Planting Date, Fungicide, and Cultivar Effects on Sclerotinia Crown and Stem Rot Severity in Alfalfa

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ABSTRACT

Sulc, R. M., and Rhodes, L. H. 1997. Planting date, fungicide, and cultivar effects on Sclerotinia crown and stem rot severity in alfalfa. *Plant Dis.* 81:13-17.

This study was conducted to determine the effect of planting date, fungicide, and cultivar on severity of Sclerotinia crown and stem rot (SCSR) and subsequent productivity of alfalfa. The cultivars Armor and A9109 were seeded no-till in May, early August, mid August, and late August 1993 and 1994 in a sod uniformly infested with sclerotia of *Sclerotinia trifoliorum*. Four applications of the fungicide vinclozolin effectively controlled the disease. Averaged over years and cultivars, disease severity (percentage of plot area affected) in the no-fungicide treatment was 4, 12, 23, and 41% for the spring, early August, mid August, and late August plantings, respectively. Armor had higher disease severity than A9109 in the 1993 seeding, but not in the 1994 seeding. Forage yield the year after seeding reflected differences in disease severity ratings. The risk of severe SCSR damage in no-till summer seedlings of alfalfa can be reduced dramatically if stands become established early enough so plants reach at least 10 weeks of age by the time apothecia emerge in the fall.

Additional keywords: *Medicago sativa*, plant age

Sclerotinia crown and stem rot (SCSR), caused by *Sclerotinia trifoliorum* Eriks., is one of the most destructive diseases of alfalfa (*Medicago sativa* L.) and other perennial forage legumes in the eastern United States (9). Infection by *S. trifoliorum* occurs in the fall, although symptoms may not be evident until the following spring. Currently, no commercial alfalfa varieties are listed as resistant to *S. trifoliorum*, and no chemicals are registered for control of SCSR in alfalfa.

A general consensus exists among researchers that older alfalfa plants are less affected by *S. trifoliorum* (9). Welty and Busbice (15) stated that, whereas plants of any age are susceptible, the incidence and severity of the disease is greatest in seedlings. Cappellini (2,3) and Rowe and Welty

(12) indicated the disease is especially important in fall seedlings the first winter after planting. Rhodes and Gilbert (9) stated that late summer or early fall seedlings of alfalfa are most vulnerable to SCSR because plants are still in the seedling stage at the time of ascospore release in the fall, whereas plants seeded in the spring are not exposed to ascospores of *S. trifoliorum* until fall, and by then will have passed the seedling stage when susceptibility is greatest. The literature contains no data collected from field studies to substantiate this statement. Dow et al. (4) found that plant age of greenhouse-grown peanut (*Arachis hypogaea* L.) affected relative susceptibility to *S. minor* Jagger. Raynal (6) referred to preliminary, unpublished work showing that some wild species of *Trifolium* and *Medicago* were resistant to *S. trifoliorum* when plants were 2 months old, but were susceptible when seedlings of 1 or 2 weeks were exposed to the pathogen. To our knowledge, the only published data to support the existence of increasing resistance to *S. trifoliorum* with advancing plant age in alfalfa are those of Brune (1) and Reichard (7). Brune (1) found that alfalfa plants were severely affected by SCSR when 2 weeks old, followed by a rapid decrease in disease severity as plant age increased to about 8 weeks. Disease severity ratings remained consistently low in plants that were 8 to 10 weeks of age or older. Reichard (7) found a similar rapid decrease in

disease severity as alfalfa seedling age increased from 2.5 to 5.5 weeks.

The studies reported by Brune (1) and Reichard (7) were conducted in controlled environments. This phenomenon of increasing resistance to *S. trifoliorum* with advancing plant age needs to be validated in field environments, because it may serve as the basis for a management tactic to reduce the risk of SCSR damage in alfalfa. Brune (1) suggested that, because plants older than 8 weeks of age were less likely to be killed by *S. trifoliorum*, adjusting the time of seeding in late summer might result in more uniform stands the following season.

