I. TOBACCO DISEASES.
II. TOBACCO BREEDING.

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BULLETIN

OF THE

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NUMBER 156. NOVEMBER, 1904.

TOBACCO DISEASES AND TOBACCO BREEDING.

BY A. D. SELBY.

I—TOBACCO DISEASES.

PRELIMINARY AND EXPERIMENTAL STUDIES OF MOSAIC DISEASE, ROOT ROT, BED ROT, BROOM RAPE AND CURING HOUSE TROUBLES IN OHIO.

INTRODUCTION.

The tobacco industry in Ohio, though apparently somewhat localized, has vital interest for the areas devoted to tobacco growing. The writer confesses a personal sympathy with tobacco growers by reason of early experience in the tobacco field. The recent establishment at Germantown, Montgomery county, of a Station test farm upon which tobacco problems are given especial consideration, brings Station officers into closer relations with the tobacco industry. Aside from such matters as arose from desultory correspondence, little attention has been given by the department in the past to the study of tobacco diseases. The present publication is issued with the double purpose of presenting some matters of present value and of securing a closer study of tobacco maladies by the growers of this staple. We should be able, in time, to increase our present limited and fragmentary knowledge of the troubles of the tobacco plant bed, the tobacco field and of the curing house.

TOBACCO DISEASES CLASSIFIED.

The tobacco plant, in common with many others, suffers from any lack of proper nutrition, and the diseases from this cause may be varied. We may have unsatisfactory growth and maturity from lack of the mineral plant foods or from lack of adequate moisture. In the present discussion, however, we shall not attempt to cover this line of troubles; we confine ourselves rather to specific maladies which may affect particular plants without touching others living under like external conditions. Here a plant may have abnormal color variations in the leaves as by yellow though not dying areas in them, at the same time that the adjoining plants of the same variety and seed strain are normal in color and healthy in behavior. Or a plant may suddenly wilt down and fail to attain full recovery and yet another may suffer from dead spots in the leaves. All these abnormal features which impair the vigor, productiveness or healthfulness of such plants, we term diseases. We shall omit here the discussion of insect injuries, though these in a sense come under one of the divisions to be considered. The root rot and the wilt are parasitic diseases as we shall see later; they are caused by specific parasitic organisms. Non-parasitic diseases are such as have no specific parasitic organisms constantly associated with them.

I. NON-PARASITIC DISEASES OF TOBACCO.

1. THE MOSAIC DISEASE.

The mosaic disease, or "Frenching", of tobacco, locally known in Connecticut as "calico," is one of unusual interest. The diseased plants exhibit such a mottled appearance of the leaves, due to the alternating areas of darker green and yellowish green in them, as to make the appearance of the plants very striking. The leaves are veritable mosaics; as such they catch and hold the interest of the observer. Certain plants will exhibit these characteristics and color markings while others near them have the normal, uniform green color. In the tobacco field, as most will recall, plants with abnormal color are quite frequent in unfavorable soil situations and especially around wet areas. This class of situations is however by no means the only one; no particular specifications may be made to apply generally in this respect. The mosaic disease occurs in practically all tobacco areas of this state and of the United States and under favorable soil conditions; indeed the disease is general throughout the tobacco growing districts of Europe and Asia as well. Along with the mottled, or mosaic appearance of the leaves we may have distortions of the leaves due to the unequal rate of expansion in the more healthy and in the diseased areas of the leaves.

PLATE I—Tobacco leaf showing Mosaic Disease.

Possibly no other type of plant disease has so long resisted the efforts of investigators to discover the cause producing it. It seems now that we must class the mosaic disease of tobacco, the yellows of the peach, peach rosette, the mosaic disease of tomatoes and the mosaic disease of forcing house cucumbers, which the writer has recently investigated at Ashtabula, Ohio, in one and the same group of maladies. To discover the actual cause, or causes of these diseases has long been the aim of students of plant pathology. In recent years decided progress appears to have been made; but as yet the final word is to be said on this matter of cause. Mayer[1] early made a careful study of the disease. He showed that the disease is transmitted by inoculation and concluded that it must be the work of bacteria. In 1898 Beijerinck[2] made a decided contribution. He showed that the juice of diseased plants, filtered through porcelain filters, yet retained the power of producing the disease when a small drop of it was injected into agrowing bud of a healthy plant; he also found that diseased tissue kept these infectious qualities even after drying and retained its injurious properties in the soil during the winter; he further demonstrated that the soil around the roots of diseased plants may affect the roots of healthy plants. Studies of the disease have been made in our country by Sturgis[3] and by Woods[4-5]. The last named publication will be of very great value to any one who wishes to study the conditions surrounding the production of the mosaic disease in tobacco. Just as in a sense Beijerinck was the discoverer of what he called "a living fluid contagium" which he regarded as the cause of the disease, Woods was able to go further and ascertain the presence of certain enzyms in the plants known as oxidizing ferments and named *oxidase* and *peroxidase*. Both these investigators were able to transmit the disease by inoculation of fluid from diseased plants into the young portions of healthy plants. The difference between the results of the one and the other is in the specific designation by Woods of the oxidizing enzym as the active agent in producing the disease.

[1]Mayer, Adolph, Ueber die Mosaikkrankheit des Tabaks. Landw. Versuch Station **32**:451-467 pl. I (1886). Review in Jour. Mycol. **7**:382-385.

[2]Beijerinck, M. W., *Verhandelingen der Koninklijke Akademie van Weten schappen te Amsterdam*, Deel 6 No. 5. See also Centb. f. Bakt. Par. &c., II, **5**:27-33 (1899).

[3]Sturgis, W. C., Conn. Exp. Station, Report (1898), 250-254.

[4]Woods, Albert F., The Destruction of Chlorophyll by Oxidizing Enzymes. Centbl. f. Bakt. Par. &c. II, 5.745 (1899).

[5]Woods, A. F., Observations on the Mosaic Disease of Tobacco. Bull. Bureau of Plant Industry, U. S. D. A. **18**:1-24, pl. I-VI.

More recently still Hunger[1-2] has investigated the mosaic disease of Deli (Sumatra) tobacco. Hunger's observations had led him to believe that the disease may be communicated by touching first diseased then healthy plants, as when the coolies seek for the young worms, that is, the larvæ which eat the tobacco leaves. He planned and carried forward an experiment, using a definite system in the matter of touching, and found as a result that a very high percentage of the healthy plants, touched directly after a diseased plant had been touched in the same tour, became diseased. Hunger has contended, as a result of his latest work, that not only is the disease infectious by means of the fluid extracts from diseased plants, but it is also infectious, we may almost say contagious, by this method of touching.

