EFFECT OF PLANTING DATE ON DRY MATTER YIELD AND NITROGEN ACCUMULATION OF ANNUAL MEDIC SPECIES EITHER CLEAR-SEEDED OR INTERCROPPED WITH CORN

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crop and Soil Sciences

1995

ABSTRACT

EFFECT OF PLANTING DATE ON DRY MATTER YIELD AND NITROGEN ACCUMULATION OF ANNUAL MEDIC SPECIES EITHER CLEAR-SEEDED OR INTERCROPPED WITH CORN

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The impact of planting date of two annual medic species (*Medicago spp.*), burr medic and snail medic on medic yield and interseeded corn (*Zea mays* L.) yield was evaluated. Medics were either clear-seeded or interseeded into corn at five planting dates ranging from 7 May to 13 July in two years. Clear-seeded medic produced up to 4 Mg ha^{-1} of dry matter yield at intermediate planting dates at 60 days after planting. In the interseeding system, medic dry matter yields were half those in the clear-seeded system. Average above-ground medic N content was 50 and 20 kg ha^{-1} in clear-seeded and interseeded systems, respectively. Interseeding at corn planting produced the greatest medic dry matter, but reduced corn yield the most. Corn yields were not reduced by interseeding 28 days after corn planting. Medics reduced fertilizer needs of corn in the subsequent year by 40 kg N ha^{-1}.

ACKNOWLEDGEMENTS

I thank the members of my guidance committee, Drs R.R. Harwood, R.H. Bernsten and J.J. Kells for their help and interest in my project. I would like to thank my major professor, Dr Oran B. Hesterman in a special way for his mentorship, and great patience while I studied under his guidance. It was fun to work with Oran in the new area of annual medics.

I wish also to thank the W.K. Kellogg Foundation for an International Study Grant Fellowship without whose financial support this thesis would not have been possible and the Government of Zimbabwe for awarding me a study leave.

Most importantly, I thank my wife Letina and son Bongani Tinotenda for their morale support and giving me time to be on the project even at their expense through out the study. I am particularly grateful to my parents who took the initial burden of paying my tuition until college. This degree is as much theirs as mine.

PREFACE

This thesis is written as a manuscript in the style required for publication in Agronomy Journal.

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INTRODUCTION

Legume cover crops have been included in cropping systems for their potential to reduce soil erosion (Scott et al., 1987), increase water infiltration (McVay et al., 1989), smother weeds (Palada et al., 1983; Hartwig and Loughran, 1989) and contribute biologically fixed nitrogen (Heichel et al., 1985, Sheaffer et al., 1989). The N contributed by legume cover crops is often the most important reason growers include them in cropping systems (Hesterman , 1988).

Medics

Medics are annual legumes in the genus Medicago. They are native to arid sites in North Africa and the Middle East that have mild, rainy winters and alkaline soils (Lesins and Lesins, 1979). In those areas, medics typically germinate in late autumn with the onset of winter rains and grow vegetatively until late spring (Brahim and Smith, 1993). Weather-resistant pods and hard-seededness allow natural re-establishment in succeeding years even if winter rains are insufficient in a season to permit seed production (Crawford et al., 1989).

Annual medics are noted for contributing nitrogen to subsequent cereals (up to 200 kg ha^{-1} ; Clarkson, 1986), improving soil physical structure, providing a high quality forage in many regions with Mediterranean climates (Crawford et al., 1989). Medics are also known for regenerating from hard seed (Crawford et al., 1989; Robinson, 1990).

Some medics are native to sites in North Africa that receive less than 250 mm of winter precipitation (Francis, 1981). Even in these regions, medics may still provide significant forage (Gintzburger, 1986). Tadmor et al.(1968) reported that local strains of *Medicago polymorpha* L. established and produced seed in a season with only 78 mm of precipitation at a site in Israel's Negev desert. In a 9-year study, Tadmor et al. (1971) observed that medics established and persisted (re-established from the soil seed bank) at a site in Israel with average water application of 235 mm.

Evaluation of annual medics in the United States has been limited. Rumbaugh and Johnson (1986) evaluated 584 accessions representing 34 *Medicago* species in Utah. In Montana, Sims and Slinkard (1991) adapted the Australian ley farming system to a conventional cropping system by replacing fallowing with a rotation of annual medics, including black medic (*Medicago lupulina* L.). They reported that small grain yields were doubled in a medic-small grain rotation compared to a fallow-small grain rotation.

The value of legumes for supplying nitrogen, reducing soil erosion and improving soil fertility in grain and forage cropping systems is well documented (Hartwig and Louhran, 1989; Sheaffer et al., 1989). In addition to traditional uses for hay, silage and pasture production, legumes have been grown in the United States as winter cover crops (Scott et al., 1987; Frye et al., 1988; Holderbaum, 1990), as intercrops with corn (Scott et al., 1987; Norquist and Wicks, 1991), and as green manure crops (Sheaffer et al., 1989; Hesterman et al., 1992;).

Two common methods of measuring the N contributed by a legume to a cropping system are total N content of the legume biomass (TNLB) and the fertilizer replacement value (FRV) (Hesterman, 1988). The TNLB method assumes that all the legume-N produced is mineralized and available to the subsequent crop. In fact, some studies suggest that only 10 to 30% of the N incorporated in legume material is absorbed by the following crop (Ladd and Amato, 1986; Harris and Hesterman, 1987) with the excess accounted for in soil organic matter, in the inorganic soil N pool, and by losses due to denitrification and leaching. The FRV is defined as the quantity of fertilizer N required to produce a yield in a crop that does not follow a legume that is identical to that produced by incorporation of the legume (Hesterman, 1988). Reported FRV's are in the range of 24 to 176 kg ha^{-1} (Stickler et al., 1958 Utomo et al., 1990).

Intercropping

Results of intercropping corn with forage legumes have been contradictory. Wicks (1974) seeded alfalfa at corn planting, using an herbicide to control weeds and found that corn yields were reduced by at least 1000 kg ha^{-1}. In contrast, Scott et al. (1987) seeded red clover, sweet clover, and hairy vetch into emerged corn. Fall cover was enhanced, but corn yield was not affected either in the year of establishment or in the subsequent year. Some researchers have recorded increases in corn yields with intercropped legumes compared with corn monocultures (Van de Goor, 1954; Nair et al., 1979; Agboola and Fayani, 1972; Nair et al, 1979). Legumes can transfer significant amounts of symbiotically fixed N to neighboring plants. A commonly reported mechanism for N transfer is decomposition of fine roots (those that are not secondarily thickened) and nodules (Dubach and Russelle, 1993).

Depletion of moisture by actively growing legumes in the early spring before corn planting can be a major liability of winter cover crops. In Michigan, when moisture was adequate, intercropping alfalfa and red clover into winter wheat by frost-seeding the legume produced good fall cover and enhanced yield of the subsequent corn crop by 4 to 62% compared to sowing wheat without legumes. However, when moisture was inadequate, in the spring of the second year, intercropping decreased corn yields (Hesterman et al., 1992). Annual medics may provide an opportunity for an interseeded cover crop that dies during the harsh Michigan winter, thereby avoiding soil moisture deficit problems that occur with other longer-lived forage legumes

In an intercropping system, legumes may smother weeds, thereby providing a non-chemical weed control option. Hairy vetch, crown vetch, subterranean clover and alfalfa have been evaluated as smother crops in corn and soybean production systems (Robinson and Dunham, 1954; Palada et al., 1983; Ilnick and Vitolo, 1986; Hartwig and Loughran, 1989). While these legumes have suppressed weeds, they have also sometimes reduced crop yields if herbicides were not used to suppress legume growth. Exner and Cruise (1993) in a 3-yr study of interseeding corn with forage legumes, observed that corn yields were not significantly reduced by intercropping per se, but were reduced when interseeding at an early date interrupted weed control. In a treatment that used herbicide, corn yield was greater than where herbicide was not used. However, yields of intercropped plots, inspite of the herbicide were still significantly below those of the sole cropped corn (control).

Schaller and Larson (1955) in Iowa, Scott and Patterson (1962) in Illinois and Norquist and Wicks (1974) in Nebraska documented that in the Midwest, practices that favor intercropping often harm the row crop and vice versa. For example, the earlier the legume is seeded relative to the corn planting date, the more likely it is that the corn plant will suffer (Pendleton et al., 1957), and as corn rows are widened, legumes are benefitted as corn yields are decreased (Tesar, 1957). Although studies have shown the potential for increased N fixation and uptake in corn-legume intercrops (Patra et al., 1986), N competition has, in practice, often played the dominant role (Tomar et al., 1988).

