Effects of Crop Rotation on the Incidence of Root-Knot Disease of Sugar Beets in Western Nebraska[1]

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Introduction

The irrigated rotation experiments at the Scotts Bluff Substation, Mitchell, Nebraska, lend themselves to a study of the effects of crop sequence, fertilization and length of rotations on the incidence of root-knot caused by *Meloidogyne* spp. The disease is of economic importance on sugar beets in the sandier soils of western Nebraska. This area approximates the territory north of the North Platte River and includes portions of Scotts Bluff, Sioux and Morrill Counties. The Tripp very fine sandy soil on the Field Station is representative of much of this area. It is agreed that root knot is essentially a disease of sandy soils (7, 12, 18),[a] but severe infections sometimes occur on clay soils (18).

Bessey (2), Godfrey (7), Shaw (16), Tyler (18), and others have reported rotation of crops as a means of decreasing the severity of the nematode disease. Atkinson (1) and Neal (11) have reported conflicting evidence as to behavior and range of hosts of the root-knot nematode, *Heterodora marioni* (Cornu) Goodey. Christie and associates (4, 5, 6) have determined that the species consist of several diverse kinds of nematodes. Chitwood (3) in 1949 has found *Heterodora marioni* to be comprised of at least five different species which have been separated from the genus *Heterodora* and placed in the genus *Meloidogyne* Goeldi, 1887.

Observations in 1947 and later indicated that the host range of the root-knot nematode in western Nebraska was narrower than previously reported (15). The determination of effects of crop rotation on root knot of sugar beets *in* western Nebraska was considered expedient because of previous host range studies. Data from crop rotation experiments are incorporated in this paper.

Materials and Methods

The rotations selected for this study were located at the Scotts Bluff Substation, Mitchell, Nebraska, (Field K). These rotations were inaugurated in 1912 dealing with various methods of utilizing irrigated land and were carried out as originally planned from 1912 to 1941.

The new rotation program inaugurated in 1942 and continued to 1949 included: studies of the value of farm manure, mineral fertilizer including chiefly treble superphosphate and ammonium sulfate, alfalfa as green manure, and sweet clover as a pasture and green manure crop when used in the various types of cropping practices. In this new program, barley replaced oats in rotations where a small grain crop was involved. Other principal crops included were alfalfa, sugar beets, potatoes and beans. The crop

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[a] Numbers in parentheses refer to literature cited.

Table 1.—New Rotation Numbers, Crop Sequences, Fertilization and Length of Sugar Beet Rotations at the Scotts Bluff Substation, Mitchell, Nebraska.

New Rotation No.	Crop Sequence and Fertilization[1]	Length of Rotation
2	beets	continuous
2D	beets (NP)	continuous
20	beets, potatoes	2
20C	beets (NP[2]), potatoes (NP[2])	2
21	beets (M), potatoes	2
35	beets, barley-sweet clover, potatoes	3
35B	beets (M), barley-sweet clover, potatoes	3
35	beets, barley, potatoes	3
35B	beets (M), barley, potatoes	3
35C	beets (NP[2]), barley, potatoes (NP[2])	3
41	beets, barley-alfalfa, alfalfa, potatoes	4
41B	beets (M), barley-alfalfa, alfalfa, potatoes	4
41C	beets (NP), barley-alfalfa, alfalfa, potatoes (P)	4
43B	beets (M), barley, beans, potatoes	4
43C	beets (NP[2]), barley, beans, potatoes (NP[2])	4
49	beets, barley-sweet clover, sweet clover pasture, potatoes	4
49C	beets (NP) barley-sweet clover, sweet clover pasture, potatoes	4
49D	beets (NP) barley-sweet clover, sweet clover cut, potatoes (P)	4
63	beets, barley-alfalfa, alfalfa (3 yrs.), potatoes	6
63B	beets (M), barley-alfalfa, alfalfa (3 yrs.), potatoes	6
63C	beets (NP), barley-alfalfa, alfalfa (3 yrs.), potatoes (P)	6
66B	beets (M), barley-alfalfa, alfalfa (2 yrs.), potatoes, beans	6
66C	beets (NP), barley-alfalfa, alfalfa (2 yrs.), potatoes (P), beans	6

[1] (M)—farm manure applied at the rate of 12 tons per acre.
(NP)—102 pounds of nitrogen and 56 pounds of P_2O_5 per acre.
(NP^2)—51 pounds of nitrogen and 56 pounds of P_2O_5 per acre.
(P)—56 pounds of P_2O_5 per acre.
Previous to 1945, the application of nitrogen amounted to 26 pounds per acre.

rotations comprise, in addition to continuous plots, rotations varying in length from 2 to 6 years (Table 1) .

