Origin and Development of The Nemared Tomato

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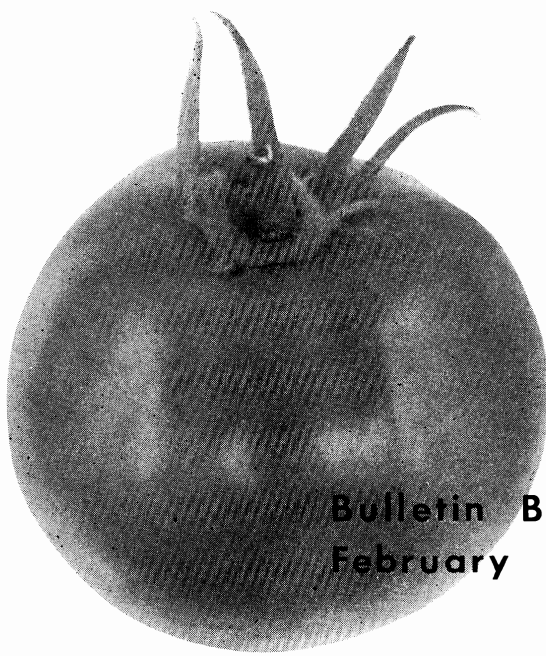

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Contents

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The Nemared Tomato

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Nemared is a nematode resistant, high-yielding tomato with good garden and commercial production characteristics. Since nematodes are a serious problem in Oklahoma, horticulturists predict the new variety can double tomato production in the state.

Nemared tomatoes under favorable conditions ripen to a deep red color without a green shoulder on the stem end. The fruits are globular, with small stylar scars. Vines attain medium height and density, with adequate foliage for good fruit protection.

The variety was developed and tested by the Oklahoma Agricultural Experiment Station in cooperation with the Hawaii Agricultural Experiment Station and U. S. Regional Vegetable Breeding Laboratory, Charleston, South Carolina.

Yield

In uniformly high populations of nematodes, Nemared yielded two to three times better than Sioux, a nematode susceptible variety (Table 1). Nemared averaged 6.8 and 17.1 tons per acre respectively for the 1959 and 1960 seasons, compared with average yields of 2.7 and 5.9 tons for Sioux. Nemared also outyielded certain other Oklahoma resistant (N) lines.

In 1963, Nemared again proved the most productive in nematode infested soil (Figure 1). The test field was not as uniformly infested as in the previous test, but was probably more typical of many commercial tomato fields. Average yields of marketable fruits for the resistant varieties, Nemared and Oklahoma N7-2-4, were 14.4 and 11.8 tons per acre respectively, compared with yields of 10.3 and 6.5 tons for the susceptible Oklahoma 39-2 and Sioux (Table 2).

Research reported herein was done under Oklahoma Station project number 1204.
Acknowledgement:

The assistance with the nursery trials of George Hedger (Idabel), Jack Marshall (Bixby), Lloyd Martin (Westville), & James Fleming (Stillwater) is gratefully acknowledged.

Nemared was included in routine yield trials designed to study and screen Oklahoma tomato breeding lines. Sioux or other lines or varieties were used as standards. These trials were conducted at the several horticultural field stations in Oklahoma.

Table 1—Yields of marketable fruits for six tomato varieties grown in nematode infested soil, Irrigation Station, Blair, 1959 and 1960.

	1959[1]		1960	
Variety	Tons/A.	Avg. Fruit Wt. Lbs.	Tons/A.	Avg. Fruit Wt. Lbs.
Nemared	6.8	0.15	17.1	0.20
N6-19-3[2]	6.2	0.11	15.4	0.20
N6-16-1[2]	6.0	0.12	6.8	0.17
N6-18-2[2]	4.0	0.15	12.0	0.20
Sioux A.	2.9	0.16	5.6	0.17
Sioux B.	2.4	0.14	6.1	0.17

Randomized block planting with four replications of 10 plant plots.
Two series of plots (eight total) of the susceptible Sioux were included in the test to provide a thorough check on the distribution of nematodes throughout the test area.
[1] Yields for 1959 for all lines and Sioux were lowered by damage to the plants by southern blight *Pellicularia rolfsii* (Curzi) West.
[2] "N-lines" are Oklahoma nematode resistant types.