The ultimate test of legume intercropping may be the impact on weed management. Not only do weeds compete with the intercropped species, they cause reduction of corn yields that may be incorrectly attributed to the intercrop. Exner and Cruise (1993) noted that reliable, weed free establishment of the interseeded legume is critical to the success of this practice. The fine seed bed required by small-seeded legumes is also ideal for weed germination.

Objectives

This research was undertaken to provide basic information on planting date response and nitrogen contribution from two species of annual medic. Specific objectives were: i) to evaluate the effect of medic planting date on biomass and nitrogen production of the medics in both a "clear seeding" and interseeded with corn, ii) to evaluate impact of medics seeded at different times on weeds and companion corn growth and yield, iii) to determine and compare the effect of interseeded legume and fertilizer-N based cropping systems on corn grain yield and N uptake and iv) to evaluate the response of a subsequent corn crop to the interseeded medics and compare this with the response to fertilizer N.

MATERIALS AND METHODS

Experiment 1: Effect of Planting Date on "Clear-seeded" Medics.

This study was conducted at the Michigan State University Agronomy Farm in East Lansing, MI. The soil type for the field used in 1993 was a Capac loam (fine-loamy, mixed, mesic Aeric Ochraqualfs), and a Conover loam (Udallic Orchraqualfs, fine loamy, mixed, mesic) in 1994. Two species of annual medics, *burr medic (M. polymorpha* L. cv. Santiago) and snail medic *(Medicago scutellata* L. cv. Sava) were seeded at five planting dates in each of two years (7 May, 21 May, 4 June, 18 June, 2 July in 1993 and 18 May, 1 June, 15 June, 29 June, 13 July in 1994). The experimental design was a randomized complete block in a split-split plot arrangement with medic species as the main plot, planting date as sub plot and sampling date as sub-sub plot. Treatments were replicated four times. The plot size was 1.5 x 6 m in 1993 and 2.4 x 6 m in 1994. Santiago and Sava were seeded at rates of 7.3 kg ha^{-1} and 28 kg ha^{-1} in 1993 and at 17 kg ha^{-1} and 36 kg ha^{-1} in 1994, respectively, with a hand-operated nursery seeder. Medic seeds were inoculated with *Rhizobia meliloti* before planting. In 1994, all plots were treated with preplant incorporated *S*-ethyl dipropylcarbamothiate (EPTC) at 3 kg a.i ha^{-1} and hand weeded when necessary. On 2 August 1994 4-(2,4-dichlorophenoxy)butanoic acid (2,4-DB) was applied at 1 kg a.i. ha^{-1}. All the plots were fertilized with 60 kg ha^{-1} of P_2O_5 and 190 kg ha^{-1} of K_2O following soil tests.

For each plot, biomass and nitrogen production were measured. Hand clippers were used to sample above-ground plant biomass from a 0.108 m^{-2} quadrat in each plot at 45, 60, 75 and 90 days after planting (DAP). Successive samples were taken from areas that had not been previously sampled.

Expt.2: Effect of Planting Date on Medic and Corn Interplantings.

This experiment was comprised of the same five planting dates and two medic species as in Expt. 1 in each of the following two cropping systems.

(a) corn + medic (with herbicide) ; no N

(b) corn + medic (without herbicide) ; no N

In addition, five treatments were included either as controls or to establish a corn yield response to N fertilizer when no medics were present. These treatments included:

(c) corn alone (no medic ; without herbicide)

(d) corn alone (no medic ; with herbicide) ; no N

(e) corn alone (no medic ; with herbicide) ; 60 kg ha^{-1}

(f) corn alone (no medic ; with herbicide) ; 120 kg ha^{-1}

(g) corn alone (no medic ; with herbicide) ; 180 kg ha^{-1}

The experiment was a randomized complete block design in a factorial arrangement becoming a split plot over sampling date. Treatments were replicated four times. Plot sizes were 3 x 6 m in 1993 and 3 x 7.5 m in 1994, with 4 corn rows per plot. Weed control treatments were either no herbicide or herbicide (pre-plant incorporated EPTC+ dichloramid at 3 kg a.i. ha^{-1}). The herbicide-treated plots were cultivated with a rotary-tiller in addition to herbicide application before planting after the third planting date.

Corn Corn (*Zea mays* L. Pioneer cv. 3751) was planted on 7 May 1993 at 58, 300 seeds ha^{-1} and 18 May 1994 at 64, 100 seeds ha^{-1}. All plots were fertilized prior to planting with 60 kg ha^{-1} of P_2O_5 and 190 kg ha^{-1} of K_2O in 1993 and 110 kg ha^{-1} of P_2O_5 and 110 kg ha^{-1} of K_2O in 1994. Nitrogen applied as ammonium nitrate was broadcast at rates of 0, 60, 120 and 180 kg ha^{-1} and incorporated at planting in designated plots. Corn grain was harvested by hand from a 5.4 and 6.0 m section of the center two rows in each plot in 1993 and 1994, respectively. Grain yields were adjusted to 155 g kg^{-1} moisture. Corn stover was sampled by harvesting stalks from the yield rows of each plot. In 1994, corn was planted in the field that had been interseeded with medics to evaluate the response of a subsequent corn crop to legume and fertilizer N.

Medic Medic seeds were inoculated with *Rhizobia meliloti* before interseeding between corn rows using a hand-operated nursery seeder. Sava was seeded at 25 kg ha^{-1} in 1993 and 32 kg ha^{-1} in 1994 and Santiago at 6.5 kg ha^{-1} in 1993 and 15 kg ha^{-1} in 1994. At the last planting date in 1993 and the two latest planting dates in 1994, medic seeding was by hand broadcasting and hand raking between corn rows because the nursery seeder could not fit in the row due to size of the corn plants.

Above-ground growth of medics was sampled at 45, 60, 75 and 90 DAP from a 1-m length in the inter-row space between the border and either the second or third corn row of each plot. Weeds and medics were separated and both components were dried, weighed and analyzed for total N content using the Kjeldahl method (except for the weeds). Corn yield and nitrogen content of grain and stover were measured in samples in two center rows after the corn ears matured (black layer).

Plant Analysis and N Calculation

All medic, weed and corn (except where otherwise noted) samples were weighed before and after drying and moisture content was calculated to express yield measurements on a dry matter (DM) basis. After drying, samples of medics, corn grain and stover were ground to pass through a 1-mm screen using a cyclone mill. Total N concentration of ground samples was determined by micro-Kjeldahl digestion of 0.100 g plant material in 12M H_2SO_4 with 1.5 g K_2SO_4 and 0.075 g Se catalyst. Following digestion, total NH_4^+ in samples was determined by Lachat Quick Chem method # 10-1-07-06-2-E (Lachat Chemicals, Inc, Mequon, WI). Total N content of materials was calculated as a product of DM content and N concentration. Corn stalks were weighed and subsampled for drying at 60^0C . Dried stalks were ground and analyzed for total N.

Statistical analysis

Experiment 1 was analyzed as a randomized complete block arranged in a split-split plot design with four replications. Medic species were main plots, planting dates was the subplot and sampling dates were sub-sub plots. Data were analyzed by General Linear Model (GLM) of SAS and means were separated by the Least Significant Difference test (LSD) (Petersen, 1985) when the ANOVA indicated a significant F ($P \leq 0.05$).

Experiment 2 was analyzed as a randomized complete block design with treatments arranged in a split-plot. Combination of medic species, planting dates and weed control were main plots while sampling dates were subplots. Data were analyzed by GLM of SAS. Significant treatment effects were partitioned by non-orthogonal contrasts using Bonferroni t-test (Gill, 1978).

Response to N fertilizer rate was determined by evaluating linear and quadratic trends from single degree of freedom comparisons. If trends were significant, regression equations were calculated and used to determine fertilizer replacement values (FRV) for interseeded medics. Fertilizer Replacement Values of legumes interseeded into corn in the interseeding year and subsequent-year, corn were calculated based on grain yield, grain N content and total plant N uptake only when a significant ($P \leq 0.05$) difference was observed between either interseeded corn or corn following medic and the control.

RESULTS AND DISCUSSION

Experiment 1: Clear-seeded medics

Dry matter yield. In both years of the experiment, there were no significant ($P \leq 0.05$) differences in dry matter yield between the two medic species. Due to significant ($P \leq 0.05$) planting date x sampling date interactions, results are discussed as effects of planting date, averaged over the two medic species.

