Spring-seeded smother plants for weed control in corn and soybean

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Interpretive summary

There is considerable interest in developing alternatives to herbicides and tillage for weed control in corn and soybeans. Spring-seeded smother plants may have potential for weed control through management of interplant competition and surface residues. Several annual medic species, Berseem clover, and yellow mustard had variable potential to control weeds when planted in a band over the corn or soybean row at planting. Smother crop establishment and weed control was better in corn than soybeans with weed control ranging from 20 to 90%. Corn and soybean yields also varied among experiments. While results were variable, we feel that the results warrant further evaluation of smother plants for weed control and soil conservation.

Key words: annual medics, Berseem clover, cover crops, integrated weed management, yellow mustard.

ABSTRACT: Considerable interest exists in the development of alternate weed management options. Spring-seeded smother plants may provide an alternative to current weed management practices through management of interplant competition and surface residues. Experiments were conducted in corn and soybeans in 1995 and 1996 at Sioux Center and Ames, IA. Caliph medic, Santiago medic, Sava medic, Berseem clover, and yellow mustard were evaluated as potential smother plants. The smother plants were seeded and incorporated in a 25-cm-wide band over the crop row immediately after crop planting. Weed suppression ranged from 19 to 90% among the smother plant species. The effect of smother plants on corn and soybean yields varied among locations, years, smother plant species, and weed pressure. In some instances, yields with smother plants were equal to weed-free crops, while at other times yields were as low as the weedy crop. These results imply that smother plants have potential for weed control. However, more research is needed to reduce variability and to gain more insight on biological, management, and competitive interactions among weeds, smother plants, and the harvested crop.

Weed management is a critical issue in sustainable agriculture because controlling weeds is intimately linked to two of the most important sources of environmental pollution associated with crop production: soil erosion, and herbicide contamination of water resources. More than 95% of the corn and soybeans in the north central United States are treated with one or more herbicide. Many studies have documented the occurrence of herbicides in surface water (Thurman et al. 1991), ground water (USEPA 1992), and rain water (Richards et al. 1987). The use of herbicides on our major crops and their effect on the environment, food safety, and human health continue to be debated.

Herbicides and tillage are the cornerstones of weed management in our major cropping systems because producers have few viable options. While improved in-field herbicide management and product handling will reduce environmental contamination and human exposure, it will be difficult for farmers to reduce dependance on herbicides until new weed control options are developed (Buhler 1996; Wyse 1992).

Smother plants are specialized cover crops developed for their ability to suppress weeds and may provide an alternative method of weed control (DeHaan et al. 1994; Williams and Wicks 1988; Wyse 1992). Additionally, smother plants could reduce soil erosion and improve soil quality (DeHaan et al. 1994; Palada et al. 1983). The use of growing plants and/or plant residue to suppress weeds is not a new idea. For example, winter rye, vetches, and clovers have been evaluated as smother plants in corn and soybean (Enache and Ilnicki 1988; Hartwig and Loughran 1989; Palada et al. 1983; Williams and Wicks 1988). However, these plant species compete with the crop for soil moisture, have poor winter survival, and require herbicides or tillage for elimination before planting. (Triplett 1985; Worsham 1991).

Feasibility of short-term, spring-seeded smother plant systems is supported by plant competition research. For example, weed interference for the first 2 to 8 weeks after corn emergence may not reduce grain yield (Hall et al. 1992; Zimdahl 1988). Therefore, it is possible that a spring-seeded smother plant could compete with corn for a similar period without reducing crop yields. Other studies show that weeds that do not emerge until 3 to 6 weeks after crops do not reduce yields (Hall et al. 1992; Knake and Slife 1965). This suggests that if annual weeds can be suppressed for 4 to 6 weeks by the smother plant, crop yields may not be reduced by weeds.