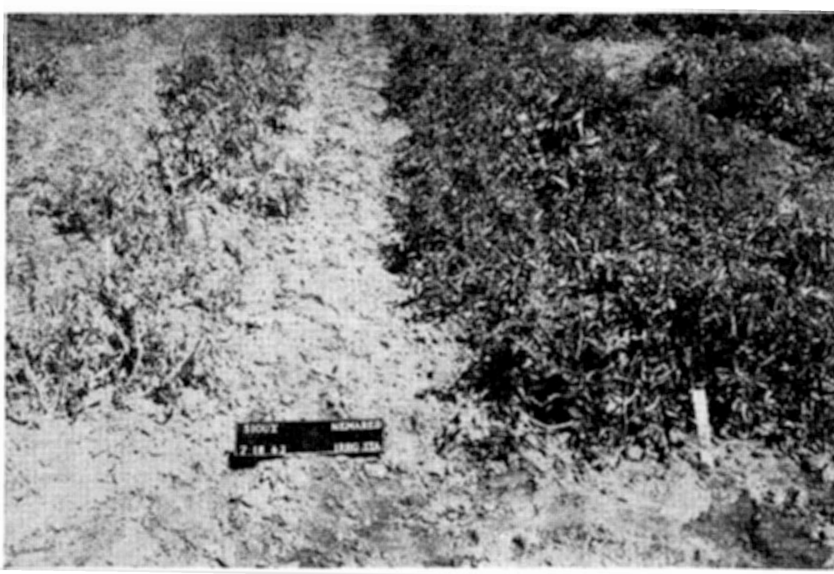

Figure 1. Nematode resistant Nemared, right, is shown with the susceptible Sioux. Plants were grown in soil infested with the root-knot nematode.

Yield results from 1960 to 1963 inclusive for the Irrigation Station, near Blair, (Table 3) are shown for Nemared in comparison to Oklahoma 39-2 and Sioux. The four-year averages were 16.1, 12.6, and 6.6 tons per acre, respectively. Sioux was not included in the 1963 trial; however, the averages are still valid since the inclusion of the 1963 data changed the overall averages very little. All plants were spaced at the recommended five feet between rows and three feet between plants.

Table 2—Early and total yields of Nemared and other tomato varieties in nematode infested soil, Irrigation Station, Blair, 1963.

Variety	Plant-Spacing as Sq. Ft./Plant[1] 15′	10′	5′	Avg. 3 Spacings
	Tons Per Acre			
Nem^red				
Early[2]	1.4	0.7	1.0	1.0
TOTAL	14.4	13.5	15.3	14.4
Okla. N7-12-4				
Early[2]	2.0	1.1	1.8	1.6
TOTAL	8.2	14.7	12.5	11.8
Okla. 39-2				
Early[2]	3.3	4 0	2.8	3.3
TOTAL	7.7	12.2	11.1	10.3
Sioux				
Early[2]	2.7	4.1	3.8	3.5
TOTAL	6.8	7.6	5.1	6.5

[1] Rows were 5′ apart. Plants were spaced 3′, 2′ and 1′ in the row to obtain 15, 10 and 5 square feet per plant, respectively.
[2] Early yields were those of the first 2 harvests—to July 17.

Table 3—Yields for three tomato varieties, Irrigation Station, Blair, 1960 to 1963.

