Efficacy of Chlorothalonil for Control of Spring Black Stem and Common Leaf Spot of Alfalfa

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ABSTRACT

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Biweekly applications of chlorothalonil were highly effective in controlling spring black stem (SBS), caused by *Phoma medicaginis* var. *medicaginis*, and common leaf spot (CLS), caused by *Pseudopeziza medicaginis*, of alfalfa. Flowable formulation of chlorothalonil provided better control of SBS measured as disease severity and percentage of canopy diseased than copper hydroxide applied at the same rate. Disease control increased in all cultivars (because cultivar Ramsey is resistant to CLS, there was no response to chlorothalonil), years, and locations with an increase in the rate of chlorothalonil applied. Severity of SBS significantly decreased and forage yield significantly increased in the cultivar Agate at the first harvest but not at the second harvest with the 1.12-kg a.i./ha rate of chlorothalonil. There was a trend toward increased seed production and decreased seed infection by *P. medicaginis* var. *medicaginis* with an increase in rate of chlorothalonil in the susceptible cultivar Ranger but not in the resistant Ramsey.

Spring black stem (SBS), incited by *Phoma medicaginis* Malbr. & Roum. var. *medicaginis* Boerema (*Ascochyta imperfecta, P. herbarum, P. medicaginis*), is an important foliage disease of alfalfa in North America.

In 1953, Kernkamp and Hemerick (6) demonstrated in greenhouse tests that SBS could virtually destroy a seed crop of alfalfa if severe infection occurred at the flowering stage; however, field experiments with several fungicides failed to provide control. In 1963, Banttari et al (1) reported that multiple applications of maneb and anilazine provided excellent control of SBS, common leaf spot (CLS), incited by *Pseudopeziza medicaginis* (Lib.) Sacc., and anthracnose (AN) caused by an unidentified *Colletotrichum* sp., on the susceptible alfalfa cultivar Ranger at two locations in Minnesota. Thiram and zineb were moderately effective and fixed copper was ineffective in controlling SBS. They indicated the disease control obtained probably would increase forage and/or seed yields. In 1964, Norton (7) reported that weekly applications with maneb reduced SBS, Leptosphaerulina leaf spot (LLS) (*Leptosphaerulina briosiana* (Poll.) Graham & Luttrell), and Cercospora leaf spot (CLS) (*Cercospora medicaginis* Ell. & Ev.) and increased forage yields of alfalfa by 44% over 2 yr in Iowa. In 1969, Willis et al (11) in Kansas reported a significant increase in forage yields of three alfalfa cultivars when sprayed weekly with mancozeb. SBS, LLS, and CLS were the major pathogens controlled. Wilcoxson et al (10) reported forage yields of Ranger increased 30% during 1971–1972 in Minnesota when SBS and CLS were controlled with weekly applications of mancozeb. Summers and McClellan (8) in 1975 reported that, of three fungicides tested in California (chlorothalonil, captafol, and mancozeb), only chlorothalonil gave significantly higher forage yields. The major foliar disease controlled in this study was CLS. In 1981, Gilchrist et al (3) in California reported that applications of chlorothalonil resulted in an increase in alfalfa forage yields of 35–50% in the first cut and 20–25% for the full season during the first two production years in field plots inoculated with *Stagnospora meliloti* (Lasch) Petrak and an unidentified *Phoma* sp. SBS, AN, incited by *Colletotrichum trifolii* Bain, and Phytophthora root rot (*Phytophthora megasperma* Drechs. f. sp. *medicaginis* Kuan & Erwin) were also present.

Studies were initiated at two locations in southeastern Wyoming in 1981 to determine the efficacy of chlorothalonil in controlling foliar diseases in alfalfa and the effect of multiple application on yield. This paper reports 1) the comparative efficacy of the flowable and wettable formulations of chlorothalonil (Bravo 500 and Bravo W75, respectively), mancozeb (Manzate 200), and copper hydroxide (Kocide 101) on the control of SBS in the alfalfa cultivar Agate and 2) the efficacy of varying rates of flowable chlorothalonil on the control of SBS and CLS in a susceptible and resistant cultivar. Preliminary studies related to this research have been reported (5).

