New York State Agricultural Experiment Station

Geneva, N. Y.

HIGH-NICOTINE TOBACCO

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Results are here reported of investigations on growing high-nicotine tobacco in New York for insect control.

Two species of tobacco were used, namely, *Nicotiana rustica*, which is the highest in nicotine content of the various species of *Nicotiana*, and *N. Tabacum* of certain fairly high nicotine varieties.

Both of these species were grown fairly satisfactorily in western New York. Their culture, however, entails considerable more labor than many other farm crops, especially the operations of topping and curing.

The yields in New York are not always satisfactory, usually ranging from 2,000 to 3,000 pounds of dry leaf per acre in favorable seasons. These yields are much lower than those obtained in irrigated sections of the arid southwest.

The nicotine content, while comparing very favorably with that of similar tobacco grown in other humid regions, is also much lower than in tobacco from the southwestern United States.

From 100 to 150 pounds of nicotine per acre may be produced in western New York as compared with 500 to 800 pounds per acre in the arid southwest.

Nicotine content varies greatly with climate, season, soil, maturity, and general cultural care.

Fertilizers, especially organic nitrogen, have increased nicotine to a small extent.

The nicotine in the woody stalk is very low; and since *N. rustica* produces about 50 per cent of stalk, this lowers the production of nicotine per acre.

Problems in utilization of tobacco dusts have not yet been solved, but are being investigated by this Station.

Some data are given as to what one may expect in the preparation of simple tobacco extracts.

As a result of this investigation it is not considered practical for the New York fruit grower to grow his own tobacco with the expectation of utilizing it for spray purposes.

It is hoped, however, that where tobacco can be grown on a large scale and high yields of nicotine secured encouragement will be given to such enterprises in the expectation of ultimately securing cheaper nicotine.
INTRODUCTION

Nicotine, the characteristic alkaloid of the tobacco plant, has occupied an important place in insect control for many years. It has had practically no competitors in its field due to its high efficiency as a killing agent for certain insect pests and the convenient forms in which it has been placed on the market. There have been some attempts made either to produce synthetic nicotine commercially or to find an efficient substitute, but with very little success up to the present.

In the United States practically all commercial nicotine has been a by-product of the tobacco industry. This industry is concerned primarily with the production and manufacture of fine tobaccos for human consumption here and abroad. Such tobaccos are usually low in nicotine, as a high percentage is not wanted in manufactured tobaccos. Waste and surplus material only are generally used for nicotine manufacture.

The limited amount of such waste material available and the extraction processes involved make commercial nicotine preparations quite expensive. Some attempts have been made, notably in South Africa,\(^1\) to grow high-nicotine tobaccos and to develop cheap methods of extraction. Direct utilization of high-nicotine tobacco dusts must also be considered in this connection.

The desirability of an increased supply and lower price has long been in the minds of the consumers of commercial nicotine. A few years ago the attention of this Station was directed to a phase of this problem which has received comparatively little attention in this country. It has long been known that different species of *Nicotiana* vary greatly in their content of nicotine. The species known as *N. rustica* seems to carry the most nicotine, and furthermore, seems to thrive under a wide range of climatic conditions. The possibilities of this plant as a source of cheaper nicotine for New York farmers has been investigated for some years by this Station and the results of this work are reported here.

NICOTINE IN TOBACCO

Nicotine is the characteristic alkaloid of tobacco upon which the peculiar value of the plant depends. In its free state it is an oily liquid, soluble in water, and having considerable volatility at ordinary

\(^1\)Reports and bulletins of the Department of Agriculture, Union of South Africa. Also, see the *Jour. Agr.*, *South Africa*, 1922–1925.
temperatures. In the plant it is usually in combination with malic and citric acid, as it readily combines with acids, being a ditertary base. It boils at close to 250°C and is extremely poisonous. Kraemer gives the extremes in which the alkaloid is found in tobacco leaf as 0.6 to 9 per cent, presumably on the dry basis.

The alkaloid is present in the plant from the time it starts growth in the seedbed, and some nicotine is retained throughout the subsequent processes of curing, sweating, and manufacture.

