Influence of Crop Rotation on Spread and Density of *Heterodera schachtii* on a Commercial Vegetable Farm in New York

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ABSTRACT

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On a 43-ha farm with 13 fields studied from 1971 to 1977, host (H) crops in the rotation were cabbage and table beets and nonhost (NH) crops were corn, wheat, and oats. In general, the number of viable eggs and larvae of *Heterodera schachtii* increased in fields with rotations of NH:H crops at a ratio of 1:2 or 1:1 and decreased in fields with rotations of NH:H crops at a ratio of 2:1 or 5:1. Crop rotation did not stop spread of the nematode from field to field within the farm. During the period of study, the number of fields with detectable nematode infestation increased from six to nine and the number of infested sampling grids within fields increased from 58 to 81. The number of fields having at least one sampling grid infested with *H. schachtii* at above the damaging level (six to nine eggs and larvae per gram of soil) decreased from four to one, whereas the number of sampling grids with a similar level of infestation decreased from 24 to one.

The sugar beet cyst nematode (SBCN), *Heterodera schachtii* Schmidt, has a wide host range involving 218 plant species in 95 genera (14). Steele (14) reported that approximately 80% of the species listed as hosts (H) are members of the Chenopodiaceae and Cruciferae. SBCN is widely distributed throughout the sugar beet growing areas of the world (4).

The introduction and spread of SBCN in New York State has been described (1). SBCN is randomly distributed in the cabbage and table beet growing areas of central New York. In a survey conducted during 1970–1971, 20 of 40 farms were found to be infested. Soil population of SBCN was low and caused no obvious losses on 18 farms but was high and caused considerable losses to table beets on the other two farms. Accordingly, a major part of our control strategy is to minimize spread and prevent the SBCN population from reaching the damaging threshold density. At present, crop rotation is the most practical and economical measure for this purpose.

SBCN causes significant yield losses to both table beets and cabbage (1,10,13). Olthof et al (10) reported that marketable yields of cabbage and table beets were reduced by an initial population density (P_i) of 18 larvae per gram of soil, while no significant yield reduction of either crop occurred at P_i of six larvae per gram of soil. Recently, the economic threshold densities of SBCN for table beets and for

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direct-seeded and transplanted cabbage were determined in New York State (1). Marketable yields of beets were reduced by 23, 25, 42, and 54% at P_i of 9, 18, 34, and 68 eggs and larvae of *H. schachtii* per gram of soil, respectively. The same P_i levels reduced marketable yields of direct-seeded cabbage by 21, 28, 46, and 54% and those of transplanted cabbage by 25, 31, 34, and 42%, respectively. Under New York conditions, the damage threshold density of SBCN to both cabbage and table beets is six to nine viable eggs and larvae per gram of soil (1).

SBCN causes severe damage to sugar beets when the crop is grown as a monoculture or in short rotations with nonhosts (NH). The level of soil infestation with SBCN determines the length of crop rotation (number of NH crops) required for effective control. For example, Jones and Petherbridge (7) concluded that at least 10 yr in NH crops was needed in heavily infested fields before sugar beets could be grown safely. In contrast, only 2- to 3-yr rotations with NH crops were required to prevent damage in lightly infested fields. Control of susceptible weeds while growing a NH crop was thought to be essential for the success of such a rotation. Hull (6) concluded that the enforcement of crop rotation (minimum of 3 yr) has largely prevented SBCN from inflicting serious losses to sugar beets in England.

Several investigators (3,8,9,15,16,18) have reported that NH crops differ in effectiveness in reducing SBCN populations in soil. The crops that are most effective against SBCN have been referred to as "enemy" or "hostile" crops (8). Wright (18) reported that alfalfa, alsike clover, red clover, white clover, chicory, corn, flax, horse beans, and rye are hostile crops in California. Notzel and Wagner (8) considered corn, chicory, and onion to be enemy plants, although the rates of decrease of cysts with viable contents were not significantly different from those in the fallow treatment. Steele and Price (15) showed that alfalfa and clover reduced the number of SBCN significantly more than did beans or peas and concluded that alfalfa gave the greatest decrease and therefore was well suited for use in crop rotations for the control of SBCN. Recently, Vinduska (16) found that barley was more effective than alfalfa, potatoes, and wheat in reducing the number of cysts with viable contents in the soil. Berbec (3) concluded that parasitism of sugar beet by SBCN is influenced by crop rotation and also by the cultivar selected.

Data on the influence of crop rotation on natural spread and population density of SBCN as well as on yield of table beets and cabbage are generally lacking. This paper reports the effect of crop rotation on spread and population density of SBCN on a commercial vegetable farm in central New York.

