Efficacy of mustard biofumigant crops for management of weeds and Fusarium wilt in spinach seed crops

Lindsey J. du Toit, Timothy W. Miller, Michael L. Derie, Brian G. Maupin, and Carl R. Libbey

Washington State University, Northwestern Washington Research and Extension Center, Mount Vernon, WA, USA 98273

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Introduction

Biofumigant action of mustard cover crops or mustard seed meal may suppress weed seed germination or seedling emergence in spinach seed crops and potentially reduce soilborne populations of some plant pathogenic fungi. A trial evaluating this hypothesis was established at the Northwestern Washington Research and Extension Center (Washington State University, USA). The study had two objectives: 1) evaluate the potential efficacy of biofumigation with mustard cover crops for control of weeds and Fusarium wilt in the cool, maritime climate of western Washington, and 2) compare mustard cover crops with mustard seed meal, a winter wheat cover crop, and metam sodium for control of weeds and Fusarium wilt.

Materials and Methods

Trials were conducted in 2002-03 and 2003-04 in a field (Puget silt loam) with a recent history of Fusarium wilt on spinach. Plots were established in the same field, but at different locations, in the two trials. The statistical design was a randomized complete block with a strip-plot arrangement of a 5 x 2 factorial treatment combination with four replications. Five main-plot treatments consisted of two high-glucosinolate mustard cover crops (a *Brassica juncea* cultivar blend and a *B. juncea* + *B. hirta* cultivar blend), a winter wheat cover crop, a high-glucosinolate mustard seed meal (*B. hirta*) amendment, and spring fumigation with metam sodium. Mustard cover crops were planted at 14.6 kg seed/ha 9 Sep 02 and 10 Sep 03 and the winter wheat cover crop was planted at 67 kg seed/ha 11 Sep 02 and 10 Sep 03. Remaining plots were left fallow until 15 Apr 03 or 31 Mar 04, when volunteer spinach and weeds were mowed and the plots rototilled. Mustard and winter wheat cover crop plots were mowed and rototilled (Figure 1), and the mustard seed meal was broadcast at 2240 kg/ha and rototilled 28 Apr 03 (Figure 2). Metam sodium (Sectagon 42) was applied at 169 L/ha in the top 7 to 10 cm soil, and 113 L/ha at 27 to 30 cm soil depth 30 Apr 03. Because mustard cover crops in the 2003-04 trial experienced severe winter kill (Figure 2), metam sodium and mustard seed meal applications were not made in 2004 and the trial was discontinued. All plots were rototilled 14 May 03, and split-plot (6.2 x 7.4 m) treatments of two proprietary female spinach inbreds, one resistant and one susceptible to Fusarium wilt, were seeded (75 cm spacing between rows, 5 to 7 cm spacing within rows) 15 May 03. Fertilizer (18-46-0) was broadcast over plots at 1.8 kg/plot 28 May 03.

Winter weed, volunteer spinach, and cover crop biomass samples were collected 28 Apr 03 (prior to cover crop incorporation), spinach crop biomass was sampled 24 Jun, 16 Jul, and 20 Aug 03, and spring weed biomass 24 Jun 03; 30- by 50-cm quadrats were used for all biomass sampling. Shepherd's-purse (*Capsella bursa-pastoris*), common lambsquarters (*Chenopodium album*), and henbit (*Lamium amplexicaule*) biomass were determined separately; other weed species were weighed together. Spring weed biomass resulting from incorporated winter wheat or winter-killed mustard was sampled 21 May 04; no other biomass sampling was conducted in the 2003-04 trial. Following spring weed biomass sampling in the 2002-03 trial, plots were maintained free of weeds by manual weeding.

Incidence of healthy, wilted, and dead spinach plants was assessed 1 and 14 Jul 03. A 50-cm length of each of four rows of spinach plants was harvested 20 Aug 03 from each plot. Plants were dried until 26 Aug, then the seed was threshed, cleaned and sized according to commercial standards. Yield was measured as weight of clean seed.

Total precipitation and mean temperature for fall 02 (Sep to Nov), winter 02-03 (Dec to Feb), spring 03 (Mar to May), and summer 03 (Jun to Aug) were 117 mm and 10.5ºC, 211 mm and 5.0ºC, 195 mm and 10.1ºC, and 20 mm and 17.2ºC, respectively. Total precipitation and mean temperature for fall 03, winter 03-04, and spring 04 were 322 mm and 10.7ºC, 216 mm and 5.6ºC, 189 mm and 11.1ºC, and 20 mm and 17.2ºC, respectively.

