IMPROVING FERTILIZER NITROGEN USE EFFICIENCY USING ALTERNATIVE LEGUME INTERSEEDING IN CONTINUOUS CORN PRODUCTION SYSTEMS

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INTRODUCTION

This experiment was conducted to evaluate legume interseeding in continuous corn production systems as alternative practices for improved nitrogen use efficiency. The objectives were to determine the benefits of corn canopy reduction on the growth of fall interseeded legume cover crops, and to evaluate the effect of interseeded legume species and nitrogen rates combined with canopy reduction on corn grain yield and grain protein.

This thesis is presented in a format suitable for publication in a professional journal.

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ABSTRACT

Many alternative management systems have been evaluated for corn (*Zea mays* L.), soybeans (*Glycine max* L.), and wheat (*Triticum aestivum* L.) production, however, most have involved rotations from one year to the next. Legume interseeding systems which employ canopy reduction techniques in corn have not been thoroughly evaluated. One study was initiated in 1994 at the Panhandle Research Station near Goodwell, OK, on a Richfield clay loam soil, to evaluate five legume species: yellow sweet clover (*Melilotus officinalis* L.), subterranean clover (*Trifolium subterraneum* L.), alfalfa (*Medicago sativa* L.), arrowleaf clover (*T. vesiculosum* L.) and crimson clover (*T. incarnatum* L.) interseeded into established corn. In addition, the effect of removing the corn canopy above the ear (canopy reduction) at physiological maturity was evaluated. Canopy reduction increased light interception beneath the corn thus enhancing legume growth in late summer, early fall, and early spring the following year prior to planting. Legumes incorporated prior to planting were expected to lower the amount of inorganic nitrogen fertilizer needed for corn production. Crimson clover appeared to be more shade tolerant than the other species evaluated. Grain yields were not affected by removing the tops at

physiological maturity when compared to conventional management. Following two years, no response to applied N as fertilizer or incorporated green manure legumes was observed. Added time will be required to evaluate these practices at this site where residual soil N was high.

INTRODUCTION

Over the past 20 years, various researchers have evaluated intercropped legumes for increased N supply in corn (*Zea mays* L.) production. As sources of inorganic nitrogen fertilizer become less dependable and prices increase, organic forms, particularly legumes, are being considered as alternative sources for non-legume crops. Dalal (1974) noted that corn and pigeon pea (*Cajanus cajan* L.) yields were reduced when intercropped compared to that grown alone, although the combined yield exceeded that of either monoculture. Searle et al. (1981) stated that corn grain yield was not affected by legume intercrop, indicating neither competitive depression nor nitrogen transfer from the legume. Nair et al. (1979) demonstrated that intercropping corn with soybeans increased yield 19.5% when compared to monoculture corn. Scott et al. (1987) noted yields following medium red clover (*T. pratense* L.) were equivalent to the addition of 17 kg ha^{-1} fertilizer-N. Coultas et al. (1996) reported that velvet bean (*Mucuna pruriens* L.) intercropping did not have a positive effect on corn grain yields, but they did obtain some indication that velvet bean intercropping reduced weed populations.

Multiple cropping systems are productive, economical and nutritionally beneficial compared to monocultures. They also provide other benefits such as greater income stability, reduced weed pressure and reduced susceptibility to soil erosion especially in small farming systems (Wade and Sanchez, 1984). Growing dual-purpose grain legumes in rotation with cereals always increases the yield of the latter (Haque and Jutzi, 1994). Land Equivalent Ratios (LER) also increased with intercropping, providing greater productivity per unit of land than monoculture production systems (Allen and Obura, 1983). Partial LERs of corn increased with increasing nitrogen while partial LERs of soybean decreased, indicating a progressive increase in the relative competitive ability of corn. Mohamed et al. (1994) reported the highest LER was obtained with interplanting corn between cotton rows at 30 cm spacing and supplied with 120 kg N/feddan (0.42 ha). Intercropping winged bean (*Psophocarpus tetragonolobus* L.) with early corn produced 14% more biomass and 39% more N per hectare than did the corn monoculture (Hikam et al. 1992).