MATERIALS AND METHODS

Two experiments were established in May 1981 near Huntley, WY, in a furrow-irrigated, 3-yr-old field of Agate alfalfa that was managed for either seed or hay, depending on weather conditions. Severe SBS had developed in the field in 1980. Experiment 1 was designed to test the efficacy of the flowable formulation of chlorothalonil at 0.55, 1.12, and 2.25 kg a.i./ha and the wettable powder formulation of chlorothalonil, mancozeb, and copper hydroxide all at 1.12 kg a.i./ha. Mancozeb was chosen because it was effective in controlling foliar diseases of alfalfa in previous studies (10,11). Copper hydroxide was included because it is the only fungicide labeled for foliar use on alfalfa. All fungicides were applied in a CO_2-pressurized sprayer set to deliver 75 L/ha. Plots 0.8 (four rows, 0.2-m spacing) × 4.6 m were arranged in a randomized complete block design with five replicates. There were four border rows between plots. Biweekly sprays were initiated in April 1981 and 1982 at the first sign of spring growth and were continued until frost (11 applications in

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Table 1. Chemical control of spring black stem on the alfalfa cultivar Agate (experiment 1, Huntley, WY, 1981–1982)

	Fungicide treatments (all 1.12 kg a.i./ha)					
				Chlorothalonil		
Disease assessment	Unsprayed check	Mancozeb	Copper hydroxide	Wettable powder formulation	Flowable formulation[a]	LSD (0.05)
1981						
Disease severity[b]	3.0	2.5	2.5	1.8	1.8	0.6
Percent canopy diseased[c]	64.9	50.1	55.0	51.6	44.0	7.9
1982						
Disease severity[b]	3.0	2.8	2.2	1.8	1.6	0.5

[a] Data for the rates of 0.55 and 2.25 kg a.i./ha are not given but were included in the regression shown in Figure 1.
[b] 1 = No disease to 5 = very severe. Values are the mean of five replicates.
[c] Percentage of canopy diseased was estimated by dividing the height of disease progression upward into the plant canopy by the canopy height. Values are the mean of five replicates.

1981 and 10 in 1982). SBS first appeared in May of both years and increased in severity during the season or until plots were harvested. Plots were monitored and rated when disease reached maximum severity in 1981 and 1982 on a scale of 1–5, where 1 = no disease, 2 = slight, 3 = moderate, 4 = severe, and 5 = very severe (9). SBS is an inner-canopy disease; therefore, a rating for each plot was obtained by opening the canopy at four random locations and averaging the four ratings. The effect of each fungicide treatment on the upward advancement of SBS within the plant canopy was also determined in 1981. The plant canopy height and the height of disease in the canopy were measured and used to estimate the percentage of canopy diseased. Plots were then cut and forage removed following local farming practices.

Experiment 2 was located adjacent to experiment 1 and was designed to determine if disease control increased forage yields. Design aspects of this experiment differed from experiment 1 as follows: only the 1.12 kg a.i./ha rate of the flowable chlorothalonil was used, there were 10 replicates, and forage yields were taken. Plots were harvested at the 10% bloom growth stage on 22 June and 27 July 1981, and forage yield was determined. Plots were cut, wind-rowed, allowed to dry, turned, and weighed when hay was near 15% moisture. Data were collected from experiment 2 only during 1981.

Experiment 3 was established in May 1981 at the University of Wyoming Research and Extension Center, Torrington. The purpose of this study was to determine the effect of disease control on seed yield and quality as well as the efficacy of varying rates of the flowable chlorothalonil. The experiment was arranged in a randomized complete block design with five replicates and a factorial arrangement of treatments. There were three fungicide treatments (0.55, 1.12, and 2.25 kg a.i./ha) and an unsprayed check and two cultivars (Ranger and Ramsey). These cultivars were chosen because they are the standard USDA checks (9) for SBS and CLS (Ranger is the susceptible check and Ramsey is the resistant check for both diseases), and these diseases were known to be the major foliar diseases of alfalfa in southeastern Wyoming (4). Plots were 1.5 (two rows, 0.76 m spacing) × 4 m and were seeded at 3.4 kg/ha. A single border row was planted between plots. The experiment was sprinkle-irrigated until the early bud growth stage, then furrow-irrigated as needed to produce maximum seed production. Fungicide treatments were applied as in experiment 1 (10 applications in 1982, nine in 1983, and 10 in 1984). Plots were rated for disease severity and/or defoliation and harvested for seed from 1982 to 1984. Defoliation was estimated on the following rating scale of 1–5, using half increments, where 1 = 0% defoliation, 1.5 = 4%, 2.0 = 15%, 2.5 = 30%, 3.0 = 50%, 3.5 = 70%, 4.0 = 85%, 4.5 = 96%, and 5.0 = 100%. Plots were cut and wind-rowed, then seed yield was determined. Seed germination was determined by the Wyoming Department of Agriculture State Seed Laboratory in 1983.