Variety	Marketable Fruit Yields 1960	1961	1962	1963	Avg. 4 Yrs.
	Tons Per Acre				
Nemared					
Early[1]	3.4	3.2	1.3	1.2	2.3
TOTAL	22.2	22.4	4.4	15.3	16.1
Okla. 39-2					
Early	1.2	7.1	0.6	3.5	3.1
TOTAL	13.8	20.5	4.5	11.6	12.6
Sicux					
Early	1.8	3.4	0.2	--	1.8[2]
TOTAL	5.9	11.6	2.4	--	6.6

[1] Early yield represented about ⅓ of the harvest seascn.
[2] 3 year average.
Plants set 3′ apart in rows 5′ apart.

A test at the Vegetable Research Station near Bixby in 1962 featured trellis tomato production. The plants were closely spaced in seven foot rows and the vines trained vertically with stakes and twine. Yield averages of Nemared, Homestead 24, and Sioux were 12.8, 7.0, and 5.0 tons of marketable fruit per acre (Table 4). Nemared yielded best at 14 square feet per plant; the other varieties did best at an intermediate spacing of 10.5 square feet per plant.

In a plant-spacing trial at the Kiamichi Field Station near Idabel in 1963, Nemared, and Oklahoma lines 36A-1, 39-2, and 32-2 were spaced at 16, 10, and 6 square feet per plant. Growing conditions were very favorable and yields were unusually high. The varieties reacted uniformly to the variations in plant spacing; interaction between variety and spacing was not statistically significant. Line 36A-1, a sister to Nemared, but susceptible to nematodes, averaged 26.1 tons per acre compared with 23.8, 20.3, and 21.3 tons for Nemared, 39-2 and 32-2 respectively (Table 5).

In a variety trial at the Eastern Oklahoma Field Station near Westville, six varieties were yield tested (Table 6). Nemared and Campbell 146 both yielded 11.6 tons per acre, while Roma, Sioux, Homestead 24, and Mammoth Wonder followed with yields of 11.4, 7.9, 7.3, and 6.4 tons.

Table 4—Yield of three tomato varieties at three plant spacings, Vegetable Research Station, Bixby, 1962.

Variety	Spacing as Sq. Ft. per Plant[1]			Avg. 3 Pl. Spacings
	14′	10.5′	7′	
	Tons Per Acre			
Nemared				
Early[2]	2.6	0 8	0.7	1.82
TOTAL	11.5	11.1	9.7	12.8
Homestead 24				
Early[2]	2.7	1.5	0.1	1.4
TOTAL	7.3	8.8	4.4	7.0
Sioux				
Early[2]	0.7	0.3	0.2	0.8
TOTAL	4.2	4.2	2.6	5.0
AVG. (TOTAL)	7.7	8.1	5.6	

Plants were set in rows 7′ apart and trellised or trained in a vertical position with stakes and twine.
[1] Plants set 2′, 1½′ and 1′ in the row provided 14, 10.5 and 7 square feet per plant respectively.
[2] Early yields were composed of the first 4 harvests—to July 17.

Table 5—Marketable yields of four tomato varieties at three plant spacings, Kiamichi Field Station, Idabel, 1963.

Variety	Spacing as sq. ft./plant 16′	10′	6′	Avg. Yield 3 Spacings	Avg. Wt. Fruits (lbs.)
			Tons Per Acre		
Nemared					
Early[1]	2.4	5.7	8.3	5.5	
TOTAL	18.7	23.8	29.9	23.8	0.41
Okla. 36A-1					
Early[1]	3.3	5.7	16.3	8.4	
TOTAL	20.8	26.4	31.0	26.1	0.35
Okla 32-2					
Early[1]	2.0	3.4	5.0	3.5	
TOTAL	17.3	21.7	25.0	21.3	0.34
Okla. 39-2					
Early[1]	4.7	5.5	9.2	6.5	6.5
TOTAL	15.6	18.8	26.5	20.3	0.40
AVG. TOTAL	18.1	20.2	28.1		

Rows were 4′ apart and plants were set 4′, 2½′ and 1½′ apart to obtain spacings of 16, 10 and 6 square feet per plant respectively.
[1] Early yields included the first 3 harvests—to June 25.

