Soil Temperature and Moisture Effects on Sclerotium Germination and Infection of Onion Seedlings by *Sclerotium cepivorum*

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ABSTRACT

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Germination of sclerotia of *Sclerotium cepivorum* in soil dampened with and without garlic extract was optimal at 18 C and −300 millibars (mb) matric potential (field capacity). Seventy-eight percent of sclerotia germinated with extract and 16% germinated without extract. Germination was confined to temperatures between 9 and 24 C at −300 mb and between −12.5 mb and −3 bars at 18 C. Interactions between temperature and soil moisture were more apparent at less optimum temperature and soil moisture combinations. Germination varied more with matric potential than with moisture content of two different soils. Only 0.4% of germinating sclerotia formed secondary sclerotia in soil. Decay of sclerotia was similar in soil with and without garlic extract and was directly proportional to increasing temperature and increasing soil moisture. Infection of host plants by sclerotia was confined to temperatures between 6 and 24 C and −45 mb and −3 bars matric potential. Disease developed more rapidly with increasing temperature within the 6–24 C range, but developed at the same rate for all permissive matric potentials at a given temperature.

Additional key words: Allium cepa, Allium sativum, white rot.

Sclerotia of *Sclerotium cepivorum* Berk., the white rot pathogen of *Allium* spp., usually were fungistatically dormant in nonsterile soil, but roots, root extracts, or volatile allyl and *n*-propyl sulfides from *Allium* spp. specifically stimulated sclerotial germination (3,5,7,14). In contrast to 70–100% germination in presence of stimulants (specific germination), only 0–18% germinated in nonamended soil or soil amended with extracts from other plants (2,5) (nonspecific germination). Sclerotia from in vitro cultures incorporated into field soil did not respond to allium-induced stimulation until after several weeks in soil (3,9); neither this delay in induced germination nor the mode of action of the stimulation are understood. Membrane-sterilized water, expressed from field soil, inhibited germination (13). When the small (0.3–0.6 mm in diameter) black sclerotia of *S. cepivorum* germinated in nonsterile soil it was by eruption of a plug of mycelium from the sclerotium medullary region through the sclerotium rind. This hyphal-plug germination occurred only once and hyphae radiated from the sclerotium which eventually collapsed (3). Another type of germination, in which separate hyphae grew from the surface of sclerotia with apparently intact rinds, was described for sclerotia produced from sterile culture placed on autoclaved soil (1), but this second type has not been described in nonsterile soil. Sclerotia recovered from field soil germinated slowly and generally did not germinate on agar unless associated organisms were eliminated (4,6,8) or selectively inhibited (6,14,16). Both types of germination were observed with surface-sterilized sclerotia on both water agar (WA) and nutrient agar, but only hyphal-plug germination was seen with nonsurface-sterilized sclerotia on nonsterile soil (9). The numbers of sclerotia recovered from field soil germinating on agar were about equal to those which specifically germinated on soil dampened with garlic extracts (9).

Although the specificity of stimulatory components from *Allium* spp. on sclerotium germination of *S. cepivorum* has been demonstrated, the effects of variation in soil temperature and moisture on specific and nonspecific germination and on infection are not clear. Locke (15) placed sclerotia recovered from naturally infested soil on nonsterile soil of unspecified dampness and observed nonspecific germination (17% maximum germination of an undescribed type) within the same narrow (10–22 C temperature range in which Walker (20) observed symptom development in onions grown in naturally infested soil. However, Locke (15) reported that infection occurred over a wider temperature range, 5–30 C, which is the same range reported for mycelial growth in culture (1,15,17,19,20). Coley-Smith (3) reported that stimulated germination (hyphal-plug type) at 20 C increased with increasing soil-water content (germination at saturation was not determined because onion seed did not germinate), but infection occurred predominantly at an intermediate soil-water content (40–90% water holding capacity, WHC). Walker (20) also reported that more symptom development occurred in naturally infested soil at intermediate soil-water contents (20–80% WHC).

