacing, but this difference has disappeared in the late harvested plants.

TABLE 11.—*Effect of spacing and time of harvest on yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from ordinary tobacco varieties, grown on different soil types, Arlington Farm, Va., 1935–36*

KEYPORT SILT LOAM, FIELD G, 1935

Variety	Spacing of plants	Yield per acre (air-dry basis)			Nicotine content (air-dry basis)			Production of nicotine per acre		
		Sept. 9	Sept. 16	Sept. 30	Sept. 9	Sept. 16	Sept. 30	Sept. 9	Sept. 16	Sept. 30
	In.	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*
Maryland Medium Broadleaf (Robinson's)	39 by 18	1,817	2,014	2,422	3.15	3.52	3.85	57.2	70.9	93.2
	39 by 36	1,559	1,685	2,128	3.25	4.38	3.81	50.7	73.8	81.1
Maryland Broadleaf	39 by 18	1,847	2,305	2,448	2.11	2.78	3.47	39.0	64.1	84.9
	39 by 36	1,947	2,252	2,671	3.03	3.51	3.54	59.0	79.0	94.5
Maryland Mammoth	39 by 18	2,228	2,525	3,021	2.34	2.52	2.95	52.1	63.6	89.1
	39 by 36	2,252	2,351	2,681	3.23	3.64	3.64	72.7	85.6	97.6
Pennsylvania Broadleaf	39 by 18	1,563	2,092	2,536	2.54	3.08	3.67	39.7	64.4	93.1
	39 by 36	1,652	1,680	1,940	3.26	3.08	3.44	53.9	51.8	66.7
Connecticut Broadleaf	39 by 18	1,431	1,840	2,103	3.54	4.49	5.02	50.7	82.6	105.6
	39 by 36	1,489	1,617	1,898	5.11	5.63	5.13	76.1	91.0	97.4
White Burley (Judy's Pride)	39 by 18	1,329	1,542	1,773	3.26	3.21	3.31	43.3	49.5	58.7
	39 by 36	988	1,323	1,497	2.98	3.01	3.57	29.7	39.8	53.4
Improved Yellow Mammoth	39 by 18	2,041	2,263	2,489	3.16	3.64	4.26	64.5	82.4	106.0
	39 by 36	1,698	1,927	2,205	4.12	4.13	4.26	69.9	79.6	93.9
Cash	39 by 18	1,434	1,843	2,109	3.26	3.64	3.70	46.7	67.1	78.0
	39 by 36	1,526	1,504	1,760	3.95	4.10	3.80	60.3	61.6	66.9
Greenwood	39 by 18	1,759	2,176	2,671	3.29	4.20	4.59	57.9	91.4	122.6
	39 by 36	1,569	1,765	2,050	4.48	4.96	4.86	70.3	87.6	99.6
One Sucker	39 by 18	1,548	1,917	2,217	2.64	2.81	2.78	40.9	53.9	61.6
	39 by 36	1,157	1,327	1,879	3.00	3.64	3.84	34.7	48.3	72.1
Madole	39 by 18	1,771	1,801	2,421	3.13	3.00	4.10	55.4	54.0	99.3
	39 by 36	1,410	1,420	1,735	3.92	3.61	4.10	55.3	51.3	71.1
Russian Red Flower	39 by 18	1,257	1,545	1,826	3.75	3.99	3.52	47.2	61.7	64.3
	39 by 36	956	1,235	1,268	3.97	3.95	3.88	38.0	48.8	49.2
Xanthi	39 by 18	[1] 966	1,061	1,264	[1] 5.89	5.95	4.70	[1] 56.9	63.1	59.4
	39 by 36	627	647	708	5.86	5.69	4.24	36.7	36.8	30.0

SANDY SOIL, "FLATS," 1936 [2]

		Aug. 31	Sept. 14	Sept. 29, Oct. 1	Aug. 31	Sept. 14	Sept. 29, Oct. 1	Aug. 31	Sept. 14	Sept. 29, Oct. 1
Greenwood	39 by 18	1,736	1,722	1,721	3.70	4.16	4.18	64.2	71.6	71.9
	39 by 36	1,567	1,586	1,463	4.36	4.80	5.23	68.3	76.1	76.5
Madole	39 by 18	1,958	1,843	2,095	3.59	3.91	3.86	70.3	72.1	80.9
	39 by 36	1,653	1,637	1,693	4.50	5.02	5.01	74.4	82.2	84.8

KEYPORT SILT LOAM, FIELD G, 1936 [3]

Greenwood	39 by 18	1,767	2,008	2,052	4.50	5.32	5.21	79.5	106.8	106.9
	39 by 36	1,425	1,758	1,795	4.97	6.53	5.92	70.8	114.8	106.3
Madole	39 by 18	2,082	2,296	2,355	4.32	5.19	4.94	89.9	119.2	116.3
	39 by 36	1,594	1,776	1,876	5.37	6.01	5.28	85.6	106.7	99.1

[1] First harvest made Aug. 30, 1935.
[2] Plants topped Aug. 1.
[3] Third picking made Oct. 1.