DeHaan et al. (1994) planted yellow mustard (*Brassica hirta* Moench) with corn at several densities and spatial arrangements and removed the mustard at various times by clipping and/or herbicide application. Results suggested that mustard planted at 500 to 1000 seed m^{-2} (46 to 93 seed ft^{-2}) in a 25-cm (10-inch) band over the corn row at corn planting was effective in suppressing weeds. Based on these results, DeHaan et al. (1994) proposed the following ideotype for spring-seeded smother plants for weed control in corn in the north central United States: a) rapid seedling emergence under cool soil conditions; b) horizontal leaf angle; c) mature leaf size of 2 by 3 cm (0.8 by 1.2 in); d) rooting depth of 2.5 cm (1 in), e) maximum height of 10 cm (4 in); f) a life cycle of 5 weeks or less; g) nondormant seed; and h) seed production potential of at least 500 kg ha^{-1} (445 lb a^{-1}). They concluded that research is needed in three general areas to facilitate development of successful spring-seeded smother plants: a) effects of various smother plant growth rates and morphologies on crop development and weed control need to be examined over a wide geographic area to better define the ideotype, b) appropriate plant species must be identified or developed based on the ideotype, and c) environmental and economic impacts of adoption of smother plant technology must be investigated.

Our objective was to further define characteristics of a spring-seeded smother plant system for corn and soybean, to examine the feasibility of using spring-seeded smother plants for weed control, and to understand and exploit the competitive interactions among weeds, smother plants, and the crop. Understanding the biology of smother plant competition for weed management will provide informa-

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tion for plant breeders, weed scientists, and others interested in developing competition-based weed management systems.

Procedures

Field experiments were conducted near Sioux Center and Ames, Iowa, in 1995 and 1996. Separate experiments were conducted for corn and soybeans. The experimental design for all experiments was a randomized complete block, split plot design. Planting dates were whole plot treatments and smother plant species the subplot treatments. Subplots were 3 (Sioux Center) or 3.8 (Ames) by 10 m (10 or 12.5 by 33 ft). All treatments were replicated four times. The corn or soybeans plus smother plant combinations were each planted on two dates at each location. The first planting was targeted as early for local conditions (April 25 at Ames and May 5 at Sioux Center for corn; May 15 at Ames and May 20 at Sioux Center for soybeans) and the second planting was two weeks later. The soil type at Ames was Clarion loam and fertility adjustments were made according to the recommendations of the Iowa State University Soil Testing Laboratory for a corn/soybean rotation. The Sioux Center soil was a Galva silty clay loam, with a manure application made each fall. The experimental fields were chisel plowed in the fall, disked, and field cultivated in the spring before planting.

Crops were planted in 76 cm (30 in) rows at both locations. Corn (Pioneer[1] 3394 and 3489 in 1995 and 1996, respectively) was planted at 69,200 seeds ha^{-1} (28,000 seeds a^{-1}) at Ames and at 74,100 seeds ha^{-1} (30,000 seeds a^{-1}) (Land-O-Lakes 5501) at Sioux Center. Soybeans (Stine 2250) were planted at 452,000 seeds ha^{-1} (183,000 seeds a^{-1}) at Ames and 425,000 seeds ha^{-1} (172,000 seeds a^{-1}) (Land-O-Lakes 2200) at Sioux Center. Planting depth was set in response to soil moisture levels at planting. The smother plants were seeded immediately following the planting of corn or soybean in a 25 cm (10 in) band centered over the crop row. Smother plant seeds were incorporated into the upper 1 cm (0.4 in) of soil with a garden rake. Smother plant species and their seeding rates are listed in Table 1. All plots received timely interrow cultivation to control weeds between crop rows. Weedy and weed-free control treatments were included in all experiments. Weed-free control plots were maintained by bi-weekly hoeing and handweeding for the entire growing season.

[1] Reference to a trade or company name is for specific information only and does not imply approval or recommendation of the company by the USDA to the exclusion of other that may be suitable.

Table 1. Species and seeding rates used in smother plant experiments at Ames and Sioux Center, IA in 1995 and 1996

Species	Seeding rate (seeds/m^2)
Caliph medic (*Medicago truncatula* Gaerth.)	200
Santiago medic (*Medicago polymorpha* L.)	200
Sava medic (*Medicago scutellata* L.)	200
Berseem clover (*Trifolium alexandrinum* L.)	200
Yellow mustard (*Brassica hirta* Moench)	500

Table 2. Smother plant density (plants m^{-2}) in corn at Ames and Sioux Center, Iowa, at 14, 28, and 72 days after planting (DAP) in 1995 averaged over planting dates

		DAP		
Location	Species	14	28	72
Sioux Center	Yellow mustard	218a*	176a	0c
	Sava medic	106b	116b	127a
	Caliph medic	111b	111b	46b
	Berseem clover	117b	128b	54b
	Santiago medic	94b	128b	15c
Ames	Yellow mustard	183a	151a	57ab
	Sava medic	136b	126a	70a
	Caliph medic	99bc	86b	42bc
	Berseem clover	96c	78b	56ab
	Santiago medic	67c	63b	40c