Moisture tension or matric potential is a better measure of moisture availability in soil than is moisture content (11,12); in this study, sclerotial germination and infection were determined at various combinations of soil temperature and soil matric potential.

MATERIALS AND METHODS

Preparation of inoculum. Sclerotia of *S. cepivorum*, isolate TL4-2 recovered from onion at Tulelake, California, were produced as described previously (9). To alleviate constitutive dormancy, sclerotia that passed through a 0.850-mm screen and remained on a 0.250-mm screen were mixed with noninfested Tulelake soil (unclassified soil, pH 6.8, 14% organic matter) enclosed in nylon mesh bags (3.5 grids per millimeter) and buried at 8-cm depth from April through July, 1976, in the field at Tulelake. Bags were recovered and the contents were allowed to air dry at 22–24 C. One to 3% of the recovered sclerotia were brittle with hollow shells, but 97–99% of the sclerotia did not crumble when handled with fine-pointed forceps and were at least 99% viable (9).

Plant extracts. Fresh garlic cloves (*Allium sativum* L. 'California Late') were blended with distilled water (250 g/250 ml) for 30 sec at low speed in a Waring Blendor. The extract was squeezed from the mixture through cheesecloth and filter paper. Undiluted and 10- and 100-fold dilutions of this extract were used to stimulate germination in soil. All extracts were freshly prepared before use. Potato extract was prepared similarly and diluted 10-fold.

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Soils. Two types of California soil were used in experiments reported here: an unclassified soil of volcanic base (pH 6.8 and 14.0% organic content) from Tulelake, CA; and Yolo fine sandy loam (YFSL) soil (pH 7.4 and low organic content) from Davis, CA. Each was collected from areas not infested with *S. cepivorum*, and held air dry in large canisters. Before use, soil was passed dry through a 2-mm screen. Unsterile soil was used in all experiments. Unless otherwise specified, all soil weights are expressed in oven-dry equivalents.

Direct observation of germination. To determine if sclerotia germinated repeatedly and if secondary sclerotia were formed in soil in the absence of host tissues, germination of sclerotia and growth of hyphae were observed directly. Sclerotia were placed in 10 rows of 10 sclerotia each on 7- × 9-cm pieces of nylon mesh (3.5 grids per millimeter) dampened with water. Nylon pieces were placed 3.5 cm from the top and against the inner surface of glass tubes (15-cm tall, 30-mm diameter). Sclerotia extended in vertical rows from 4 cm to 10 cm below the tops of tubes and between the nylon mesh and glass. A rubber stopper with a hole covered by nylon mesh was inserted into the bottom of tubes which were filled to 14 cm with 110 g of the Tulelake soil. Treatments included water, garlic extract (100-fold dilution), and potato extract used to moisten the soil in the tubes. During the experiment, soil was saturated and then allowed to dry to a water content (weight basis from a moisture release curve) equivalent to −3 bars matric potential before resaturation. Four tubes of each treatment were held in the dark at 15 C for 60 days and the experiment was repeated four times.

Effect of soil matric potential and temperature on germination. To observe germination of sclerotia in Tulelake soil at different matric potentials, 1 g of soil, 25 sclerotia, and 2 g of additional soil were alternately layered into 7-mm-deep cylinder sections of 2.4-mm diameter plastic tubing covered on one end with fiberglass screen (6.5 grids per centimeter). Different techniques were used to adjust soil above and below −300 millibars (mb) matric potential (1,000 mb = 1 bar). For matric potentials (ψ_m) between 0 and −300 mb, cylinders filled with air-dry soil and sclerotia were placed screenside down on a 1-cm-thick layer of soil on tension plates (Büchner funnels with porous, sintered-glass plates) connected by adjustable water columns to reservoirs as described by Griffin (12) and Duniway (11). Cylinders were pressed lightly into the soil to ensure contact between soil in the cylinders and on the tension plates. Two tension plate systems containing either distilled water or garlic extract (diluted 1:100) were used for each ψ_m value. To reduce the loss of stimulatory volatiles and stimulation of sclerotia in water controls, tension plates were covered with plastic bags and reservoirs were sealed except for a pinhole for pressure equilibration.