Nicotine varies greatly in different parts of the plant, but every part contains some. Furthermore, the alkaloid increases as the plant grows, so that the greatest amount is supposed to be present when the plant has reached fair maturity. After this it is thought to decrease. It is stated by some authors that when the plants are cut before full maturity the nicotine, in the leaf at least, increases after cutting, possibly due to translocation from stalk and stem to leaf.

On the other hand, the South African workers\textsuperscript{3} have shown that unless the plants are immediately sweated or flue dried after cutting, some nicotine may be used up thru metabolic changes in the freshly cut plants. In this connection the Pennsylvania Station\textsuperscript{3} reports that frosting the plants has increased the nicotine content. The authors, however, give no explanation of this fact. It is possible that the frosting of the plant before it is cut has checked any metabolic changes which might take place in the plant after cutting. Plants after cutting, unless killed, may use up some of their nicotine in such processes.

Some of the factors which affect nicotine content are given in the literature as follows: Species, variety, seasonal and climatic conditions, kind of soil, amount and kind of fertilizer used, cultural treatment, mutilation of plant, stage of maturity, method of curing, and storage.

Killebrew and Myrick\textsuperscript{4} quote Carpenter as saying that soil and fertilizers are the most important factors, and that those factors which tend to produce a coarse, rank growth containing a high percentage of albuminoids, also in turn produce high nicotine.

\textsuperscript{3}Cutler, J.V., Theron, J.J., and Osthuizen, J. Du P. \textit{Dept. Agr., Union of South Africa, Bul. 2, 1925.}


\textsuperscript{4}Tobacco Leaf. \textit{New York: Orange-Judd Co., 1916.}
Altho nicotine is the active stimulating principle of tobacco, a development of a high percentage in manufactured tobacco is not wanted. The tobaccos which are most highly prized usually contain a small percentage of nicotine. It would seem to follow, therefore, that the production of high nicotine in tobacco would require almost the opposite extremes of the various factors which make for high quality in manufactured tobacco. Most of the changes brought about in the curing and after treatment of manufactured tobaccos are fermentative ones. Such fermentative processes are supposed to result in nicotine loss, altho the matter has never been definitely investigated.

NICOTIANA RUSTICA

The genus Nicotiana is supposed to be of American origin and covers some 50 or more species. The species Tabacum supplies almost the entire product of commerce. In Mexico a species is found growing wild which is supposed to be N. rustica and which was cultivated by the Mexicans in ancient times. This species, it is thought, spread northward, probably largely thru the agency of the American Indian. In fact, even at the present time, an occasional plant of this species is found wild in New York and is looked upon as a relic of Indian cultivation. In Mexico this species is much branched, a characteristic which it still has when grown in New York. It is considered more hardy than N. Tabacum and the leaf and flower characteristics are quite different.

This species, i.e. N. rustica, was selected for the major part of these investigations. Certain features characteristic of this species, however, affected adversely the practical solution of the problem of cheaper nicotine so that a number of varieties of N. Tabacum were also used in the course of the work.

PRACTICAL ASPECTS OF THE PROBLEM IN NEW YORK

In an inquiry of the kind attempted in this investigation there are certain practical problems to be met and solved. Some of the questions which must be answered are as follows: Can the species known as N. rustica be grown in New York? Will this species mature under New York conditions? Can the yield be made sufficient to make it worth while? Will the nicotine content under New York conditions justify further work on the project? If the above questions can be answered affirmatively, how can the tobacco be utilized after it is grown and cured?
These are the questions which the work here reported has tried to answer. In addition, there is this final practical question to answer, Can the New York farmer or fruit grower afford to produce this crop, with the labor problem which its production entails, at the present prices of commercial nicotine? Or, perhaps cannot the problem of cheaper nicotine be solved by the production of high-nicotine tobaccos on a large scale by special producers in sections of the United States which are better adapted for the production of higher yields of nicotine per acre than in New York?

GROWING TOBACCO FOR NICOTINE IN NEW YORK

CULTURAL REQUIREMENTS

From the practical standpoint growing tobacco for nicotine necessitates a number of operations which are here very briefly described.

Growing the plants.—The seed is sown in outside seedbeds as early as possible, so as to produce early plants for field setting. Tobacco seed is very small and is very slow growing at first, but when once established it grows very rapidly.