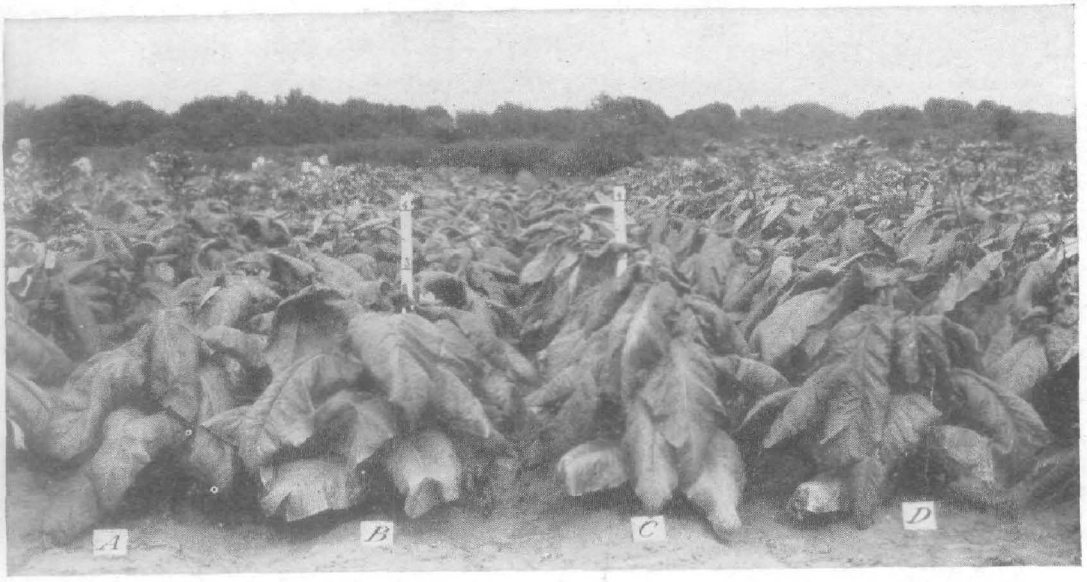

FIGURE 7.—Ordinary tobacco, spacing 39 by 36 inches, flats, Arlington Farm, Va.: *A* and *B*, Greenwood variety; *C* and *D*, Madole variety. Photographed September 10, 1936, a few days prior to second harvest date, 45 days after topping. Scale indicates height in feet. (See table 11 for nicotine production.)

The most outstanding effect apparent in tables 8, 9, and 10 is that of different dates of harvesting of *N. rustica* on nicotine yields. The harvest dates as shown were approximately 30, 45, and 60 days after the plants had been topped. The plants were usually topped around 60 days after the transplanting date. As a rule, the longer the plants were allowed to stand in the field after topping, up to 60 days, the greater the yields of nicotine per acre. This increase was due largely to the greater tonnage of dry matter produced, although in some cases there was at the same time an increase in the percentage of nicotine content. The results in table 10 appear to contradict the above generalization, but this occurred on the sandy soil on which the tests were located in connection with a period of dry, hot weather. The results on heavy soil (table 10) show large increases in nicotine yields from late harvests. The increases (tables 11 and 12) of nicotine in ordinary tobacco varieties in the late harvests as compared with the early harvests follow much the same course as with *N. rustica*, with the exception of Xanthi, which shows a lower yield of nicotine from the latest harvest. This is due to a lower nicotine content, possibly associated with the drying of the lower leaves. Possibly the same condition would prevail with all strains and species if the plants were allowed to remain in the field long enough after topping. It is noticeable that where much drying up of the lower leaves took place the yield of nicotine was materially lowered. This was due both to loss of total dry weight and a decrease in percentage content of nicotine in the *N. rustica* planted on sandy soil (table 10). With the Xanthi the total dry weight of leaf was higher in the late harvests than with earlier harvestings, but the percentage of nicotine was lower than in earlier harvestings (tables 11 and 12).

TABLE 12.—*Effect of time of harvest on yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from ordinary tobacco varieties, grown on sandy soil, "flats," Arlington Farm, Va., 1935* [1]

Variety	Yield per acre			Nicotine content			Production of nicotine per acre		
	Aug. 14	Aug. 30	Sept. 16	Aug. 14	Aug. 30	Sept. 16	Aug. 14	Aug. 30	Sept. 16
	Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*
Maryland Medium Broadleaf (Robinson's)	2,021	2,027	1,872	3.48	4.05	4.45	70.3	82.1	83.3
Maryland Broadleaf	1,795	2,141	1,827	2.93	3.72	3.95	52.6	79.6	72.2
Maryland Mammoth	2,047	2,445	2,352	2.88	3.46	4.12	58.9	84.6	96.9
Pennsylvania Broadleaf	2,121	2,186	2,364	3.42	3.85	4,32	72.5	84.2	102.1
Connecticut Broadleaf	1,494	1,662	2,060	4.15	5.01	4.94	62.0	83.3	101.7
White Burley (Judy's Pride)	1,772	2,050	1,749	3.46	4.25	4.91	61.3	87.1	85.9
Improved Yellow Mammoth (fire-cured type)	1,947	2,325	2,373	3.81	3.89	4.32	74.2	90.4	102.5
Cash (flue-cured type)	1,377	1,795	1,808	3.49	4.64	4.38	48.1	83.3	79.2
Greenwood (fire-cured type)	1,837	2,063	1,943	4.35	4.38	4.96	79.9	90.4	96.4
One Sucker (dark air-cured type)	1,646	1,817	2,179	3.42	3.59	4.55	56.3	65.2	99.1
Madole (fire-cured type)	1,830	1,992	2,341	3.94	3.95	5.01	72.1	78.7	117.3
Russian Red Flower	870	1,022	1,277	3.76	4.22	4.30	32.7	43.1	54.9
Xanthi (Turkish)	427	526	545	5.76	7.05	5.85	24.6	37.1	31.9