Soil and sclerotia were adjusted with distilled water to ψ_m values less than −300 mb to −3 bars with a pressure plate apparatus (11). After removal from the apparatus, half of the soil was sprayed with 1 ml of undiluted garlic extract per 100 ml of soil water and mixed well, and the other half was treated similarly with distilled water. No change in water content could be detected with this small amount of additional moisture, and overall soil water potentials (ψ) as determined isopiestically (10) were similar between the sprayed halves. Plastic cylinders packed with sprayed soil and sclerotia were then embedded individually in 17 g of the same soil in 50-ml beakers. Beakers were sealed with a plastic wrap which allowed gas exchange but restricted water loss. Beakers were placed in ventilated temperature chambers and incubated for different times. Moisture loss from soil in covered beakers was less than 5% of the actual water content in all treatments after 21 days. Treatments included sclerotia buried in soil with and without garlic extract at all combinations of reported ψ_m values and temperatures. Each treatment was replicated four times and selected portions of the

TABLE 1. Germination of sclerotia of *Sclerotium cepivorum* in two California soils at 15 C with and without garlic extract[a]

Soil	Wetting medium	Germinated sclerotia (%) at soil matric potential[b]: 0	−5 mb	−45 mb	−85 mb	−140 mb	−200 mb	−300 mb	LSD ($P = 0.05$)
Tulelake[c]	Garlic extract	0	9 (±10)[d]	41 (±10)	48 (±10)	52 (±4)	61 (±4)	68 (±7)	13.6
	Water	0	0	2 (±2)	2 (±2)	4 (±3)	6 (±2)	6 (±2)	4.0
YFSL[e]	Garlic extract	0	18 (±7)	34 (±13)	43 (±4)	53 (±4)	66 (±8)	78 (±11)	15.4
	Water	0	0	1 (+2)	1 (±2)	1 (+2)	3 (±2)	3 (±4)	2.2

[a] Sclerotia recovered in a germinated condition after 21 days in soil.
[b] mb = bar/1,000.
[c] Unclassified soil of volcanic origin (pH 6.8, 14% organic content).
[d] Data expressed as percentages and are the means of four replications (standard deviations in parenthesis).
[e] Yolo fine sandy loam (pH 7.4, low organic content).

TABLE 2. Combined effect of temperature and moisture tension on the germination of sclerotia of *Sclerotium cepivorum* in a California soil with and without garlic extract[a]

Temperature[c] (C)	Germinated sclerotia (%) at soil matric potential[b]: −12.5 mb	−45 mb	−100 mb	−300 mb	−1 bar	−3 bar	LSD ($P = 0.05$)[d]
9	0/0[e]	1/0	4/0	6/2	2/0	0/0	4.3/−
12	5/0	7/1	7/1	17/1	12/2	0/0	8.3/NS
15	26/0	44/7	69/11	65/4	19/1	17/0	16.1/5.3
18	31/2	52/4	75/9	78/16	62/4	21/0	16.7/8.2
21	3/0	6/1	28/2	35/1	33/1	2/0	9/7/NS
24	0/0	1/0	1/0	1/0	1/0	0/0	NS/−
LSD ($P = 0.05$)[d]	10.2/−	11.1/3.2	12.1/4.2	14.0/4.8	12.8/2.6	6.5/−	

[a] Sclerotia recovered in a germinated condition after 21 days in Tulelake unclassified soil.
[b] No sclerotia germinated at 0 or −10 bars.
[c] No sclerotia germinated at 0, 4, 6, 27, or 30 C.
[d] LSD ($P = 0.05$) was calculated only among treatments in which germination occurred. NS = no significant difference, $P = 0.05$.
[e] Data expressed as percentages and are the means of four replications. Numerator = stimulated germination with garlic extract; denominator = unstimulated germination without garlic extract.

experiment were repeated.