Field culture.—As soon as danger of frost is over the plants are field set, by hand or with a plant setter. The usual distance for \( N. \) \( rustica \) is 30 inches between rows and 12 to 15 inches in the row. Up to the time of flowering the culture is very similar to that for a cabbage crop, but when the plants come into bloom the treatment is very different.

Topping and suckering.—When the plants are well in bloom the flower head is neatly removed with a knife. This procedure has the effect of causing the plant to produce more suckers than it normally would. These are also removed from time to time. With plants of \( N. \) \( Tabacum \) this is not a difficult operation, since this species has a tall upright growth habit and sucker growth subsequent to topping is not profuse. With \( N. \) \( rustica \), however, at least in New York, it is difficult to keep the plant free from flowers and suckers, and it is questionable after the first topping to what extent this can be done from the practical standpoint.

It is the general opinion that topping and suckering have several effects on the plant. In \( N. \) \( Tabacum \) this operation gives more and larger leaf per acre and better texture for manufacturing purposes. In \( N. \) \( rustica \) it produces higher yield of desirable leaf per acre and increases nicotine content.
Harvesting.—There seems to be a point in the growth of the plant when the nicotine content reaches a peak. This peak is somewhere very near the time when the plant is mature or when the first leaves begin to yellow. If following the nicotine curve by chemical analysis cannot be effected, the plants should be cut off at the ground when most of the plants are mature and before there are any killing frosts.

Curing.—The plants can be hung up in a dry, well-ventilated place, and when dry are ready for utilization. Flue curing undoubtedly conserves nicotine, but it was found in South Africa that the expense of the method was prohibitive.

SEED SOURCES AND VARIATION IN TYPE

The possibility of variation in type and nicotine content in this species suggested that it might be well to secure seed from more than one source. After the first year, therefore, additional sources of seed were found, and plants from these sources were grown on the Station farm. In all, some six sources of *N. rustica* seed were available during the past seven years. They were as follows:

No. 1.—In 1922 a sample of seed of *N. rustica* was secured thru the courtesy of the Tobacco Office of the Bureau of Plant Industry, United States Department of Agriculture. This seed was from tobacco grown in Pennsylvania for several years.

No. 2.—In 1923 an additional sample was secured thru the courtesy of the Connecticut Experiment Station.

No. 3.—In 1923 a sample was also secured thru the courtesy of the Pennsylvania Experiment Station.

No. 4.—In 1926 a sample of *N. rustica* seed was personally collected by one of the writers from a field of this tobacco growing in Pennsylvania.

No. 5.—In 1928 a sample was secured thru the courtesy of Mr. Mewborne of the Consumers Tobacco Company of Albuquerque, New Mexico. This sample was from tobacco grown under irrigation in New Mexico the seed of which originally came from the Tobacco Office at Washington.

No. 6.—From the same source as No. 5, but of the strain of *N. rustica* known as "Poncha." This variety is thought to be more nearly the original type of Mexican tobacco than the other strains of *N. rustica*.

In 1923 some 30 seed samples of *N. Tabacum* varieties were also secured thru the courtesy of the Kentucky, Connecticut, and Virginia Experiment Stations and the Tobacco Office at Washington and were grown at Geneva. Certain varieties of this original collection have been grown each year since that date.

Considerable variation in plant characters has been noted in plants from the various seed sources. No. 1 gave plants of great variability. Variation was in several directions. In the field the plants varied from low, compact plants to very tall, spreading ones. The former had dense compact seed heads, the latter scattered and loose heads. Some were quite leafy, others quite deficient in leaf. Character of leaf also varied, some plants having broad, very dark-colored, rough, pubescent leaves, with crinkled margins, while others had longer, narrower, lighter colored, and smoother leaves. Time of maturity and nicotine content also varied among these various type plants. These variations were later made the basis for some individual plant selection studies.

Samples 2, 3, and 5 gave plants of very similar character. Plants from these sources were of good size but not tall. The seed heads were compact, the leaves broad, crinkled, dark colored, and rough. The blooming period was somewhat later and they also matured later. There was very little variation in the character of individual plants. Suckering and flowering in this type is very profuse.

No. 4 is a small-growing type, giving a rather compact plant with compact seed head. It has small smooth leaves, blooms early, and matures fairly early.

No. 6 resembles in general No. 4 more closely than any other. The leaf, however, is smaller than any of the other types, at least as grown for one year in New York.