[1] Plants set 39 by 36 inches; data on air-dry basis.

The effect of time of harvest on nicotine yields of *N. rustica* at certain other locations than Arlington Farm are shown in table 13. Here again it is evident that the late harvest consistently yielded more nicotine than the early harvest. This difference in most cases is the combined result of a difference in yields of dry matter and in nicotine content. The time between the early and late harvest dates usually was around 1 month. This same difference also is apparent at the Davis location (see table 17). It appears, therefore, that a late harvest date up to 60 days after topping as a rule is the most important condition for obtaining high nicotine yields, provided there is no excessive loss of the lower leaves by leaf-spot disease or drying.

TABLE 13.—*Effect of time of harvest on yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from N. rustica at Corvallis, Oreg., 1934; Madison, Wis., 1935–38; and Lock Haven, Pa., 1935*

YIELD PER ACRE (20-PERCENT-MOISTURE BASIS)

Time of harvest	Corvallis, Oreg.,[1] 1934	Madison, Wis.[1]				Lock Haven, Pa.,[2] 1935
		1935	1936	1937	1938	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Early	1,991	2,289	1,359	1,902	2,204	1,320
Late	2,553	3,513	1,625	2,981	3,629	1,480

NICOTINE CONTENT (20-PERCENT-MOISTURE BASIS)

	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Early	3.15	2.93	2.96	4.46	1.07	6.69
Late	3.66	4.30	3.02	5.37	2.80	7.04

PRODUCTION OF NICOTINE PER ACRE

	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Early	62.6	67.1	40.3	84.8	23.5	88.3
Late	93.4	151.0	49.1	160.0	101.6	104.3

[1] Leaf and stalk.
[2] Leaf only.

Another important requirement in obtaining high nicotine yields from *N. rustica* is that the plants be transferred to the field before any stunting takes place in the seedling stage. In order to test this effect, plants of the same age were transplanted to the field on different dates at Arlington Farm, Va. The early planting, May 25, 1936, yielded 105.6 pounds of nicotine per acre, whereas the late planting in June yielded only 63.4 pounds of nicotine per acre. The plants for this test were grown in thumb pots. Late seeding and transplanting dates were tried at Davis (see table 17, plots 4 and 10). Here it is evident that the late seeding and transplanting of *N. rustica* produced a distinctly lower yield of nicotine per acre.

The effect of fertilizers on the yield of nicotine from *N. rustica* at Lock Haven, Pa., and Upper Marlboro, Md., is shown in tables 14 and 15. Phosphate alone did not materially increase the yield of nicotine, but applications of both ammonium sulfate and kainite, in addition to superphosphate, resulted in considerable increase in nicotine (table 14). The superphosphate alone produced an increase in the dry matter, but the percentage content of nicotine was lower than in the untreated plot. Additional applications of all three materials resulted in slight increases in nicotine even up to the highest rates used. The test at Upper Marlboro (table 15) shows that nitrogen as ammonium sulfate or urea and potassium as muriate of potash are both important in increasing the yield of nicotine on the soil under test. Where the two elements are combined in high rates of application greater yields of nicotine have resulted than with either used alone.

TABLE 14.—*Effect of fertilizer on yields of tobacco, percentage content of nicotine in the tobacco, and the production of nicotine from N. rustica (Brasilia) at Lock Haven, Pa., 1935* [1]

Treatment No.	Fertilizer treatment (per acre)			Yield of dry matter per acre (20-percent-moisture basis)	Nicotine content (20-percent-moisture basis)	Production of nicotine per acre
	Ammonium sulfate	Superphosphate	Kainite			
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Pounds*
1	0	0	0	685	6.44	44.1
2	0	500	0	900	5.40	48.6
3	300	500	500	1,260	6.55	82.6
4	450	750	750	1,460	7.24	105.7
5	600	1,000	1,000	1,460	7.75	113.1

[1] Leaf only.