It has been customary to speak of the mosaic disease as a physiological one, because no parasites in the sense of living or parasitic organisms are associated with it. I have for the present contented myself with calling it a non-parasitic disease.

EXPERIMENTS TO DETERMINE COMMUNICABILITY OF MOSAIC DISEASE.

In 1904, under the direction of the writer, Mr. True Houser, field assistant of the department, conducted experiments in the plots of the test farm at Germantown along the line suggested by Hunger's work on Deli tobacco. A few inoculation tests were also made, including in all 30 plants. The plants were inoculated in different ways; some by insertion of a small fragment from a diseased plant in an incision of a healthy plant; others by injection of a watery extract of diseased plants into healthy plants. In every case the inoculated plants contracted the mosaic disease, the length of time after inoculation before appearance of evidence of the disease varying from one to two weeks, usually from 9 to 12 days.

There was no apparent difference between those inoculated near the base and those inoculated in the tender portion, although, as a rule, only the new growth showed the evidence of the disease. In some instances, where rather young leaves were inoculated, the disease afterward appeared. In this connection inoculations were made of extracts from plants suffering with what is locally known as yellow french, wherein the plant has a general yellow aspect.

[1]Hunger, F. W. T., De mozaiek-ziekte bij deli-tabak. Deel I. Verslag van de op Deli met betrekking tot de Mozaiek-ziekte genomen proeven in de jaren 1901-1902. Med. s' Lands Plantentuin **63**, Batavia, 1903.

[2]Hunger F. W. T , Die Verbreitung der Mosaik krankheit infolge der Behandlung des Tabaks. Centbl. f. Bakt. Par & c II, **11**:405-408. (1904).

Brief resume of Par. 4, Med. s' Lands Plantentuin, **63** (1903) contributed by the author.

No result was obtained and no communication of the yellow condition, thus confirming an opinion previously held that this discoloration is due to the influence of unfavorable soil conditions.

Blossoms of various plants were inoculated through the nectar by transmission of nectar from diseased plants, as by insect visitation. A slender brush of horse hair was used for this purpose. No evidences of disease were observed as a result of this method.

MOSAIC DISEASE COMMUNICATED BY TOUCHING.

The touching experiments were planned to test the danger of communicating the disease through handling first diseased then healthy plants, as in the operations of transplanting, worming, etc. The touched plants were arranged in sets of eleven plants each. In each set were three series of three plants each, marked *a*, *b* and *c*, respectively. The plant *a* of each series was touched directly after touching a diseased plant then *b* and *c* in succession without retouching a diseased plant. Series 1 was touched but once; Series 2, twice on succeeding days; and Series 3, three times on successive days. The same plant was used for *c* of both Series 1 and 2, or of Series 2 and 3, making a total of eight plants for the three series. The three remaining plants were treated as follows: one marked *P* was touched with considerable pressure (in some cases sufficient to break open the tissues of the leaf) after having done likewise to a diseased plant; one marked *S* was touched upon the stalk; and the remaining one, marked *L*, was touched upon the lower leaves. The last three plants mentioned were touched twice on succeeding days.

In all cases, where not otherwise stated, the touching was done on the upper or middle leaves.

Over 400 plants were touched, but owing to circumstances which prevented the collection of sufficient data from part of them, those with insufficient data have been omitted in the table. After the touching, the disease becomes visible, if communicated, only upon the new growth and is to be studied as in the cases of inoculation.

To insure against unintentional touching, the healthy and diseased plants were wormed and topped at separate times. The following table shows in the first part the results obtained upon touching the plants as determined upon the dates given, and also the increase of disease in the surrounding portions of the field. It will be observed from this table that the lowest percentage of plants becoming diseased under the 1*c* heading was 35.7 per cent., while the highest was 90 per cent., and the average of all the tests,

after the lapse of one month, gave an increase of disease due to this cause amounting to 68.66 per cent. Against this increase in the experiment was an increase of less than 3 per cent in the surrounding plots described in Table I as "not touched." These experiments confirm the results obtained by Hunger and show the necessity of great care if the spread of this contagious disease is to be checked. In the light of these experiments of 1904, it seems highly probable that the inferences made in 1903, as to the spread of the disease in the handling of the seedling plants, or otherwise, during the field practice of that year, are well founded.

TABLE I—Showing the results of observations and experiments as to the spread of the mosaic disease in tobacco upon ordinary plants and upon those touched with fingers after previous touching of diseased plants.

PLANTS TOUCHED

Date of touching.	Manner of touching.	Total No. of plants.	Plants diseased by Aug. 12.		Increase of disease from Aug. 12-Aug. 31		Total of disease up to Aug. 31.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.
July 26-30	3a	20	16	80	2	10	18	90
" "	3b	20	11	55	7	35	18	90
" "	3c	6	2	33.3	3	50	5	83.3
" "	2a	20	8	40	5	25	13	65
" "	2b	20	8	40	8	40	16	80
" "	1a	20	7	35	2	10	9	45
" "	1b	20	6	30	3	15	9	45
" "	1c	14	4	28.6	1	7.1	5	35 7
" "	2-3c	14	4	28.6	6	42.8	10	71.4
" "	P	20	12	60	5	25	17	85
" "	S	20	10	50	4	20	14	70
" "	L	20	6	30	6	30	12	60
" "	1-2c	6	2	33.3	3	50	5	83.3
Grand total	.....	220	96	45.66	55	25	151	68.6

PLANTS NOT TOUCHED.*

		6012	92	1.53	77	1.28	286	4.76

*At the beginning of the experiment, 119 plants of the total number, 6,012, or 1.98 per cent. were diseased in the areas herein studied.

PREVALENCE OF MOSAIC DISEASE IN SOUTHWESTERN OHIO.