Results

2002-03 Trial. The *Brassica juncea*, *B. juncea* + *B. hirta*, and winter wheat cover crops trial yielded mean dry weights of 10015, 7290, and 4743 kg/ha, respectively, prior to incorporation. Dry weight of volunteer spinach (originating from seed remaining in the field after harvest of a spinach seed crop in 2002) 28 Apr 03 was 6114 kg/ha in plots without a cover crop and 1635, 580, and 125 kg/ha with winter wheat, *B. juncea* + *B. hirta*, and *B. juncea* cover crops, respectively. Dry weight of weeds other than volunteer spinach was also reduced by 90% with mustard cover crops, compared to plots without a cover crop. Total dry biomass of all plants (weeds, cover crop, and volunteer spinach) prior to incorporation of cover crops was maximized with *B. juncea* (data not shown); biomass in other plots did not differ significantly.

Glucosinolate content of mustard seed meal averaged 180 µmoles/g defatted meal, significantly more than the 21 and 19 µmoles/g of freeze-dried tissue in *B. juncea* + *B. hirta* and *B. juncea* cover crops, respectively. This resulted in total glucosinolate applications of 4.03, 1.95, 1.54 moles/ha for mustard seed meal, *B. juncea* + *B. hirta* and *B. juncea* cover crops, respectively. The primary glucosinolate isolated from mustard seed meal was the p-hydroxybenzyl moiety (91% of total glucosinolates), while the allyl moiety was most prevalent in the *B. juncea* cover crop (94% of the total). In the *B. juncea* + *B. hirta* cover crop blend, benzyl and allyl moieties comprised 83% of total glucosinolates (47 and 36%, respectively).

All cover crop treatments afforded less effective control of weeds and Fusarium wilt than fumigation with metam sodium. For all measures of weed control, biomass, wilt incidence, and seed yield, there was no significant interaction between fumigant/cover crop treatments and spinach cultivars. However, there were significant differences among cover crop treatments for shepherd's-purse control, spinach crop biomass, incidence of wilt, and seed yield (Figures 5-8). Fumigation with metam sodium or spring incorporation of *B. juncea* or *B. juncea* + *B. hirta* cover crops, provided the best control of shepherd's-purse (Table, Figure 5). Spinach biomass (Figure 6), reduction in incidence of wilt (Figure 7), and seed yield (Figure 8) were greatest in plots fumigated with metam sodium, but not significantly different among cover crop and seed meal treatments. Incidence of wilt for the Fusarium wilt-susceptible cultivar was 2x and 6x that of the resistant cultivar on 1 and 14 Jul 03, respectively (Figure 4). The resistant cultivar yielded 5x as much seed as the susceptible cultivar. Mean healthy stand in metam sodium plots planted with the resistant cultivar was 75%. The very high incidence of Fusarium wilt in this trial resulted from much greater disease pressure than typically encountered by spinach seed growers in western Washington, as the spinach seed crop planted in the trial site the previous season had a severe outbreak of Fusarium wilt. Development of Fusarium wilt was exacerbated further by unusually warm and dry conditions for western Washington in the summer of 2003.

Results (continued)

2003-04 Trial. Winter kill of mustard cover crops was likely caused by two separate episodes of cold temperatures. The first occurred from 1 through 7 Nov 03, with an average low temperature of -4.2ºC and a maximum low of -5.7ºC. This episode resulted in an approximately 80% kill of *B. hirta* plants, but only light injury to *B. juncea* plants. The second episode was from 28 Dec 03 through 6 Jan 04, with an average low of -5.5ºC and a maximum low of -13.0ºC, which killed the remaining *B. hirta* plants and approximately 90% of the *B. juncea* plants. Only one episode of temperatures below -5.0ºC occurred in 2002-03, from 30 Oct through 4 Nov 02, during which time the average low was -4.1ºC and the maximum low was -5.0ºC. Although that episode resulted in <20% injury to *B. hirta*, it probably contributed to the lower cover crop biomass in *B. juncea* + *B. hirta* plots compared to *B. juncea* plots that year.

Spring biomass of all weed species was significantly higher in plots with winter-killed and incorporated *B. juncea* cover crops than in other plots (Table). Dry weight of shepherd's-purse, common lambsquarters, and henbit did not differ between *B. juncea* and *B. juncea* + *B. hirta* cover crops, however. Weed biomass was similar between plots with incorporated winter wheat cover crop and plots with no cover crop.