Even though intercropping usually includes a legume, applied nitrogen may still confer some benefits to the system as the cereal component depends heavily on nitrogen for maximum yield (Ofori and Stern, 1986). Chowdhury and Rosario, (1993) found that intercropping corn with mungbeans (*Vigna radiata* L.) increased yields 71% when the N application rate was increased from 0 to 90 kg/ha. Ebelhar et al. (1984) reported with no fertilizer N applied, there was an increase in corn grain yield from 2.5 to 6.2 Mg ha^{-1} with hairy vetch (Vicia villosa L.) treatment compared with corn residue. Corn yields increased 62% with applied N (0 versus 120 kg N ha^{-1}). Cowpea (*V. unguiculata* L.) yields decreased 27% from applied N. This was attributed to less dependence on applied N due to higher nodulation in late maturing cowpea cultivars (Ezumah et al. 1987). This work further concluded that cultivars of corn and cowpea are available that can be intercropped.

Intercropping a legume with a non-legume crop has been a traditional practice of farmers in subtropical and tropical countries. However, most intercropping practices evaluated in temperate climates show no economical advantages compared to conventional systems (Calavan and Wiel, 1988). Oyer and Touchton, (1990) demonstrated the benefits of fall-seeded cover-crop legumes for corn grown under conservation tillage systems in the southeast United States. Their work stressed the importance of winter cover-crop legumes for spring crop nitrogen conservation. Calavan and Wiel, (1988) noted various factors concerning intercropping systems, which included shading of legume intercrop, fertilizer nitrogen, time of planting, harvest of the taller cereal crop, density and spacing arrangements of the intercrops. Willey and Osiru, (1972) reported a 38% increase in yield when corn was mixed with beans. They suggested that, because of the marked height difference of the two crops, an increased utilization of light was probably a major contributing factor. Bryan and Peprah, (1987) noted that intercropping corn with common beans (*Phaseolus vulgaris* L.) reduced corn grain and forage yields compared to corn in monoculture but had no effect on total forage production. Cropping practices should allow at least 80% ambient illumination measured at the height of 50 cm for substantial soybean N_2-fixation (Wahua and Miller, 1978).

Canopy reduction is defined as the removal of the corn canopy just above the ear at physiological maturity, where the cut portion is allowed to drop to the soil surface. Some of the basis of canopy reduction come from regions where a relay crop like common beans is produced following corn. In order to increase light interception beneath the corn canopy for the bean plant, the tops of the corn can be removed once physiological maturity is reached. This in turn does not sacrifice the corn yield while increasing the chances of producing a bean crop that would not have been possible if planting took place following corn harvest.

Much of the past work has focused on yield levels obtained for both corn and interseeded legumes, and not the use of interseeded legumes as green manures. Olson et al. (1986) noted that interseeded alfalfa used as green manure increased average corn yields 880 kg ha^{-1}. Conventional tillage practices, have generally led to a decline in soil organic matter levels. This leads to lower soil productivity, increased surface erosion, and net mineralization of soil organic nitrogen. To maintain yields with continuous cultivation, supplemental nitrogen inputs from fertilizers, animal manures, or legumes are required (Doran and Smith, 1987). Clement et al. (1992) noted that yield increases with the application of nitrogen were comparable in sole cropping and intercropping.

The objective was to evaluate the effect of interseeded legume species and nitrogen rates combined with canopy reduction on corn grain yield and grain protein.