*Means followed by the same letter within columns are not significantly different (LSD=0.05)

Table 3. Corn and smother plant density 28 days after planting at Sioux Center, Iowa, in 1996, averaged over planting dates

Treatment	Corn density	Smother plant density
	plants ha^{-1}	plants m^{-2}
Weed-free	73,500 a*	0
Sava medic	72,400 ab	99 c
Caliph medic	69,000 abc	140 b
Santiago medic	68,500 abc	102 c
Berseem clover	65,800 bc	178 a
Yellow mustard	64,200 c	143 b
Weedy	72,600 ab	0

*Means followed by the same letter within columns do not differ according to LSD (0.05)

Emergence times of smother plants, crop, and weeds were recorded. The primary weeds observed at both locations were giant foxtail (*Setaria faberi* Herrm.), common lambsquarter (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and Pennsylvania smartweed (*Polygonum pensylvanicum* L.). Smother plant and crop stand densities were measured 14, 28, and 72 days after planting (DAP). Smother plants were counted from a 0.1 m^2 (1.1 ft^2) area in the seeded band in each of the center three rows, corn from 7.6 m (25 ft) of row, and soybean from 1 m (3.3 ft) of row length. Weed control by species was evaluated by visual estimation of biomass reduction compared with the weedy control 40 and 72 DAP using a scale of 0 (no reduction) to 100% (no weeds present). Weed density and shoot biomass data for each species was collected 40 DAP. The weeds in a 1 m^2 (11 ft^2) area of the seeded band were counted, cut, and weighed in the field. Crop height and growth stage were recorded at 14 day intervals up to 72 DAP. Grain yields of corn and soybean were determined by harvesting two (Sioux Center) or three (Ames) center rows from each plot with a combine.

All data were subjected to analyses of variance. Main effects and interactions were tested for significance. Data were tested for nonadditivity to determine if transformations were necessary, but none were. For analyses of visual estimates of

Table 4. Effect of smother plants on early planted corn (Sioux Center, 1995) and early planted soybean yields (Ames, 1996)

Treatment	Corn	Soybean
	Mg ha^{-1}	
Weed-free	8.85 a*	4.26 a
Sava medic	7.93 bc	3.15 bc
Caliph medic	7.48 c	3.48 b
Santiago medic	7.81 bc	3.30 bc
Berseem clover	8.46 ab	2.85 c
Yellow mustard	7.98 bc	3.52 b
Weedy	7.75 c	3.08 bc

*Means followed by the same letter within columns do not differ according to LSD (0.1)

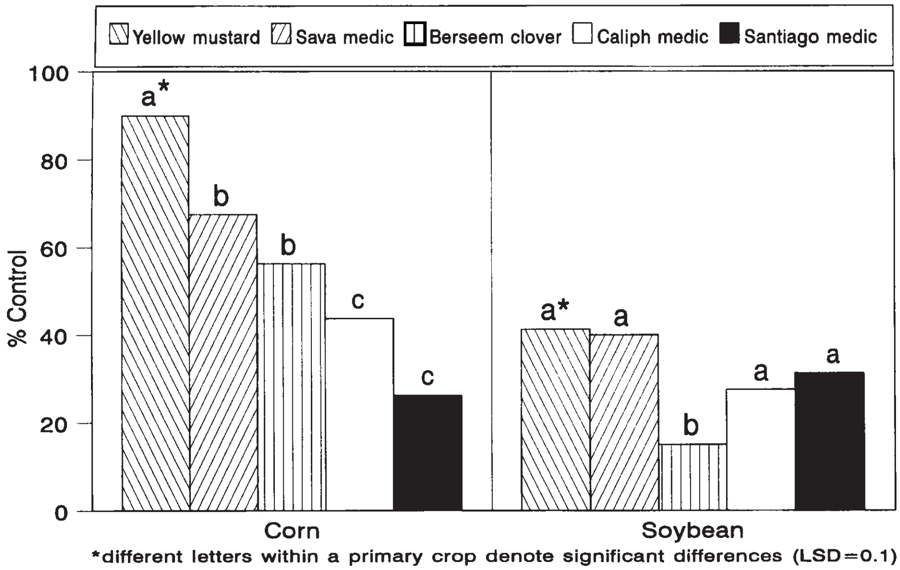

Figure 1. Weed suppression (averaged over all weed species) by smother plants 40 days after planting of corn and soybean at Ames, IA, in 1995
Data are from the early planting date for corn and soybeans

