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The Disease Resistant Varieties Burley 11A and 11B and Observations on Tobacco Black Shank in Tennessee

University of Tennessee Agricultural Experiment Station

Howard E. Heggestad

M. O. Neas

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HOWARD E. HEGGESTAD

and

M. O. NEAS

AGRICULTURAL EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE
in cooperation with
CROPS RESEARCH DIVISION
AGRICULTURAL RESEARCH SERVICE
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HOWARD E. HEGGESTAD

Research Agronomist

Beltsville, Md.

(formerly Greeneville, Tenn.)

and

M. O. NEAS

Agricultural Aide

Greeneville, Tenn.

Crops Research Division, Agricultural Research Service

United States Department of Agriculture

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INTRODUCTION

Black shank[1] of tobacco first appeared in this country as early as 1915 in the Florida-Georgia cigar-wrapper district (16). Since then, this devastating disease has spread throughout much of the major tobacco-producing areas in the United States. In Tennessee, black shank was first identified in 1935 on dark-fired tobacco. Losses due to this disease on dark-fired tobacco in Tennessee have been of little consequence since most growers follow a good system of crop rotation. The disease situation has been quite different in the burley producing areas. In East Tennessee in 1949, the year black shank first appeared it was present in approximately 35 growers' fields in Greene County (4). During the next three years blackshank appeared in several other East Tennessee counties and on many more farms. A similar build-up of this disease took place in the burley producing areas of Middle Tennessee and Kentucky and in flue-cured areas of North Carolina and Virginia (11, 12, 13, 17). Sanitary measures for control of black shank (8) are helpful but far from adequate in checking growers' losses. As a result of the continued losses in production, a coperative State-Federal burley tobacco improvement program was initiated in 1950 at the Tobacco Experiment Station, Greeneville, Tennessee to develop acceptable varieties resistant to black shank and other diseases. The primary objective of this bulletin is to report on the developmental phases and performance records of Burley 11A and Burley 11B, two tobacco varieties resistant to black shank, fusarium wilt,[2] and black root rot[3] disease, seed of which was first released to growers for planting in 1954. Brief published reports of development of these varieties were made in 1955 (3, 6).

BLACK SHANK RESISTANCE

In 1950 the breeding program for the development of burley varieties resistant to black shank was initiated. Two fields infested with black shank were secured for use as breeding plots—

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[1]Caused by *Phytophthora parasitica* (Dast.) var. *nicotianae* (Breda de Haan) Tucker
[2]Caused by *Fusarium oxysporum* (Schlect.) var. *nicotianae* J. Johnson
[3]Caused by *Thielaviopsis basicola* (Berk & Br.) Ferr.

a two-acre field in East Tennessee near Greeneville, "Malone Farm," and a one-acre field in Middle Tennessee near Columbia, "Jewell Farm." In 1949 both fields had total crop loss due to black shank. The plantings in these breeding plots in 1950 included varieties of flue-cured and cigar-wrapper types having black shank resistance, some *Nicotiana* species, and second generation hybrids from a cross between Kentucky 16 and the black shank resistant cigar-wrapper variety Florida 301, and Kentucky 16 and a flue-cured resistant breeding line. Although high resistance was obtained from the Kentucky 16-Florida 301 cross, the tobacco was poor burley type. In addition to the above plantings, Dr. W. A. Jenkins of the Virginia Agricultural Experiment Station provided ten seed lots in F_4 generation from crosses he had made involving Virginia flue-cured resistant varieties and susceptible burley varieties. It was one of these seedlots designated WBR-9 (a cross of Kentucky 16 and Vesta 64) from which the burley black shank resistant varieties, Burley 11A and Burley 11B, were developed. The black shank resistance in the new burley varieties has been transferred through a series of crosses from the cigar-wrapper variety Florida 301, which was developed by Tisdale (15) after crossing two local varieties, Big Cuba and Little Cuba. Bullock (1) was first to transfer black shank resistance to flue-cured varieties and breeding lines. Following the cross White Stem Orinoco by Florida 301, Bullock back-crossed twice to White Stem Orinoco. One of the breeding lines selected after these crosses was released as Oxford 3. Jenkins (9) crossed Bullock's strain 45 having the same breeding as Oxford 3 on Yellow Special, and this resulted in development of the flue-cured variety Vesta 64. From the cross Vesta 64 on Kentucky 16, the varieties Burley 11A and 11B were developed. Burley 11A was tested extensively, first as Greeneville 42 and later as Greeneville 42A. Burley 11B was a sister selection tested experimentally as Gr. 42B. In 1954 at the time of first release of seed to growers, Burley 11A and 11B were in F_8 generation.

