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INTERCROPPING CORN AND FORAGE LEGUMES:
DEVELOPMENT OF A CROPPING SYSTEM

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INTERCROPPING CORN AND FORAGE LEGUMES: DEVELOPMENT OF A CROPPING SYSTEM

By

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ABSTRACT

INTERCROPPING CORN AND FORAGE LEGUMES: DEVELOPMENT OF A CROPPING SYSTEM.

By

Micheal Anthony Schulz

Field studies were conducted to determine the feasibility of intercropping corn with established forage legumes (Alfalfa, Red Clover, Crownvetch, Birdsfoot Trefoil), thereby reducing erosion risks and achieving N economies, while maintaining economic corn yields. Mowing, broadcast herbicides and banded herbicide were investigated as legume suppressants during 1984-1985.

Corn yields were depressed due to inadequate legume suppression and pest damage. Both mowing and application of broadcast paraquat resulted in reliable temporary legume suppression, but none of the treatments produced season long control of legume and weed regrowth. Planting into killed legume bands, improved corn yields by enhancing corn survival. The N% measured in corn suggest that nitrogen is obtained from associated legumes only when the legume is severely repressed, and that actively regrowing legumes can deplete the soil nitrogen pool.

Nitrogen economies and maintainance of corn yields require prolonged and severe legume suppression. Suitable suppressants have not been identified.

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LIST OF SPECIES CITED

Alfalfa	Medicago sativa
Alfalfa weevil	Hypera postica
Barnyardgrass	Echinochloa crus-galli
Bermudagrass	Cynodon dactylon
Black gram	Vigna mungo
Brome, downy	Bromus tectorum
Brome, smooth	B. inermis Leyss.
Calopo	Calopogonium muncunoides
Clover, crimson	Trifolium incarnatum
, red	T. pratense
, subterranean	T. subterraneum
, white	T. repens
Cocksfoot (Orchardgrass)	Dactylis glomerata
Corn	Zea mays
Cowpea	Vigna sinensis
Crabgrass, large	Digitaria sanguinalis
Crownvetch	Coronilla varia
Dandelion	Taraxacum officinale
Dodder	Cuscuta spp.
Fescue,	Festuca elatior
, tall	F. arundinacea
Greengram	Phaseolus aureus
Groundnut	Arachis hypogea
Ground squirrel	Spermophilus tridecemlineatus
Kentucky bluegrass	Poa pratense
Kidney beans, red	Phaseolus vulgaris
Milkvetch	Astragalus cicer
Orchardgrass (Cocksfoot)	Dactylis glomerata
Paspalum	Paspalum commersonii
Pigweed	Amaranthus spp
Quackgrass	Agropyron repens
Rhodes grass	Chloris gayana
Ryegrass, Italian	Lolium rigidum
, perennial	L. perenne
Siratro	Macroptilium atropurpureum
(synonym)	Phaseolus atropurpureus
Soybean	Glycine max
Stylo	Stylosanthes guyanensis
Trefoil, big	Lotus uliginosus
, birdsfoot	L. corniculatus
, Narrowleaf	L. tenuis
Vetch, common	Vicia sativa
, big flower	V. grandiflora
, hairy	V. villosa

LIST OF CHEMICALS CITED

Alachlor	2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine
Butylate	S-ethyl diisobutylthiocarbamate
Chlorpyrifos	o,o-diethyl o-(3,5,6-trichloro-2-pyridyl) phosphorothioate
Cyanazine	2-chloro-4-(cyclopropylamino)-6-(isopropylamino) -s-triazine
Difonate[R]	o-ethyl s-phenylethylphosphonobithioate
Diniseb acetate	2-sec-butyl-4,6-dinitroacetate
Diquat	6,6-dihydrodipyrido[1,1- :2',1'-c]pyrazinediium ion
2,4-D	(2,4-dichlorphenoxy)acetic acid
EPTC	S-ethyl dipropylthiocarbamate
Fluazifop-butyl	butyl(R S)-2-[4[[5-(trifluoromethyl) -2-pyridinyl]oxy]phenoxy]propanate
Glyphosate	N-(phosphomethyl) glycine
Hexazinone	3-cyclohexyl-6-dimethylamino-1-methyl- 1,3,5-triazine-2,4-dione
Linuron	3-(3,4-dichlorphenyl)-1-methoxy-1-methylurea
Metolachlor	2-chloro-N-(2-ethyl-6-methyl-phenyl)-N- (2-methoxy-1-methylethyl) acetamide
Metribuzin	4-amino-6-tert-butyl-3-(methylthio) -as-triazin-5(4H)-one
Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion
Pendimethalin	N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine
Pronamide	3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide
Propachlor	2-chloro-N-isopropylacetanilide
Simazine	2-chloro-4,6-bis(ethylamino)-s-triazine

INTRODUCTION

In Michigan, large areas of corn (*Zea mays*) and legume forages are grown for livestock, corn and alfalfa (*Medicago sativa*) representing the two largest harvested crop areas in Michigan. Land areas in 1984 were estimated as 1,060,000 hectares of corn for grain, 160,000 hectares for silage and 710,000 hectares of hay, 80% of which was alfalfa (Espie, 1985).

Our study concerned intercropping these two crops by planting corn into established, perennial, legume hay fields, without first killing the hay crop. Intercropping is the simultaneous cultivation of one crop among or between the rows of another. Our objectives were:

Objective 1....EROSION CONTROL

To grow corn, herbicides and/or cultivation are recommended to control weeds. This leaves the majority of the ground surface bare and susceptible to erosion. An intercropped forage will provide a high degree of ground cover, and substantially reduce the erosion risk.

Objective 2....NITROGEN FIXATION.

Nitrogenous fertilizers are widely used for corn production. When a corn crop is preceded by a legume crop, a substantial reduction in the amount of fertilizer nitrogen (N) is recommended. The N supplied to subsequent crops by legumes is fixed prior to the cropping season. By maintaining a legume crop under a corn canopy, there may be a potential to continue N fixation throughout the growing season. If the currently fixed N is available to associated corn plants, additional N economies may accrue.

Objective 3....CORN YIELDS.

Maintenance of economic corn yields is essential to the commercial adoption of any cultural system for corn. It is therefore necessary to control competition from the intercropped forage, so that acceptable corn yields can be achieved. The experiments conducted primarily concerned developing a system to control this competition.

Objective 4....LEGUME YIELDS.

Directly related to the concept of retaining ground cover is the prospect of retaining a legume sward. If achieved, the sward may be utilized in any subsequent year as an intercrop or hay crop. By maintaining a canopy of desirable species there is also the possibility of inhibiting the growth of weeds.

LITERATURE REVIEW

(B1) EROSION CONTROL

The susceptibility of a soil to erosion is inversely related to the amount of ground cover (Wischmeier and Smith, 1978). Crops provide ground cover contingent on completeness of the canopy, and canopy architecture. The greatest erosion risk in corn fields is before the canopy is established and after harvest. Even after the canopy is developed there is an erosion risk associated with penetrating raindrops and water dripping from leaves (Quinn and Laflen, 1983). Reduced and zero-tillage practices leave residues on the surface which decrease this risk.

Several researchers have grown corn in living sods to reduce erosion risk. Research was conducted in West Virginia to develop a system by which, "corn can be grown in a sod suppressed by herbicide treatment, thus providing a continuous vegetative cover to increase water retention and prevent soil erosion." (Bennet et al., 1973). The effect such a continuous vegetative cover has on erosion is quantified by Hartwig (1984). In maintaining crownvetch (*Coronilla varia*) under corn in Pennsylvania, he achieved considerable reductions in water runoff and soil loss; whereas soil loss from plowed ground was 14.37 ton/ac (32190 kg/ha), only 0.02 ton/ac (45 kg/ha) was lost from the living mulch system. This reduction was attributed in part to interception of raindrops which detached soil particles. The living mulch also physically inhibited surface water flow. Maintenance of a forage crop can also lead to improvements in soil permeability and therefore water infiltration (Groenevelt et al., 1984).

B2. NITROGEN FIXATION

(B2a).....INTRODUCTION

Records of legumes grown as green manures or in crop rotations go back to the Greeks and Romans. Legumes were said to reinvigorate or manure the soil, but it was not until the nineteenth century that Boussingault, Hellriegel and others showed that this invigorating effect stemmed from the legume root nodules ability to utilize atmospheric N (historical review by Fried, 1932). Estimates of the quantity of N contributed to the soil by legumes now exist. It is estimated that, in Kentucky, a winter cover crop of hairy vetch (*Vicia villosa*) supplies a subsequent corn crop the equivalent of 90-100 kg. fertilizer N/ha. annually (Ebelhar et al., 1984). Michigan State University Fertilizer Recommendation Bulletin E-550 (Warncke et al., 1985), credits a pure alfalfa stand with the fertilizer equivalent of 112 kg N/ha.

Non-legume crops obtain N benefits when grown after a legume. What happens when they are intercropped? The early American indians may have obtained N transfer when they grew beans (*Phaseolus spp.*) among their corn. Also, N transfer would explain the improvements in corn yield when intercropped with various annual grain legumes in India (Gangwar and Kalra, 1983). In a Nigerian experiment corn when intercropped with greengram (*Phaseolus aureus*), yielded 72% more grain than corn in monoculture without fertilizer nitrogen. Monoculture corn, fertilized with 45 kg N/ha had the same yield as the intercropped corn. Cowpea (*Vigna sinensis*) and *Calopogonium muncunoides*, when intercropped with corn, did not increase corn yield (Agboola and Fayemi, 1972).

Grass/legume pastures exist world wide and the beneficial effect of the legume on grass yields is well known (Haynes, 1980). It is generally assumed that this benefit is due in part to fixed N released by the legume (Peterson and Bendixen, 1961; Churchill, 1947; Dilz and Mulder, 1962; Simpson, 1976). Chamblee (1958) demonstrated that intercropping benefits may result from other than N transfer; in the first year of growth orchardgrass (Dactylis glomerata) produced more when grown between two rows of alfalfa than between two rows of orchardgrass, both with and without root partitions separating the roots of the two species. Controversy exists as to the mechanism, timing, and extent of N release (B2b and B2c).

(B2b).....SHORT TERM EXCRETION

Thornton and Nicol (1934a) observed that grass grown in pots with alfalfa could obtain N from the alfalfa within three months of planting. They concluded that excretion had occurred, as no decay of alfalfa roots was observed. In the same year they reported a similar experiment in which N transfer was slower and less than previously reported (Thornton and Nicol, 1934b). The suggestion was that the greater grass N uptake in the first experiment was due to a greater degree of root ramification. Early greenhouse experiments in Finland consistently demonstrated excretion of N by legumes and a consequent increase in N uptake by the non-legume. The amount of N excreted sometimes amounted to half the N fixed (Virtanen et al., 1937). A much smaller percentage (0.9-1.4% of legume N) was reported by Nowotnowna (1937) when red clover, seradella or peas were grown in pots with ryegrass for 13 weeks (species names not given).

Trumble (1937) reviewed the previous literature and concluded that evidence for early and marked transference of N from growing legumes was hypothetical. He observed low levels of N transfer from alfalfa and subterranean clover (T. subterraneum) grown in pots for 12 weeks, and associated this excretion with water stress. Other researchers also found little or no transfer during active growth of various legumes (Ludwig and Allison, 1937; Bond and Boyes, 1939; Ludwig and Allison, 1940).

Wyss and Wilson (1941) attempted to recreate Virtanen's experiments in Wisconsin, even importing his seed and sand. They also present data and observations from extensive greenhouse experiments in which various legume/non-legume associations were assessed. The great majority of these experiments gave negative results as far as benefit to the non-legume is concerned. Positive results were most frequently obtained when legume development was limited. The theory was advanced that if the environmental conditions are such that the leguminous species fixes N at a rate in excess of its assimilation into new tissue, organic N accumulates in the nodules and is subsequently excreted. They associated N excretion with long days, low to medium light intensities and low temperatures

Taking a mathematical approach, Walker et al. (1954) developed an equation to describe the contributions of soil N, fertilizer N and clover N to grass. They reported a widely variable 2% - 89% of the N in grass tops originating from associated white clover. In considering this range they agreed with Wyss and Wilson (1941) that conditions which reduced photosynthesis, but not fixation (in Walker's case, moderate shading) contributed to the higher exchange rates. Stewart and Chestnutt (1974), who expanded on Walker's equations using data from 15 site years, found grass N yield was more highly correlated with the yield of clover in the previous year than with current clover yield. They also agreed with Wyss and Wilson in that the contribution of white clover to grass was quantitatively inconsistent.

Isotopic studies with ^{15}N enriched soil have been used for estimating the amount of nitrogen fixation by legumes since McAuliff et al. pioneered the work in 1958. One of the assumptions of McAuliff's method is that there is no transfer of N from legume to associated grass reference plants during the period of measurement. Vallis et al. (1977), suspecting their was transfer, included a reference plant grown in pure stand for comparison purposes. They found no significant N transfer to Rhodes grass (Chloris gayana) harvested after 13 weeks growth in association with Stylosanthes guyanensis. The same authors (Henzell et al., 1968) also report negligible (1%) transfer of fixed N from siratro (Macroptilium atropurpureum) to Rhodes grass during a 15 week greenhouse experiment. Numerous other researchers have used this technique. In Scotland ^{15}N was applied to second year pastures of perennial ryegrass or ryegrass/white clover clipped to 1 cm. There was no N transfer after 42 days growth (Haystead and Lowe, 1977). In a pot study Haystead and Marriot (1979) harvested white clover and ryegrass 26, 43, 83 and 105 days after sowing into ^{15}N enriched soil. Only at the last harvest was N transfer detected (an estimated 12% of the grass N was from fixation). In California (1982) white clover (cv. Ladino) and Italian ryegrass (Lolium rigidum cv. Wimmera) were grown in pure and mixed stands, both as greenhouse and field studies (Broadbent et al.). There was no evidence of N transfer to the grass in the short term greenhouse experiment. The spring planted field experiment was harvested three times during the year of establishment (July 30, September 25, November 29). It was estimated that at the first two harvests only 4% of the grass N was attributable to current fixation, while this jumped to 62% by the third harvest.

Ross et al. (1964) transferred pots containing siratro and Rhodes grass to growth chambers containing an $^{15}N_2$ atmosphere. They observed that a small percentage (2.3%) of the Rhodes grass N was derived from the atmosphere during 13 days exposure to $^{15}N_2$, and extrapolated this to 20 pounds N per acre annually.

A new isotope method for assessing nitrogen transfer from legumes to associated grasses was proposed by Ledgard et al. (1985). Subterranean clover plants were labeled with ^{15}N by foliar absorption, and nitrogen transfer to the grass was estimated. The plants were grown either in pots or in the field (Canberra, Australia) prior to trifoliate leaves being immersed in ^{15}N solution for three days. The plants were trimmed and allowed to grow for an additional 29 and 36 days respectively. The ^{15}N differences indicated that in the greenhouse 2.2% of the clover N had been transferred to the ryegrass while no transfer was observed in the field. The authors hypothesized that the roots of the two species were more concentrated in the finite volume of the pots than in the field, and thus any N released was more likely to be reabsorbed.

Briefly summarizing, it appears that short term underground N transfer from legumes to associated non-legumes is small in extent and dependent on environmental conditions. This agrees with Butler and Bathurst's early conclusion (1956) that the conditions for transfer of N as a result of excretion are so specific that sloughing off of legume roots and nodules is probably more important in the field.

(B2c).....LONG TERM EXCRETION

Sloughing off of nodules after legume defoliation has long been considered the primary source of N transferred to grasses from associated legumes (Wilson, 1931). Nodules and roots are seen as dying and senescing with time or after stress. Following breakdown, their N content is released to the soil and this becomes available to the associated non-legume.

The observation that non-legumes grown with legumes frequently do not benefit until the second year of the association, is interpreted to mean that appreciable N becomes available only after seasonal nodule senescence. (Churchill, 1947; Chamblee, 1958; Herriot and Wells, 1960). Stewart and Chestnutt (1974) found that grass N yield was more highly correlated with clover yield in the previous year (and also with decrease in clover yields between successive years), than with current clover yields. An Australian field experiment with cocksfoot grown alone and with alfalfa, subterranean clover or white clover did not detect any significant legume effects on grass N content or grass N yield until the fourth harvest, 16-18 months after legumes were sown into the grass sward (Simpson, 1976). Haystead and Marriott (1978) working in the United Kingdom did not detect any transfer between white clover and ryegrass until the fourth harvest. Likewise, Broadbent et al. (1982), who planted ryegrass and white clover in California in the spring, first detected substantial N transfer to the grass in late fall of the same year.

Henzell (1962) demonstrated that significant long term transfer cannot be assumed. When a variety of legumes were grown with Paspalum commersonii for two years, a minimal amount of N transfer was detected. He postulated that this was in part due to the absence of any checks to legume growth in the greenhouse.

(B2c.i) DEFOLIATION

Mitchell and Denne (1967) state that the first effect of defoliation or any other interruption of the energy substrate supply to the root system is an immediate reduction or even a cessation in the extension of root tips and probably in nitrogen fixation by the nodules. Then, as new supplies of energy continue to be unavailable to the fine root network, the cells there have to draw on their own substance for energy to maintain their integrity. As this continues they will progressively waste away with a loss of function and eventually die.

Alfalfa (Medicago sativa): Cralle and Heichel reported a 46% decline in nitrogen fixation within two days of cutting alfalfa, and a ten day recovery period. The recovery was coincidental with leaf and shoot regrowth. Fishbeck and Phillips report a 96-70% decline within three days, the extent of decline being proportional to the extent of defoliation. Vance et al. reported an 88% decline within 24 hours which took 18 days to recover. They observed no massive loss of nodules following defoliation of alfalfa but did note rapid localized senescence leading to degeneration of nodule proximal ends. Nodule meristems and vascular bundles remained intact and the nodules did resume growth as alfalfa leaf area recovered.

Dilz and Mulder (1962) have demonstrated that defoliation of alfalfa does not necessarily enhance the rate of release of N to the soil. They grew alfalfa in the greenhouse and observed slightly less release of N in the three months following defoliation, than before defoliation. Simpson (1965) found that increasing the frequency of alfalfa defoliation from every eight to every two weeks actually reduced the amount of N transferred to associated grass, during a 12-18 month growing period.

Red clover (Trifolium pratense): The much quoted article by Butler et al. (1958), indicates that red clover lost nodules following defoliation; there was little regrowth of red clover nodules during foliage recovery. Dilz and Mulder (1962) observed no enhancement of N release from red clover root systems following defoliation, despite the large N reserves later liberated to the soil on death of the red clover.

Birdsfoot trefoil (Lotus corniculatus): When trefoil was defoliated by Cralle and Heichel (1981) there was a 56% drop in the rate of acetylene reduction within two days, and a 11 day recovery period. After a second harvest 35 days later, there was a 59% drop and a 21 day recovery period. This second harvest was associated with a reduction in nodule number, which after 35 days regrowth had only recovered to 48% of the preharvest number. Butler et al. (1959) found that L. uliginosus rapidly lost nodules after defoliation.

White clover (T. repens): Wilson (1942) noted that defoliation of white clover induced nodules to pass through the same changes as those that occur on annual legumes at maturity (they became soft, lost their starch, changed color and eventually disintegrated). Butler et al. (1959) observed recurrently defoliated white clover, utilizing glass sided boxes to quantitate root and nodule changes.

When four month old white clover plants were defoliated a considerable number of roots and nodules were lost, but this loss was more than counterbalanced by new growth. The authors proposed that this rapid turnover of root and nodule tissue explained the observation that white clover was very efficient in supplying N to associated grasses when grazed in the field. Chu and Robertson (1974) found a 30% decrease in the number of nodules per plant within three days of defoliation; this was associated with a 40% reduction in root dry weight per plant. Haystead and Marriott (1978) found a 31% decrease in the number of nodules within seven days of defoliating pot grown white clover, while previously grazed field grown plants showed only a slight decrease. Dilz and Mulder (1962), when comparing white clover, red clover and alfalfa, found that cutting the legumes only enhanced the release of N from white clover.

White clover can also have a negative affect on the N balance of associated species. When grown in the greenhouse with cocksfoot, white clover competed with cocksfoot for soil N (Simpson,1965). Frequent legume defoliation reduced the competition, and induced some N transfer to the grass.

(B2c.ii) SHADING

Photosynthesis by legume leaves is reported as being saturated at 30-50% of maximum sunlight on a clear day. Light intensity is reduced to a limiting level by low solar elevation, atmospheric interception, and self shading. Except for the early stages of pasture establishment or seasonal reestablishment, or for regrowth following severe defoliation or seasonal dormancy, legumes are light limited most of the time (Ludlow, 1978).

Gibson (1976) reports that within five hours of transferring subterranean clover plants to a lower illuminance (25% of original intensity), the rate of acetylene reduction per plant fell by 40%. A 50% increase in activity was observed when the plants were transferred from the low to higher light intensity. Nitrogen fixation can be accomplished in the complete absence of light provided that enough carbohydrates are available. Kamata (1963), by applying sucrose solution to the leaves of white clover plants placed in the dark, prevented inactivation of the nodules.

In addition to the effect of light quantity on N fixation, light quality appears to play a role. Lie (1981) summarized several articles which indicate that far-red light inhibits root-nodule formation. An excess of far-red light has been found under leaf canopies in forests (Vezina and Boulter, 1966), and alfalfa stands (Robertson, 1966), due to preferential filtering of red light by chlorophyll.

Given that shading reduces N fixation, does it also induce nodule and root shedding? Shading reduces nodulation more than root growth, and root growth more than shoot growth (Pritchett and Nelson, 1951; Gist and Mott, 1957; McKee, 1962). Reductions in total nodule number and mass have been attributed to shading (Eriksen and Whitney, 1984; Cardina, 1983). Butler et al. (1959) observed marked losses of nodules and little regrowth following shading of T. repens, T. pratense and L. uliginosus. Cnu and Robertson (1974) also observed a reduction in the number and weight of nodules per T. repens plant within ten days of shade initiation. Species differences are brought out by McKee

(1962) who observed that birdsfoot trefoil seedlings required twice as much light for nodulation as alfalfa and red clover. Gibson (1965) found that nodule weight remained static when subterranean clover plants were transferred to and maintained at low light intensities.

In a recent thesis from Pennsylvania State University, Cardina (1983) describes the effects of shading on field grown crownvetch. Shading of the crownvetch by associated corn plants did not affect nodule specific activity (nitrogenase activity per gram of nodule), but did lead to a significant reduction in nodule number, nodule fresh weight and therefore in total nitrogenase activity (TNA-Nitrogenase activity per plant). As shading actually reduced the number of sloughed nodules it was proposed that the decrease in nodule number was due to reduced nodule initiation. In addition, reduced N uptake by associated corn plants indicated that shading had reduced the amount of soil N available to corn. Increased soil N uptake by crownvetch, associated with the decrease in TNA, was proposed as contributing to the apparent reduction in available soil N.

(B2c.iii) TEMPERATURE

As soil and canopy temperatures are reduced by shading (Larson and Willis, 1957) and as nodule activity is influenced by temperature (Gibson, 1977; Pate, 1977), the effect of temperature on nitrogen fixation must also be examined. Schweitzer and Harper (1980) demonstrated that soybean (Glycine max) nodule activity actually had a greater dependence on temperature than on diurnal light variation, being reduced at 18^{o}C relative to 27^{o}C.

Shading by corn influences the soil temperature. Larson and

Willis (1957), who interseeded alfalfa/red clover stands between corn rows at Ames, Iowa, present data for light intensity at the ground level and soil temperature at four inches (10 cm) deep. On August 18, when the maximum air temperature was 36°C, less than 20% of full sunlight reached the soil surface on the immediate north of east-west rows. The soil temperature there at 4pm was 6.7°C less than in areas receiving full sunlight. This corresponded to a temperature drop from 33°C, to 26°C. Legume stands and yields were frequently better in this shaded region, which the authors attributed to soil moisture differences. The optimum temperature for N fixation is close to that for optimum host-plant growth (Pate, 1977). Lie reported (1981) that all leguminous plants examined to that date, produced most growth in the temperature range, 15-25°C.

Low temperatures have been implicated as an environmental factor that influence short term excretion (Wyss and Wilson, 1941). This qualitative observation has been reiterated to the present day (Chalk, 1985). Symbiotic systems partially compensate for the adverse effect of low temperatures on specific nodule activity, by increasing nodule weight and activity (Gibson, 1976). Nodules may senesce as winter approaches, but this is not necessarily related to cold damage and is by no means universal. Clover nodules were found to overwinter in Australian alpine conditions and resumed fixation activity in the following spring (Bergersen et al., 1963). Studies of various Irish legumes, depict overwintering of nodules as a common event in all winter annual, biennial and perennial species (Pate, 1958b).

(B2c.iv) MOISTURE STRESS

Where two species are competing for water, a deficit may result. Water stress can affect Rhizobium and symbiosis via a decline in soil Rhizobium populations (Foulds, 1971), a reduction in root hair infection due to the absence of normal root hairs (Lie, 1981), and, rapid inactivation of specific nitrogenase activity (Pankhurst and Sprent, 1975; Carter and Sheaffer, 1983). Nodule activity can be restored upon watering if the nodule moisture loss is not extreme (Sprent, 1971; Engin and Sprent, 1973; Carter and Sheaffer, 1983). Drying of the soil was found to reduce the amount of transference of fixed N_2 from forage legumes to associated cocksfoot (Simpson, 1965). The implication being that in the dryer soil the opportunities for transfer were reduced.

Prolonged exposure to water stress may lead to permanent damage and shedding of nodules. Wilson (1931) reported that on the average 36% of red kidney bean (P.vulgaris) nodules were shed when soil moisture levels were reduced to 20-12.5% of the available water capacity. Nodule inactivation and sloughing off was also observed by Ismaili et al. (1983), when the nodule water potential of siratro plants was reduced to -3.0 MPa. In both these papers the length of the stress period was cited as influencing senescence. Such observations as these give credence to Trumble and Strong's (1937) early hypothesis that fluctuating soil moisture levels induce secretion of N and nodule loss.

(B2c.v) FERTILIZER NITROGEN

Combined N can have either an inhibitory or stimulatory effect on the legume/Rhizobium symbiosis. Stimulatory effects are associated with the application of small quantities of fertilizer N at sowing, or in the very early stages of seedling development (Gibson, 1976).

The inhibitory effects of combined N on root hair infection, nodule initiation, nodule development structure and function are also adequately referenced (see reviews by Gibson, 1976; Dart, 1977). A recent paper by Hopmans et al. (1984) provided evidence for an immediate decrease in the nitrogen fixation rate following the addition of inorganic N to soil.

A further complication to the system exists in mixed swards. When legumes are grown with grasses the addition of inorganic N preferentially enhances grass growth. This results in reduced legume growth and consequently reduced total N yield in the legume (Thornton and Nicol, 1934a; Peterson and Bendixen, 1961; Stewart and Chestnutt, 1974; Butler and Ladd, 1985a).

(B2c.vi) HERBICIDES

As with previous environmental manipulations, herbicides can be expected to decrease N_2 fixation via suppression of the plant. When various herbicides were applied to two month old greenhouse grown alfalfa, reductions in N_2 fixation and nodulation were associated with reduced plant growth and herbicidal injury (Peters and Ben Zbiba, 1979). More conclusive evidence is presented by Bollich et al. (1985), who planted soybeans in soil filled pots, washed in various pre-emergence herbicides and harvested 8-10 weeks later. Reductions in nodule mass and nitrogenase activity per plant occurred in some soils, with some herbicides. In vitro laboratory studies, using the same chemicals, indicated that none adversely affected R.japonicum growth. A similar pattern was observed by Cardina (1983); when atrazine was applied to intact crownvetch plants the carbon exchange rate was reduced within 24 hours, and the nitrogenase activity per plant 24 hours later. Associated in vitro studies failed to demonstrate reduced growth of crownvetch Rhizobium strains, exposed to atrazine concentrations of 0.1-10 mg/L. Abnormally high atrazine concentrations (100 mg/L) did reduce growth of in vitro Rhizobium.

Heinonen-Tanski et al. (1982), demonstrated the direct toxicity of certain herbicides to Rhizobium. They inoculated 25 red clover Rhizobium isolates to nutrient agar containing abnormally high concentrations of pesticide (100 mg/kg). Of the 26 herbicides tested, only paraquat, diquat and difenzoquat (quaternary ammonium salts), linuron and chlorbromuron (urea based compounds), and dinoseb acetate showed some toxicity to Rhizobium. Glyphosate and atrazine had no effect.

Variation in herbicide effects exist between soil types. Of four soils to which metribuzin was added (Bollich et al., 1985), only in the soil with the lowest organic matter content and coarsest texture were soybean nodules adversely affected.

B3. CORN YIELDS

(B3a).....INTRODUCTION

When two or more species are growing together they must compete for the limited resources. To quote Clements et al., 1929: "Competition arises from the reaction of one plant upon the physical factors about it and the effect of the modified factors upon its competitors".

Donald (1963), in discussing the literature on the associated growth of pairs of species observed that: the mixture yield will usually be less than that of the higher yielding pure culture and greater than that of the lower yielding pure culture, the mixture yield may be greater or less than the mean of the two pure cultures, and, there is no substantial evidence that two species can exploit the environment better than one. He concluded that cereals will be reduced in yield if they are interplanted with a forage species. The reduction may be very slight, but this will be the case only if the fodder species is heavily suppressed.

As a result of early season pasture suppression more light may reach the soil and emerging corn (Steinke, 1963), soil temperatures may rise (Larson and Willes, 1957) and pest habitat will be destroyed (rodents, insects, pathogens). Late season competition may also reduce corn yields (Bhowmik and Curry, 1983).

(B3b).....LEGUME SUPPRESSION

(B3b.1) MOWING

As forage legumes have been selected for tolerance to mowing and grazing, they quickly regrow following cutting if no other stress is applied. Selection of cutting time and severity will influence how much regrowth is present during the critical corn seedling stage.

