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Annual *Medicago* as a Smother Crop in Soybean

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With 4 figures and 3 tables

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Abstract

Use of conservation tillage and narrow row spacing in soybean [*Glycine max* (L.) Merr.] production has led to increased use of herbicides for weed control. Some producers are seeking alternative weed control methods, such as smother crops, that would reduce dependence on chemical weed control. A successful smother crop must compete strongly with weeds but minimally with the crop. In four environments, we intercropped three annual *Medicago* spp. (medics) with soybean to test their utility as a smother crop for weed control. Annual medics were intercropped with soybean at rates of 0, 85, 258, or 775 seeds m^{-2}, and the intercrops were grown with and without weed control. Increasing medic seeding rate decreased weed yields but also reduced soybean herbage and grain yields. For the weed-controlled treatment, average soybean grain yields declined 7 kg ha^{-1} for every 10 seeds m^{-2} increase in medic seeding rate. Soybean grain yield was lower when grown with *Medicago scutellata* L. cv. Sava than when grown with *Medicago polymorpha* L. cv. Santiago or *Medicago lupilina* L. cv. George. Soybean grain yield was negatively related (r = −81) to medic herbage production. In the autumn following soybean harvest, medic residue ranged from 200 to 3700 kg ha^{-1} depending on the location and seeding rate. Medics provided residue for soil protection, suppressed weeds, but also reduced soybean yields.

Key words: annual *Medicago* spp. — cover crop — intercropping — smother crops — soybean (Glycine max (.L) Merr.) — weed control

Introduction

Increased use of conservation tillage and reduced row spacing has led to a reduction in mechanical weed control and an increase in the use of synthetic herbicides for weed control in soybean. For example, currently about 95 % of the soybean acreage in Minnesota is treated with herbicide with about 6 million kg of herbicides applied annually (Minnesota Agricultural Statistics 2001). Herbicide costs account for 35 % of the variable cost of production. Because synthetic herbicides represent a significant expense and cannot be used by those wishing to be certified as organic producers, some producers seek alternative weed control strategies.

Smother crops have been proposed as an alternative weed control practice for organic soybean production (Hively and Cox 2001). An ideal smother crop should control weeds, have a relatively short growing season, provide a constant N supply, and give minimal competition to the primary crop for water, light, and nutrients (De Haan et al. 1994). In addition to weed control, smother crops have potential to provide soil cover and reduce soil erosion when soybeans are small and to leave a large amount of residue on the soil surface during autumn and winter.

There have been several examples of legume smother crop use in soybean. Oliver et al. (1992) reported that a hairy vetch (*Vicia villosa* Roth ssp. *villosa*) living mulch established into soybean reduced morning glory (*Ipomoea lacunosa* L.) and spotted spurge (*Euphorbia maculata* L.) biomass by about 90 % and large crabgrass (*Digitaria ischaemum* Schreb) biomass by about 70 % compared to weedy controls. When grown with the hairy vetch living mulch, soybean had yields that were comparable to a conventional production system using herbicide. In other research, a subterranean clover (*Trifolium subterraneum* L.) smother crop reduced weed biomass and increased soybean yield by 91 % relative to weedy control plots (Ilnicki and Enache 1992). Although they did not report levels of weed control, Hively and Cox (2001) interseeded legume cover crops into soybeans during the last spring cultivation and reported that red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), alfalfa (*Medicago sativa* L.), and black medic provided > 30 % ground cover by soybean harvest in the autumn. Although populations of smother crops influence competition for resources (De Haan et al. 1997), the aforementioned authors did not evaluate the effect of variable seeding rates on effectiveness of their smother crops.

Annual species of the genus *Medicago*, commonly known as medics, originated in the Mediterranean region (Crawford et al. 1989). They are used in that region and in Australia as winter annuals to produce forage and N in rotational systems. Australian medic cultivars have been successfully used in Minnesota as summer annual forage crops and as contributors of N to the cropping system (Moynihan et al. 1996, Zhu et al. 1996, De Haan et al. 2002). When sown in spring in Minnesota, burr medic (*Medicago polymorpha* L.) and snail medic [*Medicago scutellata* (L.) Mill.] had excellent seedling vigour, and flowered and set seed 30–45 days after seeding (Zhu and Sheaffer 1997). They reached maximum herbage dry matter accumulation about 60–70 days after seeding. Because of their prostrate growth habit, short life span, and good seedling vigour, medics have potential as smother crops. De Haan et al. (1997) used burr medic and snail medic as smother plants in corn (*Zea mays* L.) and found that, although both medics suppressed weeds, corn and medics competed strongly for resources. Consequently, medic smother crops significantly reduced corn grain yields. Because soybean provides more rapid canopy cover and greater early season competition with weeds than corn (Buhler et al. 1998), it is possible that the results of a soybean–medic smother crop system would differ from results for the corn–medic system. Therefore, our objective was to evaluate the effect of annual medic species and seeding rates on soybean yield and weed control when annual medics were intercropped with soybean.