BURLEY 11A AND 11B DESCRIPTION

Burley 11A (Figure 1) is similar to Burley 2 (7) and Kentucky 16 in leaf number, size, and spacing on the stalk. Leaves are more "cupped" than Burley 2, and the leaf surface shows a slight "crinkled" or "crepe" effect. Lower leaves are large and tend to droop somewhat more than desired. Plants are noticeably lighter colored in the field than Burley 2 and often will be ready

Figure 1.—Burley 11A on right compared with a breeding line lacking in resistance on left. Typical growth and type for Burley 11A.

to harvest one week earlier. Burley 11A cures easily under widely different curing conditions. The yield of leaf is usually less than for most other varieties when grown in absence of disease but the quality is very good with a high proportion of cigarette smoking tobacco produced. In absence of black shank the returns per acre have been comparable to those of some non-resistant varieties.

Figure 2.—Comparative growth of some tobacco varieties in the presence of black shank. Left to right: Rg (a cigar wrapper variety), Ky. 16, Burley 11B, and Burley 11A.

Burley 11B is difficult to distinguish from Burley 11A in appearance (Figure 2). Leaves of Burley 11B, especially at the top of the plant, tend to be smaller and heavier bodied. Grade quality is about equal, but in absence of disease average yields in Tennessee are slightly less. In critical tests it has proved to be somewhat more resistant to black shank, fusarium wilt, and black root rot than Burley 11A.

Burley 11A, however, is believed to be better than Burley 11B for most farms where black shank or fusarium wilt resistance is needed because of its slightly higher yields and superior quality. Manufacturers have indicated preference of Burley 11A over Burley 11B.

EXPERIMENTAL METHODS

Because of the threat of black shank and the lack of burley varieties with resistance, a comparatively large breeding program was initiated and maintained. Approximately 25,000 plants were

Figure 3.—General view of the black shank breeding plots near Greeneville, Tennessee, as they appeared in 1952. The two 50-plant row plots without plants in the center had been set with susceptible varieties; plants were killed early in the season. There was nearly total loss of the crop on this field in 1949 due to black shank. Field used as breeding plot since 1950.

evaluated for resistance to this disease in breeding plots totaling approximately 3 acres in each year from 1950 to 1954, the five-year period spent on development of Burley 11A and Burley 11B. Figure 3 shows a general view late in the 1952 season at the Malone farm plots (2 acres), a heavily infested field that has been used every year since 1950 to determine black shank resistance of selected plants by plant to row progeny tests. Beginning in 1951, yielding ability and quality characteristics of breeding lines when grown in absence of disease were evaluated as well as resistance to disease.

Relative black shank resistance of a line was determined by comparing the number of plants surviving in the breeding plot with that of known susceptible varieties such as Kentucky 16 or Burley 2. As shown in Figure 3, resistant plants were bagged to prevent cross pollination. Final plant selection was made early in October just prior to frost when roots were dug to determine extent of black shank injury. Only those plants were saved which had roots and stalks apparently free of disease or with just a trace of injury. All seeds from bagged plants with more than a trace of injury to roots were discarded, although such plants had made apparently normal growth in the black shank infested soil. Critical test of resistance of the plants saved was made the following season when progenies from the selfed plants were tested in two to four 50-plant row plots. Tests for resistance to fusarium wilt were made using pure cultures to inoculate roots just prior to transplanting and counting number of plants which survived. Black root rot resistance was evaluated by growing seedlings in infested soil in the greenhouse during the winter season.

Yielding ability and quality characteristics of each breeding line were determined at the Tobacco Experiment Station, Greene-vlle, in plantings made in absence of disease. Tobacco was grown in randomized-block tests which usually included three or four replications with 50-plant row plots of each line. Closely related lines, including those from sister plant selections the previous season, were grouped in separate tests for close comparison with each other and a standard variety, Burley 2. After curing, the tobacco was stripped from the stalk and separated into six farm grades. Each grade of each plot was weighed to the nearest .01 pound, and an appraisal of each lot of tobacco was secured from an experienced tobacco grader. Average grade index of each plot was computed after assigning according to grade an index value based on prices paid for tobacco in 1934, 1935, 1937, 1938, and 1939. The grade indices are similar to price per pound. A crop index value was secured by multiplying the average grade index with plot yield in pounds per acre. For breeding material and variety tests, the percentage tobacco most suitable for smoking purposes was determined, including in the value amounts of flying (X), cutter (C), and tan leaf (BF) grades.