For maximum productivity, alfalfa should be managed so that adequate reserves are maintained and adequate leaf area still exists after harvest (Leach, 1967). Conversely, for slowest regrowth, zero or minimal leaf area should exist after harvest. Data for greenhouse grown alfalfa (Cralle and Heichell, 1981) indicates that plants experiencing complete shoot removal regrew slower than plants experiencing partial shoot removal. If frequent clipping is used to maintain a short sward, weeds may develop to fill the voids created (Ossom et al., 1982).

If alfalfa is cut while still vegetative, the vigorously active shoot meristems are removed, and the plant has to reestablish active meristems from the crown before new growth occurs (Mitchell and Denne, 1967). In Washington state, spring (May 1) clipping of alfalfa has been shown to decrease seasonal yields relative to controls (Jackobs and Oldeaneger, 1955). Plant vigor was not influenced in the following year. Highest yields of birdsfoot trefoil have been obtained when harvest was carried out at the one tenth bloom stage (Duell and Gausman, 1957).

(B3b.ii) HERBICIDES

Recommendations for no-till planting corn into killed legume sods, and for weed control in established legumes are well documented (Moomaw and Martin, 1976; Kells, 1985; Peters et al., 1984; Foy and Wolf, 1983). Identification of suitable chemicals and rates for suppression has received indirect attention.

Glyphosate has been used to some extent for the sod-seeding establishment of alfalfa into existing alfalfa sods. Glyphosate, when applied to alfalfa in Nebraska on April 19 at a rate of 1.7 kg/ha temporarily stunted but did not kill it. Three months after spraying regrowth was in the green pod stage and constituted 60% of the harvest (3.76 Mg/ha), the other 40% being newly planted alfalfa. In the following spring only 1% of quadrats (15x15 cm) sampled contained grass weeds (Vogel et al., 1983). In Wisconsin, four rates of glyphosate were applied to quackgrass (Agropyron repens) infested alfalfa swards a few days before reseeding in the spring. A visual estimation 25 days after planting indicated that alfalfa was suppressed 79, 87, 94 and 97% relative to control plots, at rates of 0.6, 0.8, 1.2, and 1.6 kg/ha respectively. Quackgrass experienced the same degrees of suppression. Thirty eight days after planting, the low rate (0.6 kg/ha) had not killed any alfalfa, but populations were reduced from 28 plants/m^2 in untreated alfalfa, to 4.2, 2 and 2 plants/m^2 by the 0.8, 1.2, and 1.6 kg/ha rates respectively (Leroux and Harvey, 1985).

Glyphosate has been applied to alfalfa at the end of dormancy, for weed control. When applied at 0.84 kg/ha plus surfactant, injury to alfalfa was rated at 45% at the first cutting. Recovery was rapid, with no residual injury detected at the second cutting. Satisfactory weed control was reported (quackgrass, dandelion), but reinfestation occurred during the growing season (Mashhadi and Evans, 1984, Utah).

When applied to actively growing alfalfa at 0.075 kg/ha for dodder control (Cuscuta spp.), glyphosate did not suppress alfalfa vigor as visually assessed three weeks after application. Rates of 0.15, 0.30 and a split 0.075 + 0.075 kg/ha did suppress vigor (stunted growth and small leaves). At nine weeks, plants receiving the 0.15 kg/ha rate had recovered while those with higher rates were still stunted (Dawson and Saghir, 1983, Washington state).

As glyphosate is a systemic and its effectiveness is influenced by the weather following application (Kingman and Ashton, 1982), environmental differences may contribute to the variability of these results.

Although **paraquat** will desiccate legume leaves, it has been used for weed control in dormant alfalfa (Peters et al., 1984), and immediately following harvest (Foy and Wolf, 1983). Where used to burn back sod prior to planting corn, plants with adequate root reserves recover quickly and compete with the corn (Robertson, 1976). Paraquat, when applied at 0.6 kg/ha to alfalfa/grass swards prior to reseeding alfalfa in spring, had minimal effect on the alfalfa and only temporarily suppressed the grass. In the following spring 10% of the quadrats (15x15) sampled contained grass weeds, whereas none of the newly seeded alfalfa had survived (Vogel et al., 1983). In a similar experiment 0.6 kg/ha paraquat gave only 35% and 65% control of alfalfa and weeds respectively, as assessed 25 days after planting. Final alfalfa population was not affected (Leroux and Harvey, 1985).

2,4-D has also been applied to alfalfa/grass swards prior to reseeding alfalfa in the spring. A rate of 0.6 kg/ha 2,4-D amine, reduced the alfalfa population by 82% as assessed 38 days after planting (DAP), but produced zero weed control (Leroux and Harvey, 1985).

Variability in sensitivity to herbicides is brought out in an article by Taylor et al. (1982). A total of 35 legume varieties, belonging to 10 species, were tested in the spring for tolerance to 2,4-D amine at the rate of 2 lb/ac (2.24kg/ha). *Trifolium subterraneum* was the most tolerant species. White and red clover were intermediate in tolerance. When hairy vetch (*Vicia villosa*), big flower vetch (*V. grandiflora*) and common vetch (*V. sativa*) were sprayed, none survived.

Triazines have been used for weed control in legume swards. Simazine when applied to dormant alfalfa (1.12 kg/ha) can effectively remove weeds and improve alfalfa yield, but when applied to non-dormant alfalfa, can temporarily suppress yield (Peters et al., 1984). Simazine plus atrazine is recommended for quackgrass control in crownvetch prior to planting of intercropped corn, but crownvetch suppression is also expected (Hartwig, 1984).

The 1986 Michigan State University, Weed Control Guide for Field Crops (Kells, 1985), lists atrazine and alachlor for weed control in corn, and simazine, pronamide and hexazinone for weed control in alfalfa. Appropriate combinations and levels of these herbicides can be expected to give excellent weed control, plus a degree of legume suppression.

(B3b.iii) KILLED STRIPS

A compromise between killing 100% of a sod and maintaining 100%, is to kill strips that correspond to the rows of a subsequent row crop.

Tillage can be used to selectively kill strips of sod prior to planting corn. Adams et al. (1970) utilized 41 cm wide tilled strips to grow corn in 107 cm rows in bermudagrass (Cynodon dactylon) and fescue sods (Festuca elatior). In two consecutive years the strip killed plots yielded 67% (wet year) and 85% (dry year) as much corn as completely tilled plots. Elkins et al. (1983) utilized strip tillage in combination with broadcast herbicides to grow corn in tall fescue (F.arundinacea), orchardgrass, smooth brome grass and alfalfa sods. Strip tillage plus broadcast propachlor (3.4 kg/ha) and atrazine (2.2 kg/ha) resulted in 23% alfalfa survival and a corn grain yield of 7.96 Mg/ha, when 125 kg N/ha was side dressed.

In Georgia the yield of corn planted into chemically killed strips of tall fescue (20 cm strip, 102 cm row spacing) was significantly less than in completely killed fescue (Box et al., 1980). The influence of population has also been examined in Georgia. A population of 60,000 corn plants/ha gave optimum corn yields regardless of row spacing (51 cm or 102 cm), when corn was planted into chemically killed strips (20 cm) of tall fescue (Harper et al., 1980). Subsequent fescue yield was 2.6 times greater under 102 cm rows (16 cm intrarow corn spacing) than under 51 cm rows (29 cm intrarow spacing). In Illinois, over 20 treatments were evaluated for corn and grass production in chemically suppressed grass sods. These included growth retardants (e.g., maleic hydrazide), foliar absorbed herbicides (e.g., glyphosate), and root absorbed herbicides (e.g., atrazine). In addition to the chemical suppression, a band of paraquat (15-23 cm wide) was needed for acceptable corn yields (Elkins et al., 1979).

(B3b.iv) GROWTH REGULATORS

Growth regulators such as maleic hydrazide (MH) are used for corn production in chemically suppressed grass sods (Adams et al., 1970, Elkins et al., 1979). Their utility in legume swards is unsubstantiated. In greenhouse experiments, the growth of alfalfa plants receiving 0.56 kg/ha MH was similar to plants not treated (Massengale and Medler, 1958). Chlorflurecol is cited as more effective on broadleafs than on grasses (Shearing and Batch, 1982).

(B3b.v) NITROGEN FERTILIZER

When inorganic N is added to a legume/grass sward there is a decrease in legume yield and a compensatory increase in grass yield (Thornton and Nicol, 1934a; Nelson and Robins, 1957). The yield of corn when intercropped with legumes has been increased by the application of N (Stewart, 1983). Hartwig (1984) recommends applying 10-20 lb N/ac in the corn row at planting.

B4. LEGUME YIELDS

Henzell (1981) argues that the processes of N_2 fixation will eventually destroy the legume if N_2 fixation is not balanced by N losses and immobilization. Nitrogen released from the legume has the same effect on species dominance as fertilizer N; the grass is favored and legume growth is therefore impeded (Peterson and Bendixen, 1961). This lack of legume persistence is illustrated by the need to reestablish alfalfa in old swards (Leroux and Harvey, 1985; Vogel et al., 1983).

Mowing may not actually kill any plants, but it can reduce long term vigor by favoring associated weeds (Ossom et al., 1982). Inappropriate chemicals and rates will also favor weed infestation (Leroux and Harvey, 1985).

Reports on sod survival after intercropping vary. Bahiagrass growth, has been reported as "adequate for grazing" when intercropped corn yielded 27% less than conventionally cropped corn (Robertson, 1976). Good corn and soybean yields were associated with up to 60% grass survival in Illinois (Elkins et al., 1983). A "fair" stand of grass remained after two successive years of intercropped corn in West Virginia (Bennet et al., 1973). Elkins et al. (1983) report excellent corn yields in red clover, alfalfa, hairy vetch and crimson clover, but the sod cannot be maintained. Hartwig (1984) advocates caution when suppressing crownvetch prior to intercropping in Pennsylvania, especially in the first year of establishment.

B5. ESTIMATING N_2 FIXATION USING C_2H_2 REDUCTION

(B5a).....INTRODUCTION

The methods of measurement of N_2 fixation are reviewed by Hardy et al. (1973). Isotope dilution techniques have recently been reviewed by Chalk (1985).

Acetylene dependent ethylene production by nodulated legumes, less rigorously termed acetylene reduction, is a commonly used alternate substrate techique. It was proposed by Hardy (1968) and is based on the inhibition of N_2 fixation by acetylene (Schollhorn and Burris, 1967) and the reduction of acetylene to ethylene (Dilworth, 1966). Coupled with sensitive gas chromatographic techniques the assay is relatively simple to carry out and is 10^3 to 10^4 times as sensitive as ^{15}N methods. Procurement of representetive samples is a major problem in field experiments.

(B5b).....SAMPLING METHOD

Nodulated legumes have been assayed in-situ (Mahon and Salminen, 1980), as soil cores (Fishbeck et al., 1973; Goh et al., 1978; Hardy, 1968; Haystead and Marriott, 1978), as nodulated roots (van Berkum, 1980; Bollich et al., 1985; Cralle and Heichel, 1981; Fishbeck et al., 1973; Fishbeck and Phillips, 1982; Hardy, 1968; Janssen, 1972; Mahon and Salminen, 1980; Peters and Ben Zbiba, 1979; Phillips and Bennet, 1978), as excised nodules (Fishbeck et al., 1973; Hudd et al., 1980), and as various cell fractions (Hardy, 1968).

Decapitated root systems were preferred over soil cores (2.54 cm diameter) by Hardy et al. (1968) because of: heterogeneous distribution of nodules on plants, nodule injury due to the soil sampler, and, lower activity of cores compared to loose roots. Soil cores were considered useful with soil types or legumes that made root excavation difficult (Hardy, 1973). The nondestructive field method proposed by Mahon and Salminen (1980), was found to be very dependent on soil conditions.

(B5c).....SAMPLE SIZE AND DEPTH.

The size of the sample has varied greatly and is reflected in the size of the incubation chamber. Hardy (73) reports incubation chambers varying from disposable syringes to micro canopies. Hardy states that in view of the great heterogeneity in soil acetylene reduction activity, large samples are essential to obtain representative data. By contrast, in a statistical study, Goh et al. (1978) found that the smaller the soil core diameter and the greater the number of cores, the smaller the coefficient of variation. As a result of their investigations, bulked, 2.5 cm diamenter x 20 cm deep cores were adopted for measurement of white clover activity. Another example of a small diameter core is Sinclair et al. (1976) who used a 2.5 cm diameter x 7.5 cm deep core. Sinclair combined 12 of these cores per replicate and still obtained a 25% coefficient of variation.

The choice of sample depth should be governed by where the nodules are. In describing the ontogeny of tap-rooted perennial or biennial legumes in Ireland (e.g., _Trifolium pratense_, _Lotus_ corniculatus), Pate (1958b) made various observations. In the seedling year a sparsely nodulated fibrous root system developed. In subsequent seasons new growth regions of secondary roots were infected, and an investment of nodulated roots developed from latent root primordia on the tap root. The seasons nodule complement was completed by early spring, nodules remaining on the root system for 12-14 months. A large proportion of each season's nodule set survived the normal Irish winter. Lower portions of extensive root systems did not always develop nodules especially where roots were in poorly aerated soil.

Legume root and nodule distribution varies according to report. In a Wisconsin study over half of the total root growth of alfalfa and red clover occured in the top 20 cm of a well drained silt loam soil (Lamba et al., 1949). In a New Zealand mixed legume sward, 80% of the total acetylene reduction activity occuring to 20 cm, occurred in the top 7.5 cm (Sinclair et al., 1976). Likewise, 75-82% of acetylene reduction to 22.5 cm occurred in the top 7.5 cm of a New Zealand clover sward (Crush et al., 1983). By contrast, in a Californian study, less than 10% of the alfalfa nodules to 90 cm were in the top 5 cm, while most were at a depth of 10-30 cm, where soil temperatures remained at an optimal 22-27°C (Munns et al., 1977). Another example of nodules at depth comes from Minnesota, where 65% and 45% of all nodules to 60 cm deep were in the 15-30 cm deep region, for irrigated and non-irrigated alfalfa respectivly (Carter and Sheaffer, 1983).

The sensitivity of legume nodules to environmental conditions, and variation with time is brought out in a study by Fox and Lipps (1955). Alfalfa was planted on a number of soils including an acid sandy material, 90 cm thick, overlaying a heavier loessial material of higher pH. During the first season roots reached 90 cm deep, but no nodules were observed. During the second year excellent growth was coincidental with root penetration into the loess, and extensive nodulation was present in the 30-60 cm zone. After three years nodules were most abundant in the 60-90 cm zone. Alfalfa planted into the same soil amended with lime behaved quite differently. During the first season, alfalfa roots in limed soil penetrated to greater than 150 cm, and nodules were nost abundant from 0-7.5 cm deep and from 70-80 cm. There were few fibrous roots and nodules between 7.5 and 70 cm (low Ca, Mg, P zone).

(B5d).....GAS PHASE

In Hardy's original methodology (1968) the sample chamber was purged with $Ar:O_2:CO_2$ (80:20:4) for aerobic incubation, to eliminate inhibition of acetylene reduction by N_2. This step has been eliminated in some field and greenhouse work, due to the cumbersome nature of the equipment and the relative small effect it has on results (Cralle and Heichel, 1981; Mahon and Salminen, 1980; Bollich et al., 1985).

The partial pressure of acetylene used covers a wide range. Hardy (1973) reports a literature sampling of 0.002 to 0.25 atmospheres (0.2-25kPa). More recent articles gives approximately the same range: 20kPa (Hudd et al., 1980), 10kPa (Bollich et al., 1985; Peters and Ben Zbiba, 1979; Phillips and Bennet, 1978), 6kPa (Cralle and Heichel, 1981), and 5kPa (Mahon and Salminen, 1980). Excessively high acetylene concentrations decrease fixation rates (Hardy et al., 1968).

(B5e).....INCUBATION PERIOD

Assayed nitrogenase specific activity of nodules decreases with time after an initial stable period (Hardy et al., 1968; Fishbeck et al., 1973; Phillips and Bennet, 1978). If interested in extrapolating results to absolute values of N_2 fixation, the incubation period should fall with the initial stable period. If only relative values are desired, other factors such as convenience can be considered. Hardy originally proposed a 30-60 minute incubation, but periods of 48 hours have been reported (Hardy, 1973). Currently, incubation times commonly fall in the 30-60 minute range (Bollich et al., 1985; Cralle and Heichel, 1981; Hudd et al., 1980). For Mahon and Salminen's (1980) in-situ field injection technique only a 1-5 minute incubation period was used.

(B5f).....ANALYSIS

Separation and analysis of acetylene/ethylene samples has almost exclusively been accomplished using gas chromatographs with flame ionization detectors (FID), (Yatazawa et al., 1984). FIDs give excellent sensitivity but require H_2, O_2 and carrier gas sources. The bulkiness of this equipment precludes convenient field analysis and at least one alternative detector has been proposed (Mallard et al., 1977).

B6. INTERCROPPING CORN.

Four types of corn intercrop are distinguished: corn as a companion crop for forage legume establishment, corn intercropped with another annual crop plant, corn intercropped with forage grasses, and corn intercropped with forage legumes.

(B6a).....COMPANION CROPS

Research in the 1950's was concerned with the effect of corn row spacing on legume survival (Peterson, 1955; Tesar, 1957). Widening the corn rows greatly improved the stand and growth of the interplanted forage but reduced corn yields (Schaller and Larson, 1955). Increasing the intrarow corn plant population was seen as a means of maintaining corn yields. Undersown legumes reduced corn yields, even when a forage free strip was maintained under the corn row (Pendleton et al., 1957).

Soil microenvironment variations have been measured in companion crop studies (Larson and Willis, 1957). Soil moisture levels were lower and soil temperatures higher immediately south of east-west orientated corn rows. Unsatisfactory alfalfa and red clover stands were reported in this zone, and forage yields were frequently better in areas receiving considerable shade.

(B6b).....CORN/ANNUALS

In many tropical countries corn is intercropped with annual legumes and nitrogen economies result. When cowpeas, greengram or calopo were grown between corn rows in Nigeria, without additional N, the yield of shelled corn was significantly increased relative to corn grown alone (5% level). Application of 45 kg N/ha eliminated this statistical difference (Agboola and Fayemi, 1972). Competition for soil moisture may reduce potential yields. In a wet year in Kenya, yields were 5.92 and 2.5 Mg/ha for pure stands of corn and Phaseolus vulgaris respectively, compared with 4.98+0.7 Mg/ha when intercropped. In dry years intercropping was not advantageous (Stewart, 1983).

(B6c).....CORN/GRASSES

In investigating tillage systems for corn-sod systems in the southern Piedmont, Adams et al. (1970) used two methods to partially suppress bermudagrass sods. When strips (40%) of sod were tilled prior to planting corn, corn grain yields were 19% - 27% less than in conventionally tilled plots (irrigated and not irrigated respectively). Forage production during the intercrop year decreased as corn yield increased, but excellent regrowth occurred in the following year. When strips of sod were mown and treated with maleic hydrazide (9.0 kg/ha) prior to planting corn, corn grain yields were 28% - 85% less than in conventionally tilled plots (in years of above and below average rainfall respectively). Grass survival was excellent.

Bennet et al. (1973) planted corn into orchard grass suppressed with atrazine (2.2 kg/ha) and paraquat (0.5 kg/ha). Grass regrowth during the season did not seriously affect grain yields in either year, but silage yields were reduced 16% in the first year, relative to silage yield in chemically killed sods. A reduced grass stand survived after the two years of corn. Corn yields in tilled sod (plowed + 2 discings + atrazine at 2.2 kg/ha + cultivated) were much lower than in chemically suppressed sods. This was attributed to differences in soil moisture content.

Bennet et al. (1976), planted corn into various grass sods that were mown one week before planting corn, and treated with paraquat (0.56 kg/ha) + atrazine immediately after planting. Sod planted corn yielded significantly more than conventionally (plowed) planted corn. Brome, orchardgrass and fescue produced excellent regrowth when treated with 1.7 kg/ha atrazine. It was proposed that the ideal sod species for intercropping should have a wide herbicide tolerance range, remain in a state of semi-dormancy for extended time periods and then rapidly recover.

Robertson et al. (1976), planted corn into Pensacola bahiagrass treated with paraquat (0.28 kg/ha) or glyphosate (2.24 kg/ha), plus a residual herbicide. Paraquat treated bahiagrass rapidly recovered and competed with the corn for water and nutrients. In the first year corn yields in the paraquat suppressed sod were an average of 27% less than in conventionally tilled ground (rotavated + disced), but there was adequate grass regrowth for grazing. In the following two years, little difference was discernable. After three years of continuous no-tillage corn, perennial weeds were beginning to appear in the no-tilled treatments and not in the cultivated plots. The glyphosate treatment killed almost all the grass in the first year.

Box et al. (1980), planted corn in 102 cm rows into chemically killed strips (20 cm) of fescue. Five irrigation treatments were used ranging from natural rainfall to 5 cm per week. Corn grain and stalk yields were significantly less in strip killed fescue than in completely killed fescue. Irrigation increased plant yield (corn and fescue) in all but the highest treatment, where excess water decreased yield. The authors reported that the decreased plant yields in the strip killed fescue appeared to be caused by factors other than soil water and nutrient deficiencies.

Harper et al. (1980) no-till planted corn into chemically killed strips (20 cm) of fescue grown under irrigated conditions. A corn population of 60,000 plants/ha gave optimum corn yields and maintained fescue sods regardless of row spacing. Subsequent fescue yields from plots on which corn was grown at 102 cm were 2.6 times greater than from 51 cm spacings, although corn yield did not vary.

A three year study in Illinois evaluated over 20 treatments (growth retardants and sublethal herbicide rates) for corn production and sod survival in mown tall fescue and Kentucky bluegrass (Poa pratense), (Elkins et al., 1979). The authors proposed that these cool season grasses should be suppressed for two months in order to allow corn to become established with minimal competition from the grass. Growth retardants which gave best combinations of corn yield and grass production were maleic hydrazide, flouridamid and mefluidide. Herbicides with good results were glyphosate, glyphosate + atrazine, metolachlor, metolachlor + atrazine and dalapon. A band of paraquat, 15-23 cm wide, was needed in most cases for acceptable corn yields.

(B6d).....CORN/FORAGE LEGUMES

In the Proceedings of the Mines Symposium on Legume Cover Crops for Conservation Tillage Production Systems (Hargrove, 1982), numerous cover crops are discussed, but these are nearly all killed prior to planting subsequent crops. One exception is the mention of crownvetch and bigflower vetch (Vicia grandiflora) maintained under intercropped corn at Lexington, Kentucky. Crownvetch was suppressed with paraquat prior to planting corn, and bigflower vetch, an annual, was managed as a perennial by permitting some seeds to mature before killing it with paraquat. Corn yields without N fertilizer were 135 and 120 bu/acre (8.47 and 7.53 Mg/ha), respectively with crown and bigflower vetch. These yields were greater than when legume-cover-crops were killed prior to planting corn, suggesting that corn obtained some benefit from the continued association.

Elkins et al. (1983, Illinois), report on no-till corn production in chemically suppressed alfalfa sods. To suppress the alfalfa it was mown two to four days prior to planting, and sprayed with propachlor (3.4 kg/ha) plus atrazine (2.2 kg/ha). Additional treatment included establishment of tilled alfalfa strips, and the application of 125 kg/ha of side dressed N. Twenty three percent of the alfalfa sod survived, and corn yielded 7.97 Mg/ha grain. Excellent grain yields associated with considerable sod suppression were also reported for red clover, hairy vetch and crimson clover.

In a Pennsylvania State University publication recommendations are made for using crownvetch as a living mulch (Hartwig, 1984). No suppression is suggested for first year crownvetch as it establishes very slowly. If crownvetch is growing vigorously, the application of dicamba (0.28 kg/ha) is recommended. A mixture of Bladex (cyanazine) + Bicep (atrazine + metolachlor) at labeled rates is recommended for weed control without severely injuring the vetch. Higher rates of dicamba are suggested to control broadleaved weeds with foliage, if applied while crownvetch is still dormant. If dandelions are a major problem at this stage, the addition of a small amount of 2,4-D ester is suggested. If quackgrass is a problem, a split triazine treatment is recommended, but severe crownvetch suppression can be expected (2.25 kg/ha atrazine, four to six weeks before corn planting, followed by 1.12 kg/ha atrazine + 1.12 kg/ha simazine preplant or pre-emergence). Competition from crownvetch is described as reducing second year corn yields 5-10%, but it is argued that this loss has to be compared with the value of additional weed and soil erosion control, and the feeding value of fall pasture after corn grain harvest.

A current intercropping demonstration exists at the Rose Lake Plant Materials Center, East Lansing, Michigan (Soil Conservation Service). Nine herbicide treatments were applied to nine different forages prior to interseeding corn. The legume intercrops include alfalfa, four clovers, two trefoils and two vetches. In the first intercrop year (1985), paraquat combined with atrazine, alachlor or cyanazine gave the best legume control, and milkvetch, crownvetch, birdsfoot trefoil and narrowleaf trefoil produced the best regrowth. Clovers were killed by these treatments.

EXPERIMENTAL METHODS

C1. INTRODUCTION

Field experiments were carried out in 1984 and 1985 on the Kellogg Biological Station, Hickory Corners, MI. The soil type was a Kalamazoo sandy loam (Fine loamy, mixed mesic, typic Hapludalf), as described in the Soil Survey of Kalamazoo County (Austin, 1978). Climatic and irrigation data for the growing seasons is given in Tables 1 and 2. Over the two years, one herbicide tolerance experiment and seven seperate intercropping experiments were conducted in adjacent sections of the same field (Figure 1). Each legume was regarded as a separate experiment as growth stages did not coincide, and treatments could not be applied on the same date. Experiments were not carried through to a second season, except for some legume regrowth assessments in the spring of 1985. The experiments were:

1984
- CORN/ALFALFA INTERCROP
- CORN/CROWNVETCH INTERCROP
- CORN/BIRDSFOOT TREFOIL INTERCROP
- CORN/RED CLOVER INTERCROP

1985
- CORN/ALFALFA INTERCROP
- CORN/CROWNVETCH INTERCROP
- CORN/BIRDSFOOT TREFOIL INTERCROP
- ALFALFA HERBICIDE TOLERANCE

TABLE 1. 1984 GROWING SEASON WEATHER AND IRRIGATION DATA

DAY	MONTH										
	MAY			JUNE				JULY			
	TEMP		PPT	TEMP		PPT	IRR	TEMP		PPT	IRR
	MAX	MIN		MAX	MIN			MAX	MIN		
	....C°....		cm	....C°...		...cm....		....C°...		....cm.....	
1	12.2	3.3	0	25.6	10.6	0	0	29.4	11.7	0	0
2	12.2	-1.7	0	27.8	15.0	0	0	29.4	14.4	0	0
3	16.7	4.4	0	26.1	12.8	0	0	30.0	14.4	0	0
4	16.7	5.6	0.2	27.2	8.9	0	0	28.9	17.8	0	0
5	16.7	2.2	0	27.8	18.9	0	0	29.4	15.0	0	0
6	21.1	2.2	0	29.4	19.4	0	0	28.9	16.7	0.4	2.6
7	21.1	10.6	0	29.4	20.0	0.3	0	23.3	8.3	0	0
8	18.9	6.7	0	28.9	22.2	0	0	26.7	7.8	0	0
9	9.4	1.1	0.4	30.0	20.6	0.2	0	25.6	15.6	3.1	0
10	17.8	2.8	0	30.0	21.1	0	0	30.0	21.7	0.3	0
11	18.3	11.7	0.1	27.2	10.0	0	0	31.1	16.7	2.4	0
12	17.2	7.8	0	31.1	13.3	0	0	30.6	15.0	0	0
13	16.7	5.0	0.8	31.1	19.4	0.1	0	30.6	29.4	0	0
14	17.2	1.1	0	31.7	15.6	0	0	31.7	18.3	0	0
15	17.2	1.1	0	25.0	10.6	0	2.5	31.1	22.8	0	0
16	18.3	1.7	0	26.1	11.1	0	0	28.9	16.7	0	0
17	21.1	6.1	0	31.7	10.6	0	0	26.1	16.7	0	0
18	26.1	13.3	0.4	31.7	21.1	0	0	25.0	13.3	0	4.4
19	24.4	14.4	1.2	31.1	17.2	0	0	26.7	11.7	0	0
20	20.6	12.8	0.4	31.1	15.6	0	0	27.8	16.7	1.3	0
21	21.1	8.3	0	30.0	15.0	0	0	29.4	17.8	0	0
22	24.4	8.3	0.7	29.4	13.3	0	0	31.7	17.8	0	0
23	20.0	12.2	3.5	27.2	16.1	0.1	3.2	32.2	21.1	0	0
24	21.7	7.2	0	26.1	16.1	0	0	30.0	17.2	0.7	0
25	22.2	15.0	0.4	25.0	12.8	0	0	30.0	13.9	0.1	0
26	16.7	8.9	1.7	28.3	10.6	0	0	25.6	14.4	0.1	0
27	20.0	3.9	0	27.2	18.3	0.1	0	24.4	12.8	0	0
28	14.4	6.1	0.8	28.3	14.0	0	3.8	26.1	11.1	0.1	0
29	10.6	3.9	1.0	26.7	10.6	0	0	27.2	11.7	0	0
30	17.8	5.0	0	25.0	11.1	0	0	28.9	11.1	0	0
31	21.7	5.0	0					29.4	12.8	0	5.1

Abbreviations: **TEMP**=Temperature; **MAX**=Daily Maximum; **MIN**=Daily Minimum; **PPT**=Daily precipitation; **IRR**=Daily Irrigation.