MATERIALS AND METHODS

The experiment was conducted on 13 fields of a 43-ha farm west of Geneva, New York. Discussions with the owners led to the initiation of practical and economical rotations consisting of NH:H crops at overall ratios of 5:1, 2:1, 1:1, and 1:2 in three, six, one, and three fields, respectively. Corn and, less frequently, oats and wheat were the NH crops and cabbage and table beets were the H crops (Table 1).

The soil of the farm varies from silt loam to loam with a pH of 7.1. There is a downward slope from field G across fields F and E to field D (Fig. 1). Fields L and M are separated from the other fields by a deep drainage ditch with high banks. An uncultivated strip with a grass cover is located between fields H and I. The 13 fields vary considerably in size and have uneven borders. Planting and cultural practices used were according to the recommendation for commercial vegetable productions by the New York State College of Agriculture (Publication Office, Cornell University, Ithaca, NY 14853). Table beet cultivar Ruby Queen and cabbage cultivars Titanic and Round Up were grown.

At the beginning of the experiment, each field, regardless of size and shape, was divided lengthwise into 30.5-m plots (Fig. 1). Because the length of fields differed, the number of plots in the different fields varied from seven to 18. All plots were sampled in early to mid June of 1971, 1972, 1973, 1974, and 1977. Soil samples from fields planted to table beet, cabbage, or corn were collected at planting time or shortly after plant emergence. Soil samples from wheat and oat fields were randomly collected from within and between rows. One composite soil sample was collected from each plot. Each sample consisted of 40–60 subsamples collected at uniform preselected distances from a cross pattern of each plot. For subsamples, the top 2–3 cm of soil was pushed aside and a small quantity of moist soil was collected from the next 5–8 cm. The samples were placed in plastic bags and stored at approximately 5 C until processing time.

Cysts were extracted from soil by a combination of the Fenwick-type extraction procedure with centrifugal flotation (5). The total number of cysts per 600 cm^3 of soil was recorded at ×40 magnification. The number of viable eggs and larvae was determined according to the procedure described by Abawi and Mai (1). The soil samples were also processed by the pie-pan technique (11) to extract the vermiform stages of SBCN free in soil. Because the number of the latter in the samples was very low, the data were not included in the final analyses. All data obtained in this experiment were statistically analyzed by Waller-Duncan's Bayesian K-ratio (LSD) rule (17).

RESULTS

With the exception of field D, the number of viable eggs and larvae increased in fields with rotations involving NH:H crops at a ratio of 1:1 or 1:2. In contrast, sequence of NH:H crops alternating at a ratio of 2:1 or 5:1 resulted in a decrease in the number of viable eggs and larvae (Table 2). Data on the total number of cysts from the same soil samples as affected by the different rotations followed a similar pattern.

From 1971 to 1977, the number of fields with detectable nematode infestation increased from six to nine and the total number of plots with a detectable infestation increased from 58 to 81 (Fig. 1). On the other hand, the number of fields having at least one plot with a soil population of SBCN at a higher than the damage threshold density (approximately six to nine eggs and larvae per gram of soil) decreased from four to one. Likewise, the total number of plots on this farm with numbers of SBCN equal to or higher than the damage threshold density was decreased from 26 to one. From 1971 to 1977, the realistic crop rotations practiced by the grower resulted

Table 1. Cropping sequence of hosts and nonhosts of *Heterodera schachtii* grown from 1971 to 1976 in 13 fields of a commercial vegetable farm in New York

	Years						Crop rotation
Field	1971	1972	1973	1974	1975	1976	Nonhost/Host
B	Oats	Corn	Corn	Cabbage	Oats	Corn	5/1
K	Corn	Corn	Cabbage	Corn	Corn	Corn	5/1
M	Corn	Corn	Cabbage	Corn	Corn	Corn	5/1
A	Beets	Corn	Corn	Cabbage	Oats	Corn	4/2
D	Corn	Beets	Cabbage	Corn	Corn	Corn	4/2
E	Cabbage	Corn	Corn	Corn	Cabbage	Corn	4/2
F	Cabbage	Wheat	Cabbage	Corn	Corn	Corn	4/2
G	Wheat	Cabbage	Wheat	Cabbage	Corn	Corn	4/2
J	Beets	...[a]	Cabbage	Corn	Corn	Corn	4/2
L	Beets	Corn	Wheat	Cabbage	Beets	Corn	3/3
C	Corn	Beets	Cabbage	Beets	Corn	Cabbage	2/4
H	Cabbage	Beets	Cabbage	Corn	Corn	Beets	2/4
I	Beets	Cabbage	Corn	Corn	Cabbage	Beets	2/4

[a]Beets were planted but were disked in the seedling stage because of poor seedling establishment, and the field was maintained fallow.

in an overall reduction of SBCN population by 96%. During the same period, however, SBCN continued spreading within the farm, and the number of infested plots increased by 55%.