TABLE 15.—*Effect of fertilizer on yields of tobacco, percentage of nicotine in the tobacco, and the production of nicotine from N. rustica 68 at Upper Marlboro, Md., 1938*

Treatment No.	Specific fertilizer treatment [1]	Yield of dry matter per acre (20-percent moisture basis)			Nicotine content (20-percent-moisture basis)			Production of nicotine (per acre)		
		Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
		Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*
1	Potassium derived from sulphate	1,177	874	2,051	4.75	0.91	3.12	55.9	8.0	03.9
2	Potassium derived from chloride	1,252	919	2,171	4.71	1.01	3.15	59.0	9.3	68.3
3	Additional side application of 80 pounds nitrogen per acre as ammonium sulfate	1,472	890	2,362	5.81	1.25	4.09	85.5	11.1	96.6
4	Additional side application of 320 pounds potash per acre as muriate	1,388	1,001	2,389	5.74	1.43	3.93	79.7	14.3	94.0
5	Additional side application of 80 pounds nitrogen per acre as ammonium sulfate and 320 pounds potash as muriate	1,705	990	2,695	6.40	1.62	4.64	109.1	16.0	125.1
6	Additional side application of 80 pounds nitrogen per acre as urea and 320 pounds potash as muriate	1,753	1,042	2,795	6.01	1.56	4.35	105.4	16.3	121.7

[1] A basal application of 1,000 pounds per acre of 4-8-4 fertilizer was made to all plots.

The importance of adequate supplies of water at all stages of growth under field conditions is well shown by the results at Arlington Farm and at Davis, Calif. (tables 16 and 17). At Arlington Farm the results are rather striking with all strains tested except one (*N. rustica* 34752). Why this particular strain did not respond cannot be explained. The irrigation at this location consisted of additions of water by means of a hose during dry periods, but even by this crude method a distinct advantage is evident in the total yields of nicotine. The results at Davis, as shown in table 17 and in earlier tables, emphasize that high yields of nicotine were obtained from *N. rustica* under irrigated conditions.

TABLE 16.—*Effect of irrigation on yields of tobacco, percentage content of nicotine in the tobacco and production of nicotine per acre from N. rustica varieties and strains, and of ordinary tobacco, N. tabacum, topped and suckered, Arlington Farm, Va., 1934*

Variety of strain	Yield per acre (20-percent-moisture basis)			Nicotine content (20-percent-moisture basis)			Production of nicotine (per acre)		
	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
SERIES A, UNIRRIGATED PLOTS									
N. rustica:	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*
Brasilia (A)	1,691	589	2,280	8.40	2.05	6.76	142.0	12.1	154.1
Brasilia (B)	1,739	622	2,361	7.89	1.92	6.32	137.2	11.9	149.1
34752	1,473	426	1,899	8.43	3.26	7.27	124.2	13.9	138.1
34753	1,869	448	2,317	7.97	3.12	7.03	149.0	14.0	163.0
68 (A)	1,652	738	2,390	9.18	2.50	7.12	151.7	18.4	170.1
N. tabacum:									
Connecticut Broadleaf	2,098	699	2,797	3.95	.81	3.17	82.9	5.7	88.6
SERIES B, IRRIGATED PLOTS									
N. rustica:									
Brasilia (A)	1,913	605	2,518	8.65	2.58	7.19	165.5	15.6	181.1
Brasilia (B)	1,982	660	2,642	8.78	2.48	7.21	174.0	16.4	190.4
34752	1,201	338	1,539	8.48	3.96	7.49	101.8	13.4	115.2
34753	2,009	536	2,545	8.08	3.69	7.15	162.3	19.8	182.1
34754	1,716	592	2,308	7.72	2.91	6.49	132.5	17.2	149.7
68 (A)	1,960	872	2,832	9.81	2.72	7.63	192.3	23.7	216.0
N. tabacum:									
Connecticut Broadleaf	2,230	762	2,992	4.05	.86	3.24	90.3	6.6	96.9

TABLE 17.—*Effect of rate of irrigating, spacing of plants, frequency of suckering, and time of harvest on yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from N. rustica 34753, Davis, Calif., 1937* [1]

CROP HARVESTED EARLY (AUG. 17)

Plot No.	Water applied							Spacing of plants	Date of topping	Plants suckered							Yield per acre (20-percent-moisture basis)			Nicotine content (20-percent-moisture basis)			Production of nicotine per acre		
	June 5	June 26	July 10	July 20	Aug. 5	Aug. 21	Total [2]										Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk	Leaf	Stalk	Leaf and stalk
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*									*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*
1	2.1	2.7	2.1	2.1	2.4	----	15.4	18 by 36	June 23	June 23	June 30	July 8	July 15	July 24	July 31	Aug. 9	1,907	212	2,119	7.02	2.09	6.53	133.9	4.4	138.3
2	2.1	2.7	2.1	2.1	2.4	----	15.4	18 by 36	July 19	June 24	---do----	---do----	---do----	---do----	---do----	---do----	2,007	452	2,459	5.46	1.57	4.75	109.6	7.1	116.7
3	3.9	4.9	3.0	3.4	3.3	----	22.5	12 by 30	---do----	June 25	July 2	---do----	July 16	July 26	Aug. 2	---do----	2,522	618	3,140	4.76	1.80	4.18	120.1	11.1	131.2
4	3.9	4.9	3.0	3.4	3.3	----	22.5	18 by 36	Aug. 9	July 13	July 20	July 27	Aug. 2	Aug. 9	Aug. 16	----------	1,587	443	2,030	5.72	1.39	4.78	90.8	6.2	97.0
5	3.9	4.9	3.0	3.4	3.3	----	22.5	18 by 36	July 20	June 25	July 9	July 24	Aug. 9	----------	----------	----------	1,984	507	2,491	4.73	1.66	4.10	93.8	8.4	102.2
6	3.9	4.9	3.0	3.4	3.3	----	22.5	18 by 36	July 19	---do----	July 2	July 9	July 17	July 26	Aug. 2	Aug. 9	1,882	507	2,389	4.40	1.58	3.80	82.8	8.0	90.8