All strains of *N. rustica* had the same blossom characters. This species is distinguished from *N. Tabacum* by its shorter and differently shaped, greenish yellow flowers. It is characterized also by enormous seed production and its somewhat larger seed. The plants are also branching, while plants of *N. Tabacum* usually have a single flower stalk.

It is interesting to note in connection with the variation of type in *N. rustica* that Howard in India gives the principal characteristics of six varieties of this species and also illustrates and describes no less than 19 different types.
MATURITY AND YIELD

During six consecutive seasons in which \textit{N. rustica} has been grown, the later-maturing strains Nos. 2 and 3 have never completely matured all their seed before they had to be harvested. Strains Nos. 1 and 5 matured during some seasons but not in others. When weather conditions are such that the plants can be set very early and later conditions are favorable, obviating any resetting, and when the date of killing frost holds off well in the fall, most of the strains of \textit{N. rustica} mature in western New York. It is exceptional, however, to secure all these conditions in combination.

Some varieties of \textit{N. Tabacum}, however, matured seed in five seasons out of six. In 1923, the average nicotine content of 13 samples of \textit{N. rustica} from early settings was 5.39 per cent in the dry leaf. The average of 13 samples from later settings which did not mature was 3.23 per cent in the dry leaf. All these samples were from topped plants.

The total yields of dry matter per acre in \textit{N. rustica} are fairly good, but another very important factor, namely, the proportion of leaf to stalk, has not been very satisfactory in western New York. In this respect \textit{N. rustica} has not compared well with \textit{Tabacum} varieties. The branching habit of the former produces a large proportion of woody stalk, while the leaves are smaller than \textit{N. Tabacum}. In western New York the amount of nicotine in the stalk has been very low, usually 1 per cent or less, so that in order to secure a satisfactory yield of nicotine per acre the proportion of leaf to stalk must be high.

For topped plants of \textit{N. rustica} the proportion of leaf by weight on the fresh basis has never been over 60 to 65 per cent of the total green plant. On drying this percentage is lowered, since the leaf loses more weight than the stalks. The proportion on the dry basis usually runs from 40 to 50 per cent of the total. These figures agree well with similar figures on \textit{N. rustica} grown in South Africa. In \textit{N. rustica} broadcasted and not cultivated the dry leaf represented only 5.2 per cent of the total green weight of the crop.

This species has never been grown at Geneva in any large acreage so that production figures per acre under favorable seasonal conditions are not available. Calculations have been made from small areas, however, which would indicate that it is possible to secure 10 to 20 tons green material per acre. On the basis of 80 per cent water this means from 2 to 4 tons dry matter per acre. Dry leaf per acre has
ranged from 2,000 to 3,500 pounds per acre. Doubling these figures would represent approximately the yield of dry matter per acre.

NICOTINE CONTENT OF TOBACCO UNDER WESTERN NEW YORK CONDITIONS

It seems to be generally recognized that the tobacco plant is very susceptible to variations in environmental conditions. It seems especially necessary, therefore, that the crop should be grown not only a number of seasons, but that the effect on nicotine content of variations in certain cultural conditions should also be investigated.

EFFECT OF CLIMATE

The only data relevant to the effect of climatic conditions on nicotine content of *N. rustica* are such as either occur in the literature or have been obtained by personal contact with growers of this species in various localities. The small amount of data available indicates that the variations in nicotine in this plant are quite marked. In South Africa* N. rustica* has varied quite widely in nicotine, from season to season and when grown under different conditions of soil and other factors. These variations in South Africa seem to lie between the extremes of 4 and 8 per cent in the dry leaf and 1 to 5 per cent in the whole plant. About 4 per cent is considered a fair average for plants grown under normal conditions of rainfall, soil, etc.

In Pennsylvania7 as high as 6 and 8 per cent nicotine in the plants have been obtained. One Pennsylvania grower places emphasis on the fact, however, that constant attention and extreme care, as well as an intimate knowledge of plant types for seed selection, must be exercised, in order to maintain any such nicotine percentage.

In New Mexico under irrigated conditions not only very high yields per acre are secured but also a higher percentage of nicotine than the writers have as yet heard of. Some of the material runs as high as 15 per cent nicotine in the dry leaf, with some 4 per cent in the woody stalk.