The writer and Mr. True Houser have studied the disease in the Germantown district during the seasons of 1903 and 1904. Taking some 12 farms in the vicinity of Germantown, Montgomery county, including the Station test farm, there was not a single farm on which the mosaic disease did not occur in 1903. The varieties grown here are chiefly a cigar leaf filler, known as the "Zimmer"

and the Connecticut seed leaf. The percentage of diseased plants varied from less than 1 per cent. to 43.5 per cent. in these scattered areas. Upon the Station test farm, where planting was deferred until somewhat late, owing to delays incident to plotting and ditching the tobacco areas, a very curious but withal interesting state of facts was found to hold true in 1903. As is common in tobacco fields, the plots were of a definite number of rows and the results have been calculated dealing with the row as a unit, with the plot as a unit, with the fertilized plots and with the unfertilized plots of the area. The variations range from 0 to 56 per cent. of diseased plants in individual rows of the several plots and from 0 to 38 per cent. in the plants of the whole plot. No differences were discovered as between fertilized and unfertilized plots. To the writer it appears that the most striking feature exists in the extremely wide variation in the number of diseased plants in different rows of the same plot. Stated in its briefest form, we may repeat that the percentage of diseased plants varies from nothing—that is no diseased plants—to a little over half (56 per cent) in individual rows, and occasionally this range is found within the same plot. Possible explanations of this variation in the amount of disease occur to one. First, although the plants were set by machine, they were handled in removal from the plant bed, and the tendency would probably be to gather the plants from a limited area into a single bunch. Such bunches might represent a large number of plants diseased in the plant bed, despite the intention to reject diseased plants. Second, the apparent contiguous, or more or less contiguous situation of the diseased plants in the row may arise from the communication of the disease after the manner described by Hunger, as above quoted. That there was in these plots late occurrence of the disease is shown by the fact that one or more stalks in the plot, which had been shorn of the later branches of the panicle to preserve a few early blossoms for seed, became subsequently diseased. The lateness of this discovery prevented carrying out a series of carefully planned observations, as suggested by the facts already given. In 1904 the seeds from a diseased plant of 1903 were planted at Wooster but no disease occured in the progeny.

PREVENTIVE SUGGESTIONS.

Our preventive suggestions must finally be based on fuller knowledge than we now possess. Two suggestions stand out prominently in the light of the observations made during the past two seasons at Germantown.

First, all plants showing disease in the plant bed should be removed.

Second, it will be found advisable to destroy the diseased plants in the field after removal.

The reason for the first suggestion will be evident and need not be further discussed. The basis of the second suggestion is the proved communication by touching, first, diseased then healthy plants. This amounted to about 69 per cent. of infection in 1904. (See Table I). It is recognized that we must know more of the actual losses, both as to quantity and quality, resulting from the mosaic disease before we can secure the largest interest on the part of the practical tobacco grower.

Koning[1] has already shown the need for care in topping. In this, he reported the result of an experiment on a large scale, in 1897, in which diseased plants were first topped and directly a great number of healthy plants had tops broken by means of the fingers infected by the diseased plants; 88 per cent. of these healthy plants afterwards became diseased. It is clear therefore that any handling of the plants must discriminate between healthy and diseased ones. To top, worm and sucker diseased and healthy plants separately at different times, with disinfection of the hands before passing from the diseased to the healthy, is essential if we hope to limit the spread of the mosaic disease in the field after it once appears.

II. PARASITIC DISEASES OF TOBACCO.

a. DUE TO PARASITIC FUNGI AND BACTERIA.

1. ROOT ROT (BLACK ROOT).

In 1899 the writer received from Mr. B. W. White, of Neville, Clermont county, Ohio, specimen plants of size for resetting, the roots of which were attacked by a fungous disease which they had designated "black root". This trouble was described as being very bad wherever beds were made the second or third year upon ground that had been devoted previously to the seed bed. The roots of the plants were discolored externally, especially on the shin or internode immediately above the earth's surface, often accompanied by cracking and deformation (Fig. 1.). A brief examination with the microscope disclosed the constant presence of the very characteristic parasitic fungus which we may call the tobacco root rot fungus, *Thielavia basicola* Zopf[2] (Fig. 2).

[1]Koning, C. J., Die Flecken- oder Mosaikkrankheit des hollandischen Tabaks. Zeitschr. fur Pflanzenkr. 9:65-80 (1899).

[2]Zopf, *Die Pilze*. 1890, page 97.

From a drawing by J. M. Van Hook.

FIG. 1—Tobacco seedling affected with root rot.

So far as known to the writer, this is the earliest reported occurrence of this fungus upon the roots of tobacco in America, and of this a note was presented before the Botanical Club of the American Association for the Advancement of Science, at its Pittsburg meeting. (See *Science*, new series, 1900.) Peglion[1] has earlier reported upon the root rot of tobacco in Italy, attributed to the same fungus, and in America Thaxter has reported its occurrence as a root rot of the violet.[2] Some years ago the writer studied the fungus in connection with nematode enlargements upon the roots of the cultivated *Begonia rubra*.[3] Latterly, in 1903, similar specimens were received from the plant beds of the Station test farm at Germantown. The Assistant Pathologist, J. M. Van Hook, has recently discovered *Thielavia* producing root-rot of ginseng. In the first case mentioned, from Clermont county, the variety of tobacco was

[1]Attid. R. Accd. Lincei CCXCIX, V. I-II pp. 32-99.

[2]Report Conn. Agr. Exp. Station 13:166-167 (1891).

[3]Bulletin Ohio Agricultural Experiment Station, 73:228. (1896)

White Burley; the Germantown specimens were of a different variety. It is apparent that we have here a parasitic root rot disease which, while manifesting itself more conspicuously upon the young plants in the plant bed, may be communicated to the larger plants of the field should any diseased ones escape rejection. Aside from the dark color due to the reaction between the parasitic fungus and the host on the diseased areas, the symptoms of the disease are not different from other injurious root diseases.

From a drawing by J. M. Van Hook.
FIG. 2—The fungus of tobacco root rot *Thielavia basicola* Zopf. Camera lucida drawing of the fungus as it occurs upon ginseng, tobacco and begonia. *a* and *b* conidial forms; *c* ascospores. All magnified 565 diameters.

In the matter of preventive measures it is clear, from the Clermont county experience that, plant beds should be made upon new earth each year. Furthermore, all plants with black root should be rejected in resetting. The field development of the trouble remains open for study with us.

2. BED ROT.

On June 22d, of the present year, the writer observed areas in the plant beds of the Germantown test farm, in which the plants had damped off, or rotted, as a result of the attacks of some specific fungus. The destruction in these areas was strongly marked and the diseased plants showed all gradations from fallen to lesion-marked stages of the disease. (See Plate II). Specimens were collected and photographed and microscopic examinations were also made. These show that we have here injury due to the fungus *Rhizoctonia*. It is not possible at this time to state any further specific characteristics of the fungus, which does not appear to differ essentially from its forms upon other plants, including the potato.