CROP HARVESTED LATE (SEPT. 17)

7	2.1	2.7	2.1	2.1	2.4	1.8	17.2	18 by 36	June 23	June 23	June 30	July 8	July 15	July 24	July 31	Aug. 9	2,462	326	2,788	7.52	2.54	6.94	185.1	8.3	193.4
8	2.1	2.7	2.1	2.1	2.4	1.8	17.2	18 by 36	July 19	June 24	---do----	---do----	---do----	---do----	---do----	---do----	2,708	597	3,305	4.90	1.80	4.34	132.7	10.7	143.4
9	3.9	4.9	3.0	3.4	3.3	2.7	25.2	12 by 30	---do----	June 25	July 2	---do----	July 16	July 26	Aug. 2	---do----	3,731	857	4,588	3.22	2.09	3.01	120.1	17.9	138.0
10	3.9	4.9	3.0	3.4	3.3	2.7	25.2	18 by 36	Aug. 9	July 13	July 20	July 27	Aug. 2	Aug. 9	Aug. 16	Aug. 28	2,005	604	2,609	4.37	2.24	3.88	87.6	13.5	101.1
11	3.9	4.9	3.0	3.4	3.3	2.7	25.2	18 by 36	July 20	June 25	July 9	July 24	Aug. 9	----------	----------	----------	2,944	726	3,670	5.55	1.98	4.84	163.4	14.4	177.8
12	3.9	4.9	3.0	3.4	3.3	2.7	25.2	18 by 36	July 19	---do----	July 2	July 9	July 17	July 26	Aug. 2	Aug. 9	2,558	635	3,193	5.41	1.78	4.69	138.4	11.3	149.7

[1] In treatments 4 and 10 the seed germinated Apr. 12 and the seedlings were transplanted May 28; in all other treatments the respective dates were Mar. 10 and May 7.
[2] Includes 1 inch added on each of the dates, May 7, 11, 20, 28, to condition the soil and establish the plants.

DISTRIBUTION OF NICOTINE IN THE PLANT AND THE NICOTINE CONTENT OF THE RATOON CROP

Tables 7, 8, 9, 10, 15, 16, and 17 show the distribution of nicotine between the stalk and leaf of the plant. It is evident that the bulk of the nicotine is to be found in the leaf of both *N. rustica* and tobacco. Nevertheless, the stalk of *N. rustica* contains nicotine in amounts that would justify recovery. An extended study was not made of the nicotine content of the stalks of ordinary tobacco, but in the instances reported in tables 7 and 16 it is evident that the quantity is too low to justify handling the bulky and partly woody material composing the stalk. The distribution of nicotine in the leaf web, the leaf stem, and the primary stem or stalk of the *N. rustica* plant is shown in table 18. The leaf tissue is distinctly the portion of the plant containing the highest percentage of nicotine.

TABLE 18.—*Distribution of nicotine in the leaf web, leaf stem, and the stalk of N. rustica, 1934*

Variety and location	Tissue of leaf [1] (water-free basis)	Leaf stem or midrib [1] (water-free basis)	Main plant stalk [2] (water-free basis)
	Percent	*Percent*	*Percent*
No. 34752, Davis, Calif.	12.80	3.34	2.79
No. 34752, Madison, Wis.	9.60	3.16	1.17
No. 34753, Madison, Wis.	8.08	2.99	1.65

[1] 50 leaves selected from 40 plants and tissue of leaf separated from the leaf stem or midrib.
[2] Composite sample of 40 stalks.

The question has been frequently raised as to the feasibility of utilizing the second growth of basal suckers or ratoon crop for the production of nicotine. Although under some conditions a fair sucker crop may be obtained, it will be evident from previous discussions that the growth habits of *N. rustica* are such that in general this species is not able to produce a heavy secondary growth from suckers. The yield of nicotine from the ratoon crop at Madison, Wis., is shown in table 19. At Davis, Calif., the ratoon crop from *N. rustica* (fig. 8)