Table 2. Effect of different crop rotations on the number of viable eggs and larvae of *Heterodera schachtii*

Field	Crop rotation Nonhost/Host[a]	Viable eggs and larvae/600 cm^3 of soil 1971	1977	P_f/P_i[b] Individual field	Crop rotation
B	5/1	3,415	426	0.035 c	0.261 b
K	5/1	0	0	1.000 b	
M	5/1	0	0	1.000 b	
A	4/2	7,074	481	0.025 c	0.280 b
D	4/2	0	76	11.340 a	
E	4/2	7,921	369	0.007 c	
F	4/2	0	0	1.000 b	
G	4/2	0	0	1.000 b	
J	4/2	34	14	0.929 b	
L	3/3	0	95	27.473 a	27.473 a
C	2/4	0	29	3.715 ab	3.830 a
H	2/4	166	207	0.881 b	
I	2/4	752	1,023	17.049 a	

[a] Cropping sequence of nonhosts and hosts planted in each field is listed in Table 1.
[b] P_f and P_i refer to final (1977) and initial (1971) density of eggs and larvae of *H. schachtii*/600 cm^3 of soil. Data were analyzed as log-log ratio (1977/1971); mathematical mean was then recalculated as $10\ \frac{\log_{10}(77+1)}{\log_{10}(71+1)}$. Means in a column followed by same letter do not differ significantly ($P=0.05$) by Waller-Duncan's Bayesian K-ratio (LSD) rule.

DISCUSSION

Crop rotation has long been considered an important and effective control measure for plant parasitic nematodes as well as other soilborne pests (9). Rotations of a proper crop sequence influence the biologic, chemical, and physical properties of soils and have many beneficial effects. Thus, crop rotation may play a major role, depending on economic conditions, in the development of integrated control programs (9).

At the present time, crop rotation is the best economic measure available to New York's growers for the control of SBCN on cabbage and table beets. Soil fumigants are expensive and not always effective in the fine-textured soils of New York State (G. S. Abawi and W. F. Mai, *unpublished*). Only one nonvolatile nematicide (phenamiphos, Mobay Chemical Corporation, Box 4913, Kansas City, MO 64120) has been approved for use on cabbage and none has been approved for use on table beets. Furthermore, cultivars of either cabbage or table beets resistant to SBCN are not available. Because the number of SBCN in most cabbage and table beet fields is relatively low and below the damaging threshold density, New York's growers should practice a rotation involving NH:H crops at a ratio of 2:1 or, if possible, higher.