The source of the *Rhizoctonia* appears to have been in the soil employed or in the added manures. It is evident that we have here to deal with a plant bed trouble (which we have named *bed rot*) of possible serious character, as well as with the root-rot previously described. The occurence of this bed rot warns against re-seeding in old plant beds. It is quite possible that soil treatment with formalin, of the strength employed for potato treatment

From a photograph by J. M. Van Hook.

PLATE I.—Bed rot of tobacco seedlings, produced by the fungus *Rhizoctonia*.

might improve conditions, but the chances are much against the successful use of formalin in earth where tender seedlings, like those of tobacco, are to be grown and transplanted. It is necessary in all such cases to reject diseased plants. It does not appear that this fungus has been previously investigated in its capacity to injure tobacco. Subsequent to the bed studies, or during August, plants in the field were observed showing peculiar injury in a ribbon like band extending from root almost to the growing tip. These plants tend to wilt down and especially to turn to the side with this ribbon lesion. The injury, we have determined, is associated with the bed rot trouble and doubtless results from the transplanting of some seedlings marked by this fungus.

3. DECAY OF TOBACCO SEEDLINGS.

Behrens[1] has described a wilting and decaying of tobacco seedlings, in which the symptoms consist of a wilting and a slime like covering of the wilted parts. With this a dirty green color is noticed, previous to becoming black. In the later stages a fungus may be seen covering the parts, especially the young seed leaves. This is identified by Behrens as a species of *Alternaria*, possibly identical with *A. tenuis*. While it is possible that this disease may have been met with in the young seedlings of the plant bed in our tobacco districts, it has not been my privilege to examine specimens as yet. Tobacco growers are solicited to send specimens of the young seedlings which may be found drooping, or dying, in the plant bed.

4. THE GRANVILLE TOBACCO WILT.

Within the past three years a destructive wilt of tobacco has been studied in Granville county, North Carolina. The symptoms[2] are described as a drooping of the leaves, which soon become soft and flabby, as if suffering from want of water. As a rule, the lower leaves droop first, the wilting gradually proceeding from the ground upward. Frequently the leaves of one side of the plant succumb earlier than those of the other. Often even a single leaf will show only one side infected. The wilted leaves soon die, dry up, and eventually the whole stalk dies, but remains standing with its dead leaves still hanging, and is not to be confounded with the temporary wilt due to lack of moisture, excessive heat, etc. At the stage of ear-

[1]Behrens. J., Ueber den Schwamm der Tabaksetzlinge. Zeitschr. f. Pflanzenkr. 2:327-332, (1892).

[2]See Bull. N. C. Agr. Exp. Station 188: (1903). "The Granville Tobacco Wilt."

liest wilting a section across the stem shows discoloration of the woody portion; at more advanced stages the wood is found, either in its internal or outer parts, to be punctured with longitudinal black stripes. I have been informed that this disease was observed in the vicinity of Germantown during 1903. The disease differs from that known as "sore shin" in the south, in that the stem of the wilt-affected plant never topples over from loss of roots, as is true in sore shin.

FIG. 3—Tobacco plant attacked by the Granville, North Carolina, tobacco wilt. (*From Bulletin 188, North Carolina Experiment Station.*)

CAUSES OF THE GRANVILLE TOBACCO WILT.

Two studies have been published up to this time with respect to the cause of the Granville tobacco wilt. The one by Stevens and Sackett (North Carolina Agricultural Experiment Station Bulletin 188, September, 1903) the other by R. E. McKenney (Bureau of Plant Industry, Bull. 51, 1903.) Stevens and Sackett have attributed the disease to a species of bacterium and have produced the disease from cultures of the germ obtained from affected plants.

McKenney, on the other hand, has found the conidia of a fusarium in the vessels of diseased plants and attributes the causal relations to the fusarium, which also causes wilting of cotton, cowpea and other plants. Whether it may be found upon another investigation that one or both of the organisms suggested are the cause of this wilt, we apparently have here a parasitic disease of which the cause is propagated in the soil and is peculiarly adapted to be destructive in case the same soil is planted successively in tobacco. With diseases of this kind we are sure that crop rotation becomes a necessity, and soil which produces the disease may be regarded as "tobacco sick". The writer would be very much pleased to receive information concerning the occurrence of this trouble, or of similar troubles, in Ohio tobacco fields. I am indebted to Professor Stevens for the illustration of this wilt (Fig. 3).

5. LEAF BLIGHT (FROG EYE).

Tobacco, in common with most foliage plants, is attacked by more than one species of parasitic fungus which produces abnormal conditions in the leaves. Of this the leaf blight fungus, *Cercospora nicotianæ*, Ellis & Everhart, is one. This trouble has been described by Sturgis[1] as occurring in North Carolina. The writer has met with various spotting conditions on tobacco in Ohio and inserts this note respecting leaf blight to bring forward observations in this line.

6. WHITE SPECK AND BROWN SPOT.

From North Carolina has come to us the description of another disease of tobacco, under the name of white speck, attributed to the fungus *Macrosporium tabacinum* Ellis & Everhart[2]. Another species of the same genus *Macrosporium longipes* E. & E.[2] is credited in the same state as the cause of brown spot.

7-8. DOWNY AND POWDERY MILDEW.

In Java, Van Breda de Haan has reported both a powdery and downy mildew of tobacco and referred them respectively to *Erysiphe communis*, (Wallr.) Lev. and *Phytophora nicotianæ n. sp.* In Australia these mildews are reported and referred to the same fungi. The downy mildew, should it occur with us, may be expected to prove destructive. The destructive character of the downy mildew of cucumbers as well as the downy mildew or rot fungus of the potato may be recalled in this connection. The powdery mildew of the pea and of many weeds and other plants, as well as this one of tobacco, may be expected to disclose themselves by a whitish covering of the growth of the fungus and is much less liable to prove destructive.

[1]Report Conn. Agr. Exp. Station, 20:273-277 1896.

[2]See Journal of Mycology 7:134, 1892.

b. DUE TO PARASITIC FLOWERING PLANTS.