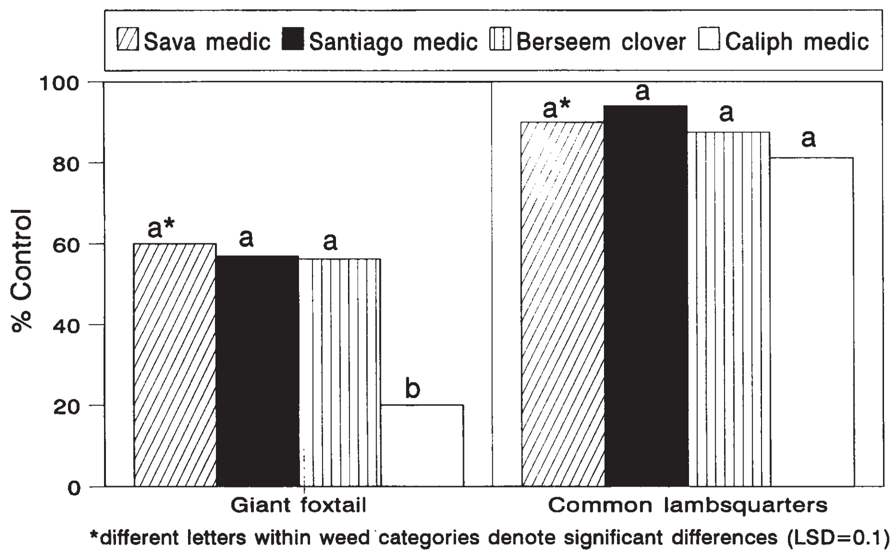

Figure 2. Suppression of giant foxtail and common lambsquarters 40 days after planting of corn at Sioux Center, IA, in 1996
Data are from early planted corn

weed control, data from the weedy and weed-free control treatments were excluded. For analyses of weed density, data from the weed-free treatment was excluded. Means were separated by Fisher's Protected LSD test at $P < 0.05$ or 0.1 using the appropriate error term based on significant main effects and interactions.

Results and discussion

Most of the parameters measured were influenced by planting date, smother plant species, location, and year. Interactions among treatment factors were also significant in most cases. Significant interactions precluded combining data over locations or years, resulting in a very large data set. For brevity, we have selected a subset of the data to illustrate the major trends in the results.

Successful establishment of smother plants occurred in all experiments except when the soil was dry at planting and followed by 14 or more days without at least 1 cm (0.4 in) of precipitation (data not shown). Establishment was always successful following early planted corn. The frequency of establishment failures increased with the later planting times. Poor smother plant establishment was a major problem in soybeans, especially in the late planted treatment. Based on the results of this research, surface spreading of seed followed by shallow incorporation at crop planting is not a viable method for establishing smother plants in soybeans.

Differences in population dynamics during the growing season occurred among the smother plant species (Table 2). Typically, initial density of yellow mustard was higher than the other species due to the higher seeding rate. By 28 DAP, differences in density decreased, but yellow mustard continued to have densities equal to or higher than the other species. However, as the growing season progressed, densities of yellow mustard declined, and by 72 DAP few mustard plants remained alive. Densities of the medic species and Berseem clover also declined during the growing season, but densities generally remained higher than yellow mustard.

The smother plant species had differential effects on crop density. The medic species usually did not reduce crop density compared with the weed-free control. However, as evident in the data from Sioux Center in 1996 (Table 3), yellow mustard often reduced corn density compared with corn without weeds or smother plants (weed-free control). This reduction in corn density may have been due to the greater early season density of yellow mustard compared with the other smother plant species or the allelopathy often associated with Brassica species (Al-Khatib et al. 1997).

The smother plant species demonstrated differences in weed suppression capabilities among crop species and years. Data from Ames in 1995 provides an excellent example of the trends in weed suppression (Figure 1). At 40 DAP, yellow mustard reduced weed biomass in early planted corn by 90%. Sava medic and Berseem clover reduced weed biomass by 55 to 65% and Caliph and Santiago medics reduced weed biomass by less than 50%. In soybeans, overall weed suppression was only 15 to 41% with no differences among the yellow mustard and medic species. Weed suppression with Berseem clover was lower than the other species.