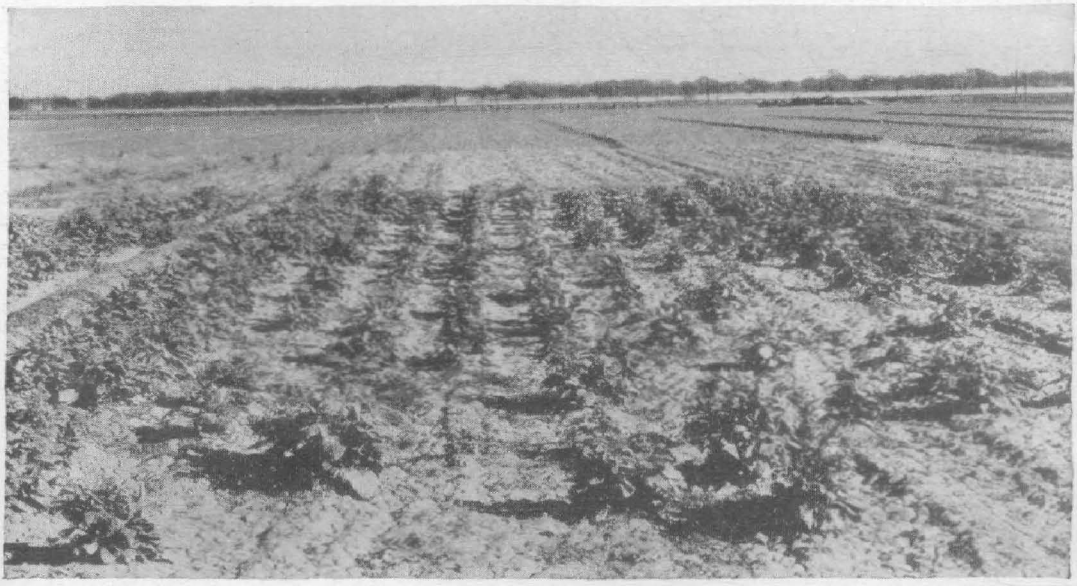

FIGURE 8.—*N. rustica*, showing sucker or ratoon growth at Davis, Calif. Photographed November 6, 1934.

was so poor that it was not considered worth harvesting for the comparison with ordinary tobacco (fig. 9), yields of which are shown in table 19. The sucker growth may be expected to show an accumula-

FIGURE 9.—Ordinary tobacco, Madole variety, showing sucker or ratoon crop at Davis, Calif. Photographed on date of harvest, November 6, 1934. (See table 19 for nicotine yield.)

tion of diseases, particularly virus or common tobacco mosaic. The yield of nicotine from the sucker crop was therefore disappointing. It would appear that delayed harvest to permit maximum accumulation of nicotine in the original crop will produce greater quantities of nicotine than early harvest to permit time for the growing of a sucker crop of low nicotine content.

TABLE 19.—*Yields of tobacco, percentage content of nicotine in the tobacco, and production of nicotine per acre from the ratoon or second (sucker) crop of N. rustica and ordinary tobacco at Davis, Calif., and Madison, Wis., 1934*

Species or variety	Yield of dry matter per acre (20-percent-moisture basis)	
	Davis, Calif.	Madison, Wis.
	Pounds	*Pounds*
N. rustica	1,256	804
Ordinary tobacco (Madole)		638
NICOTINE CONTENT (20-PERCENT-MOISTURE BASIS)		
	Percent	*Percent*
N. rustica	1.52	2.50
Ordinary tobacco (Madole)		1.03
PRODUCTION OF NICOTINE PER ACRE		
	Pounds	*Pounds*
N. rustica	19.1	20.1
Ordinary tobacco (Madole)		6.6

HAZARDS IN GROWING TOBACCO FOR NICOTINE PRODUCTION

There are always certain hazards in growing any special crop, and this is particularly true in the growing of tobacco for the production of high yields of nicotine. The weather hazard, especially the amount and distribution of moisture, appears to be the dominant factor in the growth of the *N. rustica* species in humid areas. It is clearly shown by the results presented that this species consistently produces the highest yields of nicotine under favorable conditions. Accordingly, the weather problem would appear to be largely solved by irrigation or by growing the crop in regions of ample, evenly distributed water supply. Growing the crop under irrigation in dry regions is distinctly advantageous in that the hazard of poor distribution of rainfall is eliminated. It has been pointed out that *N. rustica* is particularly sensitive to stunting at any stage during growth, and it appears that this is why dry periods can reduce the yield of nicotine so materially. From this standpoint the culture of *N. rustica* definitely presents a greater hazard than the commercial culture of ordinary tobacco. However, although little direct evidence is available regarding *N. rustica*, it is generally considered that excessively wet seasons and high humidity tend to lower the percentage content of nicotine of ordinary tobacco.

Certain insect pests and diseases attack *N. rustica* in some portions of the irrigated regions. These include leafhoppers (*Eutetex tenellus* (Bak.)), which transmit the virus disease curly top, and nematodes (*Heterodera marioni* (Cornu) Goodey), stalk borers (*Trichobaris mucorea* (Lec.)), and false chinch bugs (*Nysius ericae* (Schill.)). Most of the common pests and diseases of tobacco, including hornworms (*Protoparce sexta* (Johan.), *P. quinquemaculata* (Haw.)), wildfire (*Phytomonas tabaci* (Wolf and Foster) Bergey et al.), and other leaf spots, stalk rot (*Sclerotium rolfsii* Sacc.), and virus diseases, were found to occur to a greater or less extent wherever the crop was grown. Fortunately, *N. rustica* is highly resistant to black root rot (*Thielaviopsis basicola* (Berk. and Br.) Ferr.). At Shafter, Calif., the attacks by curly top and stalk borers were so severe and the yield of nicotine was so low that it was found necessary in these experiments to abandon culture of the *N. rustica* in favor of ordinary tobacco for nicotine production, as the latter did not suffer so severely from attacks by these two pests. The reductions in growth caused by curly top and tobacco mosaic were severe (fig. 10, *A* and *B*). The stalk rot or sore shank attacked the *N. rustica* at Houma, La., to such an extent that the crop was almost a failure.