Medic dry matter yields ranged from 0.3 to 3.9 Mg ha^{-1} averaged over the two years (Table 1). This range of dry matter yield compares well with other forage legumes that are adapted to the northcentral USA, including hairy vetch (*Vicia villosa* Roth) (0.4 to 1.4 Mg ha^{-1}; Power et al., 1991), mammoth red clover (*T. pratense* L.) (0.6 to 1.6 Mg ha^{-1}; Stute and Posner, 1993) and ladino clover (*T. repens* L.) (1.2 to 1.8 Mg ha^{-1}; Stute and Posner, 1993). Medic planting date influenced dry matter production in both years at all sampling dates (Table 1). In 1993, dry matter accumulation was greatest with intermediate planting dates (PD 14 and 28) when sampled at 60 DAP (Table 1). In 1994, medic dry matter yields were not significantly ($P \leq 0.05$) different for the first three medic planting dates. However, medics planted at these early dates produced lower dry matter yields than medics planted at the last planting date (Table 1) . The lack of a clear trend in 1994 could be explained partially by the application of 2,4 DB on 2 August for weed control. The herbicide (which is also a growth regulator) may have induced secondary growth in the last two planting dates resulting in high biomass accumulation.

Severe winter kill of alfalfa (*Medicago sativa* L.) in some years prompts the need for emergency forages in Michigan and other northcentral states (Shrestha et al., 1994). Non-leguminous crops such as sorghum, sudangrass and sorghum-sudangrass are currently being used as emergency forages in this region but they are generally lower than legumes in protein. These results suggest that annual medics have the potential for emergency forages if planted early in spring and harvested at 60 to 75 DAP. Seeding early in the spring allows the longest growing season, however, in this study, weed pressure appeared to be a major factor limiting dry matter production. Similar observations were noted by other workers (Reddy et al., 1986; Stute and Posner, 1993).

<u>Nitrogen accumulation.</u> Nitrogen concentration in Sava (25 g kg^{-1}) was significantly ($P \leq 0.05$) higher than of Santiago (21 g kg^{-1}) in 1994 averaged over the five planting dates and four sampling dates. Although the two species were not statistically different in 1993, Sava had a numerically higher N concentration. From observations, Santiago developed more quickly than Sava, reaching senescence slightly after 60 DAP, while Sava reached senescence well after 75 DAP. Taylor et al. (1982) and Fleming et al., (1989) noted that N concentration of legumes was related to maturity rather than location or season and earlier maturity of Santiago could be responsible for the lower N concentration. Nitrogen concentration of medics generally increased with delayed

planting at most of the sampling dates. Because medics that were planted later were less mature at a particular sampling date, this provides additional evidence that maturity is associated with N concentration.

Nitrogen content is determined by both dry matter yield and N concentration in legume biomass (Wagger, 1989; Hesterman et al., 1992). Therefore factors that affect each of the components will in turn affect N content. Nitrogen content ranged from 1.6 to 105 kg ha^{-1} averaged over two years (Table 1). This range of medic N content compares with other legumes such as red clover and hairy vetch (25 to 81 kg ha^{-1}; Scott et al., 1987), alfalfa and red clover (54 to 73 kg ha^{-1}; Holderbaum et al., 1990) but are lower than common vetch (156 to 192 kg ha^{-1}; Holderbaum et al., 1990).

In 1993, there were significant ($P \leq 0.05$) planting date x sampling date and species x sampling date interactions for N content (Tables 1 and 2). Larger amounts of N were accumulated in both species at 60 DAP than at other sampling dates in 1993 (Table 2). However, in 1994, medics accumulated the most N at the latest two planting dates regardless of sampling date (Tables 1 and 3). Because sampling date did not interact significantly with other factors in 1994, data on sampling date main effects are presented in Table 4. Nitrogen content of medics increased with delayed sampling in 1994. Medics sampled at 45 DAP produced only 40% of the N content measured at 90 DAP. Sampling at 90 DAP offered the medics a longer growth period than did early sampling thereby increasing dry matter yield and N content. Similar results were reported by other researchers (Hargrove, 1986; Utomo, 1986; Bruulsema, 1987; Wagger, 1989; Bollero et al., 1994). Higher N content at early planting dates in 1993 and later planting dates in 1994 corresponded to timing of dry matter production rather than to changes in N concentration, confirming that dry matter yield is the overriding factor influencing N content rather than N concentration (Reddy et al., 1986; Wagger, 1989; Holderbaum et al., 1990).

Table 1 Effect of planting date on dry matter yield (DM), N concentration [N] and N content of clear-seeded medic at four sampling dates in 1993 and 1994. Values are averages of two medic species.

		45 DAP‡			60 DAP			75 DAP			90 DAP		
Year	PD†	DM	[N]	N	DM	[N]	N	DM	[N]	N	DM	[N]	N
		Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}
1993	0	0.31	21	6.5	1.20	17	20.4	1.68	23	38.6	1.69	19	32.1
	14	1.06	21	22.3	3.11	23	71.5	3.09	22	68.1	1.25	18	22.5
	28	1.89	24	45.4	2.91	25	72.6	1.68	21	35.3	1.35	17	23.1
	42	1.12	27	34.3	1.46	25	36.5	0.95	19	18.1	1.16	21	24.4
	56	0.56	36	20.2	0.62	27	16.7	0.80	20	1.6	0.42	18	7.60
	$LSD_{.05}$	0.37	9	10.3	0.92	6	26.3	0.89	3	22.1	0.96	4	16.9
	CV(%)	36.2	32	44.0	46.0	23	52.9	51.5	14	55.6	78.9	18	75.9
1994	0	0.77	22	16.9	1.74	21	36.5	1.73	23	39.8	2.10	24	50.4
	14	1.03	21	21.6	1.20	23	27.6	1.66	22	36.5	1.57	21	33.0
	28	0.51	27	13.8	1.21	27	32.7	2.31	20	46.2	2.10	24	50.4
	42	0.76	32	24.3	1.36	23	31.3	2.09	26	54.3	1.88	28	52.6
	56	1.43	30	42.9	2.04	27	55.1	2.60	29	75.4	3.90	27	105.3
	$LSD_{.05}$	0.41	5	10.0	0.56	4	18.3	0.90	5	NS	0.99	4	29.3
	CV(%)	44.4	19	40.8	37.8	18	47.5	42.0	19	52.5	41.5	14	48.1

NS = Non significant at $P \leq 0.05$.

† Planting date expressed as days after 7 May 1993 and 18 May 1994.

‡ Days after planting.

Table 2 Effect of species on N content of clear-seeded medic sampled at four times in 1993. Data are means of five planting dates.

DAP	Santiago	Sava
	-------kg ha^{-1}-------	
45	18.6	25.8
60	36.9	58.7
75	30.8	45.5
90	22.9	18.1
LSD(0.05)	10.2	8.6

Table 3 Effect of planting date on N content of clear-seeded medics in 1994. Data are means of two medic species and four sampling dates.

PD	N content (kg ha^{-1})
18 May	34.1
01 June	30.1
15 June	38.7
29 June	40.7
07 July	70.5
LSD (0.05)	10.3

Table 4 Effect of sampling date on N content of clear-seeded medics in 1994. Data are means of two medic species and five planting dates.

DAP	N content (kg ha^{-1})
45	23.6
60	37.0
75	50.7
90	59.0
LSD (0.05)	9.1

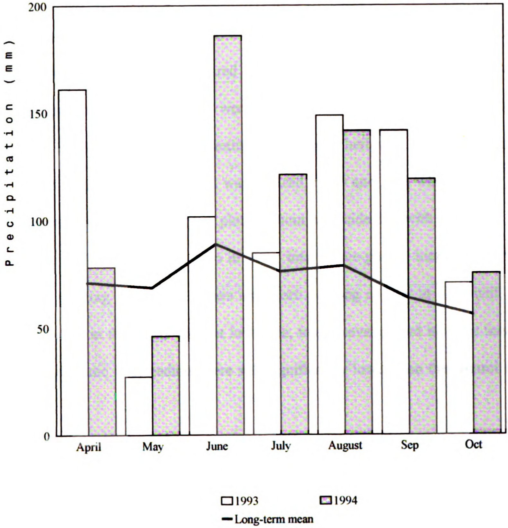

Figure 1 Monthly precipitation during the 1993 and 1994 growing seasons at East Lansing.

Experiment 2. Annual medic planting date effect on companion corn.

Corn Yields. Interseeding medics at either corn planting or 14 days after corn planting was associated with a corn grain yield reduction of an approximately 20 and 50% in 1993 (Table 5) and 20 and 37% in 1994 (Table 6), in plots with and without herbicide, respectively, when compared to corn grown with no intercrop in plots with herbicide applied. Corn grain yields were not significantly reduced when medics were interseeded at 28 days after corn planting in plots with herbicide applied in both years. Total above-ground biomass of corn was reduced by 40 and 32% when medics were simultaneously planted with corn in plots without herbicide and with herbicide respectively, in 1993 (Table 5). Also in 1993, total above-ground biomass was not reduced by planting medics at 28 days after corn planting or later in plots with herbicide, while in the plots without herbicide, total above-ground biomass increased with delayed medic interseeding, were still significantly lower than the control (Tables 5 and 7).