Materials and Methods

'Sava' snail medic, 'Santiago' burr medic, and 'George' black medic were intercropped with 'Glenwood' soybean at Becker and Rosemount, MN in 1993 and 1994. The soil at Becker was a Hubbard loamy sand (sandy, mixed, frigid Entic Hapludoll) with pH of 6.7, 40 mg kg^{-1} P, and 120 mg kg^{-1} K. The soil at Rosemount was Waukegan silt loam (fine-silty over sandy or sandy-skeletal, mixed, mesic Typic Hapludoll) with pH of 7.0, 20 mg kg^{-1} P, and 88 mg kg^{-1} K. Based on soil test information at all sites, P and K fertilizers were applied to maintain soil test levels at or above those recommended for legume and soybean production. The Rosemount soil derives from loess parent material and has an organic matter content of about 30 mg kg^{-1} whereas the Becker soil is derived from glacial outwash and has an organic matter content of about 10 mg kg^{-1}. Precipitation and temperature data are presented in Table 1. Irrigation occurred only at Becker with total water application of 23.9 and 27.7 cm in 1993 and 1994, respectively. Plots were seeded on 15 May each year. Soybean and medic seeds were treated with appropriate *Rhizobium* bacteria immediately before seeding. Glenwood soybean seed was planted to a 5-cm depth at a seeding rate of 65 kg ha^{-1} in rows 76 cm apart. Medic was seeded at 15 kg ha^{-1} to a 2-cm depth immediately after soybean planting.

The experimental design in both years was a randomized complete block in a split-split-plot arrangement with four replicates. Whole plots were 10 m long by 24 m wide and consisted of two weed control treatments: weedy or weed-controlled. The weed-controlled treatment included preplant incorporation of 0.57 kg ha^{-1} trifluralin [(2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine] and was supplemented by hand weeding during the growing season. No herbicide or other weed control was applied to the weedy plots. Subplots were 10 m long by 12 m wide and consisted of annual medic cultivars: Sava, Santiago and George at Rosemount, and Sava and Santiago at Becker. The subsubplots were 10 m long by 3 m wide and consisted of four annual medic seeding rates: 0, 85, 260, or 775 seeds m^{-2}. There were four rows of soybean in each subsubplot.

Sampling of total above-ground herbage occurred on 5 July 1993 at Rosemount and Becker. In 1994, sampling occurred on 19 July at Rosemount and Becker. Total above-ground plant material was clipped from two 0.6 m by 0.3 m areas of the middle two rows within all plots. Soybean, annual medic, and weed herbage was separated, dried at 60 °C for 48 h, and weighed. Soybean grain was harvested from 5 m of the middle two rows of each plot when plants reached physiological maturity in October each year. Seed was dried at 60 °C for 48 h and weighed; yield was adjusted to 13 % moisture before data analysis.

At Becker in 1993 and 1994 and at Rosemount in 1993, total medic residue was determined following soybean harvest by removing a 1-m^2 area from each plot, drying the residue at 60 °C for 48 h, and weighing.

Statistical analysis

Soybean grain yields and soybean and medic total herbage dry weights were analysed in a split-split-plot analysis of variance (ANOVA) within locations and harvests, using the GLM procedure of SAS (SAS Institute 1996). Weed

Table 1: Average (Avg.) monthly precipitation and air temperature at Becker and Rosemount, MN

	Precipitation (mm)					
	Becker			Rosemount		
Month	1993	1994	Avg.	1993	1994	Avg.
April	50	112	65	73	129	73
May	92	23	85	146	67	100
June	118	117	112	191	190	191
July	96	96	98	121	89	103
August	139	76	114	187	99	101
September	49	63	85	84	180	84