9. BROOM RAPE OF TOBACCO AND HEMP.

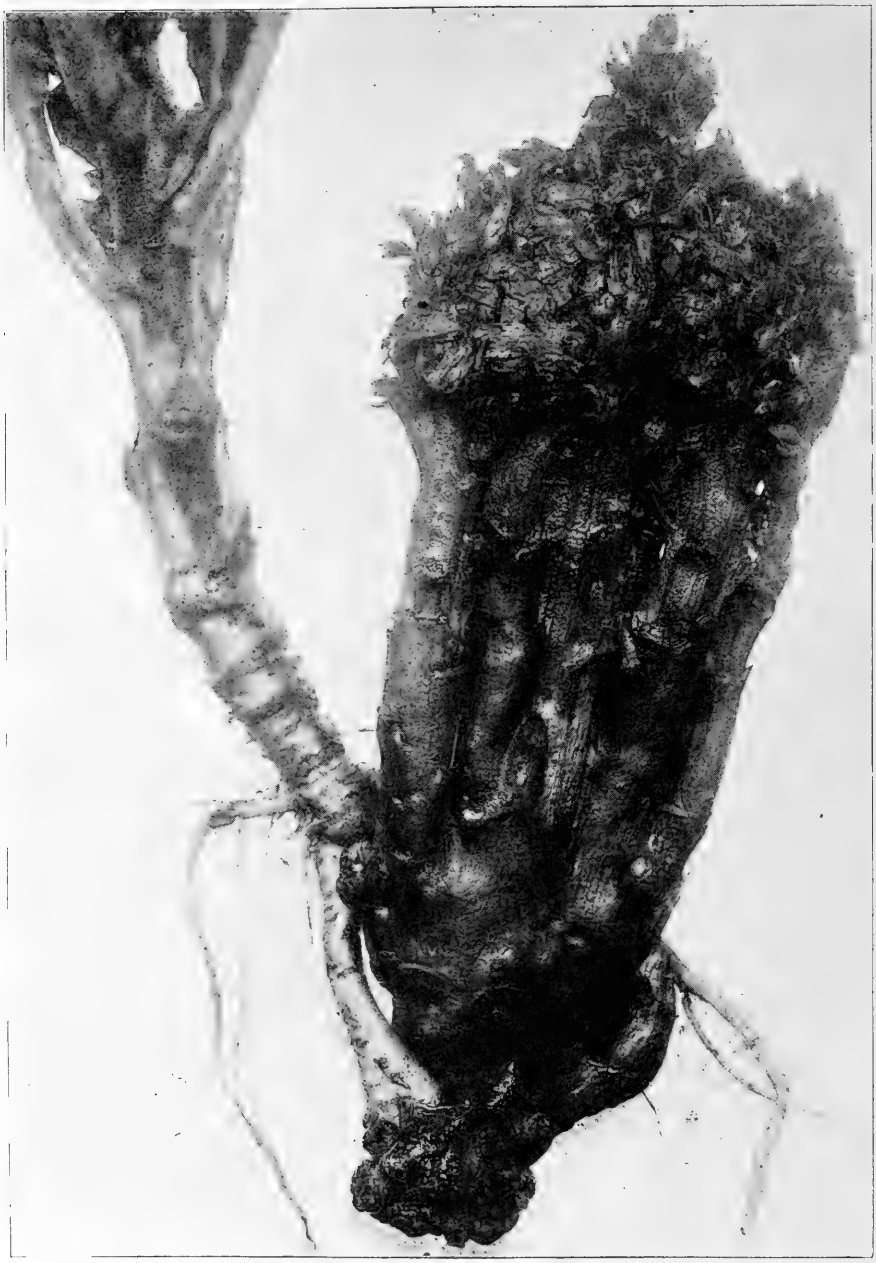
The most of our plant diseases, as we use the term, are produced by the attacks of parasitic fungi and bacteria. A few diseases, however, are due to parasitic flowering plants, such as the dodders which attack flax, alfalfa, clover and certain wild plants. These dodders are like other flowering plants, produced from seed which has matured in seed pods or capsules, but they are strongly marked by the absence of green foliage; being parasites these have not the necessity for chlorophyll to be acted upon by sunlight in elaborating food, so the plant does without the green leaves. Broom rapes, which are likewise parasitic flowering plants, are analogous in a certain way to the dodders but, different in that the broom rape is attached to underground parts of the host plant—that is to the roots—while the dodders become attachedto the parts above the earth.

The broom rape of tobacco, *Orobanche ramosa* L. was earlier known in Kentucky upon hemp than upon tobacco; it attacks also the tomato, rape, cabbage, parsnip, etc., and is known in Japan, India, Europe and the United States. It has been described and illustrated by Garman*. It is from the last named bulletin by Garman that we note the host plants of the different species of broom rapes. In this (Bulletin 105) Garman reports the occurrence of *Orobanche luduvania* on tobacco in Davis county, Kentucky. The nearest allies, among our common native plants, of this tobacco broom rape are the beech drops and the squaw root; also the flowering broom rape, which the writer has collected in the vicinity of Columbus. Any one who is particularly interested in the broom rapes of cultivated plants will do well to consult Professor Garman's Bulletin 105. The accompanying illustrations, Plates III, IV and V will show the manner in which the broom rape occurs in Ohio tobacco fields. It has been reported to the writer from a small area near Neville, Clermont county, for several years past. Specimens were sent to me by Mr. White, in 1901. The photographs from which the half tones were made were taken by the writer in September of the present year. It will be noted that the plants growing under the central tobacco plant of Plate III are in bloom, and this broom rape produces seed freely, so that it may be dispersed in the seed pod or through the seeds of plants like hemp and tobacco. It would appear less likely to become ad-

*The Hemp Broom Rape of Tobacco. Bull. Ken. Agr. Exp. Sta., **24**: 1890; & Annual Rpt. Ken. Agr. Exp. Sta., 1890, pp. 57-73, with 8 figures. Also Bull. Ken. Agr. Exp. Sta. **105**, Mch. 1903.