MATERIALS AND METHODS

One experiment was established in the spring of 1994 at the Oklahoma Panhandle Research and Extension Center near Goodwell, OK on a Richfield clay loam (fine, montmorillonitic, mesic Aridic Argiustoll). Treatment structure for this field experiment is reported in Table 1. Initial soil test characteristics and soil classification are reported in Table 2. A randomized complete block experimental design with three replications was used. Plot size consisted of four rows (0.76 m spacing) x 7.62 m. All treatments received 100 kg N ha^{-1} of urea (45-0-0) in the fall of 1995. In 1996 and for the remaining years of this experiment, treatments 1-5, 7 and 12 received no N to assess legume N fixation compared to identical treatments with 50 kg N ha^{-1} yr^{-1}. Pioneer brand 3299 corn hybrid was planted at a seeding rate of 74,000 seeds ha^{-1} on 21 April and 30 April in 1995 and 1996, respectively.

Herbicides and insecticides that were applied are reported in Table 3. Entire experimental areas were treated alike for weed control and as such, weed control was not a variable. The expected weed composition and severity was considered at each experimental site each year.

Canopy reduction was imposed by removing the tops of the corn plants just above the ear using a machete. This allowed sunlight to reach the legume seedbed. In August, when the corn had reached physiological maturity, five legume species were interseeded by hand at the following seeding rates: yellow sweet clover (*Melilotis officinalis* L.) 44.8 kg ha^{-1}, subterranean clover (*Trifolium subterraneum* L.) 44.8 kg ha^{-1}, alfalfa (*Medicago sativa* L.) 33.6 kg ha^{-1}, arrowleaf clover (*T. vesiculosum* L.) 22.4 kg ha^{-1} and crimson clover (*T. incarnatum* L.) 44.8 kg ha^{-1}. Physiological maturity was determined by periodic monitoring grain black layer formation. Following interseeding and canopy reduction, 5 cm of irrigation water was applied for legume establishment and to prevent reduction in growth caused by moisture stress. The legume seeds were inoculated prior to planting with a mixture of *Rhizobium meliloti* and *R. trifolii* bacteria. Harvest area consisted of two rows (0.76 m spacing) x 7.62 m. Harvesting and shelling were performed by hand. Plot weights were recorded and sub-sampled for moisture and chemical analysis. Subsamples were dried in a forced-air oven at 65 ^{0}C and ground to pass a 140 mesh screen. Total nitrogen concentration was determined on all grain samples using dry combustion (Schepers et al. 1989). Protein N in corn grain can be determined by multiplying %N by 6.25 (personal communication, University of Nebraska, 1997).

Interseeded legumes remained in the field until the following spring (Figure 1) when they were incorporated prior to corn planting using a shallow (10 cm) disk. Legumes were only used for ground cover and potential nitrogen fixation and as such were not harvested for seed or forage.

RESULTS AND DISCUSSION

By imposing the alternative management practice of canopy reduction, we visually observed an increase in light interception beneath the corn canopy, thus enhancing legume growth in late summer, early fall before corn harvest, and early spring the following year prior to planting. Crimson clover had superior spring growth compared to the other species evaluated as visual biomass production was greater when incorporated in early April prior to planting. Analysis of variance and single-degree-of-freedom-contrasts and treatment means for grain yield and protein are reported in Tables 4 and 5. No grain yield response to applied N was observed in either year using conventional production practices (12 vs 13, 0 N applied, and 100 kg N ha^{-1}). The lack of fertilizer N response at this site restricted adequate evaluation of legume N contribution and species comparison. Grain yields were low in 1995, a result of a severe volunteer corn problem from improper combine harvest in 1994.

There was no significant difference between grain yields when tops were cut at physiological maturity compared to the normal practice (5 vs 7, crimson clover with and without canopy reduction, with no N applied). This was attributed to the fact that when the corn plant reaches physiological maturity, all nutrient and moisture uptake has ceased. Also, it was important to find no differences between canopy reduction and conventional management because it demonstrated the applicability of interseeding in late summer. With the addition of fertilizer, no differences in grain yield were observed for crimson clover with canopy reduction and 0 N applied compared to crimson clover with canopy reduction and 50 kg N ha^{-1} (5 vs 11, Table 4). Under the two management practices with different N rates, a similar lack of differences were found (7 vs 11, crimson clover without canopy reduction with 0 N applied and crimson clover with canopy reduction with 50 kg N ha^{-1} applied).

