Phacelia, Lana Woollypod Vetch, and Austrian Winter Pea: Three New Cover Crop Hosts of *Sclerotinia minor* in California

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ABSTRACT

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A 2-year field and greenhouse study identified three cover crops as new hosts for *Sclerotinia minor*. Pathogenicity was established by planting 4-week-old transplants of six cover crops and lettuce (*Lactuca sativa*) into sand amended with sclerotia. After 4 weeks of incubation in a greenhouse, phacelia (*Phacelia tanacetifolia*), Lana woollypod vetch (*Vicia dasycarpa*), and Austrian winter pea (*Pisum sativum* L. subsp. *arvense*) exhibited disease symptoms, as did lettuce, and *S. minor* was reisolated from the diseased cover crop plants. To assess susceptibility in a field situation, seven cover crop species, lettuce, and fallow treatments were placed for two consecutive years into randomized, replicated field plots infested with sclerotia. In both the 1993 and 1994 experiments, disease was observed on phacelia, Lana woollypod vetch, purple vetch (*Vicia benghalensis*), Austrian winter pea, and lettuce. Oilseed radish, barley, and fava bean did not become diseased. When lettuce was planted after cover crop incorporation, phacelia, Lana woollypod vetch, and Austrian winter pea plots had significantly higher lettuce drop incidence than fallow plots in the first year. In the second year, only phacelia plots had significantly more lettuce drop. In a commercially planted lettuce field, lettuce drop incidence was significantly higher 1 year in plots previously planted to phacelia. This is the first report of *S. minor* as a pathogen of phacelia, Lana woollypod vetch, and Austrian winter pea cover crops in California.

Winter cover crops are planted to add organic matter to soil, improve soil structure and water infiltration, reduce soil erosion, provide nutrients for subsequent crops, and reduce nitrate loss from leaching (4,12,17). In addition, cover crops can function as trap crops, reducing soil populations of plant parasitic nematodes (2,3,6), or produce natural biocidal compounds such as glucosinolates (5,13). Because of these soil-plant nutrition and pest management characteristics, farmers in the Salinas Valley, CA, have recently shown increased interest in winter cover crops for both conventional and organic vegetable farming systems and have begun incorporating newly utilized cover crop species such as phacelia (*Phacelia tanacetifolia* Benth.) and oilseed radish (*Raphanus sativus* L.) into crop rotations.

In contrast to these benefits, cover crops also may allow plant pathogen populations to increase and thus cause problems for the agronomic crop planted after cover crop incorporation (16). In the Salinas Valley, the impact of phacelia, oil seed radish, and other cover crops on populations of *Sclerotinia minor* Jagger, the causal agent of lettuce drop, is not known. A previous report (1) pointed out that purple vetch (*Vicia benghalensis* L.) cover crops were associated with increases in lettuce drop disease of iceberg lettuce (*Lactuca sativa* L.). Because of the extensive lettuce industry in the Salinas Valley (lettuce production in 1994 in Monterey County was 43,560 ha, with a value of $505 million), information was needed on the interaction of new cover crop introductions and *S. minor*. The purpose of this study was to test winter cover crop species for susceptibility to *S. minor* and to assess the effect of cover crop plantings on lettuce drop incidence in field situations.

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MATERIALS AND METHODS

Pathogenicity tests. To test pathogenicity of *S. minor* on various cover crops, inoculum of lettuce isolate Sm 92-01 was produced on sterilized potato pieces for 6 weeks, cultures were washed free of potato residue, and the remaining sclerotia were air dried for 48 h in a fume hood (14). Twenty 4-week-old transplants of the following cover crops were potted into 10 × 10 cm pots containing sterilized sand amended with sclerotia (35 sclerotia/100 cm^3 sand): phacelia (cv. Angelia), oilseed radish (cv. Nemex), Lana woollypod vetch (*Vicia dasycarpa* Ten.), fava bean (*Vicia faba* L.), and Austrian winter pea (*Pisum sativum* L. subsp. *arvense*). Barley (*Hordeum vulgare* L. cv. U. C. 603), a commonly used cover crop that is a nonhost of *S. minor*, and lettuce (cv. Alpha) transplants were grown and transplanted in the same way. Cover crop and lettuce transplants also were grown in sterilized sand without sclerotia. All plants were incubated in a greenhouse at 23 ± 2°C/10 ± 2°C day/night temperatures.

After 4, 5, and 6 weeks, plants showing symptoms of disease were removed from pots, washed free of sand particles with tap water, soaked in 0.5% NaOCl for 5 min, and rinsed three times with sterile, distilled water. Small pieces of crown and stem tissue were placed in petri plates containing acidified potato dextrose agar (2 ml of 25% lactic acid per liter). Plates were incubated at 22 ± 2°C and resulting fungal colonies were identified. The experiment was conducted twice.