The most outstanding lines having promise for variety release were included each year in advanced variety trials made at ten or more widely separated locations in Tennessee. Using seed from the same source, seedlings were grown at each location. A variety test usually consisted of nine varieties or breeding lines with four replications and 100-plant plots. Row and plant spacing at each location was uniform; i.e., 42 inches between rows and 15 inches between plants. The tobacco, however, was fertilized and otherwise grown according to grower practices in each area. For the advanced variety trials current seasons' prices, as well as grade index, were used to evaluate quality. Other evaluations were made of the tobacco including plant measurements, percentage cured tobacco in different U. S. standard grade separations, chemical analyses, leaf-burn determinations, and manufacturers' appraisal of quality as judged by both physical and chemical characteristics.

RESULTS—Disease Resistance

Black Shank

In 1950, relatively few plants had sufficient resistance to survive in the black shank disease infested breeding plots. The breeding line WBR-9, progenitor of Burley 11A and 11B, had 31 and 25 percent survival, respectively, in East and Middle Tennessee plots. Many of the surviving plants were stunted conspicuously, and there was a trace or more of infection on roots of nearly all surviving plants. The plant 50-518-J2B, F_4 generation, (Figure 4) from which both Burley 11A and 11B were later derived, was

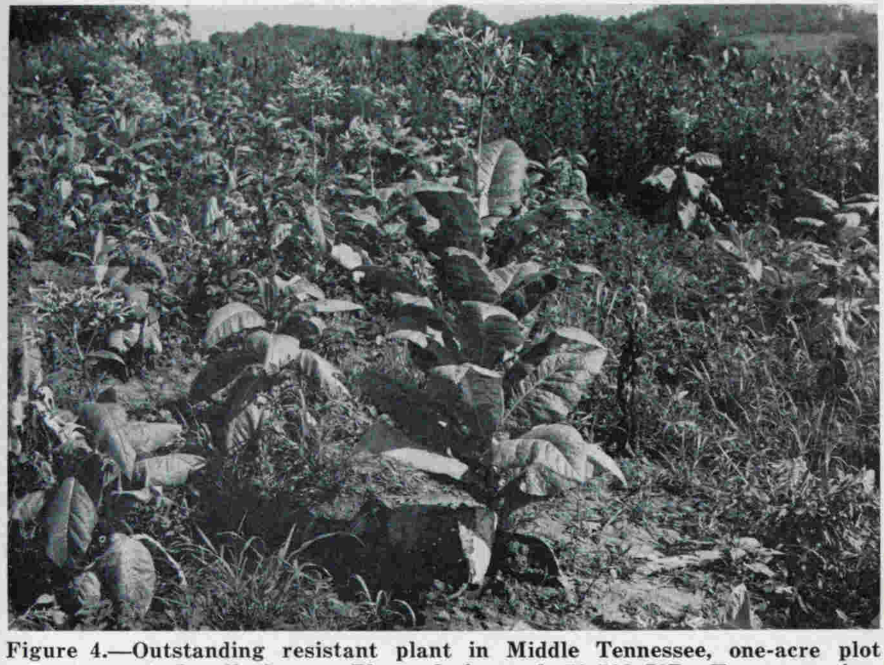

Figure 4.—Outstanding resistant plant in Middle Tennessee, one-acre plot on Jewell farm. Plant designated 50-518-J2B, F_4 generation, which later records show was progenitor of Burley 11A and 11B. August 1950.

about five feet tall, better type, and more vigorous than other plants in the one-acre breeding plot in Middle Tennessee. In 1951, the line 51-530, F_5 generation, progeny of plant 50-518-J2B had a survival of 74 and 62 percent on the plots in East and Middle Tennessee, respectively. During both the 1950 and 1951 seasons, all plants of the suspectible variety Kentucky 16 grown to check uniformity of disease infestation were killed. Infection of plants

Figure 5.—Outstanding plant in East Tennessee plot is shown on right. The plant 51-530-10, F_5 generation, was progenitor of Burley 11A. On left is shown 51-529, a sister line selection that was 100% susceptible. Extreme right: Ky. 16. All plants were killed early in season. Photograph August 18, 1951.

from resistant varieties of other tobacco types, as well as disease development on susceptible varieties, gave evidence that there was critical disease infestation in the breeding plots. By continued selection, it was possible to increase resistance. An outstanding plant (number 10 in line 51-530) considering resistance and type as planted in East Tennessee is shown in Figure 5. Burley 11A later originated from progeny fo this plant.