Due to large amounts of residual nitrogen in the soil, response to applied nitrogen (and or potential nitrogen fixation) was not observed in the first two years of the study (1-5 vs 6, 8-11, with canopy reduction and 0 N applied, and canopy reduction with 50 kg N ha^{-1}). Grain protein ranged from 107 to 117 g kg^{-1} in 1995, and from 85 to 95 g kg^{-1} in 1996 and was not affected by applied N in either year (Figure 2). Increased grain protein in 1995 compared to 1996 was likely due to elevated residual N at the time the study was initiated.

Although not evaluated in this study, mechanized canopy reduction could decrease the time required for grain to lose moisture since more sunlight would directly come in contact with the corn ears when the tops were removed. When grain moisture is high it can delay harvest and/or significantly increase drying costs.

Legume seeding rates, alternative species, method of interseeding and interseeding date will all need to be thoroughly evaluated prior to the mechanization and implementation of this practice. However, our results indicate that it is a possible alternative which deserves further consideration and evaluation.

Since nitrate leaching and soil erosion are becoming major concerns in production agriculture today, this experiment may lead to practices that can decrease both, via lowering the amount of inorganic fertilizer N needed for corn production and reducing the amount of bare soil susceptible to wind and water erosion.

CONCLUSION

Canopy reduction has been used in third world countries as a means of increasing light interception for a relay crop. Canopy reduction is imposed when the corn reaches physiological maturity when nutrient and water uptake has ceased).

Under the two different management practices (canopy reduction and conventional) evaluated in this study, no significant differences in grain yield and protein were observed. When additional fertilizer N was applied, no response was seen in grain yield or protein. This was attributed to high residual N in the soil. Further research is needed to evaluate legume seeding rates, alternative species, method of interseeding and interseeding date. However, legume interseeding using corn canopy reduction appears to be feasible but will require added evaluation at N responsive sites.

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Table 1. Treatment structure including legume species interseeded, management of corn canopy and N rate.

Treatment	Legume	Management	N rate kg ha^{-1} (1995)	N rate kg ha^{-1} (1996)
1.	Yellow Sweet Clover	Tops cut at PM	100	0
2.	Subterranean Clover	Tops cut at PM	100	0
3.	Alfalfa	Tops cut at PM	100	0
4.	Arrowleaf Clover	Tops cut at PM	100	0
5.	Crimson Clover	Tops cut at PM	100	0
6.	Subterranean Clover	Tops cut at PM	100	50
7.	Crimson Clover	Normal	100	0
8.	Yellow Sweet Clover	Tops cut at PM	100	50
9.	Alfalfa	Tops cut at PM	100	50
10.	Arrowleaf Clover	Tops cut at PM	100	50
11.	Crimson Clover	Tops cut at PM	100	50
12.	No Legume	Normal	100	0
13.	No Legume	Normal	100	100

PM- physiological maturity of corn
N applied as urea in split applications (45-0-0)

Table 2. Initial surface (0-15 cm) soil test characteristics and soil classification at Goodwell, OK.

Location	pH	Total N	Org. C	NH_4-N	NO_3-N	P	K
		---------- g kg^{-1} ---------		--------mg kg^{-1} --------		-------mg kg^{-1}------	
Goodwell	7.7	1.4	11.7	65	25	29	580

Classification: Richfield clay loam (fine, montmorillonitic, mesic Aridic Argiustoll)

pH - 1:1 soil:water, Total N and Organic C - dry combustion, NH_4-N and NO_3-N - 2M KCl extraction, P and K - Mehlich III extraction.