Seeds from the 1983 harvest were tested to determine the effect of chlorothalonil on the presence of *P. medicaginis* var. *medicaginis*. Seeds were submerged in 20% water agar in petri dishes. There were five seeds per plate and 200 seeds per treatment (total of 12,000 seeds). Petri dishes were stacked and sealed in plastic bags (20 dishes per bag) to prevent drying and stored in the laboratory at room temperature for 4 wk. Seeds, seedlings, and agar were carefully observed under a stereomicroscope for the presence of the pycnidial stage of the fungus, and the percent seeds infected was determined.

Treatment means among chemicals and formulations were compared by analysis of variance coupled with Fisher's LSD test. Simple linear regressions and second-order polynomial regressions were used to detect significant dose responses for chlorothalonil applications.

RESULTS AND DISCUSSION

In 1981 (Huntley site, experiment 1), only chlorothalonil (both formulations) significantly ($P = 0.05$) reduced SBS over that occurring in the unsprayed check (Table 1); however, there was no significant difference between formulations of chlorothalonil. When disease was measured as percentage of canopy affected, all fungicides significantly reduced disease invasion into the canopy. Flowable chlorothalonil was significantly better than mancozeb and copper hydroxide ($P = 0.05$). The flowable formulation of chlorothalonil was signifi-

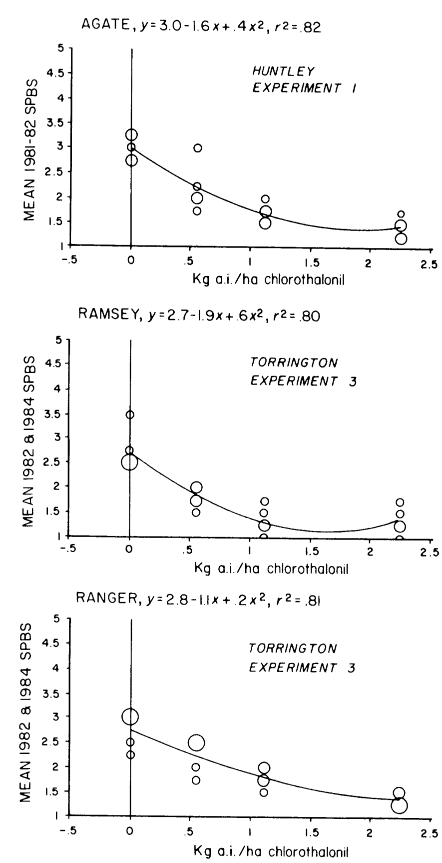

Fig. 1. Regression of rate of chlorothalonil on the severity of spring black stem in the alfalfa cultivars Agate, Ramsey, and Ranger. Plots were rated on a scale of 1–5 (1 = no disease to 5 = severe disease). Relative size of data circles corresponds to number of identical observations (five observations per rate).

cantly better than the wettable powder formulation at $P = 0.01$ but not at $P = 0.05$. In 1982, copper hydroxide and both formulations of chlorothalonil resulted in disease severity ratings significantly lower than that of the unsprayed check. Again, as in 1981, flowable chlorothalonil was significantly more effective than copper hydroxide. Regression analysis described an overall reduction in disease at the Huntley site in cultivar Agate, with increasing rates of flowable chlorothalonil averaged over both years (Fig. 1).

In experiment 3, at the Torrington location, control of SBS with chlorothalonil showed a similar response on cultivars Ramsey and Ranger (Fig. 1). Increasing rates of application significantly decreased disease severity in both cultivars, but the reportedly resistant cultivar Ramsey (9) showed a more pronounced rate response, as described by the steeper regression slope at the lower application rates, than the susceptible cultivar Ranger.

CLS also occurred in these plots in 1982. Ranger is susceptible to CLS and showed a significant simple linear response that described decreasing disease to increasing rates of chlorothalonil application (Fig. 2). Ramsey is quite resistant to CLS, and this is reflected in the almost flat, nonsignificant regression line (Fig. 2). Complete disease control was obtained at the lowest chemical rate, with no further response.