	Temperature (°C)					
	Becker			Rosemount		
Month	1993	1994	Avg.	1993	1994	Avg.
April	7	7	7	7	8	8
May	8	16	15	14	16	14
June	17	20	19	18	21	20
July	19	20	21	21	21	22
August	22	19	24	21	19	21
September	12	16	9	13	18	16

control treatments were whole plots, medic cultivars were subplots, and medic seeding rates were subsubplots. Nonnormality of medic data was attributable primarily to the presence of outliers and was not improved by data transformation, so untransformed data were used. Preliminary analysis of variance showed that yield responses to the black medic intercrop were quite different from responses to the Sava or Santiago medic. Also, black medic was used only at Rosemount and not at Becker, so black medic data were analysed separately. Following Bartlett's test for homogeneity of error variances, combined analyses of locations and years were performed using the procedures of Gomez and Gomez (1984). The seeding rate, medic × seeding rate, and weed control treatment × seeding rate effects were partitioned into linear, quadratic, and cubic contrasts. The contrasts were tested against partitioned error terms.

Weed dry weights were square root transformed following an analysis of the residuals. Square root transformed data were analysed in a split-plot ANOVA within the weedy treatment, with annual medic cultivars as whole plots and medic seeding rates as subplots. Black medic was analysed separately. Combined analysis of locations and years was performed. The seeding rate effect and medic–seeding rate interaction were partitioned into linear, quadratic, and cubic contrasts as described above. All mean values reported from these analyses were reverse-transformed.

Additional analyses of soybean grain yield, soybean and annual medic herbage, and weed herbage data were conducted without the zero medic seeding rate and with only the zero medic seeding rate. Mean yield values from these analyses were used to discuss the effects of medic cultivars on grain and herbage yield in soybean–medic intercrops.

Linear regressions of seeding rate on soybean grain yield; soybean and annual medic herbage; and square-root transformed weed herbage were calculated using the REG procedure of SAS with the stepwise selection option (SAS Institute 1996). Independent variables tested for inclusion in the model were seeding rate (RATE), $RATE^2$, $RATE^3$, INVRATE [1/(RATE + 1)], INVR2 [$1/(RATE + 1)^2$], and INVR3 [$1/(RATE + 1)^3$]. Regressions were calculated within weed treatments, within medic cultivars, and on the averages across weed treatments and medic cultivars. Regression analyses involving black medic were calculated separately from the other medic cultivars. Pearson's correlation coefficients were calculated between July herbage yields of soybean, medic, and weeds, and the October soybean grain harvest.

Results and Discussion

July herbage yield

Soybean, annual medic, and weeds contributed to total herbage dry matter yield, although the proportion of each was often affected by interactions of treatments, locations, and years. In the following discussion, we will emphasize the impacts of important treatments influencing medic, soybean, and weed yields.

Table 2: Effect of medic cultivar on soybean herbage, medic herbage, and weed herbage yields at a July harvest‡

		Yield (kg ha^{-1})			
Location and year	Medic cultivar	Soybean herbage	Medic herbage	Weed herbage	Total
Becker 1993	Santiago	450	520	60	1030
	Sava	440	720	50	1210
	$LSD_{0.05}$†	ns	110	ns	
Rosemount 1993	Santiago	360	380	60	800
	Sava	300	480	60	840
	Black	380	160	140	680
	$LSD_{0.05}$	ns	40	50	
Becker 1994	Santiago	570	40	120	730
	Sava	620	100	100	820
	$LSD_{0.05}$	ns	30	90	
Rosemount 1994	Santiago	420	130	730	1280
	Sava	420	230	560	1210
	Black	470	20	700	1190
	$LSD_{0.05}$	ns	50	ns	217

† Least significant difference at the 5 % level for comparing medic cultivars within locations and years.
‡ Values averaged for two weed control treatments.

Weed control treatment effects

Weed species and biomass production varied with location and year. Weed biomass was by far the greatest in 1994 at Rosemount, with lower weed biomass occurring in 1993 at Becker and Rosemount (Table 2). Weeds at Becker were primarily common ragweed (*Ambrosia artemissifolia* L.), common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), yellow foxtail [*Setaria pumila* (Poir.) Roem. & Schult.], and barnyard grass [*Echinochloa crusgalli* (L.) P. Beauv.]. At Rosemount, common lambsquarters, redroot pigweed, yellow foxtail, giant foxtail (*Setaria faberii* Herrm), velvetleaf (*Abutilon theophrasti* Medik), and ladysthumb (*Polygonum persicaria* L.) were present. Differences in weed species and weed mass were probably attributable to differences in soil type and undocumented previous cropping history. The sandy, low organic matter soil at Becker mineralizes less organic N and retains less inorganic N than the silt loam, medium organic matter soils at Rosemount.