Medic species significantly ($P \leq 0.05$) affected total above ground biomass of corn in 1994. Sava reduced total above-ground biomass of corn by 20% when planted on the same date with corn while Santiago produced a similar effect at the second medic planting date (1 June) (Table 6). Our results agree with Nordquist and Wicks (1974) who reported a corn yield loss of 1 Mg ha^{-1} when corn was seeded with alfalfa at corn planting. Exner and Cruse (1993) interseeded alfalfa, yellow sweet clover (*Melilotus officinalis* Lam.), red clover and alsike clover (*T. hydridum* L.) at corn planting and 28 DAP, and observed that corn yields were not significantly reduced by

Table 5 Relative grain yield (%), total above-ground biomass and total N uptake of non-N fertilized corn with interseeded medics in 1993.

PD[†]	Grain yield		Total biomass[‡]		Total N uptake	
	without herbicide	with herbicide	without herbicide	with herbicide	without herbicide	with herbicide
	-----------------------------------%-----------------------------------					
7 May (0)[‡‡]	52 (3.6)[§§]	80 (4.0)	60 (7.1)[¶¶]	68 (8.0)	71 (74)[¥¥]	84 (87)
21 May (14)	49 (3.4)	80 (4.0)	64 (7.6)	75 (8.9)	75 (78)	93 (97)
4 June (28)	52 (3.6)	104 (7.3)	67 (7.9)	98 (11.6)	74 (77)	121 (126)
18 June (42)	74 (5.2)	107 (7.5)	71 (8.4)	98 (11.6)	81 (84)	120 (125)
2 July (56)	83 (5.8)	110 (7.7)	79 (9.3)	97(11.4)	93 (97)	112 (116)
weedy check	43 (3.0)		76 (9.0)		80 (83)	
Control	100[§]		100[¶]		100[¥]	
			Selected comparisons with control[††]			
7 May vs Control	**	*	**	**	*	NS
4 June vs Control	**	NS	**	NS	*	*
weedy check vs control	**		*		*	
CV (%)	20.7		13.1		18.4	

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

NS = non significant at $P \leq 0.05$.

[†] Planting date.

[‡] Total above-ground biomass of corn.

[§] Actual grain yield is 7 Mg ha^{-1} for corn alone with herbicide.

[¶] Actual total above-ground biomass yield is 11.8 Mg ha^{-1} for corn alone with herbicide.

[¥] Actual total plant N uptake is 104 kg ha^{-1} for corn alone with herbicide.

[††] Bonferroni t-test for non-orthogonal contrast.

[‡‡] Numbers in parenthesis are days after corn planting.

[§§] Actual grain yield (Mg ha^{-1}) for each planting date is in parenthesis

[¶¶] Actual totalabove-ground biomass (Mg ha^{-1}) for each planting date is in parenthesis

[¥¥] Actual Total plant N uptake (kg ha^{-1}) for each planting date is in parenthesis

Table 6. Relative grain yield (%), total above-ground biomass and total N uptake of non- fertilized corn with interseeded medics in 1994.

PD[†]	Grain yield: without herbicide	Grain yield: with herbicide	Total above-ground biomass: Santiago	Total above-ground biomass: Sava	Total N uptake
	------------------------------%		------------------------------		
18 May (0)[‡‡]	60 (6.2)[††]	76 (7.8)	90 (9.9)[§§]	80 (8.8)	75 (72)[¶¶]
1 June (14)	66 (6.8)	84 (8.7)	80 (8.8)	103 (11.3)	81 (78)
15 June (28)	78 (8.0)	88 (9.1)	96 (10.6)	104 (11.4)	93 (89)
28 June (42)	73 (7.5)	84 (8.7)	100 (11.0)	90 (9.9)	83 (80)
7 July (56)	73 (7.5)	83 (8.5)	91 (10.0)	96 (10.6)	84 (81)
weedy check	80 (8.2)		98		89 (85)
Control	100[‡]		100[§]		100[¶]
			Selected comparisons with control[¥]		
18 May vs control	**	*	NS	*	*
15 June vs control	*	NS	NS	NS	NS
weedy check vs control	*		NS		NS
CV (%)	13.2		18.5		11.5

*, ** Significant at 0.05 and 0.01 probability levels, respectively.
NS = non significant at $P \leq 0.05$.
[†] Planting date. [‡] Actual grain yield is 10.3 Mg ha^{-1} for corn alone with herbicide.
[††] Actual grain yield (Mg ha^{-1}) for each planting date is in parenthesis.
[§] Actual total above-ground biomass is 11 Mg ha^{-1} for corn alone with herbicide.
[§§] Actual total above-ground biomass (Mg ha^{-1}) for each planting date is in parenthesis.
[¶] Actual total N uptake is 96 kg ha^{-1} for corn alone with herbicide.
[¶¶] Actual total N uptake (kg ha^{-1}) for each planting date is in parenthesis
[¥] Bonferroni t-test for non-orthogonal contrast.
[‡‡] Numbers in parenthesis are days after corn planting.

interseeding per se, but were reduced when interseeding at corn planting interrupted weed control measures. In our weed-free plots, no further weed control was done once medics were interseeded. Higher total corn N uptake was associated with plots interseeded with medics 28 days after planting or later and herbicide when compared to the control in 1993 (Table 5). Because medics interseeded 28 days after corn planting did not accumulate significant amount of N (Table 8), the results discussed are not due to medic N contribution. Other factors are responsible for the increased corn N uptake such as reduced competition for soil N between corn and medics and rotation effect that could not be separated from N contribution in this study.

Our results indicate that it is best to delay interseeding until about 28 days after corn planting, a date coinciding with the last cultivation. Seeding any earlier tends to cause competition between medic and corn which results in lower yields. Other researchers have documented yield reductions at early seeding relative to corn planting (Pendleton et al., 1986; Larson and Willis, 1957). Tesar (1957) ascribed yield reduction to interspecific moisture competition while Tomar et al. (1988) explained it as due to N competition. Researchers have given similar recommendations for Iowa (Schaller and Larsen, 1955), Ohio (Johnson, 1955) and Illinois (Pendleton et al., 1957).

Scott et al. (1987) interseeded various cover crops when corn was 0.15 to 0.30 m high and did not observe any yield changes when compared to corn alone. Unlike Scott et al. (1987), who side dressed 90 kg N ha^{-1} in corn intercrops, our corn interseedings did not receive any N fertilizer other than the soil test recommendations

Table 7 Effect of medic planting date and weed control on total above ground biomass production of interseeded corn in 1993. Data are means of two medic species.

	Without herbicide	With herbicide
PD†	-------Mg ha^{-1}------	
7 May (0)‡	7.96	9.24
21 May (14)	8.69	10.23
4 June (28)	9.1	13.35
18 June (42)	9.58	13.26
2 July (56)	10.7	13.11
LSD $_{0.05}$	1.32	1.55

† Planting date.

‡ Numbers in parenthesis are days after corn planting.

24 for P and K.

Medic Dry Matter Yield. Averaged over the four sampling dates, dry matter yields of medics interseeded into corn were higher with earlier seeding dates in both years of the experiment (Table 8). These results corroborate findings of Pendleton et al. (1957) and Reddy et al. (1986) that early planting dates provide longer growth periods and higher dry matter accumulation. Planting medic at corn planting provides a period of growth before corn canopy closure that reduces competition with the medic for light. In contrast, late plantings grow under the corn canopy for the entire season which results in low dry matter yield (Stute and Posner, 1993).

Averaged over the five planting dates, Sava produced significantly ($P \leq 0.05$) higher dry matter yields than did Santiago in both years (500 vs 300 kg ha^{-1}) (Table 9). Both medic species produced higher dry matter yields in 1993 than in 1994. This may be explained by the seasonal precipitation patterns in 1994. Total seasonal precipitation in 1993 was slightly above normal and 1994 had excessively higher precipitation compared to the long-term average (Figure 1). Excessive precipitation in 1994 caused water-logging in some of the interseeded plots which in turn promoted a high incidence of root rot disease (*Phytopthora* sp.), hence low dry matter yields.

There was a significant ($P \leq 0.05$) planting date x weed control interaction for medic dry matter yield in 1993. Plots with herbicide were associated with higher medic yields than plots without herbicide at early planting dates (Table 10). In later

Table 8 Effect of medic planting date on dry matter yield (DM), N concentration [N] and N content of interseeded medics into corn at four sampling dates in 1993 and 1994. Data are means of two medic species across weed control.