The primary objective of this research was to determine the effect of planting date on severity of SCSR and subsequent productivity of alfalfa established with no-tillage practices. Based on Brune's (1) findings, we hypothesized that spring seedlings would suffer very little SCSR damage, and disease severity would be greater in late August seedlings than in early August seedlings. In addition, we evaluated planting date effects with and without application of vinclozolin, which is highly effective in controlling SCSR in alfalfa (10), and compared planting date effects on SCSR severity in two alfalfa cultivars differing in resistance to SCSR.

MATERIALS AND METHODS

Field experiments were established in 1993 and 1994 at Columbus, OH, in a grass-clover (*Trifolium* spp.) sod uniformly infested with sclerotia of *S. trifoliorum*. To prepare the infested site, the grass-clover sod was inoculated with grain inoculum of *S. trifoliorum* in October the year before seeding. Nine isolates of *S. trifoliorum* collected in Ohio were used. The grain inoculum was broadcast on the grass-clover sod at 50 ml/m². The clover plants were colonized by mycelium of *S. trifoliorum* and abundant sclerotia were formed. The soil was a Kokomo silty clay loam (fine, mixed, mesic Typic Argiaquoll) for the 1993 experiment, and a Crosby silt loam (fine, mixed, mesic Aeric Ochraqualls) for the 1994 experiment. Soil pH was 7.0, available phosphorus (Bray P1) was over 300 kg/ha and available potassium was over 500 kg/ha.

The grass-legume sod was killed 2 to 3 weeks before each planting date with

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Salary and research support provided in part by state and federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University, and by grants from the Ohio Pest Management and Survey Program, and from a seed grant provided by the Office of Research of The Ohio State University. Journal article 55-96.

Accepted for publication 9 October 1996.

Publication no. D-1996-1112-06R
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glyphosate at 3.4 kg a.i./ha in a water volume of 187 liters/ha. Alfalfa was seeded no-till at 16 kg/ha on four dates each year. Planting dates were 20 May, 30 July, 16 August, and 31 August in 1993, and 11 May, 1 August, 16 August, and 30 August in 1994. Hereafter, these will be referred to as spring, early August, mid August, and late August planting date treatments. Plots were irrigated immediately after seeding and then regularly as needed for at least 4 weeks to ensure rapid and uniform establishment. Seedlings emerged within 1 week in the spring and within 3 days in the August plantings. Two alfalfa cultivars, Armor and A9109, were seeded at each planting date. Armor was found to be susceptible to SCSR in field studies (8), and A9109 is an experimental cultivar derived from four cycles of selection for resistance to SCSR. Two fungicide treatments, no fungicide and vinclozolin, were imposed in each planting date-cultivar treatment combination. Vinclozolin was applied at 1.12 kg a.i./ha on or near 15 September, 15 October, and 15 November in the year of seeding, and on or near 15 March in the year after seeding. On each treatment date, vinclozolin was applied in two consecutive passes in opposite directions across the plot, each pass delivering 0.56 kg a.i./ha in a water volume of 234 liters/ha. This ensured good coverage of the plants with the fungicide.

Treatments were replicated four times in a strip-split plot randomization of a randomized complete block design (13). Planting dates were whole plots, cultivars were subplots, and fungicide treatments were stripped across the cultivar subplots. Plot size for an individual experimental unit (a planting date-cultivar-fungicide treatment combination within a replication) was 1.5 × 7.5 m in the 1993 seeding and 1.5 × 5.5 m in the 1994 seeding. All plots were treated uniformly with carbofuran at 0.56 kg a.i./ha in May the year after seeding to control alfalfa weevil (*Hypera postica* Gyllenhal). Potato leafhopper (*Empoasca fabae* Harris) was controlled uniformly in all plots as needed during the summer months with permethrin at 0.17 kg

a.i./ha. Forage growth in the spring-planted plots was removed in July and the first week of September in the seeding year. Forage growth in the August plantings was not removed in the year of seeding.