Observations in 1933 and 1934 were made on 15 rotation types in Field K. About 100 sugar beets from each plot were selected at random, dug manually and roots examined. During the four-year period from 1946 to 1949 the different types of crop rotations selected totaled 22. The roots were examined after the beets were pulled mechanically and topped. The number of beets selected at random ranged from 42 to 366 per plot; this variation in number was due in part to the number of plants which survived as a result of various causes. The plants were dug at the regular harvest date, usually during the latter part of October.

Observational ratings were employed in classifying the material. An accurate determination of the degree of infection could have been obtained by counting of number of galls per beet except that large numbers of roots examined made gall counts impractical; also, many roots were broken off during digging operations. It was found that each plot could be conveniently classified into one of four categories with respect to severity or absence of infection.

Infection categories described are as follows: 0 = No sign of infection, as evidenced by the absence of any galls on the main or secondary roots; 1 = Slight infection, as evidenced by the presence of small and few galls

on the secondary roots; 2 = Moderate infection, as evidenced by the presence of larger and more galls on the secondary roots and occasional galls on the main root; 3 = Abundant infection, as evidenced by numerous large galls on the main and secondary roots with coalescing of galls a common occurrence. It was believed that this method was satisfactory and practical in the comparative determinations of amount of root knot in the experimental plots.

Table 2.—Prevalence of Root-Knot Nematode in Sugar Beets in the Irrigated Rotation Experiments 22 and 23 Years After the Rotations Were Started. Scotts Bluff Substation.

Rotation number	Crop sequence and treatment[1]	Percent of beets with galls 1933	1934
2	beets	43	22
20	beets, potatoes	31	16
21	beets (M), potatoes	27	00
22	beets, oats	35	00
18	beets, wheat	56	28
32	beets, corn, oats	43	14
35	beets, potatoes, oats	44	18
35B	beets, potatoes, oats	27	7
45—1st yr.	barley—sweet clover, sweet clover pasture, beets (1), beets (2)	00	00
—2nd yr.	barley-sweet clover, sweet clover pasture, beets (1), beets (2)	00	00
41	beets, alfalfa, alfalfa, potatoes	00	00
42	beets, alfalfa, alfalfa, oats	00	01
63	beets, alfalfa (3 yrs.), potatoes, oats	00	00
63B	beets, alfalfa (3 yrs.), potatoes, oats (M)	00	00
62	beets, alfalfa (3 yrs.), corn, oats	00	00
64	beets, oats-alfalfa, alfalfa (2 yrs.), potatoes	00	4

[1](M)—refers to application of 12 tons farm manure per acre.

A disease index method appeared satisfactory in comparative determination of the amount of disease in the experimental plots. It is as follows:

$$\text{Disease index} = \frac{\Sigma \text{ Category numbers} \times 100}{\text{Total No. of plants} \times 3}$$

The 3 in the denominator represents maximum infection and 100 is used to convert to percentage. The summarization of category numbers is obtained by multiplying the number of plants in each category by their respective category numbers from 0 to 3, and adding the products. The result is the comparative infection rating for the rotation plots.

Results

The information on the percentage of diseased beets in the rotations in 1933 and 1934, or 22 and 23 years after the rotations were established, is shown in Table 2. Root knot was present *in* the two-year and three-year rotations at this time, but was not observed in beets grown in rotations four years or six years in length. The production of sweet clover or alfalfa as legumes in the four-year and six-year rotatoins and the increase in length of rotation effected by growing these legume crops appeared to effectively control the root knot up to this time. For example, rotation 20 may be compared directly with rotation 41. These rotations are the same except that rotation 41 has two years of alfalfa. In 1933, 31 percent of the beet

roots from rotation 20 were affected with root knot and in 1934 16 percent were affected, compared with the absence of the disease in beets from rotation 41. Rotations 22 and 42 may be compared in a similar manner. Direct comparisons of the three-year rotations with the six-year rotations may be made as follows: rotation 35 and 63; rotation 35B with 63B, and rotation 32 and 62. In each instance the increase in length of the rotation and the presence of alfalfa appeared to eliminate the root-knot disease in sugar beets.