		45 DAP‡			60 DAP			75 DAP			90 DAP		
Year	PD†	DM	[N]	N	DM	[N]	N	DM	[N]	N	DM	[N]	N
		Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}
1993	0	0.32	23	7.2	1.24	21	26.6	1.77	22	39.3	0.97	13	11.7
	14	0.67	21	13.4	1.33	23	31.8	1.04	15	16.5	0.72	16	12.1
	28	0.56	25	17.2	0.52	16	7.3	0.30	17	5.1	0.22	16	3.4
	42	0.06	18	1.1	0.11	21	2.1	0.20	15	6.7	0.07	17	3.6
	56	0.05	21	1.0	0.06	22	2.5	0.10	20	0.8	0.08	14	1.1
	LSD.05	0.12	4	4.6	0.25	3	6.9	0.37	3	10.3	0.20	NS	4.7
	CV(%)	44	19	54	45	15	45	63	15	61	58	15	55
1994	0	0.35	23	8.1	0.93	19	17.7	0.35	18	6.3	0.16	17	2.7
	14	0.42	20	8.5	0.35	17	6.0	0.13	18	2.3	0.08	14	1.1
	28	0.09	21	2.0	0.23	18	4.1	0.16	16	2.6	0.09	20	1.8
	42	0.07	19	1.3	0.30	19	5.7	0.17	21	3.6	0.19	22	4.2
	56	0.16	17	3.1	0.15	21	3.2	0.23	19	4.4	0.19	18	3.4
	LSD.05	0.14	4	2.5	0.30	3	4	0.16	4	3.4	0.09	5	2.7
	CV(%)	44.4	24	64	52	20	62	43	26	43	77	25	72

NS = Non significant at $P \leq 0.05$.

† Planting date expressed as days after 7 May 1993 and 18 May 1994.

‡ Days after planting .

Table 9. Effect of species on dry matter yield and N content of medics interseeded into corn in 1993 and 1994. Values are means of five planting dates and four sampling times.

Year	Santiago		Sava	
	DM	N	DM	N
	Mg ha^{-1}	kg ha^{-1}	Mg ha^{-1}	kg ha^{-1}
1993	0.47	11.3	0.61	16.1
1994	0.14	3.2	0.34	6.6
Mean	0.31	7.3	0.48	11.4

Table 10 Effect of medic planting date and weed control on dry matter yield of interseeded medics into corn in 1993. Values are means of two medic species and four sampling dates.

	Without herbicide	With herbicide
PD†	------Mg ha^{-1}------	
7 May (0)‡	0.69	1.43
21 May (14)	0.57	1.30
4 June (28)	0.20	0.56
18 June (42)	0.13	0.07
2 July (56)	0.10	0.04
$LSD_{0.05}$	0.20	0.15

† Planting date.

‡ Numbers in parenthesis are days after corn planting.

plantings, 42 and 56 days after corn planting, medic dry matter yield was relatively unaffected by weed control measures. Exner and Cruse (1993) also reported little effect of herbicide on weed control at late plantings. Possible explanations for these results are (I) ineffectiveness of pre-plant incorporated EPTC + dichlormid at 42 and 56 days after incorporation (herbicide efficacy and longevity), (ii) due to severe weed infestations in both plots with and without herbicide, tillage was performed at the last two planting dates before seeding and also (iii) at the last two planting dates, rather than using the nursery seeder due to the corn canopy closure, seeding was by hand broadcasting and harrowing for seed incorporation and this resulted in poor medic stands.

Nitrogen accumulation. In 1994, Sava produced a higher N concentration than did Santiago when sampled at 45 and 60 DAP. After this time, however, N concentration in Sava declined while N concentration in Santiago increased with sampling date (Table 11). Nitrogen concentration for Sava was always higher than for Santiago at the first three medic planting dates in both years (Table 12). Nitrogen content for Sava and Santiago were 11 and 7 kg ha^{-1} respectively, averaged over the five planting dates and four sampling dates in the two years of the experiment (Table 9). These N content yields compare with red clover and hairy vetch interseeded into corn (8 to 29 kg ha^{-1}; Scott et al., 1987), and spring herbage N content of Nitro alfalfa and mammoth red clover interseeded into oats (10 to 14 kg ha^{-1}; Hesterman et al., 1992), but are lower than clear-seeded legumes (Wagger, 1989; Sheaffer et al., 1990). The

Table 11 Effect of species and sampling date on N concentration of medics interseeded into corn in 1994. Values are averaged over the five planting dates.

DAP†	Santiago	Sava
	-------g kg^{-1}-------	
45	18	22
60	17	19
75	19	18
90	21	17
LSD(0.05)	2	2

† Days after medic planting.

Table 12 Effect of species and planting date on N concentration of medics interseeded into corn in 1993 and 1994.

PD[†]	Santiago	Sava
	1993	
	-------g kg^{-1}-----	
0	19	21
14	19	20
28	18	19
42	19	17
56	18	17
LSD(0.05)	NS	2
	1994	
0	19	19
14	16	18
28	18	20
42	23	19
56	17	20
LSD (0.05)	2	2

NS = Non significant at $P \leq 0.05$ level.

[†] Planting date of medic expressed as days after corn planting (7 May 1993 and 18 May 1994).

lower N production by interseeded legumes, however, is at least offset by the production of a saleable crop (corn) during the first year of rotation (Hesterman et al., 1992).

Weed competition. The predominant weeds in this experiment were redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters (*Chenopodium album* L.). Weed biomass ranged from 200 to 2300 kg ha^{-1} in plots without herbicide and 20 to 600 kg ha^{-1} in plots with herbicide, averaged over the two years. Due to of significant interactions, weeds data are discussed as effect of planting date and weed control on weed biomass sampled at 45 DAP (Figure 2).

Weeds competed with corn and medics severely at times. On average, corn grain yield was reduced by 57% in plots without herbicide when compared to plots with herbicide, when both were interseeded with medics (Table 5). Because of the dry spring in 1993, there were fewer total weeds in the early seeded plots than in later seeded plots (Figure 2). It appears as if peak weed germination in 1993 was between 21 May and 18 June in this study (Figure 2). A decline in weed biomass for planting dates 18 June and 2 July indicate increased competitiveness of corn 42 and 56 days after planting, at this stage corn canopy is fully formed and relative fewer weeds are germinating under the corn canopy due to reduced light intensity (Figure 2). Aldrich (1984) concluded that competition for light is the most limiting factor inhibiting plant growth because it can not be stored or transferred within plant.. In 1994, precipitation was about normal at early seeding and much above normal in summer. Weeds

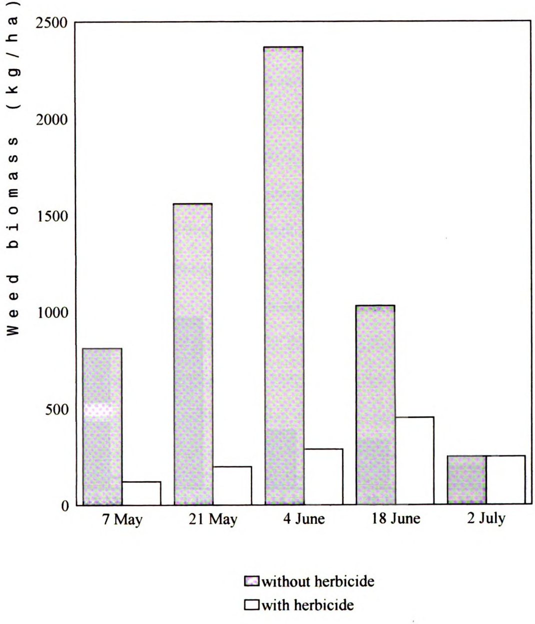

Figure 2 Weed dry matter yield at 45 DAP in corn plots interseeded with medics, at five medic planting dates with or without herbicide in the interseeding date experiment in 1993.

