

Forecasting Onion White Rot Disease

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Appreciation is expressed to C. J. Tate and S. M. Sherren for assistance in collecting and assaying soil samples and for determining disease severity in the fields and to the Rutgers Research and Development Center, Bridgeton, NJ, for their assistance in field work. I wish to thank the following farmers for their excellent cooperation during this investigation: P. C. Bylone; L. Caregnato; E. Ferrari; J. Ferrari; L. E. Ferrari; L. J. Ferrari, Sr.; L. J. Ferrari, Jr.; R. Ferrari; R. A. Flaim; D. Franceschini; R. J. Franceschini; A. Galbiati; L. Galetto; V. B. Malench; L. B. Occhetto; T. Parici; J. Quarella; C. Russo; and C. Tarabbio.

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Accepted for publication 27 February 1981.

ABSTRACT

Adams, P. B. 1981. Forecasting onion white rot disease. *Phytopathology* 71:1178-1181.

Sclerotia of *Sclerotium cepivorum* were uniformly distributed in the top 20–25 cm of soil in fields in southern New Jersey, which corresponds to the depths to which farmers plow. Fields were not uniformly infested with *S. cepivorum*; inoculum densities differed by as much as 34 sclerotia per 100 g of soil in adjacent 0.2-ha field plots. A highly significant ($P = 0.01$) correlation ($R = 0.71$) was found between the inoculum density of *S.*

cepivorum at the time of planting and white rot incidence at harvest. This relationship could be expressed as $Y = 6.41 + 12.38X - 0.65X^2$, where Y = percentage white rot of bunching onions and X = number of sclerotia per 100 g of soil. Leeks were more resistant than bunching onions to white rot; Walla Walla Sweet Spanish bulb onion was intermediate in resistance.

Additional key words: *Allium* spp.

Bunching onions (*Allium cepa* L. and *A. cepa* L. × *A. fistulosum* L.) and leeks (*A. porrum* L.) are grown in southern New Jersey on small farms located principally in three counties. On some farms, bunching onions are planted throughout the year in small fields. White rot caused by the soilborne fungus *Sclerotium cepivorum* Berk., the major disease on this crop, is a problem only on the overwintering crop planted in August–October and harvested in March–May. In the spring, a field may show 50–100% white rot. When that field is disked, plowed, and replanted during late spring or early summer, the crop is rarely damaged. However, if the field is replanted the following fall to bunching onions, the crop is likely to be severely diseased.

Both leeks and bunching onions are harvested by hand in the field. Manual labor is also used to sort, clean, bunch, and pack the commodity. Most farmers feel that it is unprofitable to harvest a field of bunching onions with more than 30% white rot because of the labor costs; thus, 30% disease can mean total crop loss.

Each summer, farmers plan which fields to plant to fall-planted crops, including spinach, parsley, leeks, and bunching onions. Some farmers have no fields free of *S. cepivorum* but continue to plant bunching onions and leeks. Others have stopped growing the crops, while others have purchased or rented new land. Sometimes the new land produces a crop with severe white rot the first year it is planted to overwintering onions.

In a greenhouse study, Adams and Papavizas (2) showed a positive relationship between inoculum density of *S. cepivorum* at the time of planting and subsequent disease severity. Preliminary unreported field studies indicated a similar relationship in production fields. This study was undertaken to develop a practical method for predicting white rot severity based on the inoculum density of *S. cepivorum* before planting bunching onions. Such a disease forecasting system would help farmers ascertain which fields are safe to plant to fall-planted leeks and bunching onions

and would reduce the risk farmers take when they acquire new land. The forecasting system also would be useful in an integrated pest management program.

MATERIALS AND METHODS

Collecting soil samples. Most bunching onions in southern New Jersey are grown on small, multicrop farms of less than 40 ha. Usually, each farmer plants several plantings of bunching onions, each about 0.2 ha in size, at several locations on the farm. Thus, for this study, fields significantly larger than 0.2 ha were divided into sections of about 0.2 ha, and each section was considered a separate field.