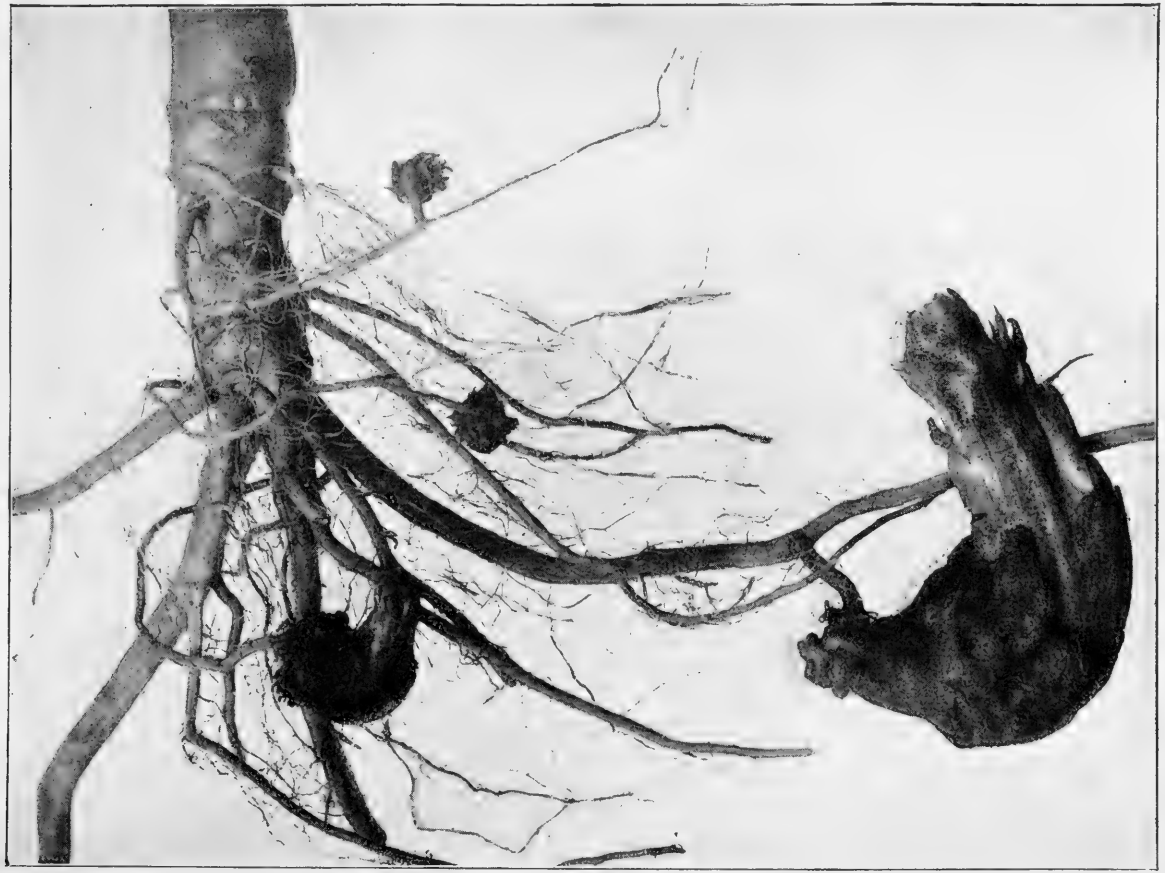
Photograph by A. D. Selby.

PLATE III—White Burley tobacco plant attacked by broom rape, *Orobanche ramosa* L.



From a photograph by A. D. Selby.

PLATE IV—Showing tobacco broom rape, *Orobanche ramosa*, fully developed on root of tobacco plant.



From a photograph by A. D. Selby.

PLATE V—Various stages in the development of the tobacco broom rape, *Orobanche ramosa*, upon the roots of tobacco.

mixed with tobacco seed. owing to the manner in which the tobacco seed is usually harvested. The area of infection in Ohio is small and confined to somewhat low bottoms skirting the river upon two different farms in Washington township, Clermont county. Infection here may have come from the transporting of seed by the water or it may have come from another source. The clusters of the broom rape often attain a very large size after the harvesting of the tobacco. The amount of seed produced must be considerable, so that it will be difficult to get these tracts of land entirely free from the broom rape, so long as tobacco growing is practiced at intervals. We have no evidence from the small area in Ohio as to attack on other plants, but Garman states that in Kentucky, infested land may be devoted to grains or grasses with safety. Caution is advised with respect to the growing of tobacco plants upon soil which is even suspicious. It will be a great drawback to tobacco culture to have other areas of the state so infested with rape as are many of the hemp and tobacco lands in Kentucky. The fact that it occurs in Ohio on tobacco would serve as a warning against its further distribution within the state.

c. CURING HOUSE TROUBLES OF TOBACCO.

The tobacco diseases previously discussed relate to the growing tobacco plant; other troubles of the curing house, that likewise cause loss and impair the quality of tobacco, sometimes occur. Those engaged in the curing and subsequent handling of tobacco will recall many unfavorable conditions, which tend to affect the quality of the crop, aside from its original quality when first cured. The fermentations in the process of curing are regarded as essential to proper flavor, but unless properly controlled these fermentations may produce unfavorable results.

10. POLE BURN OR POLE ROT.

This is a disease of the curing house, referred by tobacco growers to the effects of warm, damp, foggy weather upon the newly hung tobacco. The first symptom is noticed in the neighborhood of the veins and the midrib of the leaves where moisture is abundant; later on the disease may extend. Sturgis has given us a very full description in the Connecticut Station report for 1891, pages 168-184. The entire contents of the curing barn may be left quite worthless as tobacco by the extension of the deadly burn fungus. The disease may certainly be expected in every tobacco area in our country, as it has been known to exist in the past in Connecticut, Virginia, Kentucky, &c. The too close hanging of the tobacco,

with the weather conditions already noted, will be likely to aggravate the trouble very greatly; while more room and a limited amount of artificial heat will be found to be favorable. Insufficient ventilation will lead to bad curing. The actual organisms of the decay have been studied by Sturgis, but it is doubtful whether these are peculiar to this form of decay as against any other decays of vegetable tissues.

11. STEM ROT.

When the tobacco stalks are hung up in the curing house the leaves wilt and later dry up more or less, while the thick, succulent stem dries out but slowly. Under conditions which may prove unfavorable to the drying out, or even under average conditions, the danger of rotting at the stem is considerable. The stem rot is a disease of this character. It begins by white patches of a velvety aspect upon the diseased parts, more especially the stem. The patches may spread to the veins of the leaf and induce unfavorable results. Sturgis[1] has reported upon this disease and found it to be due in Connecticut to a fungus known as *Botrytis longibrachiata*, and Behrens[2] agrees with Sturgis except that he regards this *Botrytis longibrachiata* as a form of *B. cinerea*.

REMEDIES FOR STEM ROT.