Table 3. Herbicides and insecticides applied.

Brand name	Active ingredient	Chemical formula	Crop year	Amount applied	Purpose
Atrazine	Atrazine	6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine	95-96	2.24 kg ai ha^{-1}	Broadleaf and grass control
Dual II	Metolachlor	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide	95-96	383.1 ml ha^{-1}	Broadleaf and grass control
Karate	Lambda-cyhalothrin	[1α(S*),3α(Z)]-(+)-cyano-(3-phenoxyphenyl)methyl-3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropane-carboxylate	94-95 95-96	47.9 ml ha^{-1}	Corn borer and mite control

Table 4. Analysis of variance and single-degree-of-freedom-contrasts for grain yield, and percent protein, Goodwell, OK, 1995 and 1996.

Source	df	1995	1996	1995	1996
		------Grain yield, $(kg\ ha^{-1})^2$------		---Protein, $(g\ kg^{-1})^2$---	
		----------Mean Squares----------			

Rep	2	346,923	2,584,504	119.2	32.9
Trt	12	386,756	1,905,549	40.5	21.8
Error	24	308,048	1,861,850	41.8	3.8
Contrasts					
12 vs 13	1	1,074,085	493,379	0.6	0.4
7 vs 11	1	4,761	182,271	0.2	56.2
1-5 vs 6,8-11	1	98,609	2,631,571	0.2	27.9
5 vs 7	1	37,562	3,138,066	0.5	43.6
5 vs 11	1	15,577	1,807,750	0.5	0.8
SED		453	1,114	5	5

@, *, ** significant at 0.10, 0.05 and 0.01 probability levels, respectively. SED - standard error of the difference between two equally replicated means.

Table 5. Treatment means for grain yield and percent protein for 1995 and 1996.

Treatment	Legume	Treatment means: Grain yield, kg ha^{-1} 1995	Grain yield, kg ha^{-1} 1996	Protein, g kg^{-1} 1995	Protein, g kg^{-1} 1996
1	YSC	2,641	9,731	110	91
2	SC	2,015	10,056	108	91
3	ALF	2,228	9,661	111	90
4	ALC	1,932	10,540	117	86
5	CC	1,808	8,405	114	90
6	SC	1,843	7,958	111	90
7	CC	1,967	9,852	117	95
8	YSC	1,637	8,339	110	85
9	ALF	2,423	10,270	107	86
10	ALC	2,236	9,362	107	89
11	CC	1,910	9,503	110	89
12	NL	2,756	9,617	113	88
13	NL	2,618	10,190	117	88
SED		453	1,114	5	5

SED= standard error of the difference between two equally replicated means. YSC - yellow sweet clover. SC - subterranean clover. ALF - alfalfa. ALC - arrowleaf clover. CC - crimson clover. NL - no legume.

Figure 1. Time schedule for canopy reduction and legume interseeding.