Field tests. To assess susceptibility of cover crops in a field situation and to measure their effect on lettuce drop incidence, field plots were established in the Salinas Valley in 1993 and 1994. The experimental design was a randomized complete block with five replications. Plots consisted of two raised beds (each 1 m wide by 5 m long). Plots were separated by 1-m borders. For the 1993 experiment, all plots were infested with sclerotia prior to planting by producing inoculum of isolate Sm 92-01 as described previously. Dried sclerotia that passed through 2.00-mm but not through 0.85-mm aperture brass sieves (U.S.A. Standard Testing Sieves nos. 10 and 20, respectively) were placed into two rows on each raised bed at 1.25 cm depth with an EarthWay Precision Seeder (EarthWay Products, Inc., Bristol, IN). Inoculum was added at the rate of 140 sclerotia per m for each row.

Following plot infestation, crops were direct-seeded into the same two rows with a Cole Planet Jr. hand-planter (Powell Manufacturing Co., Inc., Bennettsville, SC) on 11 November 1992. Cover crop treatments were the following: phacelia (cv. Angelia), oilseed radish (cv. Nemex), barley (cv. U. C. 603), Lana woollypod vetch, purple vetch, fava bean, and Austrian winter pea. Fallow and unthinned lettuce (cv. Parris Island Cos) controls were also included. One day prior to planting, leguminous cover crops (two vetch species, fava bean, and Austrian winter pea) were treated with a slurry of Pea, Vetch, and Lentils Rhizobium Inoculum (Urbana Labs, Urbana, IL) at 227 g per 45 kg of seed and Pelgel sticker (Nitragin Company, Inc., Milwaukee, WI) at 482 g per 45 kg of seed.

Crops were grown to maturity and evaluated for disease incidence on 10 March 1993 by determining the total number of plants and the number of plants showing symptoms in four 1-m^2 sections per replication. Symptomatic plants were collected and *S. minor* isolated as previously described. On 3 April, plots were incorporated with a power spader (Celli SpA, 47100 Forli′ [FO], Italy), which maintained plot integrity and prevented interplot mixing of soil and plant residue. Following crop residue decomposition and bed reshaping, lettuce (cv. Alpha) was planted in two rows per bed on 26 May, thinned and grown according to commercial practices, and evaluated for lettuce drop incidence on 9 August by determining the percent diseased lettuce in each 2-bed × 5-m plot.

In preparation for the 1994 experiment, lettuce in the 1993 plots was incorporated with a power marvin incorporator that minimized interplot mixing. Plots were left as listed beds until bed shaping and cover crop planting on 10 November 1993. Crops were planted in the same plots as the previous season, resulting in two consecutive years of the same cover crop per plot. Plants were evaluated for disease incidence and collected for *S. minor* isolations on 8 March 1994, and incorporated into the soil on 16 March. Lettuce (cv. Alpha) was planted 1 June, thinned and grown according to commercial practices, and evaluated for lettuce drop incidence on 8 August.

For both experiments, fungicides were not applied during any phase of the experiment. Analysis of variance was performed on the data with the MSTAT-C statistical package and mean comparisons of disease incidence made with Fisher's protected least significant difference ($P = 0.05$).

Soil inoculum assessment. To evaluate the effect of crops on soil sclerotial numbers, soil samples were collected both years (12 May 1993 and 5 May 1994) just prior to the planting of lettuce. In each plot, eight 25-cm-deep soil cores were removed from plant rows with a 2.5-cm-diameter soil probe. The eight cores from each plot were bulked into one composite sample. Soil samples were mixed thoroughly, divided into 100-g aliquots, soaked for 2 min in a 1% Calgon (sodium polymetaphosphate) solution, and screened for sclerotia with the hydropneumatic root elutriator (Gillison's Variety Fabrication, Inc., Benzonia, MI) technique as described by Subbarao et al. (15). Sclerotia were collected and counted with a dissecting stereomicroscope at ×10 magnification. Analysis of variance was performed on the data with the MSTAT-C statistical package and mean comparisons of numbers of sclerotia per 100 g of soil were made with Fisher's protected least significant difference ($P = 0.05$).

Disease incidence in a commercial field. In 1993 and 1994, disease incidence for cover crops and lettuce was measured in a commercial field in the Salinas Valley that had a history of lettuce drop and that was planted with replicated sections of cover crops intended for nitrate leaching studies. The experimental design was a randomized complete block with three replications. Plots consisted of four raised beds (each 1 m wide by 332 m long). Cover crop treatments were phacelia, rye (*Secale cereale* L. cv. Merced), and fallow that were planted in the same plots for two consecutive winters (4 December 1992 and 3 December 1993).

