ANNUAL LEGUMES FOR CROPPING SYSTEMS OF THE NORTH CENTRAL USA

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ABSTRACT
On-farm and on-station research on the use of annual legumes in cropping systems was initiated in 1992 in Michigan. Research included studies on nitrogen dynamics, weed suppression ability, forage potential, utility as a cover crop, and optimum planting dates of barrel medic (*Medicago truncatula* Gaertn. cv. Mogul), burr medic (*M. polymorpha* L. cv. Santiago), snail medic (*M. scutellata* L. cv. Sava), and berseem clover (*Trifolium alexandrinum* L.). Nitrogen fertilizer replacement values (FRV) up to 76 kg ha^{-1} were obtained where either corn or canola followed annual legumes in rotation. The optimum seeding time of medics in a medic-corn intercrop system was about one month after corn planting. The interseeded medics were not effective in weed suppression but did contribute up to 40 kg N ha^{-1} to the subsequent crop. Forage dry matter (DM) yields of up to 3.2 Mg ha^{-1} were obtained when the legumes were harvested 60 days after planting (DAP) in early spring.

KEYWORDS
Annual medic, berseem clover, fertilizer replacement value, cropping systems

INTRODUCTION
Recent interest in cropping systems with a sustainable agriculture approach has helped boost interest in the use of legumes in the USA (Bauchan and Sheaffer, 1994). For many years, farmers have used forage legumes in cropping systems to enhance the productivity of a succeeding nonlegume crop (Hesterman, 1988). Most legumes used as forage or cover crops in the North Central USA are perennial species. In many situations, perennials have the advantage of overwintering so that seeding occurs only once every several years. However, overwintering legumes can reduce soil moisture availability to a following crop and require burndown herbicides or cultivation in early spring. Also synchronizing N mineralization with crop uptake may be difficult (Fisk and Hesterman, 1996). Annual legumes establish and grow quickly, are killed by extended cold, can be used as quality emergency forages, and can act as a suitable intercrop, green manure crop, or a rotation crop (Shrestha et al., 1995; Fisk and Hesterman, 1996; Jeranyama et al., 1996). Researchers have been exploring the use of annual legumes, most notably annual medic and berseem clover species, for cropping systems in the Midwest USA. Annual medics are self-pollinating true annuals; they flower, set seed, and die within one growing season (Bauchan and Sheaffer, 1994). Annual medics provide high quality forage (Bauchan et al., 1994) and are used on approximately 50 million hectares in Australia in pastures as a rotation crop with pastures (Crawford et al., 1989). They may improve soil structure, increase soil nitrogen, and reduce soil erosion (Lake, 1994). Berseem clover is an erect, cool-season annual legume believed to have originated in the region of Egypt and Syria (Baldridge et al., 1992). Berseem was introduced in the USA in 1896 and it has been grown successfully in Washington, Oregon, California, Arizona, and some parts of Florida (Kretschmer, 1964; Knight, 1985). Its greatest potential is as a green-chopped forage or pasture and it is known to be non-bloating (Dennis and Massengale, 1962). Berseem has also been successfully used as a green manure and a rotation crop (Baldridge et al., 1992; Westcott et al., 1995). Our objectives were to explore how annual legumes could fit into cropping systems typical of the North Central USA.

MATERIALS AND METHODS
Specific systems included in the study were: (i) corn-annual legume intercrop; (ii) wheat-annual legume-corn rotation; (iii) wheat-annual legume (frost seeding vs. drilling)-corn; (iv) annual legume-canola rotation; (v) asparagus-medic intercrop; (vi) sugarbeet-medic intercrop; and (vii) clear seeded annual legumes as emergency forages. Various aspects related to nitrogen dynamics, weed suppression ability, forage potential, utility as a cover crop, and optimum planting dates of these legumes within these systems were studied.

On-farm studies: On-farm studies were conducted in cooperation with four farmers in central Michigan in 1993 and 1994. The studies included interseeding annual legumes into corn and sugar beets, frost seeding annual legumes into winter wheat, evaluating corn yield following an annual legume cover crop, and using annual medics as cover crops and weed suppressants in asparagus. The interseeding experiments included broadcast seeding annual legumes two to six weeks after corn planting and about ten weeks after sugar beet planting. The biomass production and N accumulation of the annual legumes, effect of annual legume on corn yield, and effect of annual legumes on weed suppression in such a system were evaluated. Likewise, biomass production, nitrogen accumulation, and stand establishment of annual legumes frost seeded into winter wheat and their effect on the yield and weed control in a following corn crop was also evaluated. DM yield, N accumulation, and weed suppression ability of annual medics were also evaluated in an asparagus-annual medic intercrop system.