In the curing house, this is usually remedied by gathering the diseased stems and destroying them and by the use of germicidal sprays in houses where the trouble has been serious. A spray consisting of formalin of the strength employed for potato scab should be very useful for this purpose and may be scattered throughout the building by using an ordinary spray pump, such as is employed in orchards.

NOTES ON CURING HOUSE TROUBLE SOLICITED.

In order to present before tobacco growers some of the conditions recognized elsewhere, these brief abstracts of curing house troubles have been given in this bulletin. More complete notes and advices as to the occurrence of curing house troubles will be thankfully received and will meet with response. It will be difficult to state just what our peculiar conditions may bring forth in Ohio until strict study has been made of these conditions in the curing house.

[1]Rpt. Conn. Agr. Exp. Sta. 15:184-186 1891.

[2]Trockene und nasse Faule des Tabaks. ,,Der Dachbrand" (Zeitschr. f. Pflanzenkr. 3:82. 1893.

II. TOBACCO BREEDING.

PRELIMINARY STATEMENT CONCERNING SELECTION AND CROSSING OF TOBACCO IN RELATION TO NEW VARIETIES.

Since the establishment of the southwestern test farm of this Station, through the efforts of the Germantown Tobacco Growers' Association, the various phases of the local tobacco problems have been under study. The Department of Plant Physiology and Pathology has been requested to take up the question of producing, or securing new varieties of tobacco for "cigar filler" purposes.

In the various efforts made during the past two years, the results of which are in part indicated on subsequent pages, the botanist has been assisted by Mr. True Houser, field assistant of the department. The crossing and selection work has been done by him under the direction of the writer, who wishes to express his obligation to Mr. Houser for efficient assistance.

It has been stated by many prominent tobacco growers that the Zimmer variety, so long grown for locally, cigar filler does not meet all requirements, and that, therefore, new varieties should be sought. In undertaking an investigation of this character the general principles involved are not essentially different from those in other lines of plant breeding. The methods may be stated in brief to consist either (1) in selection or (2) in crossing followed by selection.

SELECTION-PROCESSES.

In the method of selection, new strains of established varieties are obtained by the choice of individual growing plants of the desired type, or types. These growing plants may be in special gardens or simply in the tobacco field. When suitable types are discovered the specimens are protected by bagging from undetermined cross pollination, and the plant is permitted to ripen a few of the earlier seed pods. At the time of bagging the other branches of the cluster are clipped off; the bagging must, of course, be done previous to the opening of the first blossom. The progeny from the selections thus made, must subsequently be grown, and the product after curing and fermentation, submitted to the necessary tests to determine its quality and special adaptations. It is apparent upon reflection, that this method has its limitations in regard to the extent of difference between the variety grown and the desired variety. If the variety already under culture possesses most of the desired characteristics, then this method of selection will prove well adapted; if, on the other hand, a wide

difference exists between the variety grown and the ideal new variety, either the process by selection alone must be laid aside, or a longer time allowed for the breeding work in order to secure the final end sought. The tendency of the variety under culture to variation will naturally influence greatly the length of time necessary to attain the ends in question. However, one serious difficulty in tobacco breeding, and this applies at all stages to both methods, is the relative immaturity of the tobacco plants at the time the seed selection must be made. It is but fair to state in this connection that selection alone, if unsatisfactory, must give way to other processes of breeding, and that whatever work is done must be done under the limitations imposed by the course of development run by the plants of the tobacco upon which we work.

METHOD OF CROSSING AND SELECTION.

In the second method, namely, that of crossing followed by selection, we endeavor to secure the plants for subsequent selection by crossing two given varieties. The nature of the tobacco flower and its adaptation to self-fertilization, as well as the labor necessary to insure cross pollination, must be duly considered.

While tobacco blossoms are freely visited by birds and insects with long bills or probosces, such as the humming birds and the hawk moths which lay the eggs of the tobacco worm, thus contributing to cross pollination, the tobacco blossoms are self fertile without insect or other visitation. Their adaptation to insect visitation and attraction, through the nectaries of the blossom, are but a possible co-operation in the widespread cross pollination secured in the vegetable kingdom. If, therefore, we wish to cross-pollinize, the blossoms must be emasculated by removal of the immature anthers or pollen sacs, at a time just previous to the full opening of the tobacco blossom. This period is indicated both by the development of the corolla of the flower, including its change of color, and by the slight yellowing of the anthers, or pollen sacs, at the same time. The emasculated blossoms must then be protected from insect visitation, by covering with suitable bags of a hardened paper manufactured for this purpose*. Since the anthers are removed before maturity, at this time the pistil is not mature, or receptive to pollen; the receptivity continues for some days usually, unless pollination occurs. Ripened and bright yellow s , from the sort it is desired to cross upon such an emasculated pistil, are chosen the next day, or subsequently, and upon the

*The bags used in this work were manufactured by Schmidt, Dusseldorff, Germauy, and may be obtained in various sizes.

cautious removal of the bag, applied to the stigmatic, or sticky surface of the pistil of the emasculated blossom. Caution in this manipulation is exercised so as to insure only pollination by these chosen pollen sacs. Such crossing does not change the plants upon which it is performed, but the cross-fertilized seeds will be influenced and grow, when sown, into plants having certain characteristics which resulted from the crossing. Usually these characteristics have been found to be more or less intermediate, varying from those plants showing very close resemblance to the one parent, by almost imperceptible gradations into types approaching the other parent. In our tobacco work, we have found that in all, more strictly intermediate types have prevailed in the progeny; these types partake very decidedly of the characteristics of both parent varieties. The crosses thus far made, have included, more particularly, crosses between the large-leafed "Connecticut seed leaf" variety, and the slender variety grown in the Miami valley under the name of "Cuban." The illustrations will possibly show how the crosses exhibit the intermediate characters. Most of the crosses show much larger leaves than the Cuban, but with longer internodes than the Connecticut seed leaf. The actual qualities of the cured tobacco remain to be subsequently determined.

SELECTION OF CROSSES.

In the manner above indicated, about 30 crosses were produced in 1903. The seed of some of these was lost, but 25 of them were grown during the season of 1904. These are recorded by the numbers under which the original cross-pollination was entered. In this instance, they run from No. 51 to No. 75, inclusive. The illustrations will show the variation in part. Another factor will be found in the yield of cured leaf, and still another in the quality of this leaf. For final application of the results of crosses, the favorable, or suitable sorts, must be determined by the processes of selection which have been heretofore discussed. Ten out of the twenty-five varieties have been rejected, or at least set aside, and only fifteen of these are to be planted in 1905.