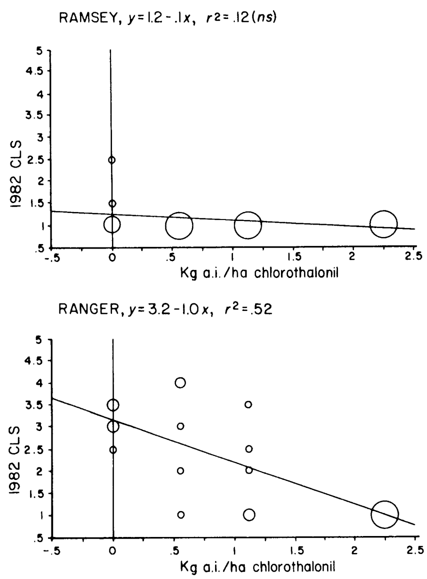

Fig. 2. Regression of rate of chlorothalonil on the severity of common leaf spot in the alfalfa cultivars Ramsey and Ranger (Torrington, experiment 3). Plots were rated on a scale of 1–5 (1 = no disease to 5 = severe disease). Relative size of data circles corresponds to number of identical observations (five observations per rate).

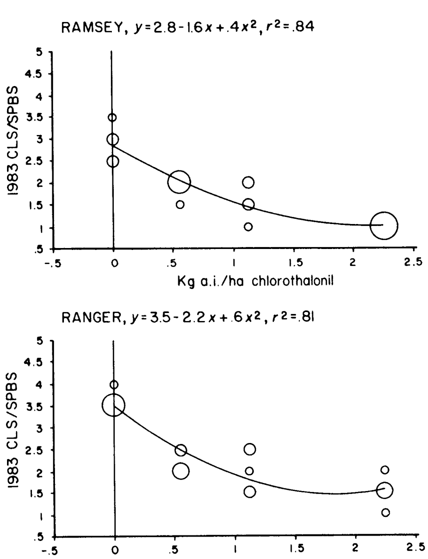

Fig. 3. Regression of rate of chlorothalonil on the severity of leaf spot (common leaf spot and spring black stem) in the cultivars Ramsey and Ranger (Torrington, experiment 3). Plots were rated on a scale of 1–5 (1 = no disease to 5 = severe disease). Relative size of data circles corresponds to number of identical observations (five observations per rate).

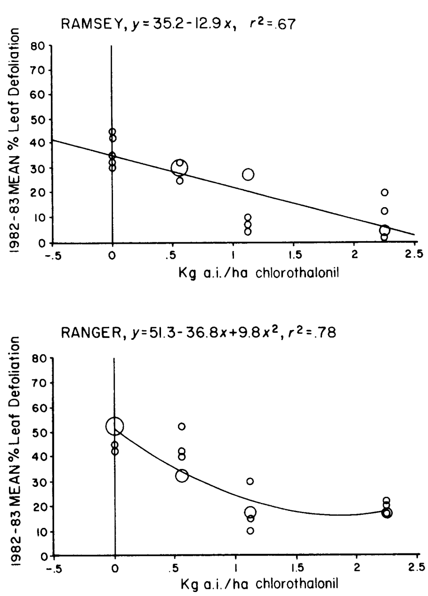

Fig. 4. Regression of rate of chlorothalonil on percent leaf defoliation caused by common leaf spot and spring black stem (Torrington, experiment 3). Relative size of data circles corresponds to number of identical observations (five observations per rate).

In 1983, experiment 3, both SBS and CLS occurred simultaneously, and it was practically impossible to discriminate visually between them with a disease severity rating. Thus, for this year, scores were combined for both diseases. Diseases developed to very high levels and caused severe defoliation, but again, increased rates of chlorothalonil significantly decreased disease in both cultivars (Figs. 3 and 4).

In experiment 2, biweekly applications of chlorothalonil (1.12-kg rate) significantly decreased the severity of SBS and significantly increased forage yield at the first harvest (Table 2). SBS did not develop on the regrowth, and there were no significant differences in forage yield between the chlorothalonil-sprayed and unsprayed treatments at the second harvest.

In experiment 3, seed yields were not significantly influenced by rate of fungicide application or disease severity in any year. Although there was a general trend toward increased seed yields with increased rate of chlorothalonil in Ranger, variation between replicates caused by uneven drying of plants was too pronounced to detect statistical significance. There was a significant increase ($P = 0.05$) in seed yield over years in both cultivars. Seed yield (grams per plot) for Ranger and Ramsey were 55, 87, 148 and 24, 48, 140, respectively, for 1982, 1983, and 1984.