Inconsistencies in weed, medic, and soybean yield response to weed control treatments caused a location × year × weed control interaction. Weed control eliminated weeds at Becker in both years and at Rosemount in 1993, but weeds were present in the weed control treatment in 1994 at Rosemount and made a small contribution to herbage yield (Fig. 1). Even without weed control, weed yields were limited to less than 10 % of the total yield at Becker each year and at Rosemount in 1993; however, at Rosemount in 1994 weeds contributed more than 50 % of the total yield.

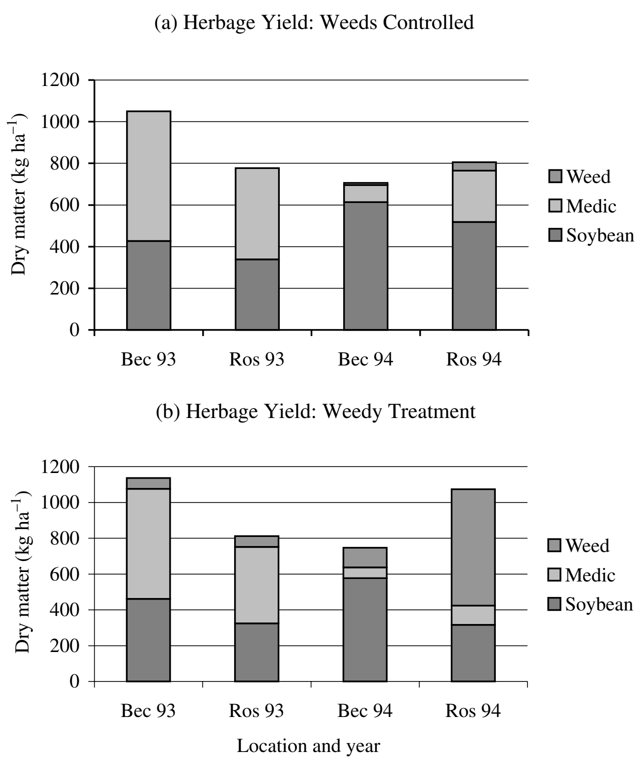


Fig. 1: Soybean, annual medic, and weed components of total herbage in July in 1993 and 1994 at Becker (Bec) and Rosemount (Ros). $LSD_{0.05}$ values are 160 kg ha^{-1} for total herbage, 130 kg ha^{-1} for soybean, 90 kg ha^{-1} for medic, and 90 kg ha^{-1} for weeds

Averaged over medic species and seeding rates, medic herbage contributed more than 50 % of the total plot herbage yield at both locations in 1993 when growing conditions were favourable for medics, but under less favourable growing conditions for medics in 1994, medics contributed less than 20 % of the total herbage yield. Medic growth had a negative effect on weed growth. Within the weedy treatments, medic herbage yield was negatively correlated with weed herbage yield ($r = -0.43$); however, based on this relatively low correlation it appears that other factors such as competition provided by soybean interacted to influence weed growth.

In 1993, for both the weedy and weed-controlled treatments, soybean herbage yield was less than medic yield and constituted less than 40 % of the total herbage yield; however, in 1994, medics were a minor component of the yield and soybeans constituted over 60 % of the herbage yield for the weed-controlled treatment at both locations and for the weedy treatment in 1994 at Becker. Averaged over locations and medic cultivars, soybean yield was negatively related to medic yield ($r = -0.48$ and -0.25 for weed-controlled and weedy treatments, respectively). Soybean yield was only minimally associated with weed yield in the weedy treatment ($r = -0.20$). This poor association may be related to variables not measured in this study such as time of weed emergence and weed density.

Medic cultivar effects

Sava consistently had greater herbage yields than Santiago at each location in each year (Table 2). Black medic grown only at Rosemount consistently had lower yields than Sava and Santiago. Because medics were intercropped with soybean in our experiment, medic yields were less than those reported by Zhu et al. (1996), who grew medics in monoculture without interspecies competition. They had reported that Sava and Santiago had similar yields (average of 3.1 Mg ha^{-1}) at a July harvest. However, consistent with our results, they also reported that black medic had lower yield than the other medics. Relative medic yields were consistent over years, locations, and weed control treatments.