Although the 1952 season was very dry, as evidenced by plant growth in Figure 3, severe black shank developed in the breeding plots. The lines in F_6 generation designated as 52-504 (51-530-10) in the East Tennessee plot and 52-507 (51-530-1) in the Middle Tennessee plot were the progenitors of Burley 11A and 11B, respectively. Both had approximately 70 percent plant survival in the East Tennessee plot by late September as compared to 50 percent for 52-521 (Gr. 41).[4] No plants in rows of susceptible check varieties survived.

[4]Gr. 41, an experimental breedling line included in extensive tests, was selected from Va. WBR-8. Although this line had excellent quality of cured leaf it was discontinued after 1953 tests because of too low yield and disease resistance.

In 1953, anticipating possible variety release the next season, greater efforts were made to secure critical evaluation of the resistance of breeding lines designated Gr. 42A, Gr. 42B, Gr. 42C, and Gr. 41. Tests were conducted in plots at two locations and on several farm fields in Tennessee and in plots of cooperating research workers in Virginia and North Carolina. At one East Tennessee location, on a naturally infested field, percentage survival at weekly intervals was determined for Burley 11A, Burley 11B, and other entries. By the end of the season, Burley 11B had 9 percent greater plant survival and 9 percent lower disease index value than Burley 11A (Table 1). There was relatively little difference

Table 1 — *Plant survival of black shank resistant varieties at weekly intervals as compared with susceptible varieties when planted on disease infested soil.*[1]

Variety	Percentage plant survival											Disease[2] index Oct. 9
	June	July				August				September		
	11	6	13	20	27	3	14	22	28	4	14	
Burley 11A	100	96	94	93	93	92	84	83	83	83	78	45
Burley 11B	100	94	93	93	92	91	88	88	88	88	87	36
Burley 1	100	85	73	64	48	28	13	9	8	7	4	98
Burley 2	100	81	69	57	47	32	16	11	10	9	7	97
Burley 21[3]	100	81	69	56	38	24	8	6	5	5	4	98
Kentucky 16	100	75	65	46	27	14	7	5	3	3	2	98

[1]Results based on 5 replications, 50-plant plots and no missing plants June 11. Transplanted June 3. By August 14, only in one replication at end of field were there any living plants in rows of susceptible varieties.

[2]Roots of dead plants and those severely diseased placed in class 4, value 100. Other plants placed in classes 0, 1, 2, and 3, with values 0, 25, 50, and 75 percent respectively.

[3]Newly developed wildfire and mosaic resistant variety (cited in reference 6).

in disease development between black shank susceptible varieties Burley 1, 2, 21, and Kentucky 16. It was interesting to note that progress of disease as determined by plant survival of both susceptible and resistant varieties was gradual with no outstanding increase in any of the weekly periods. Burley 11B showed greater survival than Burley 11A also in tests at Malone farm in East Tennessee and in plantings made in Virginia and North Carolina. In North Carolina (12) and Tennessee tests, all the burley breeding lines under consideration for release were more resistant to black shank than flue-cured varieties Dixie Bright 101 and 102. A review of results from Tennessee tests with several black shank resistant varieties was published in 1955 (3). In Table 2 more detailed data are presented for 12 varieties. Cigar wrapper varieties Dixie

Table 2 — *Comparative resistance of Burley, flue-cured, and cigar wrapper varieties to black shank.*[1]

Variety or line	Type	Percentage plants surviving July 23	September 7	October 13
Dixie Shade	cigar wrapper	98	95	95
Variety R G	cigar wrapper	95	89	89
Burley 11B	burley	99	86	64
Burley 11A	burley	99	81	50
Dixie Bright 101	flue-cured	87	33	18
Dixie Bright 102	flue-cured	80	20	5
Vesta 64	flue-cured	78	20	7
Vesta 33	flue-cured	83	19	2
Vesta 47	flue-cured	71	13	5
Vesta 5	flue-cured	47	15	3
Dixie Bright 27[2] (check)	flue-cured	12	0	0
Burley 2 (check)	burley	9	0	0

[1]Tests conducted in 1954 at Hunter and Malone breeding plots Greeneville, Tennessee. Averages from two replications 50-plant plots at each location.