When a crop is grown in a new area the hazard from insect pests and diseases cannot be predicted. Curly top and stalk borers have never been observed on the tobacco crop grown in the eastern United States. However, in some areas in the West they affect the growth of *N. rustica* so severely that this species cannot be grown with success. The attacks by stalk rot at Houma, La., are another example, although this disease is not especially serious in the tobacco-producing regions.

Leaf spot diseases of the wildfire type, to which *N. rustica* is quite susceptible, frequently caused severe losses at some locations, particularly at Lakin, Lancaster, Wenona, and Willard. They were not much in evidence at Davis and Arlington Farm. In humid regions wildfire is likely to develop in a destructive epidemic form when a

rain and wind storm, combined with persistent high humidity, occurs late in the growing season, after the plants have been topped. The common mosaic disease of tobacco severely attacks *N. rustica,* and an attack at an early stage of growth usually renders the plant worthless.

FIGURE 10.—Curly top injury to tobacco, Shafter, Calif.: *A, N. rustica; B,* ordinary tobacco. Photographed June 24, 1934.

The simplest safeguard against many of these diseases and pests is to avoid areas where they are troublesome. This appears to be particularly true of stalk rot, leaf spot, stalk borers, leafhoppers, nematodes, and curly top.

CONDITIONS AND PRACTICES FOR GROWING AND HANDLING HIGH-NICOTINE TOBACCOS

In order to produce a crop that will yield large quantities of nicotine per acre it is important to give close attention to certain details. As the *N. rustica* species produces much higher yields of nicotine than ordinary tobacco under suitable conditions, the requirements for growing this species to best advantage, which differ somewhat from those of ordinary tobacco, should be the principal consideration. *N. rustica* will not produce maximum quantities of nicotine if it is allowed to become stunted even for comparatively short periods during the seedling or later growth stages. It is therefore important to transplant promptly from the seedbed as soon as the plants attain sufficient size. Transplanting to the field as soon as danger of frost is past is also recommended, as this species makes best growth during cool moist periods, such as are commonly prevalent early in the season.

Selection of soil of high fertility and the proper texture is an important consideration, as shown by the results presented. The relatively heavy textured soils appear more consistently to produce *N. rustica* of both high yields and high nicotine content than the lighter textured soils. *N. rustica* grown for nicotine production apparently succeeds best under irrigated conditions, where the water supply can be controlled adequately, or in humid regions in which the likelihood of drought during the growing season is reduced to a minimum.

Use of a vigorously growing strain of *N. rustica* that does not mature too rapidly is another important point in growing this plant for profitable production of nicotine. The Brasilia strain appears to be one of the best available at the present time. The new strain, designated as 68, having somewhat improved habits of growth, does not always produce a higher yield of nicotine in comparisons with Brasilia, but may be used if a tall-growing type is desired. Although the planting distance in the field required for best results may vary somewhat, depending upon conditions, as a rule a distance of 15 to 18 inches in rows 30 to 36 inches apart will give satisfactory results.

Topping and suckering are operations of the utmost importance if maximum yields of nicotine are to be obtained. Suckering should begin even prior to topping in order to encourage leaf development. Hard and fast rules cannot be given in regard to height of topping. There appears to be no consistent advantage for low topping over high topping, but it is evident that topping of some kind is absolutely necessary if good yields of nicotine are to be obtained. The suckers or lateral branches should be removed after topping at regular intervals of 7 to 10 days for the first two or three operations, after which the intervals may be somewhat longer. The information shown in table 16 gives an excellent picture of operations necessary in growing *N. rustica* successfully at Davis, Calif. The dates of germination of the seed, transplanting, and harvesting are shown, as well as the spacing of the plants in the field, the dates of topping and suckering, the dates of irrigating, and the quantity of water applied at each irrigation. Modification in these operations, as shown in table 17, can be directly compared with the yield, nicotine content, and the amount of nicotine produced per acre. Although these operations might vary slightly in different locations, this tabular material serves to illustrate

a typical case. It is here strikingly evident that late harvesting materially increased the quantity of nicotine produced regardless of other modifications in treatments.

Possibly the most important consideration relative to building up a high content of nicotine in *N. rustica* is that the plants should be allowed to remain in the field for as long a time as possible—up to 60 days after topping—provided there are no serious losses of the lower leaves by drying or disease.

To avoid important losses of nicotine the curing or drying process should be as rapid as possible and should take place under conditions that will prevent leaching of the dried or partially dried material by rain or water from other sources. Once the crop is dry it will keep for a considerable period without much loss of nicotine if the moisture content does not again become high as a result of high atmospheric humidity or other conditions. The crop possibly could be baled in the same manner as hay, but the moisture contained in the leaf at the time of baling or packing must be low to avoid fermentation. Important losses of nicotine may be expected if there is any considerable fermentation at any stage of curing or drying.