Germination of sclerotia between ψ_m values of 0 and −300 mb in Tulelake and YFSL soils was compared at 15 C in a growth chamber. Sclerotia were placed in soil in plastic cylinders as described previously, and cylinders remained on tension plates for various times. To compare germination of sclerotia buried in soil with germination of sclerotia on the soil surface, 100 sclerotia were also placed directly on the surface of the soil on tension plates between the plastic cylinders. Treatments included soil moistened with either garlic extract or water.

Following incubation, soil from plastic cylinders was gently washed on a 0.250-mm screen and residue was observed for sclerotia at ×25 magnification. Sclerotia were considered germinated if a dense growth of mycelium had projected from a disrupted rind. Nongerminated sclerotia were picked from the residue and tested for viability on WA. Sclerotia placed on the soil surface were removed as they germinated and those which had not germinated after the incubation period were tested for viability on WA.

Effect of soil matric potential and temperature on infection of onion seedlings. To determine the effect of soil matric potential and temperature on infection, onion seedlings (*Allium cepa* L. 'Southport White Globe'), grown in washed sand for 20 days at 15 C, were transplanted (five per beaker) to 100-ml beakers containing soil adjusted to various ψ_m values on pressure plates and tension plates without added extract. Sclerotia were germinated at 18 C on the surface of Tulelake soil containing garlic extract (diluted 1:10) at −200 mb. Sclerotia in which the eruptive germination plug was evident were placed 1 cm deep next to each seedling in some beakers; plants in other beakers served as uninoculated controls. Beakers covered with plastic, as described previously, were placed in various temperature chambers and treatments were replicated four times. Moisture loss from covered beakers was less than 5% of the actual water content in all treatments after 21 days. Selected portions of the experiment were repeated, and a similar experiment was conducted with 3-mm diameter agar plugs taken from the edge of actively growing cultures on potato-dextrose agar used as inocula instead of sclerotia.

RESULTS

Direct observation of germination. Only hyphal-plug germination was observed from sclerotia placed between nylon and the inner wall of glass tubes filled with nonsterile soil. After the germination plug appeared, a dense growth of mycelium remained attached to the sclerotium rind for about 20 days as mycelium grew about 1–2 cm away from a sclerotium. Within a few days after mycelium stopped growing, hyphae gradually began to disintegrate, eventually leaving a hollow, collapsed rind of the sclerotium. Mean percentage germination of sclerotia in soil tubes moistened with water, potato extract, or garlic extract averaged for all four experiments, was 11, 17, and 91%, respectively, after 60 days. Means were all significantly different ($P = 0.05$). Germination (70–75% of total) predominantly occurred between 10 and 25 days after the experiment began, although some occurred even after 50 days.

A few (5% or less) sclerotia appeared to decay (collapsed without apparent germination) during the experiment in all treatments; other sclerotia that apparently did not germinate or decay remained intact. In one experiment, soil tubes irrigated with potato extract or water for 60 days were wetted with garlic extract. A flush of germination in these tubes occurred 8–10 days after this treatment and continued for several weeks until the percent germination approached that of sclerotia in tubes originally dampened with garlic extract. In another experiment, all intact sclerotia were recovered from tubes after 60 days and tested for viability on agar. The sum of the sclerotia which germinated in soil and those which remained intact and germinated after placement on agar was greater than 84% for all treatments. Hyphae radiating from sclerotia along the surface of the glass and in contact with nylon mesh and soil formed microconidial sporodochia, infection cushions (against the glass, nylon, or sandy particles behind the nylon) and sclerotium initials, but less than 0.4% of sclerotia germinating in any treatment formed a single smaller (0.2-mm diameter) secondary sclerotium. Formation of two secondary sclerotia was observed only once. Secondary sclerotia usually germinated in the garlic extract treatment (by hyphal-plug germination) 3–4 wk after apparent morphological maturity. Since more secondary sclerotia may have formed unobserved in the soil (hypha penetrated soils through the nylon mesh), soil was removed from tubes after 40 days in similar separate experiments and assayed by wet-sieving through 0.85-, 0.25-, and 0.15-mm soil screens as described previously (9). However, no additional sclerotia were recovered. Other California isolates of *S. cepivorum* also exhibited a similar pattern of stimulated germination, infection, and secondary sclerotium formation.