Soil samples, except where otherwise indicated, were taken with a soil sampling tube 2 cm in diameter. For the 1977–1978 and 1978–1979 crops, 16 subsamples were taken from each field to a depth of about 15 cm. For the 1979–1980 crop, 50 subsamples were taken from each field to a depth of about 7 cm.

The method of obtaining the subsamples varied with the shape of the field. Most fields were sampled as in Fig. 1. In odd-shaped fields, such as squares or very long, narrow rectangles, the field was divided differently to obtain representative soil samples. The 16 or 50 subsamples from each field were combined in a single plastic bag.

Most soil samples were collected and processed in the fall (September and October). However, a number of new fields were discovered in the spring and were sampled for the inoculum density of *S. cepivorum* and for white rot severity at the same time.

Assaying soil samples. The soil samples were usually assayed in a mobile laboratory immediately after they were collected so that results could be made known to the farmer immediately. Each bag of pooled subsamples was spread out on paper to dry enough to pass through a 2-mm sieve. The sieved soil samples were assayed as outlined previously (1)—briefly, this method entails wet-sieving weighed amounts of soil on a 0.18-mm sieve and examining the residue under a dissecting microscope to count the sclerotia of *S. cepivorum* in the sample. Five assays each of 10 g of soil were performed for each sample containing 16 subsamples; five assays each of 20 g of soil were performed for each sample containing 50

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subsamples. About 30 min was required for one person to process a soil sample. The pH of the soil samples was determined 1 hr after water was added to the soil (1:2.5, soil to water, v/v).

Vertical distribution of sclerotia. Soil samples from six fields from three farms were collected to determine the vertical distribution of sclerotia of *S. cepivorum*. The soil sampler used in this case was constructed from an aluminum pipe 5 cm in diameter with one side cut out. I obtained each subsample by pushing the soil sampler vertically 35 cm into the soil. The sampler was withdrawn from the soil, and the seven 5-cm segments of the soil core were removed from the sampler and put into separate plastic bags. Five soil subsamples were collected from each field and pooled. The bags of soil were brought back to the mobile laboratory, partially dried, and processed as described above.

Determining white rot incidence. During March, April, and May, the fields that had been assayed for the inoculum density of *S. cepivorum* the previous fall were revisited and assayed for the incidence of white rot as close to the normal harvest date as practical. The fields were assayed in the same pattern as the soil samples had been taken, except that two bunching onions or one leek plant was collected from each site. Thus, in a field where 50 soil subsamples had been taken, 100 bunching onion or 50 leek plants were harvested. The plants were taken to the mobile laboratory, and the percentage of plants visibly infected with *S. cepivorum* was noted.

During the 1977–1978 and 1978–1979 growing seasons, the relative susceptibility of bunching onions (cv. Long White Bunching), leek (cv. American Flag), and a bulb onion (cv. Walla Walla Sweet Spanish) was compared in plots at the Rutgers Research and Development Center near Bridgeton, NJ. Although the three types of onions have different growing periods, they were all planted and harvested at the normal dates for bunching onions. Each plot consisted of a 3-m row with seven replicates in the 1977–1978 field test and five replicates in the 1978–1979 field test. All plants were harvested and visually inspected for infection by *S. cepivorum*, and the percentage of infected plants was recorded.

RESULTS

Time of sampling of fields. Six fields were sampled and assayed for *S. cepivorum* before and after planting the 1979–1980 crop. No significant changes ($P=0.05$) were found in inoculum density. The inoculum densities increased by two and three sclerotia per 100 g of soil in two of the fields and did not change in the other four fields.

During the 1979–1980 growing season, the inoculum density in selected fields was determined shortly after planting in the fall and again at harvest in the spring. The inoculum density of *S. cepivorum* apparently did not change during the growing season. Of the five fields, three had identical inoculum densities at both sampling times. The other two fields differed by one and two sclerotia per 100 g of soil.

In the fall of 1978, four 0.2-ha fields were selected to determine the optimal sampling procedure. Sixteen pooled subsamples were collected eight times from each field as in Fig. 1. The eight soil samples from each field were assayed to determine the number of sclerotia in five 10-g samples, as described above. Analysis of the data showed that any two fields with differences in inoculum densities of 4.75 or more sclerotia per 100 g of soil were significantly different ($P=0.05$).