In 1928 seed of two varieties of *N. rustica* which were grown in New Mexico were brought to Geneva and grown during that season. These two samples were from tobacco which had had a content of nicotine from 8 to 10 per cent in the dry plant and as high as 15 per cent in dry leaf for the past few years in New Mexico. The season of

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*See footnote 2.

7See footnote 3.
1928 in western New York was not very favorable, since three weeks of hard rains followed the field setting of plants. These samples analyzed 3.57 and 4.21 per cent nicotine in the dry leaf. This indicates what effect climate, and the many factors which go along with climate may have on the nicotine content of tobacco.

**NICOTINE IN VARIOUS PARTS OF PLANT**

Very little data are available on this point for New York conditions. In 1922 nicotine content was generally low in *N. rustica*. A sample of broadcast untopped plants gave 0.80 per cent nicotine in the dry woody stalk and 1.51 per cent in the dry leaf. In 1927 *N. rustica* gave 1.05 per cent nicotine in the dry leaf stems and 3.64 per cent in the dry leaf web. In the same year *N. Tabacum* gave 0.64 per cent nicotine in the dry leaf stem and 3.54 per cent in the dry leaf web. It is generally recognized that the finer parts of the leaf contain the highest percentage of nicotine. In South Africa also the nicotine in the woody stalk has generally been quite low, the average lying around 1 per cent.

**EFFECT OF SOIL**

Here also comparatively little data are available for New York. In 1922 plants from the same seedbed were set in five different locations in the vicinity of Geneva. These plants were not topped. The nicotine results on these five lots follow:

<table>
<thead>
<tr>
<th>Soil</th>
<th>Nicotine in Dry Leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light sandy loam</td>
<td>0.59</td>
</tr>
<tr>
<td>Medium clay loam</td>
<td>0.97</td>
</tr>
<tr>
<td>Medium clay loam</td>
<td>1.00</td>
</tr>
<tr>
<td>Heavy clay loam</td>
<td>2.03</td>
</tr>
<tr>
<td>Heavy creek bottom</td>
<td>2.77</td>
</tr>
</tbody>
</table>

These figures apparently indicate that the nicotine increases with heaviness of soil texture. The difference between light sandy loam and heavy creek bottom land is in the ratio of 1:4.6.

**EFFECT OF TOPPING PLANTS**

During several seasons a part of the planting has been left untopped in order to determine the effect of topping on nicotine content of the plants. The results were as follows:

- 1922 topping gave an increase of nicotine of 0.37 per cent
- 1924 topping gave an increase of nicotine of 2.15 per cent
- 1925 topping gave an increase of nicotine of 2.19 per cent
In the case of *N. Tabacum* of seven different varieties the corresponding figures were:

1924 gave an increase due to topping of 0.79 per cent nicotine  
1925 gave an increase due to topping of 1.91 per cent nicotine

Nicotine has been increased by topping in all cases.

As stated before, it is very difficult to keep this species completely topped. Within a week or ten days after topping an even greater crop of blossoms have to be removed and this is repeated thru the growing season. The practice in this work has been to wait until a fairly large flower head has developed before topping, then to give only one or two additional toppings at intervals of several weeks.

**EFFECT OF FERTILIZERS ON BROADCAST PLANTINGS**

The purpose in making broadcast plantings was to simplify the growing of the crop. Small plats of soil usually 10 x 10 feet, were worked down to a good seedbed and seed of *N. rustica* sown rather heavily as one would sow it in an outside plant bed. The crop was simply allowed to develop without any particular attention. Before frost in the fall it was cut with a sickle and dried. In some cases it was topped with a sickle also. The nicotine content of such broadcast tobacco has been low as can be noted from Table 1.

In 1924 nitrate of soda and sulfate of ammonia either depressed the nicotine content of the plants or did not increase it. A slight increase seems to have been produced by blood alone and in combination. It is thought that the quantities of the former were too large and affected the growth of the plants injuriously. In 1925 dried blood with potash increased nicotine somewhat, also urea with potash. Dried blood with phosphorus and with phosphorus and potassium increased the nicotine somewhat. In 1926, the use of nitrate of soda and potash in combination, increasing the former by four increments, has not had any consistent effect on the nicotine content, while increasing urea by four increments in the same combination has apparently increased nicotine somewhat. No striking increases in nicotine have been made on broadcast tobacco by various commercial fertilizer treatments.