Table 6—Early and total yield of six tomato varieties, Eastern Oklahoma Field Station, Stilwell, 1963.

Variety	Yields Early	Total	Avg. Wt.[2] Fruit (lbs.)
		Tons Per Acre	
Nemared	1.7	11.6	0.40
Campbell-146	2.2	11.6	0.44
Roma	1.6	11.4	0.15
Sioux	2.2	7.9	0.35
Homestead 24	2.1	7.3	0.31
Mammoth Wonder	1.4	6.4	0.51

Plants set 3′ apart in rows 5′ apart.
[1] Early yields included the first 3 harvests—to July 16.
[2] Average fruit weight determined for mid-season harvests only.

Description

Nemared has an intermediately determinate type vine. Plant growth is fairly vigorous; leaflets are medium sized. The vine provides ample shade for the fruits, which set on in a good concentration of clusters (Figure 2). Two leaves normally separate the clusters, but only one leaf separates them near the ends of the branches.

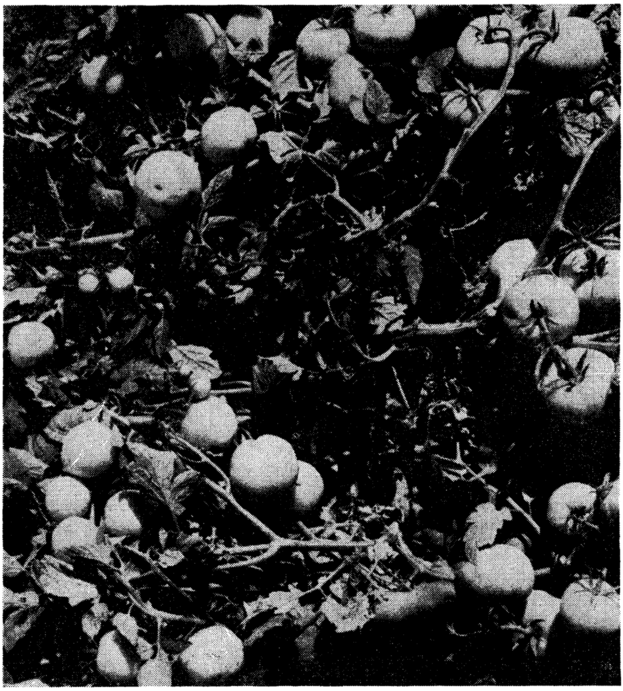

Figure 2. The Nemared has a high fruit set capacity. The fruits are almost spherical and have the uniform color factor or no green shoulder. The plant is determinate in growth habit, but not to the extreme. A fairly concentrate set of fruits are obtained without great reduction in the potential fruit production. Some foliage was removed from this plant to expose the fruit for this photograph.

The fruits are good sized, globular, and smooth, with relatively small stylar scars. They are uniformly colored without the green shoulder found in some varieties. Under favorable conditions, they ripen to an attractive red.

Nemared matures early, but not as early as Sioux. However, usually by the end of the third harvest (seven to nine days) it overtakes the latter in total yield and excells in fruit production throughout the remainder of the growing season.

Winstead and Henderson (6) recently tested resistance to wilt *Fusarium oxysporium* f. *lycopersici* (Sacc.). Their tests have confirmed the resistance to be type A (monogenic), high level type of resistance.

Origin and Development

In southern and southwestern states root-knot nematodes do considerable damage to tomatoes and other vegetables. In Oklahoma these microscopic eel worms, *Meloidogyne incogniti* var. *acrita* (Chitwood), infest the majority of home gardens and commercial vegetable fields. Control of nematodes by chemicals or other means is only partially effective, also time consuming and costly. Resistant varieties offer the most practical, effective control.

A nematode resistant tomato has developed slowly because of difficulties in finding a source of resistance and incorporating this resistance into commercially acceptable types.