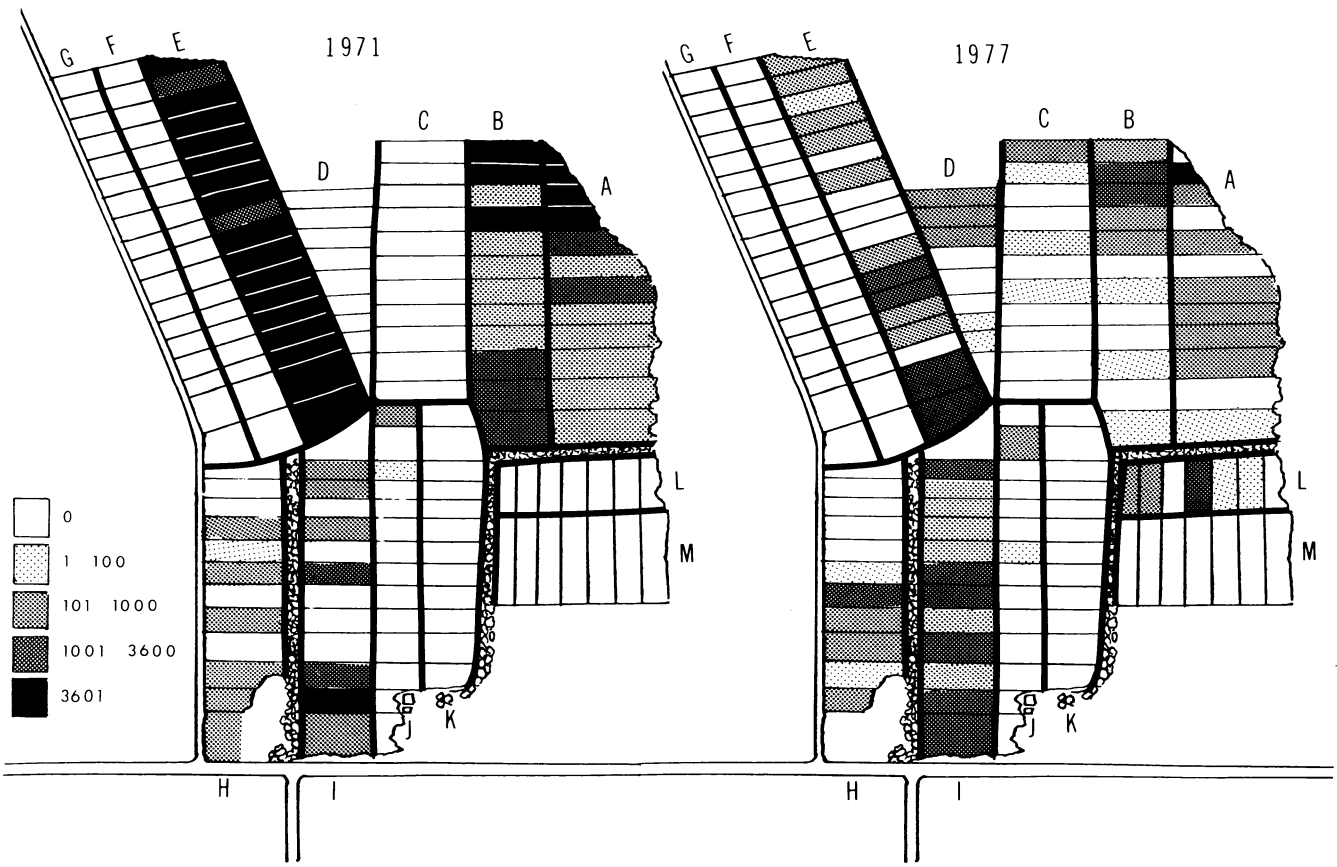

Fig. 1. Comparison of the number of viable eggs and larvae of *Heterodera schachtii* in plots of fields A–M in 1971 and 1977. Numbers presented by the different shading patterns refer to the density of viable eggs and larvae per 600 cm^3 of soil.

Proper crop rotations should be initiated not only in fields known to be infested with SBCN but also in fields with no detectable infestation. Crop rotation is more effective in preventing the buildup of SBCN to the damaging threshold density than in reducing excessively high populations to below the damaging threshold density. (7).

Our data suggest that crop rotation alone did not prevent the spread of SBCN from infested to clean fields within the farm, although it might have slowed the rate of spread. Spread of plant parasitic nematodes on a farm is influenced by physical barriers, but the movement of infested soil on farm machinery and equipment has been generally considered more important. The spread of SBCN across the permanent drainage ditch to field L (Fig. 1) substantiates this viewpoint. The buildup of SBCN in field D was due to a NH:H crop ratio of 1:2 between 1971 and 1974 and also to possible contamination with heavily infested soil from field E moved through surface water runoff. Field E was completely flooded for several days when Hurricane Agnes hit New York in early June 1972, accompanied by 280 mm of rainfall.

Poor and uneven growth of table beets due to damage by SBCN was evident only in fields A and I. Although SBCN was unevenly distributed in field I in 1971, the population built up to damaging threshold density during the period of study because of a rotation involving NH:H crops at a ratio of 1:2. Damage symptoms caused by SBCN on table beets grown in field A were severe in 1971 because table beets had also been grown in this field in 1968, 1969, and 1970. NH crops were grown in field A during 1972 and 1973, and the population of SBCN was reduced. Generally, damage symptoms were not evident on cabbage grown in field A during 1974 or on cabbage grown on any other infested field during the experiment. Aboveground symptoms of SBCN on cabbage are smaller and less firm heads, which are more difficult to observe than the stunted and red-colored foliage of table beets infected by high populations of SBCN (1). Thus, fields to be planted to cabbage and table beets, especially suspect ones or those that have been planted with host crops for several years, should be analyzed for the presence and density of SBCN before planting.

Our sampling and assay procedures were adequate for determining the overall changes in SBCN population influenced by crop rotation. However, sampling once a year and taking only 40–60 subsamples per composite soil sample from the relatively large plots maintained on the study farm were inadequate for accurately determining fluctuations in the population dynamics of SBCN and detecting low levels of infestations or small differences between fields. In addition, population counts varied considerably within fields and from year to year. Research is needed to determine the proper number of samples and subsamples required per unit area to reduce variability and also to detect small changes in nematode density. Proctor and Marks (12) reported that the number required to detect relatively small differences would be extremely high. The development of an efficient and sensitive sampling and assay is essential for establishment of diagnostic and advisory programs based on knowledge of the economic threshold densities (2).

An effective nematicide, phenamiphos, is available for use on cabbage when the economic threshold density of *H. schachtii* is reached. Combining the use of a nematicide and crop rotation with a NH crop may shorten the required rotation and warrants investigation. Information is also needed on the tolerance limit and efficiency as hosts to SBCN of the available cabbage and table beet cultivars. Sources of germ plasm resistant to this nematode should be identified, and a breeding program to incorporate such resistance into commercially acceptable cultivars needs to be initiated.

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