Although soybean herbage yields were negatively related to medic yields ($r = -0.48$ and -0.25 for weed-controlled and weedy treatments, respectively) and medics differed in herbage yields, soybean herbage yields were similar when seeded with Santiago, Sava, and black medic. Apparently, other factors in addition to medic yield caused differences in competitiveness with soybean. These results agree with those of De Haan et al. 1997), who reported that corn herbage dry weight 14 weeks after seeding was not affected by medic cultivar selection.

Seeding rate effects

Seeding rate effects on annual medic yield were affected by cultivar and weed control (significant seeding rate × medic cultivar and seeding rate × weed control interactions occurred) and the effects were consistent over years and locations. Medic yield increased with increasing medic seeding rate, but the rate and amount of yield increase were less in the weedy treatment than in the weed-controlled treatments for all medic cultivars (Figs 2 and 3). Black medic herbage yield increased linearly with increasing seeding rate, while Sava and Santiago herbage yield increased asymptotically. Sava yields increased more rapidly with increasing seeding rate than did Santiago yields. Yields of black medic were lower at all seeding rates than for Sava and Santiago.

Increasing seeding rates of Sava and Santiago medics had a negative linear effect on soybean herbage yield when weeds were controlled (Fig. 2). Soybean herbage yield declined 2 kg ha^{-1} for every 10 seeds m^{-1} increase in medic seeding rate. Soybean herbage yield declined with increasing medic seeding rate in the weedy treatment also, but the relationship was not significant at $P \leq 0.05$ (Fig. 2). Black medic seeding rate had no effect on soybean herbage yield for weed-controlled or weedy treatments (Fig. 3).

When Sava and Santiago medics were intercropped with soybean, weed herbage in the weedy treatment declined sharply as medic seeding rate increased from 0 to 85 medic seeds m^{-2} but then remained constant at higher medic seeding rates (Fig. 2). When black medic was intercropped with soybean, weed yields continued to decline slightly with increasing seeding rates (Fig. 3). This difference in medic competition with weeds is probably a result of the spreading growth habit and greater vigour of Sava and Santiago compared to black medic, so that even the lowest seeding rate resulted in rapid ground cover.

Soybean grain yield

Soybean yields were affected by locations and years. Soybean yields were higher at Becker than at