Statistical analysis of the data further showed the relationship between the number of subsamples taken from a field and the degree of confidence in the results. For example, two 0.2-ha fields where the inoculum densities differ by two sclerotia per 100 g of soil would require 119 subsamples from each to be significantly different ($P=0.05$). A difference in inoculum densities of three sclerotia per 100 g would require 53 subsamples per field; four sclerotia per 100 g would require 30 subsamples; five, 19; and six, 13 subsamples per field.

In another study, two soil samples from each of six fields were collected, one containing 50 subsamples and the other 100 subsamples. The soil samples were assayed to determine the number of sclerotia in five 20-g samples. Inoculum densities in soil

samples containing 50 subsamples did not differ significantly ($P=0.05$) from those in samples containing 100 subsamples.

Vertical distribution of sclerotia. The inoculum densities in the six fields used in this study varied from four to 32 sclerotia per 100 g of soil. Sclerotia of *S. cepivorum* were reasonably uniformly distributed throughout the top 20 cm of soil (12–18 sclerotia per 100 g of soil) (Table 1). Below this depth, the inoculum density declined rapidly, averaging only two sclerotia per 100 g of soil 30–35 cm deep. In fact, only half the fields sampled had sclerotia in the soil at this depth.

Horizontal distribution of sclerotia. In September 1978, a 2.4-ha field was divided into 12 consecutive 0.2-ha sections. Soil samples of 16 subsamples were taken from each section. The inoculum densities of these 12 sections, from south to north, were 2, 0, 0, 2, 0, 8, 4, 14, 4, 2, 36, and 18 sclerotia of *S. cepivorum* per 100 g of soil.

Part of a field on another farm was divided into 16 plots of 46 m² each. From each plot, 10 subsamples were taken, pooled, and assayed for the inoculum density of *S. cepivorum*. The results indicated extreme variation in inoculum density in a small area of a heavily infested field (Fig. 2). Sclerotia per 100 g of soil averaged 40.2 but ranged from six to 136 in the 16 plots.

In New Jersey, most fields that contained sclerotia of *S. cepivorum* had levels that ranged from one to six sclerotia per 100 g of soil. Of 142 soil samples assayed in the fall of 1979, 60 contained no sclerotia, 70 contained one to six sclerotia per 100 g of soil, and only eight contained 10 or more sclerotia per 100 g. Occasionally,

TABLE 1. Vertical distribution of sclerotia of *Sclerotium cepivorum* in six fields in New Jersey

Soil depth (cm)	Average number of sclerotia per 100 g of soil ²	Average percentage of sclerotia at each depth ²
0–5	15.3 ab	27.0 a
5–10	15.0 ab	22.0 a
10–15	12.0 ab	14.6 abc
15–20	17.7 a	20.3 ab
20–25	7.3 ab	10.0 abc
25–30	2.3 b	4.0 bc
30–35	2.0 b	2.2 c

²Values in each column not followed by the same letter are significantly different according to Duncan's multiple range test, $P=0.05$.

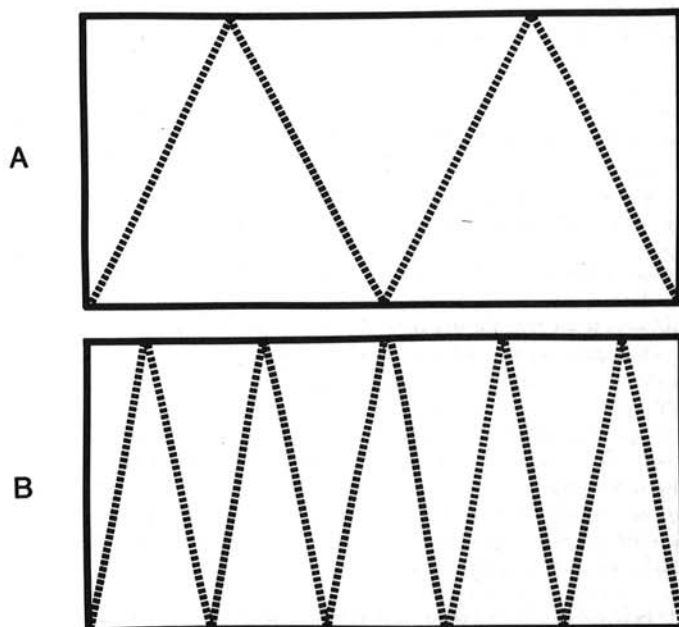


Fig. 1. Paths traveled across 0.2-ha fields to collect subsamples (dotted lines). A, On each traverse of the field, four subsamples were taken, for a total of 16 subsamples per field. B, On each traverse of the field, five subsamples were taken, for a total of 50 subsamples per field.