TABLE 1. Continued

DAY	AUGUST TEMP MAX	AUGUST TEMP MIN	AUGUST PPT	AUGUST IRR	SEPTEMBER TEMP MAX	SEPTEMBER TEMP MIN	SEPTEMBER PPT	SEPTEMBER IRR	OCTOBER TEMP MAX	OCTOBER TEMP MIN	OCTOBER PPT
	....C°....		....cm...		....C°....		....cm...		....C°....		cm
1	28.9	17.8	0	0	28.3	12.2	1.0	2.0	20.0	2.2	0
2	28.9	18.9	0	0	29.4	16.7	0	0	18.3	3.9	0
3	30.0	19.4	0.1	0	24.4	15.0	0.1	0	20.0	11.7	0
4	29.4	18.9	0.1	0	18.9	8.9	0.4	0	18.9	3.3	0
5	31.1	17.2	0	0	20.6	6.1	0	0	20.6	6.1	0
6	31.7	21.1	0	0	22.2	4.4	0	0	22.2	9.4	0
7	32.2	21.1	0	3.1	25.6	12.8	1.0	2.0	21.1	13.9	2.1
8	31.1	24.4	0.6	0	26.1	17.2	0	0	19.4	15.0	0.2
9	31.7	19.4	0	0	25.0	12.8	1.8	0	19.4	12.8	0.1
10	31.1	19.4	0.4	0	24.4	15.0	0	0	20.6	17.8	0
11	30.6	17.2	0	0	25.0	15.0	1.9	0	21.1	10.1	0
12	28.9	13.3	0	0	25.5	12.2	0	0	21.1	9.4	0
13	29.4	13.9	0	0	24.4	18.9	1.2	0	19.4	11.7	0.2
14	30.0	13.9	0	0	20.6	12.8	0	0	17.2	12.8	0.3
15	30.6	12.2	0	0	17.2	7.2	0.3	0	22.2	15.0	0.3
16	32.2	18.3	0	0	18.3	6.1	0	0	22.2	13.9	0
17	32.2	16.1	0	0	19.4	4.4	0	0	21.7	11.7	0.1
18	29.4	19.4	0	0	22.2	7.2	0	0	18.9	3.9	0
19	28.9	14.4	0	0	27.2	12.8	0	0	18.3	11.7	1.5
20	28.9	10.0	0	4.4	27.8	17.2	0	0	16.1	4.4	0.1
21	29.4	12.2	0	0	27.2	9.4	0	0	10.6	6.1	3.1
22	31.7	20.6	0	0	28.9	13.9	0	0	13.3	3.3	0
23	31.1	14.4	0	0	27.8	16.7	1.8	0	12.8	1.7	0
24	27.2	9.4	0	0	24.4	16.1	0.1	0	12.8	0.0	0
25	28.3	10.0	0	0	21.1	16.1	6.1	0	12.2	1.1	0
26	29.4	12.2	0	0	17.2	6.1	0	0	15.0	8.9	0.3
27	28.9	18.9	0	0	11.1	4.4	0	0	21.7	11.7	0.2
28	30.6	20.0	0.2	4.1	13.3	3.9	0	0	21.1	10.0	0.1
29	31.7	22.2	0	0	12.8	5.0	0.1	0	16.1	1.7	0.1
30	31.7	18.3	1.3	0	15.6	0.0	0	0	15.6	4.4	0
31	28.3	16.1	0	0					11.7	1.1	0.3

Abbreviations: **TEMP**=Temperature; **MAX**=Daily Maximum; **MIN**=Daily Minimum; **PPT**=Daily precipitation; **IRR**=Daily Irrigation;

TABLE 2. 1985 GROWING SEASON WEATHER AND IRRIGATION DATA

DAY	MONTH										
	MAY			JUNE				JULY			
	TEMP		PPT	TEMP		PPT	IRR	TEMP		PPT	IRR
	MAX	MIN		MAX	MIN			MAX	MIN		
	....C°....		cm	....C°...		...cm....		....C°...		....cm.....	
1	23.3	10.6	0	25.6	12.8	0	0	27.8	13.9	0	1.7[A]
2	19.4	3.9	0	25.6	14.4	0	0	28.3	18.3	0	0
3	21.1	2.8	0	22.2	9.4	0	0	29.4	13.3	0	0
4	22.8	7.8	0	22.2	10.0	0	0	30.0	14.4	0.2	0
5	23.3	7.2	1.0	22.8	11.7	0	0	29.4	15.0	0.1	0
6	20.0	7.2	3.6	22.8	7.2	0	0	25.0	15.6	0	0
7	20.0	5.0	0	27.2	10.0	0	0	27.8	12.2	0.2	0
8	21.7	7.8	0	30.6	15.0	0	0	33.3	22.8	0	0
9	24.4	10.0	0	30.0	21.1	0	0	32.2	17.8	0	3.4[VT]
10	25.6	13.3	0	27.8	11.7	0	0	28.9	17.2	0.2	2.3[A]
11	26.1	15.0	0	25.6	8.3	1.2	0	28.3	13.9	0	0
12	26.7	14.4	0	13.9	8.3	0.2	0	31.1	16.1	0	0
13	24.4	11.1	0	20.0	6.7	0	0	32.2	19.4	0	0
14	26.7	14.4	0	23.3	9.4	0	0	31.1	19.9	5.1	0
15	27.8	17.2	0.3	23.3	13.9	1.5	0	29.4	19.4	2.9	0
16	20.2	11.7	0.3	18.9	19.4	0.1	0	27.2	15.0	0	0
17	18.3	10.0	0	21.7	13.3	0.5	0	27.2	12.2	0	0
18	18.3	7.0	0.4	21.7	11.7	0	0	28.3	15.0	0	0
19	25.0	5.0	0	21.1	10.0	0	0	28.3	18.9	0.2	0
20	24.4	13.9	1.2	22.8	11.1	0	0	28.9	20.0	0	0
21	18.9	6.1	0	26.7	12.8	0	0	29.4	19.4	0	0
22	18.9	5.6	0	26.1	16.7	0.4	0	24.4	13.9	0	0
23	23.9	6.7	0	25.0	16.1	0.7	0	25.0	8.9	0	0
24	26.1	6.7	0	24.4	13.3	0	0	28.9	12.8	0	2.9[VT]
25	27.2	10.6	0	27.2	11.1	0	0	30.0	22.8	0	0
26	28.9	16.7	0	30.0	13.9	0	0	26.7	16.1	1.7	0
27	28.9	13.3	3.8	30.6	13.9	0	0	27.8	12.2	0	0
28	21.7	5.0	0.3	27.8	12.2	0	6.1[VT]	29.4	16.1	0	0
29	22.2	5.6	0	28.3	12.2	0	0	29.4	17.2	0	0
30	23.9	15.0	0	28.9	13.9	0	0	28.9	11.7	0	0
31	25.0	17.2	0.9					21.7	15.0	1.2	0

Abbreviations: **TEMP**=Temperature; **MAX**=Daily Maximum; **MIN**=Daily Minimum; **PPT**=Daily precipitation; **IRR**=Daily Irrigation; **A**=Applied to Alfalfa Intercrop; **VT**=Applied to Vetch and Trefoil INtercrops.

TABLE 2. Continued

DAY	AUGUST TEMP MAX	AUGUST TEMP MIN	AUGUST PPT	AUGUST IRR	SEPTEMBER TEMP MAX	SEPTEMBER TEMP MIN	SEPTEMBER PPT	OCTOBER TEMP MAX	OCTOBER TEMP MIN	OCTOBER PPT
	....C°	....	....cm	...	....C°	....	cm	....C°	....	cm
1	25.6	11.1	0	0	23.9	13.3	0	13.9	7.2	0
2	25.6	10.6	0	0	27.2	13.3	0	16.1	2.8	0
3	26.7	11.1	0	0	28.9	19.4	0	18.3	1.7	0
4	28.9	13.9	0	0	29.4	22.2	0	17.2	7.2	0.8
5	27.8	18.3	1.3	0	28.9	21.7	0.1	12.2	7.2	1.0
6	26.7	18.3	0.5	0	28.3	23.9	0	11.1	5.0	0.1
7	26.7	18.3	0.3	0	32.8	22.8	0	19.4	5.0	0
8	29.4	15.0	0	0	32.2	22.8	0	18.9	12.8	0.1
9	29.4	15.6	0	0	28.9	18.3	3.3	17.8	12.8	0.8
10	28.3	20.0	0	0	25.6	16.7	0	17.2	9.4	0.3
11	26.1	12.8	0	0	20.0	8.9	0	15.0	4.4	0.2
12	27.8	12.8	0	1.5 A	20.0	6.7	0	23.3	8.3	0.6
13	27.8	20.0	0.8	2.7 VT	17.8	3.9	0	23.3	10.6	0.1
14	27.8	17.8	0.8	0	19.4	5.0	0	18.3	8.9	0.1
15	25.6	16.1	3.6	0	21.1	8.9	0	17.8	10.0	0.5
16	26.7	13.3	0	0	23.3	7.2	0	15.6	3.3	0.1
17	27.8	15.0	0	0	23.9	13.9	0	21.1	0.6	0
18	27.8	20.0	0.6	0	27.8	18.3	0	18.9	12.8	1.8
19	23.9	11.7	0	0	27.8	16.7	0	17.8	12.2	5.1
20	20.0	12.2	0	0	27.8	15.6	0	15.6	8.9	0
21	21.7	13.9	0	0	25.6	12.8	0	14.4	5.6	0.1
22	22.8	10.6	0	0	24.4	12.8	0	15.6	7.2	0
23	26.1	13.9	0	0	26.1	18.3	0.8	18.9	11.7	0
24	24.4	18.3	1.0	0	20.0	8.3	0.1	20.6	15.0	1.4
25	24.4	15.6	1.2	0	15.6	4.4	0	18.9	3.9	0
26	24.4	15.6	0	0	14.4	9.4	0.5	18.9	5.6	0
27	26.1	15.6	0	0	17.8	5.6	0	18.3	10.0	0
28	26.7	16.1	0	0	22.2	8.3	0	16.1	0.6	0
29	26.7	17.8	0	0	22.8	8.9	0	13.3	1.1	0
30	26.7	16.7	0.6	0	21.7	13.3	0.9	12.2	2.8	0
31	22.8	10.6	0	0	21.7	13.3	0.9	12.8	1.7	0

Abbreviations: **TEMP**=Temperature; **MAX**=Daily Maximum; **MIN**=Daily Minimum; **PPT**=Daily precipitation; **IRR**=Daily Irrigation; **A**=Applied to alfalfa intercrop; **VT**=Applied to Vetch and Trefoil Intercrop.

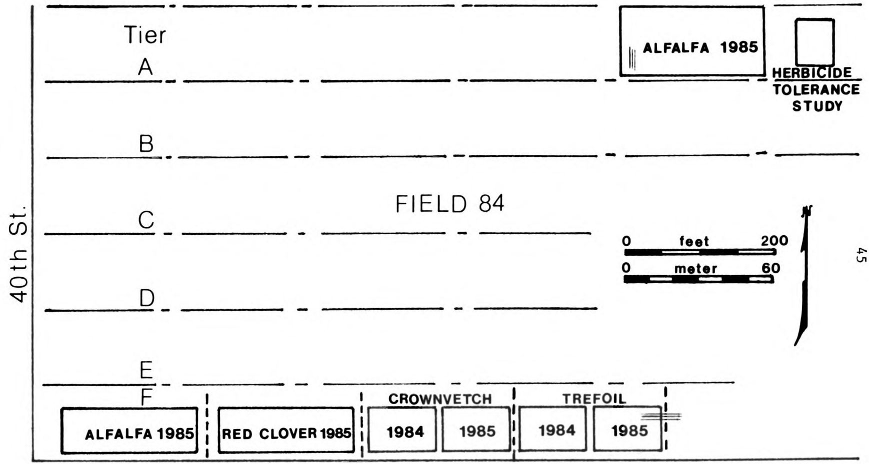


FIGURE 1. LOCATION MAP, FIELD 84, KELLOGG BIOLOGICAL STATION.

C2. 1984 INTERCROPS

(C2a).....1984 GENERAL

Legume Establishment: In spring 1983 the four legumes, Vernal alfalfa, Canadian mammoth red clover, Penngift crownvetch and Empire birdsfoot trefoil, were planted in 61 m x 20 m blocks, using a John Deere small grain drill with 17.8 cm spacings. Fertilizer was broadcast applied (224 kg/ha 0:26:26), and banded at planting (224 kg/ha 0:26:26). Eptam (EPTC) was used for weed control (3.36 kg/ha a.i., in 280 L/ha.

Corn Planting: Corn (Great Lakes Hybrid 5922) was planted into the living legumes using a Buffalo All-Flex Till Planter, Model 4500-AA, set to deliver 66000 seeds per hectare. Plots were 4.6 m x 3.0 m (15 x 10 feet) with four 76 cm (30 inch) rows per plot. Difonate 20G at 5.6 kg/ha was surface applied at planting. No fertilizer was applied in 1984.

Treatments: Various legume suppressing treatments were applied, the number and type of treatments varying for each experiment. Treatment dates are summarized in Table 3. The suppressants assessed and the symbols used in tables and throughout the text are:

M Mowing

G Broadcast Glyphosate

P Broadcast Paraquat

T Broadcast 2,4-D amine

TABLE 3. 1984 INTERCROPS: TREATMENT DATES

TREATMENT	LEGUME COVER CROP			
	ALFALFA	CLOVER	VETCH	TREFOIL
PLANTED CORN AND BANDED HERBICIDE	May 11, 84	May 11, 84	May 11, 84	May 11, 84
APPLIED INITIAL HERBICIDE TREATMENTS	May 12	May 12	May 31	May 31
INITIAL MOWING TREATMENT	May 11	May 11	June 1	June 1
REPEATED HERBICIDE TREATMENTS	May 31 Glyphosate 2,4-D plots	May 31 2,4-D plots	-	-
2nd. MOWING TREATMENT	June 8	June 8	-	-
REESTABLISHED BANDS	June 9 2,4-D plots only (mechanically)	June 9	-	June 12 All banded plots (chemically)
2,4-D TREATMENT TO MOWN PLOTS	June 9	June 9	-	-
KILLED LEGUME IN CK PLOTS	-	-	June 14	June 14
2,4-D TREATMENT TO PARAQUAT PLOTS	June 29	June 29	-	-
HARVESTED CORN	Nov 3	Nov 9	Nov 9	Nov 9

Mown treatments were established using a 91 cm wide, self propelled, hand held, sickle bar mower. Skids attached below the cutting blade allowed adjustment of cutting height. Broadcast herbicides were applied using a hand held, carbon dioxide sprayer equipped with flat fan nozzles. The herbicides used were Roundup (glyphosate), Ortho Paraquat (paraquat), and Weedstroy-AM40 (24D amine). In addition to these suppressants, three other treatments were applied:

OO No legume suppression

K Complete legume Kill (100% of ground surface)

B Killed Bands of legume, 15cm wide (20% of ground surface)

Killed bands were established at the time of planting, using flat fan nozzles mounted behind each planting shoe. Herbicide was applied as a 15 cm wide band centered on the seed slot. The banding formulation contained; Atrazine 4L (1.12 kg/ha a.i.), Crop Oil (2.35 L/ha), and Butoxone (24D ester at 1.12 kg/ha a.i.). The broadcast herbicides and the banding formulation were applied in 280 L water/ha at a pressure of 172 kPa. The banding treatment was also combined with the suppressants. Letter combinations in the text (e.g., BPT) represent combinations of suppressants and/or banding. Where a symbol is repeated (e.g., MM), the treatment was applied twice. Other symbols used in the text are:

H High herbicide rate

L Low herbicide rate

C Clippings removed

Measuring Nitrogen Fixation: An acetylene reduction technique was used to assess the relative nitrogen fixation rates in various treatments. Our preliminary investigations indicated that excavation of perennial forage legume root systems, with nodules intact, was extremely difficult. It was also found that results were more variable using the in-situ technique of Mahon and Salminen (1980), than using soil/root cores in sealed jars. The procedure selected was as follows. Surface cores (7.6 cm deep x 7.6 cm diameter) were obtained using a cylindrical sampling device centered on the legume row. The soil cores were trimmed, removing excess material, surface residue and legume shoots. After forcing the soil plug out of the sampling cylinder, it was broken up by hand, and crudely separated into loose soil material and roots. The soil material was placed in a one quart (0.95L) mason jar followed by the roots. Jars were sealed using standard lids previously fitted with rubber septums. Petroleum jelly was used to ensure an adequate sealing. Less than five minutes would normally be required for the procedure to this point. Once all the jars were sealed, 25 ml of air was removed using a syringe. This was replaced with 25 ml of commercial grade acetylene, maintained at atmospheric pressure. The resulting substrate partial pressure was approximately 3 kPa (0.03 atm). After injection of acetylene, the jars were inverted momentarily, and transported to the laboratory.

An incubation time of 2.5 hours was chosen as this allowed enough time for transit and unloading. After incubation the jars were again momentarily inverted prior to gas subsamples being drawn. Evacuated blood collection tubes (5 ml), or syringes (1 ml) were used, the needles of the syringes being forced into rubber stoppers after sampling. All gas samples were stored in a cool-room until equipment for analysis was available. Soil moisture determinations were made on all samples. A Carle Instruments, Model 9500 Basic Gas Chromatograph was used for ethylene analysis (three foot long Porapak Q column, nitrogen as a carrier gas, and a flame ionization detector). The column temperature was 60°C and a typical retention time for ethylene was 0.78 minutes. Acetylene took up to four minutes to elute.

As it was logistically impossible to sample all treatments on one day, only certain treatments were sampled throughout the season (see Tables 15, 19, 23 and 26 for treatments and dates). Two cores were removed from each plot of the chosen treatment, making eight cores per treatment. Results are presented as ethylene concentrations developed in the mason jars after incubation (parts per million)

Legume and Corn Assessment: In addition to qualitative assessments of alfalfa vigor, various quantitative assessments were made. Alfalfa height at corn planting was assessed using a meter stick at various points in the field. An additional estimate of the initial ground cover was obtained by collecting clippings from mown plots (4.6 x 3 m), oven drying and weighing the material. In the alfalfa and clover intercrops the percentage of the ground surface covered by living plant material, and the percentage of this that was weeds, were visually assessed on 7 August 1984. This procedure was repeated for all intercrops

on 22 April 1985. To better estimate cover regrowth, 51 cm x 76 cm quadrats were harvested from selected treatments in April 1985. The plant material in each quadrat was hand cut, divided into weed and legume portions and oven dried at $13^{o}C$ prior to weighing.

Corn populations in the alfalfa intercrop were assessed as plants per 30 feet (9.14 m) of row on June 21. Corn populations in all intercrops were assessed as plants per 24 feet (7.32 m) on October 4. Corn height in alfalfa and clover intercrops was determined on August 7 by measuring, five plants per plot, to the top of the extended leaves. By early July corn in certain treatments was becoming noticeably yellow. To assess whether this was associated with N differences, five, uppermost, fully expanded leaves were removed from all plots on July 11, oven dried at $13^{o}C$, ground to pass a 60 mesh sieve (250 microns), and analyzed for N content using the Kjeldahl procedure (in 1984 the Kjeldahl digestions and titrations were performed by the Crop and Soil Sciences Department, Soils Testing Lab). Five earleaves per plot were also sampled (August 17 or 27), oven dried and weighed. Corn-silage yield was determined by hand cutting ten plants from each plot. These were fed through a wood chipper, weighed, subsampled, ovendried at $13^{o}C$, and reweighed. No effort was made to separate cobs from stalks.

(C2b).....1984 ALFALFA INTERCROP

The alfalfa intercrop experiment in 1984 was a randomized complete block design (RCBD), with eighteen treatments and four

replicates. Treatment details and herbicide rates are listed in Table 4, and the experimental design is shown in Figure 2.

As alfalfa was actively growing when corn was planted on May 11, suppression treatments were applied immediately. The mown treatments (BMC, BMCM, BMM and BMCT) were cut to 5 cm and clippings removed from those treatments specified as C. Broadcast herbicides were first applied in the evening on the day after planting, when the air temperature was a relatively low 15°C. Rainfall occurred the following morning. Due to poor suppression, glyphosate and 2,4-D amine treatments were repeated on May 31 (sunny and 22°C).

The BMCM and BMM plots were removed on June 8, both alfalfa and corn plants being clipped at 10 cm. The clippings were not removed from the plots at this stage. As a comparison, treatment BMCT was sprayed with 2,4-D amine on June 9.

By June 9, it was obvious that the completely obscured corn in the 2,4-D treatments had no chance of survival. Therefore a 35 cm wide band, centered on the seed slot, was mechanically cleared with a weed whip. This also damaged some corn leaves, but did not remove any meristems.

By June 29 regrowth had reached a level judged excessive in paraquat treated plots, and 2,4-D amine was applied as a secondary suppressant to treatment BPT. No further manipulation took place prior to corn harvest on November 3. Alfalfa and corn were assessed as described in the section C2a.

TABLE 4. 1984 ALFALFA INTERCROP TREATMENT SCHEDULE

KEY			TREATMENT DISCRIPTION	
OO				
B	Banded$			
BMC	Banded	+	Mown to 5cm, Clippings Removed	May 11
BMCM	Banded	+	Mown to 5cm, Clippings Removed	May 11
		+	Mown to 10cm	June 8
BMM	Banded	+	Mown to 5cm	May 11
		+	Mown to 10cm	June 8
BMCT	Banded	+	Mown to 5cm, Clipping Removed	May 11
		+	2,4-D amine @ 0.14 kg/ha a.i.	June 9
GGH	-		Glyphosate @ 1.12 kg/ha a.i.	May 12
		+	Glyphosate @ 1.12 kg/ha a.i	May 31
BGGH	Banded	+	Glyphosate @ 1.12 kg/ha a.i.	May 12
		+	Glyphosate @ 1.12 kg/ha a.i.	May 31
BGGL	Banded	+	Glyphosate @ 0.56 kg/ha a.i.	May 12
		+	Glyphosate @ 0.56 kg/ha a.i.	May 31
P	-	+	Paraquat @ 0.56 kg/ha a.i. + 1/4% X77	May 12
BPT	Banded		Paraquat @ 0.56 kg/ha a.i. + 1/4% X77	May 12
		+	2,4-D Amine 0.14 kg/ha a.i.	June 29
TTH	-		2,4-D Amine @ 0.28 kg/ha a.i.	May 12
		+	2,4-D Amine @ 0.28 kg/ha a.i.	May 31
		+	Mechanically cut Bands	June 9
TTL	-		2,4-D AMINE @ 0.14 Kg/ha a.i.	May 12
		+	2,4-D Amine @ 0.14 kg/ha a.i.	May 31
		+	Mechanically cut bands	June 9
BTTH	Banded	+	2,4-D Amine @ 0.28 kg/ha a.i.	May 12
		+	2,4-D Amine @ 0.28 kg/ha a.i.	May 31
		+	Mechanically cut bands	June 9
BTTL	Banded	+	2,4-D Amine @ 0.14 kg/ha a.i.	May 12
		+	2,4-D Amine @ 0.14 kg/ha a.i.	May 31
		+	Mechanically cut bands	June 9
K	-		Atrazine @ 1.12 kg/ha a.i + Crop Oil @ 2.35 L/ha + 2,4-D Ester @1.12kg/ha a.i	May 11

Designations: **K**=Killed; **B**=Killed band, **M**=Mown; **G**=Glyphosate; **P**araquat; **T**=2,4-D Amine; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**=No Suppression. All chemicals applied in 280 L water/ha @ 172 kPa.
$=The formulation described under K was applied as a 15 cm wide band when corn was planted.

Rep 1			Rep 2			Rep 3			Rep 4		
BPT	BTTL	BMCT	B	TTL	BPT	TTL	GGH	BGGH	BMCM	BTTL	B
BTTH	BMM	B	P	K	BMCT	OO	BTTL	BPT	BGGL	BTTH	BTTL
BGGL	BTTH	OO	GGH	BMC	BMCM	BMM	TTH	BGGL	BGGH	GGH	BTTH
GGH	BMC	K	BGGL	BGGH	BTTL	BTTH	BMCM	BMCT	OO	BMCT	BMC
P	BMCM	BGGH	BTTL	BTTH	BMM	BMC	BTTL	P	BPT	TTL	BMM
TTL	TTH	BTTL	TTH	BTTH	OO	B	K	BTTH	P	K	TTH

10 ft. × 15 ft. (plot dimensions); N (north arrow)

OO–No Suppression B --Banded G –Glyphosate M –Mown H –High Rate

K –Legume Killed P –Paraquat T --2,4–D amine C –Clippings Removed L –Low Rate

FIGURE 2. 1984 ALFALFA INTERCROP: PLOT DIAGRAM.

(C2c).....1984 CLOVER INTERCROP

The 1984 clover intercrop was a randomized complete block design (RCBD), with eighteen treatments and four replicates. The treatments were the same as the 1984 alfalfa intercrop, except that herbicide rates used for suppression were half those used on alfalfa, and no secondary application of glyphosate was made. Treatment details and herbicide rates are listed in Table 5, and the experimental design is shown in Figure 3. Clover and corn were assessed as described in section C2a.

(C2d).....1984 CROWNVETCH INTERCROP

The vetch suppression experiment was set up as a randomized complete block design (RCBD) with nine treatments and four replicates. Treatment details and herbicide rates are listed in Table 6. The experimental design was the same as the 1984 trefoil intercrop, and is shown in Figure 4. Paraquat, mowing and 2,4-D amine were the only suppressants considered.

Banding and corn planting were carried out on May 11 when the vetch was relatively dormant. Mowing and herbicide applications were therefore postponed, and eventually carried out three weeks later (June 1), when grass weeds were becoming a problem and the vetch had just begun to grow. Vetch in the killed treatment plots (CK) was not treated until June 14, at which stage it was dense and twining. To clear the killed plots the vetch was clipped by hand to less than 2.5 cm tall, and atrazine was

TABLE 5. 1984 CLOVER INTERCROP TREATMENT SCHEDULE

KEY			TREATMENT DISCRIPTION
OO			
B	Banded[$]		
BMC	Banded	+	Mown to 5cm, Clippings Removed ....May 11
BMCM	Banded	+	Mown to 5cm, Clippings Removed ....May 11
		+	Mown to 10cm ....June 8
BMM	Banded	+	Mown to 5cm ....May 11
		+	Mown to 10cm ....June 8
BMCT	Banded	+	Mown to 5 cm, Clippings Removed ....May 11
		+	2,4-D Amine @ 0.07 kg/ha a.i. ....June 9
GH	-		Glyphosate @ 0.56 kg/ha a.i. ....May 12
BGH	Banded	+	Glyphosate @ 0.56 kg/ha a.i. ....May 12
BGL	Banded	+	Glyphosate @ 0.28 kg/ha a.i. ....May 12
P	-		Paraquat @ 0.28 kg/ha a.i. + 1/4% X77 ....May 12
BPT	Banded	+	Paraquat @ o.28 kg/ha a.i. + 1/4% X77 ....May 12
		+	2,4-D Amine @ 0.07 kg/ha a.i. ....June 29
TTH	-		2,4-D Amine @ 0.14 kg/ha a.i. ....May 12
		+	2,4-D Amine @ 0.14 kg/ha a.i. ....May 31
		+	Mechanically cut bands ....June 9
TTL	-		2,4-D Amine @ 0.07 kg/ha a.i. ....May 12
		+	2,4-D Amine @ 0.07 kg/ha a.i. ....May 31
		+	Mechanically cut bands ....June 9
BTTH	Banded	+	2,4-D Amine @ 0.14 kg/ha a.i. ....May 12
		+	2,4-D Amine @ 0.14 kg/ha a.i. ....May 31
		+	Mechanically cut bands ....June 9
BTTL	Banded	+	2,4-D Amine @ 0.07 kg/ha a.i. ....May 12
		+	2,4-D Amine @ 0.07 kg/ha a.i. ....May 31
		+	Mechanically cut bands ....June 9
K	-		Atrazine @ 1.12 kg.ha a.i. + Crop oil @ 2,35 L.ha + 2,4-D Ester @ 1.12 kg/ha a.i. ....May 12

<u>Designations:</u> **K**= Killed: **B**=Killed Bands; **M**=Mown; **T**=2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression. All chemicals applied in 280 L water/ha @ 172 kPa. **$**=The formulation described under K was applied as a 15 cm wide band when corn was planted.

Rep 1			Rep 2			Rep 3			Rep 4		
BPT	BTTL	BMCT	B	TTL	BPT	TTL	GH	BGH	BMCM	BTTL	B
BTTH	BMM	B	P	K	BMCT	OO	BTTL	BPT	BGL	BTTH	BTTL
BGL	BTTH	OO	GH	BMC	BMCM	BMM	TTH	BGL	BGH	GH	BTTH
GH	BMC	K	BGL	BGH	BTTL	BTTH	BMCM	BMCT	OO	BMCT	BMC
P	BMCM	BGH	BTTL	BTTH	BMM	BMC	BTTL	P	BPT	TTL	BMM
TTL	TTH	BTTL	TTH	BTTH	OO	B	K	BTTH	P	K	TTH

10 ft.
15 ft.

OO—No Suppression   B —Banded   G —Glyphosate   M —Mown   H —High Rate
K —Legume Killed   P —Paraquat   T —2,4—D amine   C —Clippings Removed   L —Low Rate

FIGURE 3. 1984 CLOVER INTERCROP: PLOT DIAGRAM.

TABLE 6. 1984 CROWNVETCH INTERCROP TREATMENT SCHEDULE

KEY			TREATMENT SCHEDULE
OO			
B	Banded[$]		
M	-		Mown to 5cm, Clippings Removed ....June 1
BM	Banded	+	Mown to 5cm, Clippings Removed ....June 1
TH	-		2,4-D Amine @ 0.28 kg/ha a.i. ....May 31
TL	-		2,4-D Amine @ 0.14 kg/ha a.i. ....May 31
BTH	Banded	+	2,4-D Amine @ 0.28 kg/ha a.i. ....May 31
BTL	Banded	+	2,4-D Amine @ 0.14 kg/ha a.i. ....May 31
CK	-		Mown to 2.5cm, Clippings Removed .....June 14
		+	Atrazine @ 1.68 kg/ha a.i. ....June 14

Designations: **CK**=Clipped & Killed; **B**=Banded; **M**=Mown; **T**=2,4-D; **H**=High Rate; **L**=Low Rate; **OO**=No Suppression. All chemicals applied in 280 L water/ha @ 172 kPa pressure.
$=Atrazine @ 1.12 kg/ha a.i. + Crop Oil @ 2.35 L/ha + 2,4-D ester @ 1.12 kg/ha a.i. was applied as a 15 cm wide band when corn was planted.