Conclusions

A living mustard cover crop can provide effective competition to winter weeds in the mild maritime climate of western Washington. Because we were unable to collect spring data in 2004 due to excessive winter kill of mustard cover crops, however, this trial needs to be repeated in 2004-05 before conclusions regarding biofumigant action of mustard cover crops or mustard seed meal can be offered. The effect of cover crops on spring weed seedling growth appears to be mixed. Shepherd's-purse biomass was reduced following spring incorporation of mustard in 2003, but biomass of common lambsquarters and henbit were not affected by cover cropping. Mustard species selection must be carefully considered if the cover crop is to be maintained through the winter for spring incorporation, because *B. hirta* displayed substantial potential for winter kill at temperatures below -5ºC, while *B. juncea* cultivars were apparently cold-tolerant down to approximately -10ºC. Mustard cover crops gave far poorer weed control through the winter if cold temperatures killed the plants (2003-04), and spring weed seedling weights were greater following incorporation of winter-killed mustard plants in the spring (2004) than when green plants were chopped and incorporated (2003).

Spinach crop biomass, reduction in incidence of Fusarium wilt, and seed yield were greatest in plots fumigated with metam sodium, but not significantly different among cover crop and seed meal treatments during 2003. If the crop reacts similarly to biofumigant crop or mustard seed meal incorporation in 2005, cover crops may not provide adequate control of Fusarium wilt to allow for significant reduction of rotational intervals between successive spinach seed crops.

Figure 1. Mustard and winter wheat cover crops mowed (a) and incorporated (b) on 28 Apr 03. [2002-03 Trial]

Figure 2.a. *Brassica juncea* + *Brassica hirta*, April, 2003; b. *Brassica juncea*, April, 2003; c. winter injury to *Brassica juncea* + *Brassica hirta*, December, 2003; d. slight winter injury to *Brassica juncea*, December, 2003.

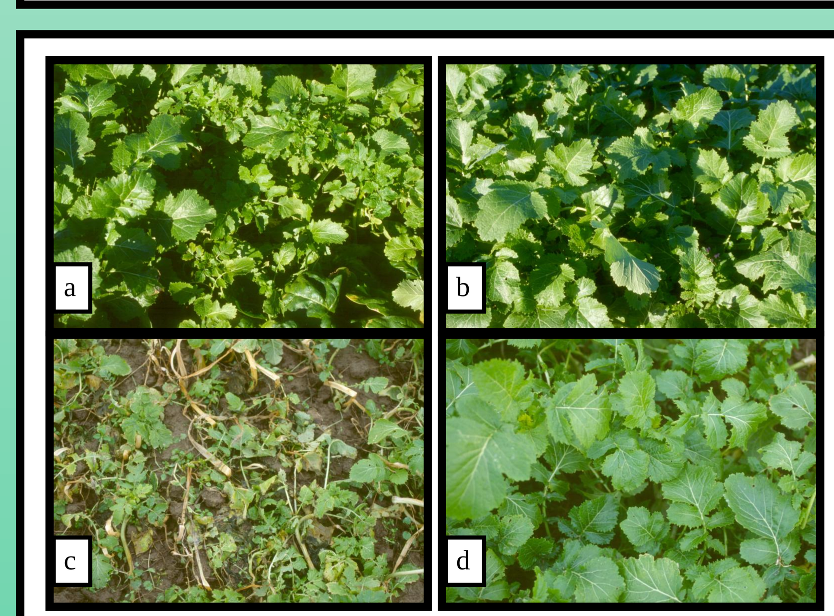

Figure 3. *Brassica hirta* seed meal at 2240 kg/ha on 28 Apr 03. [2002-03 Trial]

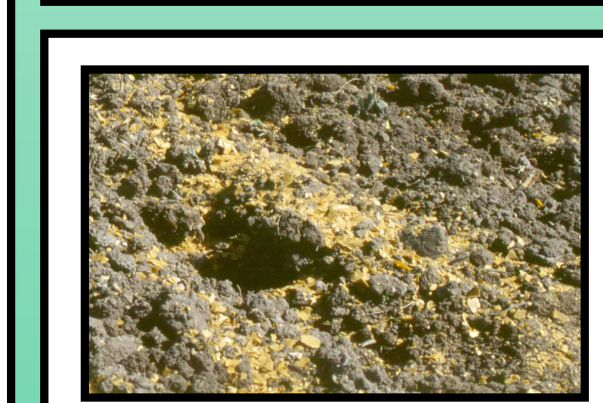

Table. Dry weight of spring weeds after incorporation of various cover crops or metam sodium treatment.