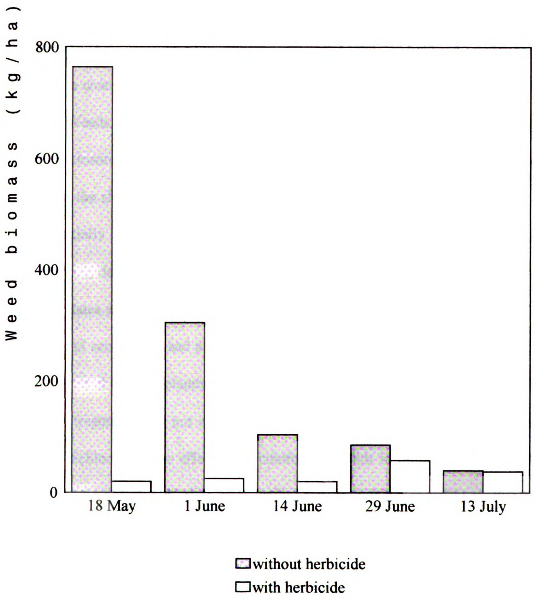

Figure 3 Weed dry matter yield at 45 DAP in corn plots interseeded with medics, at five medic planting dates with or without herbicide in the interseeding date experiment in 1994.

significantly competed for light and nutrients with both the interseeded medics and corn (Tables 5,6 and 10). In 1994, early seedings were associated with higher weed biomass at 45 DAP. Peak weed emergence occurred sometime before 45 DAP as indicated by a characteristic decline in weed biomass from the first planting date (Figures 3). Weeds germinating at corn planting have an opportunity to grow before corn canopy closure for better light interception, while later weed flushes will grow all their cycle in the shade. Reduced biomass accumulation in later dates could be explained partially by the fact that even though weeds emerged at the same time as in the first planting date, the sampling date for each medic planting date is different. Later medic dates are associated with corn canopy closure as the leaf area index increases, weed senescence and a period after peak weed germination. Due to a cultivation done at the last planting date in 1993 and last two planting dates in 1994, weed control treatments did not differ in weed biomass accumulation (Figures 2 and 3). EPTC + dichloramid was effective in controlling weeds in plots interseeded with medics for all the planting dates in 1993 except for the last date. In 1994, herbicide was effective from the first planting date up to the third planting date (14 June). As in the previous year, effect of weed control measures could not be assessed for the last two planting dates due to the confounding effect of cultivation. Several factors interact to make crop and weed competition a complex phenomenon including temporal and spatial factors. Species, density, pattern and duration have profound effects on a weeds' competitive ability (Aldrich 1994). Similarly planting geometry, date, rate and duration play a key role in a crops' competitive ability. Temporal factors include the

Table 13. Relative grain yield (%), total above-ground biomass, grain N uptake and total N uptake of non-N-fertilized corn following corn with and without interseeded medic (with or without herbicide) in 1994.

	Grain yield	Total biomass†	Grain N uptake	Total N uptake
	------------------------	%	------------------------	
Corn (medic without herbicide)	113 (5.9)‡‡	95 (7.9)§§	112 (32.5)¶¶	98 (64.7) ¥¥
Corn (medic with herbicide)	122 (6.3)	103 (8.6)	124 (36.0)	110 (72.6)
Control (corn alone)	100 (5.2)‡	100 (8.3)§	100 (29)¶	100 (66)¥
		Significance††		
Without herbicide vs control	*	NS	*	NS
With herbicide vs control	**	NS	**	*
CV (%)	19.7	17.7	20.1	19.5

*, ** Significant at 0.05 and 0.01 probability levels, respectively.
NS = not significant at $P \leq 0.05$.
† Total above-ground biomass of corn.
‡ Actual grain yield is 5.2 Mg ha^{-1} for corn following non interseeded corn.
‡‡ Actual grain yield (Mg ha^{-1}) for each weed control treatment is in parenthesis.
§ Actual total above-ground biomass is 8.3 Mg ha^{-1} for corn following non interseeded corn
§§ Actual total above-ground biomass (Mg ha^{-1}) for each weed control treatment is in parenthesis.
¶ Actual grain N uptake is 39 kg ha^{-1} for corn following non interseeded corn.
¶¶ Actual grain N uptake (kg ha^{-1}) for each weed control treatment is in parenthesis.
¥ Actual total N uptake is 66 kg ha^{-1} for corn following non interseeded corn.
¥¥ Actual total N uptake (kg ha^{-1}) for each weed control treatment is in parenthesis.
†† Bonferroni t-test for non-orthogonal contrasts.

critical period of weed interference, i.e. that period where it is essential to maintain a weed-free environment to prevent crop yield loss (Hall et al., 1992), which depends, in part, on the ability to predict the time of weed emergence relative to the crop (Swanton et al., 1991). Spatial factors may include weed thresholds, the weed density that causes tolerable crop losses (Swanton et al., 1991; Woolley et al., 1993). Competitive effect of medics could not be assessed in this experiment because weed biomass data was not collected in the corn alone (without herbicide) plots.

Corn Response to Medic and Fertilizer Nitrogen

Corn Yields; No Nitrogen Applied. Corn following corn that had been interseeded with medic produced 13 and 22% higher grain yields than corn following corn with no medic in plots without herbicide and with herbicide respectively (Table 13). This result corresponds to the greater biomass and N accumulation of medics in plots with herbicide vs without herbicide.

Total above-ground biomass of was not affected by interseeded medic in the previous crop. Although this was the case, total N uptake by corn was greater when medics were interseeded into plots the previous year with herbicide applied (Table 13). This confirms the results of Hesterman (1992) who found that total N uptake was more sensitive to interseeded legumes than was total above-ground biomass. Corn grain N content response to interseeded medic was similar to response of grain yield in our study.

Hesterman (1992) reported a non significant response of a subsequent corn crop

Table 14. Regression equations for corn grain yield (GR), grain N content (GRN), total above ground biomass (TDM) and total N in above ground biomass (TN) as a function of N fertilizer applied (x) in the interseeding and corn following corn.

Year	Equation†	R^2	Significance
1993‡	GR = 7.03 + 0.018(x)	0.77	0.0001
	GRN = 80 + 0.344(x)	0.86	0.0001
	TDM = 11.8 + 0.033(x)	0.72	0.0003
	TN = 107 + 0.49(x)	0.81	0.0001
1994‡	GR = 1.15 + 0.04(x)	0.70	0.0002
	GRN = 79 + 0.544 (x)	0.69	0.0004
	TDM = 12.6 + 0.047(x)	0.70	0.0001
	TN = 100 + 0.76(x)	0.74	0.0001
1994§	GR = 4.5 + 0.03(x)	0.90	0.0001
	GRN = 40 + 0.183(x)+ 0.0013(x^2)¶	0.95	0.0004
	TDM = 8.7 + 0.052(x)	0.82	0.0001
	TN = 60 + 0.66(x)	0.93	0.0001

† Regression equation calculations were based on 14 degrees of freedom unless otherwise stated.
‡ Interseeding year
§ Subsequent year
¶ Equation calculation was based on 13 degrees of freedom.

to legumes interseeded into oats when compared to corn following oats alone when no fertilizer N was applied. Our results indicated consistent corn response to interseeded medics in plots with herbicide in the preceeding crop. Inconsistent response of subsequent corn crop in plots without herbicide in the previous crop interseeded with medics was not due to moisture-limiting conditions previously reported in the literature (Hesterman et al., 1992), but due to insufficient N accumulated by the interseeded medics.

Corn Response to Fertilizer Nitrogen. In all cases in which variable N fertilizer rates were applied, there was a positive response of corn grain yield, total above-ground biomass, grain N content and total plant N uptake to increased rates of N fertilizer. Regression equations for grain yield (GR), grain N content (GRN), total above-ground biomass (TDM) and total plant N uptake (TN) as a function of fertilizer N application rates were obtained for each year (Table 14).

Fertilizer Replacement Values. It is common to report response of nonlegume crops to a preceding legume based on fertilizer replacement values (FRV) calculated from grain yield (Ebelhar et al., 1984; Hesterman et al., 1986; Bruulsema and Christie, 1987), but FRV based on grain N content (Hargrove, 1986) and /or total plant N uptake (Hesterman et al., 1992) may be more sensitive to N available from cover crops. Fertilizer replacement values based on total above ground biomass of corn have also been reported (Hesterman et al., 1992).

One point that has not been adequately addressed in FRV calculations is that for a FRV to be both valid and useful for producer recommendations, there must be a significantly higher yield following a legume than following a non-legume control when no N fertilizer is used in either system (Hesterman et al., 1992). There is relatively scant information on FRV of interseeded legumes in the interseeding year. We chose to calculate FRV of interseeded medics into corn based on grain yield, total above ground biomass of corn, grain N content and total plant N uptake for both interseeding year and subsequent year . Based on this criterion (significantly higher yield following the legume), FRVs could be calculated based on grain yield, grain N content and total plant N uptake only in the year following interseeding. In the interseeding year of 1993, FRV could be calculated for third (4 June) and fourth (18 June) planting dates based on total plant N uptake.

Calculated FRVs in the corn following corn interseeded with medics were 30 and 18 kg N ha^{-1} for plots with herbicide and without herbicide in the preceeding interseedings, respectively, based on grain yield (Figure 4). Fertilizer replacement values were 37 and 20 kg N ha^{-1} for plots with herbicide and without herbicide in the previous interseedings, respectively, based on grain N content (Figure 5). Also in the subsequent year, FRV was 18 kg N ha^{-1} in plots with herbicide based on total plant N (Figure 6). In the interseeding year of 1993, FRV was 25 kg N ha^{-1} for either third (4 June) or fourth (18 June) planting dates in plots with herbicide based on total plant N uptake (Figure 7). Fertilizer replacement values could not be calculated for medics in the interseeding year of 1994 and other planting dates in the interseeding year of

1993, because they produced corn yields that were lower than the control.