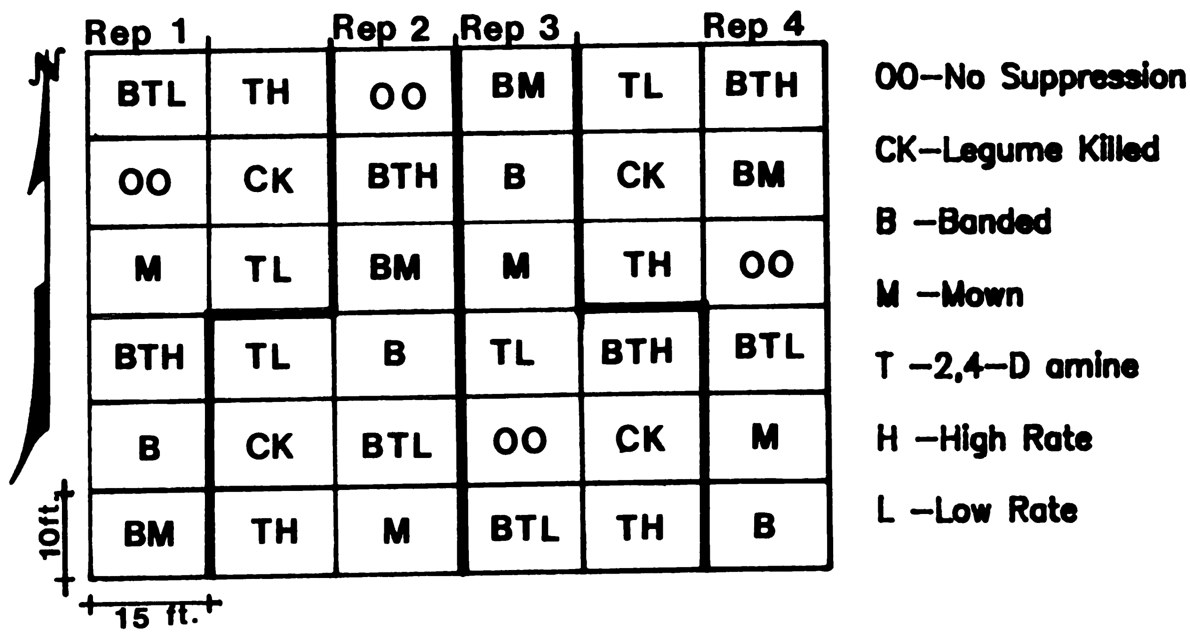


FIGURE 4. 1984 CROWNVETCH AND TREFOIL INTERCROPS; PLOT DIAGRAM.

applied. Plots received no further manipulation until silage harvest on November 9. Vetch and corn were assessed as described in section C2a.

(C2e).....1984 BIRDSFOOT TREFOIL INTERCROP

The trefoil suppression experiment was set up as a randomised complete block design (RCBD) with nine treatments and four replicates. Treatment details and herbicide rates are listed in Table 7. The experimental design was the same as the 1984 crownvetch intercrop, and is shown in Figure 4. Two rates of 2,4-D amine, Banding and mowing were the only suppressants considered.

Banding and corn planting were carried out on May 11, when the trefoil was relatively dormant. Mowing and herbicide application were therefore postponed, and eventually carried out three weeks later (June 1), when trefoil had increased to a problem level. Trefoil in the killed treatment plots (CK) was not treated until June 14, at which stage it was dense and twining. To clear the CK plots the vetch was clipped by hand to less than 2.5 cm tall, and atrazine was applied. As killed bands were being overgrown, a second banding of 2,4-D ester was applied on June 12 using a hand held, single nozzle, CO_2 sprayer, delivering 2,4-D ester at 1.12 kg/ha a.i. No effort was made to avoid hitting corn seedlings with the spray. The plots received no further manipulation until silage harvest on November 9. Trefoil and corn were assessed as described in section C2a.

TABLE 7. 1984 TREFOIL INTERCROP TREATMENT SCHEDULE

KEY		TREATRMENT DISCRIPTION
OO		
B	Banded$^{\$}$+	Bands reestablished with 2,4-D ester ...June 12
M	-	Mown to 5cm, Clippings removed ....June 1
BM	Banded +	Mown to 5cm, Clippings removed ....June 1
	+	Bands reestablished with 2,4-D ester ...June 12
TH	-	2,4-D amine @ 0.14 kg/ha a.i. ....May 31
TL	-	2,4-D amine @ 0.07 kg/ha a.i. ....May 31
BTH	Banded +	2,4-D amine @ 0.14 kg.ha a.i. ....May 31
	+	Bands reestablished with 2,4-D ester ...June 12
BTL	Banded +	2,4-D amine @ 0.07 kg/ha a.i. ....May 31
		Bands reestablished with 2,4-D ester ...June 12
CK	-	Mown to 2.5cm, Clippings Removed ....June 14
	+	Atrazine @ 1.68 kg/ha a.i. ....June 14

Designations: **CK**=Clipped & Killed; **B**=Banded; **M**=Mown; **T**=2,4-D; **H**=High Rate; **L**=Low Rate; **OO**=No Suppression. All chemicals applied in 280 L water/ha @ 172 kPa pressure.

$=Atrazine @ 1.12 kg/ha a.i. + Crop Oil @ 2.35 L/ha + 2,4-D ester @ 1.12 kg/ha a.i. was applied as a 15 cm wide band when corn was planted.

C3. 1985 INTERCROPS

(C3a).....1985 GENERAL

Legume Establishment: The Thor alfalfa stand used for the 1985 intercrop and herbicide tolerance experiments, was planted in the spring of 1984, using a John Deere small grain drill with 17.8 cm spacings. Seeding rate was 13.5 kg/ha. Fertilizer was banded at planting (224 kg/ha 8:40:10 + 2% Zinc). A split application of Fusilade 2000 (Fluazifop-butyl) was made for grass control on September 18 and October 18 (0.07 kg/ha a.i. in 280 L water/ha on both occasions). Penngift crownvetch and Empire birdsfoot trefoil stands had been established in spring 1983 (see Section C2a).

Corn Planting: Corn (GLH 5922) was planted into the living legumes using a Buffalo All-Flex Till Planter, Model 4500-AA, set to deliver 66,000 seeds per hectare. Vetch and Trefoil plots were 4.6 m x 3.0 m (15 x 10 feet) with four 76 cm (30 inch) rows per plot. Alfalfa plots were 4.6 m x 7.3 m (15 x 24 feet), with six 76 cm (30 inch) rows per plot. Difonate 20G at 5.6 kg/ha (5 lb/ac) was surface applied at planting. No fertilizer was applied in 1985.

Treatments: Various legume suppressing treatments were applied, the number and type of treatments varying for each experiment. Treatment dates are summarised in Table 8. The suppressants assessed and the symbols used in tables and throughout the text were:

TABLE 8. 1985 INTERCROPS: TREATMENT DATES

	LEGUME COVER CROP		
TREATMENT	ALFALFA	VETCH	TREFOIL
MOWED ALL PLOTS	Apr 29	May 2	-
PLANTED CORN AND BANDED HERBICIDE	May 7	May 7	May 7
APPLIED INITIAL HERBICIDE TREATMENTS	May 13	May 10	May 10
MOWING TREATMENTS	May 13	May 13	May 13
RESEEDED CORN	May 30	-	May 30
APPLIED SECONDARY SUPPRESSANT	-	-	June 1 (2,4-D)
APPLIED RESIDUAL HERBICIDE	June 1	June 1	June 1
	(Alachlor + Simazine)		
APPLIED INSECTICIDE	June 3 (Lorsban 4E)	-	-
APPLIED HERBICIDE FOR BROADLEAF WEEDS	June 14 (2,4-DB)	-	-
APPLIED N FERTILIZER	June 14	June 14	June 14
	(Ne Treatments only)		
APPLIED N FERTILIZER	July 23	July 23	July 23
	(All other N designations)		
HARVESTED CORN-Ears	Spt 28-Oct 1	Spt 27	Spt 27
-Stalks	Oct 1	Spt 28	Spt 28

M Mowing

G Broadcast Glyphosate

P Broadcast Paraquat

T Secondary application of broadcast 2,4-D amine

In addition to these suppressants, two other treatments were compared:

OO No legume suppression.

K Complete legume kill (100% of ground surface).

Nitrogen as ammonium nitrate (122 kg N/ha) was applied on two dates in the alfalfa and vetch intercrops and on one date in the trefoil intercrops:

Ne Nitrogen side dressed on June 14 (all three intercrops).

N Nitrogen side dressed on July 23 (alfalfa and vetch only).

Except for the killed plots (K), all treatments were banded (**B**). In 1985 bands were 25 cm wide and the banding formulation contained only 2,4-D ester (2.24 kg/ha a.i.). Both the banded herbicide and broadcast herbicides were applied using the same equipment as in 1984. This was also the case for the mowing treatments. Where the legume was mown prior to planting corn, farm equipment was used to cut, rake and remove the residue. For weed control in the three legumes a formulation of Lasso (alachlor at 1.12 kg/ha a.i.) + Simax 4L (simazine at 2.24 kg/ha a.i.) was broadcast applied on June 1 using a tractor mounted boom.

Measuring Nitrogen Fixation: The acetylene reduction technique used in 1984 was only slightly altered in 1985. Incubation time was increased from 2.5 hours to 17 hours (overnight). Subsamples drawn into syringes were analysed within two days of sampling. The sampling dates and treatments sampled are listed in Tables 30, 34 and 38. On August 8, samples were taken from the crownvetch plots at a depth of 10-17.5 cm as well as from 0-7.5 cm. The deeper samples came from immediately below surface samples in the same treatments.

Legume and Corn Assessment: Various measures of vigor and yield were made throughout the growing season. Corn populations were assessed as plants per 40 feet (12.19 m) of row on September 16 or 27. Corn height, to the top of tassels, was assessed on the same dates by measuring ten plants per plot. Corn harvest was carried out between September 28 and October 1. Corn yield was determined by hand harvesting ten plants from each plot in late September. The ears were removed, weighed, subsampled by removing a 2.54 cm section from each ear, and oven dried at 13°C. Following ear removal, the ten stalks were cut by hand, shredded, weighed, subsampled and oven dried at 13°C. Both oven dried samples were ground to pass a 60 mesh sieve prior to Kjeldahl analysis for nitrogen. Ground cover in the alfalfa intercrop was assessed on April 9 by clipping quadrats (20 x 30 inch), and deviding the material into weeds and alfalfa prior to oven drying. The same procedure was followed on October 3, 7 and 12 in all plots of the alfalfa, vetch and trefoil intercrops respectively. A visual assessment of ground cover and weed population was made on the same days. On October 3 the number of alfalfa crowns per 20 feet of inter-row (50 square feet) were counted.

(C3b).....1985 ALFALFA INTERCROP

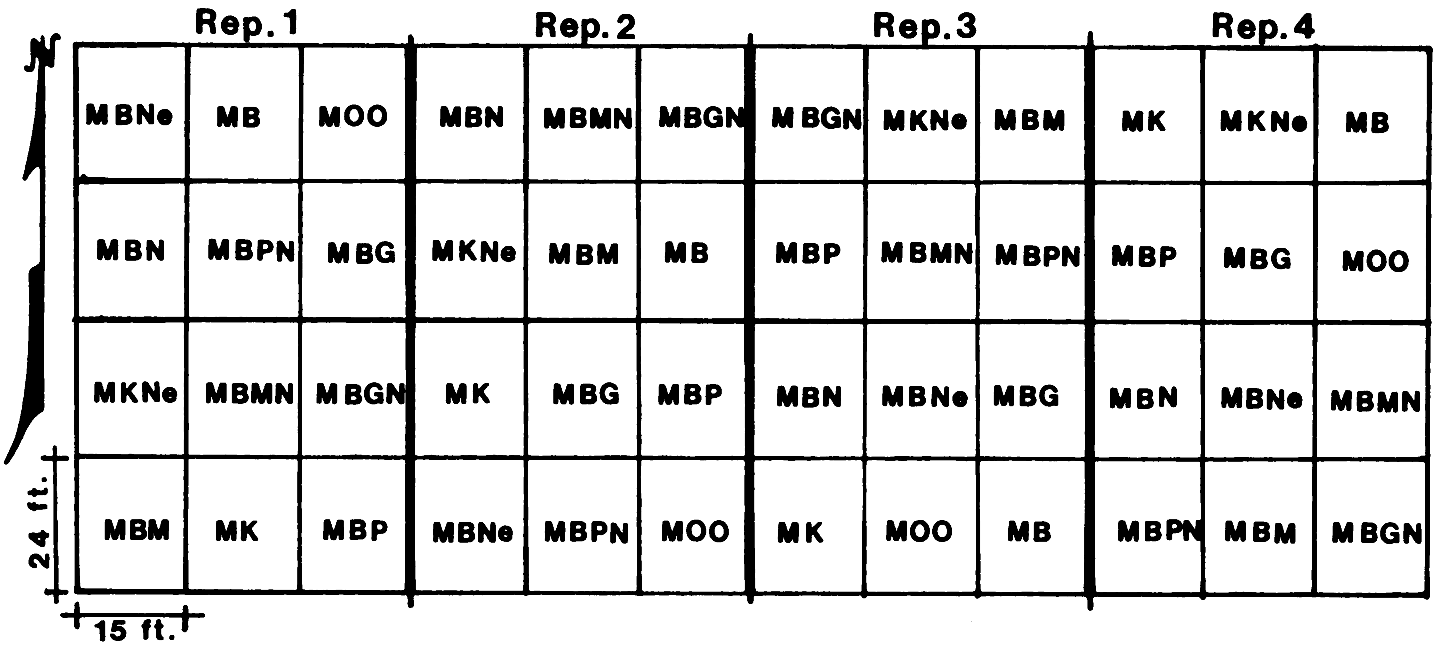
In 1985 a randomized complete block design (RCBD) with twelve treatments and four replicates was used for the alfalfa intercrop experiment. Treatment details and herbicide rates are listed in Table 9, and the experimental design is shown in Figure 5.

In order to reduce the amount of ground cover, all plots were mown to 5 cm on April 29, when alfalfa was 25 cm tall (all treatment designators for this experiment therefore include an initial M). Corn was planted on May 7 and, despite poor alfalfa regrowth, it was decided to apply the initial herbicide and mowing treatments on May 13 (sunny and 23^{o}C). Quackgrass and dandelions were growing vigorously on this date, but alfalfa was a maximum of 7 cm tall. To combat the developing weed problem alachlor (1.12 kg/ha a.i.) plus simazine (2.24 kg/ha a.i.) was broadcast applied on June 1. Broadleaf weeds still remained a problem and 2,4-DB (1.12 kg/ha a.i.) was broadcast applied on June 14. Meanwhile it was realized that one reason for the tardy regrowth was a heavy infestation of alfalfa weavil (Hypera postica). Lorsban 4E (chlorpyrifos) was applied on June 14 at 1.12 kg/ha a.i. to combat this insect problem. Nitrogen was applied to a banded (MBNe) and to a killed treatment (MKNe) in June, and to four other treatments in July (MBN, MBMN, MBGN and MBPN). Corn emergence was poor, consequently additional seed was hand planted to fill the gaps on May 30. A shorter season hybrid (Great Lakes Hybrid 2331) was used. Alfalfa and corn were assessed as described in section C3a.

TABLE 9. 1985 ALFALFA INTERCROP TREATMENT SCHEDULE

KEY	TREATMENT DISCRIPTION
MOO	Mown#
MB	Mown + Banded$
MBNe	Mown + Banded + Nitrogen side dressed (112 kg/ha)......June 14
MBN	Mown + Banded + Nitrogen side dressed (112 kg/ha)......July 23
MBM	Mown + Banded + Mown to 5cm............................May 13
MBMN	Mown + Banded + Mown to 5cm............................May 13
	+ Nitrogen side dressed (112 kg/ha)......July 23
MBG	Mown + Banded + Glyphosate @ 0.84 kg/ha a.i. ....May 13
MBGN	Mown + Banded + Glyphosate @ 0.84 kg/ha a.i. .... May 13
	+ Nitrogen side dressed (112 kg/ha)......July 23
MBP	Mown + Banded + Paraquat @ 0.56 kg/ha a.i. + 1/4% X77...May 13
MBPN	Mown + Banded + Paraquat @ 0.56 kg/ha a.i. + 1/4% X77. .May 13
	+ Nitrogen side dressed (112 kg/ha)......July 23
MK	Mown + Glyphosate @ 1.12 kg/ha a.i.
	+ 2,4-D ester @ 2.24 kg/ha a.i. .... May 13
MKNe	Mown + Glyphosate @ 1.12 kg/ha a.i.
	+ 2,4-D ester @ 2.24 kg/ha a.i. ....May 13
	+ Nitrogen side dressed (112 kg/ha)......June 14

= All plots were mown on April 29
$ = 2,4-D ester at 2.24 kg/ha a.i. applied as a 25cm wide band.
Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression. All treatment were broadcast sprayed with Simazine (2.24 kg/ha a.i.) + Alachlor (1.12 kg/ha a.i) on June 1, and with 2,4-DB (1.12 kg/ha a.i.) on June 14. All chemicals were applied in 280 L water/ha @ 172 kPa.



OO—Unsuppressed B —Banded G —Glyphosate N —Nitrogen (July)
K —Legume Killed P —Paraquat M —Mown Ne —Nitrogen (June)

FIGURE 5. 1985 ALFALFA INTERCROP: PLOT DIAGRAM.

(C3c).....1985 CROWNVETCH INTERCROP

in 1985 a randomized complete block design (RCBD) with twelve treatments and three replicates was used for the crownvetch intercrop experiment. Treatment details and herbicide rates are listed in Table 10, and the experimental design is shown in Figure 6.

In an attempt to control quackgrass, dandelions, and red clover all plots were mown to 5 cm on May 2, when the sparse vetch plants were a maximum of 7 cm tall (all treatment designators for this experiment therefore include an initial M). Corn was planted on May 7, and despite negligible vetch growth, the initial herbicide suppressants were applied on May 10 (sunny, 23^{o}C). The mowing treatments were carried out on May 13. To combat the weed problem alachlor (1.12 kg/ha a.i.) plus simazine (2.24 kg/ha a.i.) were broadcast applied on June 1. Nitrogen was applied to a banded (MBNe) and to a killed treatment (MKNe) in June, and to four other treatments in July (MBN, MBMN, MBGN and MBPN). Corn emergence was poor and replanting was considered. It was not carried out as the vetch appeared to be a failure. Vetch and corn were assessed as described in section C3a.

(C3d).....1985 BIRDSFOOT TREFOIL INTERCROP

In 1985 a randomized complete block design (RCBD) with twelve treatments and three replicates was used for the trefoil intercrop experiment. Treatment details and herbicide rates are listed in Table 11, and the experimental design is shown in Figure 6. The trefoil stand was not mown prior to planting corn on May 7, at which stage it

TABLE 10. 1985 CROWNVETCH INTERCROP TREATMENT SCHEDULE

KEY	TREATMENT DISCRIPTION
MOO	Mown[#]
MB	Mown + Banded[$]
MBNe	Mown + Banded + Nitrogen side dressed (112 kg/ha)......June 14
MBN	Mown + Banded + Nitrogen side dressed (112 kg/ha)......July 23
MBM	Mown + Banded + Mown to 5cm............................May 13
MBMN	Mown + Banded + Mown to 5cm............................May 13 + Nitrogen side dressed (112 kg/ha)......July 23
MBG	Mown + Banded + Glyphosate @ 0.84 kg/ha a.i. ....May 10
MBGN	Mown + Banded + Glyphosate @ 0.84 kg/ha a.i. .... May 10 + Nitrogen side dressed (112 kg/ha)......July 23
MBP	Mown + Banded + Paraquat @ 0.56 kg/ha a.i. + 1/4% X77...May 10
MBPN	Mown + Banded + Paraquat @ 0.56 kg/ha a.i. + 1/4% X77. .May 10 + Nitrogen side dressed (112 kg/ha)......July 23
MK	Mown + Glyphosate @ 1.12 kg/ha a.i. + 2,4-D ester @ 2.24 kg/ha a.i. .... May 10
MKNe	Mown + Glyphosate @ 1.12 kg/ha a.i. + 2,4-D ester @ 2.24 kg/ha a.i. .... .May 10 + Nitrogen side dressed (112 kg/ha)......June 14

= All plots were mown on May 2
$ = 2,4-D ester at 2.24 kg/ha a.i. applied as a 25cm wide band.
Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression. All treatment were broadcast sprayed with Simazine (2.24 kg/ha a.i.) + Alachlor (1.12 kg/ha a.i) on June 1, and with 2,4-DB (1.12 kg/ha a.i.) on June 14 All chemicals were applied in 280 L water/ha @ 172 kPa.

VETCH

Rep.						
Rep.1	MBN	MBMN	MBG	MOO	MBP	MB
	MBGN	MBM	MK	MBNe	MBPN	MKNe
Rep.2	MBM	MBNe	MBMN	MKNe	MK	MOO
	MB	MBPN	MBP	MBN	MBGN	MBG
Rep.3	MBNe	MKNe	MBN	MK	MBG	MBMN
	MOO	MBPN	MBP	MBM	MB	MBGN

N; plot size: 10 ft × 15 ft.

TREFOIL

Rep.						
Rep.1	BT	BMTN	BGN	OO	BPN	BN
	BGTN	BMN	K	BTNe	BPTN	KNe
Rep.2	BMN	BTNe	BMTN	KNe	K	OO
	BN	BPTN	BPT	BT	BGTN	BGN
Rep.3	BTNe	KNe	BT	K	BGN	BMTN
	OO	BPTN	BPN	BMN	BN	BGTN

OO—Unsuppressed
K —Legume Killed
B —Banded
P —Paraquat
G —Glyphosate
M —Mown
N —Nitrogen (July)
Ne —Nitrogen (June)
T —2,4—D amine

FIGURE 6. 1985 CROWNVETCH AND TREFOIL INTERCROPS: PLOT DIAGRAMS.

TABLE 11. 1985 BIRDSFOOT TREFOIL INTERCROP TREATMENT SCHEDULE

KEY	TREATMENT DISCRIPTION	
OO	-	
BT	Banded$ + 2,4-D amine @ 0.17 kg/ha a.i.	June 1
BN	Banded + Nitrogen side dressed (112 kg/ha)..............	July 23
BTNe	Banded + 2,4-D amine @ 0.17 kg/ha a.i.	June 1
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
BMN	Banded + Mown to 5cm....................................	May 13
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
BMTN	Banded + Mown to 5cm....................................	May 13
	+ 2,4-D amine @ 0.17 kg/ha a.i.	June 1
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
BGN	Banded + Glyphosate @ 0.42 kg/ha a.i.	May 10
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
BGTN	Banded + Glyphosate @ 0.42 kg/ha a.i.	May 10
	+ 2,4-D amine @ 0.17 kg/ha a.i.	June 1
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
BPN	Banded + Paraquat @ 0.28 kg/ha a.i. + 1/4% X77...........	May 10
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
BPTN	Banded + Paraquat @ 0.28 kg/ha a.i. + 1/4% X77...........	May 10
	+ 2,4-D amine @ 0.17 kg/ha a.i.	June 1
	+ Nitrogen side dressed (112 kg/ha)..............	July 23
K	+ Glyphosate @ 1.12 kg/ha a.i.	
	+ 2,4-D ester @ 2.24 kg/ha a.i.	May 10
KNe	+ Glyphosate @ 1.12 kg/ha a.i.	
	+ 2,4-D ester @ 2.24 kg/ha a.i.	May 10
	+ Nitrogen side dressed (112 kg/ha)..............	June 14

$ = 2,4-D ester at 2.24 kg/ha a.i. applied as a 25cm wide band.
Designations: K=Killed; B=Killed band; M=Mown; G=Glyphosate; P=Paraquat; T=2,4-D amine; Ne=Nitrogen fertilizer applied in June: N Nitrogen fertilizer applied in July; OO=No Suppression. All treatment were broadcast sprayed with Simazine (2.24 kg/ha a.i.) + Alachlor (1.12 kg/ha a.i) on June 1, and with 2,4-DB (1.12 kg/ha a.i.) on June 14
All chemicals were applied in 280 L water/ha @ 172 kPa.

was actively growing and a maximum of 12 cm tall. The lush green growth was considered ideal for suppressing with systemic herbicides, yet was not tall enough to collapse onto the corn rows. Initial herbicide treatments were applied on May 10 (sunny, 23^{o}C), three days after planting, and mowing treatments on May 13. Very few weeds were present throughout the experiment but alachlor (1.12 kg/ha a.i.) plus simazine (2.24 kg/ha a.i.) were applied for weed control on June 1. Also on June 1, 2,4-D amine (T) was applied as a secondary suppressant. Nitrogen was applied to a banded (BTNe) and to a killed treatment (KNe) in June, and to all other treatments except the unsuppressed (OO), killed (K) and a banded (BT) treatment in July. Corn emergence was poor, and additional seed was hand planted on May 30. A shorter season hybrid (Great Lakes Hybrid 2331) was used. Trefoil and corn were assessed as described in section C3a.

C4 ALFALFA HERBICIDE TOLERANCE EXPERIMENT

In order to observe a wider range of herbicides and rates than used in the various intercrops, a herbicide tolerance experiment was set up adjacent to the 1985 corn/alfalfa intercrop, on similar alfalfa.

Prior to herbicide application in 1985 the experimental area was mown (June 1) and Lorsban 4E (Chlorpyrifos) was applied for alfalfa weavil control (June 3, 1.12 kg/ha a.i.). Plots were 1.8 m square (6 feet), with a 1.2 m border (4 feet) on each side. A randomized complete block design (RCBD) was used with twenty treatments and four replicates. Treatment details and herbicide rates are listed in Table 12, and the experimental design is shown in Figure 7.

Various chemicals were applied between 1pm and 5pm on June 20, using a hand held carbon dioxide sprayer equipped with flat fan nozzles. The air temperature was approximately 22°C and the sky was clear with an occasional cloud. The products used, and symbols used in the text are:

G Glyphosate (Roundup)

P Paraquat (Orthoparaquat Plus)

T 2,4-D amine (Weedstroy AM 40)

A Atrazine (Atrazine 4L)

L Alachlor (Lasso)

S Simazine (Simax 4L)

C Crop Oil

1,2,3,4,6 Rate of application

TABLE 12. HERBICIDE TOLERANCE STUDY: TREATMENT SCHEDULE

KEY	TREATMENT DISCRIPTION		
OO			
G3	Glyphosate @ 1.26 kg/ha a.i.		
G2	Glyphosate @ 0.84 kg/ha a.i.		
G1	Glyphosate @ 0.42 kg/ha a.i.		
P3	Paraquat @ 0.84 kg/ha a.i.		
P2	Paraquat @ 0.56 kg/ha a.i.		
P1	Paraquat @ 0.28 kg/ha a.i.		
T6	2,4-D amine @ 0.84 kg/ha a.i.		
T4	2,4-D amine @ 0.56 kg/ha a.i.		
T2	2,4-D amine @ 0.28 kg/ha a.i.		
T1	2,4-D amine @ 0.14 kg/ha a.i.		
A3	Atrazine @ 3.36 kg/ha a.i.		
A2	Atrazine @ 2.24 kg/ha a.i.		
A1	Atrazine @ 1.12 kg/ha a.i.		
A1G1	Atrazine @ 1.12 kg/ha a.i.	+	Glyphosate @ 0.42 kg/ha a.i.
A1P1	Atrazine @ 1.12 kg/ha a.i.	+	Paraquat @ 0.28 kg/ha a.i.
A1T2	Atrazine @ 1.12 kg/ha a.i.	+	2,4-D amine @ 0.28 kg/ha a.i.
A2C	Atrazine @ 2.24 kg/ha a.i.	+	Crop Oil @ 1.17 L/ha.
A1L	Atrazine @ 1.12 kg/ha a.i.	+	Alachlor @ 2.24 kg/ha a.i.
SL	Simazine @ 1.12 kg/ha a.i.	+	Alachlor @ 2.24 kg/ha a.i.

Designations: **OO**= No suppression; **G**=Glyphosate; **P**=Paraquat; **T**=2,4-D amine; **A**=Atrazine; **L**=Alachlor; **S**=Simazine. Numbers following letter designators indicate the rate applied, as a multiple of the lowest rate.
All chemicals were applied on June 20th in 280 L/ha at 180 kPa., when the air temperature was 22° C.

P1	T4	A2	G2	T1	A1	T6	SL	A3	A1P1	Rep 4
A1L	A1G1	P3	T2	OO	A2C	A1T2	G3	G	P2	
A3	G3	G2	A1P	T1	A1T2	P3	T4	A2	OO	Rep 3
SL	G1	P2	A2C	A1G	T2	A1	A L	P1	T6	
A G	T4	A1T	A2	G3	G	T2	A L	OO	A3	Rep 2
G2	SL	T6	P3	A2C	T1	P1	A1P1	P2	A1	
G1	A1P1	A3	SL	G3	OO	A2C	P2	T6	T4	Rep 1
T1	A1L	A1G1	G2	P3	P1	A1T2	T2	A1	A2	

OO:No Suppression

G :Glyphosate

P :Paraquat

T :2,4--D amine

A :Atrazine

L :Alachlor

S :Simazine

1--6 :Rate Multiple

FIGURE 7. ALFALFA HERBICIDE TOLERANCE EXPERIMENT: PLOT DIAGRAM.