The low level of weed suppression by smother plants in soybeans was consistent across locations and years. The major reason for differences between corn and soybean seemed to be related to planting dates and subsequent smother plant establishment and growth. The soybeans were planted 20 or more days later than corn, generally exposing the smother plants to warmer, drier conditions following planting. Subsequently, poor seedling establishment and low levels of biomass production following soybean planting resulted in little weed suppression. All of the smother plant species evaluated were cool-season species and display slow growth and low plant vigor when exposed to high temperatures early in their growth cycle (Martin et al. 1976). This suggests that these cool-season species may not be appropriate smother plants for soybeans or other crops planted later than early May in this region.

Differences in smother crop competitiveness with different weed species were also observed. In corn at Sioux Center in 1996, giant foxtail suppression with the three medic species and Berseem clover ranged from 20 to 60%, with Caliph medic suppressing less giant foxtail than the other smother plant species (Figure 2). In the same experiment, common lambsquarters suppression was 80% or greater and there were no differences among the four smother plant species. Differential weed species response to cover crops has been observed previously (Teasdale 1997). Differences in suppression among weed species are usually attributed to differences in weed emergence times and tolerance to light competition.

The response of crop yields to the smother plant treatments also varied among experiments. At Sioux Center in 1995, corn yield with Berseem clover was similar to the weed-free control (Table 4). All other smother plants reduced yield compared with weed-free corn. It is important to note that although yellow mustard had the fewest weeds, it did not produce the greatest corn yield. This is likely due to the allelopathic nature of Brassica species (Al-Khatib et al. 1997). Reductions in corn yields may also have been caused by allowing the smother plants to survive to maturity. DeHaan et al. (1994) suggested that the smother plants be removed after 4 weeks of competition to prevent significant yield loss from yellow mustard. In this research, yellow mustard densities were declining by 4 weeks after planting, but some plants survived longer. Due to poor smother plant establishment and weed suppression, soybean yields with smother plants were similar to the weedy control and no smother plant treatment resulted in soybean yields similar to the weed-free control.

Conclusions

The data presented in this paper were intended to provide examples of the successes and failures in our attempt to develop spring-seeded smother plant systems for weed control in corn and soybean. Using living vegetation to smother weeds is not a new concept. Weed smothering cover crops have been used in crop rotations for centuries. The best example of a successful smother crop in agronomic systems is the use of a small grain as a companion crop for the establishment of perennial forage legumes. The small grain provides rapid early growth to protect the soil from erosion and compete with weeds while the slow growing forage legume becomes established. Later in the growing season the competition of the small grain is removed and the forage legume becomes the dominant plant. A spring-seeded smother plant system for corn and soybean builds on these same principles.

Spring-seeded smother plants showed potential for weed control in this research. However, inconsistencies among locations, years, and crops suggest that we have much to learn about this system. Timely establishment of an effective smother plant population presents the fundamental challenge in this system. Rapid establishment is essential for smother plants to gain a competitive advantage over weeds. Several species showed potential to become established and suppress weeds in corn, but we were less successful in soybeans. The smother plants seemed to be more successful in corn than soybeans because establishment was more rapid, uniform, and consistent during the cooler, moister conditions that followed corn planting. Yellow mustard was most efficient at reducing weed populations as previously reported (DeHaan et al. 1994), but also reduced corn yields. While the allelopathic properties of yellow mustard made it effective in suppressing weeds, yellow mustard may pose a greater risk of crop yield reduction than smother plant species that suppress weeds primarily through resource competition. The relationships among allelopathy, resource competition, weed suppression, and crop yield warrant further study.

These experiments have demonstrated the potential positive and negative impacts of using smother plants as managed competition for weed control. All species provided at least some weed suppression without herbicide use. However, the timing of establishment and subsequent smother plant life cycles may have subjected the primary crops to excessive competition causing yield reduction. Selecting smother plants with shorter life cycles will alter the duration and/or intensity of the competition. Yellow mustard, annual medics, and other species should continue to be evaluated as smother plants. Beyond their potential as an alternative weed control method, they could also provide soil cover and organic matter to reduce soil erosion, increase soil moisture retention, and improve soil quality.

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