THE COST OF GROWING *N. RUSTICA* AS A SOURCE OF NICOTINE

In the small plantings used in the present studies concerning the quantity of nicotine produced by *N. rustica* it has not been possible to obtain accurate data on the labor requirements for growing the crop. As the number of plants grown per acre is essentially the same as in the case of the burley type of tobacco, the labor requirement surveys that have been made for the latter should be more or less applicable to *N. rustica* with respect to most of the important cultural operations. One group of operations, however, would not be the same, namely, topping, worming, suckering, and spraying or dusting. This complex item would correspond more nearly to the requirements for dark-fired tobacco except that, since there are approximately twice the number of plants per acre, this figure would need to be doubled. Figures for the several major operations, derived in this way from surveys of labor requirements that have been made in the burley area and the dark-fired area of Kentucky, are shown in table 20.[10] It is evident that inexperienced labor ordinarily could not accomplish the necessary operations in the time indicated. These figures do not include many other items of cost in producing the crop, such as rent of the land, drying sheds, and the cost of marketing; and these figures may be expected, also, to vary considerably in different localities.

[10] NICHOLLS, W. D. A STUDY OF THE COST OF PRODUCING TOBACCO IN KENTUCKY. Ky. Agr. Expt. Sta. Bul. 275, pp. 435-526, illus. 1926.

TABLE 20.—*Approximate hours of man labor and horse work required for producing an acre of N. rustica tobacco and their distribution between the principal operations of culture, on the basis of requirements for growing burley and dark-fired tobacco in Kentucky*

Operation	Average man labor	Average horse work
	Hours	*Hours*
Plant bed	17	5
Field preparation	19	38
Transplanting	31	10
Cultivating with plow	13	15
Cultivating with hoe	24	
Topping, worming, suckering, and spraying or dusting	108	
Cutting and housing	58	22
Curing	1	
Total	271	90

Where irrigation is used the cost of the water will be quite variable, but at the figure of $4.00 per acre-foot, when pumped from wells of moderate depth, this item would be $5.00 per acre if the amount of water used is around 15 inches, as shown in table 17. However, this charge may be much less if gravity water is available. Although the use of fertilizers is shown to increase the production of nicotine on some soils (tables 14 and 15), as a general practice their use, except possibly in a very limited way, would hardly be profitable. Apparently it would be more satisfactory to select soils of high fertility and if necessary utilize soil-improving crops for growing high-nicotine tobacco. Extensive studies on the removal of plant food in a crop of *N. rustica* have not been conducted, but a limited number of analyses have been made, which indicate that the total ash (15 to 20 percent) and nitrogen (4 percent) content of *N. rustica* is approximately that of cigar or dark-fired tobacco.

SUMMARY

At present the commercial supply of nicotine is a byproduct of the tobacco industry. The primary purpose of the experiments here presented was to study the possibility of developing a supply of raw material for nicotine extraction in order to provide for future demands for this important alkaloid that could not be met satisfactorily from present sources.

Trials were conducted at several representative locations to determine the amount of nicotine produced by *Nicotiana rustica* as compared with ordinary tobacco and to ascertain the most favorable conditions and production methods for obtaining a high yield of nicotine per acre. Under favorable conditions *N. rustica* consistently produced more nicotine than ordinary tobacco. When grown on fertile soils under irrigation over a period of years, *N. rustica* consistently produced 150 pounds or more of nicotine per acre, which was approximately double the quantity obtained from ordinary tobacco. Of numerous varieties or strains of *N. rustica* tested, the Brasilia appears to be the most satisfactory variety available at the present time. A new strain designated as 68, which was developed through hybridization, has better growth habits in some particulars but does not always yield more nicotine than Brasilia.

It appears to be absolutely necessary to avoid stunting of the *N. rustica* plants at any stage of growth and particularly during early growth, such as by allowing the seedlings to stand too long in the seedbed, if high yields of nicotine are to be obtained. Topping and suckering at regular intervals are operations of the utmost importance for producing high yields of nicotine. The yield of nicotine can be doubled by these operations. As a rule a late harvest date, up to 60 days after topping, is an important condition for obtaining high nicotine yields, provided there is no excessive loss of the lower leaves by leaf-spot or drying.

The leaf was found to contain the bulk of the nicotine, but the *N. rustica* stalks contained sufficient quantities to justify their use for nicotine recovery.

Temporary drought during the growth period constitutes an important weather hazard in most humid regions. New disease and insect hazards in growing this crop were found in certain areas outside of the present tobacco-producing regions, illustrating the impossibility of knowing in advance just what difficulties may be encountered.

As the problem now stands, growing high-nicotine tobaccos solely for their nicotine content apparently is feasible, but does not offer a wide margin of profit on the basis of prices now paid for byproduct leaf. Commercial development would depend upon information obtained from more definite cost studies in both the producing and manufacturing phases of the problem. Development of higher yielding strains possessing desirable growth habits seems to furnish the most promising outlook for increasing the output per acre of nicotine.

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