however, small areas of a field contained 100 or more sclerotia per 100 g of soil (Fig. 2).

During the 1977–1978 and 1978–1979 growing seasons, 326 soil samples were collected and assayed, some to determine the inoculum density of *S. cepivorum* at various depths, some to determine the most practical method to sample a field, and some from fallow fields to make a disease forecast at the farmer's request. At the time of harvest from these two growing seasons, 162 fields, including several leek fields, were assayed for disease incidence. The relationship between inoculum density and disease incidence was estimated based on 121 samples from 0.2-ha fields. Curve fitting of the data for bunching onions gave the quadratic equation

$$Y = 13.84 + 2.44X - 0.02X^2, \quad (1)$$

where Y = percentage white rot and X = number of sclerotia per 100 g of soil. The correlation ($R = 0.51$) between inoculum density and white rot incidence was highly significant ($P = 0.01$).

In the 1979–1980 crop, 139 soil samples were collected and assayed, some at the farmer's request for a disease forecast. Disease incidence data could not be determined for all these fields because some were harvested or plowed down before they were revisited in the spring.

Analysis of these data indicated a highly significant correlation ($P = 0.01$) between the inoculum density of *S. cepivorum* and white rot incidence ($R = 0.71$). The relationship between inoculum density and white rot incidence was:

$$Y = 6.41 + 12.38X - 0.65X^2. \quad (2)$$

These data were derived only from fields of bunching onions. A significant correlation could not be obtained for leeks because of the small number of leek fields sampled.

In the field tests comparing three types of onions for susceptibility to white rot, bunching onions were consistently more susceptible than leeks (Table 2). The bulb onion was intermediate in resistance to the disease. The inoculum densities in these field plots were three to six sclerotia per 100 g of soil at the time of planting.

DISCUSSION

Most sclerotia of *S. cepivorum* appear to be restricted to the top 25 cm of soil, which corresponds to the approximate plowing depth on most farms in southern New Jersey. Sclerotia found below this depth were probably there as a result of deeper plowing than normal. The inoculum density was reasonably constant throughout the upper 20–25 cm. Crowe and Hall (4) showed that sclerotia as deep as 30 cm infected garlic in California and caused foliar symptoms within 12–13 wk. The same is probably true for bunching onions in New Jersey.

Sclerotia of *S. cepivorum* rarely are distributed uniformly within a field in southern New Jersey. This was readily apparent in the spring months, when areas of dead plants occurred in fields of bunching onions. Fields were found that were disease-free except for one or two areas about 5–20 m in diameter that had a high disease level. The inoculum density in one of these areas was found to be 100 sclerotia per 100 g of soil. Even in fields with 80–100% infected onions, some areas had more sclerotia in the soil than others.

Crowe et al (5) reported a reduction in the inoculum density of *S. cepivorum* within 5 wk after garlic was planted in California. This reduction did not occur in the sandy loam and loamy sand soils of southern New Jersey. In this study, no significant differences were found in the inoculum densities of six fields before and after planting or in five fields shortly after planting in the fall and in the spring before harvest.

During the 1977–1978 and 1978–1979 seasons, 16 subsamples were taken from each 0.2-ha field to a depth of 15 cm (Fig. 1A). When disease incidence data were taken in the spring by the same sampling method, it became apparent that 16 subsamples were not enough to adequately assess field populations. That is, the gap

between adjacent subsamples was often large enough to overlook areas of the field where disease incidence and inoculum density were greater than in the surrounding areas. Furthermore, the collection of 19 subsamples could detect statistically significant differences between two soil samples only if they differed by five or more sclerotia per 100 g of soil.