Phacelia plots were evaluated for symptoms caused by *S. minor* when the cover crops approached maturity (4 March 1993 and 2 March 1994). Disease incidence was determined by counting the total number of phacelia plants and the number of plants showing symptoms in fifteen 1-m^2 sections per replication. Symptomatic plants were collected and the pathogen isolated as described previously.

Following incorporation of the cover crops (16 March 1993 and 18 March 1994, respectively), the grower-cooperator planted lettuce (cv. Amigo) on 8 April 1993 and 27 April 1994. On 8 June 1993 and 29 June 1994, the incidence of lettuce drop was determined in all treatments by counting the total number of lettuce plants and the number of plants with symptoms in four 2-bed × 30-m sections per replication. The four values were used to derive a mean disease incidence per replication, and all data were analyzed as described previously.

RESULTS

Pathogenicity tests. Phacelia, Lana woollypod vetch, Austrian winter pea, and lettuce plants in infested sand wilted and collapsed after 4 or more weeks. Crown and lower stem tissues were decayed and colonized with white mycelia, and *S. minor* was reisolated from plants of all species. No other pathogens were isolated from these plants. Phacelia, Lana woollypod vetch, Austrian winter pea, and lettuce plants in noninfested sand remained symptomless. Oilseed radish, fava bean, and barley plants transplanted into infested sand did not develop disease symptoms, and *S. minor* was not isolated from stems and crowns. Results of the second experiment were the same as the first.

Field tests. Disease incidence for the cover crops was similar for 1993 and 1994 (Table 1), with phacelia, Lana woollypod vetch, purple vetch, and Austrian winter pea showing symptoms. In both years the unthinned lettuce was severely diseased. *S. minor* was reisolated from diseased phacelia, Lana woollypod vetch, purple vetch, and Austrian winter pea. No other pathogens were isolated. Oilseed radish, barley, and fava bean remained symptomless and were not infected by *S. minor*, with the exception of one fava bean plant.

Symptomatology. In the infested field tests, diseased phacelia exhibited brown, water-soaked lesions on crowns and lower stems. Lesions often girdled the plant, resulting in wilting and plant collapse. Older stem lesions were dry and dark brown or, in some cases, light tan in color. White mycelia grew on diseased stems that were in contact with soil, and sclerotia later were produced on outer stem surfaces and inside the hollow stems. Attached, senescing leaves drooped to the ground and also supported the production of sclerotia.

Diseased Austrian winter pea showed light tan discoloration of lower stems.

Table 1. *Sclerotinia minor* disease incidence on various cover crops and effects of cover crops on sclerotia numbers and lettuce drop incidence for field trials in 1993 and 1994

	Disease incidence (%)[w]		Sclerotia/100 g soil[x]		Lettuce drop incidence (%)[y]	
Cover crop	1993	1994	1993	1994	1993	1994
Phacelia	13.9	21.4	3.4	7.2	20.6	39.4
Oil seed radish	0.0	0.0	0.0	2.8	14.8	24.3
Barley	0.0	0.0	0.6	1.4	11.2	18.0
Lana woollypod vetch	18.4	27.4	5.0	8.0	22.6	31.9
Purple vetch	17.2	19.0	2.6	7.2	17.2	26.5
Fava bean	0.6	0.0	6.2	2.8	8.4	18.6
Austrian winter pea	30.3	36.5	3.2	4.6	32.4	27.7
Romaine lettuce	96.9	82.0	29.0	6.6	23.4	25.4
Fallow control	...	...	1.8	3.0	11.4	18.9
LSD[z]	5.5	8.0	11.9	NS	9.2	13.1

[w] In each plot, plants were evaluated in four 1-m^2 sections.

[x] Samples were collected just prior to the planting of the lettuce crop. Eight soil cores were taken per plot and bulked into a composite sample.

[y] All lettuce plants in the 2-bed × 5-m plots were evaluated.

[z] Least significant difference at $P = 0.05$. NS = Not significant.

These stems rapidly withered and died, resulting in circular areas of plants with dead stems and leaves. Mycelia and sclerotia of *S. minor* were found on lower surfaces of diseased leaves and prostrate stems.

Diseased Lana woollypod vetch exhibited light brown discoloration of lower stems. Stems rapidly desiccated, resulting in dead shoots. Sclerotia frequently were produced on dead stems. In addition, plants abscised large numbers of senescent leaves, which fell to the ground and were colonized by *S. minor*, resulting in the production of sclerotia.