While, during 1904, only a single row of each number was grown in a plot, in 1905 duplicate 20th acre plots will be grown of each selected number, checked by standard plots of the Zimmer and grown along with plots of the "selection" strains of Zimmer and with plots of the Cuban and Connecticut seed leaf. In this manner the habits of growth, productiveness and quality of the various crosses will be determined in the course of two to five years, according to the amount of retesting necessary.

Numbers 53, 54, 55, 58, 59, 61, 63, 64, 68, 69, 70, 71, 72, 74 and 75 have been selected for plot tests in 1905, while numbers 51, 52, 56, 57, 60, 62, 65, 66, 67 and 73 have been set aside as of less apparent merit. It will thus be seen that the procedures in plant breeding require rather long periods of time; several years are ordinarily required in the selection of a suitable type, or variety, from crosses or from more or less fixed varieties already grown. It always remains to be determined, when a cross is grown, whether the plants are uniformly of one type, and if they are not, the sort must be grown repeatedly until the type is "fixed." We made notes in the field in 1904 which show that, with the crosses thus far studied, the variation among the plants of the rows of the same number in 1904, was much less than anticipated. It is expected therefore that the fixing of type with the tobacco crosses will be less prolonged than in the case of wheat and some other plants.

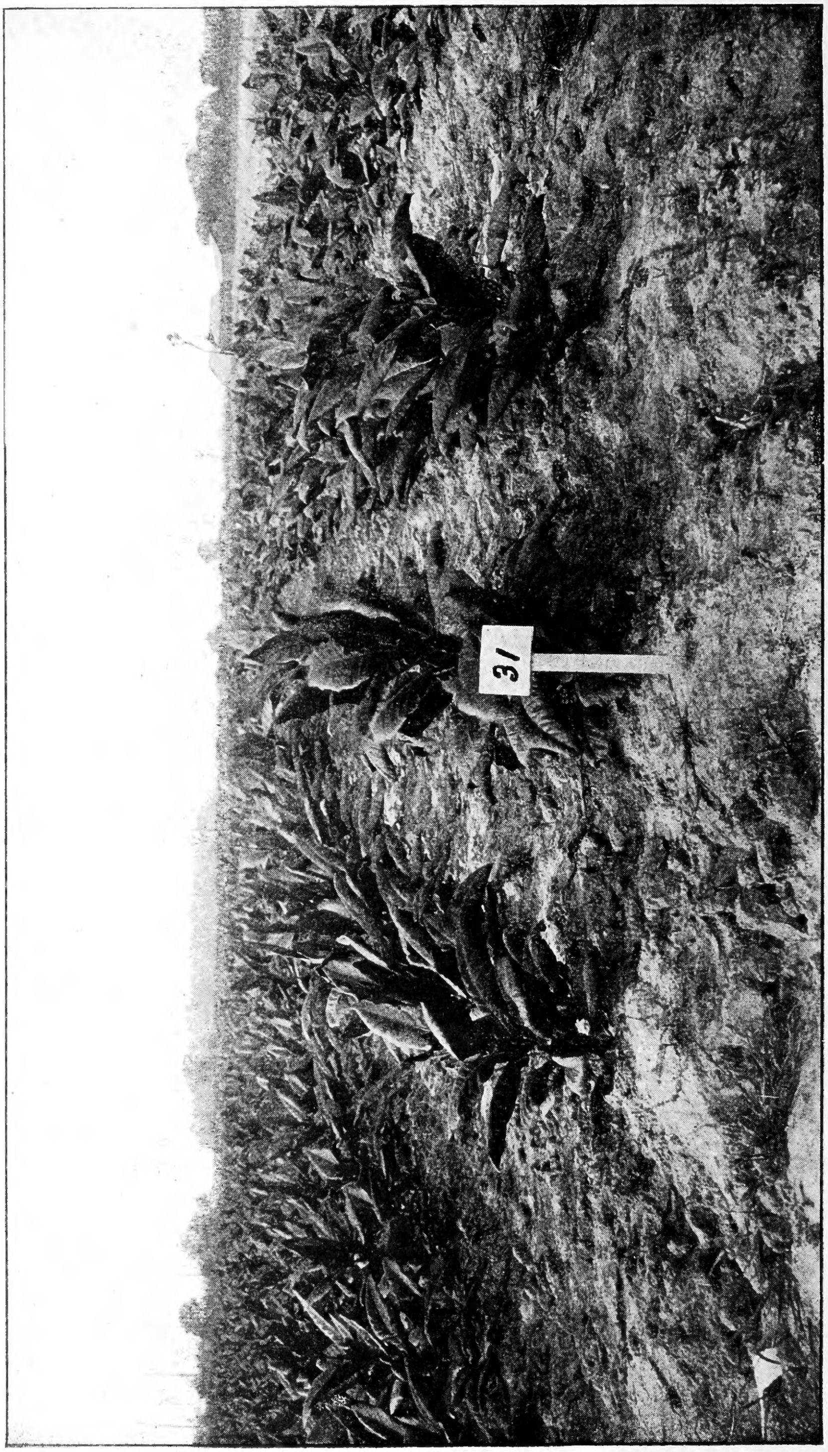
This statement of the processes employed and the progress made in breeding varieties of tobacco is published at this time, in order not only that the members of the legislature who, aided in the establishment of this tobacco test farm, and the members of the Tobacco Growers' Association, may discover the manner in which the Station is carrying out its obligations, but also that the general tobacco growing public may know something of the operations in this line. Two or more years must yet elapse before the results of this tobacco breeding will merit further publication.

From a photograph by A. D. Selby.

PLATE VI—Tobacco crosses of Connecticut Seed Leaf and Cuban varieties as grown in 1904. Numbers 53, 61, 64, and 69 have been selected for plot tests in 1905. No. 56 is less meritorious.

From a photograph by A. D. Selby.

PLATE VII—Tobacco crosses of Connecticut Seed Leaf and Cuban varieties as grown in 1904. Nos. 71, 72, 74 and 75 have been selected for plot tests in 1905. No. 73 has been set aside as of less apparent merit.



From a photograph by A. D. Selby.

PLATE VIII—A Promising strain of "Zimmer" selection grown in 1904.