[2]D.B. 27 was developed for resistance to Granville wilt but not black shank. It was included as a flue-cured susceptible check.

Shade and Rg were more resistant than Burley 11A and 11B; however, none of the flue-cured resistant varieties, including Dixie Bright 101 and 102 as well as the parental variety Vesta 64, were as resistant.

These results and information provided from tests in other states as well as performance in ½-acre or greater size field plantings made on disease infested fields in Tennessee showed that Burley 11A and Burley 11B have a very useful level of resistance.

Fusarium Wilt

By systematic screening tests started in 1952, it was found that Burley 11A and 11B had resistance to fusarium wilt. In 1954 fusarium isolates from both burley and flue-cured tobacco fields were used to inoculate the seedlings just prior to transplanting. Percentage plant survival in replicated tests was 92 and 76 percent, respectively, for Burley 11B and Burley 11A as contrasted to 31 percent for Kentucky 35, a commercial variety with wilt resistance (18), and 12 percent for Burley 2, a standard variety susceptible to this disease. In Figure 6 single row plots of each of the above four varieties are shown. Greater resistance

Figure 6.—Comparative resistance of 4 tobacco varieties to fusarium wilt. Extreme left: Ky. 35; center left: Burley 11A; center right: Burley 11B; extreme right: Burley 2.

of Burley 11A and 11B was evident by this and other tests. Also, in Tennessee fields known to be infested with fusarium wilt, practically no losses have been observed when Burley 11A and 11B were grown.

Black Root Rot

In seedling tests conducted in the greenhouse Burley 11A and 11B showed black root rot resistance comparable to that of Burley 1 (5). They are more resistant than Burley 2 (7).

Cured Leaf Results

Although much emphasis was placed on development of burley varieties having satisfactory resistance to disease, even greater research effort was directed during the period of variety development on yield and quality evaluation. All selections were first tested at the Tobacco Station, Greeneville, for yield and quality, and those showing most promise were included in replicated variety trials conducted at 10 or more locations in Tennessee. After grading and yield data were secured, the tobacco from variety tests at the different locations was assembled at a warehouse in Greene-

Table 3 — *Average of 1953 and 1954 yields, price, total amounts in flyings, cutter, and tan leaf grades, and acre value for 4 varieties at 10 locations.*[1]

Varieties[2]	Robinson farm Johnson Co.	Rutherford farm Sullivan Co.	Street farm Washington Co.	Owens farm Cocke Co.	Gaby farm Greene Co.	Tobacco Exp. Sta. Greene Co.	Moser farm Jefferson Co.	Plateau Exp. Sta. Cumberland Co.	Middle Tenn. Exp. Sta. Maury Co.	Highland Rim Exp. Sta. Robertson Co.	Average
Yield (pounds/acre)											
Burley 2	2630	2549	2477	2523	2000	2067	1937	2451	1756	1599	2199
Burley 21	2607	2497	2514	2574	1904	1987	1715	2364	1646	1428	2124
Burley 11A	2236	2426	2337	2260	1862	1939	1695	2151	1710	1535	2015
Burley 11B	2279	2412	2305	2308	1867	1755	1526	2109	1658	1489	1971
										L.S.D. at (.05)	84
										L.S.D. at (.01)	114
Price (dollars/100 pounds)											
Burley 2	58.69	56.23	59.77	57.63	54.40	59.00	45.54	53.92	52.21	48.28	54.57
Burley 21	58.47	57.92	61.03	58.92	54.49	58.98	44.21	54.51	54.10	51.02	55.37
Burley 11A	60.37	56.69	61.84	59.55	55.04	59.71	47.29	54.97	54.63	52.09	56.22
Burley 11B	60.34	58.55	61.91	59.61	55.48	58.62	48.13	55.06	53.73	52.51	56.39
										L.S.D. at (.05)	0.72
										L.S.D. at (.01)	0.97
Percentage flyings, cutters, and tan leaf (total)											
Burley 2	74.3	56.0	83.3	77.7	66.4	79.8	58.9	64.8	70.0	47.1	67.8
Burley 21	74.8	70.3	86.3	78.8	70.1	77.2	48.1	62.5	76.9	53.7	69.9
Burley 11A	80.0	57.3	85.6	82.3	66.2	78.5	60.1	73.1	75.9	62.3	72.1
Burley 11B	82.2	75.5	85.5	80.5	64.5	73.3	59.4	69.7	68.2	64.7	72.4
										L.S.D. at (.05)	4.5
										L.S.D. at (.01)	6.1
Value (dollar/acre)											
Burley 2	1544	1441	1480	1453	1093	1222	889	1321	961	772	1218
Burley 21	1527	1449	1533	1516	1054	1173	768	1273	920	728	1194
Burley 11A	1349	1381	1444	1346	1040	1194	802	1185	988	800	1153
Burley 11B	1375	1415	1425	1376	1047	1028	739	1172	921	781	1128
										L.S.D. at (.05)	46
										L.S.D. at (.01)	62