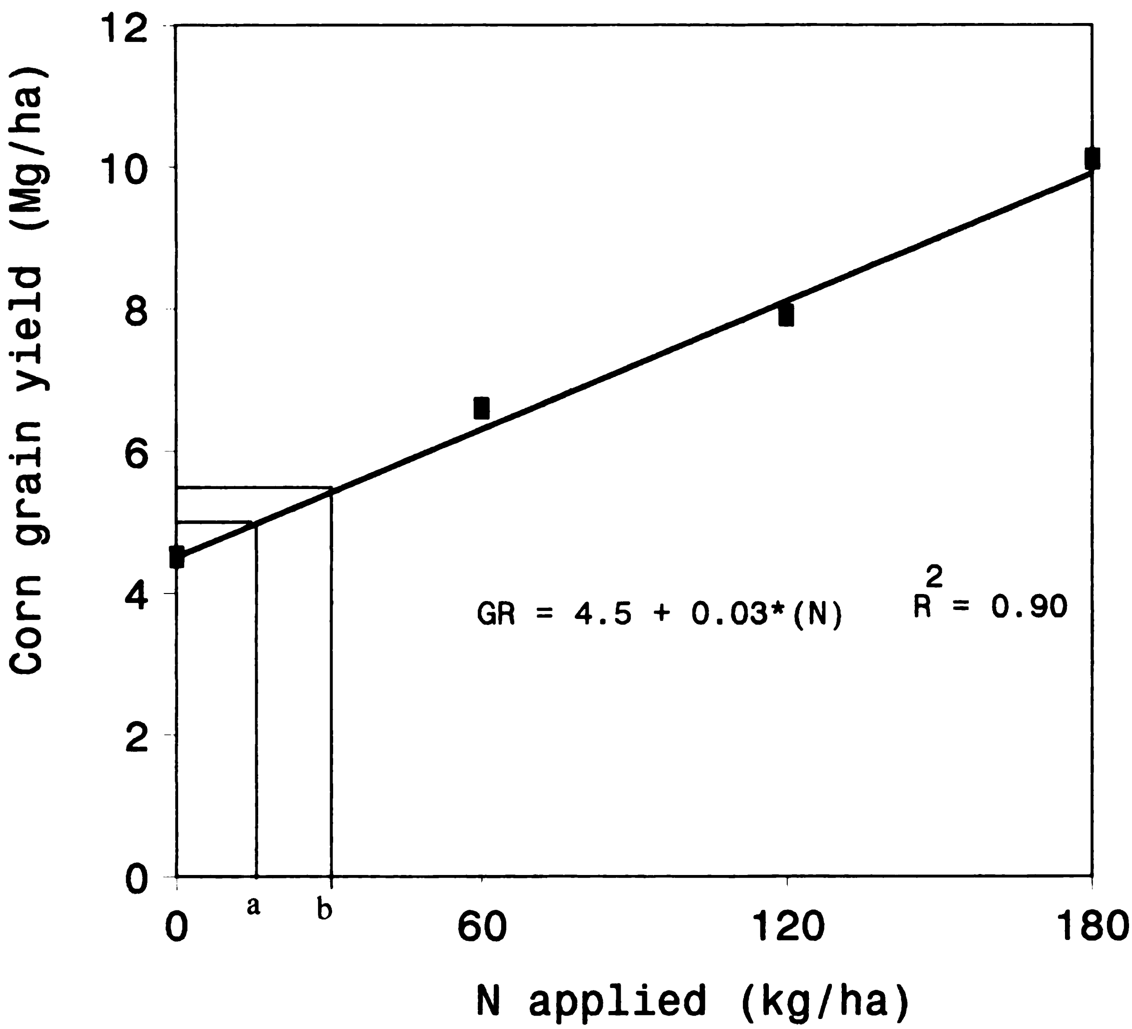

Figure 4 Corn grain yield response to applied fertilizer N in plots with no medics interseeded in the preceding year (1994). Plotted points are the means of four replications. a = 18, b = 30 and are FRV for medic interseeded in plots without herbicide and with herbicide, respectively.

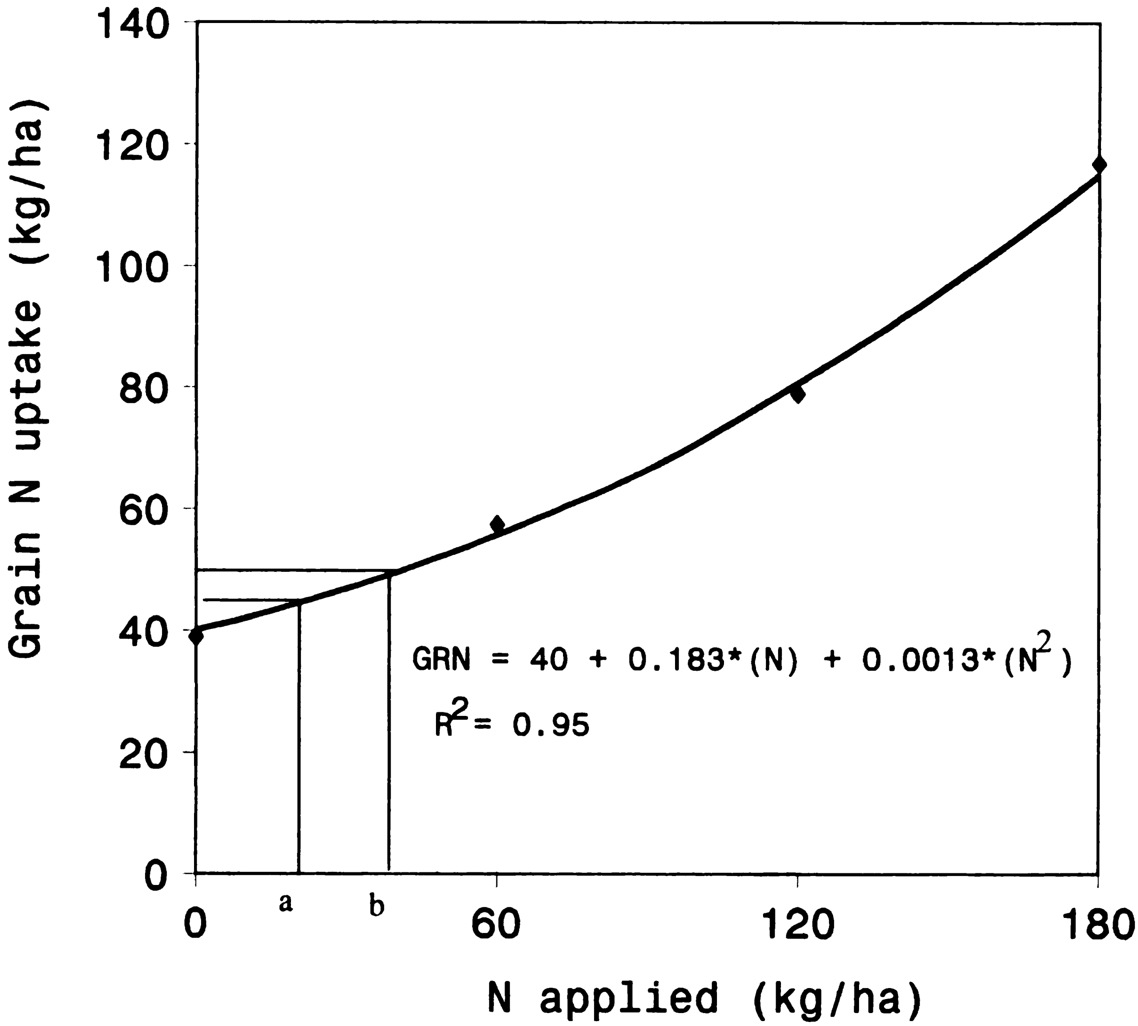

Figure 5 Corn grain N content response to applied fertilizer N in plots with no medics interseeded in the preceding year (1994). Plotted points are the means of four replications. a = 20, b = 37 and are FRV for medic interseeded in plots without herbicide and with herbicide, respectively.