Disease severity was assessed in May the year after seeding. Visual ratings of the percentage of the stand affected by SCSR (diseased and dead plants) in each plot were recorded independently by the authors. Plants were considered to be infected based on visible symptoms as described by Rhodes and Gilbert (9). The mean of the two ratings for each plot was used in data analysis. Forage yield was measured at four harvests the year after seeding. Harvest dates were 24 May, 28 June, 28 July, and 1 September in 1994, and 24 May, 3 July, 10 August, and 11 September in 1995. The harvested plot area was 1.1 × 6.1 m in 1994 and 1.1 × 4.6 m in 1995. At each harvest, forage was removed with a flail-type mower to a 7.0-cm stubble height and fresh weight was recorded for each plot. Immediately after the fresh forage from each plot was weighed, a 500- to 700-g sample was collected and dried at 60°C for determination of percent dry matter of the harvested forage. Forage dry matter yield was calculated as the product of the fresh weight and the percent dry matter for each plot. Final stand density was determined 2 weeks after the fourth harvest by visual estimation of the percent ground cover of alfalfa in each plot.

Analysis of variance was used to test the effects of years, planting dates, cultivars, fungicide treatment, and interactions for all data. Years and replications within years were considered random sources of variation, whereas planting dates, cultivars, and fungicide treatments were considered fixed.

RESULTS AND DISCUSSION

Fungicide effects. Weather conditions were favorable for apothecial production during the fall (October through December) months of 1993 and 1994. Apothecia were first observed in the experimental area on 13 October 1993 and 18 October 1994. Apothecial production continued

until mid December both years. Inoculum levels were sufficient to cause heavy damage by SCSR in both years. Four applications of vinclozolin effectively controlled the disease, as stand area visibly affected by SCSR was less than 1% in all fungicide-treated plots (data not shown). Rhodes et al. (11) had previously found that a similar treatment regime with vinclozolin effectively protected alfalfa from damage by SCSR. The fungicide-treated plots, therefore, provided an essentially SCSR-free control within the two experiments.

Planting date effects. The planting date and planting date × fungicide treatment effects were significant for all traits measured in the study, except for final stand density in 1995 (Table 1). Delayed planting dramatically increased disease severity in the absence of vinclozolin (Fig. 1). Planting date effects on disease severity ratings were consistent across years; i.e., the year × planting date and year × planting date × fungicide treatment interaction terms were not significant ($P = 0.14$). Mean disease severity ratings across the 2 years were 4, 12, 23, and 41% affected plot area for spring, early August, mid August, and late August seedings, respectively.

SCSR reduced forage yield in the absence of vinclozolin at the first harvest the year after seeding (Fig. 2A,B). The yield loss due to SCSR (yield difference be-

Fig. 1. Planting date effects on severity of *Sclerotinia* crown and stem rot of alfalfa (area visibly affected) the year after no-till establishment in a sod uniformly infested with sclerotia of *Sclerotinia trifoliorum*. Values are for the no-fungicide treatment, averaged over two cultivars and four replications. Vertical bars indicate 1 SE.

Table 1. Analysis of variance summary for traits measured in the study

Source of variation	df	1994					1995				
		Disease severity	Forage yield			Final stand density	Disease severity	Forage yield			Final stand density
			Spring harvest	Summer harvests (3)	Season total			Spring harvest	Summer harvests (3)	Season total	
Dates of planting	3	***	**	**	**	**	3	**	**	**	**
Cultivars	1	**	NS ^b	NS	NS	**	1	NS	NS	NS	NS
Dates × cultivars	3	NS	NS	NS	NS	NS	3	NS	NS	NS	NS
Fungicide treatment	1	**	**	NS	*	*	1	**	**	**	NS
Dates × fungicide	3	**	**	**	**	**	3	**	*	**	NS
Cultivars × fungicide	1	**	**	NS	**	*	1	NS	NS	NS	NS
Dates × cultivars × fungicide	3	NS	*	NS	+	NS	3	NS	NS	NS	NS

^a **, *, and + indicate statistical significance at the 1%, 5%, and 10% probability levels, respectively.

^b Not significant.

tween unprotected plots and corresponding vinclozolin-treated plots) increased with each delay in planting. There was a year $\times$ planting date $\times$ fungicide treatment interaction ($P = 0.01$) for first-harvest yield, primarily because the alfalfa in the early August seeding in 1994 did not realize its full yield potential, regardless of fungicide treatment (Fig. 2A). Alfalfa plants in that seeding date were less vigorous because of weed competition during early establishment. In 1995, forage yield declined with delayed seeding in both fungicide-treated and untreated plots; however, the decline was dramatically greater where vinclozolin had not been applied (Fig. 2B). Although there was a year $\times$ planting date $\times$ fungicide treatment interaction, the ranking of planting dates for yield loss due to SCSR was consistent across years. This is more apparent when yield in unprotected plots is expressed as a percentage of yield in vinclozolin-treated plots. In 1994, first-harvest forage yield in unprotected plots was 95, 80, 73, and 62% of that in the corresponding vinclozolin-treated plots for spring, early August, mid August, and late August