[1]These tests show comparative performance of resistant varieties in the absence of black shank and fusarium wilt and either none or mild amounts of wildfire and mosaic. Values shown are average results at each location from 4 replications with 1/100th acre plots. Prices are current seasons' prices for all markets.

[2]Burley 21 is a newly developed wildfire and mosaic resistant variety.

ville for critical evaluation of quality by leaf men of cooperating cigarette manufacturing companies. Samples also were removed for laboratory analyses and smoke and taste tests.

Yield, price, and grade quality comparisons from 2 years' tests at 10 locations are presented in Table 3. Burley 2 produced higher yields than Burley 11A and Burley 11B at all locations. Considering the average values for all locations, the difference between Burley 2 in yield and value per acre and that of both Burley 11A and 11B was highly significant. In quality, however, as measured by average price and percentage flyings, cutter, and tan leaf, the black shank resistant varieties were significantly better than Burley 2. Burley 21 was intermediate with respect to both yield and quality. In Tennessee tests Burley 11A has produced slightly higher average yield and value per acre than Burley 11B; however, the difference was not statistically significant! In North Carolina variety tests, Burley 11B has been higher yielding and has had better quality than Burley 11A (14).

Yield data from the 1955 variety tests at twelve locations in Tennessee revealed about the same relative performance for the varieties as in Table 3. Based on a grade index, the varieties were more nearly the same in quality than in the previous two seasons. In Maury and Robertson County tests in 1955, Burley 2 was superior in value to Burley 11A; whereas, the 1953 and 1954 data had shown Burley 11A to be slightly superior.

Burley 11A and 11B are about the same as Burley 2 in nicotine content, but slight improvement in leaf burn is indicated by the data. Nicotine analyses and burn determinations have been made on samples from at least three variety tests in each season. Reports from manufacturers have shown Burley 11A and 11B to be satisfactory in taste and aroma. Although both are acceptable, manufacturers, judging by leaf appraisal and laboratory tests, have indicated preference of Burley 11A over Burley 11B.

Foundation Seed

Foundation seed of Burley 11A and Burley 11B used for production of commercial seed lots is saved in breeding plots where black shank resistance of selected plants can be determined (Figure 7). Only seed heads of the most vigorous growing best type plants are bagged. At the time of seed harvest, plant roots are examined and seed is saved only from plants with no conspicuous disease on roots and those with just a trace of injury.

Figure 7.—Foundation seed is saved in breeding plots where black shank resistance of selected plants can be determined. Center row: Ky. 16 killed early by black shank. Left: Rows of Burley 11A with bagged seed heads for foundation seed. Right: Experimental breeding line.

OBSERVATIONS ON BLACK SHANK IN TENNESSEE

Disease Development and Appearance

Black shank is an important destructive disease affecting burley and other types of tobacco grown in the United States. With susceptible varieties, growers have experienced losses ranging from only a few plants to loss of all plants on several acres. Although crop rotation including sod crops is of much value in reducing soil infestation, the fungus causing the disease may live in the soil for four years or more after the field is planted to crops other than tobacco. Consistently, greatest losses have been observed in those fields in tobacco the second season following appearance of the disease. For example, in 1949 an East Tennessee grower harvested less than two percent of the plants from a 2½ acre field which had, in the previous season, produced more than a ton per acre of good cured leaf (4). Examination revealed that the surviving harvested plants also had roots damaged by black shank. In 1948 a few diseased plants had been observed late in season in a low, poorly drained corner of this field. Occurrence of black shank, however, was not considered. A susceptible variety should never be grown in a field in which black shank appeared the previous year.