Crop rotation is probably the most important single method of control of root knot (2, 7, 16, 18). The studies as entered in Table 3 indicate that length of rotation had a definite effect on root knot of sugar beets. The average disease index values for the four-year period for the unfertilized plots in rotations 2, 20, 33, 35, 41, 49 and 63 were 82, 94, 34, 31, 33, 37 and 24 percent, respectively. This trend was evident for each of the four years 1946, 1947, 1948 and 1949. A similar tendency was noted for the comparable fertilized plots.

Ludecke (10) and others found that nutrition affects the amount of root knot. Oteifa (13) reported that potassium affects reproduction rate of *Meloidogyne incognita.* A potassium fertilizer was reported as helpful in protecting plants from nematode injury (18). In the four-year study, application of farm manure or commercial fertilizer did not consistently alter the severity of root-knot in all types of rotations. A decrease resulted in the continuous sugar beet plot (No, 2D) with application of commercial fertilization. Farm manure and commercial fertilizer decreased the disease in the two-year rotations. Some beneficial effects due to fertilization appeared in the four-year rotations in which sweet clover was employed as a legume (Nos. 49C, 49D); this was not the case in the other four-year rotations or in the three- or six-year rotations.

The effect of different crops in a sequence on root knot seemed probable. As shown in Table 3, no apparent differences were manifest in the three-year rotations in which barley (No. 35) was used in lieu of the barley-sweet clover combination (No. 33). No marked difference resulted where sweet clover was substituted for alfalfa. Either legume may be effective in decreasing root knot as King (8) reported that alfalfa is an effective and practical control of root-knot nematode of cotton. Although a new rotation program was inaugurated in 1942, some of the six-year rotations are directly comparable from 1912 to 1949. Such is the case with rotations 63 and 63B in which barley was substituted for oats and the sequence was changed, but was similar for both rotations. Rotation 63B had less disease than 63 during the four-year period with about 50 percent less in amount in 1948. Rotation 63C showed less disease than 63 of these two above rotations, which may be due to fewer amounts of beets in the history of this rotation, beets being started in 1937; the difference may also be due to artificial fertilization.

Since there is no rotation comparable to Rotation 66B and 66C without manure or artificial fertilizer applications it is difficult to determine whether the decrease of root knot was due to manurial or artificial fertilization on the particular rotation or to some other factors. Rotation 66C,

Table 3.—Effects of Crop Sequence, Fertilization and Length of Rotations on the Infection of Sugar Beets with *Meloidogyne* sp. at Scotts Bluff Substation, Mitchell, Nebraska, for the Period 1946-1949.

Rotation number[1]	Disease Index				
	1946	1947	1948	1949	4-year ave.
2	53.97	100.00	100.00	73.68	81.91
2D	51.51	100.00	89.90	51.56	75.24
20	80.89	100.00	98.59	98.00	94.36
20C	25.35	37.48	44.67	22.22	32.43
21	43.83	56.84	61.85	59.06	55.40
33	23.74	30.39	57.67	25.19	33.75
33B	55.01	31.45	62.42	65.01	53.47
35	18.67	12.08	40.67	52.70	31.03
35B	21.67	40.11	15.00	50.00	31.70
35C	19.51	29.97	53.09	18.12	30.17
41	11.90	39.16	56.00	26.19	33.32
41B	10.34	9.74	56.90	10.62	21.92
41C	14.60	53.84	52.46	27.52	37.11
43B	12.82	35.97	37.35	5.77	22.97
43C	9.52	2.42	34.00	31.30	19.31
49	20.34	53.45	38.94	55.46	57.05
49C	22.34	17.18	15.75	18.64	17.97
49D	22.91	6.48	13.01	16.11	14.60
63	20.85	25.58	23.33	28.81	24.14
63B	20.67	19.38	12.38	26.15	19.63
63C	16.18	17.30	25.12	9.70	17.06
66B	19.00	11.06	14.81	7.08	12.90
66C	14.21	12.99	24.62	28.40	20.06

[1] See Table 1 for description of rotations.

which had a definite background of alfalfa and beets since 1912, did exhibit less root knot than rotation 63. Rotation 66 B, which is directly comparable to 66C from 1942 to 1949, showed the least amount of root knot for the 1946-1949 period. In 66B beets were first included in 1936; this and the fact that the soil was maintained at a high nitrogen level may account for the decrease in the nematode disease.

Discussion

One of the most common recommendations for the control of root knot is crop rotation. The most promising method is that of growing crops which are not susceptible to root knot until the nematodes are starved out. Even this rotation program may be replete with many difficulties in the irrigated areas of western Nebraska.