plantings, respectively (Fig. 2A). In 1995, first-harvest yield in the unprotected plots was 92, 88, 64, and 48% of that in the corresponding vinclozolin-treated plots for spring, early August, mid August, and late August planting dates, respectively (Fig. 2B). Thus, there were changes in magnitude of differences among planting date treatments across years, but no changes in their ranking. These yield data confirm the differences in disease severity observed among planting dates (Fig. 1).

Forage yield summed over the three summer harvests (second through fourth harvests) quantified the carryover effect of SCSR damage to alfalfa stand productivity (Fig. 2C,D). Planting date and planting date $\times$ fungicide treatment effects were significant and consistent across years. The yield loss due to SCSR was greatest in the late August planting. Total seasonal forage yield reflected the cumulative damage of SCSR to alfalfa stands the year after seeding (Fig. 2E,F). The cumulative yield loss due to SCSR increased with delayed date of planting: 0.30, 0.95, 2.28, and 3.76 Mg/ha loss of dry matter in unprotected

plots for spring, early August, mid August, and late August plantings, respectively, averaged over years. Total forage yield for the season (averaged over years) in unprotected plots was 98, 94, 85, and 73% of that in vinclozolin-treated plots for spring, early August, mid August, and late August plantings, respectively.

The greatest loss in yield due to SCSR occurred in the first harvest, when plants were directly affected by the pathogen (Fig. 2A,B). The unprotected plots in the

Fig. 2. Effects of planting date and fungicide treatment on forage yield of alfalfa the year after no-till establishment in a sod uniformly infested with sclerotia of *Sclerotinia trifoliorum*. (A,B) First-harvest yield. (C,D) Forage yield summed over the second through fourth harvests. (E,F) Total seasonal forage yield (sum of all four harvests). Values are averaged over two cultivars and four replications. Vertical bars indicate 1 SE.

Fig. 3. Effects of planting date and fungicide treatment on final stand density (visual ground cover) of alfalfa the year after no-till seeding into a sod uniformly infested with sclerotia of *Sclerotinia trifoliorum*. Values are averaged over two cultivars and four replications. Vertical bars indicate 1 SE.

Fig. 4. Planting date effects on severity of *Sclerotinia* crown and stem rot (area visibly affected) in two alfalfa cultivars the year after no-till establishment in a sod uniformly infested with sclerotia of *Sclerotinia trifoliorum*. Values are for the no-fungicide treatment, averaged over four replications. Vertical bars indicate 1 SE.

early and mid August plantings recovered considerably during the summer (Fig. 2C,D). In alfalfa stands, stem numbers per plant increase as plant populations decrease (5), resulting in yield compensation in stands with lower plant populations. Yield loss due to SCSR over the summer harvests reflects the degree of plant density loss and reductions in future yield potential of the stand. For example, the early August planting had forage yields during the summer similar to those of the spring plantings, regardless of fungicide treatment (Fig. 2C, D). Visual stand density in early August plantings was slightly lower than that in the spring plantings (Fig. 3). Presumably, the loss of stand density in the early August planting was not great enough to offset the yield compensation through increased production per plant. In contrast, forage yield loss due to SCSR damage was still evident during the summer for the late August plantings (Fig. 2C,D). Apparently, the reduction in stand density in that treatment (Fig. 3) was greater than any compensatory effect of increased production per plant.

The literature indicates that severity of SCSR in alfalfa varies with plant age or time of seeding (2,3,12,15). To our knowledge, this is the first published data quantifying this phenomenon in the field. Based on the observational evidence in the literature, we expected the spring-sown alfalfa to be less vulnerable to SCSR than late-summer-sown alfalfa. That was indeed the case, especially when spring and late August seedlings were compared. Even more noteworthy were the incremental losses to SCSR with only 2-week delays in planting during August. These data confirm our hypothesis that alfalfa plants older than 8 to 10 weeks would be more tolerant or resistant to infection than younger plants when exposed to ascospore inoculum of *S. trifoliorum* under natural field conditions. Plant age at the time of first apothecia appearance in the field was about 6, 8, 10, and >21 weeks in the late August, mid August, early August, and spring plantings, respectively. Greatest damage due to SCSR occurred in the late August plantings, corresponding closely with previous con-

trolled environment studies in which disease severity increased exponentially in plants less than 8 weeks of age (1).