Although the overall level of seed infection by *P. medicaginis* var. *medicaginis* was low, there was a significant ($P = 0.05$) decrease in infection in Ranger with the high rate of chlorothalonil. Percentages of seed infection with rates of 0, 0.55, 1.12, and 2.25 kg a.i./ha were 5.2, 4.3, 4.1, and 2.9% for Ranger and 5.5, 4.3, 4.3, and 4.7% for Ramsey, respectively. *Colletotrichum trifolii*, previously not reported on alfalfa in Wyoming, was recovered in 4.6 and 2.4% of seed from Ranger and Ramsey, respectively. Differences between cultivars and fungicide rates were not significant.

Seed germination of Ranger and Ramsey was unaffected by the rate of chlorothalonil applied in 1983 at Torrington. Seed germination for chlorothalonil rates of 0, 0.55, 1.12, and 2.25 kg a.i./ha was 92, 91, 87, and 89% for

Table 2. Efficacy of chlorothalonil in controlling spring black stem on the alfalfa cultivar Agate and its effect on forage yield (experiment 2, Huntley, 1981)

Treatment	First growth[a] Disease severity[b] (17 June)	First growth[a] Forage yield[c] (t/ha) (21 June)	Second growth[a] Disease severity[b] (20 July)	Second growth[a] Forage yield[c] (t/ha) (27 July)
Chlorothalonil sprayed	1.8	5.1	Trace	4.5
Unsprayed check	2.7	4.6	Trace	4.4
LSD (0.05)	0.3	0.3	···	NS

[a] Values are the mean of 10 replicates.
[b] 1 = No disease to 5 = very severe.
[c] Forage yield is adjusted to 15% moisture.

Ranger and 88, 87, 87, and 86% for Ramsey, respectively.

The broad-spectrum fungicide chlorothalonil proved highly effective in controlling both SBS and CLS. Disease severity, defoliation, and the percentage of the canopy diseased were significantly reduced with biweekly fungicide applications. Applications of the flowable formulation of chlorothalonil resulted in significantly better disease control than maneb and copper hydroxide when applied at the same rate. Our studies agree with those of Banttari et al (1) and Broscious and Kirby (2), who reported fixed copper less effective in controlling SBS on Ranger than other fungicides tested. Our findings also agree with those of Summers and McClellan (8), who found chlorothalonil highly effective in controlling CLS. In most cases, the higher rate of flowable chlorothalonil resulted in the greatest reduction in disease severity. A positive response to chlorothalonil can be expected from cultivars that are susceptible to foliar pathogens endemic to the area where the cultivar is grown. Lower disease severity, but a similar rate response, can also be expected in cultivars with only a moderate to low level of resistance. Very limited or no response should be expected from cultivars with a high level of resistance. The prevalence of these two diseases confirms our earlier report that SBS and CLS are the major foliar diseases of alfalfa in southeastern Wyoming (4). AN, which was not detected in the earlier study, occurred at Torrington in 1983 and 1984; however, incidence was very low and disease severity was not evaluated. Limited data indicate forage yields may be increased with biweekly applications of chlorothalonil. This agrees with earlier reports by Norton (7), Willis et al (11), Wilcoxson et al (10), Summers and McClellan (8), Gilchrist et al (3), and Broscious and Kirby (2), who reported forage increases ranging as high as 50% with fungicide applications. Although the increase in seed production from chlorothalonil was not significant, there was a definite trend toward higher yields in the susceptible cultivar with increasing rates of chlorothalonil applied during years when disease was severe. This agrees with Kernkamp and Hemerick (6), who found SBS devastating to the alfalfa seed crop in greenhouse tests. There was a significant decrease in seed infection by the SBS fungus with an increased rate of chlorothalonil applied. Increased seed yields and a lower level of infection could possibly be reduced further with increased rates and number and proper timing of fungicide applications during seed formation. This is particularly true for areas where SBS is more severe and the level of seed infection may be higher. Even though a reduction in seed infection will reduce primary inoculum, the biological value of such a reduction may be of little importance unless complete control or near eradication is obtained.

Recent studies conducted by Broscious and Kirby (2) addressed frequency and timing of fungicide application on forage yield of alfalfa. They found that one to three applications applied before the first harvest failed to increase yields, whereas one or two applications of mancozeb before the second or third harvest produced significant yield increases, indicating fungicide application may be economical.

Chlorothalonil is not labeled for use on alfalfa; however, application for federal label has been submitted. Additional studies should focus on reducing the number of applications and determining optimum timing of applications if an economically feasible disease control program using chlorothalonil is to be developed.

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