Heavy losses may occur the first season black shank appears if there is spread by drainage water from one infested field to another (Figure 8). A large area of this field was flooded and

Figure 8.—Black shank on a farm near Nashville, Tennessee, August 22, 1950. The disease apparently was carried to the farm by drainage water and destroyed about 1½ acres of tobacco the first year it appeared.

the disease destroyed approximately 1½ acres of tobacco. At the border of the more heavily diseased area, black shank continued to spread throughout the season, and various stages of disease development were observed (Figure 9). With high temperatures, as in July, and moist conditions plants are killed in a very few days after first appearance of wilting. After wilting, leaves of burley tobacco turn a light golden color and scattered plants killed by black shank are very conspicuous in a field among healthy plants. As leaves dry they darken and become brown. The shank of the plant turns black for several inches above the soil surface, as shown by the plant on the right in Figure 10. When the stem is split longitudinally, the interior of the stalk will be dark as far as the stalk is black on the outside, and the pith of the affected area of the stem separates into discs shown by split stalk on left of

Figure 9.—Black shank showing several stages of disease development. Picture taken at border of more heavily diseased area shown in Figure 8.

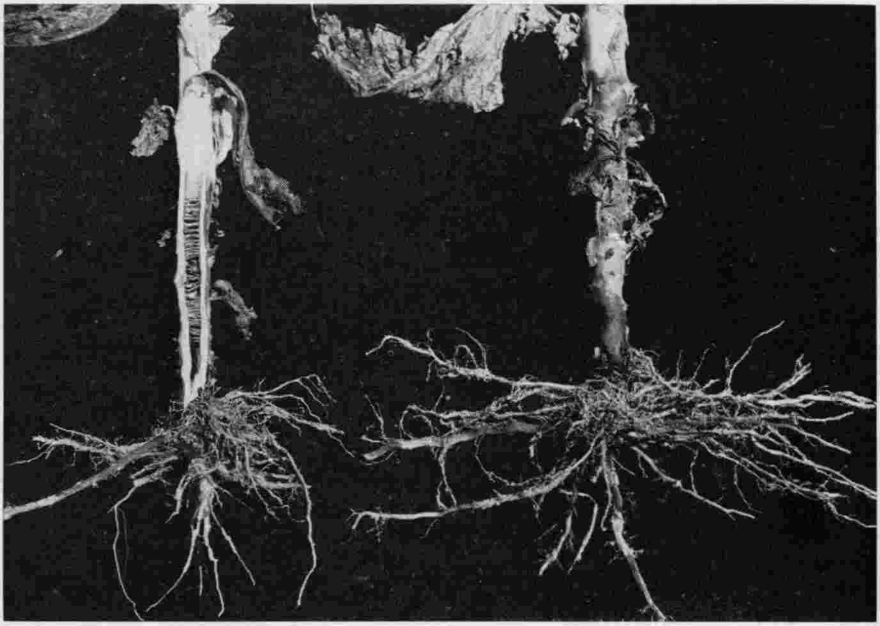

Figure 10.—Symptoms of black shank. Left: Split stem of plant showing pith separated in discs, a characteristic symptom of this disease. Right: Black shank diseased plant with dead roots and basal portion of stem black.

Figure 10. Strands of gray fungus mycelium usually can be observed between the discs. The above symptoms help to distinguish black shank from other less serious stalk diseases. Very young plants in the field show somewhat different symptoms. The pith tends to collapse before separating into discs, and there may be dark streaks in the vascular area at the base of the stem.

Leaf Infection

The importance of leaf infection with black shank was evident from observations in breeding plots and farmers' fields. Plants of susceptible and resistant varieties were killed as a result of infection of lower leaves continuing to develop until the disease spread to the stems and roots (Figures 11a and b). The large leaf spots usually develop only following periods of 48 hours or more with warm, wet, humid conditions. During a rainy period, many swimming spores of the fungus are produced. Most of the leaf infection results from splashing by beating rains of spores and infested soil onto leaves, as was observed in connection with leaf-spot development shown in Figure 11b. When conditions are

Figure 11a.—Severe black shank leaf-spot development on lower leaves of Gr. 42C, a black shank resistant breeding line.