The crops planted in the rotation systems must be free from nematode attack, so that the larvae in the soil may not obtain nourishment for survival and development. The main crops in this area are sugar beets, **field** beans, potatoes, alfalfa, sweet clover, corn and barley.

Fortunately, field beans, potatoes, corn and barley are not susceptible to the root-knot nematodes in western Nebraska. Alfalfa and sweet clover were slightly susceptible, and may aid the nematode in surviving. Similarly many weeds, such as pigweed, lambs quarters, fireweed, blue lettuce and foxtail would also be important in this respect. Weeds are very important *in* the irrigated areas in cultivated fields, and along irrigation canals.

The length of rotations was one of the major factors in controlling root-knot. Sugar beet monoculture and two-year rotations apparently were very favorable for nematode survival and development. After 22 and 23 years of operation of the rotations root knot was present in beets from the two- and three-year rotations but was absent in the four- and six-year rotations. But 35 years after the establishment of the rotations, the disease was present in beets from the four- and six-year rotations also, although to a lesser extent than in the shorter rotations. It appeared that the main crop grown in the rotations which favored the survival of the nematode was sugar beets.

Heavy fertilization is recommended in connection with root knot control possibly because a well nourished plant is more able to form new roots and thereby replace those invaded by the nematodes (10, 17). Fertilization gave beneficial results in certain irrigated rotations in reducing the disease in western Nebraska. Application of commercial fertilizer (NP) and manure caused a marked decrease in the incidence of root knot, particularly in the shorter rotations. In the two-year rotations commercial fertilizer and manure markedly reduced the severity of the disease. The application of commercial fertilizer (nitrogen and phosphorus fertilizer applied in amounts approximately equivalent to the nitrogen and phosphorus applied as a manure in the two comparable two-year rotations) compared with manure applications caused a greater reduction in disease. Similar beneficial results were obtained in total tonnage of roots and total sugar production (14). In the three-year rotaions which did not contain a legume, no marked differences resulted in amount of root knot as compared to the rotations where a legume was included, providing manure or artificial fertilizer was applied. This is not in accordance with sugar yields obtained in such rotations in the same area (14). In the longer rotations the fertility status of the soil was at a high level. This may be a partial explanation for less response to any particular fertilization practice in these longer rotations as compared to the short rotations.

Elements which were studied previously in these rotations and which may affect root knot in the fertilization practices are nitrogen, phosphorus and potassium (9, 14). The first two elements have been shown to be increased in the soil by the employment of manure, commercial fertilization, or legume, or a combination of a legume with either of the other two (9, 14). The increase of these two elements in the soil could be associated with a decrease in disease as evidenced in the continuous and two-year rotations. According to Rhoades and Harris (14) and Kubota, Rhoades, and Harris (9) the inclusion of a legume in a rotation at the Scotts Bluff Substation caused a decrease in the exchangeable potassium; the non-legume rotations did not cause a decrease of this element, whereas manure application increased the exchangeable potassium content of the soil. It is possible that the increase in potassium content of the soil due to manurial applications may decrease root knot (18). The decrease in exchangeable potassium due to the inclusion of a legume in a rotation may not have been instrumental in affecting the disease since it was not lowered to a level to be critical for sugar beet production. Apparently

alfalfa in a rotation affects the disease from another standpoint other than potassium content of the soil as King (8) indicated this legume is an effective control for root knot of cotton when used in a rotation.

Summary

A study of the effects of crop rotations on root knot of sugar beets was conducted at the Scotts Bluff Substation, Michell, Nebraska. Besides continuous cropping, four different lengths of rotations were involved as well as various fertilization and cropping practices.

A root-knot index, which was employed to designate the amount of disease, indicated a consistent tendency for an increase in disease with a decrease in length of rotation. The severity of disease decreased sharply after the continuous and two-year rotations, although a few cases of abundant disease appeared in the three- and four-year rotations. Root knot was common in the short rotations 22 years after inauguration of the rotations, but was also present in the larger rotations 35 years after the program was started although to a lesser extent.

Fertilization applications decreased root knot in the short rotations. Farm manure decreased the amount of disease *in* the two-year rotations and commercial fertilizer consisting of nitrogen and phosphorus caused a decrease in the disease in the continuous and two-year rotations, and four-year rotations in which sweet clover was employed as a legume. No such marked beneficial effects were apparent in the other four- and six-year rotations.

There were no marked differences in root knot due to crop sequence in the rotations compared.

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