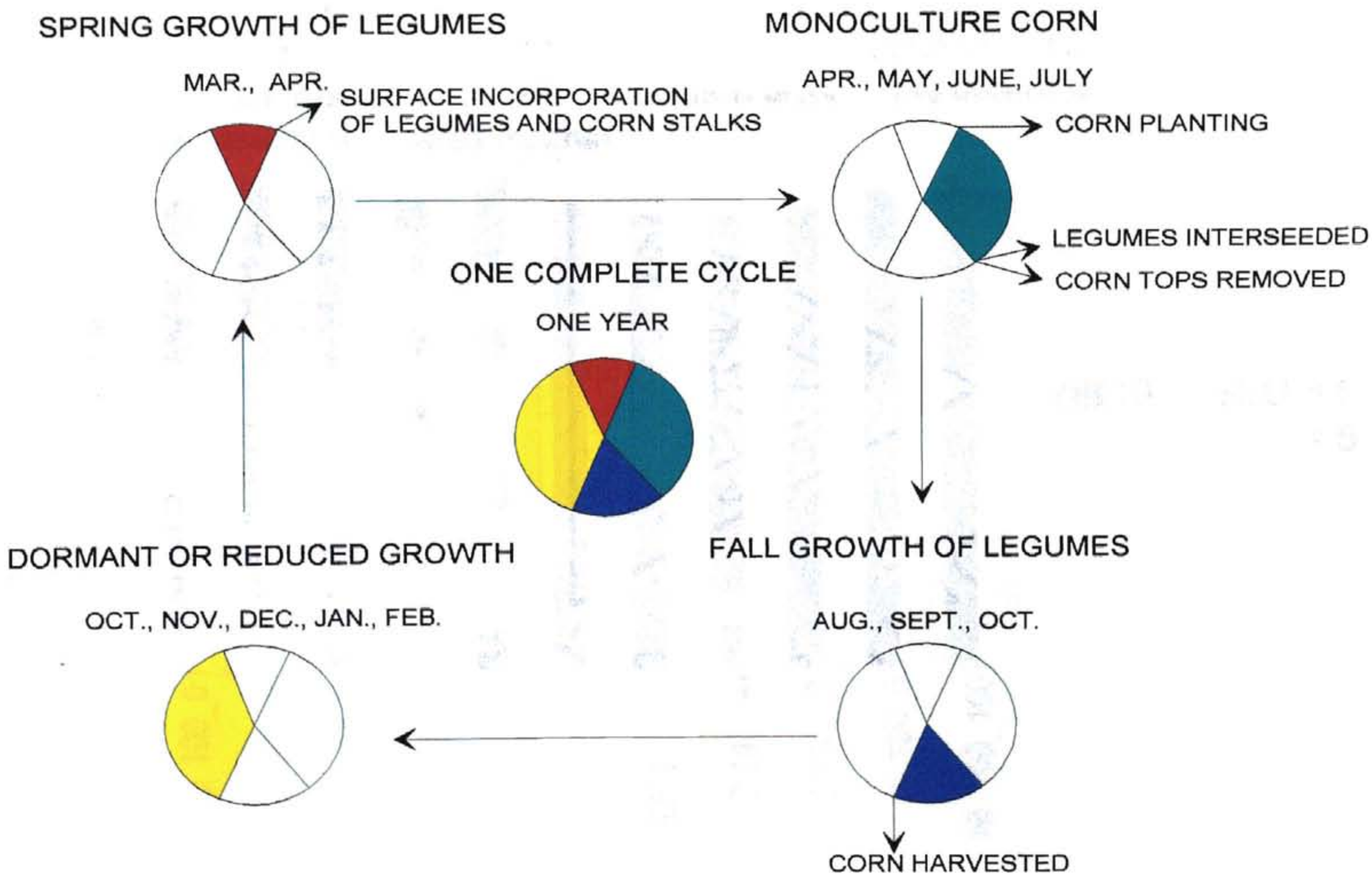


Figure 2. Grain protein for 1995 and 1996 YSC - yellow sweet clover, SC - subterranean clover, ALF - alfalfa, ALC - arrowleaf clover, CC - crimson clover, NL - no legume, CCN - crimson clover with no canopy reduction, 100_0, 100_50 and 100_100 - N rate combinations in kg ha^{-1} for 1995 and 1996, respectively. SED - standard error of the differences between two equally replicated means).