All chemicals were applied in 280 L water/ha at a pressure of 172 kPa. Various rates were used as listed in Table 38. When numbers follow letter designators they refer to the rate applied, expressed as a multiple of the lowest rate used. The borders between plots were mown on July 1 and August 8, and used to obtain soil cores for acetylene reduction assays.

Herbicide damage was qualitatively assessed on several dates. Alfalfa height, ground cover, weed fraction and flowering fraction were assessed quantitatively on August 1. Surface-soil cores were removed on several occasions for determination of acetylene reduction activity. These were analysed as described in section C3a.

To determine at what depths nitrogen fixation was taking place, a soil monolith, 55 cm long, 33 cm wide and 60 cm deep, was removed from the alfalfa field on August 8. The soil was washed away, and the remaining roots and attached nodules were cut into six depth increments. The roots and nodules from each 10 cm increment were placed in an incubation jar for five hours and analyzed for acetylene reduction activity using the method previously described.

A more systematic approach was taken on August 27 when monoliths were removed using a tractor mounted sampling apparatus. One monolith was taken from each replicate of the 00, P3, and A3 treatments, and from four randomly selected locations in the mown alleys. The monoliths, which were 18 inches deep, 9 inches wide and 3 inches thick were divided into 18 three inch soil cubes. One cube from each depth was discarded. The remaining 12 cubes were placed in separate, one quart (0.95 L) incubation jars and sealed prior to temporary storage in the shade. When an entire replicate had been sampled (approximately every hour), 25 ml of air was removed from the each jar and replaced by 25 ml of acetylene at atmospheric pressure. The jars were incubated over night (21 hours) prior to two gas samples being drawn. These were stored in a cool room prior to analysis for ethylene concentration over the following two days.

RESULTS AND DISCUSSIONS

D1. 1984 INTERCROPS

The 1984 intercrops were assessed as summarized in Table 13 and expanded on in (C2a), the 1984 General Methods section.

(D1a).....1984 ALFALFA INTERCROP

ALFALFA: Alfalfa was actively growing and approximately 30 cm tall when corn was planted and initial treatments were applied. An average of 170 g/m^2 of oven dried plant material was removed from mown plots at this time.

On May 18, one week after treatments were applied, there had been little regrowth in the mown plots. Paraquat treated alfalfa was completely burnt off, although some stems remained upright. By contrast, neither glyphosate rate had visibly suppressed the alfalfa, although some alfalfa plants were slightly chlorotic. This poor control was due in part to adverse weather conditions; cool temperatures and rain having followed the application of herbicide. As with glyphosate, 2,4-D amine had not visibly suppressed alfalfa. The glyphosate and 2,4-D amine treatments were reapplied on May 31.

TABLE 13. 1984 INTERCROPS: DATES OF ASSESSMENT

	LEGUME COVER CROP			
ASSESSMENT	ALFALFA	CLOVER	VETCH	TREFOIL
COVER-Height	May 11	May 11	May 11	May 11
-Mass	May 11	May 11	June 1	June 1
CORN POPULATION	June 21	-	-	-
ACETYLENE REDUCTION AND SOIL MOISTURE	June 21 July 5	June 25 -	June 25 July 5	June 26 July 13
CORN LEAF N%	July 11	July 11	July 11	July 11
ACETYLENE REDUCTION AND SOIL MOISTURE	July 26	July 25	July 25	July 26
CORN HEIGHT	Aug 7	Aug 7	-	-
VISUAL COVER	Aug 7	Aug 7	-	-
EARLEAF	Aug 17	Aug 17	Aug 27	Aug 27
ACETYLENE REDUCTION AND SOIL MOISTURE	Sept 19	Sept 19	Sept 19	Sept 19
CORN POPULATION	Oct 4	Oct 4	Oct 4	Oct 4
CORN SILAGE HARVEST	Nov 3	Nov 9	Nov 9	Nov 9
VISUAL COVER	Apr22 1985	Apr22 1985	Apr22 1985	Apr22 1985
HARVESTED COVER	Apr30 1985	Apr22 1985	Apr22 1985	Apr21 1985

Alfalfa in plots which received killing rates of 2,4-D ester, had collapsed, forming a dense mat over the ground surface, which in some locations extended to the seed slot. The banding formulation had resulted in minor alfalfa deformation, but unsuppressed plants were rapidly closing over gaps created by the corn planter. This can be partially attributed to the spray nozzle location behind the planting shoes. The shoes temporarily pushed aside the tall alfalfa plants, and much of the spray was lost to the soil surface, rendering the foliar absorbed 2,4-D ester impotent.

By June 8 corn seedlings in mown, paraquat and killed plots were up to 15 cm tall. Mown alfalfa had regrown to 25 cm and was taller than the corn, but bands were still evident. Consequently secondary mowing and 2,4-D treatments were applied. Paraquat treated alfalfa had regrown to 12 cm, but did not require secondary suppression until three weeks later. Alfalfa sprayed with the high rate of glyphosate was necrotic on June 8, and the low rate had produced chlorosis and wilting. Both rates eventually resulted in the death of most alfalfa plants and any corn seedlings contacted. No difference was discernible between the two 2,4-D amine rates, both having slightly restricted alfalfa growth but not enough to prevent the canopy closing over corn seedlings (note that glyphosate and 2,4-D were reapplied). Mechanical rebanding of 2,4-D treated plots temporarily alleviated this problem.

One month after planting, it was apparent that the glyphosate and 2,4-D plots were failures as far as alfalfa supression and corn stands were concerned. By contrast, in the killed alfalfa plots (K), corn populations were relatively high and plants strong. Despite the intended lethal herbicide rates (K), some alfalfa plants had survived.

The ground surface covered by living plant material and the contribution of weeds was assessed on August 7 (Table 14). Only the killed treatment (K) resulted in a reduction in cover relative to the 100% cover in unsuppressed plots (00). In addition, while only 10% of the unsuppressed cover (00) was weeds, 60% of the cover in killed plots (K) was. Of the suppression treatments, mowing resulted in the lowest weed percentages (20-30%), and glyphosate the highest (60-80%). Subtracting weeds from ground cover indicates that only 20-40% of the ground surface was covered by alfalfa in the glyphosate plots. Mown plots had 60-80% of their surfaces covered by alfalfa.

Another visual assessment was made of regrowth on April 22 in the year after suppression (Table 14). At this stage two of the glyphosate treatments (BGGH and GGH), had low cover values (40 and 60%). The same two treatments had less than 30% of their sufaces covered by alfalfa. Plots treated with the high rate of 2,4-D amine (TTH and BTTH) also had low alfalfa cover ratings (less than 35%). Mown plots still had high cover rankings and low weed percentages. The application of 2,4-D amine as a secondary suppressant was associated with a slight reduction in alfalfa survival.

Quadrats harvested on 30 April 1985 indicated that the single mowing (BMC) had not greatly reduced alfalfa regrowth, but mowing plus 2,4-D amine had (Table 14). Paraquat plus 2,4-D amine (BPT), and the treatment intended as lethal (K), had also reduced alfalfa regrowth. Very little difference was observed in weed regrowth.

Very little can be concluded from the acetylene reduction measurements in the alfalfa intercrop. In the surface layer sampled,

TABLE 14. 1984 ALFALFA INTERCROP: GROUND COVER ASSESSMENTS

TR'T	VISUAL ASSESSMENT $$ 7 AUG. 1984 COVER	WEEDS	22 MAY 1985 COVER	WEEDS	HARVEST ASSESSMENT$ 30 MAY 1985 ALFALFA	WEEDS	WEED FRACTION
	.... PERCENTAGES		....		...g/m²....		%
OO	100 a	10 e	90 ab	20 b	190 a	50	21
B	100 a	10 e	100 a	20 b	-	-	-
BMC	90 a	20 de	90 ab	30 ab	170 a	60	26
BMCM	100 a	20 cde	80 ab	20 b	-	-	-
BMM	90 a	30 cde	100 a	50 ab	-	-	-
BMCT	100 a	30 cde	70 abc	30 ab	60 b	60	50
GGH	100 a	80 a	60 bc	60 a	-	-	-
BGGH	100 a	80 a	40 c	30 ab	-	-	-
BGGL	100 a	60 ab	80 ab	50 ab	-	-	-
P	100 a	30 cde	100 a	50 ab	-	-	-
BPT	90 a	40 bcd	100 a	60 a	80 b	80	50
TTH	90 a	50 bc	60 bc	60 a	-	-	-
TTL	100 a	40 bcd	100 a	60 a	-	-	-
BTTH	90 a	50 bc	70 abc	50 ab	-	-	-
BTTL	100 a	30 cde	90 ab	50 ab	-	-	-
K	60 b	60 ab	70 abc	60 a	40 b	50	56
Sig.Level	1%	1%	1%	1%	1%	ns	ns
5% LSD	13	18	25	27	41	-	-
1% LSD	18	24	33	37	58	-	-

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same lower case postscript or without postscripts are not significantly different at the level indicated
$$=Percentage of the ground surface covered and the percentage of this that was weeds, as visually assessed on two dates.
$=Oven dry weight of alfalfa and weeds cut from quadrats

measured ethylene production was low and extremely variable. Statistical analysis is therefore precluded. Table 15 presents the mean and median values for each treatment sampled on each date, along with the range and coefficient of variation. If the ranges are considered, a general decrease in activity as the season progressed can be inferred. Comparisons between dates are not strictly valid, as sample and incubation conditions varied. Of the treatments sampled, the twice mown treatment (BMCM) and the unsuppressed alfalfa (00) had the highest overall activity.

The moisture contents of the surface soil cores is also given in Table 15 (for weather and irrigation data see Table 1 in Methods). Of the treatments sampled on June 21 and July 5 those with the least cover had the wettest surface soil (K and BGGL). On both these days the unsuppressed alfalfa plots had the lowest soil moistures. Both sampling dates were preceded by a week of dry weather, during which depletion of the soil water reserves appears related to the extent of ground cover. By July 26, no soil moisture differences existed between treatments as rainfall had preceded sampling. The situation had reversed on September 19, the unsuppressed treatment (00) being the wettest and the killed treatment (K) by far the driest. At this stage the low soil moisture level in killed plots can be related to depletion by the vigorous corn plants.

CORN: Corn populations in the 1984 alfalfa intercrop were measured on two dates (Table 16). In the untreated (00) and banded-only (B) treatments, corn seedlings could not emerge through the dense legume canopy. The situation was slightly improved in the 2,4-D amine treatments but populations were still relatively low. Corn was

TABLE 15. 1984 ALFALFA INTERCROP: C_2H_2 REDUCTION & SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION # MEAN	MEDIAN	RANGE	CV	SOIL MOISTURE$ CONTENT
	.........ppm.........			%	g/g
			JUNE 21st		
OO	9	5	0-24	96%	7.6 a
BMCM	21	5	2-95	154%	10.3 ab
BMCT	4	2	1-11	100%	10.6 ab
BGGL	1	1	0-2	114%	13.0 bc
P	4	3	0-10	94%	10.3 ab
TTH	3	1	0-22	225%	9.0 a
K	2	1	0-10	195%	13.5 c
			JULY 5th		
OO	13	4	0-52	139%	10.6 a
BMCM	12	12	0-22	75%	10.8 a
BMCT	6	4	0-20	120%	11.8 ab
BGGL	0	0	0-2	190%	15.7 bc
P	5	4	0-12	96%	12.3 ab
TTH	0	0	0-0	-	14.3 ab
K	0	0	0-2	97%	18.0 c
			JULY 26th		
OO	10	4	0-36	131%	15.7 a
BMCM	6	2	0-21	142%	17.1 a
BGGL	6	1	0-25	218%	15.0 a
P	2	1	0-10	162%	16.6 a
TTH	1	1	0-4	174%	17.4 a
K	0	0	0-1	283%	15.6 a
			SEPTEMBER 19th		
OO	4	3	2-9	92%	21.2 c
BMCM	1	1	0-2	112%	20.5 bc
BGGL	1	0	0-5	184%	19.7 bc
P	4	4	1-9	84%	19.3 b
TTH	0	0	0-2	200%	19.1 b
K	0	0	0-1	116%	12.7 a

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **C**=Clippings Removed; **OO**= No Suppression; **CV**=Coefficient of variation

#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 2.5 hours incubation.

$=Soil moistures determined for soil cores in incubation jars, numbers within each day with the same lower case postscripts are not significantly different at the 5% level

TABLE 16. 1984 ALFALFA INTERCROP: CORN POPULATIONS AND HEIGHTS

TREATMENT	POPULATION (June 21)	POPULATION (Oct 4)	HEIGHT (Aug 7)
	plants/hectare	plants/hectare	cm
OO	1100 d	1300 e	40 cd
B	0 d	500 e	0 d
BMC	57100 a	38100 abc	120 bc
BMCM	62100 a	51100 a	160 ab
BMM	61700 a	57000 a	160 ab
BMCT	53500 a	49300 a	150 b
GGH	10400 cd	11700 de	160 ab
BGGH	9300 cd	9400 de	200 ab
BGGL	23300 bc	23800 bcd	170 ab
P	55600 a	37700 abc	150 b
BPT	60600 a	54700 a	190 ab
TTH	21200 bc	24200 bcd	150 b
TTL	17200 bcd	16600 cde	130 b
BTTH	31900 b	40100 ab	200 ab
BTTL	18300 bcd	20000 b-e	180 ab
K	52400 a	55200 a	240 a
Sig. Level	1%	1%	1%
5% LSD	14720	16130	61
1% LSD	19640	21520	81

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same lower case postscript are not significantly different at the level indicated

sparse wherever suppression had failed to remove the living cover. Commonly, small excavations were evident where the corn seedlings should have been, or the seedling had been cut off at the ground surface. Numerous ground squirrels (Spermophilus tridecemlineatus) were observed in the field, and it was concluded that these contributed to the poor corn stand. Glyphosate treated plots (G) had low corn populations due to both competition and direct herbicide kill.

Treatments that temporarily eliminated the cover during corn emergence (mowing and paraquat), resulted in initial corn populations comparable to that in killed alfalfa (K). By October the populations in these initially successful treatments had decreased, especially in those least suppressed (BMC and P). This is graphically depicted in Figure 8. The population decrease in the plots treated only with paraquat (P) was in fact significantly greater (5% level) than in the more heavily suppressed paraquat treatment (BPT). During the same period, the corn population in killed alfalfa (K) did not decrease.

To assess the relative vigor of corn throughout the season a number of measurements were made: corn height, leaf mass and silage mass. Corn in killed alfalfa (K) was at least 45 cm taller than in suppressed alfalfa on August 7 (Table 16). At the other extreme, unsuppressed (OO) and banded-only (B) plots produced much shorter corn than the suppressed plots. The relatively tall corn in glyphosate treated alfalfa can be attributed in part to the low corn populations, and the resulting abscence of intraspecific competition. Partial elimination of interspecific competition helps to explain the slight, non-significant increase in corn height associated with banding (e.g., BGGH vs GGH, BTTH vs TTH, BTTL vs TTL).

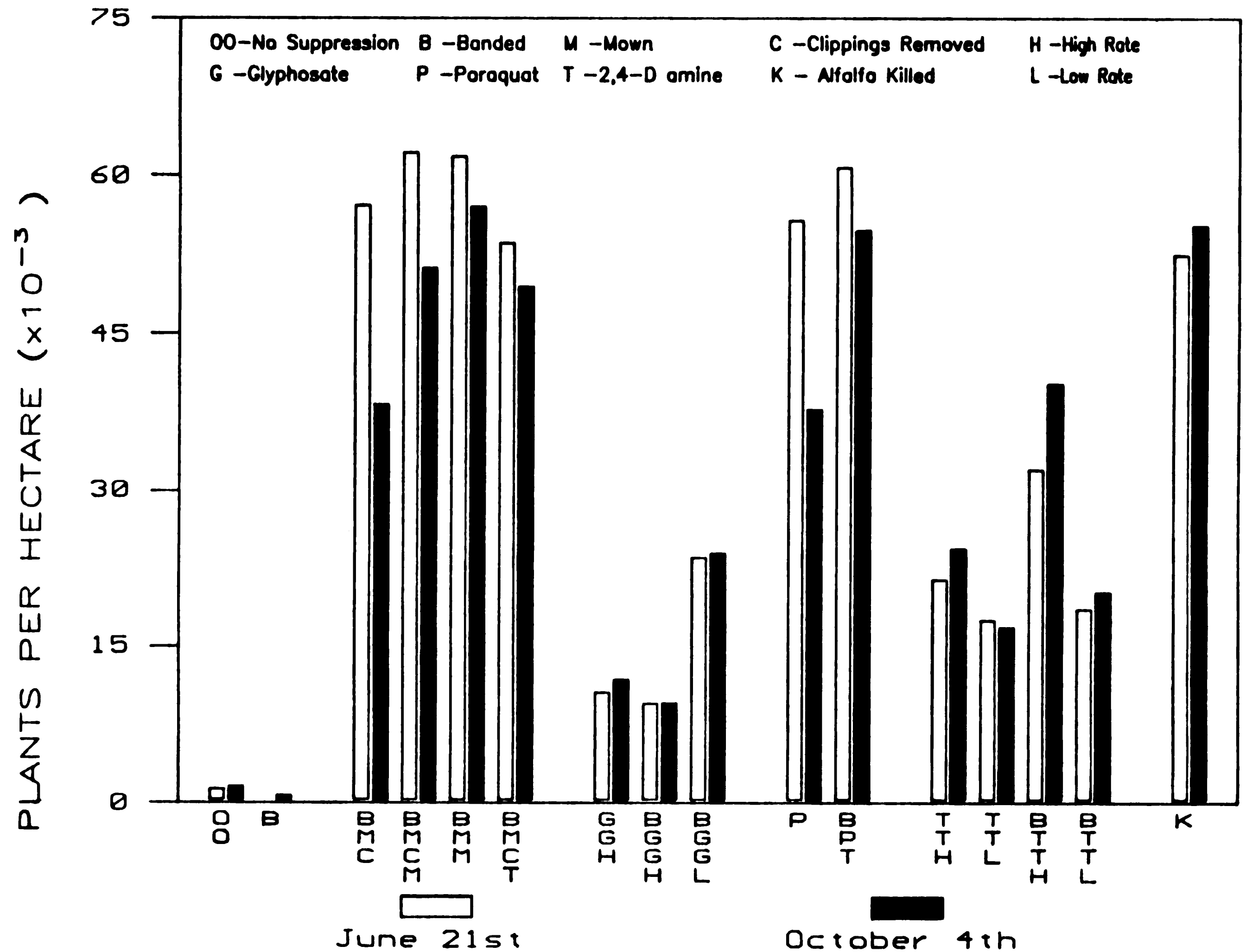


FIGURE 8. 1984 ALFALFA INTERCROP: CORN POPULATIONS ON TWO DATES.

Corn height data is in agreement with other measures of individual plant vigor presented in Table 17. Of the uppermost fully expanded corn leaves collected on July 11, only those from the BPT, GGH and BGGH treatments were statistically equivalent in mass (1% level) to those from killed plots. By August 17, corn in two of the glyphosate treatments produced heavier earleaves than corn in killed alfalfa. The mass of earleaves in the 2,4-D treatments had also increased relative to those in the killed plots. The lack of intraspecific competition in these cases was apparently more than compensating for interspecific competition.

When the corn was harvested in November, another shift in relative mass per plant had occurred (Table 17). The treatments that produced significantly lighter (5% level) corn plants than the killed treatment (K) were the unsuppressed (OO) and banded-only (B) treatments, which produced no corn at all, and the BMC, BMCM and P treatments. Corn mass in the 2,4-D treatments had continued to increase relative to that in killed alfalfa (Figure 9 illustrates this increase on an yield/area basis). Corn plants from glyphosate treatments were lighter than those from 2,4-D treatments, possibly due to the cumulative effect of heavy weed infestation in the plots which received glyphosate. Only in the rebanded 2,4-D amine treatments was there an increase in corn mass associated with banding.

Even though corn plants were not harvested till November, a difference in moisture content was evident. Silage from mown and paraquat treatments was drier than that from the treatment where alfalfa was killed alfalfa. Silage from the low 2,4-D treatment was also drier than silage from killed plots, and drier than that from the

TABLE 17. 1984 ALFALFA INTERCROP: CORN YIELD ESTIMATES, AND N%

TRT	LEAF July 11 MASS	LEAF July 11 NITROGEN	EARLEAF Aug 17 MASS	SILAGE (Nov 3) MASS	SILAGE (Nov 3) YIELD	SILAGE (Nov 3) MOISTURE
	g/leaf	%	g/leaf	g/plant	Mg/ha	%
OO	0 e	*	0 e	0 d	0 d	*
B	0 e	*	0 e	0 d	0 d	*
BMC	0.6 bcd	1.21 c	1.9 cde	114 cd	4.34 bcd	46 e
BMCM	0.8 bcd	1.31 c	1.7 de	207 abc	10.58 ab	49 de
BMM	0.6 bcd	1.60 c	2.5 bcd	141 bc	7.98 abc	50 de
BMCT	0.7 bcd	1.05 c	2.1 cd	115 cd	5.56 bcd	54 cd
GGH	1.0 abc	3.39 ab	3.7 abc	171 abc	2.69 cd	62 a
BGGH	1.1 ab	3.24 b	4.8 a	179 abc	1.64 cd	60 abc
BGGL	0.8 bcd	3.05 b	4.2 ab	180 abc	4.47 bcd	60 abc
P	0.7 bcd	1.70 c	2.7 bcd	136 bc	4.68 bcd	52 de
BPT	1.4 a	1.59 c	2.6 bcd	200 abc	10.73 ab	51 de
TTH	0.3 d	4.05 a	3.0 a-d	239 abc	5.82 bcd	63 a
TTL	0.7 bcd	3.14 b	2.9 a-d	219 abc	4.97 bcd	54 cd
BTTH	0.7 bcd	3.25 b	3.8 abc	265 ab	10.25 ab	60 abc
BTTL	0.5 cd	2.92 b	3.5 a-d	278 a	6.64 abc	55 bcd
K	1.4 a	2.81 b	4.1 a	240 abc	13.14 a	61 ab
Sig. Level	1%	1%	1%	1%	1%	1%
5% LSD	0.42	0.74	1.44	100	4.87	6
1% LSD	0.56	0.77	1.92	134	6.50	6

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same lower case postscript are not significantly different at the level indicated

high 2,4-D treatment. The extent of competition appears to have influenced both the yield and rate of maturity.

Examination of corn leaf N% in Table 17 reveals two distinct groups. The mown and paraquat treatments all produced corn leaves with N% between 1.05% and 1.71%, while the corn leaves from killed, glyphosate and 2,4-D amine treatments all had greater than 2.80%. This second range appears high, but as differences were consistent throughout the replicates, significant treatment effects at the 1% level were detected. Speculation as to why the difference occurred can take several directions. As N% shows no relationship to plant (leaf) size, dilution of the available N in larger plants can be ruled out. The lower corn populations in glyphosate and 2,4-D treatments may have resulted in each plant having access to more soil N, but this would not explain the high N% in killed alfalfa plots (K). Differences due to variation in physiological growth stage may have contributed, although the extent of visual yellowing in the mown and paraquat treatments suggests a real difference existed. As the alfalfa in glyphosate and 2,4-D treatments was suppressed to a greater extent on the sampling date, than alfalfa in mown and paraquat treatments, it is possible that the greater degree of suppression had induced release of N from the alfalfa, and allowed subsequent N uptake by the corn. Once again, this would not explain the high N% in killed alfalfa plots (K). Another possibility is that the active regrowth of alfalfa in mown and paraquat treatments required large inputs of N, which could only be met by depleting the soil N pool. This last explanation best describes the observed results.

If the masses of Table 17 are converted to yields per hectare and then expressed as a percentage of the level achieved in killed alfalfa plots, a comparison can be made between the dates (Figure 9). Such a presentation also takes into account the treatment dependent populations. In July (open bars), only the BPT treatment approached the killed treatment (K) in leaf yield (94%). The twice mown treatment, BMCM, was a poor second with 51%. In August (hatched bars), the highest relative leaf yields were in the BMM, BPT and BTH treatments, all of which were approximately 60% of the killed treatment. At the final harvest (solid bars), BMCM, BPT and BTH had silage yields approximately 80% of the killed treatment. Such a presentation reveals that the BPT corn was consistently amongst the best performers throughout the season. Also, all four 2,4-D treatments systematically improved throughout the season, so that the BTH treatment had an equivalent final yield to BPT. Mown treatments did not behave in any systematic way, but as mentioned, the BMCM treatment also had an equivalent final yield to BPT. Corn yields in glyphosate treated plots were consistently low due to poor corn populations.

SUMMARY: In 1984 Alfalfa grew vigorously prior to the early May corn planting. The initial applications of glyphosate and 2,4-D amine failed to adequately suppress alfalfa. Repeat applications greatly reduced alfalfa stands and allowed weeds to invade. The difference in response was attributed to weather conditions. Mowing and paraquat treatments resulted in the most complete temporary removal of cover, and the smallest reduction in final alfalfa stand. Treatments which produced poor early suppression resulted in low corn populations, due to both physical competition and pests resident in the

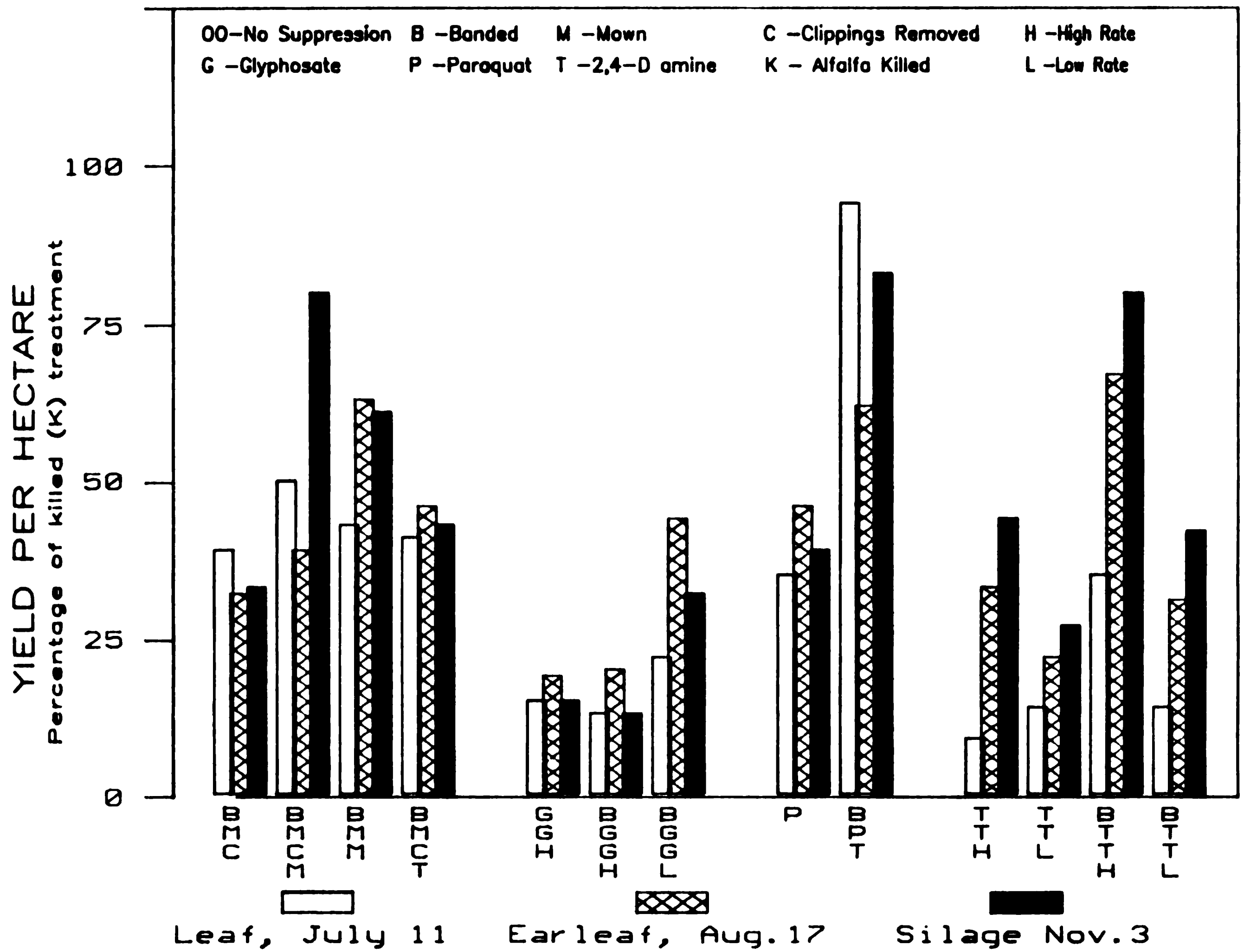


FIGURE 9. 1984 ALFALFA INTERCROP: RELATIVE LEAF AND SILAGE YIELDS/HECTARE

alfalfa stand. Banding improved final corn yield in the otherwise competitive 2,4-D amine treated plots. Effectiveness of the banding formulation was reduced by poor contact with alfalfa foliage. Treatments which produced good early alfalfa suppression (paraquat and mowing), allowed acceptable corn populations to establish, which declined as alfalfa regrew. The maximum corn yield in suppressed alfalfa (BPT treatment) was 63% of the highest yield in a completely killed legume in 1984. June and early July soil moistures suggest that the ground cover was depleting soil moisture reserves. Nitrogen levels in corn leaves suggest that actively regrowing alfalfa may compete with corn for soil nitrogen, but final corn yields were not related to leaf nitrogen content. Acetylene reduction rates of surface samples were very low and no treatment differences were detected.

Recommendations arising from this experiment include the need to adequately remove alfalfa during corn establishment. For this purpose paraquat and mowing should be used in preference to glyphosate and 2,4-D. Banding can also be used to spatially separate corn and alfalfa. Greater care must be taken to ensure that banded herbicides are applied correctly. Control of regrowth in order to eliminate competition for soil moisture and nitrogen is also necessary. All suppression treatments failed in this respect.