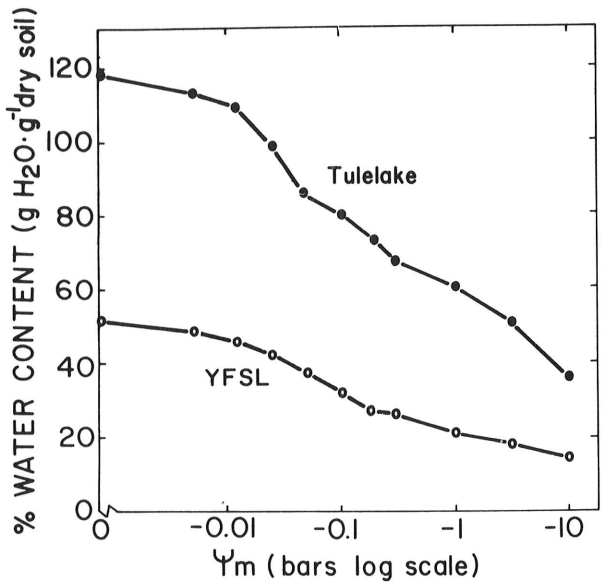

Fig. 1. Relationship between water contents and matric potentials (ψ_m) of an unclassified Tulelake soil and Yolo fine sandy loam soil (YFSL) undergoing drying on tension or pressure plates.

Germination and decay of sclerotia at various temperatures and soil matric potentials. Immediately after sclerotia were placed in soil at various soil matric potentials 98% of sclerotia could be recovered intact and viable. No sclerotia had germinated within 7 days after placement in any of the treatments. When sclerotia for which the eruptive germination plug of mycelium had just emerged were placed in soil at various ψ_m values and temperatures and then recovered at different times, the dense growth of mycelium persisted for at least 15 days; therefore, sclerotia which germinated in soil after only 7 days could be distinguished when recovered up to 21 days after experiments had begun. Based on these observations, sclerotia that were recovered in each experiment 21 days after experiments had begun were classified in three groups: ungerminated but viable; germinated; and decayed, nonviable, or missing. Germination which occurred in or on soil amended with garlic extract is referred to as stimulated germination and germination which occurred without garlic extract is referred to as unstimulated germination. Stimulated germination of sclerotia buried in Tulelake and YFSL soils at 15 C is shown in Table 1. Germination increased from 0% at 0 bars matric potential for both soils to 68 and 78% at −300 mb for Tulelake and YFSL soils, respectively. Differences between germination of *S. cepivorum* in the two soils were not statistically significant, even though the water contents of the two soils were quite different (Fig. 1). Unstimulated germination of buried sclerotia increased from 0% at 0 bars to 3–6% at −300 mb for both soils. Stimulated germination of sclerotia buried in soil and sclerotia placed on the soil surface (data not shown) were similar at most matric potentials although twice as many sclerotia germinated on the surface of soil at a ψ_m value of −5 mb than germinated in soil. Numbers of sclerotia that decayed or that remained ungerminated but viable were similar in

both soils.

The percentage of germination by sclerotia after 21 days of burial in Tulelake soil at various soil matric potentials and temperatures is shown in Table 2. The optimum treatment combination for stimulated germination of sclerotia was at 18 C for most ψ_m values and at −300 mb for most temperatures. Stimulated germination only occurred between 9 and 24 C and between −12.5 mb and −3 bars. Interaction between matric potential and temperature was apparent from the wider range of temperatures and ψ_m values over which germinatin occurred at near-optimum conditions, compared with the narrower ranges at more restrictive conditions. For unstimulated germination (soil dampened, but without garlic extract), the optima for germination were the same as for stimulated germination, but percentages of germination were lower and the ranges permitting germination were narrower (Table 2).