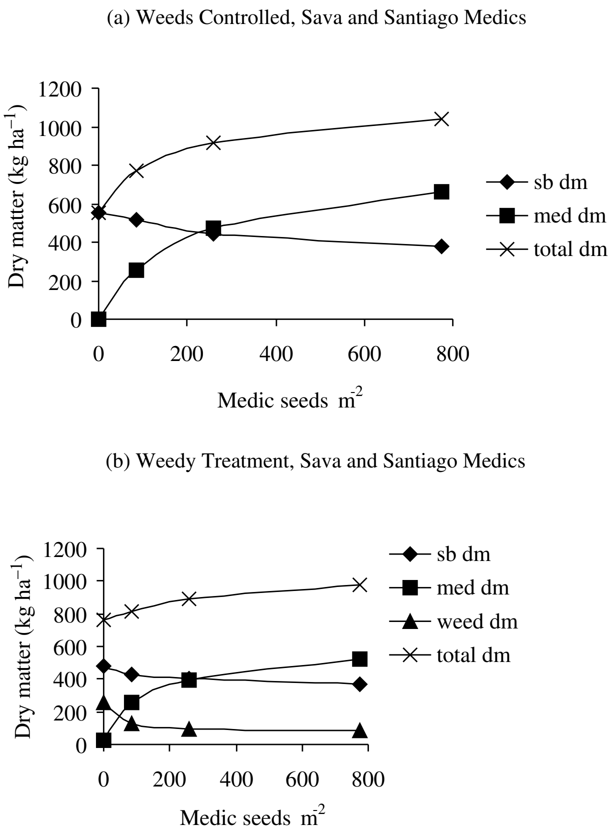


Fig. 2: Herbage yields in early July at medic seeding rates (RATE) of 0, 85, 258, or 775 seeds m^{-2}. Medics included Sava snail medic and Santiago burr medic. Sb dm = soybean dry matter; med dm = medic dry matter; weed dm = weed dry matter; total dm = total herbage dry matter. (a) The weed-controlled treatment included soybean and annual medic herbage. The regression equations were: soybean herbage (kg ha^{-1}) = 535 − 0.2(RATE); $R^2 = 0.90$, $P \leq 0.05$; medic herbage (kg ha^{-1}) = $e^{5.7-5.7[1/(RATE+1)]}$; $R^2 = 0.97$, $P \leq 0.05$. (b) The weedy treatment included soybean, annual medic, and weed herbage. The regression equations were: soybean herbage (kg ha^{-1}) = 454 − 0.1(RATE); $R^2 = 0.83$, $P = 0.09$; medic herbage (kg ha^{-1}) = $e^{5.2-4.9[1/(RATE+1)]}$; $R^2 = 0.97$, $P \leq 0.05$; weed herbage (kg ha^{-1}) = $94 + 136\,[1/(RATE+1)] + 49\,[1/(RATE+1)]^2$

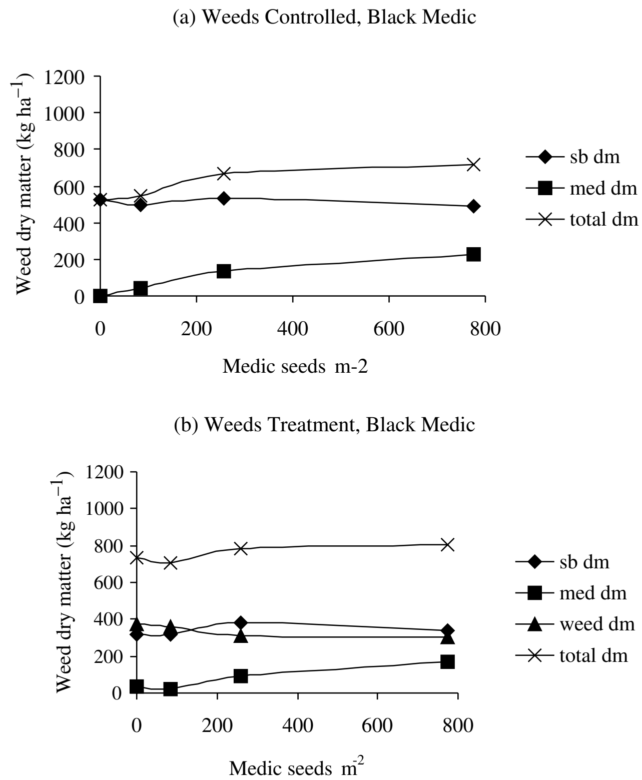


Fig. 3: Herbage yields in early July at black medic seeding rates (RATE) of 0, 85, 258, or 775 seeds m^{-2}. Sb dm = soybean dry matter; med dm = medic dry matter; weed dm = weed dry matter; total dm = total herbage dry matter. (a) The weed-controlled treatment included soybean and annual medic herbage. The regression equations were: soybean herbage: regression equation not significant; medic herbage (kg ha^{-1}) = 23.5 + 0.3 (RATE); $R^2 = 0.93$, $P \leq 0.05$. (b) The weedy treatment included soybean, annual medic, and weed herbage. The regression equations were: soybean herbage: regression equation not significant; medic herbage (kg ha^{-1}) = 29.2 + 0.2(RATE); $R^2 = 0.93$, $P \leq 0.05$; weed herbage (kg ha^{-1}) = 424 − 0.3(RATE) + 0.00005(RATE2); $R^2 = 0.99$, $P \leq 0.01$

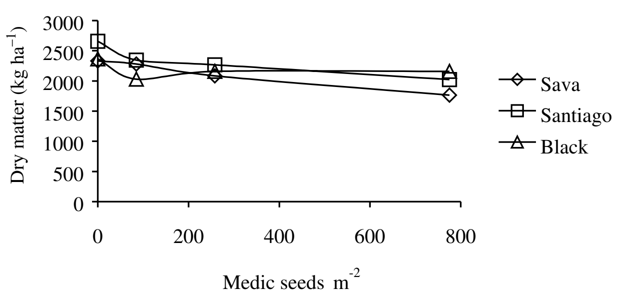
Rosemount in both 1993 and 1994 (Table 3). Soybean yields averaged 2476 kg ha^{-1} at Becker and 1353 kg ha^{-1} at Rosemount. Yields at Becker were probably greater than at Rosemount because at Becker, plots were irrigated to meet evapotranspiration losses. The experiment at Rosemount was not irrigated and, because of the low water-holding capacity of the soil, soybeans typically have a yield reduction caused by moisture stress.