(D1b).....1984 RED CLOVER INTERCROP

CLOVER: Clover was actively growing and approximately 18 cm tall when corn was planted and initial treatments applied. An average 80 g/m^2 of oven dried plant material was removed from the mown plots at this time. On May 18 the situation was very similar to the alfalfa experiment. Paraquat and mown treatments were devoid of excessive ground cover, but mown plots were already regrowing. The killing herbicide treatment (K) had successfully collapsed the canopy; the dense mat produced would have covered the seed slot, if the planter had not partially removed clover from this area. The banding formulation had induced the same result on a localized basis. Glyphosate and 2,4-D amine treatments had produced no visible effect.

By June 8, paraquat, mown and 2,4-D treatments were again as described for the alfalfa treatments on this date. Paraquat treated and mown clover were vigorously regrowing. The double application of 2,4-D amine had only slightly suppressed clover growth. Clover in the glyphosate treatments was slightly stunted, especially at the high rate, but was vigorous enough to completely obscure the corn seedlings.

A visual assessment of ground cover on August 7 (Table 18), indicated that the killed treatment (K) had been successful in eliminating ground cover. Three suppression treatments (BMM, BMCT and BPT), had significantly reduced (1% level) the amount of ground cover. All other suppression treatments except the low glyphosate rate (BGL) had maintained ground cover by increases in weed percentage. The BGL treatment and the banding-only treatment (B) were not severe enough to allow a large number of weeds to invade.

TABLE 18. 1984 CLOVER INTERCROP: GROUND COVER ASSESSMENTS

	VISUAL ASSESSMENT$$			HARVEST ASSESSMENT$		
	7 AUG. 1984		22 MAY 1985	22 MAY 1985		
TR'T	COVER	WEEDS	WEEDS	CLOVER	WEEDS	WEED FRACTION
	.... %		....	...g/m^2....		%
OO	100 a	0 c	10	210	50	19
B	100 a	10 b	40	-	-	-
BMC	100 a	30 ab	30	-	-	-
BMCM	100 a	30 ab	30	90	40	31
BMM	80 b	40 a	40	-	-	-
BMCT	80 b	20 abc	20	140	50	26
GH	100 a	30 ab	40	190	60	24
BGH	100 a	30 ab	40	-	-	-
BGL	100 a	10 bc	40	-	-	-
P	90 a	30 ab	50	110	90	45
BPT	80 b	30 ab	40	-	-	-
TTH	100 a	30 ab	30	130	30	19
TTL	100 a	40 a	60	-	-	-
BTTH	90 a	30 ab	30	-	-	-
BTTL	100 a	30 ab	40	-	-	-
K	10 c	30 ab	10	20	20	50
Sig.Level	1%	5%	ns	ns	ns	-
5% LSD	14	20	-	-	-	-
1% LSD	18	-	-	-	-	-

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression; **LSD**=Least Significant Difference.
Numbers within a column with the same lower case postscript or without postscripts are not significantly different at the level indicated
$$=Percentage of the ground surface covered and the percentage of this that was weeds, as visually assessed on two dates.
$=Oven dry weight of alfalfa and weeds cut from quadrats

In the spring of the following year, all suppression treatments were associated with non-significant increases in visual weed percentage (Table 18). Quadrats harvested in May 1985, indicated that the unsuppressed clover (OO) had the most regrowth and the killed clover (K) the least. Of the suppression treatments harvested, the doubly mown (BMCM) and paraquat treatments (P) were associated with the least clover regrowth. A large portion of the regrowth was weeds in the paraquat treatment.

As with the alfalfa intercrop experiment, an enormous amount of heterogeneity was inherent in acetylene reduction samples, and measured ethylene production was low. Median values are presented as representative of treatment levels, as they are not biased by individual high activity levels (Table 19). Ranges are also presented, as the upper limits are representative of the potential of each treatment sampled. On the first sampling date, samples from unsuppressed (OO) and mown plus 2,4-D treated clover (BMCT) produced the highest acetylene reduction activity. On the second date (July 25), all treatments had extremely low activity levels. On September 19 only the unsuppressed treatment had appreciable activity. This is the only data from all eight experiments indicating a prolonged reduction in nitrogen fixation activity associated with suppressants. Samples from plots in which the clover had been killed (K) had negligible activity on all three days.

Soil moisture contents in the treatments sampled for acetylene reduction analysis are also presented in Table 19 (for weather and irrigation data see Table 1 in Methods). The first two dates were preceded by rain or irrigation, while only 0.3 cm occurred in the six

TABLE 19. 1984 CLOVER INTERCROP: C_2H_2 REDUCTION & SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION $ MEAN	MEDIAN	RANGE	CV	SOIL MOISTURE# CONTENT
	.........ppm..........			%	g/g
			JUNE 25th		
OO	15	10	1-69	150%	11.4
BMCM	3	3	1-6	50%	12.2
BMCT	34	24	2-127	119%	11.8
BGL	13	10	3-25	85%	13.1
P	8	6	2-18	81%	7.5
TTH	4	4	1-9	75%	8.5
K	1	1	0-2	86%	11.7
			JULY 25th		
OO	4	1	0-12	127%	13.5
BMCM	2	2	1-4	56%	15.5
BGL	2	2	1-3	35%	14.4
P	3	2	0-10	106%	13.9
TTH	3	3	0-7	76	14.8
K	1	0	0-6	157%	13.3
			SEPTEMBER 19th		
OO	62	61	2-121	102%	16.0 b
BMCM	8	5	1-23	122%	16.3 b
BGL	5	5	0-14	95%	16.6 b
P	7	6	1-14	82%	14.9 ab
TTH	8	5	1-16	125%	15.1 b
K	0	0	0-1	116%	12.7 a

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **C**=Clippings Removed; **OO**= No Suppression; **CV**=Coefficient of variation

#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 2.5 hours incubation.

$=Soil moistures determined for soil cores in incubation jars, numbers within each day with the same lower case postscripts are not significantly different at the 5% level days prior to September 19. Only on September 19 were there statistical differences (5% level). Soil moisture levels on this date were lowest in the killed clover (K), that is, the treatment with the least amount of cover and the most vigorous corn.

CORN: Corn populations in the 1984 clover intercrop are presented in Table 20. The paraquat treated, doubly mown and the mown plus 2,4-D amine treated plots produced corn populations statistically equivalent (5% level) to the killed clover treatment (K). Not coincidentally, these were the treatments which best removed clover from the plots during corn emergence and establishment. Low populations in glyphosate and 2,4-D amine treated plots were due to failure to suppress the clover. The difference between the BMC and BMCM corn populations can be attributed to death of emerged seedlings in the singly mown treatment, as clover regrowth out-competed the corn. A second mowing served to delay this regrowth. Banding when combined with 2,4-D amine (BTTH and BTTL) increased the number of surviving corn plants relative to 2,4-D alone (TTH and TTL).

On August 7 corn plants were tallest in plots with least competition from clover (K, BPT and BMM. Table 20). No corn plants were visible in the unsuppressed clover (OO) and those in banded-only plots (B) were extremely spindly and short. Unbanded 2,4-D amine plots had the shortest corn of any suppression treatments.

Differences in yield estimates per plant (Table 21), are not as clear cut as for alfalfa. Zero suppression (OO) and banding-only (B) did not allow corn to develop. Corn leaves collected on July 11 indicated that only the paraquat plus 2,4-D treatment (BPT) produced corn plants equivalent in size to those in killed clover (K). All

TABLE 20. 1984 CLOVER INTERCROP: CORN POPULATIONS AND HEIGHTS

TREATMENT	POPULATION Oct 4	HEIGHT Aug 7
	plants/ha	cm
OO	3600 e	0 f
B	5800 e	35 ef
BMC	38600 a-d	110 b-e
BMCM	61000 a	140 bcd
BMM	56500 ab	150 abc
BMCT	40400 a-d	100 b-e
GH	24700 cde	100 b-e
BGH	28700 b-e	130 bcd
BGL	13000 de	80 c-f
P	57400 ab	120 bcd
BPT	52900 abc	170 ab
TTH	15300 de	80 c-f
TTL	15300 de	70 def
BTTH	28700 b-e	100 b-e
BTTL	35900 a-d	90 b-e
K	61400 a	230 a
Sig. Level	1%	1%
5% LSD	22140	57
1% LSD	29530	76

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same lower case postscript are not significantly different at the level indicated

TABLE 21. 1984 CLOVER INTERCROP: CORN YIELD ESTIMATES AND N%

TREATMENT	LEAF (July 11) MASS	LEAF (July 11) NITROGEN	EARLEAF (Aug 17) MASS	SILAGE (Nov 9) MASS	SILAGE (Nov 9) YIELD	SILAGE (Nov 9) MOISTURE
	g/leaf	%	g/leaf	g/plant	Mg/ha	%
OO	0 e	*	0 d	0 e	0 d	*
B	0 e	*	0.8 cd	28 de	0.30 d	*
BMC	0.5 cd	1.90 d	2.1 a-d	134 b-e	5.09 cd	39 d
BMCM	0.5 cd	2.29 cd	2.2 abc	148 a-d	9.06 bc	46 bcd
BMM	0.6 bc	2.63 bcd	2.2 abc	171 abc	9.53 bc	43 cd
BMCT	0.4 cde	1.86 d	2.3 abc	149 a-d	6.04 cd	38 d
GH	0.4 cde	2.01 d	1.7 bcd	57 cde	2.54 d	47 bcd
BGH	0.6 bc	2.59 bcd	2.5 abc	155 a-d	4.59 cd	38 d
BGL	0.2 cde	2.58 bcd	1.2 bcd	70 cde	1.51 d	42 cd
P	0.5 cd	2.69 bcd	3.0 ab	241 ab	12.56 ab	47 bcd
BPT	1.0 ab	2.62 bcd	3.0 ab	173 abc	9.14 bc	47 bcd
TTH	0.1 de	2.59 bcd	0.7 cd	133 b-e	2.26 d	59 ab
TTL	0.1 de	3.88 a	1.6 bcd	113 b-e	2.13 d	61 a
BTTH	0.3 cde	3.03 abc	2.5 abc	144 a-d	5.50 cd	53 abc
BTTL	0.4 cde	2.68 bcd	1.5 bcd	99 cde	3.50 cd	49 a-d
K	1.1 a	3.30 ab	4.1 a	278 a	16.75 a	46 bcd
Sig. Level	1%	1%	1%	1%	1%	1%
5% LSD	0.31	0.75	1.58	104	4.62	10
1% LSD	0.41	1.00	2.11	139	6.17	13

Designations: **K**= Killed; **B**=Killed Bands; **M**=Mown; **T** =2,4-D; **P**=Paraquat; **G**=Glyphosate; **H**=High Rate; **L**=Low Rate; **C**=Clippings Removed; **OO**= No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same lower case postscript are not significantly different at the level indicated

other treatments produced much lighter leaves, especially the low glyphosate rate and unbanded 2,4-D. The earleaf data indicates that on August 17 corn in killed clover was still larger than in other treatments. Only the two paraquat treatments produced earleaves equivalent in mass (5% level) to those from the K treatment. Of the suppression treatments, glyphosate and 2,4-D amine produced some of the smallest earleaves. The relationships between treatments were similar for whole plant masses (November 9). Killed clover plots produced the heaviest plants, followed by the two paraquat treatments and the BMM treatment.

Corn leaf N% from the clover intercrop (Table 21) do not reveal the distinct treatment effects noted in the alfalfa intercrop. The lowest N% are once again from the mown treatments, although not all mown treatments had low values. Leaves from the TTL treatment had a higher N% than those from the killed clover, and were significantly higher (5% level) than all other treatments. The differences in nitrogen content may have been due to differences in growth stage.

Figure 10 presents the yield estimates per unit area as a precentage of the yield achieved in the K treatment. As explained for the alfalfa intercrop, the individual populations for each treatment (Table 18) were used to convert yield per plant to yield per hectare. This figure demonstrates that relative yield estimates changed little throughout the season in all but the two paraquat treatments and the BTTH treatment. In P and BTTH treatments the estimates increased with time while in BPT the estimate decreased. The suppression treatment which gave the highest silage yield per hectare was the unbanded paraquat, which yielded 75% as much as the K treatment. The next best

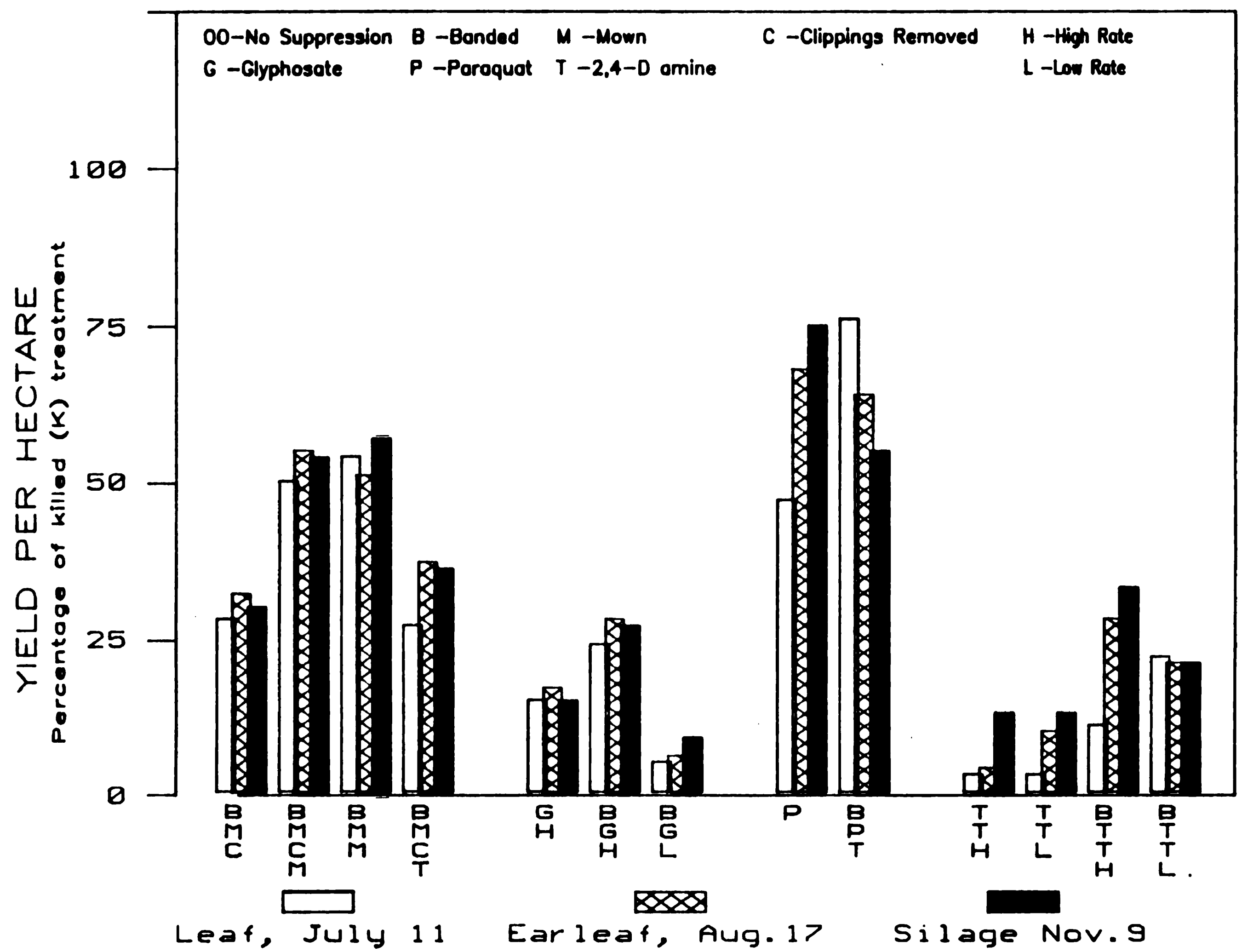


FIGURE 10. 1984 CLOVER INTERCROP: RELATIVE LEAF AND SILAGE YIELDS/HECTARE

yields were in BMM, BPT and BMCM treatments, which yielded 57%, 55% and 54% as much as K.

SUMMARY: In 1984 moderate clover growth had occurred prior to the early May corn planting. The initial applications of glyphosate and 2,4-D amine failed to adequately suppress clover, as did a second application of 2,4-D. Any degree of suppression was associated with an increase in the weed population. Mowing and paraquat treatments produced adequate but temporary clover suppression, and contrary to findings with alfalfa, the largest reduction in spring growth in the following year. Treatments which produced poor early suppression resulted in low corn populations. Banding improved final corn yield in the otherwise competitive 2,4-D amine treated plots. Treatments which produced good early clover suppression (paraquat and mowing), allowed acceptable corn populations to establish. Paraquat was much more injurious to clover than it was to alfalfa, which explains the relatively high corn yields in paraquat suppressed clover. The maximum corn yield in suppressed clover (P treatment) was 75% of the highest yield in a completely killed legume in 1984. Acetylene reduction rates of surface samples were very low and non conclusive, although the September data suggests that all suppression treatments sampled, had reduced the fixation rate.

Paraquat should be further investigated as a red clover suppressant as it produced early burn-back sufficient to allow satisfactory corn establishment and subsequent growth. Paraquat must be combined with a suitable weed contol herbicide to combat the large weed populations that develop when clover is temporarily removed.

(D1c).....1984 CROWNVETCH INTERCROP

VETCH: Vetch was realively dormant and approximately 5 cm tall when corn was planted. Consequently the application of suppressants was postponed for three weeks (June 1). An average of 37 g/m^2 of oven dried plant material was removed from mown plots at this time, much of which was grassy weeds. Vetch therefore does not appear suited to early spring nitrogen fixation at this site. A flush of growth occurred after corn planting and by June 8, unsuppressed vetch was approximately 30 cm tall. This was associated with 11 cm of rainfall in the latter part of May. Vetch in plots that were mown had not regrown, and both 2,4-D rates had induced collapse of the vetch. There were no visual differences between the two rates. By July 3 mown vetch was approximately 15 cm tall and flowering. Corn in mown plots was taller than the vetch but exhibited leaf curling, suggesting water stress. Vetch in 2,4-D treated plots was still yellow and prostrate, especially in those plots receiving the higher rate. In subsequent weeks vetch grew in a vigorous, spreading fashion in all treatments completely obscuring most corn in unbanded plots. Although vetch growth was delayed due to both natural and applied factors, growth in July was much more vigorous than the associated corn. Thus all plots except those which were physically cleared and sprayed on June 14 (CK), had 100% ground cover in the latter part of 1984.

In 1985 when weed regrowth was visually assessed (Table 22), there were no significant differences. When quadrats were harvested from certain treatments on 21 May 1985, less vetch had regrown in the sampled 2,4-D treated plots (BTL) than in the sampled mown plots (BM),

TABLE 22. 1984 VETCH INTERCROP: GROUND COVER AND CORN POPULATIONS

TREATMENT	GROUND COVER: VISUAL WEED RATING$$ Apr22.85	GROUND COVER: HARVESTED COVER$ May 21.85: VETCH	WEEDS	WEED FRACTION	CORN POPULATION
	%	...g/m^2....		%	Plants/ha.
OO	40	-	-	-	26000
B	50	290	60	17	43100
M	50	-	-	-	39900
BM	30	270	50	16	44000
TH	20	-	-	-	46200
TL	40	-	-	-	40400
BTH	50	-	-	-	56100
BTL	60	170	100	37	49300
CK	20	80	50	42	48900
Sig.Level	ns	ns	ns	-	ns

Designations: **CK**=Killed; **B**=Banded; **M**=Mown; **T**=2,4-D; **H**=High Rate; **L**=Low Rate; **OO**=No Suppression;
$$=Percentage of the ground cover visually assessed as weeds.
$=Oven dry weight of alfalfa and weeds cut from quadrats

and more weeds were present in the BTL plots.

Ethylene concentrations produced in acetylene reduction assays were negligible (see median values in Table 23). The vetch exhibited less acetylene reduction activity than the other three legumes monitored. Soil moisture contents did not vary between treatments on any of the sampling dates.

CORN: Although 66,000 seeds per hectare were planted, the average corn population achieved in the vetch intercrop was approximately 44,000 (Table 22). As with the alfalfa intercrop, the poor populations can be attributed to both competition from the legume and enhancement of pest habitat by the presence of the living cover. Highest corn populations were achieved in the 2,4-D treated and killed vetch. The corn population in the killed vetch (CK) was almost twice that in the unsuppressed vetch (OO). Recall that both these treatments were unsuppressed for a month after corn planting, at which stage the vetch in CK plots was mechanically removed and atrazine applied to control regrowth. This suggests that the corn had emerged in the unsuppressed vetch but competition from the vetch had prevented its survival. Corn population varied greatly within treatments.

On July 11 when leaves were removed from corn plants in the banded plots, there was no significant difference in their masses (Table 24). Leaves from the treatment receiving the low 2,4-D rate (BTL) did have a higher N% than the other treatments sampled, including the high 2,4-D rate. The reason for this is not immediately obvious. If the effect was due to secretion of nitrogen from the vetch as a result of suppression, corn in plots treated with the higher rate would be expected to have the higher nitrogen content. At the sampling date

TABLE 23. 1984 VETCH INTERCROP: C_2H_2 REDUCTION AND SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION # MEAN	MEDIAN	RANGE	CV	SOIL MOISTURE$ CONTENT
	.......ppm.........			%	g/g
			JUNE 25th		
OO	2	1	1-5	87%	12.6
M	1	0	0-4	169%	11.8
TH	2	1	0-6	137%	13.1
			JULY 5th		
OO	2	0	0-10	219%	6.7
M	2	0	0-9	215%	8.5
TH	1	1	0-2	90%	9.1
			JULY 25th		
OO	2	0	0-14	255%	13.7
M	34	0	0-245	264%	13.5
TH	17	3	0-77	162%	14.9
			SEPTEMBER 19th		
OO	70	0	0-281	200%	16.9
M	0	0	0-1	200%	18.9
TH	2	0	0-9	183%	16.2

Designations: **M** =Mown; **T** =2,4-D; **H**=High Rate; **OO**= No Suppression; No comparisons were significantly different on any of the sampling dates
CV=Coefficient of variation
#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 2.5 hours incubation.
$=Soil moistures determined for soil cores in incubation jars, with no significant differences on any days.

TABLE 24. 1984 VETCH INTERCROP: CORN YIELD ESTIMATES AND N%

TREAT.	LEAF (July 11) MASS	LEAF (July 11) NITROGEN	EARLEAF (Aug 27) MASS	SILAGE (Nov 9) MASS	SILAGE (Nov 9) YIELD	SILAGE (Nov 9) MOISTURE
	g/leaf	%	g/leaf	g/plant	Mg/ha	%
OO	-	-	0.2 c	10 c	0.32 c	44
B	0.5	1.34 b	1.1 b	36 abc	1.52 bc	54
M	-	-	1.1 b	25 bc	1.01 bc	63
BM	0.6	1.50 b	1.6 ab	32 bc	1.75 bc	40
TH	-	-	1.3 b	31 bc	1.30 bc	60
TL	-	-	1.5 ab	32 bc	1.29 bc	58
BTH	0.6	1.53 b	1.7 ab	72 a	3.97 a	50
BTL	0.7	1.86 a	1.8 ab	58 ab	2.73 ab	54
CK	-	-	2.2 a	44 abc	2.18 ab	56
Sig.Level	ns	5%	1%	1%	1%	ns
5% LSD	-	0.30	0.62	28	1.36	-
1% LSD	-	-	0.84	38	1.84	-

Designations: **CK**=Killed; **B**=Banded; **M**=Mown; **T**=2,4-D; **H**=High Rate; **L**=Low Rate; **OO**=No Suppression. **LSD**=Least significant difference. Numbers within a column with the same lower case postscript are not significantly different at the level indicated

2,4-D treated vetch was beginning to regrow, while banded and mown vetch was flowering. The vetch receiving the high rate of 2,4-D may have exhausted much of its reserves in order to survive and consequently had to deplete the soil N pool in order to regrow.

Despite the high level of initial competition, corn plants in killed vetch produced the heaviest earleaves (Table 24). Banding was associated with a non-significant increase in earleaf mass in all suppression comparisons (compare M and BM, TH and BTH, TL and BTL), while banding-only (B) significantly (1% level) increased the earleaf mass relative to unsuppressed plots (00).

At the final harvest the banded 2,4-D treatments (BTH and BTL) produced the heaviest corn plants. Banding had an especially beneficial effect on silage mass when combined with the high rate of 2,4-D (compare TH and BTH). All the trends in silage mass were mirrored in silage yield per hectare. All corn yields were well below those in associated alfalfa and clover intercrops.

SUMMARY: In 1984, crownvetch only began to grow after the early May corn planting date. Mowing inhibited regrowth for approximately two weeks, while the 2,4-D treatments inhibited regrowth for slightly over a month. Banding enhanced both corn population and yield per plant. Competition after corn establishment as well as during, is implicated in reducing final corn yields. The highest silage yield for the experiment (BTH treatment) was 24% of the highest yield in a completely killed legume in 1984. The nitrogen content of corn leaves sampled in vetch treated with the low 2,4-D rate, was for higher than that in vetch treated with the high 2,4-D rate. Acetylene reduction rates in the surface cores sampled were extremely low and no treatment differences were detected.

Vetch does not provide ground cover and nitrogen fixation during spring, and fails to meet the objectives of the proposed intercropping system. Its growth after July is vigorous, requiring suppression if corn yields are to be maintained. Advantage may be taken of crownvetch's poor spring growth to establish corn. Associated weed control is mandatory.

(D1d).....1984 BIRDSFOOT TREFOIL INTERCROP

TREFOIL: Trefoil had only begun to grow and was approximately 5 cm tall when corn was planted. Consequently the application of suppressants was delayed for three weeks (June 1), at which stage trefoil had developed to a problem level. An average of 81 g/m^2 of oven dry plant material was removed from mown plots on this date. By June 8 unsuppressed trefoil was up to 35 cm tall and completely obscured the corn. Both 2,4-D rates had reduced the rate of trefoil growth but no appreciable wilting and deformation was visible. Regrowth in the mown plots had not yet outgrown the corn, but was vigorous. The bands established at planting were no longer visible. A second banding was successful in reestablishiing killed strips. The trefoil between the bands regrew vigorously and all plots except those which were physically cleared and sprayed on June 14 (CK) had 100% ground cover by July.

In 1985 when weed regrowth was visually assessed, there were no significant differences between treatments but weed regrowth was highest in all banded treatments (Table 25). Mowing and 2,4-D were not associated with any increase in weeds. The 2,4-D treatment (BTL) was associated with a significant decrease (5% level) in the amount of harvested trefoil regrowth. While none of the suppression treatments were severe enough to more than temporarily restrict trefoil growth in the year of application, trefoil regrowth in May of the following year was reduced in the sampled 2,4-D treatment (BTL).

Measured acetylene reduction activity in the trefoil, was much greater than in the other three legumes (Table 26). This was possibly

TABLE 25. 1984 TREFOIL INTERCROP: GROUND COVER AND CORN POPULATIONS

TREATMENT	GROUND COVER: VISUAL WEED RATING$$ Apr22.85	GROUND COVER: HARVESTED COVER$ May 21.85 TREFOIL	WEEDS	WEED FRACTION	CORN POPULATION
	%	...g/m^2...		%	Plants/ha
OO	25	-	-	-	8500 c
B	50	290 a	50	17	14400 bc
M	30	-	-	-	45300 a
BM	45	280 a	40	16	45800 a
TH	15	-	-	-	38600 ab
TL	25	-	-	-	15700 bc
BTH	55	-	-	-	46600 a
BTL	50	180 ab	70	28	31800 abc
CK	25	90 b	10	10	41700 ab
Sig. Level	ns	1%	ns	ns	1%
5% LSD	-	89	-	-	21710
1% LSD	-	127	-	-	29420

Designations: **CK**=Killed; **B**=Banded; **M**=Mown; **T**=2,4-D; **H**=High Rate; **L**=Low Rate; **OO**=No Suppression;
$$=Percentage of the ground cover visually assessed as weeds.
$=Oven dry weight of alfalfa and weeds cut from quadrats

TABLE 26. 1984 TREFOIL INTERCROP: C_2H_2 REDUCTION & SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION# MEAN	MEDIAN	RANGE	CV	SOIL MOISTURE$ CONTENT
	.........ppm.........			%	g/g
			JUNE 26th		
OO	92	51	0-362	128%	8.7
M	80	50	3-179	89%	9.1
TH	25	10	1-121	162%	9.2
			JULY 13th		
OO	17	17	0-34	77%	17.8
M	39	28	1-128	107%	18.8
TH	10	10	1-19	76%	18.4
			JULY 26th		
OO	30	20	4-85	98%	11.0
M	13	7	1-46	112%	12.1
TH	15	17	1-25	53%	11.0
			SEPTEMBER 19th		
OO	75	63	10-164	93%	14.8
M	80	78	12-151	84%	14.9
TH	15	13	0-34	100%	16.6

Designations: **M**=Mown; **T**=2,4-D; **H**=High Rate; **OO**= No Suppression; No comparisons were significantly different on any of the sampling dates
CV=Coefficient of variation
#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 2.5 hours incubation.
$=Soil moistures determined for soil cores in incubation jars, with no significant differences on any day.

due to the extensive mat of fibrous roots near the soil surface. The trefoil treated with the high 2,4-D rate (BTL), generally had a lower acetylene reduction activity level than the mown (M) and unsuppressed (OO) trefoil. As with the other experiments, spatial variability precluded meaningful statistical analysis. Soil moisture was not related to treatment on any of the four acetylene reduction sampling dates.