Cultivar effects. The planting date $\times$ cultivar interaction was not significant for any of the traits measured (Table 1), indicating that the planting date effects discussed previously were consistent across both cultivars. Cultivar effects were not consistent across years (Table 1). In 1994, A9109 suffered less SCSR damage than Armor (Fig. 4). The cultivars did not differ in disease severity ratings in 1995 (Fig. 4). Forage yield and stand density data reflected the differences observed in disease severity ratings; Armor was inferior to A9109 in 1994, but not in 1995 (Table 2). Armor was inconsistent across years in disease severity rating, averaging 28% in 1994 and 17% in 1995, whereas A9109 averaged 17% both years. In contrast, seasonal yield loss due to SCSR (averaged over planting dates) for A9109 increased from 0.94 Mg/ha in 1994 to 2.25 Mg/ha in 1995, whereas yield loss for Armor differed little among years: 2.02 Mg/ha in 1994 and 2.08 Mg/ha in 1995. In the late August planting, seasonal yield loss due to SCSR was 2.02 Mg/ha for A9109 and 3.92 Mg/ha for Armor in 1994. In 1995, seasonal yield loss due to SCSR in the late August planting was similar for both cultivars: 4.62 Mg/ha for A9109 and 4.47 Mg/ha for Armor. Inconsistency in cultivar performance across years has been found in previous studies (L. H. Rhodes, *unpublished*).

Planting date had a greater influence than cultivar on degree of SCSR damage to alfalfa in this study. Yield loss due to SCSR was 2.90 and 4.03 Mg/ha more for the late August than the spring planting date in 1994 and 1995, respectively. Yield loss due to SCSR was 1.91 and 3.71 Mg/ha more for the late August than the early August planting date in 1994 and 1995, respectively. In contrast, yield loss due to SCSR varied at most by 1.89 Mg/ha between cultivars in 1994, and there was no difference between cultivars in 1995 ($P = 0.46$).

These data demonstrate that the risk of SCSR damage is minimal when alfalfa is

seeded in the spring. When alfalfa is seeded no-till in late summer, the risk of SCSR damage is dramatically reduced in Ohio and surrounding regions if the seedlings emerge by early to mid August and weather conditions are favorable for good growth during the fall months. Recommended late summer seeding dates are 1 to 15 August in northern Ohio, and 1 to 30 August in southern Ohio (14). Our study demonstrates that seeding alfalfa toward the later part of these recommended time frames could result in a dramatic increase in disease losses to *S. trifoliorum*. Earlier seeding is encouraged where *S. trifoliorum* inoculum may be present, but the dilemma for producers remains in that timely establishment is dependent on adequate soil moisture supply. Delayed emergence due to lack of moisture will result in younger plants at the time of ascospore release, with the consequent increase in susceptibility to SCSR. Therefore, the benefit of achieving genetic resistance to *S. trifoliorum* cannot be minimized.

ACKNOWLEDGMENTS

We thank Sam Stratton, FFR Cooperative, for providing seed of A9109 alfalfa and Jim Moutray, ABI Alfalfa, for providing seed of Armor alfalfa used in this study.

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Table 2. Forage yield and final stand density of two alfalfa cultivars the year after no-till establishment in a sod uniformly infested with sclerotia of *Sclerotinia trifoliorum*^a

Year/cultivar	Forage yield			Final stand density
	First harvest	Summer harvests (3)	Season total	
1994				
A9109	84**b	99	93*	100*
Armor	70	94	85	91
1995				
A9109	76	91	85	94
Armor	70	96	87	94

^a Values are the percentages of the disease-free controls (obtained by four applications of vinclozolin), and are averaged over four planting date treatments and four replications.

^b ** and * indicate significant difference between cultivars for a trait within a year at the 1% and 5% probability levels, respectively.

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