For these reasons, 50 subsamples were taken from each 0.2-ha field to a depth of 7–8 cm during the 1979–1980 crop. Vertical distribution studies indicated that samples collected to a depth of 7–8 cm should not differ in inoculum density from those collected to a depth of 15 cm. The collection of 50 subsamples allowed the detection of a statistically significant difference in the inoculum density of two fields that differed by three or more sclerotia per 100 g of soil. This soil sampling procedure provided a fairly good representation of the fields sampled and is equivalent to one subsample per 40 m², which appears to be the most practical number of subsamples to collect from a field to detect sclerotia of *S. cepivorum*.

The relationship between inoculum density and white rot incidence (equation 2) shows that it is practical to forecast disease incidence of white rot of bunching onions in New Jersey. At inoculum densities above nine sclerotia per 100 g of soil, however, the equation is inaccurate, because little data could be obtained from fields with both high inoculum and high disease incidence. Many fields with high inoculum levels in the fall were plowed down because of insect damage or disease severity before they could be sampled for actual white rot incidence.

The relationship between inoculum density and white rot incidence is not entirely accurate for another reason. In this study, white rot incidence was determined at the approximate harvest date for the crop. Adams and Springer (3) showed that infection of seedlings by *S. cepivorum* reduced plant stands by about 30–35% in the fall months.

The equation for predicting white rot incidence (equation 2) indicates that at zero sclerotia per 100 g of soil, 6% white rot can be expected. Because a total of 100 g of soil was assayed from each soil sample, the minimum inoculum density that could be detected was one sclerotium per 100 g of soil. To improve the sensitivity of the assay method, more or larger samples would have to be assayed. From a practical standpoint, this is hardly worth the effort, because a total of 200 g of soil must be assayed to detect 0.5 sclerotia per 100 g of soil.

In their study in British Columbia, Utkhede et al (8) stated that they did not necessarily expect a correlation between inoculum density and white rot incidence. In this study, such a correlation was expected and found. Adams and Papavizas (2) reported that to obtain 50–60% white rot in greenhouse studies would require about 25 sclerotia per gram of soil. Though useful for greenhouse

TABLE 2. Incidence of white rot (%) in onions²

Type of onion	Growing season	
	1977–1978	1978–1979
Long White Bunching	46 a	75 a
Walla Walla Sweet Spanish	32 ab	28 b
American Flag Leek	15 b	11 b

² Values not followed by the same letter are significantly different ($P = 0.05$).

84	8	6	49
19	8	50	136
10	48	81	23
40	62	11	8

Fig. 2. Diagram illustrating the variation in the inoculum density of *Sclerotium cepivorum* in a field. Each number represents the number of sclerotia per 100 g of soil for that plot. Each plot was 1.5 × 30.5 m.

experiments, these data do not apply to field conditions.

Field plot studies indicated that bunching onions were significantly more susceptible to white rot than leeks; this was confirmed in the limited number of leek fields assayed in this study. A bulb onion, Walla Walla Sweet Spanish, was intermediate in susceptibility. Utkhede and Rahe (6) found that most bunching and sweet Spanish type onions were more susceptible to white rot than most dry bulb type onions.

By dividing large fields into 0.2-ha portions, portions of fields with no sclerotia can sometimes be found. This helps farmers in southern New Jersey decide where to plant their overwintering crops of bunching onions, leeks, parsley, and spinach. The latter two crops could be planted in *S. cepivorum*-infested fields.

The methods used to obtain soil samples and to determine the number of sclerotia in samples should be applicable to other onion-growing areas. If the soil samples contain a high level of organic matter, a different assay method should be used. The methods developed by Utkhede and Rahe (7) or Crowe et al (5) appear to be useful for such soil types.

The inoculum density-disease incidence relationship is useful for forecasting disease in southern New Jersey. Whether this relationship is valid in other onion-growing areas where white rot is a problem remains to be established. The work of Crowe et al (5) indicates that this relationship would not apply to garlic in

California, where 0.1–1 sclerotium per 100 g of soil resulted in 10–85% white rot.

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