Treatment	Shepherd's-purse		Common lambsquarters		Henbit		Other weed species		Total weeds	
	24 Jun 03	21 May 04	24 Jun 03	21 May 04	24 Jun 03	21 May 04	24 Jun 03	21 May 04	24 Jun 03	21 May 04
	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$	$g/0.15\ m^2$
B. juncea	0.79 c	0.34 a	8.53	1.75 a	0.66	0.65 ab	0.10	6.22 a	10.09	8.96 a
B. juncea + *B. hirta*	1.55 bc	0.21 ab	5.29	1.05 ab	0.52	0.80 a	0.05	0.85 b	7.41	2.92 b
Winter wheat	3.65 ab	0.01 b	4.57	0.03 c	1.82	0.36 bc	0.82	0.14 b	10.86	0.53 c
Metam sodium[a]	1.02 c	0.06 b	7.56	0.37 bc	0.45	0.30 c	0.08	0.31 b	9.11	1.04 bc
Mustard seed meal	4.76 a	---	3.74	---	1.39	---	0.41	---	10.30	---
Pr >F	0.0099	0.0480	0.4200	0.0016	0.6705	0.0127	0.4168	0.0001	0.8531	0.0001

[a]Metam sodium applied only in 2003; because plots were not treated in 2004, results for this treatment represent fallow plots.
Means followed by the same letter not significantly different at the *P* = 0.05 level.

Figure 4. Fusarium wilt-susceptible (left) vs. resistant (right) spinach cultivars on 15 Jul 03. [2002-03 trial]

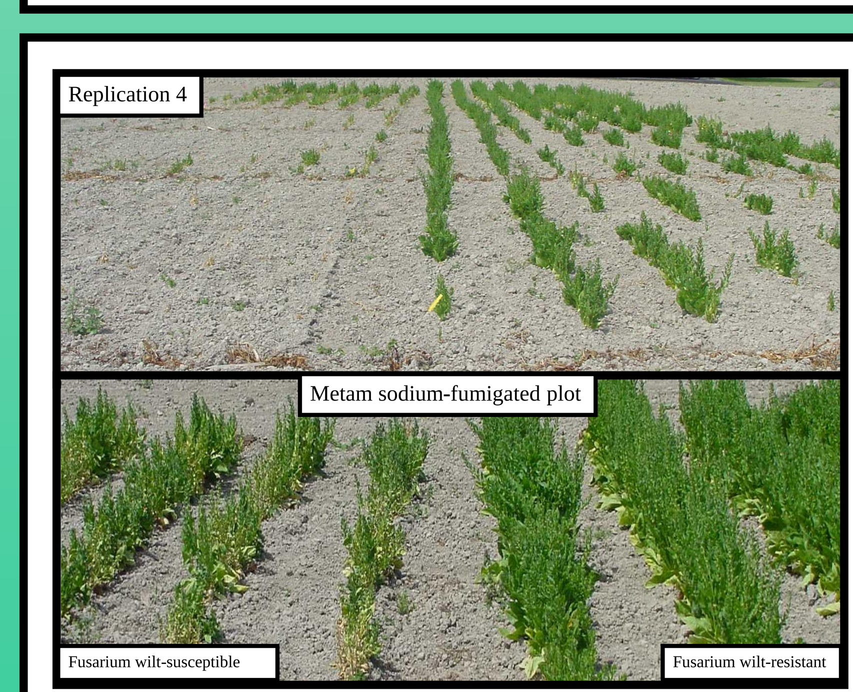

Figure 5. Percent control of shepherd's-purse and common lambsquarters on 13 Jun 03. [2002-03 Trial]