Lettuce drop incidence. In the 1993 field experiment, lettuce plots previously planted to phacelia, Lana woollypod vetch, Austrian winter pea, and unthinned lettuce had significantly higher lettuce drop incidence than fallow plots (Table 1). In 1994, incidence of lettuce drop was significantly greater in plots previously planted to phacelia than in fallow plots.

Soil sclerotial numbers. In the 1993 field experiment, only unthinned lettuce plots had significantly more sclerotia than fallow control plots, and no significant differences were observed between the cover crop treatments (Table 1). In 1994, no significant differences in number of sclerotia were observed among any of the treatments (Table 1).

Disease incidence in a commercial field. In 1993, disease caused by *S. minor* was not observed on phacelia. However, when the field was planted to phacelia the following winter, a mean disease incidence of 1.8% was detected in the phacelia planting. Symptoms of diseased plants were similar to those found in the artificially infested field, and *S. minor* was the only pathogen isolated from diseased phacelia plants.

Lettuce drop incidence varied between the two years (Table 2). For the 1993 crop, lettuce drop incidence was significantly higher in the phacelia plots than in the rye and fallow plots. However, in the 1994 season, drop incidence was very low, with fallow plots having the highest incidence.

DISCUSSION

This is the first report of *S. minor* as a pathogen of phacelia, Lana woollypod vetch, and Austrian winter pea cover crops in California. These cover crops have not been previously reported as hosts of *S. minor*. In artificially infested plots, phacelia plantings were associated with significantly higher lettuce drop incidence for the subsequent lettuce crop in both seasons. Lana woollypod vetch and Austrian winter pea were associated with higher lettuce drop incidence in the first year only.

S. minor failed to cause disease on oilseed radish, barley, and fava bean cover crops in greenhouse or field tests. For both the 1993 and 1994 field experiments, lettuce drop incidence in these three cover crop treatments was not significantly different than in the fallow treatment.

Diseased phacelia plants were detected in commercial lettuce fields in the Salinas Valley. In commercial fields, the impact of phacelia winter cover crop plantings varied, with phacelia being associated with significantly higher lettuce drop incidence in 1 year.

While the data on sclerotia numbers were inconclusive, further investigations would be warranted to clarify how phacelia, Lana woollypod vetch, Austrian winter pea, and other susceptible cover crops might contribute to the inoculum potential of *S. minor* and the epidemiology of lettuce drop disease in Salinas Valley fields. This would be particularly important because of recent findings that other lettuce rotation crops such as basil (*Ocimum basilicum* L.), cauliflower (*Brassica oleracea* L. var. *botrytis* L.), endive and escarole (*Cichorium endivia* L.), fennel (*Foeniculum vulgare* Mill.), and radicchio (*Cichorium intybus* L.) are susceptible to *S. minor* and might also add inoculum to the soil (7–11). Organic lettuce producers must be especially cautious because they cannot use conventional protectant fungicides to protect crops from higher *S. minor* populations that might result from disease on cover crops and the incorporation of this infested biomass.

When selecting cover crops, growers need to consider a series of factors, including soil conditioning benefits, plant nutritional aspects, and pest management advantages and disadvantages. This can lead to a complex decision-making process. Oilseed radish, for example, offers the advantages of not being a host for *S. minor* and being a potential trap crop for sugarbeet cyst nematode (*Heterodera schachtii* Schmidt). However, this cover crop species is a host to the clubroot pathogen (*Plasmodiophora brassicae* Woronin) and two species of root-knot nematodes, *Meloidogyne incognita* (Kofoid & White) and *M. javanica* (Treub) (3). Phacelia is not a host to cyst nematode (2), but is susceptible to root-knot nematode (3) and, as shown in this study, is a host to *S. minor*. While vetch species can supply nitrogen for the subsequent crop (12), they are also hosts of *S. minor* (1) and *Meloidogyne* spp. (5) and can allow *Pythium* and *Rhizoctonia* populations to increase (16). In choosing cover crop species, the degree of cover crop susceptibility to pests and the relative importance of these pests for subsequent agronomic crops will need to be evaluated.

Table 2. Lettuce drop incidence in a commercial lettuce field in the Salinas Valley following phacelia, rye, and fallow cover crop treatments in 1993 and 1994

Cover crop	Lettuce drop incidence (%)[z] 1993	1994
Phacelia	8.5	0.7
Rye	2.0	0.3
Fallow	4.2	1.4
Least significant difference ($P = 0.05$)	1.4	0.6

[z] In each plot, plants were evaluated in four 2-bed × 30-m sections.

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