Sclerotia not accounted for by either the germinated or ungerminated but viable categories were classified as decayed (Table 3). The percentage of all sclerotia which decayed was directly associated with increasing temperature and increasing (becoming less negative) matric potential and this relationship was not influenced by the extent of germination.

The percentage of sclerotia remaining ungerminated but viable after 21 days is not listed, but a datum for each treatment may be calculated by adding percent germination (Table 2) and percent decay (Table 3) figures and subtracting the total from 100. The number of ungerminated but viable sclerotia was affected by the extent of both germination (especially in soil dampened with garlic extract) and decay.

Infection of onion seedlings at various temperatures and soil matric potentials. Seedlings in Tulelake soil at various combinations of temperature and soil ψ_m values were removed from beakers and infection by *S. cepivorum* was determined by isolations. The day on which any plants in beakers first showed symptoms of white rot also was recorded for each treatment. Symptomless plants were checked for infection after 22 days, but none was detected. In both uninoculated and inoculated treatments, some or all plants wilted at −3 and −10 bars but *S. cepivorum* was not isolated from any of these plants. Times for disease to develop at various temperatures in soils at various ψ_m values are shown in Table 4. Disease development time decreased with increasing temperature, but no apparent infection or disease development occurred at less than 6 C or higher than 24 C. Disease only developed between −45 mb and −3 bars, but the temperature range was more restricted at −3 bars than at other matric potentials more conducive to sclerotial germination. Time for symptom development was not affected significantly by matric potential. Infection from agar plugs with actively growing mycelium occurred at the same combinations of temperature and matric potential as infection from germinating sclerotia, except that infection also occurred at 9 C and −3 bars. Time for symptom development

TABLE 3. Combined effect of temperature and moisture tension on the decay of sclerotia of *Sclerotium cepivorum* in a California soil with and without garlic extract[a]

Temperature[c] (C)	Decayed sclerotia (%) at soil matric potential[b]: 0	−12.5 mb	−45 mb	−100 mb	−300 mb	LSD ($P = 0.05$)[d]
6	5/6[e]	2/3	1/1	0/0	0/0	3.7/3.3
9	39/35	21/28	14/14	5/4	0/0	9.9/8.5
12	62/58	36/40	18/22	7/10	2/4	12.6/14.1
15	68/71	67/70	44/54	12/12	2/5	12.6/10.5
18	84/80	62/68	45/52	15/16	5/8	11.5/11.3
21	98/96	72/74	56/59	24/23	9/11	14.2/12.4
24	99/100	77/85	76/76	28/29	19/22	11.5/10.2
27	100/100	91/92	88/91	55/52	16/13	18.4/17.5
30	100/100	100/100	98/97	69/60	20/23	15.9/14.0
LSD ($P = 0.05$)[d]	13.3/14.2	10.5/8.7	14.4/11.5	9.4/11.2	6.6/7.4	

[a] Sclerotia were classified as decayed if deteriorated, nonviable or missing after 21 days in Tulelake unclassified soil.
[b] No sclerotia decayed at −1, −3, or −10 bars.
[c] No sclerotia decayed at 0 or 4 C.
[d] LSD ($P = 0.05$) was calculated only for treatments in which some, but not all, sclerotia were classified as decayed.
[e] Data expressed as percentages and are the means of four replications. Numerator = decay in soil with extract; denominator = decay in soil without extract.

TABLE 4. White rot development on onion seedlings inoculated at 1-cm depth with germinated sclerotia of *Sclerotium cepivorum* and incubated at various temperatures and soil matric potentials[a]

Temperature[c] (C)	Postinoculation symptom development time (days) at soil matric potential[b]: −45 mb	−100 mb	−300 mb	−1 bar	−3 bars
6	20	17	15	19	—[d]
9	15	9	9	12	—[d]
12	9	8	8	8	11
15	6	7	7	8	9
18	7	6	6	7	8
21	5	5	5	4	5
24	4	4	4	4	4
LSD ($P = 0.05$)[e]	2.1	2.4	2.6	2.8	2.2