Nematodes, as plant pests, are unique in many respects. They are worm like in the young stage, as small as 0.1 millimeter long. The females enlarge greatly during egg production and are visible as minute pearly while objects to the naked eye. They are found in infested root tissues. Upon infestation by nematodes, root cells enlarge and rapidly multiply, making the roots irregularly swollen or galled (Figure 3). Galling lowers the normal functioning capacity of the roots, substantially reducing plant growth and fruiting ability. In time, the galled roots break down, the plant wilts and eventually dies.

The microphotographs (Figure 4) show female nematodes of varying ages in relation to the galling or enlargement of the root tissues of susceptible tomatoes. As indicated by the mass of eggs, the rate of reproduction in this nematode species is very high. When roots of resistant tomatoes are invaded by nematodes, little or no galling occurs and the roots remain normal; the plant continues to be vigorous and productive.

Dean and Struble (2) showed that susceptible and tolerant root tissues respond differently to the feeding of root-knot nematode. In resistant roots there is a localized breakdown, or necrosis, of the cells around the nematode. This breakdown seemingly isolates the nematodes so they cannot obtain an adequate food supply.

A wild, small-fruited species of tomato from South America, *Lycopersicon peruvianum* (Muller), was found to be nematode resistant. It was generally incompatible in crosses with the cultivated tomato.

Dr. Paul Smith, (4) California Agricultural Experiment Station, layed the foundation stock for breeding nematode resistant tomatoes by obtaining several plants in the species cross by using a specialized embryo culture technique. Dr. Victor Watts, (5) of the Arkansas Experiment Station, found a partially fertile individual in the California hy-

Figure 3. Shown here are root systems of three tomato plants badly infested with root-knot nematode. Severely galled roots, such as these, are incapable of functioning normally and plant growth is retarded. The deterioration and decomposition of the galled tissues eventually resulted in the plants' death.

brids and established fruiting individuals from the backcross to the cultivated tomato. Dr. W. A. Frazier of the Hawaii Experiment Station improved the Arkansas line by additional backcrossing to improved Hawaiian tomatoes.

In 1948 approximately 60 tomato families representing the species cross were planted for observation in nematode infested soil at the Oklahoma Experiment Station at Perkins. These families were from four sources—Dr.s W. A. Frazier, Hawaii; J. M. Walters, Florida; Victor Watts, Arkansas; and Mr. L. F. Locke, Woodward, Oklahoma.

The most promising lines were from Hawaii and in three years of field screening, genetically homozygous resistant families were established. Selection for fruit size and type was continued for two more generations and resistant types were fixed with fruits about two-thirds the size of standard commercial varieties.