Figure 11b.—Development of Phytophthora, black shank, leaf spot on nonresistant tobacco (Burley 2) following severe wind and rain storm July 7, 1953. Picture taken July 20.

favorable, as in mid-July, the leaf spots may enlarge until the fungus enters the midrib and progresses into the stem of the plant. Growth of the fungus in the leaf lamina is arrested as soon as the weather becomes dry and sunny; but when in basal midrib and stem tissue of lower leaves, it may continue to develop until roots are affected and plants are killed. Leaves of present resistant varieties appear to be as susceptible to leaf infection as those of nonresistant varieties. Stems of susceptible varieties, however, appear to be more easily invaded than stems of resistant varieties. Greatest difference between susceptible and resistant varieties is in amount of root infection. Plants in breeding lines with good stand-up characteristics have shown less leaf infection than plants with drooping and relatively large lower leaves. Efforts made to avoid possibility of infested soil being deposited onto leaves will help reduce disease losses. Cultivation should be avoided in black shank infested fields, as such cultivation will spread the loose infested soil to disease-free areas of the field and also wound leaves and roots, increasing the amount of plant infection. After cultivation, the infested soil is more likely to come in contact with the leaves where infection by the fungus and disease development may occur as described above. There should be only enough cultivation to give satisfactory control of weeds.

Crop Rotation

A striking effect of crop rotation in reducing amounts of black shank infestation in soil was observed in 1950 in a field near Nashville, Tennessee (Figure 12). In 1948, the entire field as shown was in tobacco and there were scattered plants killed by black shank in the portion of the field nearest the farm yard,

Figure 12.—Effect of crop rotation in reducing soil infestation with black shank. Area in foreground in tobacco 1948, 49, and 50. Total loss of plants occurring early in season. Background in tobacco in 1948 and 1950, in pasture in 1949—several diseased plants present in 1948 but disease loss in 1950 much less than with continuous tobacco foreground. Jewell farm, Middle Tennessee, August 22, 1950.

including that with large tobacco plants in background of Figure 12. After tobacco harvest, the field was seeded with a cover crop and the portion of the field having conspicuous black shank in 1948 was used for pasture the next year; whereas, the remainder of the field was again planted with tobacco. Severe disease loss occurred over much of the field in 1949, including the area shown in the foreground. As about an acre portion of this field was to be used in 1950 for breeding studies, the remaining part of the field as shown in Figure 12 was planted with susceptible tobacco. Plants in the area with continuous tobacco culture (foreground) were killed early in the season, but those in the background in the area that was in pasture for one year following first disease appearance did not show much disease development until plants approached blooming stage. When photographed on August 22, approximately 10 percent of the plants were conspicuously diseased in this area as contrasted to 100 percent killed early in the season in the area with continuous culture.

Experience in Tennessee with crop rotation, as well as reports from other investigators (2, 10), seems to indicate that infested fields must be planted to crops other than tobacco for 4 years or more before soil infestation with the black shank fungus will be eliminated or reduced sufficiently to grow a crop successfully with a susceptible tobacco variety. Along with crop rotation, there should be protection of the fields from recontamination. The observation described above shows striking beneficial effects from even a short rotation. To get best results in the more heavily infested areas, it is recommended that the resistant varieties Burley 11A and Burley 11B be grown in at least two-or three-year rotation with other crops. Grass and legume crops are better in the rotation than row crops because there will be less chance of spreading infested soil to new areas. A good system of crop rotation will result in other benefits as well as help control black shank.

Summary

Resistance of Burley 11A and Burley 11B to black shank is sufficiently high so that on light to moderately infested fields few, if any, plants of the resistant varieties are killed, although a high percentage of plants may be lost in comparable plantings of susceptible varieties. For best results in the more heavily infested areas, it is recommended that the resistant tobacco be grown in rotation with other crops. The newly developed varieties Burley 11A and 11B also have high resistance to fusarium wilt and black root rot.

Yield, performance, and quality characteristics of Burley 11A and Burley 11B have been satisfactory in variety tests conducted in the absence of black shank or fusarium wilt. Yields are likely to be slightly less than for Burley 2. Burley 11A is higher yielding at most locations than Burley 11B. Manufacturers have indicated preference of Burley 11A over Burley 11B. Foundation seed is saved only from plants grown on black shank infested soil where resistance of selected plants can be determined.

Observations on black shank disease, including appearance, development, and losses, are presented. The role of leaf infection and benefits from crop rotation are discussed.

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