[a] Plants not diseased after 22 days were uninfected based on observation and failure to isolate the pathogen from plants. Data are means of four replications.
[b] No disease developed at soil matric potentials of 0, −12.5 mb, or −10 bars.
[c] No disease developed at 0, 4, 27, or 30 C.
[d] — = No infection within 22 days.
[e] LSD ($P = 0.05$) was calculated only among treatments in which symptoms occurred. Times of disease development were not significantly different ($P = 0.05$) among soil matric potentials at any temperature when treatments were excluded in which no disease occurred.

varied from an average of 9.5 days at 6 C to an average of 3.5 days at 24 C for ψ_m values at which infection occurred from mycelium on agar plugs.

DISCUSSION

The data relative to the influence of temperature on germination generally confirm and extend observations by Locke (15) who studied only nonstimulated germination, and those of Walker (20) who reported the results of studies of disease development at constant temperature in naturally infested soil. These data also are in agreement with Locke (15) in that infection can be initiated by mycelium over a wider range of temperatures than the range to which germination of sclerotia is restricted. In our experiments no infection or disease was observed at 27 or 30 C, whereas Locke reported that as much as 10% infection occurred at 30 C. Whether the differences are due to technique or other factors is uncertain; Locke reported no details of the methods he used. Walker did not report disease development at 6 C or at temperatures higher than 22 C; germination probably did not occur at these temperatures. In the present study, symptoms developed more rapidly with increasing temperature between 6 and 24 C.

Data for effects of soil moisture on sclerotium germination conflict with those of Coley-Smith (3) who indicated that stimulated germination generally increased with increasing soil moisture levels. We observed a decrease in germination as soils became drier or wetter than field capacity (−300 mb). Part of this discrepancy may due to the difference in measuring soil moisture (he used soil water content); also, he did not determine percent germination at saturation. Soil water content is a less accurate way of measuring the availability of soil water to microorganisms than is soil matric potential (11,12) as used herein, because soils of a given water content may vary in the extent that water is bound to soil particles. For example, in our experiments germination occurred predominantly above a ψ_m value of −3 bars which for two different soils corresponded to a water content of about 60 and 20%, respectively (Fig. 1). If the two soils instead had been compared at equivalent soil water contents, the results would not be as straightforward.

Germination was similar in our two soils at each ψ_m value tested, a result which suggests that germination is influenced more by moisture tension than by soil water content (Fig. 1). However, other soil characteristics also may influence germination. Results reported here agree with both Coley-Smith (3) and Walker (20) in that infection and disease occur at intermediate levels of soil moisture. The rate of symptom development, however, was not significantly affected by the range of matric potentials that permitted infection (Table 4).

The percent of sclerotia that decayed in soil was not related to germination because decay was similar in treatments with and without garlic extracts which differed widely in the amount of germination. In general, wetter and warmer conditions increased the percent decay. These results support those of Scott (17) who indicated that flooding might eradicate sclerotia from infested soil. However, in most natural conditions soil rarely remains wetter than −300 mb (field capacity) for more than a few hours or days and appreciable decay would not be expected during such short periods at near saturation. Direct observation of sclerotia in soil tubes irrigated to saturation and allowed to dry to approximately −3 bars moisture tension before rewetting, revealed little decay. These data support reports that sclerotia remain ungerminated but viable for extended periods of time in field soil in the absence of *Allium* spp. hosts (2), and that sclerotial populations decline due to stimulated germination during the season when *Allium* spp. crops are grown; thus, continued survival appears to require production of sclerotia on infected host plants (9). Direct observations of sclerotia in tubes of soil in which very few secondary sclerotia were seen, agree with those of Scott (18) who concluded that *S. cepivorum* is a poor competitor for nutrients in soil. That a slight but significantly higher level of germination (17%) occurred in soil irrigated with potato extract compared with soil irrigated with water (11%) conflicts with other reports (2,3), but greatly increased germination with garlic extracts (85%) agrees with these same reports.

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