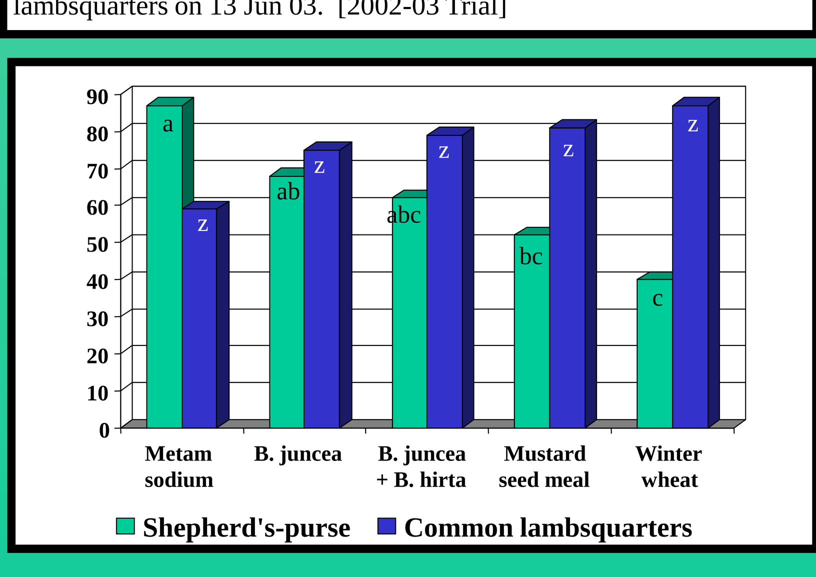

Figure 6. Dry weight of weed and spinach crop seedlings on 13 Jun 03 ($g/0.15\ m^2$). [2002-03 Trial]

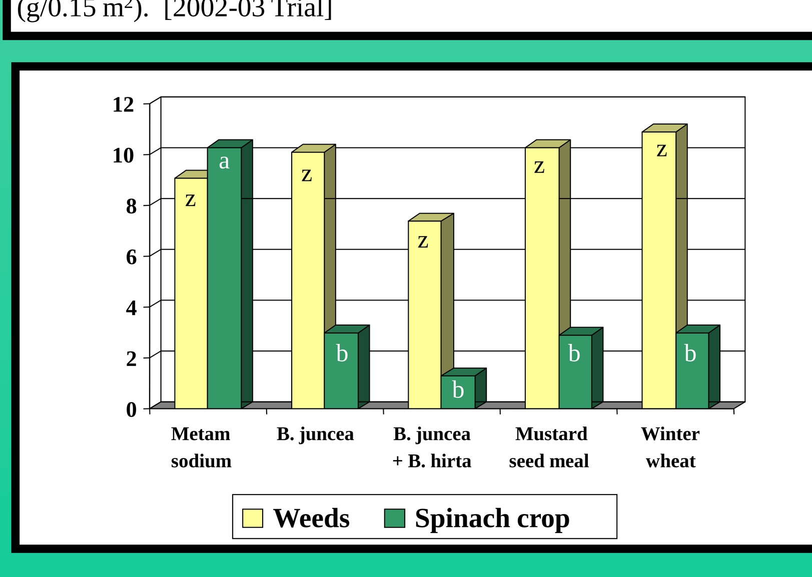

Figure 7. Percent of non-wilted spinach plants/m of row. [2002-03 Trial]

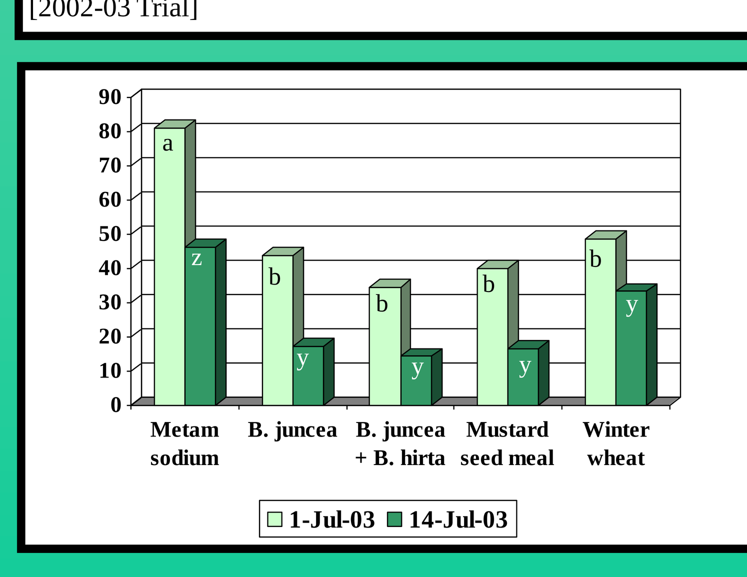

Figure 8. Spinach seed yield (g/2 m of row).