**NICOTINE IN VARIETIES OF N. Tabacum**

In 1923 seed of some 30 varieties of *N. Tabacum* were secured and grown at Geneva. It was thought that if the nicotine content of some of these varieties was sufficiently high some of the plant characters, such as proportion of leaf to stem, production per acre, and ease
of topping, might be superior to *N. rustica*. Out of this lot all were
discarded except those which appeared promising in plant characters.
These were analyzed for nicotine. During successive years others

Table 1.—Effect on Nicotine Content of *N. rustica* of Fertilizers in
Broadcast Plantings.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fertilizer treatment in pounds per acre</th>
<th>Percentage nicotine in dry leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1922</td>
<td>2,000 pounds of 6–12–10; home mixed</td>
<td>1.51</td>
</tr>
<tr>
<td>1923</td>
<td>Same as above</td>
<td>2.95</td>
</tr>
<tr>
<td></td>
<td>Same as above</td>
<td>2.09</td>
</tr>
<tr>
<td></td>
<td>Same as above</td>
<td>2.58</td>
</tr>
<tr>
<td>1924</td>
<td>Nitrate of soda, 500</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 1,000</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 1,500</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Dried blood, 1,000</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 500; dried blood, 500; sulfate of amonia, 500</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>Sulfate of ammonia, 750</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Nothing</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>Nothing</td>
<td>0.87</td>
</tr>
<tr>
<td>1925 topped</td>
<td>Nothing</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>Dried blood, 500; muriate of potash, 500</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Urea, 200; muriate of potash, 500</td>
<td>3.10</td>
</tr>
<tr>
<td></td>
<td>Dried blood, 500; superphosphate, 1,000</td>
<td>2.87</td>
</tr>
<tr>
<td></td>
<td>Nothing</td>
<td>2.38</td>
</tr>
<tr>
<td></td>
<td>Dried blood, 500; muriate of potash, 500; superphosphate, 1,000</td>
<td>2.94</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 100; urea, 200; muriate of potash, 500; superphosphate, 1,000</td>
<td>2.85</td>
</tr>
<tr>
<td></td>
<td>Nothing</td>
<td>2.43</td>
</tr>
<tr>
<td>1926</td>
<td>Nitrate of soda, 100; muriate of potash, 300</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 200; muriate of potash, 300</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 300; muriate of potash, 300</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Nitrate of soda, 500; muriate of potash, 300</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Urea, 50; muriate of potash, 300</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Urea, 100; muriate of potash, 300</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Urea, 200; muriate of potash, 300</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td>Urea, 300; muriate of potash, 300</td>
<td>1.56</td>
</tr>
</tbody>
</table>

were discontinued until 1926, since when only two of the original lot
have been grown.
It will be noted from Table 2 that some of these varieties after the first two years compare very favorably in nicotine with many samples of *N. rustica*, but all are uniformly lower than the better strains of *N. rustica*. At Geneva some of these varieties have excellent plant characters. They are easily grown and handled. The proportion of leaf to stalk has been better than for *N. rustica*. Topping and sucker ing is easily accomplished, and harvesting and curing are simpler. Therefore, plant selection or crossing with *N. rustica*, if the two species will cross, might prove valuable with several of these *N. Tabacum* varieties.

### Table 2.—Nicotine Content of Varieties of *N. Tabacum* Grown at Geneva

<table>
<thead>
<tr>
<th>Variety Name</th>
<th>Source</th>
<th>Percentage of Nicotine in Dry Leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1923</td>
</tr>
<tr>
<td>White Burley</td>
<td>Ky.</td>
<td>1.10</td>
</tr>
<tr>
<td>Penn, Broad Leaf</td>
<td>D. C.</td>
<td>1.14</td>
</tr>
<tr>
<td>Big Havana</td>
<td>Va.</td>
<td>1.37</td>
</tr>
<tr>
<td>Big Orinoco</td>
<td>Va.</td>
<td>1.38</td>
</tr>
<tr>
<td>Lizard Tail Orinoco</td>
<td>Va.</td>
<td>1.23</td>
</tr>
<tr>
<td>Kentucky Pryor</td>
<td>Va.</td>
<td>1.64</td>
</tr>
<tr>
<td>Blue Pryor</td>
<td>Va.</td>
<td>1.40</td>
</tr>
<tr>
<td>Yellow Pryor</td>
<td>Va.</td>
<td>1.53</td>
</tr>
<tr>
<td>Yellow Pryor</td>
<td>Ky.</td>
<td>1.50</td>
</tr>
<tr>
<td>Yellow Pryor</td>
<td>D. C.</td>
<td>1.47</td>
</tr>
</tbody>
</table>

*Untopped. This table also shows something of the effect of seasonable factors on nicotine content.