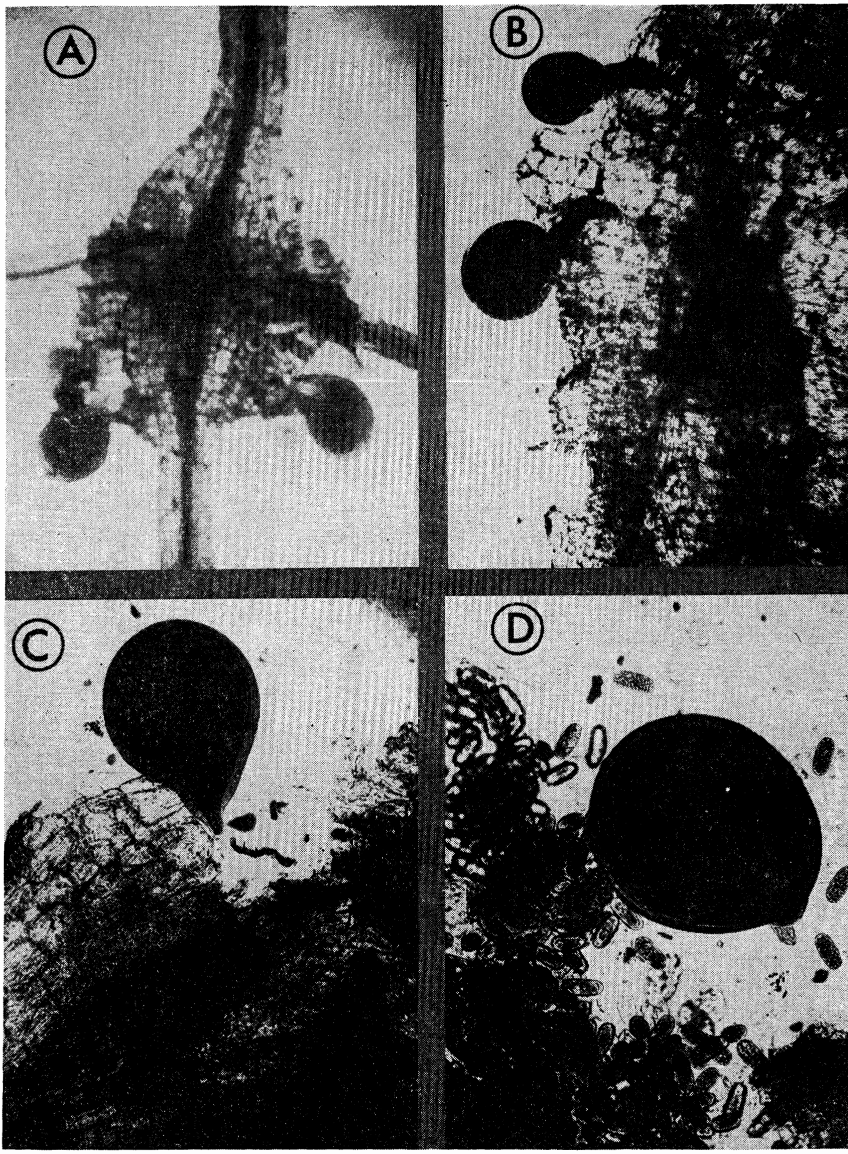

Figure 4. (A) When the cells of the susceptible root are invaded by root-knot nematode they multiply and become greatly enlarged to form galls. Various stages in the development of the female nematode are shown. (B) Immature stage in feeding position in galled root. (C) Female almost mature. (D) Mature egg laying female surrounded by egg mass. (Photographs were obtained with the assistance of Harendra S. Parikh)

In 1952 the best resistant lines were backcrossed to a tomato with large standard fruit size, 25-33-2F, provided by Dr. Fred Andrus of the Southeastern Regional Vegetable Breeding Laboratory. This line appears resistant to *alternaria, septoria, stemphylium,* and *fusarium.* Families from this backcross were screened for nematode resistance in nematode infested field plots and selected for fruit size and commercial type from 1953 to 1958.

In a greenhouse test in 1960, six plants, three from each of two families, proved to be homozygous resistant. In 1961, foundation seed from these plants was grown in the Perkins field on nematode infested soil. The new variety, Nemared, was established as a composite of the six lines and released after the completion of the 1961 growing season.

Screening for Nematode Resistance

The objective of the screening operations was to assure effective exposure of the tomatoes to the nematodes. Susceptible plants were identified by their galled roots. Fields of light sandy soil at Perkins and Blair (Figure 5), known to be infested with nematodes, were managed to

Figure 5. Nematode resistant lines in a 1960 screening trial on infested soil, at the Irrigation Experiment Station, Blair, Oklahoma.

encourage a uniformly high population of nematodes. Roots of susceptible individuals galled extensively when grown in this infested soil. Thus, families with resistance to root-knot were established by selecting gall-free individuals for several generations. Some susceptible individuals escaped the nematodes damage the first season, but they were readily identified on repeat tests the following season. Individuals were also selected for horticultural and commercial superiority.

Progress in breeding nematode resistant tomatoes was accelerated by advancing the breeding lines one generation in the greenhouse during the winter. First, seedlings were exposed to the root-knot parasite in highly infested soil in greenhouse flats; then, resistant plants were grown to maturity to obtain seed for field plantings.