Weed control treatments, locations, and years interacted to affect soybean grain yield. The interaction occurred because grain yield for the weed-controlled treatment was higher than yields for the weedy treatment for all location-years except for Becker in 1993, when yields were similar for the weedy and weed-controlled treatments. This probably occurred because weed pressure was low at Becker in 1993 compared to 1994 and irrigation at Becker reduced potential competition for water between existing weeds and the soybean. Another source of variation causing a significant interaction may have been the severe reduction in grain yield by the weedy treatment compared to the weed-controlled treatment in 1994 at Rosemount.

Table 3: Weed herbage yields and grain yields for weedy and weed-controlled treatments

	Yield (kg ha^{-1})			
	Weedy		Weed-controlled	
Location and year	Weed herbage	Soybean grain	Weed herbage	Soybean grain
Becker 1993	60	2250	0	2180
Rosemount 1993	60	1430	0	1610
Becker 1994	110	2590	10	2880
Rosemount 1994	650	140	40	2230
$LSD_{0.05}$	90	150	90	150

Interseeding medics with soybean decreased soybean grain yields compared to the no medic treatment (Fig. 4). When averaged for locations and years, the weed-controlled treatment had higher grain yields than the weedy treatment for all medics and seeding rates. The weed control by seeding rate interaction occurred because, for the weed-controlled treatment, average soybean grain yields declined 7 kg ha^{-1} for every 10 seeds m^{-2} increase in medic seeding rate. For the weedy treatment, yield declined 4 kg ha^{-1} for every increase of 10 medic seeds m^{-2}.



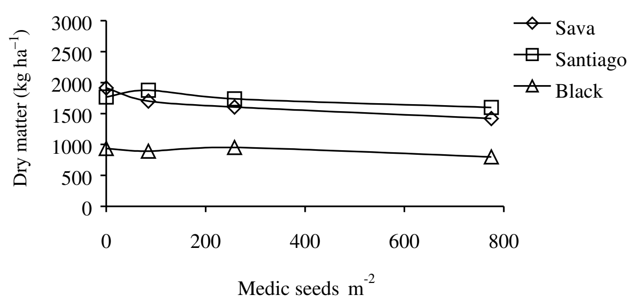


Fig. 4: Soybean grain yields at medic seeding rates (RATE) of 0, 85, 258, or 775 seeds m^{-2} for Sava snail medic, Santiago burr medic, and George black medic. (a) The weed-controlled treatment. Regression equations: Sava: yield (kg ha^{-1}) = 2321 − 0.73(RATE); $R^2 = 0.99$, $P \leq 0.01$; Santiago: yield (kg ha^{-1}) = 2386 − 0.47(RATE) + 270.79/(RATE3); $R^2 = 0.98$, $P \leq 0.01$. The regression equation for black medic was not significant. (b) The weedy treatment. Regression equations: Sava: yield (kg ha^{-1}) = 1912 − 0.28(RATE) −42.18($\log_e$RATE); $R^2 = 0.99$, $P \leq 0.01$

Soybean grain yield was consistently lower when grown with Sava than when grown with Santiago when averaged for all medic seeding rates. Averaged for locations, years, and weed control treatment, soybean grain yield was 1817 kg ha^{-1} from plots intercropped with Sava, and 1976 kg ha^{-1} from plots intercropped with Santiago ($LSD_{0.05} = 80$ kg ha^{-1}). Yields of soybean that were grown with black medic at Rosemount were 2178 kg ha^{-1}. This suggests that, although medics had similar effects on soybean yield in July, because Sava had greater herbage yields it was ultimately more competitive than Santiago or black medic with soybean with regard to soybean grain production. Santiago and Sava had similar rates of maturity.

Relationship between July herbage and soybean grain yields

As expected, there was a positive relationship between July herbage yield of soybean and October grain yield for both weedy ($r = 0.60$) and weed-controlled treatments ($r = 0.50$) when averaged for all locations and years. In the weed-controlled treatment, a negative relationship ($r = -0.81$) between July medic herbage yield and soybean grain yield suggests that the annual medic competed with soybean thereby reducing yield; however, when weeds were present, July medic yield was not significantly ($P \leq 0.01$) related to soybean grain yield. As expected there was a significant negative relationship ($r = -0.66$) between July weed herbage and soybean grain yield when weeds were not controlled.