CORN: Corn populations in the trefoil intercrop were an average of 32,000 plants per hectare (Table 25). As with the alfalfa intercrop, the poor populations can be attributed to both competition from the legume and enhancement of pest habitat by the the living cover. The highest populations were in the mown treatments and in the banded plus high rate of 2,4-D. Banding had a beneficial, if not statistically significant, effect on corn populations in 2,4-D treated plots. The corn populations in killed trefoil (CK) was greater (1% level) than that in the unsuppressed trefoil (OO). This suggests that competition in the second month after corn planting reduced the corn population in the OO treatment, as the OO and CK treatments were equivalent for the first month.

On July 11 when leaves were removed from corn plants in the banded plots, there was no significant difference in their masses (Table 27). Likewise, leaf N% were statistically equivalent.

On August 27 the banded treatments still produced ear leaves of equivalent mass. Banded treatments all produced heavier earleaves than their unbanded equivalents. Of the additional treatments sampled on this date the killed trefoil (CK) produced by far the heaviest corn leaves.

TABLE 27. 1984 TREFOIL INTERCROP: CORN YIELD ESTIMATES AND N%

TREATMENT	LEAF (July 11) MASS	LEAF (July 11) NITROGEN	EARLEAF (Aug 27) MASS	SILAGE (Nov 9) MASS	SILAGE (Nov 9) YIELD	SILAGE (Nov 9) MOISTURE
	g/leaf	%	g/leaf	g/plant	Mg/ha	%
OO	-	-	0.3 c	8 c	0.08 c	54
B	0.3	2.08	1.4 bc	47 bc	0.81 bc	59
M	-	-	1.5 b	40 bc	1.68 bc	65
BM	0.4	1.95	1.7 b	66 b	2.97 ab	53
TH	-	-	1.0 bc	30 bc	1.50 bc	62
TL	-	-	0.8 bc	22 c	0.63 bc	64
BTH	0.4	1.94	1.8 b	67 b	2.97 ab	55
BTL	0.3	1.98	1.6 b	46 bc	1.54 bc	54
CK	-	-	3.6 a	147 a	5.32 a	55
Sig.Level	ns	ns	1%	1%	1%	ns
5% LSD	-	-	0.85	31	1.95	-
1% LSD	-	-	1.15	43	2.65	-

Designations: **CK**=Killed; **B**=Banded; **M**=Mown; **T**=2,4-D; **H**=High Rate; **L**=Low Rate; **OO**=No Suppression; **LSD**=Least significant difference. Numbers within a column with the same lower case postscript are not significantly different at the level indicated

At the final harvest corn plants in the killed trefoil (CK) were much heavier than those in suppressed trefoil, which in turn were heavier than those in unsuppressed trefoil (OO). Banding-only (B) was associated with a large increase in corn mass, relative to corn mass in unsuppressed trefoil (OO). Silage yields per hectare were consistent with mass per plant. The highest yielding suppression treatments (BM and BTH), both produced a low 2.97 Mg/ha.

SUMMARY: In 1984 birdsfoot trefoil began to grow vigorously in late May, experiencing only a temporary setback when mowing and 2,4-D treatments were applied. The double banding treatment enhanced both corn population and final yield. Competition after corn establishment as well as during, is implicated in reducing final corn yields. The highest silage yield achieved in suppressed trefoil (BM and BTH treatments), was only 17% of the highest yield in a completely killed legume in 1984. Acetylene reduction rates in the surface cores sampled, were much higher than in any other legume sampled in 1984. Activity levels in 2,4-D treated trefoil were reduced relative to unsuppressed and mown trefoil.

Trefoil must be suppressed to a greater degree than in this study, as growth was vigorous throughout the season. A rate of 2,4-D amine higher than that used, or a burn-back treatment with paraquat are suggested. These must be combined with appropriate residual herbicides.

D2. 1985 INTERCROP RESULTS AND DISCUSSION

The 1985 intercrops were assessed as summarized in Table 28 and expanded on in (C3a), the 1985 General Methods section

(D2a).....1985 ALFALFA INTERCROP

ALFALFA: Alfalfa was actively growing when the experimental area was mown on April 29; an average of 190 g/m^2 of oven dried plant material was removed, 25% of which was weeds. When corn was planted on May 7, negligible alfalfa regrowth had occurred and the soil moisture was 23% by weight. This relatively high soil moisture value was due to heavy rain on the preceding two days (4.6 cm). By contrast only 3.1 cm had fallen in the previous month.

By June 1, nineteen days after suppressants were applied, only the unsuppressed plots (MOO) and banded-only plots (MB) showed any alfalfa regrowth. The tardy regrowth was attributed to the dry conditions, alflafa weevil infestation and stress induced by the suppressants. Alfalfa regrowth in the MOO and MB plots was enhanced by the application of insecticide, but nearly all plants in the mown, paraquat and glyphosate treated plots died. Most treatments therefore resembled a completely killed no-till situation.

The extensive death of alflafa can be seen from data collected on October 3 (Table 29). Even banded-only plots (MB, MBNe and MBN) had reduced alfalfa survival and ground cover rankings. The majority of the reduced cover in the suppressed plots (mown, glyphosate and paraquat) consisted of weeds. The unsuppressed plots (MOO) clearly had

TABLE 28. 1985 INTERCROPS: DATES OF ASSESSMENT

	LEGUME COVER CROP		
ASSESSMENT	ALFALFA	VETCH	TREFOIL
COVER-Yield	Apr 29	-	-
ACETYLENE REDUCTION AND SOIL MOISTURE	May 2	-	-
	May 7	-	-
	May 13	-	-
	May 22	-	-
	May 24	-	May 24
	-	-	June 5
	June 7	June 7	June 7
	-	June 27	June 27
	-	Aug 8	-
CORN HEIGHT AND POPULATION	Spt 16	Spt 27	Spt 16
CORN SILAGE-Ears	Spt 28-Oct 1	Spt 27	Spt 27
-Stalks	Oct 1	Spt 28	Spt 28
COVER-Visual and Harvested	Oct 3	Oct 7	Oct 12
LEGUME POPULATION	Oct 3	-	-

TABLE 29. 1985 ALFALFA INTERCROP: GROUND COVER ASSESSMENT, 3 OCT. 1985

TREATMENT	VISUAL GROUND COVER	HARVESTED GROUND COVER (Oven dried)			ALFALFA POPULATION
		ALFALFA	WEEDS	WEED	
	%	....g/m^2....		%	Crowns/m^2.
MOO	80 a	36 a	56	61 b	21.0 a
MB	30 bc	3 b	29	91 a	4.0 bcd
MBNe	30 bc	2 b	22	92 a	5.0 bc
MBN	40 b	13 b	57	81 ab	7.2 b
MBM	20 bcd	3 b	34	92 a	1.9 cd
MBMN	30 bc	3 b	49	94 a	2.9 bcd
MBG	10 cd	0+ b	23	99 a	1.8 cd
MBGN	30 bc	2 b	30	94 a	2.6 bcd
MBP	30 bc	0+ b	25	99 a	0.4 cd
MBPN	20 bcd	0+ b	12	99 a	0.5 cd
MK	0 d	0 b	0	-	0 d
MKNe	0 d	0 b	0	-	0 d
Sig. Level	1%	1%	ns	1%	1%
5% LSD	15	13	-	18	3.2
1% LSD	23	19	-	25	4.7

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the level indicated. **O+**=Trace amounts of cover present more ground cover than any other treatment (visual cover, harvested alfalfa and alfalfa crowns per square meter).

An enormous drop in measured nitrogen fixation activity during May, is apparent from the ethylene concentration data presented in Table 30. On May 2, four days after mowing, samples from under mown stands (MOO) had a fraction of the activity under unmown stands (OO). The subsequent drop in the acetylene reduction activity of unmown alfalfa and the failure of mown alfalfa to recover with time, can be attributed to the additional stress of insect infestation and drought. The data for May 24, indicates that the additional stress of suppressants had effectively eliminated nitrogen fixation along with the plants. Soil moisture did not vary between treatments on any of the acetylene reduction sampling dates.

CORN: Corn populations were not influenced by treatment, as all treatments approximated a complete kill situation (Table 31).

In the relatively unsuppressed MOO treatment corn heights were depressed (Table 32). Silage mass per plant was reduced by the surviving alfalfa in MOO plots, and the much lower level of competition in banded-only plots (MB). Even mown (MBMN), glyphosate (MBGN) and paraquat (MBP) treatments had significantly lighter (5% level) corn plants than did the killed treatment (MK). The same relationship held true for yield per hectare (Table 31). Even the low levels of ground cover present in this experiment contributed to reductions in associated corn yield.

Silage N% (Table 32) were not influenced by the degree nor type of suppression. The application of fertilizer nitrogen did increase corn N% in all but the doubly mown plots (MBMN). Corn silage

TABLE 30 1985 ALFALFA INTERCROP: C_2H_2 REDUCTION & SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION # MEAN	MEDIAN	RANGE	CV	ALFALFA HEIGHT AT SAMPLING	SOIL MOISTURE$ CONTENT
	........ppm........			%	cm	g/g
			May 2nd			
OO	1400	1000	550-2700	65%	40	12.9
MOO	45	45	0-130	93%	3	12.5
			May 7th			
OO	490	319	65-1400	90%	46	18.6
MOO	15	0	0-60	171%	3	22.9
			May 13th			
OO	180	115	60-500	88%	46	11.3
MOO	0	0	0-0	-	10	14.9
			May 22nd			
OO	170	130	74-420	76%	46	10.6
MOO	180	86	62-620	113%	20	16.8
			May 24th			
MOO	57	47	5-180	108%	15	7.9
MBM	0	0	0-0	-	0	9.8
MBG	0	0	0-0	-	0	10.3
MBP	0	0	0-0	-	0	7.1
			June 7th			
MOO	170	150	20-320	83%	15	14.5
MBM	0	0	0-0	-	0	9.4

Designations: **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **OO**=No Suppression; **CV**=Coefficient of variation.
#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 17 hours incubation
$=Soil moistures determined for soil cores in incubation jars, were not significantly different on any sampling date.

TABLE 31. 1985 ALFALFA INTERCROP: CORN POPULATION, HEIGHT AND YIELD

TREATMENT	POPULATION (Sept 16)	HEIGHT (Sept 16)	SILAGE EARS (Sept 28)	SILAGE STALKS (Oct 1)	SILAGE TOTAL
	Plants/ha	cm	...........Mg/ha.............		
MOO	51100	170 c	2.68 d	2.72 d	5.40 d
MB	56600	210 ab	6.60 c	4.61 bc	11.20 c
MBNe	48300	200 b	7.09 abc	4.70 abc	11.78 abc
MBN	50800	210 ab	6.77 bc	4.56 c	11.33 bc
MBM	52200	220 ab	8.13 abc	4.90 abc	13.04 abc
MBMN	55900	210 ab	7.50 abc	4.59 bc	12.08 abc
MBG	53700	220 ab	8.13 abc	4.83 abc	12.96 abc
MBGN	58300	210 ab	8.11 abc	5.11 abc	13.21 abc
MBP	56400	220 ab	8.28 abc	5.02 abc	13.30 abc
MBPN	58000	230 a	9.55 ab	5.70 abc	15.24 abc
MK	56100	230 a	9.63 a	6.20 ab	15.83 a
MKNe	55700	230 a	9.22 abc	6.24 a	15.47 ab
Sig. Level	ns	1%	1%	1%	1%
5% LSD	-	18	2.08	1.20	3.14
1% LSD	-	24	2.80	1.62	4.22

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the level indicated.

TABLE 32. 1985 ALFALFA INTERCROP: SILAGE MASS, MOISTURE AND N CONTENT

TREAT.	OVEN DRY MASS EARS	STALKS	TOTAL	MOISTURE EARS	STALKS	NITROGEN EARS	STALKS
	......kg/10 plants.......			..............%.................			
MOO	0.52 c	0.53 c	1.05 c	61 a	74	1.22 cd	1.37 a
MB	1.18 b	0.83 b	2.01 b	47 b	72	1.16 d	0.90 c
MBNe	1.46 ab	0.99 ab	2.45 ab	46 b	67	1.36 a-d	1.22 ab
MBN	1.39 ab	0.90 ab	2.29 ab	47 b	69	1.53 a	1.37 a
MBM	1.57 ab	0.95 ab	2.52 ab	45 b	70	1.37 abc	1.25 ab
MBMN	1.39 ab	0.86 ab	2.25 ab	48 b	70	1.37 abc	1.27 ab
MBG	1.51 ab	0.90 ab	2.41 ab	44 b	70	1.31 bcd	1.04 bc
MBGN	1.38 ab	0.87 ab	2.25 ab	46 b	69	1.47 ab	1.34 a
MBP	1.46 ab	0.89 ab	2.35 ab	45 b	70	1.33 a-d	0.97 c
MBPN	1.64 a	0.99 ab	2.63 ab	43 b	68	1.48 ab	1.27 ab
MK	1.72 a	1.11 ab	2.83 a	44 b	70	1.31 bcd	1.17 abc
MKNe	1.66 a	1.13 a	2.75 a	44 b	71	1.47 ab	1.30 ab
Sig.Level	1%	1%	1%	1%	ns	1%	5%
5% LSD	0.28	0.20	0.44	3	-	0.15	0.28
1% LSD	0.41	0.29	0.65	5	-	0.20	-

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the level indicated.

yields were not influenced by fertilizer nitrogen, the implication being that nitrogen was not limiting in this cultural system. Ear moistures indicate that corn from the unsuppressed plots was least mature at harvest (Table 32).

SUMMARY: The initial mowing in combination with water shortage, insect infestation and treatment stress, largely eliminated alfalfa from all but the least suppressed treatment (MOO). This is in stark contrast to 1984, when similar treatments failed to adequately suppress alfalfa. The two alflafa intercrops demonstrate the unpredictable nature of the proposed cropping system, and complicate recommendations. The maximum corn silage yield in suppressed alfalfa (MBPN treatment) was 93% of the highest yield in a completely killed legume in 1985, but only 16% of the ground surface was covered, this being mostly weeds. Even low levels of competition from alfalfa and weeds can be related to decreases in corn silage yield, but not to silage N%. Fertilizer nitrogen produced increases in silage N% but not in silage yield. The killed alfalfa can be credited with supplying enough nitrogen to the corn to maintain yields. High initial acetylene reduction rates in unsuppressed alfalfa decreased precipitously during May in response to environmental stress. Levels in singly mown alfalfa also fell, but were not eliminated. Acetylene reduction in doubly mown, glyphosate treated and paraquat treated alfalfa was eliminated along with the alfalfa.

(D2b).....1985 CROWNVETCH INTERCROP

VETCH: The vetch stand was sparse and a maximum of 7 cm tall when mown for weed control on May 2. When corn was planted on May 7 negligible vetch regrowth had occurred.

On June 7, twenty eight days after suppressants were applied, the killed plots (K) were virtually vetch and weed free. In paraquat treated plots, the few plants observed were prostrate and small. Quackgrass was endemic and broadleaf weeds were evident between the bands. The pre-plant mowing apparently favored weeds more than the vetch. Glyphosate treated and mown plots were similar to paraquat treated plots, with slightly more vetch visible. Bands were evident as broadleaf free zones, 30-35 cm wide. Quackgrass was a problem in the bands, as no residual herbicides with quackgrass activity were applied.

It was late July before vetch began to grow vigorously. On July 23, vetch in the control plots (MOO) was dense and up to 30 cm tall. Plots that were treated with glyphosate or paraquat still had sparse cover but vetch plants were up to 20 cm tall. Some vetch regrowth had even occurred in the killed plots (K). By August 8 all plots supported thick, twining vetch stands which had outgrown any weeds present.

Assessments on October 7 (Table 33) indicate that all treatments had high, and statistically equivalent amounts of vetch and weed cover. The relatively unsuppressed MOO treatment did however yield the most vetch. Weed populations were generally high, especially in paraquat treated plots. Nitrogen fertilizer was in all cases associated with a nonsignificant decrease in vetch yield.

TABLE 33. 1985 VETCH INTERCROP: GROUND COVER ASSESSMENT, 7 OCT. 1985

TREATMENT	VISUAL GROUND COVER	HARVESTED GROUND COVER		
		VETCH	WEEDS	WEED
	%	....g/m^2....		%
MOO	100	220	70	24
MB	100	140	120	46
MBNe	100	80	190	70
MBN	100	120	110	48
MBM	100	110	70	39
MBMN	100	90	120	57
MBG	100	140	100	42
MBGN	100	120	80	40
MBP	100	120	170	61
MBPN	100	40	200	83
MK	80	180	70	28
MKNe	100	90	120	57
Sig. Level	ns	ns	ns	ns

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression;

The acetylene reduction activity for the vetch intercrop is presented in Table 34. Mown vetch (MOO) sampled in June had lower activity levels than unmown vetch (OO), suggesting a reduction in activity level associated with removal of shoot material. When vetch was sampled in August, there were no clear differences in surface activity between the suppression treatments. Vetch had reappeared as young succulent plants in the killed plots (MK) by this date, and exhibited considerable activity in the surface layer. Samples taken below this (10-17.5 cm), had much lower activity levels. The concentration of activity near the surface in MK plots is consistent with development of new nodulated roots by new seedlings or regenerating crowns. Activity under mown vetch (MOO) was equivalent at both depths. Soil moisture did not vary between treatments on any of the sampling dates.

CORN: Populations presented in Table 35 range from 20,000 to 30,000 plants per hectare, the higher number being less than half of the planted level. The low populations were not related to treatment, and were probably caused by failure of the planter to place the seed at the appropriate depth in the wet soil (23% gravimetric moisture).

Silage yields per hectare (Table 35) were relatively low in the crownvetch intercrop, and were closely related to mass per plant. The low maximum yield in suppressed vetch (5.0 Mg/ha), was due in part to the low populations. Corn heights (Table 35) and silage yield per plant (Table 36) were influenced by both the degree of suppression and the application of fertilizer nitrogen.

Considering the effect of suppressants without the addition of nitrogen (MOO, MB, MBM, MBG, MBP ANN MK): The killed vetch treatment

TABLE 34. 1985 VETCH INTERCROP: C_2H_2 REDUCTION & SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION# MEAN	MEDIAN	RANGE	CV	SAMPLING DEPTH	SOIL MOISTURE$ CONTENT
	........ppm........			%	cm	g/g
				June 7th		
OO	187	87	23-420	94%	0-7.5	7.9
MOO	32	0	0-133	172%	0-7.5	9.1
				June 27th		
OO	336	65	8-1702	178%	0-7.5	8.1
MOO	4	0	0-29	246%	0-7.5	7.3
				August 8th		
MOO	24	10	0-77	133%	0-7.5	16.7
MBN	154	131	0-334	96%	0-7.5	14.6
MBM	117	106	0-252	101%	0-7.5	14.8
MBG	46	17	0-219	185%	0-7.5	16.2
MBP	40	12	0-177	173%	0-7.5	16.2
MK	244	285	0-345	68%	0-7.5	16.1
MOO	18	12	0-44	116%	10-17.5	15.5
MK	12	3	0-61	208%	10-17.5	15.2

Designations: **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **OO**=No Suppression; **N**=Nitrogen fertilizer applied in July; **CV**=Coefficient of Variation.

#=Ethylene concentrations developed in sealed jars containing acetylene and a soil core from the depth indicated, after 17 hours incubation

$=Soil moistures determined for soil cores in incubation jars, were not significantly different on any sampling date.

TABLE 35. 1985 VETCH INTERCROP : CORN POPULATION, HEIGHT AND YIELD

TREATMENT	POPULATION (Sept 27)	HEIGHT (Sept 27)	SILAGE EARS (Sept 27)	SILAGE STALKS (Sept 28)	SILAGE TOTAL
	Plants/ha	cm	...............Mg/ha		....
MOO	30100	120 e	0.15 c	0.57 d	0.72 e
MB	25800	130 de	0.42 c	0.58 d	1.00 de
MBNe	25800	170 abc	1.97 abc	1.72 a-d	3.69 a-d
MBN	27800	170 abc	1.92 abc	1.44 bcd	3.38 b-e
MBM	26300	140 cde	0.60 c	0.70 cd	1.30 cde
MBMN	29200	160 a-d	2.23 abc	1.55 bcd	3.78 a-d
MBG	28700	150 b-e	1.07 bc	1.31 bcd	2.38 b-e
MBGN	29200	170 abc	3.01 ab	1.99 ab	5.00 ab
MBP	29700	140 cde	0.84 bc	0.99 bcd	1.82 cde
MBPN	20600	160 a-d	1.92 abc	1.44 bcd	3.36 b-e
MK	21100	180 ab	2.27 abc	1.83 abc	4.10 abc
MKNe	19600	190 a	3.56 a	2.80 a	6.36 a
Sig. Level	ns	1%	1%	5%	5%
5% LSD	-	24	1.74	1.24	2.91
1% LSD	-	33	2.37	-	-

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the level indicated.

TABLE 36. 1985 VETCH INTERCROP: SILAGE MASS, MOISTURE AND N CONTENT

	OVEN DRY MASS			MOISTURE		NITROGEN	
TREATMENT	EARS	STALKS	TOTAL	EARS	STALKS	EARS	STALKS
	......kg/10 plants.......			..............%................			
MOO	0.05 e	0.19 e	0.24 f	68 a	69	1.49	1.29 a-e
MB	0.19 e	0.25 de	0.44 ef	58 b	69	1.25	1.01 cde
MBNe	0.77 bcd	0.68 bc	1.44 bcd	49 bcd	67	1.25	1.02 b-e
MBN	0.64 cde	0.49 cde	1.13 cde	53 b	72	1.33	1.38 a-d
MBM	0.22 e	0.26 de	0.48 ef	57 b	70	1.24	1.01 cde
MBMN	0.80 bcd	0.55 cd	1.35 bc	51 bcd	73	1.36	1.45 ab
MBG	0.36 de	0.44 cde	0.80 def	54 b	69	1.19	1.01 cde
MBGN	0.99 bc	0.66 bc	1.65 bc	50 bcd	70	1.30	1.43 abc
MBP	0.32 de	0.35 de	0.67 dfe	52 bc	69	1.20	0.97 de
MBPN	0.91 bc	0.70 bc	1.60 bc	68 a	69	1.34	1.55 a
MK	1.23 b	0.92 b	2.15 b	42 c	69	1.07	0.89 e
MKNe	1.99 a	1.47 a	3.46 a	43 cd	68	1.49	1.11 b-e
Sig.Level	1%	1%	1%	1%	ns	ns	1%
5% LSD	0.40	0.22	0.58	6	-	-	0.31
1% LSD	0.54	0.30	0.79	9	-	-	0.44

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least Significant Difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the level indicated.

(MK) produced the tallest and heaviest corn, and the mown-only treatment (MOO) produced the shortest and lightest. Plots which received suppressants in addition to being banded (MBM, MBG and MBP), produced slightly taller and heavier corn plants than the banded-only treatment (MB), but these were all intermediate between MK and MOO. At harvest, ears from the least suppressed plots (MOO) were at least 10% more moist than those from banded and partially suppressed plots, while ears from heavily suppressed plots (MK) had at least 10% less moisture (Table 36). Competition from the vetch had apparently delayed maturity. The same pattern was true for corn N%, although the extent of the differences varied.

The application of N consistently increased corn height and silage yield. Fertilizer N had no consistent effect on corn moisture but generally increased corn N. Nitrogen was apparenty limiting to corn production in the crownvetch intercrop. Application of N to mown plus banded vetch in June did not increase corn N%, while July application did (compare MBNe and MBN).

SUMMARY: As in 1984, crownvetch did not grow until July, weeds however did. If weeds could be controlled a competition free environment would exist during corn establishment. Vetch did grow vigorously after this date. Corn yields were depressed by vetch regrowth and the low corn population. Unlike the 1985 alfalfa intercrop, fertilizer nitrogen increased both corn N% and yield, suggesting that nitrogen was limiting in this intercrop. The highest corn yield in suppressed vetch (MBGN), was 30% of the highest yield in a killed legume in 1985. Acetylene reduction rates during July were lower in mown than in unsuppressed vetch.

(D2c).....1985 BIRDSFOOT TREFOIL INTERCROP

TREFOIL: The trefoil stand was actively growing but a maximum of 12 cm tall when corn was planted on May 7. Unsuppressed trefoil continued to grow vigorously, and was 20 cm tall on May 13 when mowing treatments were applied. at this date, the banding formulation had already resulted in prostrate yellow strips. By June 5, twenty six days after suppressants were applied, the unsuppressed trefoil was up to 40 cm tall and completely obscured corn seedlings. The corn in the banded-only plots was also obscurred from view. By contrast no trefoil was present in the killed plots. Bands were clearly evident in mown and glyphosate or paraquat treated plots, and trefoil had regrown to 12 cm in the mown plots. Some coarse trefoil stems in the paraquat and glyphosate treatments had survived and were shading the corn row. Trefoil, in plots which had received 2,4-D as a secondary suppressant four days earlyer, was wilted. Previously unsuppressed trefoil in banded plots (BT) had collapsed on the corn row in response to 2,4-D. The 2,4-D temporarily suppressed growth so that on June 27, mown plus 2,4-D treated trefoil was 18 cm tall, while mown trefoil was 30 cm tall.

A dense, twining trefoil stand, with mature seedpods, existed in the unsuppressed and banded-only plots on July 23. Seed had set but pods were still green in glyphosate, paraquat and mown plots. In these treatments, trefoil was 15, 25 and 46 cm tall respectively, and was overgrowing the bands. Maturity had been delayed and the stand was shorter in plots which received 2,4-D. No trefoil was present in killed plots.

Visual assesssment of ground cover on October 12 indicates that only the lethal treatment (K) had reduced cover (Table 37). Quadrats cut on the same day demonstrate that some trefoil regrowth had occurred in the killed plots but this was negligible. Trefoil yields in the mown, glyphosate and paraquat treatments were less than in the unsuppressed treatment. Weed populations on this date and throughout the season were low and not treatment dependent.

Acetylene reduction activity data for the trefoil intercrop is presented in Table 38 along with soil moisture values determined for these samples. As in 1984, activity in the trefoil stands was considerably higher than in the alfalfa and vetch. The May sampling indicates that the primary suppressants, especially glyphosate and paraquat, had reduced the activity level relative to the high level in unsuppressed (OO) plots. This high activity level in unsuppressed plots was not duplicated in any of the June samplings. Of the treatments sampled on June 5, only samples from the mown plus 2,4-D plots (BMT) had a clearly reduced activity level. Note that they also had the shortest trefoil. Excessive spatial variability prevented meaningful statistical analyses. The June 27 data suggests that the mown-only treatment (BM) had less activity than the BMT treatment, possibly due to 2,4-D delaying maturity. Reduction activity was not related to soil moisture and soil moisture was not related to treatment.

CORN: Despite the reseeding, final corn population was influenced by treatment, the two least suppressed treatments (OO and BN) producing the lowest population (Table 39). The average population for the experiment was 44,000 plants per hectare, well below the

TABLE 37. 1985 TREFOIL INTERCROP: GROUND COVER ASSESSMENT, 12 OCT 1985

TREATMENT	VISUAL GROUND COVER	HARVESTED GROUND COVER		
		TREFOIL	WEEDS	WEED FRACTION
	%	...g/m^2...		%
OO	100 a	380 a	40	10
BT	100 a	370 ab	10	3
BN	100 a	410 a	70	15
BTNe	100 a	290 abc	50	15
BMN	100 a	130 cd	60	32
BMTN	90 a	220 a–d	50	19
BGN	100 a	220 a–d	30	12
BGTN	100 a	260 abc	20	7
BPN	100 a	280 abc	30	10
BPTN	100 a	150 bcd	50	25
K	20 b	40 d	10	20
KNe	10 b	10 d	40	80
Sig.Level	1%	1%	ns	-
5% LSD	10	160	-	-
1% LSD	14	217	-	-

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **T**=2,4-D amine; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least significant difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the level indicated.

TABLE 38. 1985 TREFOIL INTERCROP: C_2H_2 REDUCTION & SOIL MOISTURE DATA

TREATMENT	ETHYLENE CONCENTRATION # MEAN	MEDIAN	RANGE	CV	ALFALFA HEIGHT AT SAMPLING	SOIL MOISTURE $ CONTENT
	........ppm........			%	cm	g/g
				May 24th		
OO	680	305	64-2739	150%	35	7.1
BM	423	322	51-1319	322%	8	7.7
BG	282	249	6-633	81%	20	8.2
BP	182	157	16 358	67%	20	8.3
				June 5th		
OO	178	108	11-541	116%	46	7.7
BT	113	84	0-344	108%	30	7.3
BMT	32	34	7-55	52%	10	8.6
BGT	94	109	0-173	80%	30	10.9
BPT	170	34	13-525	134%	30	8.3
				June 7th		
OO	68	66	4-161	85%	50	6.1
BM	71	29	0-292	156%	13	8.1
BMT	41	42	10-68	75%	10	9.7
				June 27th		
OO	66	31	4-203	112%	46	5.2
BM	8	2	0-49	213%	30	7.1
BMT	42	14	0-182	146%	20	6.4

Designations: **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **OO**=No Suppression; **T**=2,4-D amine; **CV**=Coefficient of variation.
#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 17 hours incubation
$=Soil moistures determined for soil cores in incubation jars, were not significantly different on any sampling date.