Root galls from susceptible tomatoes were finely ground for inoculation of the sandy soil. Ten or more grams of chopped galls were incorporated into the soil of each flat; the flats were incubated at 80-85°F over an electric cable (Figure 6), and kept favorably moist for 10-15 days and until the seedlings were at the transplanting stage. The seed of the test lines was planted in vermiculite at the same time as the innoculation.

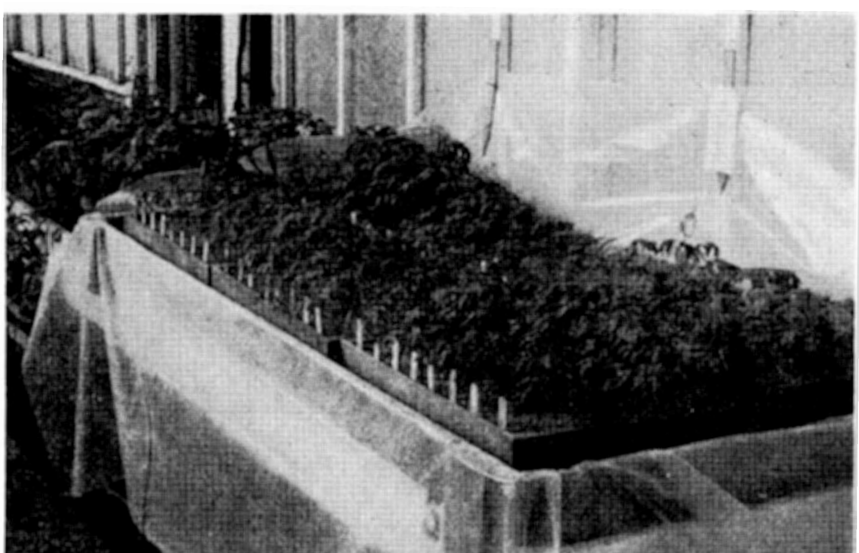

Figure 6. Seedling plants are screened for resistance to nematodes by growing them in inoculated soil flats in the greenhouse. Heating cables are placed under the flats to maintain the temperature at a uniform level favorable to nematodes.

When the seedlings were large enough, they were transplanted in a one and one-half inch checkerboard pattern in the innoculated soil. Ten seedlings of a nematode-susceptible dwarf tomato (Easily differentiated from the test seedlings) were set in each flat to verify the effectiveness of the inoculation.

In approximately two months, the seedlings were removed from the flats and classified according to galling responses (Figure 7). Some families exhibited homozygous resistance, others segregated in the anticipated three resistant to one susceptible ratio (Table 7.).

Nematode Resistant F_1 Hybrids

The limited number of root-knot resistant tomato varieties available at the present time obviously do not meet the requirements for the commercial crop in many regions and for certain specialized areas in