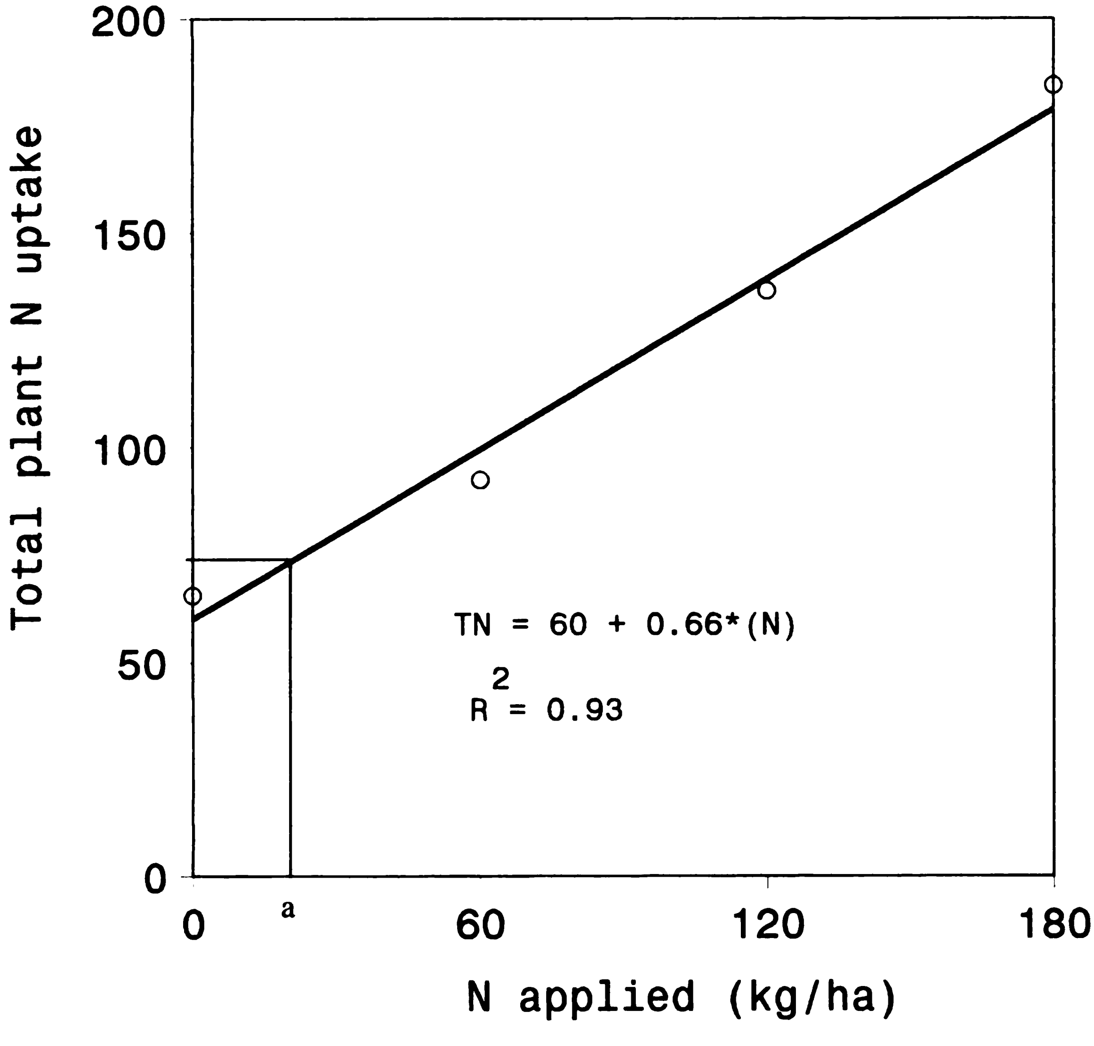

Figure 6 Total plant N uptake response to applied fertilizer N in plots with no medics interseeded in the preceding year (1994). Plotted points are the means of four replications. a = 18 and is FRV for medic interseeded in plots with herbicide.

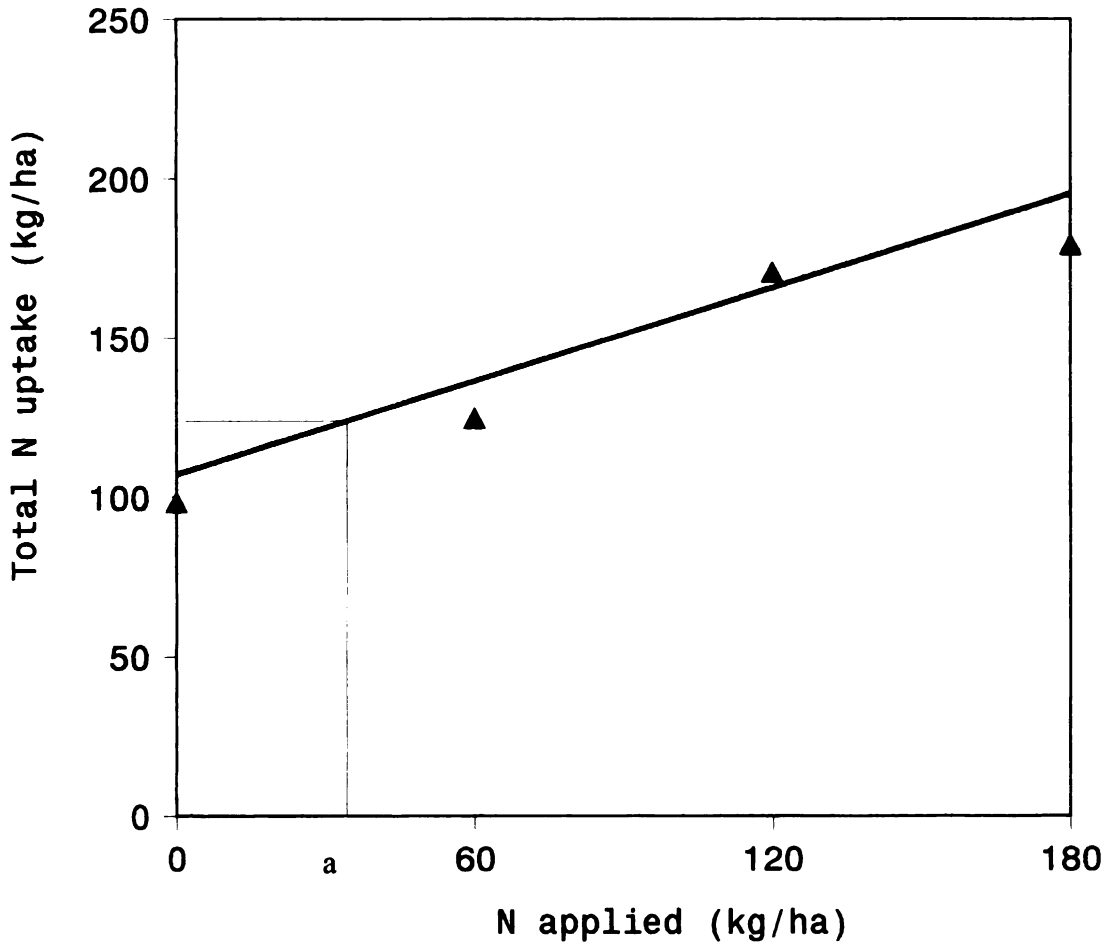

Figure 7 Total plant N uptake response to applied fertilizer N in plots with no interseeded medics in the interseeding year of 1993. Plotted points are the means of four replications. a = 25 and is FRV for medic interseeded at 28 or 42 days after corn planting.

CONCLUSIONS

Clear-seeded medics produced dry matter yields of up to 4 Mg ha^{-1} and accumulated N of up to 100 kg ha^{-1}. These values of dry matter and N yield compare well with other forage legumes that are adapted to the northcentral USA. Highest yields were associated with intermediate planting dates at 60 and 75 days after planting in the clear-seeded system. Results for clear-seeding suggest that medics have the potential for emergency forages when compared to the non-leguminous crops such as sorghum or sudangrass currently being used. However, further research is needed to determine the forage quality of medics together with crude protein obtained from this study.

Interseeding medics at corn planting or 14 days after corn planting reduced corn yields by approximately 30%. Corn yields were not reduced when medics were interseeded 28 days after corn planting, suggesting that it is best to delay interseeding medics into corn this time to minimize competition with corn. The herbicide used was effective in weed control and was associated with higher corn and medic dry matter yields.

Corn yields following corn with interseeded medics increased by an average of 17% compared to corn with no medic. The current research suggest that medics have a unique niche in Michigan in which they could be clear-seeded (grown alone) as emergency forages or as intercrops with corn. Medics life cycle is 60 to 90 days in Michigan and thus will live and die within a growing season eliminating the need for a burndown herbicide associated with most perennial covers. Including medics in cropping systems via interseeding with corn may be an effective way of contributing biologically fixed N. However, N accumulation in the interseeded medics is relatively lower than clear-seed cover crops. Further research is needed in weed suppression effects of medics. The current study could not provide an assessment of competitive effects of medics.

Medics reduced fertilizer needs of corn up to 40 kg N ha^{-1}. Although benefits in the second year accrued to the intercropping system especially the N reduction, genuine N contributions of medics could not be given as they were confounded with rotational effects. The method used in this study, FRV measures the overall effect of growing corn in rotation with corn + medics, but the N and rotation effects are not separated and a direct measurement of N contributed from legume plant material is not obtained. Research methods that measures direct contribution of N by medics may have to be used in future research to correctly attribute N changes to medics.

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