**Variation in Nicotine Content of Individual Plants of *N. rustica***

As a basis for plant selection studies to obtain plants with higher nicotine content, nicotine analyses of a large number of individual plants were made. All such plants were of course untopped for seed production and the flower heads were bagged to prevent cross fertilization. Plants each year have been propagated from seed produced by the individuals showing both desirable plant characters and relatively high nicotine. As might be expected, in many cases plants having the highest nicotine content have not been desirable from the plant type standpoint. Table 3 shows the range in nicotine content of a number of these selections.

These results indicate that there is considerable range not only in the nicotine in different selections as a whole, but also in individual
plants of many of the selections. A good basis for individual plant selection is also indicated. Selections 1, 2, and 3 represent the three plants originally selected and the variation in nicotine in individual plants of these selections. Further selections of plants from their progeny were continued, the plants with desirable leaf character and highest nicotine content being selected each year following. Thru a period of five or six years such selections have maintained a nicotine content from 1 to 2 per cent higher than plants from general seed sources.

Table 3.—Nicotine in Individual Plants of N. rustica, Untopped.

<table>
<thead>
<tr>
<th>Percentage of nicotine in dry leaf in 12 strains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>3.02</td>
</tr>
<tr>
<td>3.64</td>
</tr>
<tr>
<td>2.82</td>
</tr>
<tr>
<td>2.69</td>
</tr>
<tr>
<td>3.22</td>
</tr>
<tr>
<td>2.64</td>
</tr>
<tr>
<td>3.97</td>
</tr>
<tr>
<td>2.47</td>
</tr>
<tr>
<td>2.82</td>
</tr>
<tr>
<td>2.89</td>
</tr>
</tbody>
</table>

Effect of Seasonal Conditions

Some effect of season can be observed by studying the nicotine content of some strains of N. rustica which have been grown from practically the same seed source thru several seasons. Some data of this kind are available for three seed sources and are given in Table 4.

Table 4.—Nicotine Content of Three Strains of N. rustica Grown from the Same Seed Source for Several Successive Seasons at Geneva.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage of nicotine in dry leaf in topped strains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. 34</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>1922</td>
<td>2.40</td>
</tr>
<tr>
<td>1923</td>
<td>4.70</td>
</tr>
<tr>
<td>1924</td>
<td>5.30</td>
</tr>
<tr>
<td>1925</td>
<td>5.94</td>
</tr>
<tr>
<td>1926</td>
<td>4.54</td>
</tr>
</tbody>
</table>

The effect of season on the nicotine content of certain varieties of N. Tabacum has already been noted in Table 2.
These results with both species indicate that the seasonal factor is an important one. Strain No. 34, for example, varied during five seasons from 2.40 to 5.94 per cent; No. 35 from 3.84 to 5.65 per cent in four seasons; and strain No. 5 from 3.99 to 6.26 per cent in four seasons. In other words, the nicotine may be doubled or cut in half in two successive seasons, even when the plants are grown both seasons from the same lot of seed.

UTILIZATION OF HIGH-NICOTINE TOBACCO

There seems to be two possible ways in which these high-nicotine tobaccos might be used by fruit growers in case such tobacco is available. One is by using the finely ground material directly as a dust or spray and the other is by using some means of water extraction of the nicotine. The practical aspects of neither of these two means have as yet been sufficiently investigated to warrant any recommendations. Further work on this problem of utilization is being carried out by this Station. For the benefit of the man who has some tobacco on hand and who wishes to try out the extraction method on a small scale, the following data are given.

The nicotine in tobacco is quite soluble in water and the main problem involved in extraction methods without the use of special apparatus is in the separation of the solid material from the extract. Herein lies one of the values of higher nicotine tobacco dusts, since the higher the nicotine the less the amount necessary per gallon of water, and consequently the greater the proportion of extract recovered.