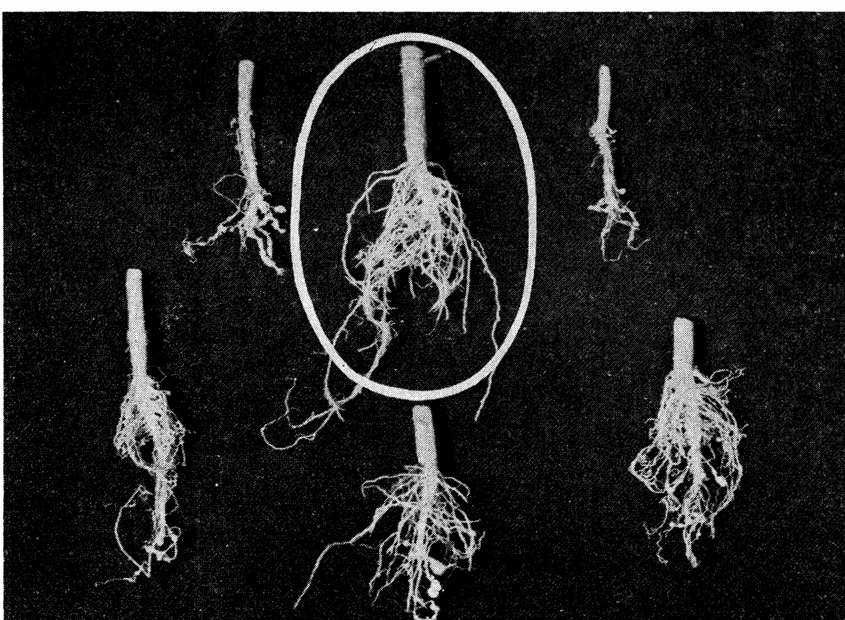

Figure 7. After a month or more the seedling plants are removed from the infested soil and the resistant plants without galls, (middle, top row) are saved for seed production. Susceptible individuals are discarded.

tomato production. For instance, in greenhouse tomato production a root-knot resistant variety would prove most valuable.

Barham and Winstead's report of 1957 (1) indicated that the resistance found in the South American tomato is effective against four root-knot nematode species—*Melodogyne incognita, M. incognita* var. *Acrita, M. javanica,* and *M. arenaria.* Resistance was indicated to be monofactorial, i.e., controlled by a single incompletely dominant gene. They reported however that the level of resistance in the first generation cross of homozygous resistant and homozygous susceptible plants is sufficient to warrant their use for tomato production in soil infested with one or more of the above species of nematodes.

Frazier and Dennett (3) reported in 1949 that nematode resistance in the tomato is a highly dominant genetic character. They suggested that F_1 hybrids, obtained by crossing available resistant lines with susceptible varieties, might immediately provide nematode resistant tomatoes acceptable for commercial production.

Table 7—Classification of tomato seedlings as not galled (resistant) or galled (susceptible) in greenhouse screening test, Stillwater, 1961.

Lines		Individuals[1] Selected 1960	Number of Seedling Plants (Roots)		
			Not Galled	Galled	Total
Resistant:					
	A	1	33	0	33
		2	33	0	33
		3	37	0	37
	B	1	74	0	74
		2	77	0	77
		3	75	0	75
	TOTAL		329	0	329
Segregating 3:1:					
	A	1	50	15	65
		2	47	19	66
		3	47	17	74
	B	1	41	12	53
	C	1	22	7	29
	TOTAL		207	70	287

Plants were grown in soil infested with root-knot for approximately 1½ months before they were removed and classified according to their reaction to the nematodes.

[1] These individuals were selected for resistance to nematodes in the 1960 field-screening trials.

F_1 hybrid resistance was confirmed by local observations. Approximately 200 F_1 individuals in infested field plots at Perkins in 1952 had normal gall free root systems. Roots of Stokesdale, a susceptible variety, were severely galled in the same test. Approximately 200 F_2 plants, grown the following season, segregated at the anticipated 3:1 ratio of resistant (not galled) to susceptible (galled).

F_1 hybrids from crosses of Nemared and other resistant Oklahoma lines with susceptible varieties are under observation at this station. The susceptible varieties were selected to provide hybrids adapted to greenhouse as well as field culture. At present, this study is in the preliminary stage, but some facts are evident. Nemared combines well with most of the varieties in current tests and productive F_1 hybrids result with attractive marketable tomatoes, i.e., smooth, deep, solid, and well colored. Some F_1 hybrids combining Nemared with other greenhouse varieties are presently in commercial production.

Growers of greenhouse tomatoes might find the F_1 hybrid from a cross between Nemared and their favorite variety a satisfactory solution to their nematode problem. The effort required to produce the seed for the hybrid would be a small investment with a good dividend.

F_1 hybrids from Nemared crossed with locally adapted determinate varieties and breeding lines show promise. A Westernred-Nemared F_1 hybrid has a high fruit set, heat tolerance, and improved fruit quality. There is a good possibility for finding a nematode resistant F_1 hybrid for use in western Oklahoma and other areas where heat tolerance is essential for good tomato production.

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