TABLE 39. 1985 TREFOIL INTERCROP: CORN POPULATION, HEIGHT AND YIELD

TREATMENT	POPULATION (Sept 16)	HEIGHT (Sept 16)	SILAGE EARS (Sept 27)	SILAGE STALKS (Sept 28)	SILAGE TOTAL
	Plants/ha	cm	............Mg/ha		....
OO	17700 c	140 e	0.24 e	0.47 c	0.71 c
BT	44000 ab	170 d	1.97 cde	1.83 bc	3.80 bc
BN	32500 bc	170 d	1.49 de	1.81 bc	3.30 bc
BTNe	41100 ab	190 bcd	3.26 cde	3.02 b	6.28 b
BMN	53100 a	180 cd	3.97 cd	2.88 b	6.85 b
BMTN	44000 ab	190 bcd	4.80 cd	2.87 b	7.67 b
BGN	42600 ab	180 cd	4.29 cd	2.54 bc	6.83 b
BGTN	47400 ab	170 d	5.32 bc	3.14 b	8.46 b
BPN	43100 ab	170 d	3.12 cde	2.10 bc	5.22 bc
BPTN	46500 ab	200 abc	4.32 cd	3.31 b	7.63 b
K	53100 a	220 a	8.54 ab	5.70 a	14.24 a
KNe	56900 a	210 ab	9.70 a	6.75 a	16.45 a
Sig. Level	5%	1%	1%	1%	1%
5% LSD	18960	18	2.66	1.58	4.00
1% LSD	-	24	3.61	2.15	5.43

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **T**=2,4-D amine; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least significant difference; Numbers within a column with the same postscript or without a postscript are not significantly different at the significance level indicated.

planted level of 66,000 seeds per hectare.

As with all other experiments clear differences in height and mass per plant existed between corn in killed trefoil (K) and unsuppressed trefoil (OO). Corn height (Table 39) and mass (Table 40) were not influenced by type of primary suppressant. All primary suppressants produced corn plants only slightly taller and heavier than banding-alone (BN). At the final harvest, corn-ear moisture and N% were highest in the unsuppressed trefoil (OO). This suggests a difference in corn maturity associated with the degree of trefoil competition. The use of 2,4-D as a secondary suppressant resulted in a small, nonsignificant increase in both corn height and yield per plant, in all but the glyphosate treated plots. Moisture and N% were not influenced by the secondary suppressant.

The only fertilizer N comparisons are for the banded plus 2,4-D treatments (BT) and the killed trefoil treatments (K). Fertilizer N, when applied in June (Ne), increased corn height in BT plots but did not in K plots (Table 39). A less pronounced effect is evident in silage mass per plant at harvest (Table 40). The difference in response to fertilizer N may be due to greater release of organic N from the highly stressed trefoil nodules in K plots than from the less stressed nodules in BT plots. Fertilizer N had no effect on silage moisture content, and little effect on N%.

SUMMARY: Birdsfoot trefoil was actively growing but did not require mowing prior to corn planting. In 1985 it was the only legume which grew in May and June. Weeds were never a problem due to the lush, early trefoil growth. Banding enhanced corn populations and yields. The primary suppressants, while temporarily clearing the

TABLE 40. 1985 TREFOIL INTERCROP: SILAGE MASS, MOISTURE AND N CONTENT.

	OVEN DRY MASS			MOISTURE		NITROGEN	
TREAT.	EARS	STALKS	TOTAL	EARS	STALKS	EARS	STALKS
	......kg/10 plants.......			..............%.................			
OO	0.07 d	0.18 d	0.25 d	59 a	68	1.91 a	1.36
BT	0.44 cd	0.40 cd	0.84 cd	52 abc	70	1.26 b	1.32
BN	0.48 cd	0.58 c	1.06 bc	56 ab	69	1.57 ab	1.74
BTNe	0.76 bc	0.73 bc	1.49 bc	53 abc	69	1.30 b	1.47
BMN	0.75 bc	0.55 c	1.30 bc	50 bcd	68	1.44 b	1.68
BMTN	1.02 b	0.66 c	1.68 b	48 bcd	68	1.39 b	1.43
BGN	1.01 b	0.59 c	1.60 bc	47 cd	70	1.39 b	1.54
BGTN	0.94 bc	0.61 c	1.55 bc	49 bcd	70	1.41 b	1.56
BPN	0.68 bc	0.50 cd	1.18 bc	53 abc	69	1.42 b	0.65
BPTN	0.77 bc	0.58 c	1.35 bc	49 bcd	69	1.28 b	1.58
K	1.60 a	1.08 ab	2.68 a	45 cd	71	1.32 b	1.22
KNe	1.70 a	1.22 a	2.92 a	43 d	68	1.51 b	1.37
Sig.Level	1%	1%	1%	5%	ns	1%	ns
5% LSD	0.38	0.26	0.56	8	-	0.27	-
1% LSD	0.52	0.36	0.76	-	-	0.37	-

Designations: **K**=Killed; **B**=Killed band; **M**=Mown; **G**=Glyphosate; **P**=Paraquat; **T**=2,4-D amine; **Ne**=Nitrogen fertilizer applied in June: **N** Nitrogen fertilizer applied in July; **OO**=No Suppression; **LSD**=Least significant difference. Numbers within a column with the same postscript or without a postscript are not significantly different at the significance level indicated.

ground cover, did not control regrowth, all plots being overgrown by the end of July. Use of the primary suppressants in conjunction with banding only slightly increased corn yield per plant compared to banding alone. When 2,4-D was applied as a secondary suppressant it delayed trefoil regrowth, producing a small increase in silage yield. Both corn silage moisture and N% were higher in unsuppressed trefoil than in suppressed trefoil, suggesting a relationship between corn maturity and competition. A difference in the extent of organic N release is implied by the slightly greater corn yield response when fertilizer N was applied to suppressed, compared to killed trefoil. The highest corn yield in suppressed trefoil (BGTN) was 51% of the highest yield in a killed legume in 1985. Acetylene reduction rates in the surface cores sampled, were higher than in any other legume sampled in 1985. Primary suppressants had reduced the rate in May, while on June 27 the application of 2,4-D as a secondary suppressant to mown plots was associated with a higher rate than in mown-only plots.

D3. ALFALFA HERBICIDE TOLERANCE EXPERIMENT

At the start of the experiment alfalfa was 20-30 cm tall and appeared to have recovered from earlier weevil damage. The gravimetric soil moisture was 9% and the alfalfa nodules exhibited relatively high acetylene reduction activity (Table 42, June 20). On the day after spraying, only the paraquat and 2,4-D treated plots exhibited herbicide damage. Three days later herbicide symptoms were well advanced. While the low glyphosate rate (G1) had not visibly damaged alfalfa, the two higher rates (G2 and G3) had induced wilting and partial collapse. The three paraquat treatments had produced a range of symptoms ranging from partial leaf burn (low rate, P1), to complete burn and collapse (high rate, P3). Likewise the 2,4-D plots varied according to rate. Only very slight deformation was evident in the plots treated with the two lower 2,4-D rates (T1 and T2), but the high rate (T6) had induced collapse of the canopy. Of the atrazine treatments, only the high rate (A3) had induced slight chlorosis. Addition of crop oil to atrazine had increased the amount of chlorosis. Alfalfa in atrazine plus alachlor (A1L) and simazine plus alachlor (SL) plots was indistinguishable from that treated with the high rate of atrazine (A3). The extent of suppression in atrazine plus glyphosate (A1G1), atrazine plus paraquat (A1P1) and atrazine plus 2,4-D (A1T2) plots was dependent on the amount of glyphosate, paraquat and 2,4-D applied.

By July 1 the two highest glyphosate treatments (G2 and G3) had largely eliminated the alfalfa, but small deformed plants were still visible. All paraquat treated plots were already growing back. The two lowest 2,4-D treatments (T1 and T2), had produced very little effect. Alfalfa in atrazine treated plots exhibited burnt leaf edges, the addition of crop oil having enhanced this.

The quantitative visual assessment presented in Table 41 generally agree with the previous qualitative observations. Atrazine-only had not influenced any of the yield parameters. Glyphosate at the two higher rates (G2 and G3) had greatly reduced alfalfa height, ground cover and alfalfa flowering fraction, while increasing the weed fraction. The weeds present were predominantly seedling broadleaf plants, which if fully grown would have constituted a much larger portion of the ground cover. The Paraquat rates had delayed the maturity of alfalfa but had not greatly influenced ground cover or weed fraction on this date. Effects of 2,4-D were very rate dependent, the two lower rates (T1 and T2) having very little effect. The high 2,4-D rate (T6) gave equivalent alfalfa control to the high glyphosate rate (G3), but due to a heavy grass weed population, the amount of ground cover in T6 plots was more than twice that in G3 plots. The atrazine plus glyphosate (A1G1), atrazine plus paraquat (A1P1) and atrazine plus 2,4-D (A1T2) treatments had little effect as the glyphosate, paraquat and 2.4-D rates were on the low end of their activity spectrums. Likewise the atrazine plus alachlor (A1L) and simazine plus alachlor (SL) treatments had little effect.

Acetylene reduction data for soil surface samples are presented in Table 42. Of the ten treatments sampled on July 4, two weeks after treatment, activity was detected only in unsuppressed alfalfa (00), and in the plots treated with the low atrazine rate (A1). These values were themselves very low compared to the unsuppressed alfalfa on June 20. The very low soil moisture (average of 4.2%), indicates that

TABLE 41. HERBICIDE TOLERANCE STUDY: VISUAL ASSESSMENTS, 1 AUG. 1985

TREATMENT	ALFALFA HEIGHT	GROUND[$] COVERED	WEED[$$] FRACTION	FLOWERING[#] FRACTION
	cm	%	%	%
OO	50	90	10	90
G3	27	40	23	3
G2	30	55	24	16
G1	43	80	4	65
P3	38	84	6	28
P2	37	84	9	26
P1	43	80	6	63
T6	31	83	55	38
T4	35	75	20	48
T2	46	94	9	59
T1	49	90	24	89
A3	52	87	14	78
A2	50	93	16	78
A1	48	92	24	86
A1G1	43	84	6	50
A1P1	43	84	3	53
A1T2	41	86	26	51
A2C	48	92	16	80
A1L	52	92	10	48
SL	50	90	11	68

Designations: **OO**= No suppression; **G**=Glyphosate; **P**=Paraquat; **T**=2,4-D amine; **A**=Atrazine; **L**=Alachlor; **S**=Simazine. Numbers following letter designators indicate the rate applied, as a multiple of the lowest rate.

$=Percentage of the ground surface visually assessed as covered by living vegetation

$$=Percentage of the ground cover visully assessed to be weeds.

#=Percentage of alfalfa plants visually assessed as in full bloom.

TABLE 42. HERBICIDE TOLERANCE STUDY: C_2H_2 REDUCTION IN SURFACE CORES

TREATMENT	ETHYLENE CONCENTRATION# MEAN	MEDIAN	RANGE	CV	SOIL MOISTURE$ CONTENT
	.........ppm..........			%	g/g
			June 20th		
OO	102	54	30-424	128	9.0
			July 4th		
OO	9	5	0-25	117	4.1
G3	0	0	0-0	-	4.5
P3	0	0	0-0	-	4.5
T6	0	0	0-0	-	4.0
A3	0	0	0-0	-	4.5
A2	0	0	0-0	-	4.3
A1	2	0	0-9	217	4.6
A2C	0	0	0-1	250	4.2
A11	0	0	0-0	-	4.1
SL	0	0	0-0	-	3.6
			July 23rd		
OO	52	22	0-171	128	7.2
G3	2	0	0-7	187	9.6
P3	7	1	0-38	224	7.8
T6	2	0	0-9	245	8.6
A3	3	1	0-10	145	7.8
Mown	14	2	0-71	198	7.0
			August 16th		
OO	21	8	0-97	182	15.4
P3	12	7	0-29	104	15.7
T6	28	2	0-112	164	14.9
A3	6	1	0-27	182	13.9
A1L	22	11	0-56	123	14.5
SL	9	10	0-18	87	14.6
Mown	17	2	0-94	217	15.4

Designations: **OO**= No suppression; **G**=Glyphosate; **P**=Paraquat; **T**=2,4-D amine; **A**=Atrazine; **L**=Alachlor; **S**=Simazine. Numbers following letter designators indicate the rate applied, as a multiple of the lowest rate. All herbicides were applied on June 20th.The area from which mown samples were obtained was mown on July 1st and again on August 8th.

#=Ethylene concentrations developed in sealed jars containing acetylene and a surface soil core (0-7.5cm), after 17 hours incubation

$=Soil moistures determined for soil cores in incubation jars.

conditions were far from ideal for fixation. On July 23 both the soil moisture and the acetylene reduction activity had increased. Unsuppressed alfalfa exhibited far more activity than any other treatments sampled, but as usual, a great deal of variability was present. Activity in the mown borders was slightly greater than in the chemically treated plots, despite ten extra days recovery period for the treated plots. Heavy rain on August 15 preceded the last surface sampling date, consequently soil moistures were on average of 14.9% by volume. All herbicide treated plots sampled had recovered additional activity, and no distinct differences were discernible. Glyphosate treated plots were not sampled on this date as very few alfalfa plants survived in plots receiving the high rate of glyphosate (G3).

As the acetylene reduction activity of surface soil was very low and extremely variable, it was decided to take samples at a greater depth. Figure 11 presents the findings of the preliminary investigation. A peak of activity occurred between 20 and 30 cm deep. This corresponded to the boundary between the sandy loam surface soil and underlying sandy clay. Root nodules and reduction activity decreased rapidly below this boundary.

When acetylene reduction samples were systematically taken from unsuppressed, mown, paraquat treated and atrazine treated alfalfa on August 27, the same pattern was borne out. Samples from these treatments respectively had 18%, 9%, 4% and 6% of their activity in the surface 7.5 cm (Figure 12 and Table 43). All treatments had at least 60% of their activity between 7.5 and 23 cm deep, below which the activity levels fell precipitously. In the mown alfalfa, 62% of the activity occurred between 15 and 23 cm deep. Neither mowing nor

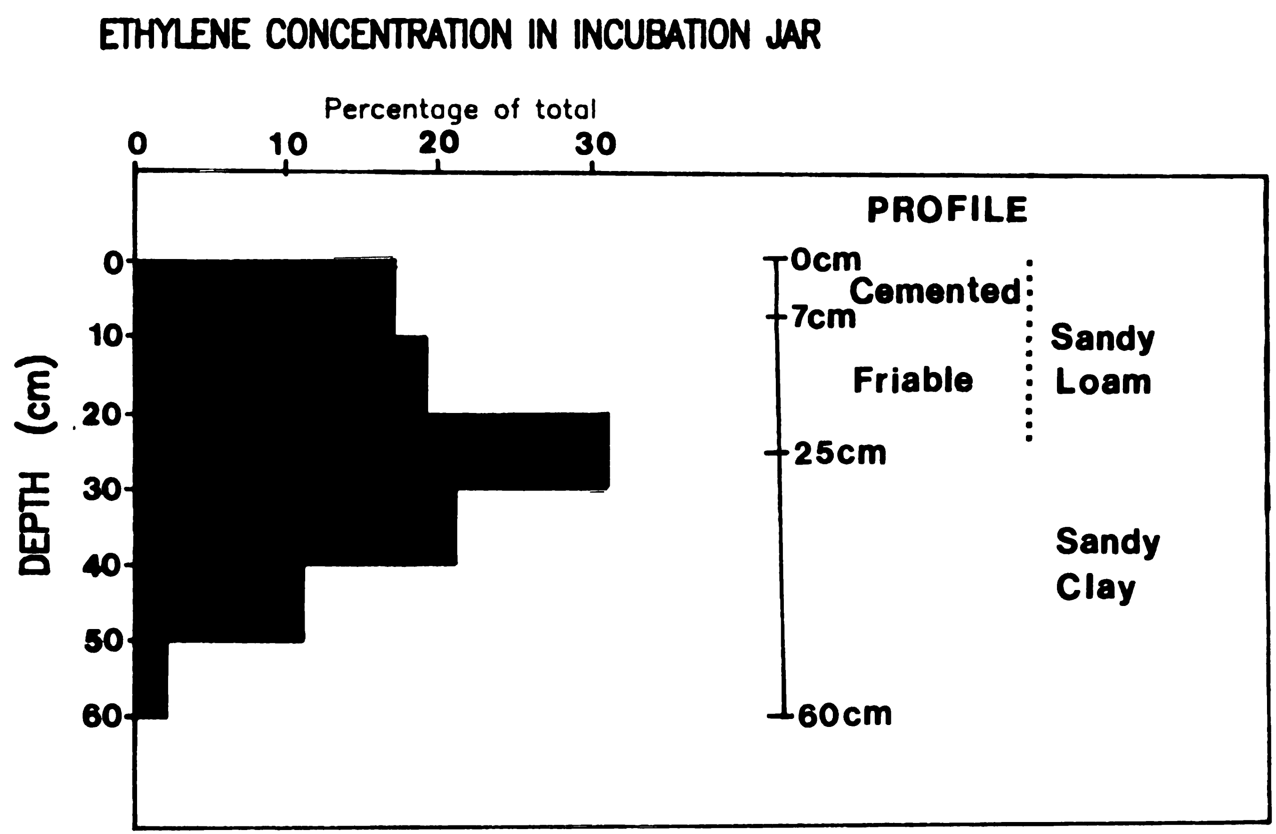


FIGURE 11 ACETYLENE REDUCTION ACTIVITY AT SIX DEPTHS IN A MONOLITH REMOVED FROM AN ALFALFA FIELD, AUG.22

TABLE 43. HERBICIDE TOLERANCE STUDY: C_2H_2 REDUCTION AT SIX DEPTHS.

TREATMENT	ETHYLENE CONCENTRATIONS DEVELOPED AT DEPTHS INDICATED#						
	0-8cm	8-15cm	15-23cm	23-30cm	30-38cm	38-46cm	Total
	ppm						
OO	51	80	90	18	16	0	286 bc
P3	23	280	297	34	9	10	652 a
A3	10	37	100	26	5	1	179 c
Mown	42	91	304	32	13	2	483 ab

Designations: **OO**= No suppression; **P**=Paraquat; **A**=Atrazine. Numbers following letter designators indicate the rate applied, as a multiple of the lowest rate. All herbicides were applied on June 20th. The area from which mown samples were obtained was mown on July 1st and again on August 8th.
#=Ethylene concentrations developed in sealed jars containing acetylene and a soil cube (7.5cm), after 21 hours incubation. Values are means of eight incubation jars, sampled August 27th. Numbers within a column with the same lower case postscript are not significantly different at the 5% level.

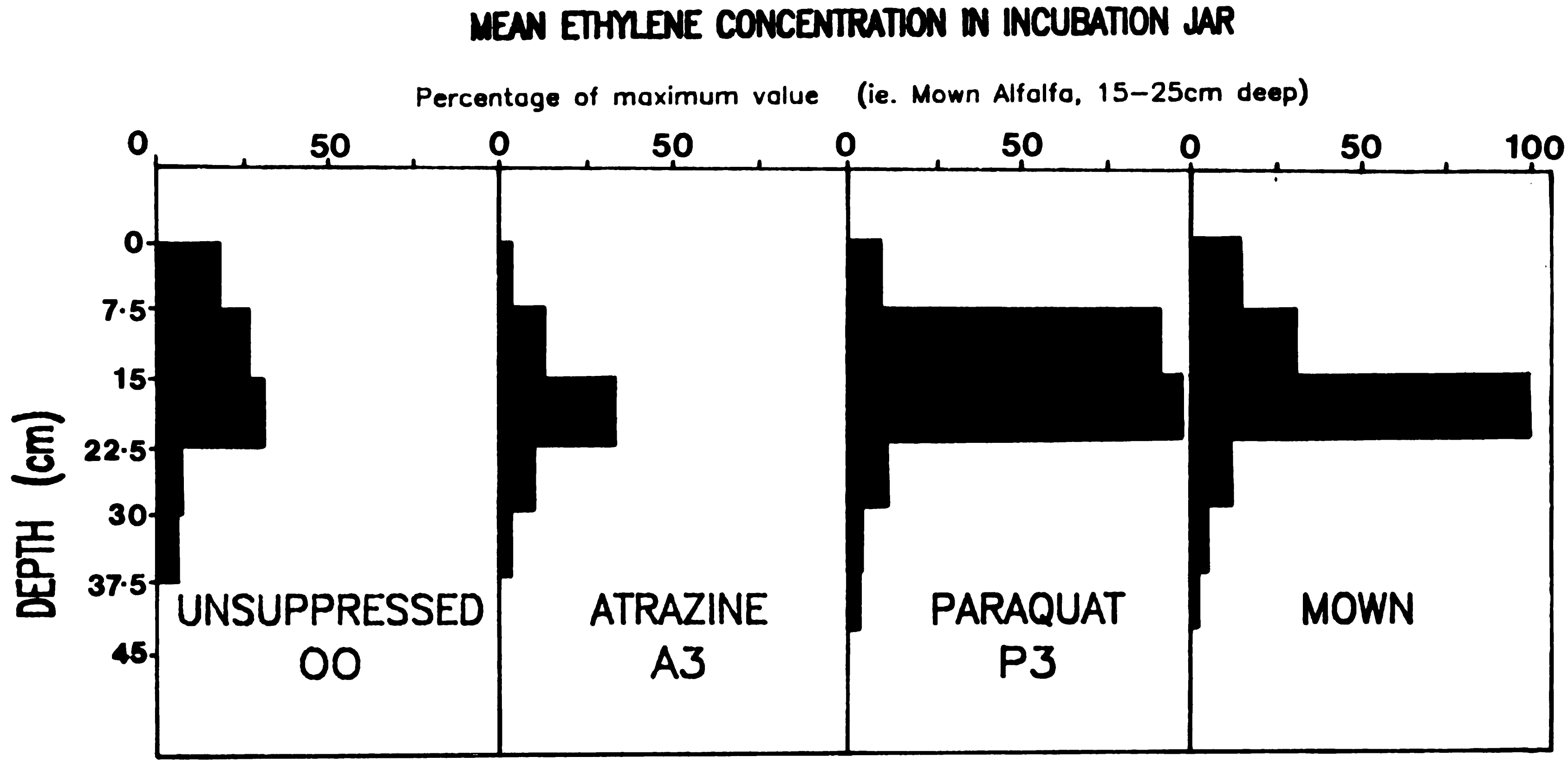


FIGURE 12 HERBICIDE TOLERANCE STUDY: ACETYLENE REDUCTION ACTIVITY IN FOUR TREATMENTS AT SIX DEPTHS, AUG.27

paraquat had permanently decreased the acetylene reduction activity. Levels in the atrazine treated plots were low but comparable to unsuppressed alfalfa. As well as having the highest percentage of activity in the surface layer, the unsuppressed plots had the highest absolute value in this region. Alfalfa in unsuppressed and atrazine treated plots was flowering on the sampling date, while mown and paraquat treated alfalfa was vegetative. This difference in maturity possibly explains the rate differences.

SUMMARY: The major insight gained from this experiment concerns depth of sampling for acetylene reduction analysis. All treatment sampled to depth had at least 60% of their activity between 7.5 and 30 cm deep. Clearly, surface sampling is not at all representative of the total solum activity. In this soil, sampling to 25 cm would account for at least 80% of the total reduction activity. The surface samples taken indicate that acetylene reduction rates were low and variable but were not permanently eliminated by our high paraquat and 2,4-D rates. Neither were they eliminated by the labled rates of atrazine plus alachlor and simazine plus alachlor applied.

As far as rates are concerned, the high rates of paraquat and atrazine can be applied to unstressed alfalfa, with no adverse effects two months later. The high 2,4-D rate (T6) resulted in only 37% of the ground surface being covered in alfalfa and 46% in grass weeds. If permanent reduction in alfalfa stand is desired, this rate could be used but must be coupled with a grass herbicide. The same was true for the second glyphosate rate (G2), broadleaf weeds being the problem in this case. Simazine and alachlor rates had little influence on alfalfa growth.

CONCLUSIONS

RESULTS: At the lower Michigan location, alfalfa and red clover produced active growth prior to corn planting in early May. Birdsfoot trefoil began growing in May. Crownvetch did not start growing until July, at which time a large weed population had developed.

Efforts to produce corn in living legume swards resulted in large reductions in the yield of one or both components. When more than 50% of the ground cover was retained, the maximum corn silage yield was 74% of the highest yield in chemically killed sod. This occurred in the paraquat-only treatment (P) of the 1984 clover intercrop. Corn yields were usually much lower, the average yield in suppressed sods being only 28% of that in chemically killed sod. Low corn yields can be attributed to one of the following:

1. Inadequate initial legume suppression due to inappropriate herbicide rates or adverse weather conditions. Corn seedlings could not grow through the dense canopy.
2. Herbicide induced collapse of tall legume plants onto the seed slot, and the resulting inhibition of corn emergence.
3. Pest damage associated with rodents and insects resident in the forage sod.
4. Legume regrowth following adequate temporary suppression, and the

resulting competition for soil resources (water, nutrients).

Low legume survival was associated with:

1. The reapplication of systemic herbicides, made necessary by inadequate initial suppression.
2. Unforseen additional stress in the form of insect infestation and water shortage.

Predictable suppression was not achieved with glyphosate and 2,4-D. Paraquat and mowing gave reliable early suppression and frequently featured in treatments producing the higher corn and legume yields. No foliar absorbed herbicide gave acceptable season long control. Banding was associated with increases in corn population and yield. The amenity of bands was reduced by failure to ensure adequate contact between spray and leaves, and failure to control perennial weeds in the band.

Weeds became a problem when ground cover was temporarily removed. Herbicides for weed control must be assessed in terms of their effect on legume growth. When atrazine was applied to actively growing alfalfa at up to 3.46 kg/ha a.i., growth was not greatly influenced. As a smaller rate than this is labelled for killing alfalfa sod (in combination with 2,4-D ester), caution must be exercised when applying atrazine to stressed alfalfa. Alachlor plus simazine rates recommended for no-till corn production were also used in alfalfa, crownvetch and birdsfoot trefoil stands without visually damaging the legume.

There was no evidence supporting the hypothesis that corn obtained nitrogen from an actively growing legume. Response to fertilizer N suggests that N is transferred from associated legumes only when the legume is severely repressed. In the 1985 alfalfa intercrop, where practically all the alfalfa had been killed, corn yield was not influenced by fertilizer nitrogen. The N% of corn tissue suggests that actively regrowing legumes can deplete the soil N pool.

Results of acetylene reduction analyses of N fixation in surface samples, were extremely variable and not representative of the profiles N fixing potential. Under afalfa sod, a peak of activity occurred between 15 and 25 cm deep.

RECOMMENDATIONS: Within the framework of investigated techniques, and using recommended rates of commonly available herbicides (Kells, 1986), the system which would give the best combination of corn yield and late season legume regrowth, includes the following steps:

1. If quackgrass is anticipated to be a problem, apply pronamide in the previous fall at the recommended rate for established alfalfa sods (1.68 kg/ha a.i). Removal of perennial weeds prior to the year of intercropping appears essential for success, as any measures taken later will also eliminate the legume.
2. Mow prior to planting corn if it is anticipated that the legume will be more than 15 cm tall on the proposed planting date. Paraquat may be used instead of mowing. The objectives here are to eliminate the risk of tall plants collapsing onto the corn row when eventually suppressed, and to remove pest habitat. This operation should be carried out approximately two weeks prior to planting, to allow for removal of the cuttings, application of residual herbicides and,

regrowth of the legume.

3. As soon as possible after mowing apply residual, soil active herbicides for annual weed control. Recommended rates for control of annual broadleaves and grasses in corn should not permanently damage the perennial legumes. Simazine (1.12 - 2.24 kg/ha a.i) plus alachlor (2.8 kg/ha a.i), or another recommended grass herbicide (butylate, cyanazine, metolachlor, pendimethalin) would be appropriate. Ideally the mixture chosen should also inhibit legume regrowth.

4. At planting time establish 30 cm wide killed legume bands using nozzles attached in front of each planting shoe. If negligible regrowth has occurred since mowing, atrazine (2.24 kg/ha a.i) should ensure a killed strip. If leafy material is present include 2,4-D ester (1.4 kg/ha a.i), or glyphosate when grass weeds have persisted (1.26 kg/ha a.i). The positioning of the spray nozzles in front of the planting shoes ensures that foliar absorbed herbicides are applied to leaves and not to a bare strip temporarily created by the shoe.

5. Apply a starter fertilizer to the corn, including a nitrogen component to enhance the corn seedlings chances of outgrowing the legume.

6. Directed or broadcast sprays of 2,4-D amine can be applied after corn emergence if legume regrowth is thought excessive. The rate depends on the legume species and the corn growth stage. A single application of 0.28 kg/ha a.i. should temporarily suppress, when applied under suitable weather conditions.

Another recommendation concerns monitoring N fixation using acetylene reduction. Samples must be taken to 25 cm in order to be representative of the total profile. The literature suggests that one inch (2.54 cm) diameter cores are satisfactory, as long as several are bulked to account for soil heterogeneity.

FUTURE RESEARCH: Although the concept of corn and forage legumes growing together has many attractions, the methods necessary for success are often antagonistic, and the correct technology has not as yet been identified. To produce economical corn yields in an established forage legume, a suppressant must be identified which arrests legume growth and reduces its resource requirements. The erosion risk would also be reduced by the presence of a dormant mat of vegetation. While overcoming problems of competition and erosion, such an approach does not solve the pest problems inherent in a complex ecosystem. If pests are to be controlled, consideration should be given to removing the legume cover, at least during the initial corn growth stages. Likewise, appreciable nitrogen transfer will only occur if the legume is killed or heavily suppressed. Suitable suppressants have not been identified. The ideal suppressant should completely subdue the legume during corn establishment, have residual activity, and have a large margin of error, that is, the lethal rate should far exceed the suppressing rate. It is unlikely that all requirements will be met by a single product. Mowing or paraquat have potential if combined with a suitable residual herbicide. Further research should be directed towards identifying suitable residual suppressants from a wide range of chemicals (herbicides, growth retardents, fertilizers).

Another tactic would be to identify a legume that grows during the cool spring and fall months but is dormant during summer. When managed as a winter cover crop, such a legume would satisfy our N fixation and ground cover objectives. The probability of success with this strategy decreases as the length of the growing season decreases, and the opportunity for spring and fall growth decreases.

Research is needed to determine if stressing legumes induces loss of nitrogenous compounds to the soil, and if such a nitrogen source can be utilized by associated corn in the same growing season. Glasshouse experiments with $_{15}N$ would provide the neccessary precision and controlled conditions.

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