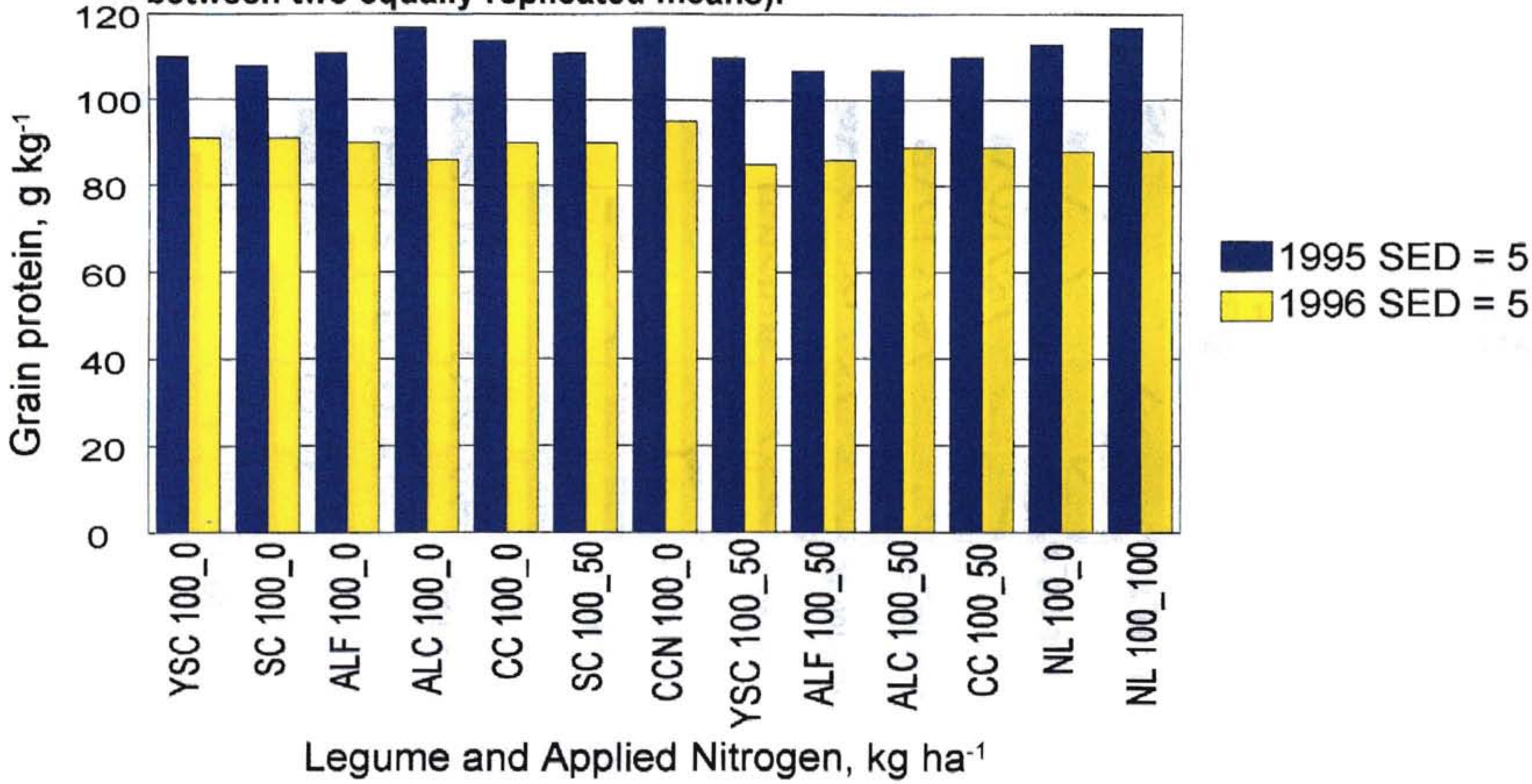
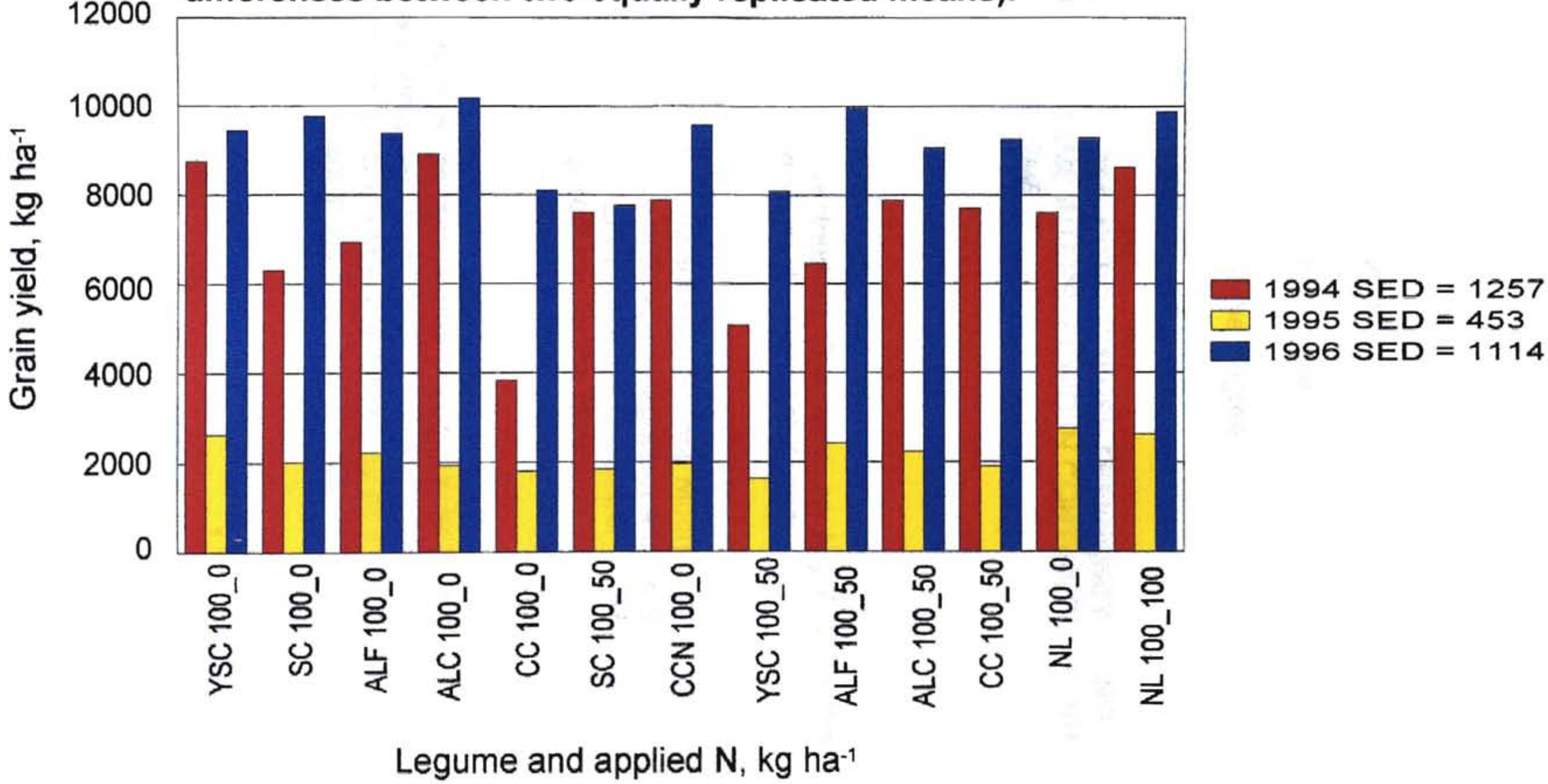


Figure 3. Corn grain yields for 1994, 1995 and 1996 (YSC - yellow sweet clover, SC - subterranean clover, ALF - alfalfa, ALC- arrowleaf clover, CC - crimson clover, NL - no legume, CCN - crimson clover with no canopy reduction,100_0, 100_50 and 100_100 - N rate combinations in kg ha^{-1} for 1995 and 1996, respectively. SED - standard error of the differences between two equally replicated means).



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