A practical trial of simple extraction methods gave the following results. In this work a definite quantity of water was used and in it was soaked a quantity of tobacco dust proportional to its nicotine content, i.e., the higher the nicotine content the less the amount of dust used per gallon of water.

From a tobacco dust containing 1.4 per cent nicotine there was recovered as extract after 3 hours' soaking in water 81 per cent of the water added. This amount of extract contained 65.6 per cent of the original nicotine present in the tobacco.

After 15 hours' soaking practically the same proportion of extract was recovered which contained 68.5 per cent of the original nicotine. After 24 hours' soaking 70.5 per cent of the nicotine was recovered.

With tobacco containing 3.2 per cent nicotine, the proportional recovery of volume of extract and nicotine rose materially. Even in
one hour’s soaking of such a tobacco 86 per cent extract was obtained which contained 80 per cent of the original nicotine. After 15 hours’ soaking 84 per cent of the nicotine was recovered.

When a tobacco dust was used containing 5 per cent nicotine, recovery was still greater. After one hour’s extraction, there was recovered 95 per cent of extract containing 89 per cent of the total nicotine. After 15 hours, 91 per cent of the nicotine was recovered.

From these results it can readily be seen that nicotine is quite soluble and that there is a decided advantage in using tobacco containing higher nicotine as there is a larger recovery in both quantity and quality of extract.

On the basis of these results, the following proportions have been calculated. Taking into consideration both volume of extract and percentage of total nicotine recovered in soaking, the following are the quantities of tobacco dust required to make up a spray solution containing two different percentages of nicotine. These percentages are based on 3/4 pint and 1 pint of Black Leaf 40 in 100 gallons of water, and give respectively, approximately 0.045 and 0.06 per cent nicotine.

If a 1 per cent nicotine dust is used it requires 43 and 57 pounds per 100 gallons to give the equivalent of 3/4 pint and 1 pint, respectively, of Black Leaf 40. For a 2 per cent tobacco the corresponding quantities are 20 and 27 pounds per 100 gallons. With a 3 per cent tobacco 13 and 17 1/2 pounds are necessary. For a 4 per cent tobacco 10 and 13 pounds are required, while for a 5 per cent tobacco only 8 and 10 1/2 pounds per 100 gallons are necessary to give the above spray strengths of nicotine when soaked for six hours in that quantity of water.

DISCUSSION

Altho it has been found that high-nicotine tobacco can be successfully grown in western New York, certain other aspects of the problem have a very practical bearing.

The nicotine content has compared very well with similar tobacco grown in other humid regions, but both yields and nicotine content fall far below that of the same species grown under irrigation in the arid Southwest.

With the best cultural care, fertilization, and attention to seed selection a nicotine content of 4 to 5 per cent could probably be maintained in *N. rustica* in western New York, but yields per acre
have been somewhat disappointing. A yield of 2,000 to 3,000 pounds of dry leaf means 80 to 150 pounds of nicotine per acre. This is very low when compared with 500 to 800 pounds of nicotine per acre in the arid Southwest. An important factor which makes for low production of nicotine per acre in New York is the low percentage in the woody stalk and the large percentage of woody stalk in the plants of *N. rustica*.

Plant selection, fertilization, careful topping, and culture have raised the nicotine content some but not strikingly.

Considering the labor of growing the crop, the labor and facilities necessary for curing it, and the problems involved in its final utilization for insect control, it would not be practical in the writers' opinion, for New York fruit growers to produce and manufacture their own nicotine. However, growing high-nicotine tobacco for commercial nicotine manufacture, especially when utilized in the form of tobacco dusts, is a very practical procedure. For production on a large scale for this purpose, however, it is very questionable if the humid regions can compete with the irrigated soils of the arid Southwest where very large yields and high percentages of nicotine are secured.

Any farmer, however, who desires to grow the crop and is willing to meet the necessary labor requirements of curing it and who wishes to extract it for spray purposes can do so by following the methods described here.

It is believed that any effort made by commercial companies to grow high-nicotine tobacco and to manufacture it in the interests of a larger and cheaper supply of commercial nicotine will be of benefit to the New York fruit grower, and therefore, should be encouraged.