Annual medic autumn residue

Medic residue measured at soybean harvest in 1993 at Becker and Rosemount and in 1994 at Becker was substantial. The medics had died and dessicated, prostrate brown stems remained; most leaves had senesced and fallen to the soil. Because the medic residue had lodged and slightly decomposed it was mostly below the first soybean node; therefore, it did not interfere with soybean harvest. The quantity of medic residue following soybean harvest was similar for Sava and Santiago medics but varied over locations and seedling rates. The greatest medic residues occurred in 1993 at Rosemount where yields of 2018, 2483, and 3700 kg ha^{-1} occurred for the 85, 260, and 775 seeds m^{-2} rate. At Becker in 1993, yields for the same seeding rates were 1390, 1730, and 2500 kg ha^{-1}, respectively. The residues in Becker in 1994 were 200, 474, and 929 kg ha^{-1} for the 85, 260, and 775 seeds m^{-2} rates. Residues from soybeans probably would have remained on the soil throughout the winter, thereby decreasing the risk of wind and water erosion of soil. By the following spring, the leaves had disappeared and decomposed stem mulch remained.

Conclusions

Annual medic smother crops reduced weeds but also soybean grain yields compared to a soybean monocrop with weeds controlled. Sava annual medic competed with soybean more than did Santiago medic, and both Sava and Santiago competed more than black medic. The soybean–medic intercrop yielded more total herbage than the soybean monocrop for all three medic cultivars, with the highest total July herbage yields at the highest medic seeding rate.

Increasing annual medic seeding rate (from 0 to 775 seeds m^{-2}) decreased soybean grain yield. Average soybean grain yields declined 7 and 4 kg ha^{-1} for every 10 seeds m^{-2} increase in medic seeding rate for the weed-controlled and weedy treatments, respectively. Annual medics also contributed autumn residue for soil cover during the winter. The quantity of residue increased with increasing medic seeding rate, but was as high as 3700 kg ha^{-1}.

Use of annual medic smother crops has potential to improve environmental quality by replacing herbicides and increasing soil cover. Annual medic intercrops also have potential to increase soil N status through biological dinitrogen fixation that would decrease use of purchased N fertilizers applied to subsequent crops. Decreased purchase of herbicides and N fertilizers should reduce production costs and provide some compensation for the decreased grain yields and medic seed costs. The use of legume intercrops may be most advantageous in organic production systems where producers cannot use synthetic fertilizers and pesticides and where a premium is paid for grain production. Premiums for organic grain may offset the yield reduction associated with intercropping.

Zusammenfassung

Annuelle *Medicago* als Deckfrucht in Sojabohne

Konservierende Bodenbearbeitung und enge Reihenabstände führten zu einem erhöhten Herbizideinsatz in Sojabohneanbau (*Glycine max* (L.) Merr.). Eine Alternative zum chemischen Einsatz, ist der Anbau von Deckfrüchten. Diese sollten eine hohe Konkurrenzkraft gegenüber Beikräutern aufweisen, ohne die Kulturfrucht nennenswert einzuschränken. Drei annuelle *Medicago* sp. (medics) Spezies wurden an vier Standorten auf ihre Eignung als Deckfrucht mit Sojabohnen zur Beikrautunterdrückung geprüft. Die Aussaatstärke der ‚medics' umfasste 0, 85, 258 und 775 Samen m^{-2} kombiniert mit und ohne chemischer Kontrolle. Eine steigende Aussaatstärke senkte sowohl den Beikrautanteil als auch die Biomasse und den Kornertrag der Sojabohnen. In der chemisch kontrollierten Behandlung nahm der durchschnittliche Sojabohnenertrag um 7 kg ha^{-1} pro 10 Samen m^{-2} Aussaatstärke ab. Der Kornertrag der Sojabohnen war beim Mischanbau mit *Medicago scutellata* L. cv. Sava geringer als mit *Medicago polymorpha* L. cv. Santiago oder *Medicago lupilina* L. cv. George. Eine negative (r = − 81) Korrelation bestand zwischen Sojabohnenkornertrag und der ‚medic' Biomassebildung. Nach der Ernte der Sojabohnen umfassten die Reste der ‚medic′ Biomasse 200 bi 3700 kg ha^{-1} in Abhängigkeit von dem Standort und der Aussaatstärke. Die Untersuchungen zeigen, dass ‚medics' grundsätzlich geeignet sind, den Boden zu bedecken (schützen) und Beikräuter zu unterdrücken, wobei allerdings der Sojabohnenertrag reduziert wird.

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