On-station studies: On-station studies were conducted at the research farms of Michigan State University at East Lansing and Kellogg Biological Station (KBS). Studies were conducted at East Lansing from 1993 to 1995 on the effect of planting date on dry matter yield and nitrogen accumulation of annual medic species either clear-seeded or intercropped with corn. Medics were seeded at five planting dates ranging from May 7 to July 13 as an intercrop with corn or as a sole crop. Corn was planted in all the plots in the subsequent years and FRV's of each system were determined. Other studies at East Lansing and KBS from 1994 to 1996 explored the ability of annual legumes to suppress weeds when interseeded in corn. Treatments included interseeding annual legumes at different densities (6-8 kg ha^{-1} and 12-15 kg ha^{-1}) in corn. Experiments were also conducted at East Lansing and KBS to evaluate the DM yield and forage quality of annual medics and berseem clover as an emergency forage. The experiment included clear seeding annual legumes in early spring and harvesting them 60 DAP followed by a second harvest 30 days later. Treatments in this study also included growing the species for 90 days as a green manure crop. The treatments were followed by canola (*Brassica napus* L.) and the FRV of these species when managed as a forage or green manure crop was determined. A wheat-annual legume-notill corn rotation study was also conducted at East Lansing and KBS. Legumes were no-till drilled into wheat stubble in early August followed by no-till corn in spring. Dinitrogen fixation by the legumes was measured using ^{15}N isotope dilution methods. The FRV of the legume in the no-till corn was also determined.

RESULTS AND DISCUSSION
On-farm studies: Santiago medic established successfully into no-till corn and accumulated up to 30 kg ha^{-1} N when seeded three to six weeks after corn planting. Likewise, Santiago established well when drilled between asparagus rows and accumulated up to 16 kg ha^{-1} N. However, the medics did not establish successfully when interseeded into sugarbeets. The medics were unable to suppress weeds in these studies. Frost-seeding studies on the annual legumes showed that berseem clover frost seeded successfully, accumulated up to 98 kg ha^{-1} N, and contributed significantly to increases in the yield of a following corn crop. Annual medics did not withstand frost seeding.

On-station studies:

Planting date experiment. The medic-corn intercrop experiment showed that planting medics approximately 28 days after corn minimized competitive interactions with corn (Table 1). Planting medics and corn at the same time reduced corn yield by 30%. However, medics reduced N fertilizer needs of corn in the subsequent year by 40 kg ha^{-1}.

Medic-weed interaction study. The presence of annual legumes at different densities in the corn had no effect on corn grain yield. Total weed biomass was not reduced by planting density and there were no species differences.

Wheat-annual legume-notill corn study. Studies conducted at East Lansing and KBS in 1994 and 1995 showed that, on average, Santiago, Mogul, and berseem accumulated 70, 129, and 58 kg ha^{-1} N, respectively at East Lansing and 70, 67, and 48 kg ha^{-1} N, respectively at KBS. During June, available soil N was greater in corn plots following Mogul and berseem than following no cover. The FRV of Santiago, Mogul, and berseem at KBS was 20, 65, and 40 kg ha^{-1} N, respectively. Dry weight of spring annual and perennial weeds were reduced following cover crops. Annual legumes demonstrated good potential for contributing N to a following no-till corn crop and reducing spring annual weeds.

Use of annual legumes as a forage or green manure crop. Annual medics and berseem produced similar or higher yields than alfalfa in the seeding year when planted in early May and harvested 60 DAP (Table 2). Regrowth of annual medics was less than regrowth of alfalfa. Berseem produced an average DM yield of 2.2 Mg ha^{-1} at 60 DAP and 1.8 Mg ha^{-1} at second harvest (30 days after first harvest). The crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentration of the annual medics ranged from 144 to 187 g kg^{-1}, 276 to 355 g kg^{-1}, and 361 to 470 g kg^{-1}, respectively at 60 DAP. Likewise, average CP, ADF, and NDF of berseem at 60 DAP was 200 g kg^{-1}, 279 g kg^{-1}, and 395 g kg^{-1}, respectively. FRV of up to 76 kg ha^{-1} was obtained from the legumes for the following canola crop. Annual medics can be used as emergency forages, however, only the first harvest was suited to mechanical harvest. Berseem clover is suited to mechanical harvesting twice during the season and has forage DM yield and quality comparable to alfalfa at both harvests. Annual legumes, especially Mogul and berseem, can be used successfully as a rotation or green manure crop and can provide N benefits to the subsequent crop.

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Table 1

Medic N accumulation and corn yield at various medic interseeding dates.

Days after	1993		1994	
corn planting	Medic N Produced	Corn Yield	Medic N Produced	Corn Yield
	kg ha^{-1}	Mg ha^{-1}	kg ha^{-1}	Mg ha^{-1}
0	38 b*	6.3 c	45 a	7.0 c
14	45 a	7.0 b	16 b	7.8 b
28	39 ab	8.3 a	22 b	8.8 a
42	22 c	8.2 a	15 b	8.9 a
56	16 d	8.3 a	13 b	9.0 a

*Means followed by the same letter are not significantly different at P<0.05.

Table 2

Average DM yield (mean of two locations) of annual medics and berseem clover at Harvest 1 (60 DAP) and Harvest 2 (90 DAP).

	1994 DM Yield			1995 DM Yield		
Species	Harvest 1	Harvest 2	Total	Harvest 1	Harvest 2	Total
	Mg ha^{-1}					
Alfalfa	2.0	1.5	3.5	2.2	1.8	4.0
Mogul	3.2	2.0	5.2	2.1	1.9	4.0
Santiago	2.0	1.1	3.1	2.1	0.9	3.0
Sava	2.3	0.8	3.1	2.2	0.1	2.3
Berseem	2.0	1.9	3.9	2.5	1.9	4.4